# Reducing the risks of cyclone storm surge inundation on the atolls of Tokelau

# Atafu

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# Atafu

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# Executive Summary

On 25 February 2005 Tropical Cyclone Percy affected the atolls of Tokelau. The cyclone was of category 3 intensity as it passed around 100 km to the south west of Tokelau, intensifying further as it past through the northern Cook Islands with sustained winds measuring from 178 to 249 km/hr. The cyclone resulted in widespread damage, particularly on Fakaofo and Nukunonu. On Atafu the storm surge and large waves resulted in overwashing of parts of the motu. Inundation was also an issue on Nukunonu and Fakaofo.

In the aftermath of Cyclone Percy, the United Nations Development Programme (UNDP) in Samoa commissioned NIWA to provide technical support to the Government and people of Tokelau to assist in the future reduction of coastal hazard risks, particularly associated with cyclonic-induced storm surge and wave overtopping and inundation (known as the Tokelau Seawall Project).

The main purpose of this document is to provide the UNDP with recommendations for potential priority assistance to Tokelau for reducing the risks associated with cyclone storm surge inundation. However, this has been developed within a more detailed strategic framework which aims to develop a set of guiding recommendations and options for consideration by the Atafu administration for the long-term reduction of the risks associated both with episodic cyclone storm surge inundation and longer-term adaptation to climate change.

In developing such a strategy for managing coastal hazard risk on Atafu it is important to note that:

1. **There is no "silver bullet"** i.e., no one option that will solve all the problems. A programme of reducing risk involves a range of inter-related activities, the composition of which will vary from location to location (e.g., between the ocean and lagoon shore etc.) and over time.

2. **Reducing risk is a journey not a destination**. Reducing the risks of cyclone related erosion and inundation damage is hard work, requiring difficult decisions, and is a continuous and ongoing activity integral to development decision-making at individual, village (atoll), and national levels.

3. Building **adaptive capacity**, the ability of the coastline, the community and individuals to cope with, adjust, respond, or even take advantage of, variability and extremes in climate, including potential long-term climate change, is critical.

A series of recommendations were developed within four general risk reduction themes:

1. Ensuring protection of the natural coastal defences (reef, reef flat, beach and coastal margin) and identifying the underlying causes of human impacts on reducing the effectiveness of these natural defences and how such impacts could be effectively reduced.

2. Options for land management planning both for future development and consideration of the potential for developing a long-term strategy for the movement of key infrastructural or other buildings from high risk areas.

3. How risks of damage to property and content could be reduced through building design, i.e., accepting that inundation is a natural occurrence (and will always be an issue on Atafu) and designing and constructing buildings and infrastructure to take account of this.

4. Protection measures, including the needs of both existing seawall structures, and requirements for future structural solutions with an emphasis on structures that: (1) enhanced the natural defences and were more sensitive to the important natural processes occurring on Atafu, (2) optimised to be more effective in reducing inundation, and (3) more sustainable in terms of both the length of time the structure is effective, and in terms of ongoing maintenance costs.

Based on the discussions held in Tokelau, and the resulting recommendations that have been developed, the following are suggested as priority areas for the UNDP to consider supporting:

1. Materials for the urgent maintenance of the existing gabion seawall (Recommendation 14).

2. Seed money to assist with the commencement of community planting initiatives and associated awareness programme (Recommendations 1, 2 & 3).

3. Contribution to a demonstration project commencing the construction of Phase 1 of the berm structure (Recommendation 15).

The series of recommendations outlined in this report are not intended to be a "quick fix" but rather a long term and sustained approach to reducing the risks to people, property and infrastructure of cyclone related inundation and erosion, long term coastal evolution of the motu, and any exacerbation of these impacts caused by global climate change. It is based on the growing evidence from around the Pacific region that integrating risk management of natural hazards in to individual / community / national decision-making is a far more cost-effective strategy than a "wait and see" approach to managing both episodic disasters such as cyclones or longer term factors such as the consequences of sea-level rise.

The approach has attempted to complement and contribute to the suggested approaches to risk management of natural hazards (RMNH) in the Pacific region outlined in the recently published World Bank policy note *Not if but when: adapting to natural hazards in the Pacific Island region* (Bettencourt et al. 2006). Specifically, the recommendations involve actions at individual, community and national levels and associated coordination and interaction between these activities. They include actions that are highly visible (such as seawall construction) as well as actions that encourage changing behaviours and mindsets. As far as possible a "no regrets" approach has been adopted in the development of the recommendations, the aim of which is to ensure that as far as possible the communities of Tokelau will still be able to consider a range of risk reduction options in the future rather than being constrained to a narrow risk management approach due to past or present day decisions (which is the situation that Fale on Fakaofo now finds itself in where future risk management options are very limited).

Whilst many of the risk reduction activities will be coordinated at atoll level, there is a need for coordination at national level:

- To mainstream these risk management measures in to national economic and social planning, budgeting and decision-making processes.

- To provide support and guidance to the three atolls to continue to progress implementation of the recommendations.

- To provide coordination with donor and support agencies, such as the UNDP, New Zealand, SPREP, SOPAC and potential other sources of support.

- Encouraging donors to assist and support pro-active and long-term risk management activities rather than focus on episodic disaster recovery which needs to be fundamental aim of the Tokelau administration.

How this is best achieved (e.g., whether such responsibility lies within one unit such as the Environment Unit, or within the whole of Government will need to be determined by the Tokelauan decision-makers.

To underpin all future risk management activities in Tokelau is a need for a sustained program of public awareness activities, and capacity building at both community and national levels to support a proactive approach to reducing coastal hazard risk. Specifically this requires the development of support mechanisms within the National Government agencies to better empower each of the three Tokelau communities to proactively manage natural hazard risks, to help identify and provide the resources needed to do so, and to move from intentions (suggested in this report) to actions. To begin with there is a need to disseminate, and discuss at community levels, the findings of the recommendations contained within this report, but in the longer term will need to include:

- Targeted information on hazard occurrence, climate variability and change for a range of audiences, e.g., Government policy and decision makers, community leaders and members, school children.

- Fostering of action plans in each community, based on the general recommendations and timelines suggested in this report, but with specific target actions and timeframes, and identification of who will do it.

- Training for national and community leaders in developing community approaches to reducing natural hazard risks. Whilst formal mechanisms such as on-island training courses will be integral there again needs to be a longer term focus with activities such as mentoring for technical support being introduced, and an emphasis on approaches that can be repeated and sustained.

# 1. Introduction

## 1.1 Background

On 25 February 2005 Tropical Cyclone Percy affected the atolls of Tokelau (Figure 1). The cyclone was of category 3 intensity as it passed around 100 km to the south west of Tokelau (the only wind measurement available was the 3 hourly recording at Nukunonu which recorded 59.3 km/hr at 03:00 NZST on the 27 February) with the cyclone going on to intensify as it past through the northern Cook Islands with sustained winds measuring from 178 to 249 km/hr. The cyclone resulted in widespread damage, particularly on Fakaofo and Nukunonu. On Atafu also the storm surge and large waves resulted in overwashing and inundation of parts of the motu[1].

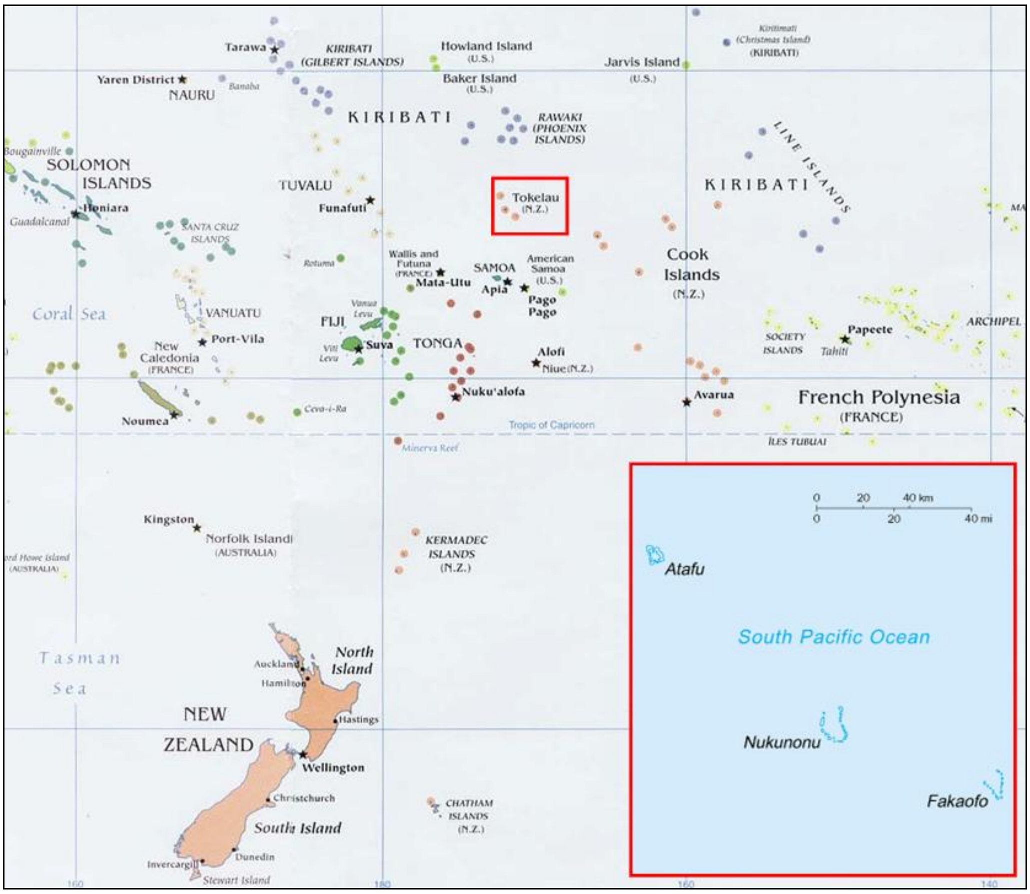


**Figure 1:** Location of the three atolls of Tokelau.

[1] Small islet on an atoll.

Further details of the damage caused by the cyclone are given in the UN Disaster assessment and Coordination (UNDAC) Damage assessment Report (Laurence & Hill, 2005).

In the aftermath of Cyclone Percy, the United Nations Development Programme (UNDP) in Samoa commissioned NIWA to provide technical support to the Government and people of Tokelau to assist in the future reduction of coastal hazard risks, particularly associated with cyclone-induced storm surge and wave overtopping and inundation (known as the Tokelau Seawall Project).

Overall details of the project were summarised in the initial terms of reference for the project with the expected outcome to *"…. provide a sound mitigating response for Tokelau through appropriate seawall structures that will protect not only the existing infrastructure and resources on all the atolls but most importantly the lives of the people of Tokelau"*.

This objective was reviewed and discussed with the UNDP as part of the project inception assessment and subsequently the scope was widened with the primary goal *to reduce risk to loss of life, damage to coastal infrastructure and coastal environmental areas from the devastating impact of storm surge from cyclones* (UNDP, 2005). Rather than focus primarily on seawall structures, the project was broadened to identify and optimize a <u>range</u> of both short term and longer term options for achieving a sustainable risk management approach over the long term. Whilst the focus is on reducing risks associated with cyclone-induced inundation and related coastal hazards, the approach adopted within the report aims to compliment and contribute to the suggested approaches to risk management of natural hazards (RMNH) in the Pacific region outlined in the forthcoming World Bank policy note *Not if but when: adapting to natural hazards in the Pacific Island region* (Bettencourt et al. 2006).

The in–country consultation and assessments were conducted between 05 July and 13 July 2005 by Mr Doug Ramsay, NIWA, assisted during the visit to Tokelau, by Mr Heto Puka, Manager of Finance, Tokelau Apia Liaison Office. The scheduled passenger and cargo ferry MV Tokelau was used to transport the project team, with up to 2 days spent on each atoll. On each atoll an initial meeting was held with the Council of Elders (*Taupulega*), followed by discussions with the Women's Group (*Fatupaepae*), working or married men (*Aumaga* or *Taulelea* respectively) and a further, more detailed discussion, with the *Taupulega* at the end of the visit. A full walkover survey and collection of building and infrastructure information was also conducted. Details of the visit schedule and summary of the discussions are provided in the de-briefing report (Ramsay, 2005b).

## 1.2 Overview of the outputs of the study

This document is one of a series of reports prepared as part of the study, which include:

- An inception report completed prior to the trip to Tokelau (Ramsay, 2005a)
- A de-briefing report, summarising the visit and discussions held in Samoa and Tokelau (Ramsay, 2005b).
- A technical review of cyclone information and wave / water-level design information covering all three atolls (Ramsay, 2005c).
- This report for Atafu (one of three, the other two covering Nukunonu and Fakaofo) which details options and recommendations for reducing cyclone storm surge inundation risks for both the short and long term.

## 1.3 Previous studies and ongoing activities

An assessment of damage due to wave overwashing and inundation caused by Cyclone Wini on the 28 February 1987 was conducted by Bakx (1987) and also summarised by Richards (1990, 1991). This detailed the physical conditions during the cyclone, the damage on all three atolls that occurred, and provided a series of recommendations, which included:

1. *"An immediate replanting programme should be initiated. Quick growing hardy species should be established just inland of the beach creast…..Based on observations on Atafu Island the vegetation barrier should extend for 20 m inland of the beach crest….."*
2. *"Buildings should be located as far back from the seaward facing shoreline as practicable and a "no development zone" established for any future construction along the coast."*

3. *"Wherever possible low and intermediate vegetation, of the type which has an extensive root network, should be established between buildings particularly within the central village area."*

4. *"Large bare areas of land such as used for the purposes of the playing fields or tennis courts, should be located away from built up populated areas and not in the central village area or on the seaward facing coastline."*

5. *"The establishment of a minimum building level should be investigated. This may necessitate raising the height of concrete foundations, within reason, to reduce either the likelihood or the impact of flooding of buildings."*

A programme of seawall construction, using gabion basket construction, was commenced following Cyclone Ofa (February 1990) by the New Zealand Defence Force (NZDF) and Tokelau based on designs developed by Maccaferri, the manufacturers of the gabion baskets, (Brockliss, 1990). Seawall construction was not completed before the NZDF departed, with Tokelau continuing the work.

To assist with completion of the project, UNDP funding (US$295,000) commenced in 1990 and lasted up to 1994. However, in December 1991, Cyclone Val damaged and destroyed many of the as yet uncompleted seawall structures. Hence a further UNDP funded Special Programme Resources project followed between 1992 and 1995 for limited reconstruction of the areas damaged by Cyclone Val.

By March 1992, 190 m of gabion seawall had been constructed on Atafu along the ocean side to the north and south of the boat channel. An assessment by Maccaferri, commissioned on behalf of the UNDP and Office of Tokelau Affairs (OTA), (Brockliss, 2002) recommended the continued extension of the seawall by about 150 m around the southern end of the island towards the lagoon and by a further 180 m northwards along the ocean side (Stage 2). Further stages were to further extend the seawall to the north on the ocean side by 170 m and on the lagoon side by 400 m. This report also raised concerns (noted in Mclean, 1993) that the design recommendations had not been followed, specifically:

- The seawall had been constructed some 5 – 15 m too far down the beach.

- Over the northern 40 m, the wall had been raised higher by about 1.5 m.

Both these issues have had important bearing on the subsequent performance of the seawall, particularly with respect to the length of time that the gabion baskets have lasted before being damaged.

Concerns over potential adverse environmental impacts due to the seawall construction resulted in the UNDP/OTA commissioning a scoping environmental impact assessment (Shuma, 1992). This recommended that a detailed EIA be conducted to identify the likely long term positive and detrimental impacts of the seawall construction.

As part of the *Tokelau Environment Management Strategy* (TEMS) project (Toloa, 2000), Prof. Roger McLean was commissioned by the South Pacific Regional Environment Programme (SPREP) and the OTA to visit Tokelau and to undertake the EIA of the existing and proposed extensions to the gabion seawalls (McLean, 1993). However, no further external funding was provided to continue the coordinated construction of the seawalls based on the recommendations contained within the EIA. Despite this other ongoing *ad hoc* seawall construction, of varying construction standards has continued, typically relating to the reclamation of land on the lagoon side of Atafu.

In addition to the EIA, McLean and d'Aubert (1993) prepared a report on the *Implications of climate change and sea-level rise for Tokelau* as part of a series of reports coordinated by SPREP. Both the EIA and this report are important documents within the context of the present study, with the overall discussions and findings contained within still highly relevant. This project aims to build on the findings of these reports.

In 2001, the NZ Ministry of Foreign Affairs and Trade (MFAT) commissioned an assessment of Tokelau's Infrastructure needs and priorities (Opus International Consultants, 2001) as a basis for future decision-making and funding allocation. This confirmed seawall repair and further construction, which had always been a high priority on Tokelau's development agenda, as such. However, the generic approach to the recommendations made for further seawall construction, and lack of consideration of other approaches to reduce such risks within the report raises, considerable concern about the appropriateness, environmental consequences and sustainability of the recommendations.

A number of other activities have also been ongoing in Tokelau, particularly over the period since Cyclones Ofa and Val affected the atolls, which has contributed to the reduction in risk associated with cyclone storm surge inundation. Of most relevance has been the programme of housing re-development through a housing grants scheme which commenced in the mid 1980s. As a cost saving measure, water tanks tended to be built under the house, raising the floor level. This measure has resulted in the floor levels of the housing being generally raised above the level that would typically be inundated due to cyclone storm surge, or waves overtopping and overwashing the motu. This activity has resulted in a significant reduction in associated damage to individual property and their contents.

Recently, the UNDP have commenced funding a programme to strengthen disaster management and preparedness in Tokelau. Part of this project involves improving the equipment and capacity to receive and disseminate tropical cyclone warnings, development of a tropical cyclone operational plan and improved capacity to exchange information including redundancy within the system.

## 1.4 Scope of this report

The main purpose of this document is to provide the UNDP with recommendations for potential priority assistance to Tokelau for reducing the risks associated with cyclone storm surge inundation.

However, this has been developed within a more detailed strategic framework which aims to develop a set of guiding principles and options for consideration by the Tokelauan administration for the long term reduction of the risks associated with cyclone storm surge inundation. It is hoped that by developing a longer-term framework that this will help reduce the *ad hoc* approach to the reduction of coastal hazard risks that has occurred in the past and will help increase community resilience to future climate variability and extremes and the changes that may occur due to climate change and sea-level rise.

As such, this report aims to:

- Assess a range of strategic coastal hazard risk reduction options for reducing such risks on the people, developed infrastructure and property and natural environment of Atafu.

- Provide guidance for coastal hazard risk reduction policies to be integrated in to the economic and social planning functions and decision-making processes for future development and resource management over the next 10 to 20 years and longer.

- Identify opportunities for maintaining and enhancing the natural coastal environment, including the natural coastal defences on Atafu.

- Identify any necessary monitoring activities to aid future decision-making and to develop a set of risk indices to measure long term effectiveness of the risk reduction measures.

# 2. Natural coastal change on Atafu

## 2.1 Introduction

The motu on atolls are constantly changing and evolving in response to the natural processes that drive such changes (waves, tides, currents and the effects that climate variability and change has on these processes). A fundamental challenge for communities living on such motu is carry out development in a way that recognises and accommodates such change. It is often human impacts or interventions to these natural processes that can cause or exacerbate both short and longer term environmental problems.

Hence a critical issue in developing a long-term management approach to reducing the risks of coastal hazards to people on Atafu is an appreciation of the natural physical processes that are causing change at an atoll, motu and localised scale. Whilst it is appreciated that little geological or physical process studies have been conducted on any of the atolls of Tokelau, fundamental processes can be recognised based on observations and studies of other atoll environments.

It is not intended to provide a detailed overview of atoll processes and short and long term changes to motu but rather to summarise these as a series of statements and take-home messages to be borne in mind when considering (1) appropriate risk mitigation options, and (2) future development projects. A more detailed discussion of such processes is provided by McLean, 1993 and McLean and d'Aubert, 1993).

## 2.2 An overview of key natural physical processes on Atafu

*1. Motu are formed by cyclones*

All land on Tokelau has been formed by deposits of sand, coral rubble and boulders that have been deposited on the reef flat by many cyclones over many years.

The motu are founded and anchored on a coral conglomerate platform which likely formed when sea levels were slightly higher (0.5 m to 1 m) between 2000 and 4000 years ago. These platforms (known as *te papa*), which are at a higher level than the present day reef flat, are exposed along the western side of the atoll. The formation of the motu in roughly their present day form is partly related to a fall in sea level over the last 2000 years (sea levels began rising again about 150 years ago).

2. *Cyclones are important for the continued growth of motu*

Whilst cyclones can cause erosion and damage, their occurrence is vital to the long term future of the motu on Atafu as they continue to supply fresh sand and coral rubble to build the motu around the island. This counters the loss of sand and coral rubble that occurs from the motu, due to both natural processes, such as sand being transported in to the lagoon, and increasingly, and of greater consequence, due to human impacts, e.g., sand mining.

**Figure 2:** Accretion along the northwest coastline (left) and at southern end (right) of Atafu.

This fresh supply of sand and coral rubble can be seen in a number of forms: as banks of storm rubble on the reef flat which gradually migrate towards the beach, boulder tracts on the reef flat, or new accumulations of coral rubble or sand on the ocean beaches (which may only gradually appear in the weeks or months following a cyclone). On Atafu, such accumulations are most evident on the north western corner of the inhabited motu, and at the southern end (Figure 2). Along the northwestern coast, such accumulations does not tend to build up any significant present day increase in land, rather it acts as a source of beach sediment feeding the southern and north eastern shorelines of the motu (see Figure 5 below).

The most significant accumulation of land is occurring at the southern end of the motu. There is a suggestion that over 200 years ago, the area between the present Administration Building and the church was once a tidal inlet and passage between the ocean and lagoon side (Huntsman & Hooper, 1996). Substantial accretion of land of some acres occurred during the Great Cyclone of 1914 (Huntsman and Hooper, 1996) which *"….were soon divided and allocated, planted and peopled. Although an immediate disaster, the cyclone brought long-term gain."* However, as the southern part of the motu is the most recent, it is also the lowest part (i.e., hasn't been built up by successive cyclones – see below) which makes it vulnerable to overwashing and inundation. It is also the part of the motu where the largest changes, in terms of the position of the shoreline, will occur during storm and cyclone events.

*3. Cyclones are important for building up the elevation of the motu*

When water overtops and overwashes the ocean side of the motu, it transports sand and coral rubble from the ocean side and deposits it on to the land. Over time this builds up the motu. It is also part of the process that has supplied sand and rubble to build out the motu on the lagoon side. This is why the ocean side of Atafu is much higher than the lagoon side, and why the older parts of the island (area around the power generation building / pig pens) is more stable and less prone to overwashing than the younger parts of the island (south end of the island / lagoon shores).

Over time this can result in significant increases in the elevation of the motu. For example, archaeological surveys of Atafu, (Best, 1988) found evidence of communities of Atafu and Fakaofo around 1000 years ago living on land levels between one to two metres lower than they are today:

> *"… the islets on which the present-day villages of Atafu and Fakaofo are situated were between one and two metres lower than the present surface, and thus more vulnerable to storm waves".*

This emphasises the importance of ensuring this long-term natural build up of the motu is allowed to continue particularly in the context of a future where sea levels will continue to rise.

*4. Beaches do not stay the same shape*

The shape of the ocean side beaches on Atafu changes in response to the size of the waves. This is a natural response during cyclones and does not necessarily mean that erosion is occurring (despite the possible loss of front line coconut or pandanus or exposure of roots). The beach will typically gradually build back up after the cyclone (which is what is presently occurring after Vyclone Percy) but this is a much slower process (see above).

The large waves that occur during a cyclone tends to erode the finer sand-sized beach sediment from the beach and move it seawards over the reef flat to leave the larger coral rubble (essentially increasing the natural armouring on the beach). The changes to the shape of the beach will depend on the interaction between the amount and size of the coral rubble on the beach and the particular wave and water level conditions.

Where there is a lot of coral rubble (or smaller waves / lower water level) a storm berm will tend to build up with the upper part of the beach becoming steeper (green profile in Figure 3). An example of this is the beach on the ocean side of Fenuafala on Fakaofo (Figure 4 left). Where there is less coral rubble, i.e., the beach has more sand or small coral rubble (or where people have removed the larger coral rubble), the beach crest will tend to move landward and the beach slope becoming more shallow (red profile in Figure 3). An example is the ocean beach along the village frontage on Atafu (Figure 4 right). Such a situation makes wave overtopping and overwashing more likely to occur.

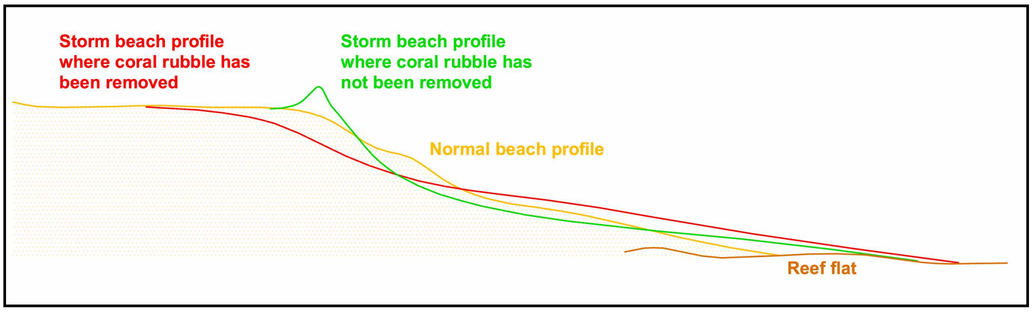


**Figure 3:** Beach profile change caused by large waves and the impact of removing coral rubble from the beach.

**Figure 4:** Storm ridge built up on the ocean side on the motu of Fenuafala (Fakaofo) where there is a healthy coral rubble beach with little overwashing occurring during cyclone Percy (left), and the beach along the village on Atafu (right) where much of the coral rubble has been removed (still ongoing) which will have significantly contributed to the cut back of the beach crest and overwashing that occurred during cyclone Percy (and previous cyclones).

5. *The movement of sand and coral rubble along the coastline is also important.*

Both cyclones and the day to day wave conditions also move sand and coral rubble back and forward along the shoreline. The dominant wave direction determines the main direction of the movement. If more beach sediment is transported from an area of beach, than is transported into the same area, then coastal erosion will occur. Activities that disrupt or change this natural movement of beach sediments, such as sand mining, building inappropriate seawalls that block sediment movement etc. normally leads to increased coastal erosion problems or loss of beach.

On Atafu, beach sediment tends to get moved to the south along the western facing ocean beach (Figure 5) from the area where there is natural beach build up along the north western side of the motu. In addition to build up at the southern end of the atoll during cyclone events (as happened in 1914), this further results in the southern end of the coastline tending to build up. Sand that is moved around the southern end of the motu will tend to be deposited on the lagoon side and will either be transported in to the lagoon or along the lagoon shore (for example the build up of sand against the southern section of reclamation on the lagoon side).

6 *Natural vegetation on the coastline traps sediment and helps stop overwashing*

The natural vegetation found at the top of the beach plays a big part in reducing erosion and in reducing how far waves that overtop the beach travel inland. The roots of plants and trees help to hold sediment, especially sand in place. The deeper and more extensive the root system, the greater degree of stability. Undergrowth and low shrubs and bushes, helps trap sand and coral rubble being overwashed when large waves overtop the crest of the beach, reducing the amount of water and sediment entering village areas.

It was notable on all the atolls that the areas where overwashing was most severe during Cyclone Percy corresponded to the areas where the most significant clearing of vegetation had occurred (e.g., particularly the school areas of Nukunonu and Fenuafala). This is a pattern that has been evident when overwashing has occurred during cyclone to have affected the Tokelau atolls over the last century (e.g., the reports by Bakx, 1987 and Richards, 1990, 1991)

**Figure 5:** Dominant directions of sediment movement along the coastline of Atafu (adapted from McLean, 1993).

# 3. The present day situation

## 3.1 Introduction

This section provides a snapshot of the current situation with regards to the status of the natural and built coastal defences on Atafu, and the risks to people, property and infrastructure. It provides a baseline for developing the future coastal management recommendations discussed in Section 4. The summary is based on discussions and a walkover survey, part of which was conducted in the company of members of the *Taupulega*, during the visit to Atafu by the project team.

## 3.2 Natural coastal defences

The outer sections of the reef on Atafu are likely to be in a relatively healthy state, in terms of the protection it provides to the shoreline, with few human impacts likely to be of significance. However, short and longer term damage due to cyclone events has been noted in the past (Laboute, 1987) and also due to coral bleaching episodes related to higher sea surface temperatures during at least two strong El Niño periods over the last twenty five years.

The only place where human activities have significantly impacted on the outer reef system is at the reef channel at the southern end of the motu. However, there is little present day evidence that this is having any significant impact on the adjacent coastline.

Removal of coral rubble from the beach and reef flat for construction projects has been ongoing for many years. Traditionally rubble was taken from the closest beach and reef areas to the village (i.e., the shoreline north of the boat channel). However, for gabion construction, rubble was taken from the boulder tract south of the boat channel and from the accreting northern part of the motu. The EIA recommended that no further rubble be taken from the first source for future gabion construction.

The negative impacts of these past activities have now been recognised by the community. Now most of the much sand and coral rubble for both community and private projects is collected from a “sacrificial” motu elsewhere on the atoll. However, small-scale sand mining and coral rubble removal from the ocean beaches is still ongoing and observed at a number of locations during the walkover survey (Figure 6). The impacts from past (and ongoing) sand and coral rubble removal have a direct relation to degree of overwashing and cutback of the beach crest experienced during

Cyclone Percy and previous cyclones along approximately 650 m of the ocean beach from the boat channel to opposite the northern end of the school.

**Figure 6:** The removal of sand or coral rubble from anywhere along the west coastline (up to and including the area in front of the pig pens) will impact on the natural supply of beach material to the south, substantially reducing the protection to the village provided by the beach. Small scale removal of larger coral rubble over many years from the ocean beach in front of the village appears to be a contributing factor to potentially increased overtopping and overwashing of the beach in this area.

Also contributing to the reduced effectiveness of this section of natural defence has been the removal of the natural vegetation, particularly the clearing of low bush and undergrowth as people have built housing. The lack of vegetation behind the beach at the cemetery increases the risk of wave overtopping and overwashing also in this area.

Such activities have substantially increased the susceptibility of this section of the coastline to be overtopped and overwashed during cyclone or during large swell events which coincide with a high tide. Even if all sand mining and coral rubble removal activities were stopped, the impacts are still going to be experienced for many years into the future.

Most of the lagoon shore fronting the village has been reclaimed with seawalls constructed along much of the frontage. This is discussed in the next section.

## 3.3 Built coastal defences (seawalls)

Figure 7 summarises the extent of built coastal defence structures around Atafu.

The discussions held on Atafu identified a different attitude to coastal defences on the ocean compared to the lagoon side, something that McLean (1993) also noted. On the ocean side seawalls are viewed as community assets with construction carried out as a community project by the Aumaga. On the lagoon side, seawalls construction is related to the reclamation of land and as such is typically carried out by the particular landowner.


**Figure 7:** Summary of the location and type of seawalls constructed around Atafu.

Approximately 130 m of gabions have been constructed to the south of the access point to the boat channel and about 200 m to the north. The rubble used to fill many of the gabions is rounded and not well suited for effective packing within the baskets. However, at the southern end, a section of approximately 30 m protecting a house is in good condition having been well constructed, using flat, well rounded stones, and maintained (Figure 8, left). The remainder of the southern section, from a small access gap to the reef channel access is in much poorer condition (Figure 8, right). The top 3 gabion baskets are typically exposed above the beach that fronts the toe of the structure along this section. Approximately 60 to 70% of these baskets have burst at the top. At present the sides of the baskets are generally intact with much of the coral rubble still in situ. However, further deterioration of the wall will be rapid. Over a distance of about 20 m to the south of the reef access point, the crest of the wall has been heightened by adding a second layer of baskets (Figure 9, left).

**Figure 8:** Southern section of gabion seawall on the ocean side at the southern end (left) and looking towards the boat channel access point (right).

Immediately north of the channel access point (Figure 9, right), only a thin layer of coral rubble covers the bottom half of the gabion wall. Many of the baskets are damaged at the toe of the structure. A second layer of gabion baskets, placed on the crest of the wall along approximately 50 m, is also in poor condition. However, north of this section, along much of the remainder of the structure, the gabions are in better condition, with only minor damage. This is largely due to better construction and the protection provided by a wider beach fronting the wall, with only the top one or two gabions exposed, and in some areas well vegetated immediately behind the crest of the structure (Figure 10).

**Figure 9:** Gabion wall south (left) and north (right) at the channel access point.

**Figure 10:** Gabion baskets in a reasonable condition towards the northern end of the gabion seawall.

Only one section of gabion seawall has been privately constructed on the ocean side, in front of the current *Pulenuku's* house 240 m to the north of the access point to the boat channel, consisting of three layers of stepped gabion baskets built well down the beach (Figure 11, left). The gabions are still relatively intact but damaged at the ends where the wall has exacerbated erosion effects. The wall is unlikely to provide any significant protection to the land behind and in its present state is likely to be damaged beyond repair within a relatively short space of time.

To the north of the cemetery the wall around the pig pens also functions as a seawall in terms of reducing inundation due to waves overtopping the beach crest. The coral block wall was built in the early 1980s and was built back from the beach crest with the natural vegetation retained seaward of it (Figure 11, right). Whilst the pig pens are on a very stable section of the island, overtopping waves have never entered the pig pens, and provides a very good example of an effective, long-lasting seawall solution to reduce risk inundation due to wave overtopping.

**Figure 11:** Short section of private gabion basket wall (left) and the coral block wall fronting the pig pens (right). Note the thick vegetation on the left between the wall and the beach.

On the lagoon side, seawalls perform a different function having generally being built privately to enable land to be reclaimed, a practice that has a long tradition in Tokelau. Due to the low-lying nature of the land on the lagoon-side, the walls are not intended to, and do not prevent inundation of land during high storm surges in the lagoon. Virtually the entire village frontage on the lagoon side has been reclaimed, the exceptions being the small boat berthing areas located in gaps between the walls.

Most walls have low vertical faces of traditional coral slab construction, Figure 12. The crests of some walls have been cemented to improve stability, while gabion baskets have been placed on a couple of short stretches to increase wall elevation. The condition of the many sections of walls varies considerably, from those that are well maintained, to those that provide minimal protection.

**Figure 12:** Coral block walls on the lagoon shore of Atafu.

Given the relatively sheltered location of the lagoon side of the village in Atafu, the walls do not have to withstand any significant wave impacts and with occasional maintenance are generally sufficient to protect the reclaimed land from significant damage, the exception being where the crest of the wall has been built higher than the filled land behind it making the structure more prone to damage.

## 3.4 Community buildings

The building survey recorded use, wall type, foundation type and approximate floor level for each of the Government and community buildings on Atafu. Based on this survey, a relative appraisal of the potential risk of each building was made. This was defined as a combination of:

- Location risk (i.e., based on where the building was located) where:
  - Low – little risk of storm surge or wave overtopping reaching building.
  - Medium – occasional inundation and / or generally low water levels.
  - High – inundation occurs during most cyclones and / or inundation depths are high.
- Building risk (i.e., based on essentially the floor elevation relative to the surrounding ground level) where:
  - Low – floor level is well above likely inundation levels and / or foundations unlikely to be damaged due to water depth or velocity.
  - Medium – floor level likely to be above all but the most severe inundation levels.
  - High – inundation of building possible due to inundation levels likely to be experienced during cyclones and / or foundations potentially susceptible to damage due to water depth or velocity.

Details are summarised in Table 1 with a spatial representation of overall community building risk, shown in Figure 13.

Most of the key community buildings and infrastructure have been well sited on Atafu - for example the power generator, (Figure 14, left). The community buildings at most risk are the bulk storage sheds (Figure 14, right). The UNDAC Cyclone Percy damage assessment (Laurence & Hill, 2005) noted that around half the stock was washed away, and other stock had to be written off, with the sheds all damaged to some extent. However, subsequent discussions suggested that most of the stock had been moved to a safe location prior to the cyclone and that little stock was actually damaged despite water entering the building. No claim had been made by Atafu for replacement of damaged stock due to the cyclone.

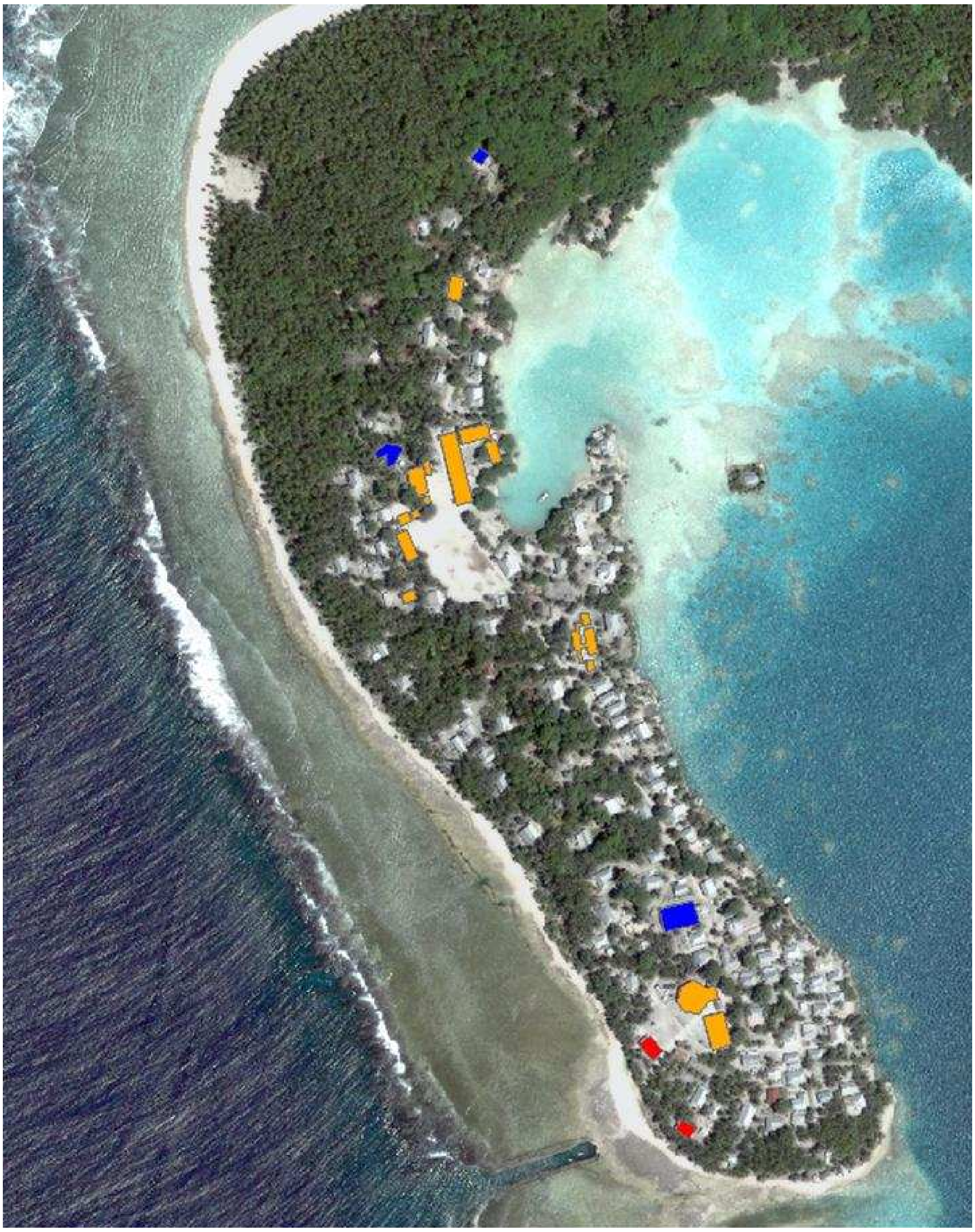

**Figure 13:** The relative risk of inundation or damage to community buildings due to waves overwashing Atafu. Red = high risk, Orange = medium risk, Blue = low risk.

**Table 1:** Summary of storm surge inundation risk to government and community buildings.

| Infrastructure | Location risk rating | Building design risk | Overall risk associated with storm surge inundation |
|---|---|---|---|
| Church | Low | Low | **Low risk**: Currently demolished but likely to be at low risk due to location in central part of village, high floor level and typically surrounded by boundary walls which act as inundation barriers |
| Power station | Low | Low | **Low risk**: Built in centre of the motu, with a high floor level |
| Administration building | Medium | Low (main part) | **Medium risk**: Overwashing waves from the ocean side will reach the Administration building and inundate the lower level. |
| Store / Admin building | Medium | Low | **Medium risk:** Overwashing waves from the ocean side may cause some low level inundation of the store and Administration buildings. |
| Bulk storage (building materials) | High | High | **High risk**: Located at the southern end of the island on low lying land. Whilst protected by the seawall, inundation of the building is likely due to the low floor level. High risk of damage if seawall fails. |
| Bulk storage | High | High | **High risk**: Located at the southern end of the island on low lying land. Whilst protected by the seawall and further back from the other bulk store, inundation of the building is likely due to the low floor level. |
| Solar panels / satellite dish | Med | Low | **Low risk**: In an area that has experienced overwashing from the ocean side during previous cyclones but raised well above any potential significant impacts. |
| School | Med | Med | **Medium risk**: Main buildings on lower-lying land on lagoon side. Surrounding land will get inundated but most floor levels likely to be above water level in all but the most severe events. The most landward buildings have lower floor levels but these are on higher ground. |
| Hospital | High | Med | **Medium - High risk**: On low-lying land on lagoon side. Surrounding land will be inundated with potentially some minor inundation within the hospital (floor levels < 1 m above surrounding ground levels. |
| PWD building | Med - High | Med | **Medium risk**: On low-lying land on lagoon side. Surrounding land will get inundated due to high lagoon levels but floor levels likely to be above water level in all but the most severe events. Currently not used. |

The damage assessment also noted that inundation around the hospital caused septic tanks to overflow with a large amount of debris in the water (which would have substantially increased the hazard to people accessing the hospital). The hospital buildings are of recent construction with a water tank underneath. However, the floor level is around or just less than 1 m above the surrounding ground level which may result in minor inundation of the building. The damage assessment suggested water inundated the hospital buildings during Cyclone Percy but this was apparently not the case.


**Figure 14:** The location and construction of Atafu's power generation building (left) is a good example of community infrastructure at low risk from storm surge inundation risk. It is located well inland, in a stable area of the motu. If high storm surge levels in the lagoon do result in some minor inundation, the floor level is well above likely inundation levels. The bulk storage sheds (right) have a history of having their contents, and the structures themselves damaged during cyclone events.

## 3.5 Housing

There did not appear to be significant inundation-related damage to the main housing stock during Cyclone Percy with little noted by the damage assessment team or raised with the project team during this visit. Some erosion and scouring around the corners and foundations of certain buildings on the lagoon side was observed (noted in Figure 15). Most building damage was related to wind damage.

The building survey identified 112 primary housing units (cook houses or sleep-outs attached to the main house were not included). Of this number, one was derelict, two were under construction and only three had two storeys. It was noted on all atolls that the level of damage to property and contents was much less during Cyclone Percy than during past cyclone events that have caused significant inundation of the inhabited sections of the motu. This is largely due to the practice, which began after the introduction of the housing grant scheme, of raising floor levels either by constructing the water tank under the house, using concrete piles or a raised concrete slab. Figures 16 and 17 summarise the number of houses and their approximate floor elevations (relative to the surrounding ground surface).

**Figure 15:** Damage to a building (left) likely due to debris impact, and scouring around the foundation (right) caused by overwashing water during Cyclone Percy. Both properties are located on low-lying land on the lagoon side on the promontory east of the school.

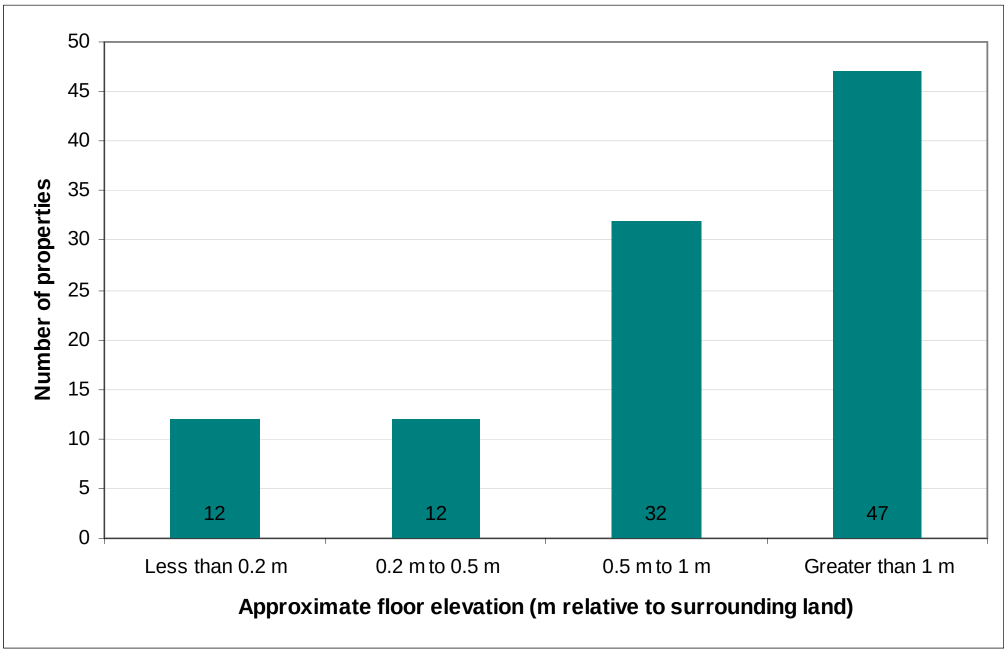


**Figure 16:** Summary of the number of houses with various floor levels on Atafu.

**Figure 17:** Floor levels of residential properties relative to surrounding ground levels. Red = < 0.2 m, Orange = 0.2 – 0.5 m, Yellow = 0.5 – 1 m, Green = 1 – 2 m, and Blue = > 2 m.

### 3.6 Extent of inundation during Cyclone Percy

From the damage assessment report, and our own discussions with the *Taupulega* and other members of the Atafu community, Figure 18 attempts to summarise the total extent of the inundation during Cyclone Percy.


**Figure 18:** Approximate areas on the inhabited area of the motu inundated during Cyclone Percy. Note inundation will not have occurred at the same time at all locations.

The main location where waves overwashed from the ocean to the lagoon side was around the school area. From discussions with residents in this area, similar overwashing occurred during Cyclones Val, Ofa, Tusi and in 1966. Waves also overtopped the gabion seawalls, inundating the cleared area in front of the administration buildings and entering the bulk storage sheds.

On the lagoon side, maximum water depths were generally above 0.5 m but less than 1 m on the lowest lying areas, again in the vicinity of the school and hospital. From discussions of past cyclone events it would appear that inundation from the lagoon side will reach the road down the centre of the village / edge of the banana plantation, with the low-lying promontory / reclamation between the hospital and school being the worst affected.

### 3.7 Cyclone damage estimates

No quantified estimate of direct or indirect damage has been made after Cyclone Percy and whether such damage was attributable to either wind or inundation. It would appear most direct costs related to:

- Structural damage to the bulk storage shed.
- The supply of provisions in the aftermath of the event.
- Labour costs associated with the clean-up.
- Only one house appeared to have suffered structural damage due to inundation with another suffering some minor scouring of foundations.

In addition there will have been considerable indirect costs, such as ongoing loss of agriculture production, and also direct and in-direct intangible impacts on the Atafu community.

Damage estimates of previous cyclones, quoted in the *Tokelau Infrastructure Study* (Opus, 2001) provide damage estimates for the whole of Tokelau from previous cyclones as:

| | |
|---|---|
| Cyclone Wini (may also include Tusi?) | USD$500,000 |
| Cyclone Ofa | USD$2,400,000 (NZ$4,000,000) |
| Cyclone Val | USD$750,000 |

Again, there are no estimates of the relative contribution of damage caused by wind and by inundation or erosion, with the majority of damage typically caused by the former. Developing a system and template for systematically recording and quantifying damage following a cyclone is something that would be of considerable benefit.

# 4. An overview of the future management of coastal hazard risks on Tokelau

## 4.1 Introduction

Episodic cyclone events will continue to cause damage on Atafu in the future. On average a cyclone event that has the potential to cause a significant amount of damage (due to wind and / or wave inundation) appears to occur about once every 10 years with a likelihood of occurrence during periods of El Niño periods. However, their actual occurrence is variable, e.g., from occurring on consecutive years as happened in 1990 and 1991 (Ofa and Val), or with longer gaps, e.g., the 14 years between Cyclone Val and Percy.

This section provides an overview of the approach adopted to the development of a long-term and sustainable programme, described in Section 5 to 9, for reducing cyclone and other climate related coastal hazard risks facing Tokelau. Many of these recommendations had been stated before (e.g., Bakx, 1987). However, it is important to note that, even with effective and continued implementation of all the recommendations in this report, small atolls such as Tokelau will still have residual risks associated with cyclone events. Whilst it is possible to reduce the damage and impacts associated with such cyclones (discussed in this and subsequent chapters), there will always be more severe events, likely to occur around every 30 to 50 years, where substantial external assistance will be required to Tokelau in the aftermath.

## 4.2 A strategic approach to reducing risk

Cyclone related risks are not just caused by the occurrence of the cyclone, and its hazardous characteristics (e.g., high winds and / or storm surge and large waves with associated inundation and erosion); risk is also a function of:

1. The nature of the elements (people, property, community infrastructure etc.) at risk from the hazards created by the cyclone.

2. How vulnerable (or resilient) these elements are (e.g., building location, construction or condition; state of the natural coastal defences; socio-economic conditions etc.).

This highlights the fact that coastal hazard risk is a combination of both natural and human factors. Indeed, in most coastal locations of the world, coastal hazard problems typically have their origins in human actions rather than "abnormal" coastal behaviour (Dahm, 2005). However, historically the management of such risks has focussed on attempting to adjust the natural coastal processes, typically through engineering structures such as seawalls to "hold the line" rather than considering adjusting human behaviour and approaches to developing the built environment.

In many cases such human actions have exacerbated or caused further problems, reduced the long-term adaptive capacity of the natural coastal defences, and over the longer-term is often the most expensive (both in terms of capital and maintenance cost) form of risk reduction (but not the most effective). Such an approach has also lead to: (1) a narrow management focus; (2) a reactive approach to managing coastal hazard risk; (3) ignoring the human dimension of the problem, often leading to increasing intensification of development in hazard-prone areas, and the problem becoming more complex and difficult over time (Dahm, 2005).

The limitations of such a management approach has led to increased realisation that a more proactive and strategic approach incorporating a wide range of social and environmental objectives, is required for the development of more resilient communities exposed to coastal hazards. Embodied in such an approach is the need for a strong emphasis on awareness, information and communication through a participative process.

In developing such a strategy for managing coastal hazard risk on Atafu it is important to note that:

- **There is no "silver bullet"** i.e., no one option that will solve all the problems. A programme of reducing risk involves a range of inter-related activities, the composition of which will vary from location to location (e.g., ocean to lagoon shore, between different atolls) and over time.

- **Reducing risk is a journey not a destination**. Reducing the risks of cyclone related erosion and inundation damage is hard work and is a continuous and ongoing activity integral to development decision-making at individual, village (atoll), and national levels.

- It is critical to build **adaptive capacity**, which is the ability of the coastline, the community and individuals to cope with, adjust, respond, or even take advantage of, variability and extremes in climate, including potential long-term climate change.

## 4.3 Sustainable economic development

Implementing such an strategy for managing coastal hazard risks should also consider and contribute to Tokelau's economic development aspirations. In 2002 the Council of Faipule developed a vision for sustainable economic development on Tokelau, defined as "*our people improving the quality of their lives on Tokelau*". As part of this vision, six goals were developed:

1. A self-sustaining process of economic growth.

2. Creation of jobs at acceptable wages with appropriate benefits and career progression.

3. Producing goods and services that meet the social needs like affordable housing, reliable energy supplies at lower costs, better health care and education.

4. Community control, accountability and participation in the process of making decisions.

5. Broadening business and asset ownership within the community.

6. Respect for our unique cultural heritage and traditional ways.

Episodic natural disasters, such as cyclones on Tokelau, can result in high degrees of economic and social consequences in the months and years following such events which impact directly on the goals outlined above. Introducing pro-active (rather than re-active) risk reduction approaches into the development planning process is a well established and effective approach to reducing such consequences and will contribute directly to the goals and aspirations outline above. All recommendations outlined in the following sections have been developed taking account of the above goals.

### 4.4 Developing a risk reduction programme on Atafu

During the discussions on Atafu, a range of potential risk mitigation options were discussed. This not only included reducing the risks associated with cyclone-related inundation, but also discussing ways of reducing the impacts of potential longer-term coastal changes including those associated with long term climate change.

It was emphasised that the focus of the project was not just on seawalls but on a wide range of options for reducing storm surge inundation risk with the aim of developing a strategic approach involving a mixture of short and long term objectives and options. Options discussed and developed included:

- Ensuring protection of the natural coastal defences (reef, reef flat, beach and coastal margin) and identifying the underlying causes of human activities that reduce the effectiveness of these natural defences and how such impacts could be effectively reduced (Section 5).

- Options for land management planning both for future development and consideration of the potential for developing a long-term strategy for the movement of key infrastructure or other buildings from high risk areas (Section 6).

- How risks of damage to property and content could be reduced through building design, i.e., accepting that inundation is a natural occurrence (and will always be an issue on Atafu) and designing and constructing buildings and infrastructure to take account of this (Section 7).

- Protection measures, including the needs for both existing seawall structures, and requirements for future structural solutions with an emphasis on structures that: (1) enhanced the natural defences and were more sensitive to the important natural processes occurring on Atafu; (2) optimised to be more effective in reducing inundation; (3) more sustainable in terms of the longevity of the structure, and in terms of ongoing maintenance costs (Section 8).

In developing such an approach, the emphasis during the discussions on each atoll was placed on identifying activities that:

- Could be initiated and implemented at individual and island-community levels without the need for significant external assistance from the donor community.

- Could build on past on-island experience of implementing measures to reduce the risk of cyclone related inundation.

- Could be easily implemented using equipment that would realistically be expected to be available on Tokelau (e.g., could be built using an excavator rather than specialist equipment) and on-island skills (rather than rely extensively on external contractors).

- Looked for ways to reduce or streamline the need for large amounts of manual labour to implement solutions.

Outlined in the next sections are a series of recommendations for consideration by the decision-making process within the Atafu community. Also provided is a suggestion as to how these recommendations could be implemented, priority, and the timeframes over which the recommendations would be implemented (in terms of short-term, < 5 years, medium-term, 5-10 years, and long-term, > 10 years) and over which the benefits would be achieved. Also noted are potential equipment, labour and material requirements as well as a brief summary of the anticipated environmental, social and economic benefits and costs of the overall recommendations, how sustainable the recommendations are, and how they contribute to Tokelau's overall sustainable economic development goals.

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# 5. Protecting and enhancing the natural coastal defences

## 5.1 Overview

The careful management of the natural coastal environment and the resources found there, is the single most important coastal defence policy for Atafu.

Along the ocean side of the motu, the reef, reef flat, beach and vegetated beach crest is the natural coastal defence protecting the village. It is a vital community asset. Activities, such as sand and coral rubble removal from the beach or reef flat, clearing of natural vegetation, and building housing close to the ocean shore all act to substantially reduce the effectiveness of this defence, to the detriment of the community.

Developing effective approaches to reducing the impacts of such detrimental activities and addressing the underlying socio-economic causes of such activities is vital to maintain the effectiveness of this natural defence. The Atafu community is already making such efforts, for example reducing the impacts caused by sand and coral removal from the ocean beach, with the majority of sand for community and construction projects is now sourced from a 'sacrificial' motu elsewhere on the atoll. However, this is a time consuming and labour intensive activity not only on Atafu but also on Nukunonu and Fakaeofo where typically it takes 10 men about 4 hours to collect 2 tonnes of sand which is transported back using the barge. In most other Pacific Island nations, developing an alternative source of sand is the critical component in reducing beach sand mining impacts.

The following recommendations are made:

**Recommendation 1:** The removal of sand and coral rubble from the ocean beach and reef flat along the western coastline of Atafu needs to be regulated by the community.

**Recommendation 2:** The clearing of natural vegetation be discouraged for at least 50 m behind the vegetation line at the ocean shoreline.

**Recommendation 3:** A rolling programme of repairing the natural coastal defences, through replanting natural shoreline vegetation, to help trap and bind the sands on the upper beach crest, be initiated as an ongoing community project along a 700 m length of the ocean shoreline from the channel access point to north of the school.

**Recommendation 4:** A suitable sand pump to access lagoon sand resources needs to be acquired to enable a long-term source of construction sand to be secured to meet Atafu's future development needs without impacting on the natural coastal defences, and to reduce the considerable time and labour commitment required to currently meet present day demands .

## 5.2 Implementation of the recommendations

| Recommendation | Priority | Implemented over: | | | Risk reduction benefits over: | | |
|---|---|---|---|---|---|---|---|
| | | Short | Medium | Long | Short | Medium | Long |
| **1** | High | | | | | | |
| **2** | High | | | | | | |
| **3** | High | | | | | | |
| **4** | High | | | | | | |

Implementation of *Recommendations 1 and 2* could be achieved through a combination of developing village rules to be exercised by the *Taupulega* and a programme of community awareness to highlight the impacts and promote good practice. Development of a series of radio broadcasts may be an appropriate method of achieving this.

The responsibility for developing and implementing a community re-planting programme (Recommendation 3) could be carried out by a number of community groups (*Amaga*, *Fatupaepae*, youth, school project) under the direction of the *Taupulega.* One possible way is to have community planting days on the anniversaries of major cyclone events (Percy, Val, Ofa, Tusi, 1966, 1914 etc.) as a way of reminding the community about the impacts of past cyclones and the purpose of the activity.

The planting should focus primarily on establishing coconut and pandanus in a 20 to 30 m (minimum) strip from the current vegetation line:

- The methodology for planting of coconuts and other plants should be developed on the advice of community experts knowledgeable in the such activities.
- Fertiliser may need to be used to help establish new plants and a suitable traditional mulch around the plants to minimize wind and water erosion and help the soil retain moisture.
- Regular watering may need to be conducted initially to help the plants establish.

- Access points from the village to the ocean beach should be limited as much as possible.
- Leaves, fronds and branches deposited by the trees within the strip should not be swept up but allowed to remain.
- Periodic planting will be required to replace plants that haven't grown or have been affected by future cyclone events (it is important to appreciate that the plants in this area are sacrificial and re-establishing vegetation cover will be required after cyclone events).

Other natural shoreline vegetation, particularly the creeping vine (*totolo*) which is a good sand binder and low shoreline shrubs should also be established in the areas close to the current vegetation line. It is suggested that the initial focus should be on the area to the ocean side of the school and school playing fields, working southwards towards the boat channel access point over a number of years. The full benefits of the scheme will only begin to be realised over the longer term (i.e., beyond 10 years) as the plants mature.

Sand deposits within the lagoon at Atafu represent a much more sustainable source of sand than current sand sources. Acquisition of a small generator powered sand pump mounted on the barge to suck sand from relatively shallow areas in the lagoon (< 10 - 15 m deep) would provide a readily accessible sand resource, at a much reduced labour cost and time commitment. This has previously been identified as a requirement for all three atolls within the *Tokelau Infrastructure Study* (Opus International Consultants, 2001) with both high environmental and developmental benefits resulting. Furthermore if further coastal defence activities outlined in Section 8 are commenced, a significant sand supply is an integral component of these activities.

Whilst there are various types of pumps for dredging sand, most have a capacity well in excess of that required on Atafu. Low capital cost and maintenance requirements are also important. From discussion with pump suppliers an air operated diaphragm pump was recommended (e.g., the AOD series of pumps from Price Pump Co[2].). This pump has the advantage of being oil free, has minimal parts for maintenance, and has proven reliability.

This pump would be located on the barge, powered by a small petrol driven air compressor, and would "hoover" sand from the seabed. Some modifications to the

2 www.pricepump.com

barge would need to be done to provide fixings for the pump and generator and to allow the sand to be sieved in to the barge, and the water returned to the lagoon.

## 5.3 Main constraints to implementation

- Potential conflict between an individuals rights as a land owner (to clear vegetation, collect sand from the beach in front of their property, prevent vegetation being planted on their property etc.), versus the best interests of the overall community (1, 2 & 3).

- Long-term maintenance of community enthusiasm for ongoing replanting initiatives (3).

- Difficulty of enforcing village rules related to sand mining and vegetation removal (1, 2).

- Availability of funding for capital purchase of sand pump & generator (4).

- Long-term maintenance of sand pump and generator equipment (4).

## 5.4 Summary of expected benefits and costs.

| | Benefits | Costs |
|---|---|---|
| Environmental | • Long term increase in the natural resilience of the natural coastal defence on the ocean side (Rec. 1,2,3).<br>• Potential impacts relating to the removal of sand from the lagoon are likely to be minimal given the very small amount being taken in relation to the overall resource (and much lower impact than taking sand from a beach). Site specific impacts can be minimized by limiting the amount taken in any one place and ensuring activities are located away from any coral heads (*akau*), (4) | |
| Social | • Long term benefit to the Fakaofo community in assisting the reduction of risks associated with cyclone inundation (Rec. 1,2,3).<br>• Considerable benefit in reducing labour requirements to meet sand demand (4). | • Ongoing continual community labour commitment for replanting exercise, (Rec. 3). |
| Economic | • Limited external / materials costs (Rec. 3)<br>• Significant economic benefit in reduced cost of construction sand, (4)<br>• Complements other risk management measures in reducing economic impacts of cyclone disasters. | • Moderate and continual labour costs, (Rec. 3).<br>• Moderate capital costs for equipment purchase and ongoing maintenance costs, (4). |
| Sustainability of recommendations | • Dependent on community motivation but requires little external funding, equipment or assistance for ongoing implementation, (Rec. 1,2,3). | |
| Contribution to sustainability development | • Contributes to long-term reduction of impacts on individuals, community and economy during cyclone inundation and coastal hazards.<br>• Enables community control, accountability and participation in risk reduction measures (Rec. 1,2,3). | |

# 6. Village planning to avoid coastal hazards

## 6.1 Overview

Incorporating coastal hazard considerations in to both the individual and community decision-making process when considering the location of new or re-built infrastructure, community buildings and residential property is an extremely effective way of reducing the risks associated with coastal hazards and a vital component in avoiding or reducing future risk associated with cyclone or other long-term coastal hazards.

### 6.1.1 Future buildings and infrastructure

One of the most effective ways to reduce risk is avoiding building or locating essential infrastructure in areas that are known to experience inundation during cyclone events. From the inundation caused by Cyclone Percy, and from discussions with the community of inundation extents during previous cyclones, Figure 19 summarises, in a simple format, the main areas within the village that can be considered high hazard zones.

These are areas that during past cyclones have experienced overwashing and inundation and can be expected to be the areas most likely to be affected in future events. The areas highlighted in red are those areas that are primarily affected by water overwashing from the ocean side. Areas highlighted in orange are those areas where inundation due to high lagoon water levels is the primary cause of inundation (Note: this does not mean that the areas that are not highlighted will not experience inundation). There are also many other social, economic and environmental factors that need to be taken in to account for effective land use management planning.

The following recommendations are made:

**Recommendation 5:** No further community buildings or essential infrastructure development be constructed with the high hazard (red or orange) zones.

**Recommendation 6:** That the Atafu community discuss, develop and implement an approach (with assistance from land-use managing planning experts) that addresses the needs of both the community and the individual landowners, to restrict further residential building development within the high hazard red zone.

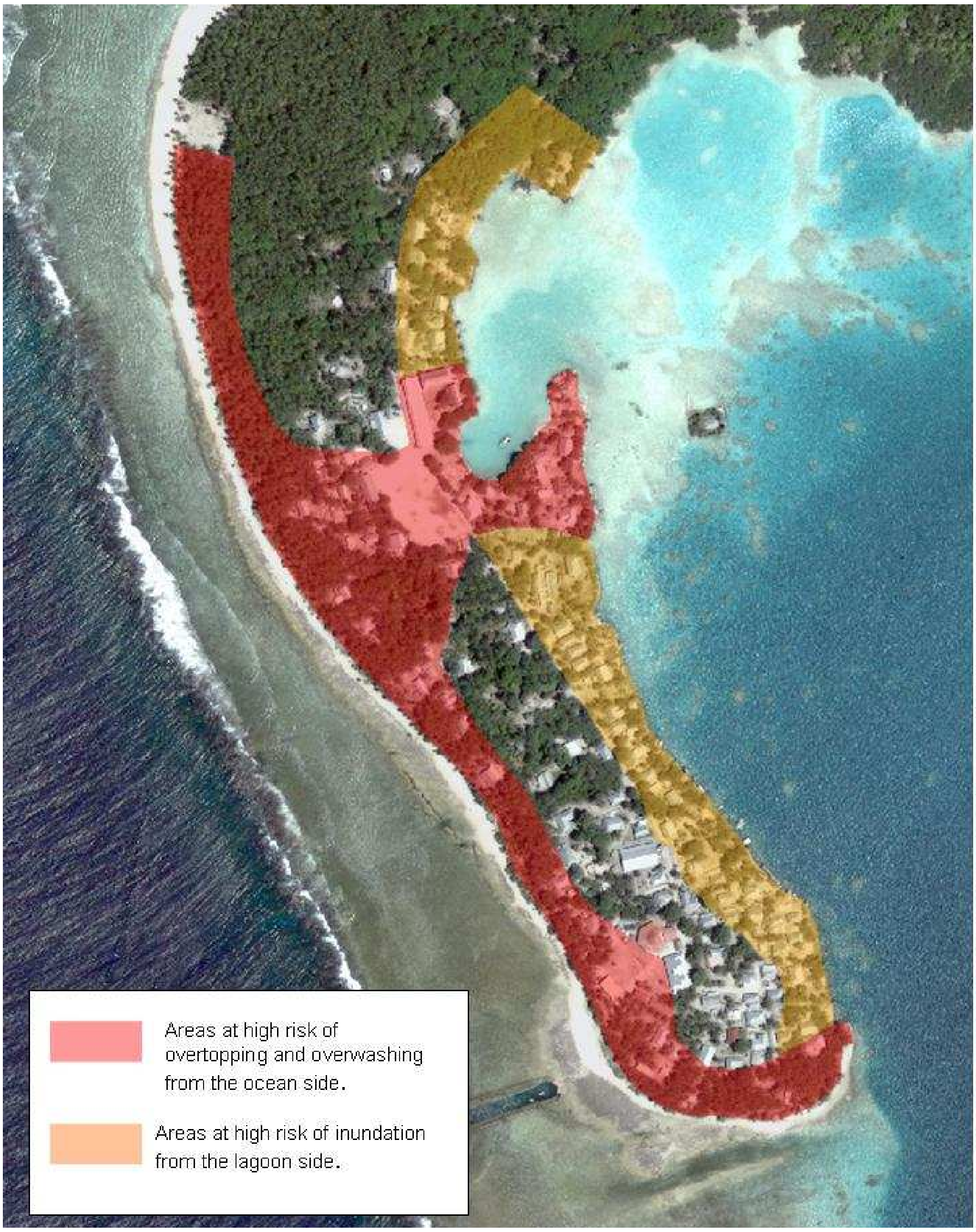


**Figure 19:** Summary of areas within the village at high risk from inundation. Note an inspection was not made of the northern part of Atafu but the same general buffer zones around both the ocean and lagoon coasts should be applied to any new development in this area.

**Recommendation 7:** On the lagoon side (orange zone), further future residential building be allowed only if no other safer building locations are available to the particular land-owner provided that the floor level of the property is constructed to be at least 1 m above surrounding land levels (see below), is built as far landward as possible, and does not involve further reclamation of land.

**Recommendation 8:** In undeveloped areas to the north of the existing village, the provision of a buffer zone of undisturbed vegetation of no less than 30 m width from the vegetation line on the ocean shoreline, 50 m width from the lagoon shore (landward of the road), with any construction also avoiding lower-lying areas.

### 6.1.2 Existing buildings and infrastructure

Whilst many of Atafu's community buildings and infrastructure are well located (e.g., the power plant) there are a number of buildings that are highly susceptible to inundation damage (Table 1). In the short term the main focus needs to be on reducing the risks to the two bulk storage sheds, and in the longer-term the hospital and school.

On the ocean shoreline there is a small number of residential property at high risk due to their location. The risks to these building and inhabitants will continue to increase over time. Also the presence of these buildings reduces the overall effectiveness of the development of the re-vegetated buffer zone (Recommendation 3) as an integral component of the natural coastal defence along the ocean side of the motu.

**Recommendation 9:** Both bulk storage sheds should be relocated to a safer location to avoid future building and content damage. Re-construction of these building should also incorporate flood proof walls (up to about 1 m high) and the ability to quickly flood proof the access points. An open sided, covered area could be constructed over the existing floor area of the landward bulk storage shed to provide temporary storage when offloading cargo.

**Recommendation 10**: During the normal cycle of replacement / upgrading of the school and hospital buildings, the floor levels of these buildings should be increased to at least 1.2 – 1.5 m above surrounding ground levels. In the longer-term, consideration should be given to the potential for relocating the hospital to an area of less inundation risk.

**Recommendation 11:** That the Atafu community discuss and develop an approach and method of implementation, that addresses the needs of both the community and the individual landowners, to enable individual land / property owners located in high risk areas on the ocean shoreline to relocate either landward within their property, or to a suitable new safer site. In the long-term such mechanisms may need to be applied to assist property owners located on low-lying areas on the lagoon shoreline.

## 6.2 Implementation of the recommendations

| Recommendation | Priority | Implemented over: | | | Risk reduction benefits over: | | |
|---|---|---|---|---|---|---|---|
| | | Short | Medium | Long | Short | Medium | Long |
| 5 | High | | | | | | |
| 6 | High | | | | | | |
| 7 | Med | | | | | | |
| 8 | High | | | | | | |
| 9 | High | | | | | | |
| 10 | Med | | | | | | |
| 11 | Med | | | | | | |

Developing appropriate and effective land management and planning policies and practices that meet both individual and community (atoll) aspirations is never an easy task. The *Tokelau Environmental Management Strategy (TEMS)* identified the development of such a policy (Programme Profile 1), with the associated strengthening of an Environment Unit to implement such measures (Programme Profile 2). It is suggested that these recommendations fit well with the framework of the Tokelau Integrated Environment Management Project (TIEMP), also being funded by the UNDP, which has a core objective of developing an Environmental Policy and Management plan and associated capacity building and awareness activities.

In terms of recommendations 6, 7, 8 and 11, the planning and management framework process needs to consider, develop and implement, within: (1) a Tokelauan context and (2) that meets the needs of both individual and community aspirations, some or all of the following:

- Restrictive zoning mechanisms.
- Design controls (see next section).
- Building set backs.
- Community reserves (e.g., community natural coastal defence buffer zones along the ocean frontage).
- Land swaps and transferable development rights (to aid landowners with little alternative options to locate property outside high risk zones, or where construction would increase the overall level of risk to the community through environmental damage).

Developing such a framework will take time to reach an effective consensus and will require outside assistance to facilitate its development. Associated with this will need to be a programme of awareness and capacity building at both Government and community decision-making level as well as awareness building at general community level. An important aspect will concern how such a land planning and management framework would be implanted in practice on each atoll (e.g., via the *Taupulega* or some form of development review / community planning forum) and the relative role of any national Environmental Unit. It will need to include an appropriate and well defined conflict resolution process.

It is anticipated that regional organisations such as SPREP may also have a role to play, with associated donor support, in coordinating and assisting Tokelau develop such a framework and associated activities.

However, a number of the recommendations outlined above, particularly relating to community infrastructure can be implemented directly by the *Taupulega* (Recommendation 5) and, in the case of recommendation 9 the relocation of the bulk storage sheds, through allocation within the annual budget process (or through negotiated donor support).

### 6.3 Main constraints to implementation

- Limited land out with private ownership for infrastructure development (5, 9, 10).

- Potential conflict between an individuals rights as a land owner (to build on their land etc.), versus the best interests of the overall community (6, 7, 8, 11).

- High density of development on lagoon and southern sections of the motu increasing pressure for reclamation and development in high hazard zones.

- Potential social (and potentially financial) impacts relating to relocation recommendations (6, 11).

- Lack of funding (either from donors or within Tokelau budget) to facilitate the relocation of community infrastructure currently located in high risk locations (9, 10).

## 6.4 Summary of expected benefits and costs.

| | Benefits | Costs |
|---|---|---|
| Environmental | • Long term increase in the natural resilience of the coastal defences along the ocean shoreline (Recommendations 5, 6, 8, 9, 11). | |
| Social | • Long term overall benefit to the overall Atafu community in assisting the reduction of risks associated with cyclone inundation from the ocean side.<br>• Improved awareness and incorporation of coastal hazard risk considerations within individual and community development decision-making. | • Potential for significant impacts on a number of individual land / property owners |
| Economic | • Should be the primary risk management tool on Atafu with the most significant financial and economic benefits in the long term | • External assistance required over a relatively long time frame to enable the development and introduction of appropriate planning frameworks.<br>• Potential high costs associated with relocation options, with benefits only realised over a long period.<br>• Potential financial impact on individuals currently located in high hazard areas. |
| Sustainability of recommendations | • Dependent on (1) continual political will for integrating risk management in to decision-making process, (2) continued community awareness and support to promote changing public behaviour. | |
| Contribution to sustainability development | • Contributes to long-term reduction of impacts on individuals, community and economy due to cyclone inundation & coastal hazards.<br>• Enables community control, accountability and participation in risk reduction measures (Rec. 8 & 11) | |

# 7. Risk reduction through building design

## 7.1 Overview

The activities by the community in Atafu, over the last ten to fifteen years, in building housing with: (1) concrete water tanks under the property; and (2) in a few cases on concrete piles, has had the greatest impact in terms of reducing risks to property and content damage due to storm surge inundation. In discussions on Atafu, damage to buildings and their contents due to water inundation was minimal compared to events that happened prior to the construction of such housing (e.g., the damage caused by the cyclone in 1966)

Typically two to three houses a year are commenced through the Housing Grant Scheme (either a replacement for an existing house or construction of a new house).

The following recommendations are made:

**Recommendation 12:** That the Housing Grant Scheme be continued (and potentially accelerated).

**Recommendation 13**: That coastal hazard risk reduction (through implementation of the relevant Recommendations 1 to 11 above) is an integral component to the plans for recipients of a housing grant. In other words, recipients of Government funds should not increase the potential for coastal related damage, either to the particular property or to the general Atafu community).

The majority of damage to residential property and other buildings during Cyclone Percy was due to wind damage. Whilst outside the scope of this report, it is suggested that an assessment of current building design practice is carried out by a suitably experienced engineer to identify potential improvements in the wind resistance of buildings in Tokelau.

## 7.2 Implementation of the recommendations.

| Recommendation | Priority | Implemented over: | | | Risk reduction benefits over: | | |
|---|---|---|---|---|---|---|---|
| | | Short | Medium | Long | Short | Medium | Long |
| **12** | High | | | | | | |
| **13** | High | | | | | | |

Implementation of *Recommendation 12* can be easily achieved by the *Taupulega* through continuation of the Housing Grant Scheme. If possible the emphasis should be on replacing (or relocating) existing housing with floor levels less than 0.5 m, which are located in the hazard zones identified in Figure 19 above). Comparing Figures 17 and 19, this suggests there are eight houses with floor levels below 0.5 m on the lagoon side, and around 12 houses in the high risk zone on the ocean side.

At present the Housing Grant Scheme provides $11,000 for construction materials, $9,000 for the water tank, and $3,500 for sanitation. In total a normal sized house costs around $40,000 with the excess being provided by the family constructing the house.

Ensuring that recipients of housing grants do not increase or exacerbate coastal related risk, *Recommendation 13*, (either to themselves or the community) could be achieved through a series of general guidelines that grant recipients must adhere to. These guidelines would be based on the relevant Recommendations 1 to 11 outlined above.

Observations of damage to buildings in Asia affected by the Boxing Day tsunami highlighted that buildings elevated on well founded piles generally experienced less damage than buildings with solid walls or foundations due to the reduced restrictions on water flows (i.e., water was allowed to flow under the buildings). Significant and widespread damage to solid foundations due to overwashing flows during a cyclone event is only likely to occur during the most severe cyclone events. However, under more moderate events damage to such foundations could occur to specific property where there is a high volume of debris in the water or the building is located very close to the beach.

Whilst it cannot be stressed strongly enough, it is vital to ensure that further residential property is <u>not</u> constructed within the high hazard zones identified in Figure 19. If for a particular reason this cannot be avoided consideration should be given to the use of piled foundations, ensuring that the piles are well founded to withstand overwashing forces, braced where necessary, and have sufficient structural connection to the main structural frame of the house..

### 7.3 Constraints to implementation

- Pressure on Tokelau budget to continue funding the housing loan scheme and lack of funds to accelerate it (12).

- Potential conflict between an individuals rights as a land owner (to build on their land etc.), versus the best interests of the overall community (13).

- High density of development on lagoon and southern sections of the motu increasing pressure for reclamation and development in high hazard zones (13).

### 7.4 Summary of expected benefits and costs.

| | Benefits | Costs |
|---|---|---|
| Environmental | • Should reduce further property development in the immediate coastal zone assisting long term increase in the natural resilience of the natural coastal defence on Atafu (Rec. 12 & 13). | |
| Social | • Continued improvement in housing standards.<br>• Substantial reduction in cyclone damage to, and inundation of, housing and associated tangible direct property damage and intangible impacts on household members. | |
| Economic | • Much improved housing standard with reduction in potential for structural and contents damage. | • Continued financial commitment to support the Housing grant scheme |
| Sustainability of recommendations | • Well established programme incorporated within the Tokelau budget process. | |
| Contribution to sustainability development | • Contributes to long-term reduction of impacts on individuals, community and economy due to cyclone inundation & coastal hazards.<br>• Enables community control, accountability and participation in risk reduction measures. | |

# 8. Risk reduction through protection measures

## 8.1 Overview

As discussed in Chapter 4, coastal defences such as seawalls built to 'hold' or 'advance the line' are often viewed as 'solutions' to coastal hazard problems. Unfortunately such actions tend to be reactive and are rarely the most effective options in the long-term, often leading to other environmental damage, e.g., loss of beach, and an expectation that such defences will be maintained *in perpertuum* leading to ever increasing financial commitment to maintain and upgrade such defences.

As Atafu has discovered with the gabion seawalls, coastal defences constructed to 'hold the line' along the ocean beach have a limited lifespan, at best probably around 20 years given the limited types of construction and equipment available (and even then with considerable maintenance likely to be required). In general seawalls are an expensive option, typically only 'buy some time', and should only be used as a last resort where assets are at direct risk and there are no other options to reduce this risk. Whilst on small motu such as Atafu, there is always considerable pressure to reclaim land, such activity is rarely consistent with reducing coastal hazard risk, particularly on the ocean side.

However, structural protection measures do have a role to play in such risk reduction through complementing and enhancing the activities outlined in Sections 5 to 7. Alternative approaches for construction of such protection measures on Atafu are discussed below. The approach recommended below (and for the future) is to ensure that all existing walls are properly maintained and functioning before considering construction of any new structures.

### 8.1.1 Existing coastal defences.

The potential long-term effectiveness of the gabion seawall on Atafu has been reduced by departures to the recommended design. Firstly the seawall has been placed between 5 to 15 m too far down the beach, making it more prone to damage, and secondly by raising the crest height of the wall by stacking gabion baskets one on top of the other. However, movement of beach material southwards along the ocean side has resulted in a beach forming at the toe of the structure, helping to protect it during normal wave conditions.

The gabion seawall is viewed by the community of Atafu as an important community asset, and one which has played a role in reducing the magnitude of damage during Cyclone Percy. Loss of the structure would be of significant detriment to the general well-being of the Atafu community, particularly until the bulk storage sheds can be moved to a safer location. Whilst the tops of many of the gabion baskets have split, the shape of the overall structure remains, with much of the coral fill still in situ. With maintenance, the structure can still perform a useful role over the short to medium term. However, the structure will quickly deteriorate if no maintenance activities are carried out.

It is also important to appreciate that construction using gabion type materials, whilst far from ideal in such a coastal environment exposed to wave action, does have advantages in the context of Tokelau given the limited construction materials and methodologies available.

**Recommendation 14:** Maintenance of the existing gabion seawall, to extend its effective life, is a priority activity before the defence degrades further and before any further protection works are considered.

On the lagoon side, construction and maintenance of the existing coral block walls fronting most of the residential property is the responsibility of the individual land-owner. As the defence function is to protect the individual land-owners land (rather than inundation protection for the greater benefit to the general community), it is suggested that responsibility for the continued maintenance of such structures should rest with the individual landowner.

### 8.1.2 New structural protection measures (ocean side).

Discussions concerning the need for future structural solutions focused on the primary objective of reducing the frequency and / or magnitude of water overwashing and inundating the main inhabited areas of the village (rather than reclamation or protection of land). In addition to the general considerations for future activities outlined in Section 4.4, other important issues guiding how such structures would be developed include:

- Constructing ‘hard’ defences such as seawalls within the beach system generally would have a long term impact on the natural coastal defence system and if extended further north on Atafu, would increasingly exacerbate erosion problems.

- Given the construction material and methodologies available on Tokelau, such structures, placed within the beach system, generally required significant amount of maintenance and typically have a relatively short lifespan compared to other forms of structure (a good alternative example are the pig pens on Atafu, which due to their location built back from the vegetation line, had prevented inundation but also lasted a much longer time).
- The gabion seawalls are still overtopped by waves during cyclone conditions, exacerbated by the defences being too far seaward from that initially designed, causing scouring behind the structure.

Based on the example of the pig pens, a number of different designs were developed in consultation with the Atafu community, which aimed to compliment the measures being recommended (1, 2, 3, 5, 6, 8, 9 & 11) to increase the resilience and enhance the function of the natural defence in the long-term, and help reduce the damage and risks to the village caused by overtopping and overwashing during cyclone events. These are discussed in the next section.

**Recommendation 15:** A long-term (phased) programme of constructing defences, located back from the vegetation line, be commenced along the sections of coast most at risk from overtopping with the aim of complementing and enhancing the other risk reduction activities discussed in the previous sections.

Other forms of defence structure were discussed during the community meetings, particularly relating to offshore structures located on the reef flat to help dissipate wave energy (for example breakwaters using concrete armour units such as those used to build the breakwater at the entrance to the port at Apia). Cost, environmental issues, and construction logistics all make such structures unfeasible in Tokelau’s situation.

Based on these considerations, the construction of engineered seawalls or other forms of “hard” coastal defence, seaward of the vegetation line (i.e., in a similar location on the beach as the existing gabion seawall) is not considered an appropriate coastal management or cost effective solution for reducing the potential for wave overtopping and overwashing along any other section of the ocean shoreline on Atafu at this time.

## 8.2 Implementation of the recommendations.

| Recommendation | Priority | Implemented over: | | | Risk reduction benefits over: | | |
|---|---|---|---|---|---|---|---|
| | | Short | Medium | Long | Short | Medium | Long |
| **14** | High | | | | | | |
| **15 (Phase 1)** | High | | | | | | |
| **15 (Phase 2)** | Med | | | | | | |
| **15 (Phase 3)** | Low | | | | | | |

### 8.2.1 Gabion repairs

Repair to the existing gabion defences, *Recommendation 14*, can be conducted in two phases:

Phase 1 would involve:

- Replacement of gabion baskets on the top two layers which are substantially damaged (i.e., where the sides and tops of the baskets are burst). Replacement baskets should be galmac coated with a PVC sleeve. The existing baskets are only zinc coated – the galmac coating and PVC sleeve is more rust resistant (about 1.5 times better than the existing baskets thereby increasing the lifespan of the baskets). There should be sufficient coral rubble available from the existing baskets to fill the replacements. However, if more rubble is required it should be flat and slabby rather than rounded and sourced from the locations recommended in the original EIA.

- Scraping off the coral rubble which is presently built up over the bottom half of the seawall, covering of the entire structure with continuous sheets of PVC and zinc coated wire mesh, contoured and laced to the baskets underneath (Figure 20), and **replacing the coral rubble back at the toe.**

- The vertical upper section of the wall either side of the channel access point should be rebuilt as a stepped wall to the level of the land behind.

Phase 2 (which may need to be conducted at the same time as Phase 1) would involve repairing the toe of the structure. It is estimated that this needs to be conducted along approximately 50 m to the north and south of the access point to the channel. The toe and crest of such a structure are typically the most susceptible components of such a seawall. It is suggested that the bottom layer of gabions be removed and replaced by a mass concrete toe beam, Figure 20, (similar to the suggestion made in the *Tokelau*

*Infrastructure Report* (Opus International Consultants, 2001). Ideally this would be keyed in to the underlying beach rock and would possibly also require anchor bolts grouted in to the underlying beachrock as detailed in the Infrastructure report. The toe beam will provide more robust support to the toe of the structure but should not be large enough to have a detrimental impact on beach processes through increased wave reflection. If the uncovering of the toe of the structure reveals significant damage to the bottom layer of gabions along additional sections, such work may need to be extended further.

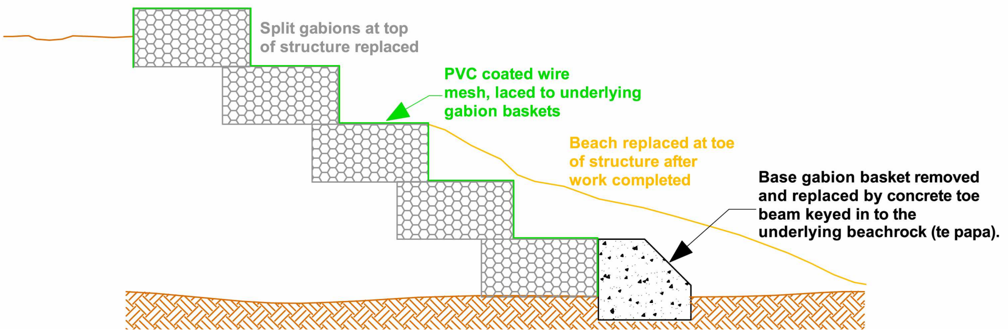


**Figure 20:** Repair details to gabion seawall.

The maintenance suggested above should extend the life of the structure over the short to medium term depending on the frequency and severity of cyclone events in the coming years and volume of beach fronting the structure. Prolonging the lifetime of the seawall means that the focus can shift to planning and implementing the relocation of the bulk storage sheds (Recommendation 9) Maintenance to repair split mesh should be conducted periodically and should be a <u>priority</u> before any further new construction work is carried out.

### 8.2.2 New berm structures (ocean side)

Designs for further engineering work to reduce the potential for overwashing waves inundating the village were developed during the community meetings and are shown in Figures 21 & 22.

The intention is that the structures would work in conjunction with recommendations 1 to 3 detailed above, and land management and planning recommendations (5, 6, 8 and 11). A berm (replicating a natural storm beach berm) parallel to the shoreline would be created between 15 to 25 m back from the present vegetation line just seaward or close to the highest part of the natural storm berm (the closer to the shoreline it is placed the less effective it will be in terms of reducing overtopping waves). This would:

- Allow the beach to continue to respond in a natural manner, both during storm events and over the long term;
- Define the landward edge of the high hazard buffer zone and the area for ongoing replanting efforts (Recommendation 3);
- Reduce the potential for waves overtopping the beach to continue to overwash across the motu;
- Limit the exposure of the structure to any significant wave attack, toe or crest damage, hence increasing the lifespan and effectiveness of any such structure.

Two methods of construction were discussed. The first, and the preferred method, would be to create a berm using Terrafix Soft Rock[3] containers (Figure 21). These are strong bags of various sizes which are filled with sand and used in marine works. Due to the lack of heavy lifting equipment the smaller sized 0.35 $m^3$ or 0.75 $m^3$ bags would need to be used. For stability the larger size would be preferable but this may be beyond the lifting capacity of the new Bobcat excavator that was about to be delivered to Atafu. If so, some consideration may need to be given to the hire of a larger loader / excavator from Samoa during any construction phase. The other advantage of using the small bags is that they can easily be replaced if damaged.

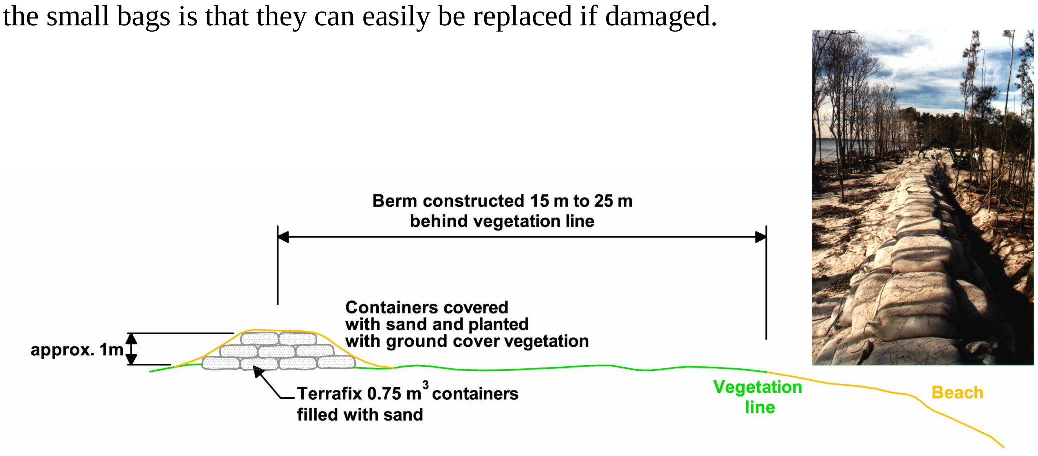


**Figure 21:** Berm structure created from Terrafix soft rock containers. The inset photograph shows a similar berm application (photograph courtesy of Soil Filters Australia Pty Ltd).

[3] E.g. http://www.geofabrics.com.au/terrafix.htm

Construction of such a structure will require a significant source of sand, beyond what could realistically be supplied from collecting and loading the barge by hand from the ‘sacrificial’ motu. This is where the sand pump (Recommendation 4) forms a vital component of the project and will be required prior to commencement of the construction of such a structure.

The completed structure would be create a berm around 1 m high. Figure 21 shows a cross-section using nine containers. On sections of the coastline where the overwashing risk is lower, or where the structure is located further back from the vegetation line, a reduced cross-section using six containers may provide sufficient stability, reducing the construction cost of the structure significantly.

Ideally the structure would be covered with sand and low ground cover plants such as the creeping vine (*totolo*) to help bind the sand and protect the bags from people walking over them. The structure also needs to be continual, i.e., the effectiveness of the structure would be compromised significantly if gaps are left for access purposes or due to a particular landowner refusing to allow construction on their land.

The second option is to create a gabion berm (Figure 22). As with the previous design this would be located 15 to 25 m behind the vegetation line close to or just seaward of the crest of the storm berm. It is similar to the original gabion designs suggested by Brockliss (1992), albeit located further back, with the function purely to act as a secondary line of defence in reducing wave overwashing of the entire motu. As with the scheme above, this design allows the beach system to continue to act as the primary defence and but will reduce the potential for ocean waves entering the village, particularly if the area between the vegetation line and the defence is well vegetated. The concrete crest beam will provide extra stability to the defence but it is suggested that land levels (e.g., using fill from the excavated foundations) are built up immediately behind the defence and stabilized with low ground cover vegetation.

This defence would be more expensive than the option suggested above and will require a substantial volume of coral rubble. However, it is an alternative solution if a more sustainable and less labour-intensive source of sand does not occur.

The construction of such a berm along sections of the ocean frontage will be a long term endeavor dependent on both labour and funding availability. It is suggested that the first phase be treated as a demonstration phase, with review and evaluation of the methodology (construction lessons, ways to reduce labour commitment etc.) and performance, prior to the construction of further phases. It is suggested that the main priority for the first phase should be the area to the seaward side of the school (approximately 120 m in length) that has experienced overtopping and overwashing during most of the cyclone events that have affected Atafu (Figure 23).

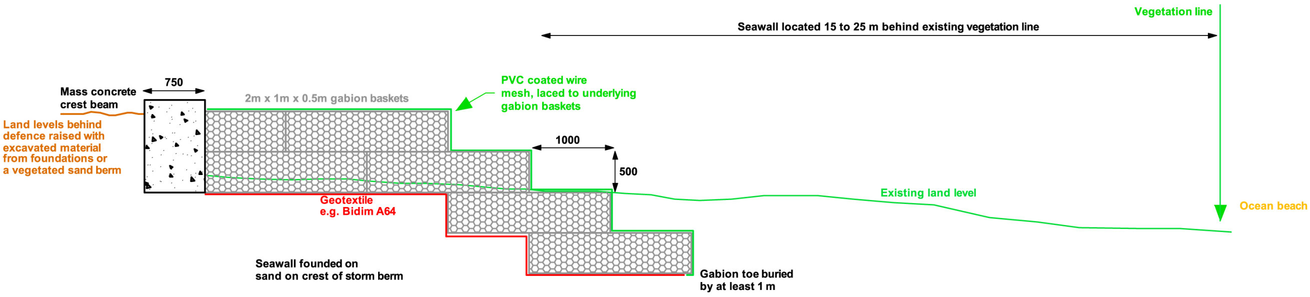


**Figure 22:** Gabion berm option. Dimensions in mm unless otherwise stated.

Depending on the review, further phases could be considered, for example:

- Phase 2: In front of, and to the south of, the Administration buildings as a long term replacement for the gabion seawall when it reaches the end of its lifespan (it is unlikely that a direct replacement for the gabion seawall could be justified for both environmental and economic reasons).

- Phase 3: Extending southwards from the first phase.

During the community discussions it was apparent that traditional seawall structures were the only mechanisms suggested for future risk reduction activities. Again some form of community awareness programme needs to be carried out in conjunction with any further work highlighting the issues and impacts related to *ad hoc* and inappropriate coastal defences structures.

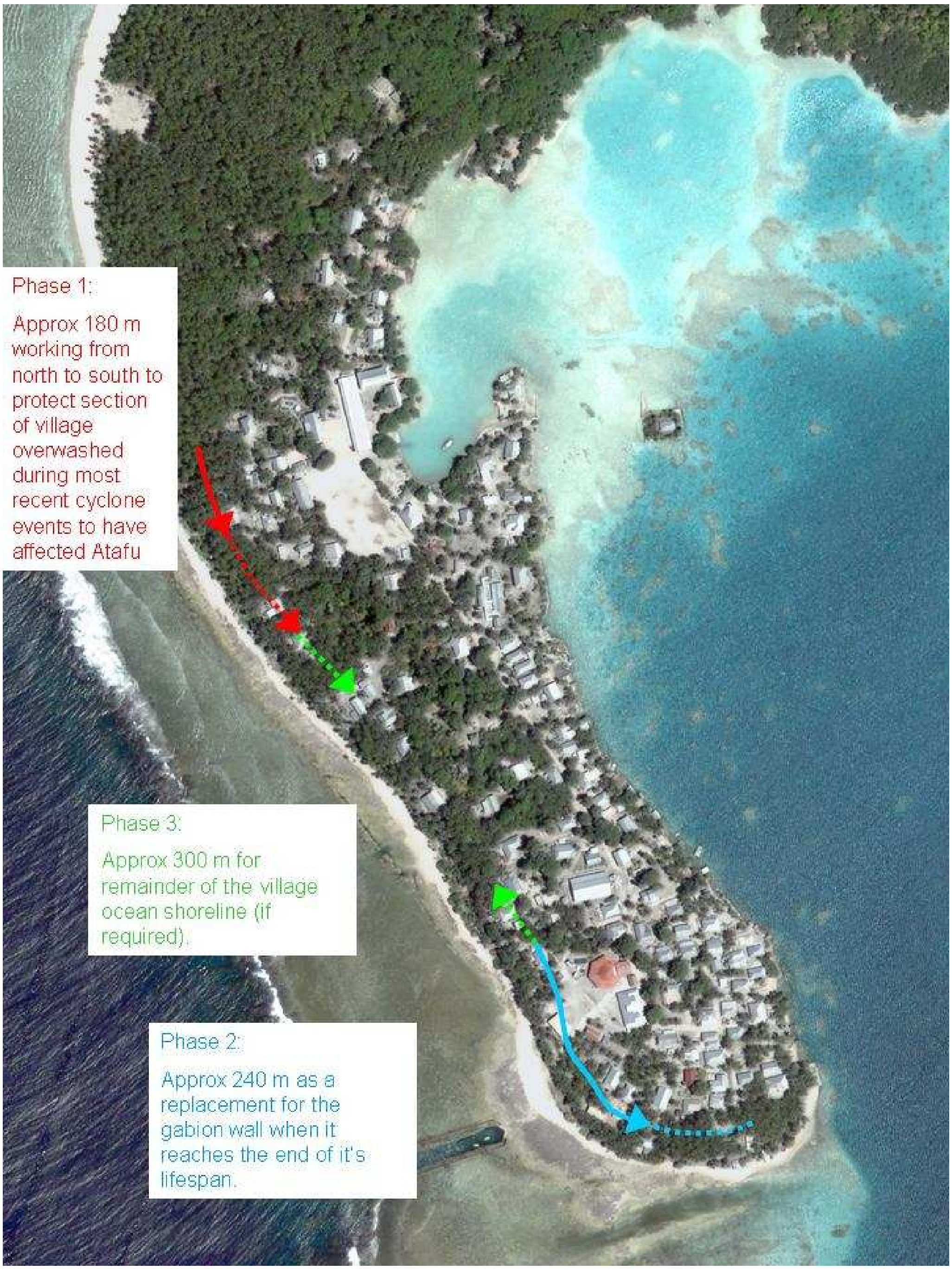


**Figure 23:** Construction phasing and approximate location of berm defences

### 8.2.3 Constraints to implementation

- Further damage to the gabion structures before repairs can be fully carried out (14).

- Allowance for annual maintenance of seawall structures on the ocean side needs to be incorporated within the Tokelau budget process.

- Potential conflict between best interests of the overall community and individual landowners (allowing construction of such a structure through their land (15).

- Lack of funding for construction of berm structures.

## 8.3 Summary of expected benefits and costs.

| | Benefits | Costs |
|---|---|---|
| Environmental | • Environmental impacts on coastal processes associated with construction of the berm structure minimal compared to traditional forms of seawalls (Recommendation 15).<br>• Impacts associated with construction material requirements less for the berm structure than with gabions (assuming sand is sourced from the lagoon) (15). | • Still requires substantial volumes of sand and coral rubble to be sourced. |
| Social | • Substantial reduction in cyclone damage to, and inundation of, housing and associated tangible direct property damage and intangible impacts on household members. | |
| Economic | • Reduced potential for inundation and damage to property and infrastructure.<br>• More resilient structures with reduced maintenance commitment to maintain serviceable performance. | • Requires considerable financial commitment over the next 10 years to upgrade defences. |
| Sustainability of recommendations | • Needs to be: 1) integrated in to Tokelau's annual budget, and 2) strategic approach to upgrading the defences needs to have support of donor community. | |
| Contribution to sustainability development | • Contributes to long-term reduction of impacts on individuals, community and economy due to cyclone inundation & coastal hazards.<br>• Enables community control, accountability and participation in risk reduction measures. | |

# 9. Immediate priorities and future implementation

## 9.1 UNDP priorities

A primary purpose of this report is to identify priorities for the most effective and efficient use of current UNDP funding to help reduce future risks associated with cyclone related coastal erosion or inundation, within the context of the recommendations developed in the previous sections.

Based on the discussions held in Tokelau, and considerations of the recommendations developed in the previous sections, the following are suggested as priority for Atafu, in order of importance:

1. Required materials for the urgent maintenance of the existing gabion seawall (Recommendation 14).

2. Seed money to assist the commencement of community planting initiatives and associated awareness programme (Recommendations 1, 2 & 3).

3. If remaining funds are available, a demonstration project commencing the construction of Phase 1 of the berm structure (Recommendation 15).

These recommendations should be considered draft at present, dependent on the exact requirements of Nukunonu and Fakaofo.

### 9.1.1 Priority 1: Repairing the ocean side gabion wall (Recommendation 14)

Details of the repairs required to the gabion seawalls are provided in Section 8.2. Without such repairs the defences, due to their present state, will quickly deteriorate. The initial impact will be related to structural damage and possible destruction of the bulk storage shed located directly behind the seawall. Further deterioration of the seawall will also increase the potential for damage and inundation to the second bulk storage shed and to other community buildings and property due to overwashing waves over the southern section of the motu during future cyclone events. Prolonging the life of these gabion seawalls will allow the focus to shift to the implementation of longer term strategies to manage such risks along this section of the motu.

Associated costs for maintenance activities described above are:

| **Gabion basket repairs** | **$** |
|---|---|
| 250 No. 2 m x 1 m x 0.5 m galmac and PVC coated gabion baskets @ $55 per basket (ex Apia) | 13,750 |
| 20 No. roles (2 m x 50 m) of galmac and PVC coated mesh @ $135 each (ex Apia) | 2,700 |
| Lacing wire and miscellaneous | 5,000 |
| **Mass concrete toe beam (150 m total)** | |
| 70 $m^3$ sand @ $120 per $m^3$ | 8,400 |
| 825 No. bags of cement @ $14 per bag | 11,550 |
| Formwork and miscellaneous | 5,000 |
| **TOTAL (materials)** | **$46,400** |

Labour costs associated with repair activities / construction of the mass concrete toe beam, (with the exception of the supply of sand), and fuel costs for the excavator, have not been included in the above costs.

Additional environmental impacts caused by the maintenance works are considered to be minimal as there should be sufficient coral rubble from the existing baskets to fill the replacements. If further coral rubble is required it should be sourced from the northern end of the motu as recommended in the EIA (McLean, 1993) and should be flat and slabby rather than angular or rounded. Live *porites* coral taken from the *akau* within the lagoon (as has been used to fill gabions at some locations on Nukunonu and Fakaofo) should not be used.

The gabion baskets and mesh proposed are more durable and rust resistant than the original zinc coated wire used gabion baskets. With the maintenance suggested it is anticipated that the structure would continue to provide a similar level of protection for between another five to fifteen years, the lifespan depending largely on the frequency and timing of cyclone events over the coming years and on ensuring periodic maintenance to repair split mesh is carried out in the future. The maintenance costs of around $80 per metre for the mesh repairs and $170 per metre for the mass concrete toe beam (excluding labour) are significantly less than the cost of new defence structure at this stage and permits the planning and implementation of longer term risk reduction activities (e.g., relocation of the bulk storage sheds).

### 9.1.2 Priority 2: Initiating community awareness and risk reduction programmes (Recommendations 1, 2 & 3)

Key to the long term reduction in cyclone induced inundation risk is the need to ensure that human impacts on the function of the natural coastal defences are reduced with a long-term programme of aiding the repair of past impacts initiated.

It is suggested that funding be provided to support community awareness activities associated with the development of the village rules to address detrimental sand mining and vegetation clearing activities (Recommendations 1 & 2). It is also suggested that assistance (seed funding) be provided in the setting up of a community programme for repairing the natural coastal defences through a rolling programme of replanting natural shoreline vegetation (Recommendation 3.

| Recommendation | Description | $ |
|---|---|---|
| 1 & 2 | Assistance and materials for development of awareness programme. | $2,500 |
| 3 | Hand tools (wheel barrows, spades, gloves) for community replanting programme | $1,000 |
| 3 | Fertiliser | $1,000 |
| | **TOTAL** | **$4,500** |

### 9.1.3 Priority 3: Initiation of new berm seawall (Recommendation 15)

Assistance with the construction of the first phase of the berm defence (Recommendation 15) is also something that the UNDP may consider. There will not be sufficient funds available to fully support this component and development of the project will require support from either Tokelau or other funding sources.

The Phase 1 involves approximately 120 linear metres on the seaward side of the school (Figure 23) along a section of coast that has experienced overwashing during most cyclone events to have impacted on Atafu. This would provide enhanced protection from overwashing waves (which is the main cause of flowing water and hence risk to people wading through it) to part of the school (which is used as an emergency shelter), and around 15 residential properties. It is suggested that a six bag cross-section (i.e., a base of three bags, two on the middle layer and one at the crest) be trialled (but there may be a need to widen the structure with a further three bags as shown in Figure 21).

It is suggested that the UNDP component be limited to assisting with part (or all) of the supply of materials for the construction of the berm structure, outlined below:

| **Description** | **$** |
|---|---|
| 480 No. 0.75 $m^3$ Soft Rock containers @ $75 each (ex Apia) | 36,000 |
| Bag filling apparatus, hand-held sewing equipment, stitching material and miscellaneous | 5,000 |
| 360 $m^3$ sand @ $72 per $m^3$ | 25,920 |
| **TOTAL (materials)** | **$66,920** |

The cost of the defence (excluding labour for construction) is around $560 per linear metre. If a nine bag cross-section is required this cost would increase to around $815 per linear metre. By comparison traditional forms of sea defences close to the shoreline will be well in excess of $1,000 per linear metre. Further, the lifespan of the structure should last well in excess of any comparable traditional seawall structure assuming periodic maintenance and repair is carried out.

The quantities of sand required for this scheme will require a sand pump (recommendation 4). As this has benefit to Atafu beyond this project (i.e., provided a source of construction sand for a range of development projects) it is suggested that this be considered, either by Tokelau with their annual budget, or from other developmental partners such as New Zealand.

Costs associated with the sand pump are:

| **Description** | **$** |
|---|---|
| Air operated diaphragm pumps (model AOD3) and associated fittings | 5,000 |
| Generator / compressor | |
| Barge fittings | 3,000 |
| **TOTAL** | |

There are no estimates of current sand usage on Atafu. However, based on existing labour and fuel costs, it is estimated that sand costs around $45 - $50 per tonne. The sand pump should result in a substantial reduction in labour and fuel costs. The new unit cost of sand is conservatively estimated at around $30 per tonne. Based on the volume of sand required for the above scheme, the saving in sand costs more than offsets the capital cost of the sand pump and associated equipment.

Atafu is also probably the most suitable atoll to trial the sand pump option, having a shallower lagoon, a new Bobcat excavator (that could be used to move the sand off the barge within minimum labour, and the berm structure recommendations (which is less well suited to the other two atolls).

### 9.1.4 Linkages to other UNDP programmes

Two other relevant UNDP programmes are currently being implemented in Tokelau, the Strengthening Disaster Management and Preparedness project (SDMP), and the Tokelau Integrated Management Project (TIEMPS). Many of the recommendations suggested in this report are of direct relevance to the aims and objectives of these two programmes.

Table 2 summarises the recommendations detailed above of direct relevance to the two programmes and identifies areas, mainly related to awareness and capacity building activities which could be linked.

**Table 2:** Summary of linkages between the recommendations in this report and the Strengthening Disaster Management and Tokelau Integrated Environmental Management programmes.

| Recommendation | SDMP | TIEMPS | Details |
|---|---|---|---|
| 1 | ● | ● | • Awareness activities |
| 2 | ● | ● | • Awareness activities |
| 3 | | ● | • Awareness activities |
| 4 | | | |
| 5 | | ● | • Incorporation of recommendations within Environment Policy and Management Plan development & associate awareness and capacity building activities |
| 6 | | ● | |
| 7 | | ● | |
| 8 | | ● | |
| 9 | | ● | |
| 10 | | ● | |
| 11 | | ● | |
| 12 | | | |
| 13 | ● | | • Awareness activities |
| 14 | | | |
| 15 | ● | | • Awareness activities |

## 9.2 Future implementation

The series of recommendations outlined in the sections above are not intended to be a "quick fix" but rather a long term and sustained approach to reducing the risks to people, property and infrastructure from cyclone-related inundation and erosion, long term coastal evolution of the motu, and any exacerbation of these impacts caused by global climate change. It is based on the growing evidence from around the Pacific region that integrating risk management of natural hazards into individual / community / national decision-making is a far more cost-effective strategy than a "wait and see" approach to managing both episodic disasters such as cyclones or longer term issues such as sea-level rise.

The approach has attempted to complement and contribute to the suggested approaches to risk management of natural hazards (RMNH) in the Pacific region outlined in the forthcoming World Bank policy note *Not if but when: adapting to natural hazards in the Pacific Island region* (Bettencourt et al. 2006). Specifically, the recommendations involve actions at individual, community and national levels and associated coordination and interaction between these activities. They include actions that are highly visible (such as seawall construction) as well as actions that encourage changing behaviours. As far as possible a "no regrets" approach has been adopted in the development of the recommendations, the aim of which is to ensure that Atafu will still be able to consider a range of risk reduction options in the future rather than being constrained to a narrow risk management approach (for example this is the situation that Fale on Fakaofo is now in where future risk management options are limited).

Whilst many of the risk reduction activities will be conducted at atoll level, there is a need for coordination at national level:

- To mainstream these risk management measures into national economic and social planning, budgeting and decision-making processes. Regional organisations such as SOPAC and tools such as the Comprehensive Hazard and Risk Management (CHARM) program may have a role to play.

- To provide support and guidance to the three atolls to continue to progress implementation of the recommendations.

- To provide coordination with donor and support agencies, such as the UNDP, New Zealand, SPREP, SOPAC and potential other sources of support.

- Encouraging donors to assist and support pro-active and long-term risk management activities rather than focus on episodic disaster recovery which needs to be fundamental aim of the Tokelau Administration.

How this is best achieved (e.g., whether such responsibility lies within one unit, e.g., the Environment Unit, or within the whole of Government) will need to be determined by the Tokelauan decision-makers.

To underpin all future risk management activities in Tokelau is a need for a sustained program of public awareness activities, and capacity building at both community and national levels to support a proactive approach to reducing coastal hazard risk. Specifically this requires the development of support mechanisms within the National Government agencies to better empower each of the three Tokelau communities to proactively manage natural hazard risks, to help identify and provide the resources needed to do so, and to move from intentions (suggested in this report) to actions. To begin with there is a need to disseminate, and discuss at community levels, the findings of the recommendations contained within this report, but in the longer term will need to include:

- Targeted information on hazard occurrence, climate variability and change for a range of audiences, e.g., Government policy and decision makers, community leaders and members, school children.

- Fostering of action plans in each community, based on the general recommendations and timelines suggested in this report, but with specific target actions and timeframes, and identification of who will do it.

- Training for national and community leaders in developing community approaches to reducing natural hazard risks. Whilst formal mechanisms such as on-island training courses will be integral there again needs to be a longer term focus with activities such as mentoring for technical support being introduced, and an emphasis on approaches that can be repeated and sustained.

## 9.3 Monitoring how risk changes

The measures outlined above are intended to provide some ideas and suggestions for consideration by the *Taupulega* and communities of Tokelau to help reduce risks due to cyclone storm surge and other coastal related hazards in both the short and longer term. Such risks to the community in Atafu will change with time. Some activities or decisions will increase such risks, other activities will reduce them. An important aspect to help inform decision-making is to monitor and assess how such risks are changing over time and whether the relevant decisions that have previously been made have been effective in helping reduce coastal hazard related risks.

Outlined below is an initial attempt at developing a set of quantifiable measures that could be used to assess how the risks associated with cyclone storm surge inundation and other coastal hazards change over time. It is by no means a complete list and may well require further refinement in the future. By carrying out an assessment of the relevant factors that will increase or decrease risk on say an annual basis, the progress that Atafu makes in reducing their risks to coastal hazards can be monitored.

| No | Increasing risk | | Present | | Decreasing risk |
|---|---|---|---|---|---|
| 1 | Sand / coral rubble removed from ocean beach within last 6 months | ⬅ | Yes | ➡ | No sand / coral rubble removed from ocean beach on Atafu within last 6 months |
| 2 | Vegetation cleared within 30 m of the vegetation line on the ocean side within last 6 months | ⬅ | Yes | ➡ | No vegetation cleared within 30 m of the vegetation line on the ocean side within last 6 months |
| 3 | Replanting of natural vegetation along the ocean coast within the last year | ⬅ | No | ➡ | No replanting of natural vegetation along the ocean coast within the last year |
| 4 | No further residential or community buildings, or essential infrastructure development within the high hazard red zone | ⬅ | 40 | ➡ | Further residential or community buildings, or essential infrastructure development within the high hazard red zone |
| 5 | Construction of new housing commenced within the high hazard (orange) zone within the last year | ⬅ | 0 | ➡ | No construction of new housing commenced within the high hazard (orange) zone within the last year |
| 6 | Housing or community infrastructure built within 30 m of the vegetation line on the ocean side north of the school | ⬅ | 0 | ➡ | No housing or community infrastructure built within 30 m of the vegetation line on the ocean side north of the school |
| 7 | Additional housing or community infrastructure built within 50 m of the lagoon shore north of the school | ⬅ | 0 | ➡ | No additional housing or community infrastructure built within 50 m of the lagoon shore north of the school |
| 8 | Bulk storage sheds in high risk zone | ⬅ | 2 | ➡ | Bulk storage sheds moved out of the high risk zone |
| 9 | No environmental planning awareness and capacity building activities carried out within the last year | ⬅ | No | ➡ | Environmental planning awareness and capacity building activities carried out within the last year |
| 10 | Consideration and development of planning mechanisms to aid individuals to reduce their own risk levels | ⬅ | No | ➡ | No mechanisms to aid individuals to reduce their own risk levels |
| 11 | More houses with floor levels less than 0.5 m above land level | ⬅ | 30 | ➡ | Less houses with floor levels less than 0.5 m above land level |
| 12 | No Housing Grant awards over the last year to families with existing houses with a floor level less than 0.5 m | ⬅ | ? | ➡ | Housing Grant awards over the last year to families with existing houses with a floor level less than 0.5 m |
| 13 | Guidelines for integrating coastal hazard risk reduction measures are not developed and implemented within the Housing Grant Scheme | ⬅ | No | ➡ | Guidelines for integrating coastal hazard risk reduction measures are developed and implemented within the Housing Grant Scheme |
| 14 | No inspection and repair of split gabions carried out in last year | ⬅ | No | ➡ | Inspection and repair of split gabions carried out in last year |
| 15 | Increase in total length of seawall structures constructed on the lagoon side over last year. | ⬅ | No | ➡ | No increase in total length of seawall structures constructed on the lagoon side over last year. |

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