# Implications of Climate Change and Sea Level Rise for Tokelau

## Report of a Preparatory Mission

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Funded by the United Nations Environmental Project (UNEP),
in support of the Office of Tokelau Affairs.

Apia, Western Samoa
March 1993

# Foreword

The first Intergovernmental Meeting on Climate Change and Sea Level Rise for the South Pacific Region was held in Majuro, Marshall Islands, in 1989. It was organised by the South Pacific Commission (SPC) and South Pacific Regional Environment Programme (SPREP) to create a public awareness on the future implications of these issues to the governments. Subsequently, necessary actions are being undertaken to address these issues in order to develop appropriate policies.

In this meeting, SPREP member governments gave the mandate to SPREP to coordinate and act as clearing house on all climate change and sea level activities for the region.

The United Nation Environment Programme (UNEP) then provided financial assistance through SPREP (use of SPREP Climate Change Task Team Group) to undertake preparatory missions to Tonga, Kiribati, Tuvalu, Cook Islands, Guam, Palau, Federated States of Micronesia, Western Samoa and Tokelau to discuss the study with the governments, and to prepare reports before undertaking in-depth studies on the impacts of climate change.

The main task of this mission to **Tokelau** was to prepare a report in close consultation with the government officials, identifying areas for in-depth study into the potential impacts of expected climate and sea level changes on the natural environment and the socio-economic structures and activities of **Tokelau**. In addition, it identified suitable and available response options to avoid or mitigate the impacts of climatic changes.

It is anticipated that the **Tokelau** government will have the opportunity to closely examine these recommendations in the report, and to advise SPREP and other organisations accordingly.

Vili A. Fuavao
**Director**

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# 1. Introduction

## 1.1 Background

In late 1991 the South Pacific Regional Environmental Programme (SPREP) sponsored a series of preparatory missions to a number of small island nations in the Pacific to consider the implications of climate change and sea level rise on those nations. The present report on Tokelau is one of that series.

The Tokelau mission, like the others, had been stimulated by a concern over the possibility of major environmental changes to small islands consequent upon global warming and especially the threat of sea level rise which had been expressed at a number of regional and international fora and conferences. Four examples can be cited. First, the Report by a Commonwealth Group of Experts titled 'Climate Change: Meeting the Challenge' (Commonwealth Secretariat, 1989) and presented to Commonwealth Governments in September 1989 noted (p.72):

> "A particular focus of concern has been the future of low lying coral atoll islands which include several nation states, the Maldives, Tuvalu, Kiribati, and several other territories, Tokelau, the Cocos and Keeling Islands..... These islands arouse concern on several grounds. First, their very low elevation means that their whole future could be endangered by sea level rise. Second, even a small increase in sea level could result in proportionately large land losses since typically their circumference is very large in relation to their existing land area. Third, many of these small island states are already highly vulnerable to natural disasters and that vulnerability could be increased."

Second, the Male Declaration on Global Warming and Sea Level Rise, issued at the conclusion of the Small States Conference on Sea Level Rise held in the Republic of Maldives in November 1989, recognized that although the entire world would be adversely affected by climate change and sea level rise:

> "low-lying, small, coastal and island States will face a decidedly greater predicament. Sea-level rise would cause extensive damage to the land and infrastructure of those countries and even threaten the very survival of some island states. The possibility also exists of an increase in the frequency and/or intensity of natural disasters related to climate change, global warming and sea level rise"

Third, the Intergovernmental Panel on Climate Change (IPCC) Impact Assessments Report, (1990, p.6-3) commented:

> "Many small island countries would lose a significant part of their land area with a sea-level rise of 1m. Coral atoll nations, such as Kiribati, Marshall Islands, Tokelau and Tuvalu, Cocos and Keeling Islands, are particularly vulnerable to inundation and erosion because they are generally below 3m elevation and narrow, implying few possibilities for retreat."

Fourth, the communique from the 22nd South Pacific Forum held at Pohnpei in the Federated States of Micronesia in July 1991 stated:

> "global warming and sea level rise were the most serious environmental threats to the Pacific region. The cultural, economic and physical survival of Pacific nations was at risk."

In the light of such formal and forthright statements, it was not surprising that the local and regional media in the Pacific took up the issue. For instance, in 1989 the widely read current affairs and business magazine *Pacific Island Monthly* had as its feature article a special report titled: "The Greenhouse Effect: Where Have All The Islands Gone?" The report argued that "Atoll states are the most helpless of all nations in the face of the greenhouse effect", and concluded with a rather gloomy, if qualified, forecast: "Some of the most recently populated islands in the world may be depopulated... and some of its most recently formed islands may disappear forever." Tokelau was identified as one of those 'islands'. And, the 'World' section of the *Sydney Morning Herald* (7 December, 1991, p.13) carried a report under the banner "Plea to West as Doomed Island Nation awaits Greenhouse Disaster" which opened

"The tiny island-nation of Tokelau is facing extinction. Its unique people, who for generations have lived on a mere 12 square kilometres of land in the middle of the South Pacific, have been told that within decades their homeland could be rendered uninhabitable by the greenhouse effect."

## 1.2 Contextual Considerations

The foregoing quotations, those presented to or sanctioned by governments and inter-governmental agencies on the one hand, and those contained in magazines and newspapers (as well as in the local press and on radio) on the other hand, provide one of the contexts for the present study. The effects of such reports on island governments, officials, elders and not the least island residents themselves was, as several Tokelauans told us, one of uncertainty, bewilderment and genuine fear about the future for their families, lands and livelihood. This fear was heightened and reinforced by the experience of two recent storms in Tokelau, Tropical Cyclone OFA in February, 1990 and Tropical Cyclone VAL in December, 1991, which raised in people's minds questions such as: Is this the start of the greenhouse effect? Is the apparent increase in cyclone incidence a consequence of global warming? Will cyclone frequency continue to increase in the future in parallel with sea level rise? These events and questions provide a second local context for this study.

There was also a third context, which had input into the first, and that related to the work carried out under the auspices of SPREP which dealt specifically with climate change issues in the region As Aalbersberg and Hay (1992) have pointed out for the South Pacific much of the work on greenhouse-induced climate change and sea level rise undertaken in the late 1980s was pursued by SPREP following a request from the United Nations Environment Programme (UNEP), through its Regional Seas Programme, to assess the potential impacts on Pacific island countries. SPREP was assisted in this work by the Association of South Pacific Environmental Institutions (ASPEI) with the main results presented as a series of case studies and review papers (Pernetta and Hughes, 1990; Hughes and McGregor, 1990) and as a popular booklet (Hulm, 1989).

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Much of this and other work conducted during the late 1980s was influenced by scenarios presented at the Villach Conference on the Greenhouse Effect in 1985 which predicted a rise of global temperature between 1.5 and 4.5°C and a sea level rise of between 20 and 140cm in the following 50 years. For the South Pacific regional case studies, the ASPEI team adopted a 2°C rise in temperature by the year 2100AD for the tropical Pacific region with a rate of warming of 0.3°C per decade, and a 1m rise in sea level by around the year 2050 with the rise continuing beyond that date. Both estimates were regarded by the team as being 'conservative' (ASPEI, 1990).

None of the case studies carried out at that time dealt specifically with Tokelau, though Pernetta (1990) did attempt to develop an index of island susceptibility to sea level rise and climate change for each nation within the SPREP region, based upon a number of factors including island type, insularity, relative relief, maximum altitude, number of islands etc. Four categories were distinguished with Category A being the most susceptible. The Category A nations included those "composed entirely of atolls and raised coral islands which will be devastated if projected rises occur and consequently such states may cease to contain habitable islands" (Pernetta, 1990, p.23). Tokelau, the Marshall Islands, Tuvalu and Kiribati were the four states included in Category A, with Tokelau being classed as the most vulnerable of this group.

This combination of international and regional statements and conferences, together with reports on the South Pacific such as those just mentioned, amplified by media commentaries and the recent storm experiences, all fuelled the specific concerns of Tokelau officials and residents about an uncertain future with gobal warming and sea level rise. More recently, through a combination of downward revisions in scientific assessments of the magnitude of projected global warming and sea level rise, (e.g. Wigley and Raper, 1992) as well as more detailed studies on potential impacts and vulnerability of atolls (eg. Sullivan and Gibson, 1991), a more optimistic view of the future for atoll states is emerging. How this will affect the perceptions of Tokelauans about their future is yet to be seen, but at the time of our visit a rather pessimistic view prevailed.

## 1.3 Mission brief

The terms of reference for this mission were similar to those for missions to other countries in the region, and are detailed in Appendix I.

The main purpose was to prepare a proposal for a programme of assistance to undertake an in-depth study of the potential impact of expected climate changes (primarily sea level and temperature rise) on the natural environment and the socio-economic structures and activities of Tokelau. This would include the identification of response options which may be suitable and available to avoid or mitigate the expected negative impact of climatic changes. The study was to be undertaken in close consultation with the Office for Tokelau Affairs, based in Apia, Western Samoa.

Specifically we were given three groups of tasks:

- to examine and evaluate the available information affecting the physical and biological environments of the islands and assess the available demographic, social and economic data for Tokelau.

- to present an overview of the current state of knowledge concerning the greenhouse effect and its possible consequences for Pacific Island nations and to present the results of previous UNEP sponsored studies conducted in the South Pacific outlining the potential applicability of these studies to Tokelau.

## 1.5 Structure of Report

This report consists of several parts, each of which addresses one or more of the terms of reference. Section 2 provides a brief description of Tokelau's natural environment including its geographical setting, weather and climate, landforms, soils, vegetation and land use. It is clear from this description that (1) natural resources (except for marine resources) are quite limited; and (2) there is a lack of up-to-date survey data on many aspects of the natural environment. This situation must be rectified before environmental planning in any comprehensive manner can take place. Section 3 provides a brief statement on administration, population and socio-economic activities. Key elements include the disjunct location of the nation's administration and Tokelau's dependence on a MIRAB economy.

These two sections serve as background to an assessment of the factors which are believed to be particularly relevant to potential impacts of global warming and sea level rise. Section 4 gives a perspective on the formation of atolls and the role of sea level change in island formation and development. This leads on to an evaluation of island vulnerability to sea level rise, which needs calibrating through field survey and air photo analysis. Oceanographic factors are discussed in Section 5. Recent global sea level changes and variations in mean sea level in the central Pacific region are described. From this analysis it is concluded that the magnitude of short-term, inter-annual and seasonal variations in sea level are likely to continue to dominate the regional record of sea level change over the next few decades as they have done in the recent past, and in so doing dwarf any secular global sea level rise. Section 6 discusses climatic and meteorological factors. Again the Tokelau region is dominated by short-term variations, particularly those associated with the El Nino - Southern Oscillation (ENSO) phenomenon. For this reason it is difficult to indicate with any certainty that there will be recognizable changes in rainfall or drought frequency, or in the magnitude and intensity of tropical cyclones.

Some of the data included in the previous three sections were discussed with OTA officials and at a public meeting in Apia. How environmental changes including climate change and sea level rise are perceived by Tokelau's managers and residents is the subject of Section 7. This analysis clearly shows there is a great deal of uncertainty about the future for Tokelau and surprisingly rather little concern about the possibilities of human-induced environmental deterioration. These considerations lead on to some brief comments on future environmental planning in Tokelau and specifically those included in the UNCED - State of the Environment national assessment (Section 8). The establishment of the Tokelau Environmental Management Strategy (TEMS) project as a key element in future planning is also discussed. The report concludes with a series of specific recommendations (Section 9) which could be followed up within the general context of that project.

# 2. Tokelau - The Natural Environment

## 2.1 Geographical Setting

Tokelau comprises three atolls located in the central Pacific between 8 and 10°S latitude and 171 and 173°W longitude, and about 480km north of Western Samoa. Funafuti, the capital of Tuvalu lies some 880km to the west and the Phoenix Islands in Kiribati some 500km to the north (Figure 1). The three atolls, Fakaofo, Nukunonu and Atafu are aligned northwest-southeast and they rise steeply from the ocean floor which is at depths of about 4km around the atolls (Roberston and Kibblewhite, 1966). Fakaofo, the southernmost atoll is 64km from Nukunonu which in turn is 92km south of Atafu, the northernmost atoll (Figure 2).

The atolls are typical coral atolls with an encircling reef surrounding a lagoon. Importantly the reef rim is continuous and there are no natural passages through it to permit ship access to the lagoon. The reef rim is exposed at low water, isolating the lagoon as a 'lake' at such times.

The total land area of Tokelau is about 12sq km which is made up of 127 separate motu or small islets. The motu vary in size from about 90m to 6km in length and a few meters to 200m in width. The largest atoll is Nukunonu with 4.7sq km on 24 motu, followed by Fakaofo with 4sq km on 61 motu and Atafu with 3.5sq km on 42 motu. All of the motu are located on the reef rim (Figure 2) and all are made up of wave deposited coralline sand and gravel derived from the adjacent reef and lagoon. There are no volcanic deposits or outcrops of continental rock. The motu all possess features typical of such environments-small size, low elevation, poor soils and a limited terrestrial biota.

## 2.2 Climate and Weather

The following comments are taken mainly from a report on Tokelau's weather and climate prepared by Thompson (1986). Further details on Tokelau's climatological setting, which are particularly relevant to climate change and sea level rise issues are presented in Sections 5 and 6.

Tokelau is located within the easterly trade wind zone and its climate is characterized as tropical and marine. The trade winds dominate the weather patterns from May through October and form the 'background' winds throughout the remainder of the year, although from December to March westerly or northwesterly monsoon winds do occur and these may equal or exceed in frequency the easterly trades in some seasons. The trades are associated with predominantly fair weather and relatively light though variable rainfall, while the northerly and westerly winds are associated with greater cloud cover and higher rainfall.

Tokelau lies in a steep rainfall gradient between the South Pacific wet zone to the south west where mean annual rainfall exceeds 3500mm, and the very dry equatorial zone to the northeast where mean annual rainfall is below 1000mm. Tokelau records an average 2760-2780 mm per year, but there is a marked seasonality in rainfall incidence, with the 6 months between October and March typically accounting for 60 per cent of the annual total, and December and January 25 per cent of the annual fall. Monthly rainfall varies with recorded totals ranging from 27 to 641 mm in June at Atafu, 14 to 415 mm in September at Nukunonu and 69 to 693 mm in January at Fakaofo. Interannual rainfall variability is moderate and appears crudely related to the phase of the Southern Oscillation Index (SOI). High or low rainfalls lasting more than a month are rare.

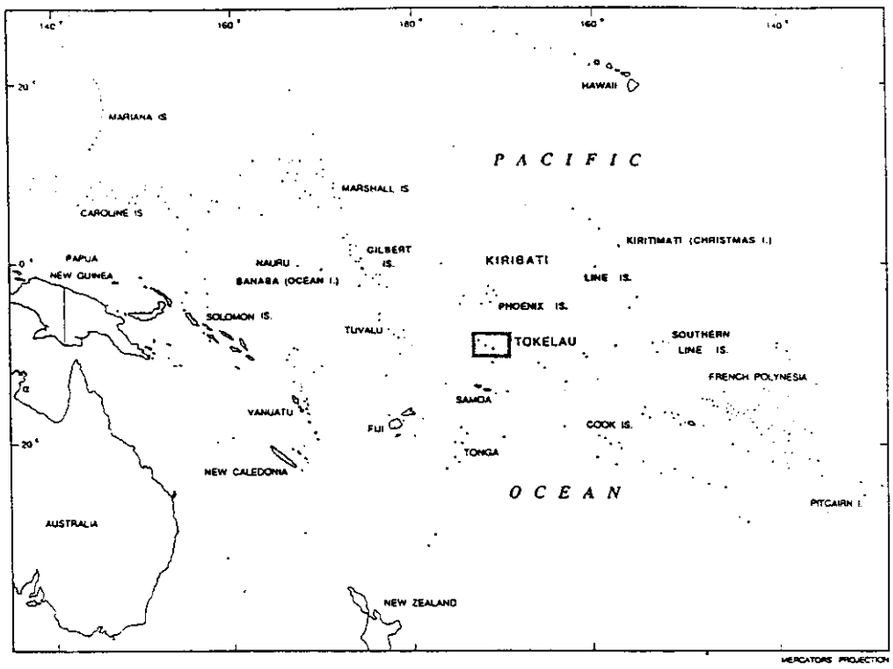


*Figure 1: Location of Tokelau in the wider Pacific*

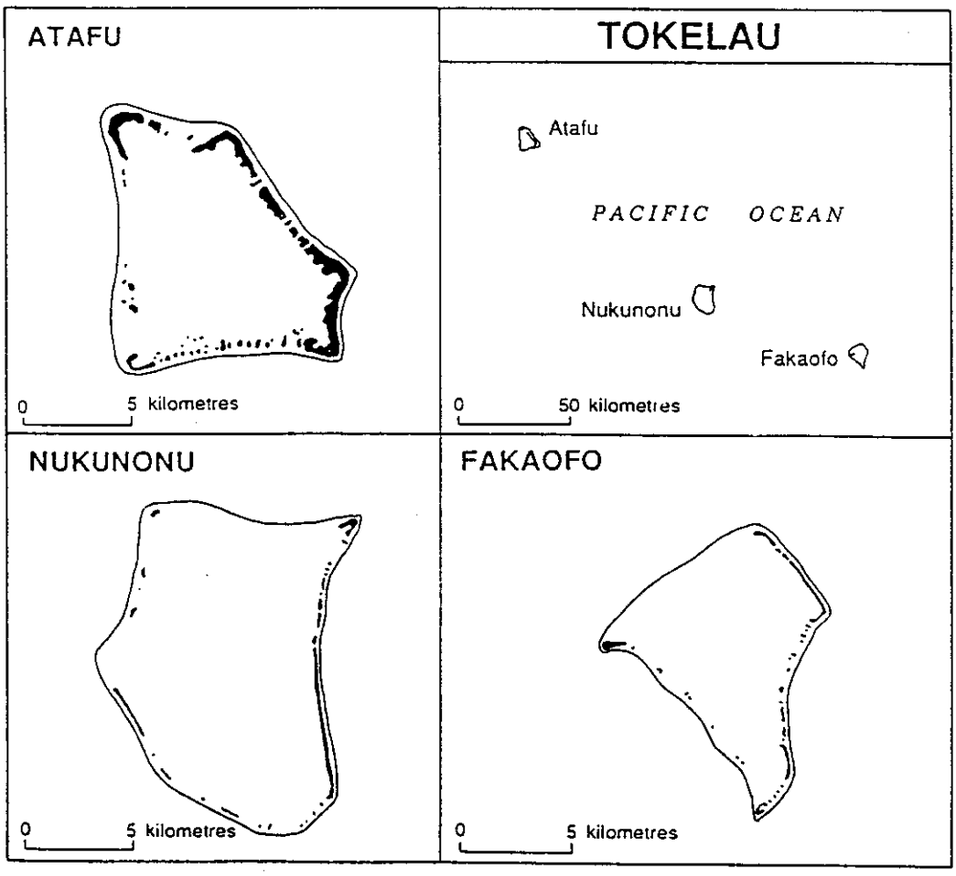


*Figure 2: Location and general outline of three atolls in Tokelau*

Air temperatures are high all year round with a mean average temperature of 28°C and mean daily maximum and minimum of 31°C and 25°C respectively. Annual sunshine hours average 2310 hours or 55 per cent of the total possible. June, July and August are the sunniest months and December, January and February the cloudiest, with 60 per cent and 49 per cent of possible sunshine hours, respectively. Monthly potential evapotranspiration ranges from 122 to 149 mm.

In Tokelau even a few consecutive days without any rainfall at all is not common. Indeed, Thompson (1986) calculated that for any 14 day period, the probability of no rain is virtually zero, though there is a 19 per cent chance the total rain will be between 100-150mm. If 'dry spells' are periods of at least 15 consecutive days with less than 1mm of rain per day, and 'drought' is 15 or more days without rain, then Tokelau experiences about four dry spells and two or three droughts per decade. Recent examples include the five-month long drought event on Fakaofo from March-July 1976 and on Nukunonu in the same year, when there were 145 days of moisture deficit between May-October 1976. Corresponding rainfall reached only 371mm, the lowest on record for a 7-month period. The majority of dry spells and drought occur between April and November.

Strong winds from northerly to westerly directions occur at intervals during the 'summer months' and these sometimes reach gale force. On occasions this bad weather causes damage on the islands. Tropical cyclones sometimes form in close proximity to Tokelau, but it is only rarely that they develop into storms while in the vicinity. However, as Thompson (1986 p.7) points out, because the Tokelau islands are low lying coral atolls, storm surges and/or gale force winds generated by tropical cyclones several hundreds of kilometres away have swept over the islands with devastating effect. Notable storm events occurred in January 1914, December 1925, January 1936, February 1941, November 1941, December 1957, January 1966, November 1972 and January 1978.

More recent events include the storm waves in February 1987 which struck Tokelau during a period of high spring tides and were associated with two cyclones several hundred kilometres away to the southeast and southwest (Richards, 1991), and Tropical Cyclone OFA and Tropical Cyclone VAL which developed in the vicinity of Tokelau in late January - early February 1990 and December 1991 respectively. Damage reports were prepared on these cyclones and are available at OTA.

## 2.3 Island Landforms and Soils

To our knowledge there has been no systematic survey of landforms or soils of the Tokelau islands. Hooper and Huntsman (1987) note that the eastern shore of each atoll, facing the prevailing wind and currents, has the largest islets (motu) with some islets extending several kilometers along the reef rim. The largest islet of the group, on Nukunonu atoll, is 6.4 km long and 300 m wide (Parham, 1971). Characteristically these elongate islets have their highest ground along the ocean side where there is a crest of rough coral rubble and boulders sloping down to a narrow ocean beach and reef flat. Towards the lagoon there is a much longer and gentler slope. Such an asymmetric cross-island profile is typical of atoll motu in the region (McLean and Hosking, 1991).

With reference to soils, Reynolds (1972) made brief observations on the three atolls of Tokelau in 1971 and collected some soil samples, while Parham (1971) mentions some aspects of the soils affecting vegetation communities. Reynolds (1972) notes that because of storm catastrophies, current, wave and wind action, and natural and man-made burials and excavation, the pattern of atoll soils can be very complex, although the soil types themselves are few and simple in nature. The soils parent material is composed almost entirely of calcium and magnesium carbonate and many of the soils are immature or skeletal in nature. The soils

range from essentially unaltered sands and gravels through a stoney and very stoney complex to soils where some profile development has occurred with the incorporation of organic matter into the surface layers. Usually the darker (and presumably older) soils occur towards island centres, a feature also noted by Parham (1971) who commented that on most motu, the soil of the interior is a dark brown to black sand, with a high organic content derived from the humus of decaying vegetation and guano. This contrasts with the light greyish brown sand with lower organic matter of beach-crest locations.

Typical analyses of the soils are presented by Reynolds (1972) who noted that low fertility levels were the most outstanding feature. All soils analysed were highly calcareous with 59 to 98 per cent calcium carbonate, high pH values, low to very low organic carbon and medium to low total nitrogen values. Exchangeable magnesium and sodium levels were moderate to high with high exchangeable calcium and low potassium levels. All soils had a low water-holding capacity and even those associated with the raised food garden beds and excavated taro pits had a high proportion of coral sand mixed with the organic debris. These brief observations of Tokelau's soils are consistent with Pacific atoll soils in general (see Morrison, 1990).

## 2.4 Island Vegetation

Parham (1971) described the vegetation type occurring on the islands in the late 1960s. He noted that the vegetation of all the motu, as viewed from the air or from the deck of an approaching vessel, provides a dense canopy of foliage extending from the beach, with the overhanging fringe of *Cocos, Pandanus, Scaevola* and *Messerschmidia* rising beyond to the forest of coconut palms with *Cordia* and *Guettarda* and many other trees and shrubs to reach heights of 10 to 20 m.

Parham identified three typical zones on the islets extending from the active beach to the interior.

1. the unstable foreshore of fresh sand, rubble or hard-pan which is practically devoid of vegetation except in its upper slopes where occasional plants such as the creeping sand-binder *Triumfetta* (totolo), the grass *Lepturus* (mutia) and the sedge *Fimbristylis* (tuise) occur as pioneers on recently formed or eroded substrates.

2. the beach-crest zone, which occupies a narrow, 10-20m wide strip on the more stable substrate backing the active beach. This zone supports several plant communities comprising a distinct association of trees and shrubs with their seedlings and a few herbaceous plants in the ground cover. *Scaevola* (nahu) forms a windbreak, up to 3m high on the seaward face of the beach-crest while *Messerschmidia* (tauhinu) which grows to a height of about 4m is also common often associated with the wild *Pandanus* (fala vao). *Pemphis* (gagie) scrub up to 4m or more high occurs on both ocean and lagoon sides of the islets, particularly on outcrops of hard-pan coral and rocks in the most open exposed sites. A more complex *Pandanus - Guettarda* community also occurs on the beach-crest. This community generally has a canopy that rises above the preceding scrub types and comprises several layers. The coconut palm *Cocos* (nui), screwpine *Pandanus* and the trees *Guettarda* (pua pua) *Cordia* (kanava) *Hernandia* (puka vaka) and *Morinda* (nonu) are all common in the upper storey to 6-8m high. The shrubs *Scaevola* and *Messerschmidia* together with the fig *Ficus* (mati) are common in the shrubby understorey, and the parasitic creeper *Cassytha* (fetai) and the liane *Ipomea* (fue) conspicuous climbing on trees and shrubs.

## 2.6 Marine Resources

Marine resources of the reef, lagoon and surrounding sea are abundant and fishing is a mainstay of the Tokelau lifestyle. Fish also forms a major component of the Tokelauan diet. Based on a survey of Fakaofo carried out from June to September 1986, lagoon and reef fish account for 55 per cent of all animal protein consumed and tuna and tuna-like species from offshore about 20 per cent (Gillet and Toloa, 1988).

The following comments are based primarily on Humphries and Collins (1991) who note that Tokelau's fisheries comprise an inshore lagoon and reef fishery and an offshore pelagic and deep water fishery. The lagoon fishery is mainly for domestic consumption although there is a small-scale commercial component consisting of a few individuals wishing to supplement their income and some send fish to relations in Western Samoa. Main species in the lagoon and reef fishery are great trevally, bigeye scad, goatfish, garfish, parrotfish and surgeonfish. In the offshore fishery tuna and tuna-like species (yellowfin, wahoo, skipjack, dogtooth) are mainly caught and the deep water fishery comprises mainly snapper, shark, groupers and emperors.

In most cases individuals will fish at their discretion and primarily in the lagoon and reef areas. Community fishing has decreased since the advent of motor boats, but is still organised periodically by the village elders. Commercial fishing is still at an early stage of development. Three projects are receiving top priority at present: fish processing; trochus plantation and fish aggregation devices. These projects are being developed in consultation with the traditional community elders.

Information on the state of fish stocks is limited and there is no regular monitoring program except for tuna and trochus. The reef and lagoon ecosystems have been surveyed for selected species for their commercial viability but a complete ecosystem profile is not available (Humphries and Collins, 1991). Such an inventory could become part of the Tokelau biodiversity program and also be used as a basis for considering the relationships between traditional and modern marine conservation measures.

A comprehensive bibliography on fisheries-related subjects up to 1988 has been prepared by Gillet (1988) who has also compiled copies of various reports on fisheries in Tokelau from 1988-1992. These reports are bound into a single volume held by the Director of Agriculture and Fisheries, OTA.

# 3. Society, Economy and Administrative Structure

## 3.1 Administration

Constraints on the development of reliable communication and transportation facilities have posed significant problems in administration of the three atolls. Tokelau's isolation influenced where the center of administration is located today and therefore how the country is administered.

In 1925 administration of Tokelau came under the control of the New Zealand government. The Office for Tokelau Affairs (OTA), or "Tokelani", is located in Apia, Western Samoa. Tokelau has chosen to maintain links with the New Zealand government and its status as a non-self-governing territory (Connell, 1983). By continuing its close ties with New Zealand, Tokelau aims to work towards a greater degree of self-government and economic self-sufficiency.

The administrator for Tokelau is based in Wellington and delegates most powers of administrative authority to the Official Secretary of the OTA. Administration extends to the three atolls of Tokelau. The General 'Fono' is the central governing authority based in Tokelau. It comprises representatives from the Council of Elders, the groups of women, youth, and 'aumaga' (able-bodied men) of each atoll. The Council of Elders are the local governing authority of each atoll and comprises the heads of families and males older than 60 years. Every six months a General Fono is organised to discuss and decide the internal affairs of Tokelau.

Communication between Apia and Tokelau has presented many administrative problems. In the early 1980s an airlink was established with Western Samoa using an amphibian aircraft chartered from Tuvalu, but this was soon discontinued. Past shipping services have varied in their transportation capabilities, reliability and frequency of visits (5-10 week intervals). The *MV Wairua*, chartered from Suva, has provided the most consistent Apia-Tokelau-Apia service at roughly monthly intervals. In an attempt to improve transportation between the atolls themselves the OTA purchased an "inter-atoll vessel" *Tutulo* which was delivered early in 1992. Since this vessel has only just begun operating it remains to be seen how viable the service will be.

The improvement of shipping services to Tokelau is in preparation for the relocation of the OTA to Tokelau. The need to relocate the OTA has also spurred a reorganisation in the Tokelau Public Service. Establishment of a Department of Transportation and Communication is part of the restructuring which aims to improve transportation and communication from Tokelau to the outside world (Office for Tokelau Affairs, 1991). Reliable telecommunication links, both telephone and facsimile, are essential before relocation of the OTA can take place.

## 3.2 Demography

Since 1900 there have been significant changes in the structure of Tokelau's population. In 1900 approximately 858 Tokelauans inhabited the three atolls. By 1966 the number of inhabitants had risen to 1,901 (Connell, 1983).

In 1965 the New Zealand government estimated that a population of 1,250 was the maximum carrying capacity of the atolls. The Tokelau Islands Resettlement Scheme, implemented in 1965, encouraged Tokelauans to migrate to New Zealand. A severe tropical cyclone in 1966 added extra impetus to the decision of many Tokelauans to move. In 1971 the number of government-sponsored migrants was 356 and by 1975 the total number of Tokelauans living in New Zealand was 1,849 (Department of Statistics, 1988). The scheme was withdrawn in 1975 at the request of the Tokelauan administration who were concerned with the depletion of Tokelau's economically active population (Connell, 1983). However, assistance from New Zealand is still provided for education and training of Tokelauans overseas.

The 1986 census recorded a population of 1,690 Tokelauans living in Tokelau, a reduction from 1966 (Department of Statistics, 1988). An unofficial population estimate for Tokelau in 1991 is 1,573, a further reduction. A growing number of Tokelauans are living overseas, with 4,500 now residing in New Zealand (Humphries and Collins, 1991).

The population of Tokelau today settles in four villages, which are characteristically located on the lee shore of western islets of the atolls. Migration between the atolls has occurred mainly through inter-atoll marriages and job placements. Growth of the four villages is obvious. Both Atafu and Nukunonu have one village each. Atafu's village expanded onto newly deposited material left after the severe cyclone of 1914. Today it is extending in the opposite direction requiring more land to be cleared for houses. While Nukunonu is significantly less densely populated the village has also grown. A bridge linking to a close islet has accommodated the expansion. Fakaofo has two villages. The second village was established in 1970 on a larger neighbouring motu. The creation of a second village aimed at providing an alternative location for houses, thereby relieving pressure on the limited land and water resources of the original settlement (Peat, 1984).

The 1986 population total suggests that natural population growth is being matched by emigration with the unofficial 1991 total suggesting that emigration may be exceeding natural population growth. While this trend may subdue any population growth problems, this situation may not always be prevalent. There are presently no demographic policies for Tokelau and family planning advice is given on a demand basis only. The resource base of Tokelau is very limited and the integration of market based economies and related consumer products into the traditional economy is already placing different types of pressure on island resources and is testing the carrying capacity of land and sea for waste (Humphries and Collins, 1991).

## 3.3 Economy

Similar to other Polynesian atolls Tokelau has endeavoured to integrate the western market-based economic system into its traditional economic systems. Fish, coconut, breadfruit and pandanus are the basic foods in Tokelau. Tokelau's isolation has, in the past, continued the dependence on traditional food with a very low consumption of imported foodstuffs. However, during the 1970's imports of flour, sugar, rice, kerosene and tobacco rose dramatically. A cooperative store on each atoll distributes all imported products. The village elders use the profits returned to the villages at their discretion. In 1989-90 sales from the stores of the three atolls totalled NZ$1.2m. With very few investment opportunities there is a trend towards consuming rather than saving (Humphries and Collins, 1991).

In the recent past Tokelau's income was derived from export tax on copra. Income from copra reached a peak of WS$87,154 between 1974-75. Prices have since fallen and income generated from copra lowered to WS$30,700 between 1979-80 (Connell, 1983). Copra and other food crops are very susceptible to cyclone damage and slow recovery after cyclone events delays gathering and production of exports. With limited possibilities to further develop land resources for income generation, there are more promising opportunities to be had through greater commercialization of offshore fisheries and possibly aquaculture.

Other revenue is collected from export tax on handicrafts, duties on selected imported commodities, the provision of public services, freight charges, the sale of postage stamps and coins, and externally generated income from Exclusive Economic Zone access fees. From 1981-82 this income totalled NZ$547,450, but in 1982-83 was less than NZ$374,000. Revenue collected in 1990 was estimated NZ$0.64m, or NZ$380 per capita. This contributes a very small fraction of total government revenue and disposable income. The bulk of local revenue is indirectly aid-derived via levies and duties (Humphries and Collins, 1991).

Tokelau's isolation, inadequate transport facilities and the lack of amenities have discouraged the development of a tourist industry. There are no policies at present to encourage tourism, unlike elsewhere in many other Pacific island countries. However, the Tokelauan economy is in other ways similar to the majority of Pacific island economies, with migration, remittances, aid, and bureaucracy (MIRAB) acting as significant components (Bertram and Watters, 1985).

## 3.4 Migration and Remittances

The total number of Tokelauans in New Zealand is significantly smaller than most other Polynesian populations. In 1971 there were 1,195 and by 1981 there were 2,295. However in the last two decades the Tokelauan population in New Zealand (approximately 4,500) has risen above the total residing in Tokelau.

The limitations and marginality of the traditional economy have been the principal influences on emigration. Most Tokelauans have migrated to New Zealand out of the desire to improve living standards living (Department of Labour, 1979). Better opportunities in education and employment draw them to New Zealand providing them with money to send back to Tokelau.

Although remittances to Tokelau are not as dramatic as those amounts sent to other Pacific island countries, they are an additional source of income to most households in Tokelau. In the period between October 1985 to September 1986, 189 of 257 private dwellings in Tokelau received remittances from overseas and within Tokelau to add to their household income (Department of Statistics, 1986). In 1989-90 NZ$0.2m or NZ$120 per capita of remittances was injected into the Tokelauan economy and represents a significant external source of household cash (Humphries and Collins. 1991).

## 3.5 Aid

The Public Administration Office of Tokelau and the New Zealand government agree that Tokelau's objective is for greater economic self sufficiency. However, over the past two decades financial assistance has increased. In 1982-83 New Zealand budgetary aid to Tokelau was NZ$1.9m. New Zealand provided NZ$3.9m of budgetary aid in the year ending March 1989, and in the year ending March 1990 a total of NZ$4.1m, or NZ2l,426 per capita, of budgetary assistance was managed by the OTA (Humphries and Collins, 1991). The United Nations Development Programme, a major aid donor, has provided substantial funds for Tokelau's development projects and in 1982 prepared its first Tokelau Five-Year Country Programme (Connell, 1983).

## 3.6 Bureaucracy

The implementation of the Public Service in Tokelau (TPS) in 1976 provided the first employment opportunities for 10% of the population. Most were employed as teachers, medical aides, and labourers for public works and national agricultural programmes and projects.

Despite limited opportunities for employment in Tokelau, jobs have been created in the public service on the atolls and in Apia. Today most individuals, especially males, are partially employed or economically active. In 1983 the elders agreed that all waged positions, especially casual labouring, would be rotated to ensure that all families would be supported by a public service wage earner (New Zealand Ministry of Foreign Affairs, 1983).

The 1986 census shows that out of 257 households 117 earn income from TPS salaries, 102 of whom earn greater than NZ$1,500 annually. Of the 171 Tokelauans that bring money to households from casual TPS wages 169 earn less than NZ$1,500 annually (Department of Statistics, 1988). The income derived from permanent and casual salaries and waged positions held with the TPS totalled NZ$1.7m in 1989-90 (Humphries and Collins, 1991).

## 3.7 Health and Nutrition

Traditional foods are still important components in Tokelauan diet. However, these food crops are very susceptible to cyclone damage. Pulaka, breadfruit, banana, paw paw and coconuts are severely affected by salt water flooding, high winds and sea spray. Food shortages after the cyclones place much pressure on the communities and obtaining crops from traditional sources after a cyclone requires the plants to recover before they produce. Large scale imports of food and technical supplies, supplied by New Zealand, assisted Tokelau in coping after cyclone events and began their acquaintance with imported foodstuffs.

Since the 1960's the volume of imported foodstuffs has increased dramatically. Imports of sugar, rice, flour, tinned fish, mutton flaps and tobacco have changed Tokelauan diets and practices of gathering food markedly. Many of the new health problems in Tokelau are associated with changes in diet and exercise patterns. There are a rising number of cases of obesity, hypertension, diabetes, coronary diseases, respiratory diseases, alcoholism and malnutrition.115

# 4. Atoll Development and Sea Level Change

## 4.1 Geological Perspective

Hooper and Huntsman (1987 p117) note that: "No geological research has been done in the group, and its relationship to other islands in the region in not entirely clear". The plate-tectonic map of the southwest Pacific (AAPG, 1981) does provide data relating to the macro-scale geological setting of Tokelau, and Robertson and Kibblewhite (1966) provide reconnaissance bathymetric data around the three atolls.

In the absence of specific geological and geomorphological information on Tokelau general models from other locations and data from similar nearby islands and atolls including those in Kiribati, Tuvalu and the northern Cooks must be used instead.

These islands and atolls, like those elsewhere in the world, consist of a pile of coral limestone overlying a volcanic basement at depth. The origin of such islands, lying hundreds of kilometres from the nearest volcanic or continental land mass, and surrounded by water 3-5km deep, has been widely debated though Darwin's ideas are still the most widely accepted. Darwin (1842) distinguished three types of reefs: fringing reefs, barrier reefs and coral atolls and suggested that these evolved through an ordered sequence. With subsidence of the volcanic seamount and upward reef growth the initial fringing reef becomes a barrier reef which in turn evolves into an atoll with a reef rim surrounding a lagoon. The resulting reefs and lagoons take on various shapes and sizes dependent on the nature and size of the original volcano and the processes of coral growth.

This simple subsidence model has been confirmed through drilling; initially to the west of Tokelau at Funafuti in Tuvalu in 1896-98 where a drill hole was still in limestone at a depth of 330m and on several atolls in the Pacific in the 1950s including Enewetak (Marshall Islands) where basalt was reached after penetrating 1300m of limestone. This simple model has been incorporated into more complex models associated with plate tectonic theory. With reference to the mid-oceanic islands, Scott and Rotondo (1983) suggest that as new lithosphere is formed along the East Pacific Rise, older crust moves northwest towards Asia, cools and causes ocean deepening. Some distance from the East Pacific Rise relatively fixed melting anomalies produce volcanic island chains which in warmer waters develop reefs and grow into atolls. The northwest-southeast aligned linear archipelagoes, such as the Gilbert Islands and Line Islands result from these processes, and it may be that the Tokelau chain has a similar origin.

It is important to recognize that Darwinian subsidence takes place over very long periods - millions of years - and that to all intents and purposes it can be ignored in the present context. Schofield (1977a) notes that in the central Pacific during the Cenozoic: "the average rate of sinking has been about 0.025m per 1000 years, [0.025mm/yr] with a possible increase to about twice this value in the last 5 million years. These rates are insignificant compared with the 15m per 1000 years rate of sea level rise during its major period of post-glacial trangression....".

## 4.2 Sea Level Changes in the Late Quaternary

In addition to slow subsidence and horizontal movement of the basement the islands have also been subject to fluctuations in ocean water level as a result of the waxing and waning of the ice sheets throughout the Quaternary period. During the last 2 million years sea level has risen and fallen many times and has been superimposed on these lithospheric changes.

The pattern of sea level rise and fall, which has been much more substantial than that of subsidence during the last glacial cycle, is shown in Figure 3. Note that the last time sea level was around its present position (during the last interglacial) was about 125,000 years ago. Since then sea level has fallen, reaching its lowest level (-100m) some 20,000 years ago, at which time the islands of Tokelau would have been emergent and similar in appearance to present-day Banaba, Nauru and Nuie. Subsequently, with the melting of the ice sheets in the northern hemisphere, sea level rose and flooded the islands and permitted the growth of coral over the last interglacial land surface. This sequence is shown schematically in Figure 3.

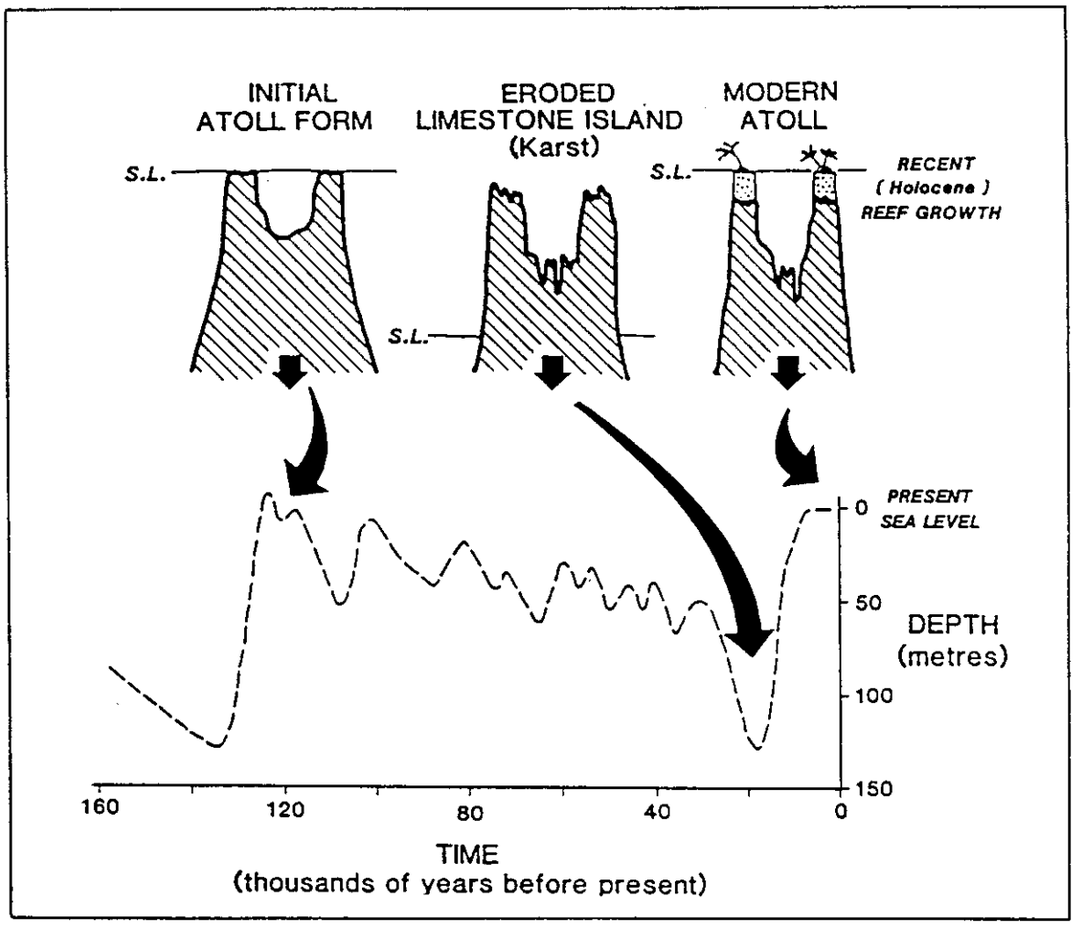


*Figure 3: Sea level change and atoll response during the Late Quaternary (From Woodroffe and McLean, 1992)*

At Tarawa the presence of the older reef (radiometrically dated at 125,000 years BP) has been confirmed by drilling. It occurs at a depth of 11-17m below the islands and indicates the base of the modern sequence rests on reefs of last interglacial age (Marshall and Jacobsen, 1985). The depth to the pre-Holocene platform at Enderbury Island in the Phoenix group is not known although a grey recrystallised reef limestone at about -13m is presumably of Pleistocene age (Tracey, 1980, p.253).

Growth of the modern reefs and development of the present form of the atolls and islands has taken place more recently, in the last few thousand years. Radiometric dating of corals from boreholes on Tarawa atoll reported by Marshall and Jacobsen (1985) show that Holocene reef growth began about 8000 years ago, which is consistent with the time of initiation of major reef growth on other Pacific atolls (eg. Enewetak and Mururoa). Vertical accretion rates on Tarawa range from 5-8m per 1000 years. These rates are reasonably typical for windward reef flats on the Great Barrier Reef, but are considerably higher than the rates of 2-3m per 1000 years for Mururoa (Labeyrie et al., 1969) and of 1-2m per 1000 years for the uppermost parts of Enewetak and Bikini atolls (Tracey and Ladd, 1974). Such rates provide an important perspective when considering future coral growth in response to the projected rise in sea level over the next few decades discussed later in this report.

## 4.3 Holocene Sea Level Change and Island Formation

Figure 4A presents the general pattern of relative sea level change over the last 8,000 years deduced from data from atolls to the southeast (Cook Islands, Woodroffe et al. 1990) to the north (Phoenix Islands, Tracey 1972, 1980) to the northwest (Gilbert Islands, Schofield 1977) and to the west (Tuvalu, McLean and Hosking, 1991) of Tokelau. This shows a rapid rise from 8-6000 years ago (a continuation of the post-glacial sea level rise), sea level first reaching around its present position 4-6000 years ago, passing above that level to around +1m 2-4000 years ago, and subsequently falling to its present level in the last 1-2000 years. Geomorphological evidence for the higher stand has been described from Kanton (Guinther, 1978) from emergent in situ coral and *Tridacna* at Enderbury dated at 2150 and 2650 yr BP (Tracey, 1972, 1980) and from an emergent and truncated reef (dated 4680-4310 yr BP) and emergent algal ridges (dated 4220 and 3420 yr BP) on Suwarrow atoll in the Cook Islands (Woodroffe et al., 1990).

Based on the foregoing data a three stage model relating sea level change to reef growth, reef flat formation and island formation has been developed and is illustrated in Figure 4B. This model is believed to be applicable in general terms to all of the islands mentioned and probably to Tokelau as well. It is clear that the islands are very young in age, and that although the processes of island erosion and accretion are continuing to this day, the basic form of the islands has been preserved partly as a result of the net fall in sea level in the last 2000 years (Schofield, 1977b). It also suggests that islands and reef flats can be at different stages of development; at the present time some of the reef flats and islands are at an early stage of development; others at a more mature stage.

Where the three atolls of Tokelau fit into this sequence is presently not known. A geomorphological investigation will be required to rectify the lack of local data. The relevance of such a study is also clear. For instance, for the islands cited above the evidence shows that sea level has fallen to its present position (unlike many other places such as the eastern USA where it has risen and is still rising) which means that when the greenhouse sea level rises it will initially occupy levels where it has already been in the recent past. Thus, the vulnerability of atoll islands to future sea level rise may be determined to a large extent by whether the islands developed in the period before 2000 years ago at the time of higher sea level or whether they have accumulated since that date. The former islands will certainly be more resilient in the face of sea level rise than the latter.

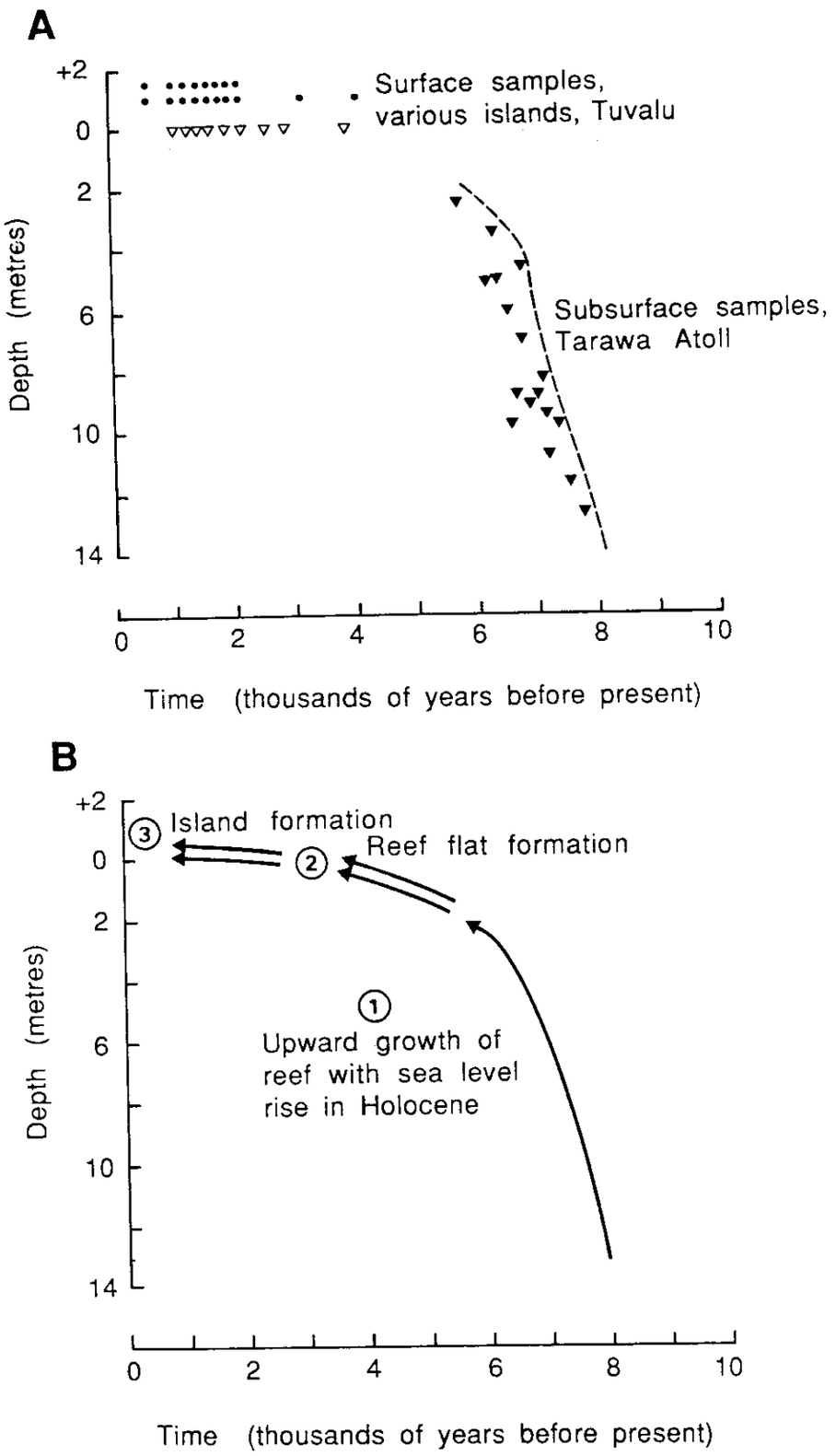


*Figure 4: Atoll reef and island response to Holocene sea level change.*

*A. Subsurface data from Tarawa (from Marshall and Jacobsen, 1985) and surface data from Tuvalu, elevations schematic (unpublished data from McLean)*

*B. Three phase model of geomorphological change (from McLean and Hosking, 1991).*

3. the more protected central area of the islets is more luxuriant in number of species, their abundance and density of growth at all levels. The coconut palm is the dominant overstorey tree and reaches 10-20m high. Trees include *Cordia* which occurs particularly on the outer edges of the coconut woodland, *Pisonia* in limited stands and *Guettarda* and *Pandanus*. Seedling trees and tall shrubs of these and other species form a crowded understorey together with low shrubs such as *Pipturus* (fau) and the terrestrial and epiphytic ferns such as *Asplenium* (lau mei) and *Phymatodes* (lau maile). The dense low ground cover and heavy accumulation of fallen leaves, branches and logs makes passage difficult through such areas.

In discussing the biogeographical relationships of the indigenous Tokelau flora, Parham (1971) notes that although it is composed of a limited number of species (39): "the indigenous vegetation of this isolated group of islets in the Central Pacific ocean has been stable and self-regenerating up to comparatively recent time". While most of the indigenous plants have a wide pantropic or Pacific distribution, some generally common littoral species are very rare or missing altogether. These include the beach-crest trees *Ochrosia, Callophyllum* and *Barringtonia* which "may have disappeared largely as a result of their utilisation by man as a source of timber and firewood".

In addition to the indigenous species Parham identified 20 introduced species including 13 cultivated for food or ornamentals and 7 adventive weeds, all of which are found almost exclusively in and around the village islets or in gardens.

## 2.5 Land Use and Land Resources

The main uses of the land in Tokelau are for settlement (villages, buildings, facilities) for agricultural production including the growing of food crops for people and livestock (chickens and pigs) for copra production and for collecting materials for building, firewood, gardening and other purposes.

Vegetation is the predominant natural resource on the islets and the past and present use of plants has been recently documented by Whistler (1988) who notes that almost all of the native species are or were utilized in some way. Whistler provides specific details of the Tokelauan plant names and their ethnobotanical uses, but for present purposes more general aspects relating to land resource use in Tokelau is given by Hooper and Huntsman (1987) on which the following summary is based.

Coconuts and pandanus are the main food crops grown on all the islets away from the village areas, and there are usually ample supplies of both available. The islets also supply many other economically useful resources to the gathering parties which visit them regularly in canoes and small boats from the villages. The parties commonly collect crabs, the occasional bird, octopus and fish from nearby reefs, supplies of *Asplenium* leaves for use in food preparation, coconut and pandanus leaves for thatching and handicrafts, as well as wood of various kinds for canoes and houses. In the early 1970s, before people began to be heavily involved in a monetary economy, the importance of all these resources was considerably greater than it is at present. Pulaka (*Cytosperma*) is also cultivated on the eastern islets in both Fakaofo and Atafu in pits dug down to the level of the freshwater lens. Pulaka pits are subject to damage from intrusive sea-water during storms and high tides. Breadfruit (*Artocarpus*) is grown in all of the villages and is an extremely important food resource. Most trees produce two good crops a year. Pigs and chickens are kept by almost every household, and they are like pulaka, an important part of the food supplies for ceremonial occasions.

## 4.4 Island Vulnerability to Sea Level Rise

It is generally believed that the two most significant physical impacts of sea level rise on coral islands will be: (1) erosion of the shoreline; and (2) inundation of low-lying areas by seawater. The first reduces island size, the second reduces island 'freeboard'. Thus island size and elevation are seen as critical parameters in any assessment of the potential impact of sea level rise.

The precise impact on a coral island however, will be dependent not just on absolute size and absolute elevation, but also on several other factors relating to the reefs, lagoons and islets. These include:

(a) Characteristics of the reefs and reef flats:

- reef size, total area, length of perimeter etc.;
- reef flat width, the wider the reef flat the greater the potential area for sediment production and dissipation of wave energy;
- reef flat elevation, this is significant in assessing the role of the reef in protecting or exposing an island to sea level rise; and,
- reef and reef flat condition, nature of surface, smooth or rough, bare or sediment covered, healthy or impoverished.

(b) Characteristics of the lagoons:

- lagoon depth, relative relief, slope of lagoon margins;
- lagoon sediments, productivity, availability;
- lagoon vegetation, sea grass cover acts as sediment trap and baffles wave action; and,
- lagoon orientation, fetch in relation to prevailing and storm waves, exposure.

(c) Characteristics of the islets (motu):

- number and location of islets, position and distance relative to reef edge;
- islet size, shape eg compact, elongate;
- length of islet shoreline relative to islet size;
- proportion of reef flat occupied by islets;
- islet elevation, absolute level relative to tides, topographic variation, cross-islet profile;
- islet sediments, unconsolidated sands, gravel, rubble or consolidated lithified hardpan, beachrock, conglomerate; and,
- islet soils and vegetation, cover, root density stabilizing ability, indicators or islet maturity.

The foregoing characteristics individually and in combination will affect the susceptibility of the islands to sea level rise. While the derivation of some indices of individual island vulnerability should be possible using relatively simple methods based on analysis of large scale maps, charts and aerial photography, to obtain data of the required resolution ground survey and field levelling and measurement are essential. Because of the obvious visual differences in reef, lagoon and island geography between the three atolls of Tokelau and their motu, it is most unlikely that sea level rise will impact all of the islets equally. While it is not possible at this stage to conclude which islands are the most vulnerable and which islands are the least vulnerable to erosion and inundation, some effort should be made to gather the required data for such an evaluation.

# 5. Oceanographic Factors

## 5.1 Introduction

Scenarios of future sea level rise as a consequence of global warming were alluded to in secion 1 and longer term sea level changes were assessed in the previous section. Here we review the record of sea level change in the recent past, initially at a global scale before focussing on the central Pacific region in the absence of any tide gauge data from Tokelau. The magnitude of recent and contemporary variations in mean sea level in the region (based on data from nearby islands in Kiribati and Tuvalu) is shown to be large and to be a response to a complex set of inter-related oceanic and climatic factors including the equatorial ocean current and trade wind systems. What long-term changes will take place in ocean circulation and ocean-atmosphere interaction in the central Pacific as a result of the greenhouse effect, and how these will affect sea level in the region, is not known. But it is most unlikely that there will be any lessening in the magnitude of fluctuations in mean sea level in the short-term.

## 5.2 Sea Level Changes During the Past Century

There have been several attempts to determine the pattern of global sea level change over the last century using tide gauge records from around the world. For the International Panel on Climatic Change (IPCC) report Warrick and Oerlemans (1990) tabulate 13 different estimates of global mean sea level rise over various periods during the last 100 years. These range from about 0.5mm/yr to 3.0mm/yr, with most lying in the range 1.0-2.0mm/yr: "a range that is remarkably insensitive to data analysis methods used in the estimation procedure" (Barnett, 1984) despite the very strong geographical bias in favour of the northern hemisphere of 'reliable' tide gauges and the need to allow for tectonic and other local influences. However, as Barnett (1983) points out, the "lack of data in the southern hemisphere and mid-ocean regions means one must accept significant risk in interpreting the results in terms of 'global' changes".

Notwithstanding this lack of global coverage, there have been a few attempts to utilise the available data and to search for regional patterns within the global context. These include the analysis of Gornitz and Lebedeff (1987) who used two methods which gave global rises of 1.0mm/yr and 1.2mm/yr. More significantly, they produced a series of composite regional average sea level curves for 11 regions, including the Pacific Islands region which covers the western and central Pacific between 140°E and 140°W and over 20° north and south. Their analysis indicates that sea level is rising in all but three regions, one of which is Pacific Islands. Figure 5 clearly shows the difference between the global and Pacific Islands results. Note: first, the large year to year variation in the Pacific Islands record; and, second, the difference in the trend lines which show a Pacific Islands trend of only +0.1 mm/yr for the whole record and a change from rising trend up to 1931 to falling trend in sea level since 1932. These trends are obviously quite different to the 'global' average.

## 5.3. Recent Variations in Mean Sea Level in the Central Pacific

A number of tide gauge stations have been operating around the Central Pacific since the early 1970s and a few have records going back to the 1950s and earlier. Monthly mean sea level data for several stations for the last 20 years are plotted in Figure 6. These data, show that there is a very high variability in mean sea level from month to month and from season to season. Interannual variations in mean sea level are also large, the most obvious one being the 1982-3 El Nino event (sea later). There are also differences in the longer term trends, but these are not consistent for all stations. The records for Kiritimati and Tanton show no discernible long term trend over this period or over the previous 20 years.

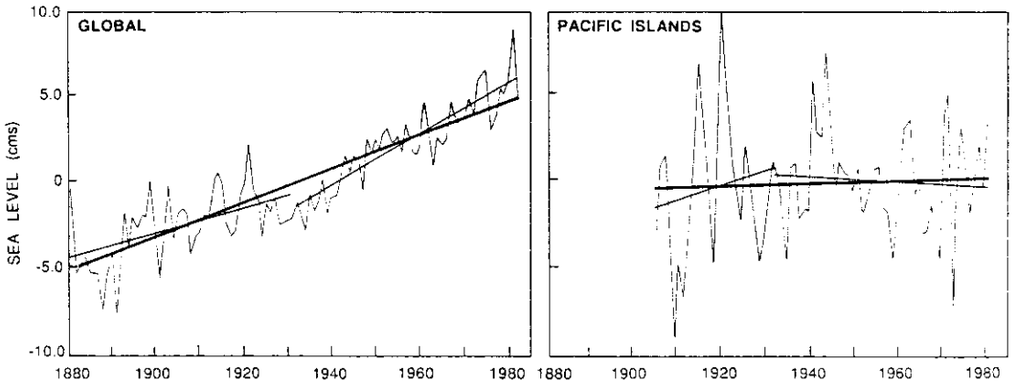


*Figure 5: Global and Pacific Islands sea level curves for the last 100 years. Bold line epresents least squares slope for length of record; light lines represent least squares slopes for the intervals 1880-1931 and 1932-1980. The global curve includes data from over 200 tide stations around the world; the Pacific Islands curve is based on 6 tide stations in the mid-western Pacific region (After Gornitz and Lebedeff, 1987, Figure 7).*

It is very clear from these records that sea level variability is presently large, both temporally and geographically, and that the magnitude of some of the short term fluctuations fall within the range of those predicted for the greenhouse related sea level rise. The reasons behind some of these fluctuations are summarised below.

### *5.3.1. Seasonal Variations in Mean Sea Level and Ocean Currents*

Seasonal variations in sea level are related to changes in strength of the major zonal equatorial currents and the strength, area and location of the trade wind systems (Wyrtki, 1974). The pattern of ocean currents which run from east to west and the countercurrent which runs in the reverse direction (ie. from west to east) is shown schematically in Figure 7A. These currents pass directly through the islands of Kiribati, Nauru and the Marshall Islands, the northern Cooks, Tokelau, Tuvalu, the Solomon Islands and New Guinea. All tide-stations in the region show a strong seasonal cycle in sea level, in the order of 10-20cm with extremes of over 30 cm, reflecting the strength of ocean current flows; for instance an increase in flow velocity increases the cross-flow water slope and this is registered as a rise in water level at a tidal station in the midst of the flow. Large annual and interannual variations of the major zonal currents of the central Pacific for the period 1970-87 have recently been described by Taft and Kessler (1991). Their analysis is based on sea level data from a number of tide stations from Midway atoll in the north to Tahiti in the south, this traverse being located orthogonal to the main current directions and to the east of Tokelau.

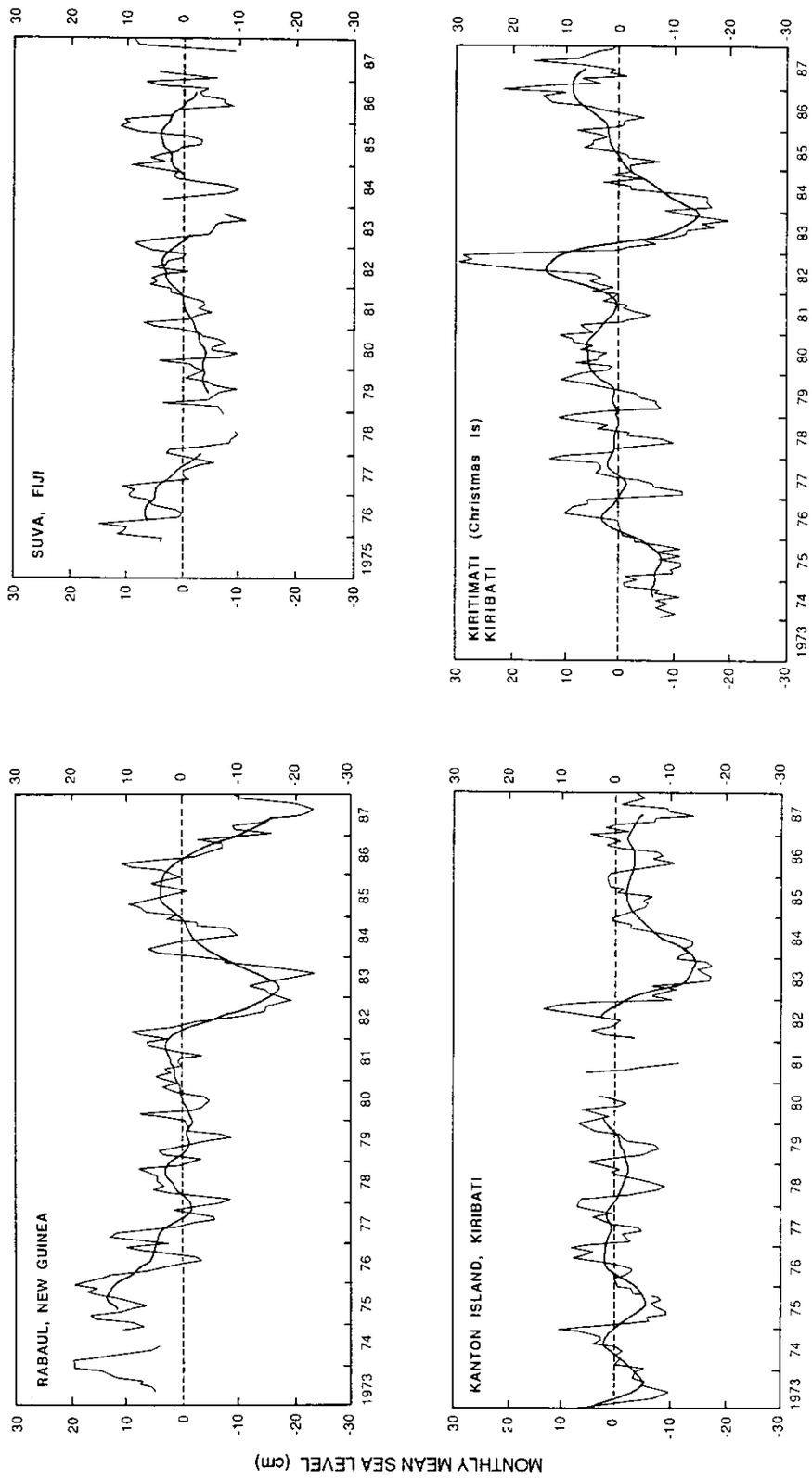


*Figure 6: Monthly mean sea level for four tidal stations in the Pacific, 1973-1987 (After Wyrki, 1990).*

### *5.3.2. Sea Level during El Nino events*

In addition to the relatively regular seasonal variations in sea level in the central Pacific there are also interannual variations the most important of which is the El Nino phenomenon. Wyrtki (1975) showed that El Nino is triggered by the breakdown of the trade wind system in the central and western Pacific. During normal periods of strong easterly trades, there is a sea level set-up in the west equatorial Pacific with an overall west-to-east downward slope of the sea surface along the equator. This slope shows very clearly in Figure 7C. However, when the trade winds weaken the potential energy of this sloping water surface is released; the accumulated warm water in the western Pacific propagates eastward and the sea surface bulges up as a moving rise in sea level passing from west to east across the Pacific. At Kiritimati sea level reached a maximum of +28 cm in November 1982 with a subsequent low of -21cm in October 1983. This El Nino was quite an exceptional event and resulted in extremely rapid and large variations in sea level extending over a period of about a year right across the Pacific. Tokelau was not immune from these variations. Indeed several Tokelau people vividly recalled the low sea level phase, when the lagoons became 'lakes' isolated from the ocean. Water level was some 20-30cm below normal for a period of 2-3 weeks. Lagoon fish and corals were killed in the stagnant and heated water and there was a putrid smell all around the atoll. The 1982-83 El Nino has been the subject of many studies (for example by Lukas, Hayes, Wyrtki 1984: Wyrtki 1984). Changes in sea level during the 1986-87 event are also shown on the time series in Figure 6 and details of this lesser event have been covered by Cheney and Miller (1990)

## 5.4. Recent Sea Level Change and Variability: Summary

Several points emerge from the preceding analysis. First, there are very great differences between the global sea level record and that of the central Pacific region over the last few decades. Second, close linkages have been established between sea level behaviour and other climatic and oceanographic parameters, operating at a variety of time scales: eg. seasonal, interannual etc. Third, the absolute and relative magnitude of variations in mean sea level in the region are large (up to 50cm during the 1982-83 El Nino) especially in view of the fact that the tide range is generally low. Finally, local sea level effects due to changes in ocean current patterns and trade wind regimes are likely to dominate the sea level record in the central Pacific over the next few decades, just as they have done in the past. In the long-term such variations will be superimposed on any greenhouse induced global sea level rise.

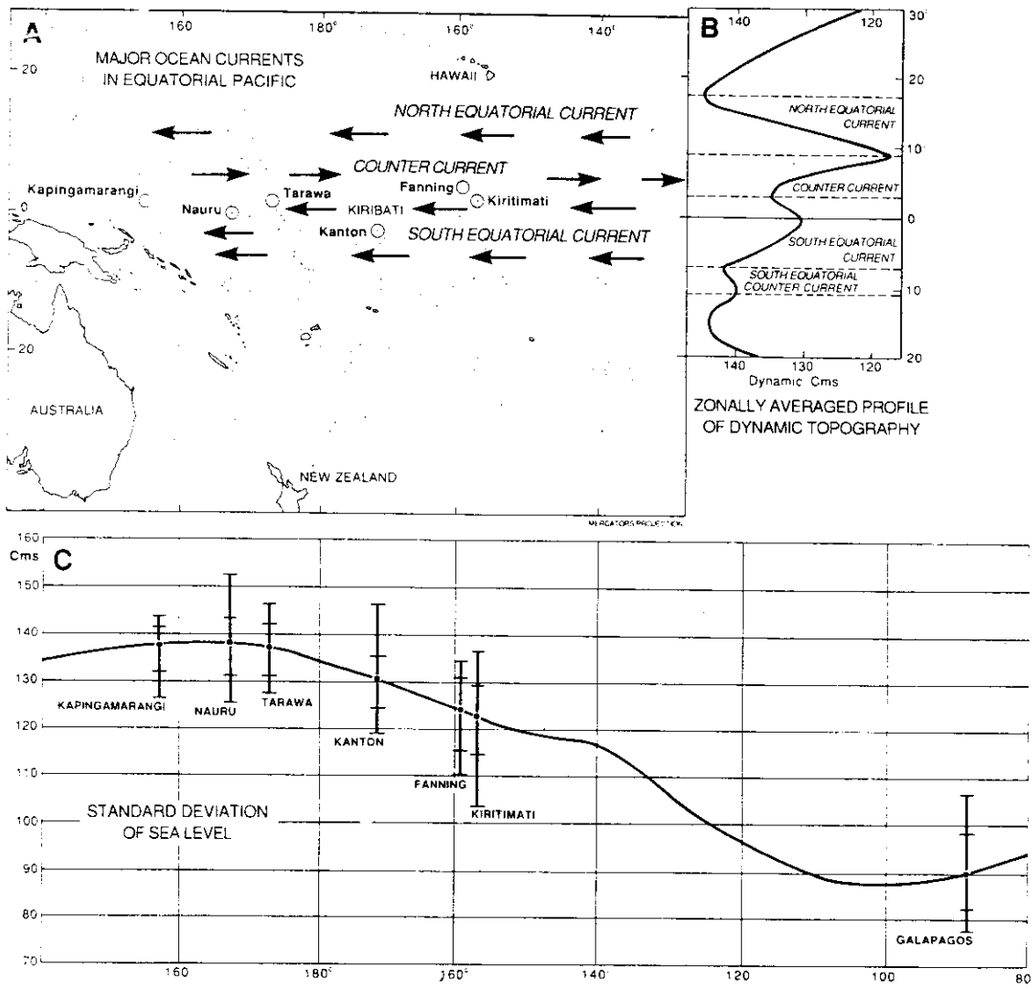


*Figure 7: Relationship between sea level and ocean currents in the equatorial Pacific.*

*A. Major zonal currents and location of islands where tide gauges have been used for C.*

*B. Meridional profile of sea surface dynamic height relative to 500 db. A zonally averaged mean annual profile showing the system of 'ridges' and 'troughs' in the sea surface (After Wyrtki, 1974, Fig 1).*

*C. Slope of sea level along the equator. For the tide gauge stations variability of sea level is shown by vertical bars giving the highest and lowest monthly mean and the standard deviation relative to the long term mean at each station prior to 1982 (After Wyrtki, 1984, Fig 1).*

*Note: Tokelau is located south of Kanton.*

# 6. Climate and Meteorological Factors

## 6.1 Introduction

There are no greenhouse predictions of climate changes specifically for the central Pacific Ocean. However, it has been suggested (in Whysall, Cooper and Bigg, 1987) that alterations in the trade wind system will cause changes in tropical rainfall and in the location and intensity of the Intertropical Convergence Zone (ITCZ). One suggestion is that increased sea surface temperatures and seawater evaporation would result in increased precipitation over the oceans in low latitudes. Another scenario is that the tropical atmosphere will become more stable and decrease rainfall potential. It has also been suggested that the range, frequency and intensity of tropical cyclone activity will increase (Buddemeier and Oberdorfer, 1989).

In the tropical Pacific the dominant climatic fluctuation is the El Nino- Southern Oscillation (ENSO) phenomenon. Hence a major consideration for the future is the possible state of the ENSO phenomenon under greenhouse warming conditions. There is currently little information available on a greenhouse scenario for ENSO (Holland, et. al. 1988), although Lau (1985) was able to reproduce the temporal evolution of individual ENSO episodes occurring in the 1962-1976 period using numerical simulation modelling.

Three features characterise conditions in ENSO locations. First, there are large temporal (especially interannual) variations in some climate elements. Second, there are large spatial (latitudinal and meridional) differences in climate patterns. And third, the climatic elements are all closely inter-related, including for example trade wind strength, sea surface temperature, and rainfall and these in turn are coupled to some of the oceanographic parameters mentioned in the previous section. Irrespective of any gradual secular change that may result from greenhouse conditions, it is therefore likely that the future climate of Tokelau will continue to be characterised by a high degree of temporal variability, as it is at present.

## 6.2 Rainfall and Drought

Figure 8 maps the distribution of mean annual rainfall in the central Pacific region and the caption highlights the main points relating to Tokelau. To the north and east there is a steep rainfall gradient to the equatorial dry belt, and to the west a gradient to the high rainfall region centred to the west of Tuvalu. The implications of such gradients for Tokelau are clear. Any persistent zonal or meridional shift in the processes which cause rainfall (or drought) from global warming could have a significant effect on the geographical distribution of rainfall. A meridional displacement of the isohyets to eastward would result in increased rainfall in Tokelau, while a westward shift would heighten the incidence of drought.

The map of mean annual rainfall disguises temporal variability. The amplitude of rainfall differences from year to year can be quite large, and shorter and longer spells of dry and wet conditions also occur, such as the drought on Fakaofo from March-July 1976 and Nukunonu from May-October 1976. The reason for such temporal variations in rainfall are now relatively well known and have been covered by Thompson (1986, 1987). In simple terms the persistence of extremes in rainfall distribution are linked to the Southern Oscillation Index (SOI), a measure of air pressure difference in the Pacific, and known to be closely correlated with several climate elements.

When the SOI is positive sea surface temperatures in the eastern Pacific are cool, the easterly trade winds are strong and/or extensive and low rainfall (or if persistent, drought) results in Tokelau. When the SOI is negative the easterly trades are less frequent or weaker and moist westerly winds relatively more important, sea surface temperatures are higher and higher rainfall results. Since the 1970s, five of the seven dry years have been associated with positive SOI and four of the seven wet years with negative SOI. That is, in Tokelau "low rainfall periods are likely to be associated with a positive SOI, while high rainfall periods are likely when the SOI is negative" (Thompson, 1986, p.19).

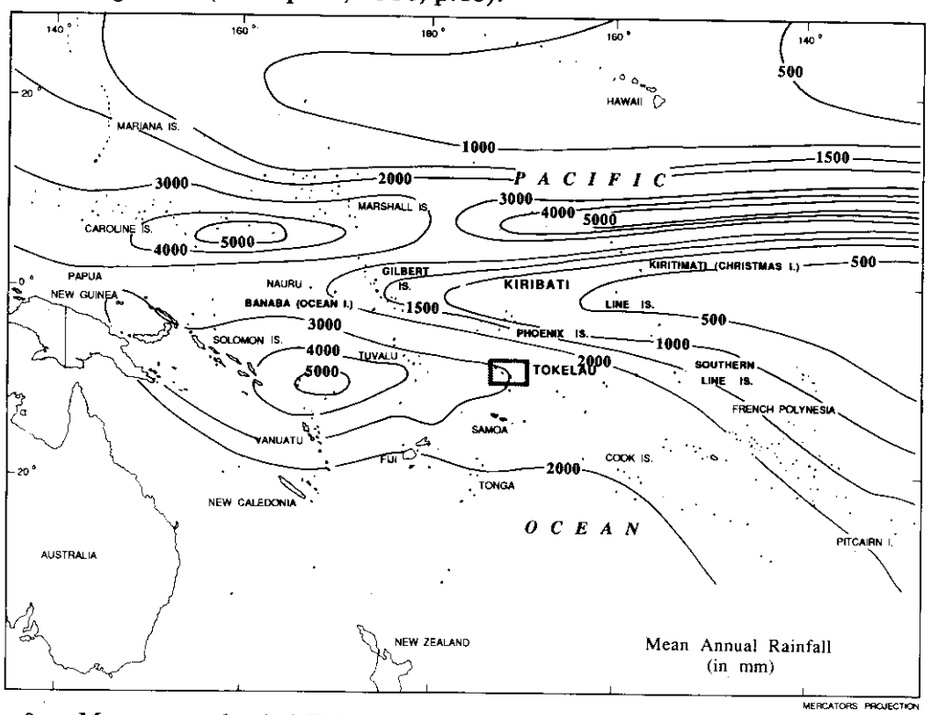


*Figure 8: Mean annual rainfall (in mm) over the central Pacific Ocean (after McLean, 1980, Figure 9).*

*The main features can be summarised as: (1) an equatorial dry belt extends from the South American coast westward through the Line, Phoenix and Gilbert Islands; (2) Two wet zones flank this belt, one running zonally north of the equator, the other centred between the Solomon Islands and Tuvalu and corresponds in location to the Intertropical Convergence Zone (ITCZ). The wet zones overlie pools of warm sea water, while the lower rainfall zone in the east reflects cooler sea surface temperatures; (3) Tokelau lies between the wet zone to the west and the dry zone to the north and east.*

## 6.3 Changes in the Trade Wind Regime

As a result of increased warming in higher and mid-latitudes, (associated with the greenhouse effect) a decrease in the latitudinal temperature gradient would be expected to lead to a decrease in strength of the zonal winds by as much as 20 per cent. Winds in Tokelau are presently governed chiefly by seasonal movements of the Intertropical Convergence Zone and Equatorial Doldrum Belt. Easterly trade winds prevail throughout year (Figure 9). During drier months (April-September) easterlies are more frequent while winds between north and west prevail during the wetter part of the year (October-March). Winds are usually light and gales rare. Strong winds are more frequent from the westerly quarter and are usually associated with squally showery conditions. In some years monsoonal westerlies are frequent while in others they may occur only for a few days. Seasonal and interannual variations in wind strength and direction in Tokelau are superimposed on longer term changes in the tropical Pacific wind field that have only recently been recognized.

## 6. *Conclusion*

The field reconnaissance was of limited duration and geographical scope. Only the four village motu were visited and discussions with officials and residents were too brief to explore the issues raised in this report. Moreover, each of the four village islands are located on the western rim of the atolls to the lee of the southeasterly trade winds and seas and more exposed to the summer westerlies. Most of the land area on each atoll is on the opposite eastern side. Thus the foregoing comments on island geomorphology and vulnerability refer particularly to the western motu. With current projections of climate change and sea level rise through to the year 2050, it is concluded that the islands in Tokelau will not suffer the fate suggested in the introduction to the main report. But, the islands will continue to be highly vulnerable to accelerated sea level rise, particularly the village motu, and will continue to experience large interannual variations in sea level and fluctuations in climate, including droughts and storms as they have done in the past.

## 7. *Itinerary of Visit*

**Saturday 5 December**

| | |
|---|---|
| 2300 | Departed Apia, M V Wairua |

**Sunday 6 December**

| | |
|---|---|
| | Enroute Apia-Tokelau |

**Monday 7 December**

| | |
|---|---|
| 0645 | Arrive Fakaofo. Met with Peni Semisi (Faipule) and George Tinielu (OTA). Inspected gabions and tour around Fale. Met with Keli (seawall construction foreman) |
| 0945 | Level survey, transect 1 ocean reef edge, gabion wall to Falepopo (copra shed) assisted by Apeti |
| 1030 | Return to boat |
| 1100 | Depart Fakaofo for Nukunonu |
| 1530 | Arrive Nukunonu |
| 1545 | Met with Pio Tuia (Executive Officer). Inspected seawalls, channel to bridge, private gabions on lagoonside. Met with Steve Brown (UNV) |
| 1815 | Return to boat |
| 2000 | Depart Nukunonu for Atafu |

**Tuesday 8 December**

| | |
|---|---|
| 0700 | Ashore at Atafu. Met with Kuresa Nasau (Faipule) and Maka Toloa (Executive Officer) |
| 0830 | Levelling survey of three transect across island and gabions |
| 1130 | Inspected gabions southern end |
| 1200 | Lunch put on by Women's Committe |
| 1300 | Welcome by Paulo Kitiona (Pulenuku) and meeting with Elders to discuss purpose of visit. Chair and translator Dr Iosefa. Steve Brown in attendance. |
| 1430 | Discussions and walk with Faipule and Steve Brown to north of island. Inspected pig pen wall, rubble bank on oceanside formed during storms, return to village. |
| 1700 | Left for ship |
| 1800 | Departed Atafu for Nukunonu |

**Wednesday 9 December**

| | |
|---|---|
| 0900 | Ashore at Nukunonu |
| 0900 | Levelling surveys, three transect from ocean to lagoonside across island |
| 1150 | Return to ship |
| 1245 | MV Wairua departs for Fakaofo |
| 1715 | Arrive Fakaofo |
| 1715 | Levelling surveys across Fale, continuation of transect 1 plus transects over private gabion walls and pig pen wall. |
| 1900 | Return to ship |

**Thursday 10 December**

| | |
|---|---|
| 0815 | Ashore at Fale and transported to Fenuafala |
| 0830 | Levelling survey across Fenuafala, ocean to lagoonside |
| 1000 | M V Wairua departs for Apia |

**Friday 11 December**

| | |
|---|---|
| 1530 | Arrive Apia |

Analysis of 64 years of marine surface wind data from 5°N to 5°S by Whysall, Cooper and Bigg, 1987) show that during the period 1940-44 there was a strong westerly anomaly which was concurrent with a collapse of the trade winds and with anomalies in sea surface temperature and sea level pressure. During this period the warming of the oceans and the westerly wind anomaly resembled a prolonged El Nino. In the period 1950-81 there was a trend towards zonal and meridional strengthening of the trade winds over much of the Pacific Ocean. This is consistent with the cooling of the atmosphere between 1945-70 and slight warming of the ocean during the same period. There is also evidence in the data for the trend to decrease or even reverse in the mid-1970s (Whysall, Cooper and Bigg, 1987).

Two points arise from this analysis. First, alterations in the trade wind system are expected to cause changes in tropical precipitation, and in the location and intensity of the Intertropical Convergence Zone. And second, changes in the trade wind field appear to have been occurring over long time (decadal) scales, whereas previously only seasonal and interannual variations had been clearly recognised. Such longer term changes are implied under greenhouse conditions, but higher frequency variations in wind speed and direction (seasonal and interannual) can still be expected to dominate in Tokelau in the future.

## 6.4 Tropical Cyclones and Storm Surges

Many studies on the greenhouse effect suggest there will be some increase in the present range, frequency and intensity of tropical cyclone activity as a result of global warming, and, that with a higher sea level, the problems of storm surges will become more acute. For instance, Emanuel (1987) has suggested that tropical cyclones may increase in intensity as a result of sea surface warming. His model shows that relatively large increases in intensity occur with small increases in sea surface temperature. But his analysis pertains only to the maximum intensity and has no direct implications for either average intensity or frequency of occurrence. Holland, et. al. (1988) consider it likely that cyclone activity will increase in the central south Pacific as a result of increases in sea surface temperature, but they caution that detailed regional predictions are not possible at this stage.

Potential changes in tropical cyclone activity may have special significance for Tokelau given that it lies south of the equatorial doldrum belt where hurricanes are extremely rare (because of the lack of cyclonic vorticity or background rotation near the equator and because there are often zones of strong vertical windshear through the troposphere, both of which inhibit cyclone formation) and immediately to the northeast of the core region of the south Pacific hurricane belt (Figure 9). Any persistant equatorward or easterly movement of the core region towards Tokelau would likely result in increased cyclone activity in the group. There is, however, no certainty that this will occur under greenhouse conditions. Nor is there any certainty that the 'apparent' increase in storm activity in the Tokelau region in the last five years reflects a 'real' increase.

However, notwithstanding both possibilities, it is very clear that locally generated storms as well as extra-equatorial storms, will continue to impact the islands in the future and that any environmental planning must take this fact into account. Moreover, Tokelau's experience of the storm waves in February 1987 suggests that meteorological information alone is not enough and that weather forecasts need to be matched with tidal information to identify when unusually high tides ("danger days") can be expected (Richards, 1991).

Also these recent examples serve to illustrate how the islands initially formed and grew. Evidence for earlier episodes of accumulation are apparent in the stratigraphy of the motu which show successive layers of coral gravel (kilikili) and sand (oneone) built up during storms and longer periods of normal wave activity. Periods of land stability and the presence of vegetation are also evident in the subsurface stratigraphy as dark humus rich soil layers with charcoal indicating human activity. Such layers indicate that the motu were much lower than at present and when, as Best (1986) found during his archeological survey, conditions for settlement were "far more difficult than those of today." He concludes that:

The islands on which the present-day villages of Atafu and Fakaofo are situated were between one and two metres lower and thus more vulnerable to storm waves

This comment is equally applicable to Nukunonu where stratigraphic sections excavated for the placement of the gabion seawall indicate an occupation layer at least lm beneath the present surface. Clearly, in all cases there has been substantial build up of the motus since those earlier days of occupation.

Finally, surveys across the four villages carried out during the present visit show that these motu all have an asymetrical profile with the highest elevation at the oceanside ridge and the surface dipping down towards the lagoon. Such profile indicate that the motu have extended lagoonward as a result of westerly storm wave erosion, deposition and washover, the lagoonside beach initially migrating across the conglomerate platform and then onto the shallow sandier parts of the lagoon shore. On Fenuafala, Atafu and to the north of the Akau Loa on Nukunonu, sandy sediments derived from the lagoon have also aided this process. But on Fale (Fakaofo) and south of Akau Loa at Nukunonu further lagoonward extension of the motu is limited because the shoreline drops off into deep water.

*5. Island Vulnerability to Future Sea Level Rise and Storms*

In section 4.4 of the main report a list of natural internal factors were identified that will affect the susceptibility of atoll islands to future sea level rise. These factors include: (1) characteristics of the reefs and reef flats; (2) characteristics of the lagoons; and (3) characteristics of the islands themselves. A comparable list could be developed for future storm impacts.

The role of past sea level changes in the origin and development of atoll islands, and the role of past storms in island erosion and building in Tokelau, were examined in the previous two sections, which provide a perspective with which to assess island response to future sea level rise and storms. Providing that coral growth and the production of reefal sands and gravels can keep pace with sea level rise, it is likely that the islands in Tokelau will continue to grow in elevation and size under the most recent projections for sea level rise and climate change given earlier in this report.

However, if substantial modifications are made to the natural reef-beach-island systems through injudicuous removal of reefal materials, pollution and deterioration of reefal quality, excavation of boat channels and the construction of seawalls that impede or prohibit sediment transfers, then vulnerability will increase. Such activities have already taken place on and around the village motu. Major developments such as the construction of airstrips, extension of boat channels and further concentration of activities in these areas will exacerbate the problem. On the other hand, there are abundant alternative motu on each atoll, though the possbility of internal resettlement appears not to have been seriously considered. In this regard attention is drawn to the four recommendations made in section 9.6.

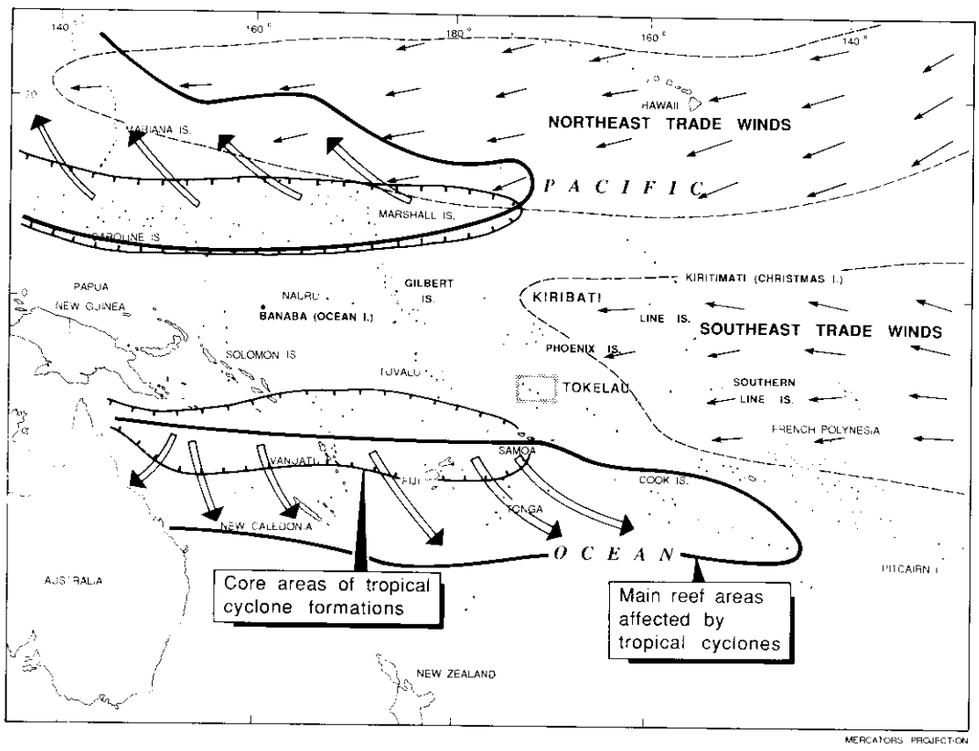


*Figure 9: Location of Tokelau in relation to trade wind and tropical cyclone belts.*

*Note: (1) Tokelau lies to the west of the core area of the southeast trade winds. While the annual mean trade wind field extends into the Tokelau region, the area depicted on the map is always covered by the trades (Based on Wyrtki and Myers, 1975, Fig 13A). (2) Tokelau lies to the northeast of the core area of tropical cyclone formation in the southwest Pacific, which produces on average about 7 hurricanes per year. However, cyclones do develop to the north of the core area in the Tokelau-Tuvalu region, but they are not as frequent as to the south. To the north of Tokelau is the doldrum belt, which is essentially a hurricane-free area.*

No emergent corals in growth position were found during the limited field observations in Tokelau, but the widespread occurrence of conglomerate platforms on all three atolls suggests that Tokelau has experienced a similar sea level history. Thus the three stage model relating sea level change, reef growth, reef flat formation and island formation as portrayed in Figure 4 does appear applicable to Tokelau. Critical in this interpretation is the presence of the conglomerate platform (the coral 'hard-pan' or te papa) which in Tokelau (i) is comprised of tightly cemented coral rubble; (2) has an essentially planar surface; (3) is only occasionally inundated at high tide; and (4) forms a distinct step between the contemporary reef flat and motu beach (on surveyed cross-sections the step is 0.5 - 1.0m high).

The conglomerate platform is exposed along the ocean side of most motu where it forms a solid pavement, typically 20 - 50m wide, extending seaward from the base of the active beach. On none of the four village motu does the conglomerate platform occur on the lagoonside, a point which has relevance when considering island evolution and stability. Extensive areas of conglomerate platform are exposed on reef flats along the western rim of the atolls. These include named sites such as Ulupapa south of Atafu vllage; Na Papa, Na Papa o Atawhu and Te Mata Papa between the islands of Motuhaga and Te Puka o Mua on Nukunonu; and, Te Papa (the piggery area) immediately to the north of Fale on Fakaofo.

While further work on the origin and age of the conglomerate platform is required, generally its role is clear. Virtually all of the motu in Tokelau appear to have accumulated on this solid raised basement, which probably became emergent with the recent fall in sea level. There are two implications of this. First, when sea level rises in the future it will initially occupy levels where it has alredy been in the past (presumably 2-4000 years ago). And, second, the conglomerate platform, together with the high coral rubble ridge along the oceanside of the motu, offers some natural protection and stability to the islands against storm waves and sea level rise.

The extensive exposures of conglomerate platform without vegetated motu presently upon them are more problematic. Whether or not they have all supported motu in the past is not known. Nor is it known whether or not they will provide locii for the development of motu in the future. However, there is evidence to suggest both possibilities. For instance, residents on Nukunonu indicated that sedimentary deposits and vegetation were more extensive on the conglomerate platforms between Motuhaga and Te Puka o Mua in the past. Likewise on Te Papa (the piggery area) on Fale at Fakaofo. On the other hand incipient motu, in the form of sand deposits emergent at halftide, cover several of the conglomerate platforms along the southwestern rim of Nukunonu. In either case the role of storms, either as erosional agents or as providers of coral rubble to form ridges of sand and gravel is critical.

### *4. Role of Storms in Island Building and Erosion*

While the destructive effects of cyclones VAL, OFA and earlier TUSI were uppermost in residents minds on all three atolls, most recognized that in addition to the erosion of shorelines and stripping of soil from around the bases of exposed coconut palms, pandanus roots and tree trunks, (and undermining of house foundations, slab seawalls, etc), the storms had also washed sands and stones on to parts of the motus. Some of this material had come from the erosional sites and some fresh from the adjacent oceanside reef flats. Not only were sediments deposited on the surfaces of motu, but in places new banks of storm rubble appeared on reef flats (such as the 40m wide boulder tract in front of the village at Atafu) or new ridges of coral gravel accumulated near to or against the oceanside beaches (such as the extensive natural 'reclamation' along the northern half of Atafu).

These examples serve to illustrate the fact that storms are both erosional and depositionai events. Generally, under natural conditions, the net effect is to primarily enlarge islands and increase their elevation, rather than reduce their area and height.

# 7. Environmental Perception

## 7.1 Introduction

Results of indepth discussions with eight OTA directors, members of Tokelau's Council of Elders, residents and teachers in Tokelau conducted in July 1991 (d'Aubert, 1992), will be combined with results of informal discussions with 18 OTA staff conducted in 1992 during the present mission's visit to the OTA. The aim of both sets of research was to gain an appreciation of the awareness among Tokelauans concerning the components of Tokelau's environment and perceptions of the atolls vulnerability towards changes that they think may happen in the future, including the impacts of climate change and sea level rise.

## 7.2 Perceptions of Environmental Change

The overwhelming majority of those spoken to identified that "the way of life" was Tokelau's most meaningful characteristic. The community living; the peacefulness and lack of stress - "no hassles"; the "Tokelau way of thinking"; plentiful food and the abundance of fish: the beauty of the lagoon, reef and oceans; and Tokelau's small size and intimacy, were all considered part of "the quality of life". Most Tokelauans believe they have an intimate understanding of their atoll environments. Some have specialised traditional knowledge of the plant and animal life of the lagoons and motu. This traditional knowledge extends to their ability to read the most subtle of changes in the behaviour of the sea currents and tides, the different seasons and weather patterns.

Recently many Tokelauans have observed environmental changes that they are less able to explain. The observation most immediately identified as being very significant is that the length of time between each of the last five major cyclones to hit Tokelau has decreased: 1914----1966----1987----1990-----1991. Other changes which they have also observed include unexpected sea level fluctuations. For example, a very low tide event over approximately three weeks destroyed all coral and reef life and when the water returned the high tide level rose and has remained higher than the previous high tide mark. Other observations made were: unusual changes in wind directions for specific seasons; changes in ocean currents adversely affecting fishing patterns; changes in the behaviour of certain migratory fish; and a 'hotter' sun. The elders in the village councils expressed their concern over these changes and question whether they are signs of a changing climate related to global climate warming. A number of administrators in the OTA are aware that these events are related to the El Nino/Southern Oscillation.

In addition to these observations, many Tokelauans have recently become acquainted with the concepts of climate change, greenhouse effect and sea level rise. However, many find it hard to conceive what climatologists, scientists and the like are describing. Nevertheless, these issues have made Tokelauans talk amongst themselves and question the causes of past and present changes they have observed in their atoll island environments. It should be noted that there could very well be some inter-play in their interpretations of climate change and changes in their own local environment.

# Annex 3: Report on Visit to Tokelau, December 1992 by R F McLean

## *1. Introduction*

After completing the final draft of the present report one team member (RFM) visited Tokelau to undertake an environmental impact assessment of the existing and proposed extension to the gabion seawall protection, and, at the same time, to undertake work in accordance with the terms of reference for the climate change preparatory mission.

The MV "Wairua" departed Apia at 2300 hr Saturday 5 December and returned at 1530 hr Friday 11 December. In all, a total of 23 hours was spent on the three atolls, approximately 8 hours on Fakaofo, 5 hours on Nukunonu and 10 hours on Atafu. Informal discussions were held with village leaders on each island, shorelines and shore protection works were inspected and levelling surveys across the four village motu were carried out. Only on Atafu was a formal meeting with elders and island officials held. A detailed itinerary of activities is appended.

## *2. Perception of Climate Change and Sea Level Rise Issues*

Island leaders had been advised that the primary purpose of the visit was to do with gabion seawall construction and shore protection and discussions focussed on these issues. Discussion on the longer term questions of climate change and sea level rise was limited. This I put down to several factors. First, in the past few months there had been little publicity and comment about the greenhouse effect, climate change and sea level rise. Second, there were more pressing concerns about the current cyclone season and whether or not the seawalls would provide effective protection. This concern was highlighted by the fact that the visit coincided with the first anniversary of Cyclone Val. Third, other environmental issues such as waste management and pollution were of more immediate concern because of the presence of a UNV (Dr Steve Brown) from the Environmental Unit who was conducting workshops in the islands at the same time.

Notwithstanding the foregoing priorities, the visit confirmed that many resident Tokelauans are sceptical about the prospect of sea level rise for reasons given in Section 7 (Environmental Perception) of this report. It appears that while officials of the OTA are aware of, and are concerned about, the possible long term consequences of climate change and sea level rise for Tokelau, island resident themselves do not equally share that concern. Two further observations are opposite. First, that the linkages between several environmental issues and their interrelationships are not widely appreciated. And second, there appears to be little awareness that some of the current activities in the islands may exacerbate rather than reduce the potential impact of sea level rise (and storms). In this context the recommendations concerning improved environmental awareness through education programs (Recommendation 8) and initiatives through the Tokelau Environmental Management Strategy project require ongoing support.

## *3. Geomorphic Observations and Sea Level Change*

The role of Holocene sea level changes on atoll reefs and islands was discussed in Section 4. It was noted that on some atolls in the central Pacific region there is good geomorphic and radiometric evidence, in the form of emergent algal ridges, in situ corals and conglomerate platforms, to indicate a higher sea level of up to + lm 2-400 years ago and sea level falling to its present position in the last 1-2000 years.

After cyclones many Tokelauans are particularly aware of the atolls vulnerability. The land, trees, houses, animals, people, everything is vulnerable to the high winds and storm surges. A few Tokelauans are concerned with the methods by which Tokelau will adapt to impacts of climate warming and if it will be feasible to stay in Tokelau. However, we were surprised to find that:

> "Most people are still comfortable about the future, there is little that can be done to stop sea level rise, and the worst will have to happen before serious action is taken" (OTA staff member, 1992).

## 7.3 Belief in Climate Change and Impacts

When asked to share their belief about the likelihood of climate change impacts, the majority of administrators in the OTA felt they could not afford to ignore what they had heard because most scenarios suggested that low lying atolls will be the first to experience severe impacts, (see Section 1.1 and 1.2). Three themes emerge from the collective views of administrators as to what may happen in the future. Firstly, most decision-makers believe Tokelau will have time to adapt because of the gradual nature of the sea level rise phenomenon. Secondly, some fear that eventually the motu will not be able to support the population any longer as droughts lengthen and become more frequent and as fresh water lenses shrink. Thirdly, others believe that a very severe cyclone or a series of cyclones may wreak so much damage as to render the atolls uninhabitable.

When asked if they fear tropical cyclones of greater frequency and intensity more than sea level rise, some replied that while tropical cyclones are an ongoing immediate threat it has proven possible in the past to recover from them, whereas sea level rise could flood and destroy their world completely. In addition to looking at cyclones as normal events and expecting them during the hurricane season, many Tokelauans are confused about all the man-made environmental change and how they influence natural events.

Discussions on the atolls indicated that a large proportion and wide cross-section of the village communities have heard about climate change, greenhouse effect and sea level rise ideas and concepts. However, it is not clear that there is a full understanding of the processes involved in these phenomena.

> "I do not want to agree with it. I want to learn more. I think it might happen but it is so horrible to think about" (OTA staff member, 1992).

Lack of understanding results from the complexity of the topic(s) and also may be a reflection of the avenues through which Tokelauans have received information. For example, radio broadcasts occasionally make reference to the issue and newspapers that reach the islands sometimes have articles about climate change. These are usually very general descriptions of the processes and are not aimed at a Tokelauan audience. They are not in the Tokelauan language. Often such articles/items sensationalise the issue and are confusing. A study carried out in New Zealand found many inaccuracies in newspaper reporting of climate change (Bell, 1989). Because these reports are fragmentary it is quite possible they are taken out of context and confused with other issues. For example, some asked if climate change and nuclear testing are related.

## Annex 2: Programme of Visit to the Office for Tokelau Affairs, Apia, Western Samoa, February 1992.

Thursday 23.1.92 : University of Waikato, Hamilton, New Zealand.
Both team members met for discussions concerning mission timetable to Western Samoa and Tokelau. Combined sources on relevant background material/information on Tokelau.

Thursday 30.1.92 : University of Auckland, Auckland, New Zealand.
Both team members met to discuss disruption to mission timetable and proposed work timetable.

Sunday 23.2.92 : Apia, Western Samoa.
1st team (RFM) member arrived 6am.

Monday 24.2.92 : Office for Tokelau Affairs, Apia.
am:- Met with Foua Toloa, Director of Agriculture and Fisheries, outline program.
pm:- Briefing with Casimilo Perez, Official Secretary; inspected photograph albums and library resources at OTA.

Tuesday 25.2.92
am:- Meeting with OTA Directors as a group.
pm:- Discussions with individual Directors; 2nd team (AMd'A) member arrives 11.10pm.

Wednesday 26.2.92
am:- Team met with representative Elders.
pm:- Talk with SPREP representatives at SPREP HQ; library research.

Thursday 27.2.92
am:- Public Lecture to Tokelau people and others at OTA.
pm:- Discussion with representatives from UNDP and SPREP.

Friday 28.2.92
am:- 1st team member departs.
2nd team member reviews relevant documents.
pm:- Continued review of documents and discussions with Director of Agriculture and Fisheries.

Monday 2.3.92
am:- Discussions with Official Secretary, Director of Administration, and Director of Health.
pm:- Interviews with eight staff members in OTA.

Tuesday 3.3.92
am:- Discussions with Director of Finance and Director of Education.
pm:- Interviews with six staff members in OTA.

Wednesday 4.3.92
pm:- Interviews with members of Tokelauan community residing in Western Samoa.

To date, there have been few opportunities for Tokelauans to have these concepts explained in a forum where they can ask questions and discuss their ideas in their own language. However, the emerging awareness of the issues may be seen as a beginning point for some kind of information dissemination programme. It should also be noted that many Tokelauans do not believe climate change impacts will happen, especially sea level rise. To reinforce this attitude is their strong belief and commitment to Christianity and specifically in God's promise not to flood the world again (After the great flood God made a covenant with Noah stating that whenever people saw a rainbow they could be assured that there would be no flooding of the world again).

> "When there are no more rainbows, I will prepare for sea level rise". (Nukunonu Village Elder, 1991)

Such beliefs should be considered seriously when developing any educational programme concerning these issues for the Tokelauan people need to be dealt with, with sensitivity and respect. Most permanent residents, as opposed to Tokelauans living outside Tokelau, have different opinions towards the reality of global climate change impacts like sea level rise.

> Older people and those who live in Tokelau don't believe it, while those outside Tokelau are starting to question and wait and see (Teacher, 1992).

The opportunities to have the processes of global climate warming, sea level rise and more frequent cyclones explained by experienced scientists have also been rare. During the 1992 visit, a public lecture was held to discuss these issues. To some degree ideas were presented which Tokelauans, up until then, had not heard or able to question. As a result some views have modified:

> Before hearing Roger I was very worried. Most material I've read spells out a sense of doom and a need to react urgently. It appears some of my fears are ill-founded. However, I still think it's a big problem and needs to be dealt with by Tokelau (OTA Director of Department, 1992)

## 7.4 Future Condition of the Environment

During the 1992 fieldwork, OTA staff were asked to express their ideas on the future of Tokelau's environment. It was surprising to see a general lack of understanding of the range of environmental problems facing Tokelau today and into the future. It was particularly apparent among the women spoken to. They admitted to knowing very little about climate change and greatly appreciated the brief informal descriptions given. What this revealed was that if the priority environmental concern in Tokelau is climate change, and the women know very little about it, what is the chance that they understand more pressing environmental concerns affecting Tokelau today? For example, an immediate problem is the pollution of water lenses by household detergents as pointed out in the UNCED report. The link here is that women are the ones who are more likely to undertake cleaning activities using these items. It is essential therefore that communication of environmental issues must be directed to the relevant groups.

This indicates that even among members of the administration, the center of information dissemination, a large number of Tokelauans do not fully understand the consequences of certain activities taking place in Tokelau today, towards the atoll environment, let alone the processes of climate change and sea level rise. While it should be noted that many replies given to questions on the future of Tokelau's economy, culture, population and living conditions, indirectly referred to impacts on the environment, the majority of people did not voice or apparently recognize that link.

(c) an overview of current environmental management problems in the country and an assessment of how such problems may be exacerbated by climatic changes;

(d) a detailed proposal for a joint programme of assistance to host country for the in-depth evaluation of potential impacts of expected climatic changes on the natural environment and the socio-economic structures and activities of the country including the identification of policy or management options suitable to avoid or mitigate the impact of climatic changes, the proposal should identify the workplan, timetable and financial requirements of the in-depth evaluation as well as the possible institutional arrangements for carrying out the evaluation.

Those Tokelauans who are at the forefront of dealing with environmental concerns (mainly Directors of Departments) were much more aware of the consequences of activities that are taking place in Tokelau's life style now. Many were sure that the condition of Tokelau's environment would change in the future and emphasised that it is very vulnerable and that without an environmental management scheme it would almost certainly deteriorate.

Living in Tokelau depends a great deal on how we manage the environment. In order to survive we have to care for the environment. Tokelau is so small we can't afford to dirty the back yard. I can tell resources are being placed under pressure, even depleted, and we should take strong action (OTA Director of Department, 1992).

The majority of people associated pressures on resources with deterioration of the environment. While some Tokelauans believe that pressure on land and sea resources will ease with migration, others see that if inappropriate resource management practices continue there will be significant changes to the environment. With no efforts to replant coconut, pandanus and breadfruit trees after cyclones and cutting down of trees to extend villages, there will be less protection from cyclones and more erosion of the land. Some people see that the location of houses, as a result of the housing scheme, is not conducive to community living and proper Environmental Impact Assessments should have been done.

A few Tokelauans recognize the need for future processing of dried fish to be monitored so as not to deplete lagoon fish stock. They also stressed the need for improved monitoring of the Exclusive Economic Zone. No one referred to the need to monitor private catches using nets and outboard powered dinghies. This has been identified as posing a major problem for fish stocks in the UNCED report (Humphries and Collins, 1991).

Some believe that if the young Tokelauans were to learn about the environment the community will become more aware of what is good and bad for the environment. Others think that the elders are more conscious of issues and in a piecemeal way are applying laws to maintain resources. The example given was that no one is allowed to throw stones at birds anymore. However, the UNCED report identifies that the Councils of Edlers are having difficulty in coming to grips with applying laws to regulate activities for reasons they do not fully understand (Humphries and Collins, 1991).

Conclusions drawn from this research revolve directly around information dissemination and communication of environmental issues to several levels within Tokelau. Information should continue to be disseminated among government decision-makers. This should be passed on to specific adult groups, the elders, the women and the aumaga, through education programmes. In turn appropriate information should be communicated to youth groups and school pupils through education programmes and field exercises.

# Annexes

## Annex 1: Terms of Reference

The terms of reference for this mission on Tokelau was similar to that for the missions to other countries in the region.

*Purpose of the mission*

The main purpose of the mission is to prepare, in close consultation with the Office for Tokelau Affairs, a proposal for a programme of assistance to undertake an in-depth study of the potential impact of expected climate changes (primarily sea level and temperature rise) on the natural environment and the socio-economic structures and activities of Tokelau, including the identification of response options which may be suitable and available to avoid or mitigate the expected negative impact of climatic changes.

Specifically the mission would

(a) examine and evaluate the available information affecting the physical and biological environment (terrestrial and marine) of the islands comprising the country;

(b) examine and carry out a preliminary assessment of the available demographic, social (including archaeological and cultural) and economic data;

(c) present, via a public lecture or radio broadcast as appropriate, an overview of the current state of knowledge concerning the greenhouse effect and its possible consequences for Pacific Island nations;

(d) present to the national authorities, organisations, institutions and experts the results of UNEP sponsored studies, specifically those conducted in the South Pacific (eg. Kiribati) and South Asian Seas areas outlining the potential applicability of these studies in the host country;

(e) discuss with the national authorities, organisations, institutions and experts their perceptions of the consequences of the potential impacts of climatic change and seek their views on the suitable response options, and

(f) identify national authorities, organisations, institutions and experts which may participate in the in-depth study expected to follow the mission, and determine the modalities of co-operation between the legal and administrative structures of the country with the team which will assist in the implementation of the in-depth study.

On the basis of the activities referred to above, prepare a joint report containing:

(a) a general overview of the climatological, oceanographic, geological, biological and socio-economic factors which may be relevant to or affected by the potential impacts of expected climatic changes;

(b) a preliminary identification of the most vulnerable components and sites of the natural environment, as well as the socio-economic structures and activities which may be most critically affected by expected climatic changes;

# 8. Future Environmental Planning

## 8.1 Introduction

Environmental planning, management and protection in Tokelau is at a very rudimentary stage, but this situation is rapidly changing. For instance, at the time of our visit the Department of Agriculture and Fisheries was heavily involved in addressing a range of environmental issues. At that time it also became clear there was an inadequate number of skilled personnel that could be used for environmental planning and management and that this deficiency needed to be rectified. In the interim the work load was being carried by two or three senior OTA officials.

## 8.2 Report for UNCED on State of Environment

Nevertheless, recently there has been considerable initiative and support for environmental policies to be put into place. Work carried out in 1991 for the United Nations Conference on Environment and Development (UNCED) produced a report on the "State of the Environment" (SOE) in Tokelau, (Humphries and Collins, 1991). Funded by the United Nations Development Programme (UNDP) through the South Pacific Regional Environment Programme (SPREP), the report highlighted the potential for environmental problems to occur in Tokelau and the urgent need for environmental policies to be implemented to mitigate some potential disasters.

A number of major conclusions arose from the UNCED/SOE national assessment

- The paramount long-term threat is that of climate change, for which the fundamental solution is not within the control of Tokelau. Only adaptive solutions are possible: protective constructs and emigration.

- Development has been *ad hoc* without due consideration given by donor organisations to social and environmental implications of budgetary assistance and aid projects.

- The ongoing trend towards a monetary economy based on aid and remittances is socially destabilising, an economic risk and environmentally deleterious.

- The current knowledge base and institutional capabilities are not at a level needed to deal with the present and impending environmental problems.

- Tokelauans still have the option of modifying the direction of change provided that there is the political will, budgetary assistance funds are committed to integrated environmental management, external technical support is available, and aid donors assume complementary responsibilities.

A number of social and organisational needs for setting the course of development towards sustainability, and for maximising the opportunities for Tokelau, were also identified, as well as a range of specific projects and programmes. Issues urgently requiring attention in the short-term were identified as:

- Undertake an assessment of the environmental effects of the construction activities for the sea-wall and housing scheme giving consideration to alternative designs and technologies.

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- Establish integrated liquid, solid and toxic waste management strategies with expert advice on environmentally suitable household chemicals and products; recycling opportunities; waste management options; opportunities for land-application of waste and sewage; opportunities for minimising waste production.

- Develop a Lagoon and Reef Conservation Strategy incorporating the establishment of: an ecosystem profile; protection areas; regulation of fishing; monitoring of fishing effort and stocks; monitoring of effects of land-based pollution sources.

- Investigate the localised pattern of fish poisoning.

## 8.3 Tokelau Environmental Management Strategy.

The content and recommendations of the UNCED/SOE report have the full support of the OTA and the Council of Elders. The OTA has already taken action in establishing an administrative authority to deal with environmental policy. Based on the recommendations of the UNCED/SOE report the OTA has proposed that a "Tokelau Environmental Management Strategy" (TEMS) be developed with assistance through SPREP's National Environment Management Strategy Project funded by UNDP.

The proposed programme considers not only the key issues of the UNCED report that need immediate attention, but also the internal capabilities of the Tokelau Public Service and local institutions in implementing programmes and projects, and the availability of assistance from regional and international organisations.

The objective of the Tokelau Environmental Management Strategy will be to strengthen in-country environmental management capabilities. This will be done through:

- Organisation, management and coordination in the formulation of policies and in the implementation of programmes and projects;
- Personnel support and technical assistance;
- Resource inventory (ecosystem profile), environmental impact assessment and special studies;
- Education and training including on-the-job training; and,
- Conduct trials on a wide range of appropriate technology.

The OTA propose to approach the programme in two stages due to present organisational and database limitations. Stage One involves the recruitment and on-the-job training of an Environmental Officer who will run the Environment Unit created during the recent restructuring of the OTA. It also involves the recruitment and orientation of a UNV Environmental Manager who will prepare in conjunction with the Environmental Officer a detailed Work Programme and Budget for Stage Two.

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# 9. Recommendations

Following discussions with the Official Secretary, the Director of Agriculture and Fisheries, Directors of other departments, Elders and staff, it was evident that steps towards addressing environmental concerns relevant to Tokelau were being considered. We fully support the initiative being taken in the establishment of the Tokelau Environmental Management Strategy and the Environmental Unit.

It should be noted that due to unforeseen circumstances the team was unable to travel and conduct fieldwork in Tokelau at the time of the mission visit to the Office for Tokelau Affairs in Western Samoa. However, it was agreed at the time that a visit of both team members to Tokelau was very important to the validity of the mission and any of its recommendations. In the event such a visit, proposed initially for May 1992, was not carried out.

While the lack of first hand on-site experience does reduce the value of this report to a degree, some of the recommendations which follow do address the question of follow up field survey(s).

## 9.1 Available Information and Source Material.

The mission was specifically asked to: (1) examine and evaluate available information affecting the physical and biological environment (terrestrial and marine) of Tokelau; and (2) examine and carry out a preliminary assessment of the available demographic, social (including archaeological and cultural) and economic data. Much resource material on these topics is contained in publications and reports held in the library and departmental offices of OTA, and these resources were made available to us for perusal. Nevertheless bibliographic services, cataloguing, shelving and consolidation of holdings in the library, for a number of reasons, is not as good as desirable. Not all relevant publications (particularly commissioned reports) are available in the library. Many useful reports etc. are held in departmental offices at OTA, and are not catalogued centrally. Rapid access to such resources is essential if an in-depth study (and the TEMS) is to be carried out efficiently. We therefore recommend:

*(1) that all resource materials relating to Tokelau be consolidated, catalogued and shelved in the library;*

*(2) that procedures should be established to ensure that several copies of all reports, publications etc are received from consultants, agencies etc (or are copied in-house) and that at least one copy is housed permanently in the library; and*

*(3) that procedures should be established to issue and record materials loaned from library holdings.*

## 9.2 Bibliography

There is, to our knowledge, no comprehensive and up-to-date bibliography on Tokelau held at OTA. *We recommend that such a bibliography should be prepared as a matter of urgency using existing but out-dated bibliographies such as those of Krause (1969) and Gillet (1988) as a basis.* Assistance from the University of the South Pacific Library and particularly from its Pacific Information Centre (PIC) could be sought in the first instance. Commissioned reports of specific relevance to Tokelau rarely get included in such bibliographies and it is essential that these be incorporated on a continuing basis by library staff.

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## 9.3 The Natural Environment

While there have been some surveys on aspects of Tokelau's natural environment, most of the terrestrial studies were carried out during the 1960s and are clearly out-dated (although some surveys relating specifically to fisheries resources are of more recent vintage). Moreover, the early land surveys were not comprehensive and the present land resource and environmental data is inadequate for planning purposes. In order to redress this deficiency some general and more specific surveys are proposed.

*(1) A land resource survey of all the islands in Tokelau should be carried out.*

The survey would cover landforms, soils, vegetation, land use, land tenure etc. and would provide an essential basis for long-term environmental planning and management. It could be based on the methodology used in the recently completed land resources survey of Tuvalu (see for example McLean and Hosking 1991). Some of the materials necessary for such a survey such as vertical aerial photographs are available from the Royal New Zealand Air Force. However, the existing photographs were flown in 1973 and consideration should be given to obtaining funding or support for an updated coverage. For lagoonal and marine resources mapping satellite imagery (eg. SPOT) could be used but such imagery has lesser value for land resources mapping where higher resolution data is required. Clearly, field survey is also necessary to ground-truth air photo and satellite image interpretation.

In addition to the general survey of terrestrial and marine ecosystems, specific surveys are also required to assist in the identification of the most vulnerable components and sites of the natural environment, particularly those most susceptible to sea level rise. The types of data to be collected were listed in an earlier part (section 4.4) of this report. Specifically,

*(2) We recommend that field surveys of the islets and adjacent reef flats highlighting geomorphic features, elevations and water level indicators, be carried out.*

The methodology for such surveys, which involve cross-section and profile measurements using levelling techniques, is now well established and has recently been used in Kiribati (Woodroffe and McLean, 1992). Such field survey in conjunction with air photograph analysis could be used to identify any long-term patterns of coastal change, including storm induced change, and to provide a baseline for monitoring possible sea level and storm induced changes. It would be an advantage to carry out the proposed survey in conjunction with investigations of shore protection works, sea wall construction, and sand and aggregate resources.

*(3) Island groundwater resources should be surveyed and evaluated.*

Such an evaluation should aim to determine the size of the potable water resource and its variability over time. These surveys could be carried out either in conjunction with the geomorphic/topographic surveys mentioned in (2) above, and/or with the land resources survey (1) above.

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## 9.4 Sea Level Change and Variability

To our knowledge there are no tide gauge records available for Tokelau and for the summary of past and recent trends in monthly mean sea level, secondary data from tide stations in the central Pacific region have been used in this report. Those data have shown a high degree of variability between stations although major trends have been relatively coherent. However, the lack of a tide station to the east of Tokelau means any extrapolation of results to Tokelau cannot be done with a high degree of certainty. Nevertheless, an analysis of primary data from the closest tide stations to Tokelau has not been carried out with the view of such extrapolation. Primary data from the Pacific Sea Level network is available from TOGA, based at the University of Hawaii, and in the absence of tide gauge records from Tokelau, we recommend that

*(1) a detailed analysis of the existing records from tidal stations in the region should be undertaken. Stations would include Tarawa, Kanton, Kiritimati, Funafuti, Pago Pago and Suva. These are part of the TOGA network.*

Recognizing that there are regional trends and local patterns in the magnitude and rate of sea level change and variability, and that any extrapolation determined from tide stations located a considerable distance away from Tokealu is not entirely satisfactory, some attempt should be made to reconstruct the local sea level changes over recent years. For this purpose biological indicators may be used. Large flat topped corals (microatolls) are found on reef flats on many atolls and these can be used to indicate water levels over the last two or three decades or more. Techniques for such analysis have recently been developed (see Woodroffe and McLean, 1990). Thus,

*(2) We recommend that an analysis of coral microatolls be carried out to determine the local pattern of sea level change over the last several decades to confirm whether or not the sea has been rising in the Tokelau group.*

## 9.5 Sea Level Monitoring

In June 1991, Australia's National Tidal Facility was commissioned to implement a program to monitor mean sea level in the South Pacific, which involves the establishment of eleven sea level stations in the region (Lennon, 1991). It was made quite clear during our discussions with OTA officials that they had a strong desire to have Tokelau included in the Australian monitoring network. While it appears unlikely that any new stations will be added to that network some tidal measurements should be made.

*(1) we recommend that funds should be sought to install a conventional tide gauge on one of the atolls of Tokelau ; and,*

*(2) that if a permanent placement is not possible the gauge should be installed on a temporary basis, at least for a year or two but preferably longer.*

The tide station should be similar to those in the TOGA network with the objective being to compare and correlate Tokelau records with those from long-run stations in central Pacific.

## 10. References


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## 9.6 Village Motu

At present, village settlement is concentrated on four motu on the three atolls of Tokelau. There is, however, accumulating evidence to suggest that environmental problems such as coastal erosion, breakdown of shore protection structures, deterioration of ground water quality and supply, rubbish disposal etc. are rapidly increasing on village motu and it may be that those motu will not be able to support such levels of population and environmental quality in the future, regardless of global warming and sea level rise. This needs to be confirmed in the first instance, before considering other possible alternative motu for settlement. We thus make a series of recommendations:

*(1) that the environmental conditions of the present four village motu and their adjacent reefs and waters be investigated in order to determine the long term sustainability and population carrying capacity of the motu in relation to sea level rise and climate change and other environmental changes;*

*(2) that a number of motu on each atoll be evaluated as potential sites for settlement, in the event the present village motu become uninhabitable;*

*(3) that island communities, through the Council of Elders and other organisations participate in the evaluations proposed in 1) and 2) above, and make recommendations on their alternative or preferred options and the reason(s) for the choice; and,*

*(4) that an Environmental Impact Assessment (including social impact) be undertaken on the present village motu and any recommended in 3) above.*

It is envisaged that the above matters should be proceeded with generally and incrementally, recognizing that such issues may be precipitated by a number of possible causes including serious contamination of the freshwater lens, devastation during a hurricane or storm wave event etc. and perhaps accelerated by sea level rise.

Note, the authors do not consider that the worst possible scenario, that of complete destruction of all of the lands of Tokelau, and wholesale emigration from the islands, should be considered at all before the four recommendations above are addressed.

## 9.7 Information Receipt and Dissemination

One of the major problems that emerged from our work on perception of future environmental change, and was also quite obvious during discussions with officials and residents, was the heavy reliance on media reports for basic information relating to global warming and sea level rise. This is not surprising and is certainly not peculiar to Tokelau, but occurs elsewhere throughout the world. Reliable and relevant local or regional information is not easy to come by and invariably requires considerable expertise in making deductions from global scale scientific assessments, impacts and response options. Thus, it is unlikely that much higher resolution information than that included in this report, will become easily available in the future. In view of this we recommend:

*1) that Tokelau officials should continue to exert pressure on governmental and inter-governmental agencies, scientists, consultants etc by requesting specific predictions for and information relating to Tokelau and the region, and not be satisfied with global-scale predictions or forecasts; and*

2) *that information concerning the impacts of climate change and sea level rise continue to be passed on from national scientific organisations in New Zealand, Australia and the wider Pacific, appropriate government departments, and regional and international agencies to the OTA, recognizing that SPREP has a particular role to act as a clearing house for information on climate change for the region.*

Information appropriate for administrative decision-makers, elders, community leaders, adult education and the population at large is needed.

## 9.8 Education

Issues relating to climate change and sea level rise are complex, long term issues which require some understanding of natural environmental processes as well as human impact, environmental deterioration and conservation. We therefore recommend:

*That education of all Tokelauans about environmental issues relevant to Tokelau emphasise:*

- *the need to be aware that all actions taken now will affect the unique conditions of Tokelau's 'way of life' in the future;*
- *the need to look 50-100 years into the future;*
- *the need to appreciate that while Tokelau has coped after cyclones (a natural event) it is vulnerable to pollution, depletion of resources etc (events caused by actions of people);*
- *the need to share knowledge and ideas between young and old generations.*

## 9.9 Conclusion

Finally we believe that given (1) the publicity and momentum generated by the concerns about global warming, sea level rise and increasing cyclone frequency; (2) by the initiatives taken this far by OTA; and, (3) by the small size of the nation, its land area, people and administrative structure; that many of the above recommendations could form part of the brief for the Environmental Unit. They are also consistent with those being developed for the Tokelau Environmental Management Strategy project which we believe requires full financial and technical support for its establishment and continuance.