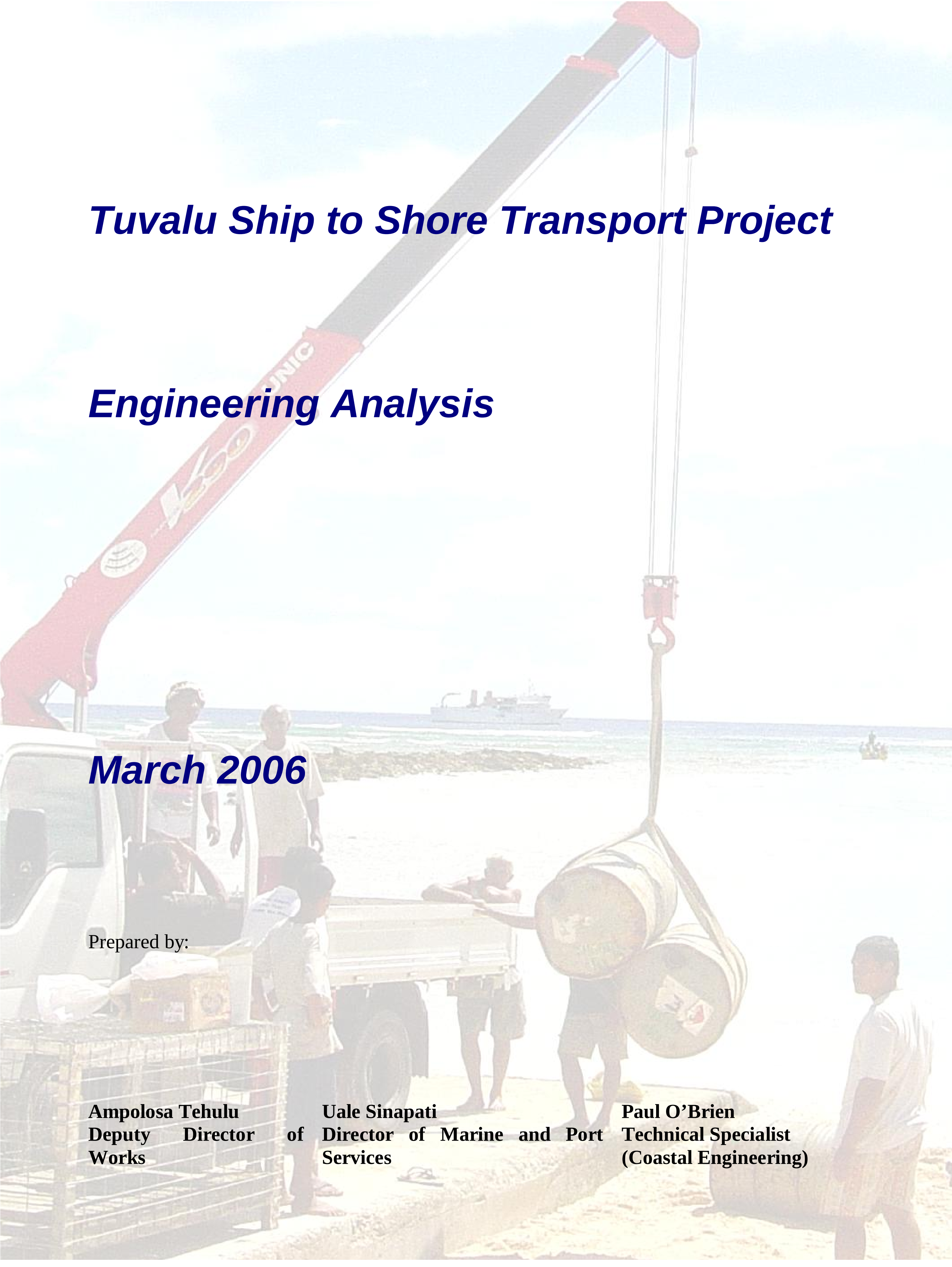

Tuvalu Ship to Shore Transport Project

Engineering Analysis

March 2006

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Foreword

This report describes the tasks (and associated services performed by Cardno ACIL Australia Pty Ltd (Cardno ACIL)) undertaken through the Pre-Design Study for the Tuvalu Ship-To-Shore Transport. All information in this report, is in accordance with the Scope of Services agreed in the contract between Cardno ACIL and the New Zealand International Aid and Development Agency (NZAID) ("the Client"). The Scope of Services was defined by the requests of the client, time and budgetary constraints imposed by the client, shipping schedules and by availability of access to the project sites.

This report has been prepared on behalf of, and for exclusive use of, the client, as required for ongoing planning and implementation needs, and follows consultation between the Pre-Design Team and stakeholders (including the Agencies of the Government of Tuvalu involved in the Project, community representatives, other donors and agencies working in the region). The report is subject to, and issued in connection with, the provisions of the agreement between Cardno ACIL and the client. Cardno ACIL accepts no responsibility whatsoever for, or in respect of, any use of or reliance upon this report by any third party.

1 Introduction

A review of the Tuvalu Reef Channels Project was undertaken between July and September 2003 by a team comprising of Mr. Doug Ramsay (NIWA); Ms Ursula Kaly (SOPAC); Mr. Talaesea Moulogo (Public Works Department, GOT); and Mr. Sokiata Tofiga (Department of Marine, GOT). The Review Team travelled to all of the nine atolls and islands of Tuvalu to discuss the requirements for the safe and efficient transfer of passengers and cargo. They consulted extensively with relevant Government Ministries, the Kaupule and other stakeholders on each of the islands.

All of the sites were visually examined, following which feedback and further discussions with stakeholder groups resulted in the development of a prioritised list of works for each of the outer islands. Indicative costings for each element of the proposed works were developed, and five priority projects were nominated for urgent action.

Both NZAID and the GOT have accepted the recommendations of the Review and have commissioned the preparation of a Project Design Document. As part of the development of that Document, this Engineering Analysis has been undertaken to assess the port and harbour engineering works specified in the Review.

The Analysis is primarily aimed at ensuring that the proposed engineering works, structures, equipment and materials are appropriate; and to identify and include any omissions. The Analysis required obtaining further information with regard to the complexity, timing, logistics, materials and procurement required for implementation of Review recommendations.

2 Existing Ship to Shore Transport

2.1 The Process

Throughout Tuvalu's outer islands, the visiting inter-island vessels moor offshore while passengers and cargo are ferried to and from shore in smaller lighters (referred to locally as work boats). With the exception of Nukufetau, where the inter-island ships can safely enter a sheltered lagoon, this transshipment of passengers and cargo entails the work boats having to negotiate the hazardous conditions that frequently prevail on the fringing coral reefs surrounding each island. It relies considerably on favourable tides and sea conditions to minimise the risks associated with the transfers between the ship and the shore.

The establishment of small boat channels through the fringing reefs of the islands has assisted in reducing the risks associated with such activities, by enabling the work boats to negotiate a less severe passage across the outer edge of the reef. Nevertheless the process still relies significantly on the skill of the work boat operators to traverse the boat channels.

Despite the improvements afforded by the reef channels, capsizing of work boats is still a very real risk under certain adverse sea, weather and tide conditions. The channels can be difficult to identify during poor weather, at night, or when conditions are such that the edge of the reef is awash by a large and confused sea state. Once within the channels themselves, conditions can still be very hazardous due to shoaling and breaking waves, as well as the strong currents which frequently flow out to sea through the channels.

For the purposes of examining the transport of passengers and cargo from the inter-island ships onto the various outer islands, the process can be considered to comprise of the following operations:

§ the *ocean-side operations* - where passengers and cargo are transferred from the inter-island ships which moor offshore of each island into the smaller work boats;

§ the *transit voyage* – where the work boats then ferry passengers and cargo between the ship and the island foreshores; and

§ the *island-side o*perations – where, following the arrival of the work boats at the island foreshores, cargo and passengers are delivered onto the island itself.

Figure 2-1 illustrates the transshipment process conceptually. It flows in reverse when passengers and cargo are to be collected from the island and transported onto the ship.

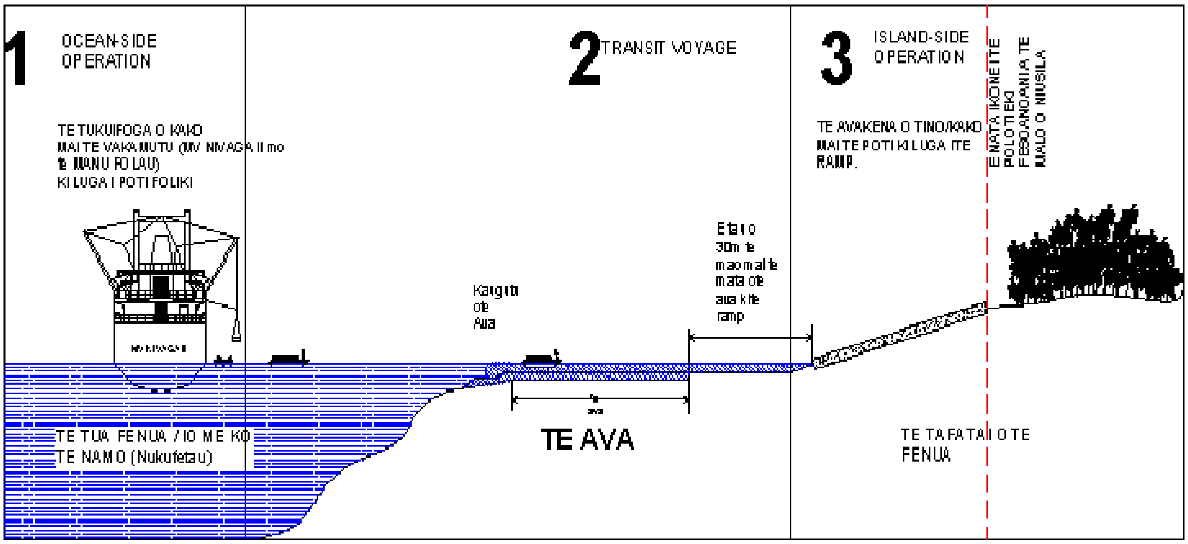


Figure 2-1 The Ship to Shore Transport Process

The process consists of a number of primary components, namely:

- the inter-island ships
- the workboats
- cargo
- passengers
- reef channels
- nav aids
- beach ramps
- crane trucks
- island tractors and trailers

Some comment on each of these various components is warranted, as they have particular characteristics which impose constraints and limitations on the current operation of the ship to shore transport process.

2.2 Components of the Process

2.2.1 The Inter-island Ships

Tuvalu's inter-island shipping service is provided by two passenger/cargo vessels operated by the Marine Department, these being the *Manu Folau* and the *Nivaga II*.

The *Manu Folau* is the most recent addition to the service, having been built and registered in 2002. It has a length of 41.0 metres; a beam of 9.4 metres; a laden draft of 3.7 metres, and operates under a gross tonnage of 582T. Of particular relevance to the TSSTP is its capacity to load and offload cargo from its hold and off its deck into the work boats moored alongside. There are two cranes mounted aft which can separately handle cargo, each crane is rated at 2 tonne capacity.

The *Nivaga II* has an overall length of 58.0 metres; a beam of ?? a laden draft of ????. The vessel has two derricks mounted on the front deck which typically operate in a union purchase arrangement which has a rated 2 tonne capacity. However each derrick can be configured to lift on its own - in which case the rated capacity is a 7 tonne lift. This means that all heavy cargo items requiring delivery to the outer islands are normally transported and offloaded by the *Nivaga II*.

(a) Manu Folau

(b) Nivaga II

Figure 2-2 Tuvalu's Inter-island Vessels

2.2.2 The Work Boats

When considering possible improvements to the handling and transfer of cargo and passengers, it is important to appreciate the limitations of existing and planned work boat designs.

Each of the two inter-island vessels has two work boats that transfer cargo and passengers to shore. These boats are worked exceptionally hard. Under even the most moderate operating circumstances they collide violently and often with the sides of the ships during ocean-side operations; they are grounded on coral beaches and reef platforms when fully laden to facilitate island-side unloading and loading; and they inevitably strike the uneven bottom and sides of reef channels as they negotiate the hazardous passage through and across the fringing coral reefs.

In the past, the Marine Department has given significant consideration to the most appropriate work boat design for the extreme conditions under which they must operate. The primary conclusion has been that the work boats should be of timber construction.

Other forms have been trialed (aluminium, rubber-inflatable, steel, and various composites) at various times. Whilst each of these has demonstrated some advantages, the rigorous working of the boats inevitably requires on-going repairs of both a minor and major nature. Timber boats can be readily repaired, either on board the main ship or ashore on the outer islands. Other forms have required repair methods that in the past have involved specialised skills and using equipment only available overseas.

Consequently the work boats have mostly been flat bottom timber dories driven by stern mounted out-board motors. The durability of timber boats depends upon the robustness of their construction. A work boat can be constructed to specific overall dimensions using different structural sizes and species of timber. Experience in Tuvalu has shown that whilst boats manufactured using smaller sizes and lower grades of timber are cheaper, this is really false economy as they typically require constant repair and only last some 6-9 months.

More robust construction using better grades of timber and larger structural sizes cost more, but typically last around 2 years as they withstand the rigors of the operating environment better. Unfortunately in the past, whilst budgeting for better replacement work boats, the Marine Department has found it necessary to opt for the cheaper work boats due to financial constraints at the time of replacement.

At the present time, whilst each of the two work boats on each ship are basically the same, those on the *Manu Folau* and the *Nivaga II* differ. Those on board the *Nivaga II* are larger; being 7.4m long, 2.1m wide and around 1m deep. The *Manu Folau*'s work boats are 6.4m long, 1.7m wide and approximately 0.75m deep.

Since the *Nivaga II* has the greater lifting capacity, it delivers heavy items (such as the crane trucks now on each island) and was the vessel that transported the excavator, barges, etc for the reef blasting team in the late 1990's. When transferring large heavy items ashore, the two work boats are lashed together and the items placed on board. This transfer operation clearly requires favourable sea and weather conditions.

The Marine Department is currently seeking prices for the fabrication of work boats to the same design as those originally supplied with the *Manu Folau*. These are slightly larger than the ones currently on board the *Nivaga II*, being 7.5m long, 2.5m wide and 1.1m deep. They are reputed to be able to transfer sedan cars to shore.

Should better, safer, more robust work boats be manufactured and supplied to both of the inter-island vessels then this will also assist considerably in the transfer of any heavy construction equipment associated with the TSSTP. However when developing construction methodologies for this Engineering Assessment, the work boat designs currently in use on the inter-island ships have been used. Nevertheless consideration should be given to the procurement of better work boats to support the construction activities of the TSSTP should the planned replacement boats not eventuate.

Another component of the current work boat designs that has been closely examined by the Marine Department are the out-board motors. There is currently a practice of using primarily 40hp Yamaha motors on all work boats. Whilst increasing the power of the out-board motors (and therefore the speed and maneuverability of the work boats) seems at first a desirable enhancement, this is not necessarily the case under all operating scenarios.

When operating the work boats, the drivers frequently need to manually lift the motors by tilting them on the transom so as to lift the propeller above the line of the keel. This is typically required during the passage of the reef channels during low tides. It often needs to be done very quickly when circumstances require (and often in treacherous conditions) in order to clear submerged rocks, to navigate through shallow waters, and when grounding to offload at the island. The tilt locks on all work boat motors have been removed to facilitate the quick uplift and the return to position of all 40hp motors.

The work boat operators have difficulty lifting motors larger than 40hp because they are quite heavy. Channel improvement works proposed under this TSSTP are aimed at alleviating some of these instances where the motors need to be lifted, nevertheless there will invariably be occasions when this still needs to be done quickly to avoid an accident.

There are a number of islands where the existing channel is quite deep and the shore landing can be undertaken without the need to tilt the engines at all. This the case for the island of Nanumea, where more powerful outboard engines on the work boats to negotiate the hazardous currents and wave conditions would be most beneficial.

Likewise, there is often significant benefit to the ship to shore operations that such transfers be undertaken as quickly and efficiently as possible when favourable tide and weather conditions provide operational windows. In such circumstances, there would also be substantial benefit in being able to utilise more powerful engines to speed up this transfer process. Indeed, both the *Manu Folau* and the *Nivaga II* carry 48hp engines to use on their work boats in such circumstances.

Consequently consideration needs to be given to utilising motors up to 60hp on the work boats under certain operating conditions. There are adequate skills within the current crews of the *Manu Folau* and the *Nivaga II*, as well as in workshops on Funafuti and the outer islands, to undertake routine servicing and repairs to these larger outboard motors.

However if larger more sophisticated motors than 60hp were to be introduced on the work boats, there would be a need to train and properly resource a group of specialised mechanics to support them. This reliance on a limited number of people having to use specialised diagnostic and repair equipment compromises the current flexibility with regard to quickly resolving mechanical and electrical problems with larger outboards. Furthermore, it would be necessary to determine whether outboards larger than around 60hp would impose too great a load on the current work boats.

(a) Manu Folau Work Boat

(b) Nivaga II Work Boat

Figure 2-3 Work Boats Currently Used

2.2.3 Cargo

The quantities of cargo transported throughout the outer islands is documented elsewhere in this Pre-design Report. Nevertheless it is of some importance to this assessment of the current operations of ship to shore transport to have an appreciation of the types of cargo that are handled.

Primarily this consists of:

- *general cargo* - which includes a wide range of food, frozen goods and household items sold through the local island store (*fusi*), as well as agricultural produce, fish, building materials, and the very wide array of items required to provision and meet the needs of the various island communities.
- *fuels* - such as diesel, petrol and kerosene.
- *livestock* - typically pigs and poultry.

There is occasionally the need to transport large items such as motor vehicles and tractors. This requirement is likely to increase in the future.

The Tuvalu Cooperative Society (TCS) consigns the largest amount of general cargo since it provisions the *fusi* on each island (apart from Niulakita which does not have a *fusi*). Many of the general cargo items can be lost or spoiled by sea spray, rain, immersion in water lying in the bottom of the work boats, and their accidental dropping into the sea.

Bags of rice, flour, sugar and cement are particularly prone to spoilage and they are carried in large quantities to the outer islands. These items are usually carried in 20kg or 25kg bags, except for sugar which is usually supplied in 50kg bags. Other cargo is typically packed in cardboard boxes and therefore can also be damaged by wetting or by crushing during loading / unloading operations.

Fuel is normally shipped in 200 litre steel drums. The Tuvalu Energy Commission (TEC) ships most of the fuel consumed on outer islands. This is used to fuel the generators that supply electrical power to the outer island communities - the exception again being Niulakita, which uses only solar power.

Livestock is typically shipped by individuals, families or groups. Pigs and poultry are the main livestock transported to and from the outer islands. Usually these are caged when delivered for shipment. However in the past, pigs were accepted un-caged on voyages of the *Nivaga II*. Whilst the Marine Department is attempting to discourage this practice, there is still resistance by some island communities to implement this policy.

One of the main challenges faced by the Marine Department when shipping cargo is that of inappropriate packing standards. This particularly relates to building materials on behalf of private individuals or groups. Frequently items such as roofing, timber, plywood sheeting, etc. are delivered for shipping unsuitably bound or packaged. This presents problems when trying to lift these items from the ship into the work boats and then transporting them ashore.

2.2.4 Passengers

The numbers of passengers using the inter-island shipping service are presented elsewhere in this document. Passengers are required to either move or be moved between the ship and the work boats, and between the work boats and shore. This must frequently occur during rough sea conditions and inclement weather, making such transfers hazardous.

A major challenge to the safe transfer of passengers between the inter-island ships and shore is the extensive range in mobility of the passengers themselves. As expected the wide spectrum of people travelling throughout the islands of Tuvalu reflect that of the general population. This includes those who are fit and strong, as well as those who are elderly, young, sick or of limited physical ability.

The main objective of the TSSTP is to improve ship to shore transfer, and to therefore make it safer and more attractive to those in the community who might presently consider any travel undertaking beyond their capabilities.

2.2.5 Reef Channels

The reef channels provide navigable routes across the fringing reefs that surround all of the islands and atolls of Tuvalu. Anecdotal evidence suggests that historically settlements on the islands tended to be established at locations opposite natural depressions or breaks in the fringing reef that enabled canoes and fishing boats to access the open ocean with minimal risk. As the need for improved and safer access inevitably grew, so too did the ability to provide it - with the evolution of improved engineering techniques and robust mechanised equipment. Consequently the naturally formed access routes in the fringing reef adjacent to the established settlements were exploited by excavation and blasting techniques to provide for a deeper, wider passage.

New Zealand's assistance with reef channel works in Tuvalu dates from 1976 with the construction of the channel at Nui. Since 1987 New Zealand has provided assistance on several occasions in relation to reef channels on most of the outer islands. The project, known as the *Tuvalu Reef Channels Project*, was conducted in each of the eight outer islands of Tuvalu over the following 15 years and resulted in new channel creation, improvements to existing reef channels and undertaking other associated works.

It is widely acknowledged that the various reef channels and their recent enhancements have contributed significantly to improving the safety of passenger and cargo transport to the outer islands. Nevertheless the unpredictable and often severe nature of ocean conditions means that the passage through the reef channels of Tuvalu will always be a risky undertaking. Perhaps the only exception to this is at Nukufetau, where the inter-island ships can enter the very large central lagoon and the work boats can then access the main shore landing across the protected waters of the lagoon.

The extent to which the main reef channels provide a safe passage across the reef crest and the fringing reef behind it varies throughout the islands. Whilst a significant factor is the location of the channel with respect to the sea conditions that prevail on the outer reef edges, other factors that considerably influence their effectiveness are their physical dimensions of width, depth and length - all of which vary from island to island.

For example, the reef channel at Nanumea was cut during WWII to link the central lagoon to the ocean. This is quite a wide and deep channel, however even many of the most experienced work boat operators nominate this channel as one of the most hazardous ones to negotiate. This is because the very high current flowing seaward through the channel on an ebb tide presents a risk when wanting to enter the channel entrance quickly to avoid being swamped by the often large and confused sea state that consequently exists at the channel entrance.

The reef channels of Niutao and Niulakita are also those most respected by the work boat operators. Not only are they shallow at low tides, but they are relatively short and therefore the beach landing often has to be undertaken in the surf zone. Niutao has the largest amount of cargo losses of all the outer islands - as a consequence of the treacherous reef channel.

General guidelines relating to the development of new reef channels and modifications to existing channels have been developed by Kaly & Jones (1990) and updated by Kaly (1999). These represent as comprehensive a guide as can currently be found for such work in the Pacific. Nevertheless, they are general in nature and need to be supported by site specific environmental assessments to properly account for local conditions and natural processes.

2.2.6 Alternative Channels

Tuvalu lies within the trade wind zone so the prevailing winds are from the easterly sector. Most of the reef channels are therefore located on the western side of the islands since this is the more sheltered side with respect to the prevailing trade winds. However, in most years from December through to March, winds between west and north usually equal or exceed the easterlies in frequency. Consequently the sea conditions on the usually sheltered western side of the islands can become quite rough, with large waves propagating towards and breaking on the western fringing reef.

During this westerly season conditions in the reef channels and on their sea approaches can become quite severe and their navigation by boats fraught with risk. The season unfortunately coincides with the Christmas holiday period and with the commencement and completion of school years - and is therefore at a time when considerable inter-island travel is undertaken by Tuvaluans. During such times, alternate landings are typically made on the eastern side of the islands, however there are few formal reef channels that have been constructed at such locations. There is a need to provide for safer alternative channels on most islands during adverse westerly conditions.

2.2.7 Nav Aids

Despite the difficult passages that work boats and local fishing boats have to frequently navigate, there are very few formal navigation beacons installed throughout the outer islands. There are some improvised marker poles installed at various locations that assist in the identification of particular hazards, or to mark an appropriate passage entrance - but most are in disrepair. A few have had reflective marks attached at some point but most of these have since detached or deteriorated so as to be ineffective.

At Vaitupu, solar powered starboard / port lights have been mounted on steel poles on the breakwater heads of the harbour, but these have not been working for several years due to confusion regarding responsibility for their maintenance.

The technique usually applied by the work boat operators is to use distinct onshore features or particular reef features as references to guide their approaches and passage through the various channel entrances. Certainly it is this instinctive familiarity and identification of features which enables the local fishermen to safely and frequently navigate through the often treacherous conditions in their island’s reef channels. The work boat operators have developed similar skills through instinct and experience.

Nevertheless, work boat operators on both the *Nivaga II* and the *Manu Folau* were able to relate incidences when their best judgments proved incorrect and accidents ensued.

All have remarked in discussions with the Pre-design Team that navigation aids would assist considerably in their safe negotiation of the reef channels - with some islands requiring such aids more than others. The transfer of cargo between ship and shore is undertaken both during the day and at night; during fine weather and in driving rain; so navigation aids that provide assistance across the range of likely operating conditions are necessary.

2.2.8 Beach Ramps

In 1994-1995 Canada Fund implemented a project to construct concrete beach access ramps on Nanumaga, Niutao (Muli Channel), Nukufetau, Nukulaelae, Niulakita, Niutao (Kulia Channel) and Nui. The initial intent of these ramps was to facilitate easier unloading of work boats by providing a trafficable concrete ramp across the sandy beach down to where the boats land. They were viewed as being of considerable advantage since they would enable tractors with trailers, and particularly crane trucks (which were at that time being planned for each of the outer islands) to access the work boats to offload cargo.

An unfortunate impact of these cross-shore structures was their adverse effects on natural beach processes and the erosion that they initiated - particularly at the Muli Channel site on Niutao. The specific impacts at each ramp location have been documented by the Review Team, and there are strong recommendations that the ramps be removed. It is important to appreciate the rational for this recommendation because any replacement beach access system will need to address many of these issues.

Waves arrive on island foreshores at an angle - which at times can be only a few degrees different to that of the shoreline itself. Nevertheless, it is this subtle angled wave approach that initiates the longshore movement of sand on these foreshores. This approach angle changes whenever the direction of the waves change. Since the direction of waves tend to be seasonal (evidenced in Tuvalu by the westerly and the easterly seasons), the direction of sand movement is often reversed.

Thus, in one season the sand may move away causing the beach to recede, and in the next it may return and naturally reinstate the beach. Alternatively there may be no apparent change in the beach. However this does not necessarily mean that sand is not being moved on the shoreline. It is often just that the amount of sand being moved alongshore in one direction is about the same as the amount being moved along in the other. There is consequently no net change and the beach looks the same.

If this natural longshore movement is impeded by a concrete ramp, the sand will build up against the supply side of the ramp obstruction. As there is no material moving passed the ramp onto the other (downdrift) side, it will start to erode. In time, the gradual build up of sand on the supply side of the ramp may reach the point where it starts to move around or over its end - this is called *by-passing*. When this occurs, the supply of sand to the downdrift shoreline will be established. The on-going long term erosion of this foreshore caused by the ramp obstruction will therefore stop and the eroded shoreline will tend to stabilise at its current position.

However if there is a reef channel close to the end of the ramp, the sand which is bypassing the ramp can be swept into the channel. Once in the channel, there are no natural processes acting which can bring it out of the deeper water and back onto the beach. It can also be carried offshore by the currents in the channel where it is effectively lost to the island forever.

A solid obstruction like a ramp across the swash zone and into the intertidal area will impact on sediment movement and instigate erosion. Given Tuvalu's limited land resources, alternative options that will not adversely impact on the delicate coastal processes of these island foreshores need to be considered.

Also, the intertidal section of most ramps are very slippery. There are frequently accidents where people slip, sometimes whilst carrying cargo. The slippery surface also means that vehicles cannot operate on the seaward end of the ramps - which is the area in which they are most required. From time to time the various island communities attempt to clean the marine growth from the surface to make them less hazardous. However experience has shown that this only offers a short-term solution since the marine growth is quickly re-established within about a fortnight.

Because of their adverse impacts on natural beach processes, the concrete beach ramps need to be replaced with a system that enables vehicle access across the beach (and where necessary onto the reef platform at low tide) so that the cargo brought to shore in the work boats can be offloaded and brought onto the island efficiently and safely. However, unlike concrete ramps, the system of vehicle access must allow the natural coastal processes that shape the beach to continue uninhibited.

A proposal for the implementation of an "*enviro-ramp*" at Niutao was developed by Kaly (1999) and advocated by the Review Team for application at a number of appropriate locations on outer islands. The system is a variation on the board and chain roadways that are used at many locations worldwide for managing pedestrian and vehicle access across dunes and sandy foreshores.

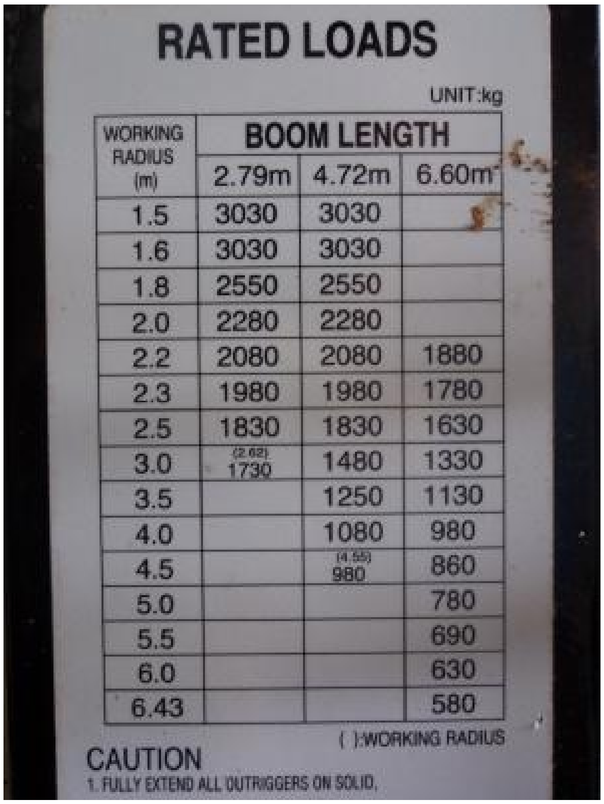
The enviro-ramp concept entails robust timber planks bound together by rope to form a ladder-type arrangement that is laid out on the surface of the beach to provide a trafficable surface. The top of the structure is permanently anchored at the top of the beach slope, whereas the bottom is tethered to the reef platform. During severe wave conditions, the ramp is released from its tethers at the base, then pulled up the beach onto itself by a tractor or a crane truck for protection. It is re-deployed when adverse conditions abate.

The intent of the enviro-ramp is to allow normal beach processes to continue with little impact on the longshore transport of sand on the foreshore. Enviro-ramps have yet to be constructed or deployed on the outer islands. Another possible system of cross beach access is discussed in later sections of this report.

2.2.9 Crane Trucks

Crane trucks of 3 tonne lifting capacity have been provided under a Japanese funding program to all of the outer islands except Niulakita and Vaitupu. All are Isuzu NPR66L model cargo trucks with a wooden rear tray, fitted with a UNIC URV293 crane located between the cabin and the tray. On Nanumea and Nanumaga they are able to assist with the unloading of cargo from the work boats (from a wharf within the central lagoon and from the concrete beach ramp respectively). At Nui this can also occur, but the crane truck's effectiveness is compromised during many high tides because of wave activity on the ramp. On Nukulaelae, Nukufetau and Niutao they cannot be used because there is no trafficable access out to the boat landing site, either across the beach or onto the reef platform at low tide.

Of particular relevance to the TSSTP is the capacity of the crane trucks to handle cargo items. Their lifting capacity depends upon the extension of the boom and the radius of the lift (ie. distance from the centre of the crane's rotation). The 3 tonne capacity is the maximum lift at the minimum working radius of 1.5m. The table below gives the rated loads at different working radius and boom lengths. For example, the crane can lift 1080kg at a radius of 4m from the centre of its rotation but must have the boom extended out to 4.72m to do so.



RATED LOADS

UNIT:kg

WORKING RADIUS (m)	BOOM LENGTH		
	2.79m	4.72m	6.60m
1.5	3030	3030	
1.6	3030	3030	
1.8	2550	2550	
2.0	2280	2280	
2.2	2080	2080	1880
2.3	1980	1980	1780
2.5	1830	1830	1630
3.0	(2.62) 1730	1480	1330
3.5		1250	1130
4.0		1080	980
4.5		(4.55) 980	860
5.0			780
5.5			690
6.0			630
6.43			580

( ):WORKING RADIUS

CAUTION

1. FULLY EXTEND ALL OUTRIGGERS ON SOLID.

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Through application of these tables and diagrams, the operational limits of the crane truck can be determined. However as a general guideline it appears that the trucks can lift and slew the following approximate loads onto their tray:

- boom extended towards the front and over the cabin: approximately 1250kg
- boom extended over the side of the truck (ie. at 90º to truck) : approximately 2200kg
- boom extended out over the rear of the tray: approximately 650kg

It is important to appreciate that the crane trucks are only 2WD and not particularly suited to heavy working, rough terrain or the marine environment. Consequently (except at Nanumaga where the ramp extends down to the end of the reef channel) they cannot go across the beach to where the work boats arrive on the shoreline.

Whilst their ability to unload cargo from the work boats is somewhat limited, they have proven to be of significant value for general use on the islands. Consequently the various Kaupule have expressed a reluctance to the notion of taking the trucks onto the reef platform at low tide where the rough, irregular surface and small salt water pools represent an unfavorable working environment.

Another significant constraint on the effectiveness of the crane trucks to handle cargo is their cost to hire. Many private individuals, families and even government offices find the cost to hire the crane truck from the Kaupule prohibitive for the small amount of cargo delivered to them. Consequently they prefer to manually unload from the work boats, carry the items up the beach and either manhandle them to their destination or use hand carts to transport them further. On some islands, this private cargo represents a significant amount of the total delivered. Yet it is not uncommon to see a crane truck sitting idly on the foreshore while most of the cargo is manually unloaded and transported to its final destination - a slow, physically challenging and unpleasant process for some people. Even the TCS and TEC (which are the largest importers of cargo on each island) in many instances find it cheaper to hire manual labour to unload the work boats than to hire the crane truck.

So there are not only the limitations imposed by the physical environment of the foreshore area to overcome in order to effectively utilise the crane truck for island-side operations, but important socio-economic ones as well.

2.2.10 Island Tractors and Trailers

All of the outer islands (except for Niulakita) have at least one working tractor with a trailer that can be towed behind. Typically these are Massey Ferguson tractors (although there are some Farmliner models on some islands). The trailers are usually 2 tonne Giltrap trailers. The tractors and trailers are owned and operated by the island Kaupule who hire them out to individuals or groups. The hire rate is determined by each Kaupule and therefore varies from island to island. All Kaupule indicated in discussions that they would be willing to hire their equipment to any visiting construction team. Each island has a small workshop facility to assist in the repair and maintenance of the mechanical plant on the islands.

By necessity, the island Kaupule maintain the tractors from only a limited maintenance budget and consequently do not store an extensive range of spare parts. Typically parts are acquired where necessary by appropriating the necessary items from a similar model in disrepair. Where these cannot be procured, the machine can sit idle for some time before the necessary parts can be ordered and received.

The embassy of the ROC located in Funafuti has proposed funding for the provision of 4WD Massey Ferguson tractors (Model MF5355) and tipping trailers for outer islands. Should these be provided to the outer island Kaupules, then they would prove to be of considerable use to the activities of a TSSTP construction team.

2.3 Ocean-side Operations

2.3.1 Cargo Transfers

Prior to each voyage of the inter-island ships, the Tally Officer on board will collate the cargo manifest in Funafuti to ensure that the items are stowed in the hold of the vessel in a way that they can be identified by their island of destination and readily accessed for unloading. That officer is also responsible for accounting for passengers coming aboard.

Upon arrival offshore of an outer island, the Tally Officer then keeps track in the hold as to what cargo is dispatched ashore. Typically general items are loaded into cargo nets which are then hoisted out of the hold by the ship's crane/derrick, slewed across the deck, and then lowered over the side into the work boats. There are typically two crew in the work boat during this operation, both of whom are required to position the load in the boat and release the lifting gear from the load.

A disadvantage of the crane arrangements on the *Manu Folau* is that the crane operator cannot see the work boats alongside. Consequently when lowering and maneuvering the load into the work boats, the crane operator relies on hand signals from an observer watching overboard from the side of the ship. Whilst this means of communication has evolved into an effective system, it nevertheless has considerable shortcomings when the offloading operations are undertaken during rough sea conditions. Injuries to the work boat crew can occur, as can damage or loss of some cargo items.

In an effort to minimise the number of cargo transfers from the hold, the nets are usually filled close to capacity. When lifted, the drawing together of the top of the net can cause items enclosed within it to be crushed, particularly those near the top. It needs to be acknowledged that efforts are made by the stevedores when loading the nets to minimise any such potential for crushing, nevertheless this inevitably occurs due to the very nature of this cargo handling technique. Cardboard boxes containing frozen items, canned foods, general grocery items for sale in the *fusis,* etc are particularly prone to crushing damage.

Bagged items such as cement, floor, rice, sugar are often simply lifted on their pallets and loaded into the work boats. However if it is raining then these items can become wet as there is no cover available until they reach the work boats. Tarpaulins are then placed over the items in an attempt to protect them from spoilage by rain. However when there is driving rain and winds, the effectiveness of the tarpaulins is considerably diminished.

Once placed in the work boat, the load is released from the hook and the entire load (net included) is thereby delivered onto the floor of the work boat. This releasing can often mean that items in the loosened net move or tumble from the placed stack - further adding to potential damage and loss overboard. The bottom of the work boats are often very wet and have a considerable amount of water sluicing back and forward. This can also spoil or damage those items placed directly on the floor.

Fuel drums are lifted by the ship's cranes/derricks using chains and drum lifting hooks. They are then slung over the side and lowered into the work boats. The drums can be lifted either individually, or up to four at a time using a special chain tackle arrangement. The lifting arrangements for fuel drums differ somewhat on the two ships. On the *Manu Folau* fuel drums are lifted and loaded into the work boats on their ends, whilst the handling in the *Nivaga II* means they are lifted and loaded on their sides. This has implications when unloading the work boats at the island.

Not all cargo can be offloaded in the cargo nets. There are many loose items which can only be lifted individually (e.g. motor-cycles, outboard motors, livestock cages, aluminium dinghies, household appliances, etc) and there are others that require a bundled lift (e.g. building materials such as timbers, roofing, reinforcing bars, etc.). These are lifted by the cranes/derricks using slings.

The *Nivaga II* has two derricks which typically operate in a 2 tonne capacity union purchase arrangement. However each derrick can be configured to lift on its own - in which case the rated capacity is a 7 tonne lift. Heavy items requiring delivery to the outer islands are therefore shipped and offloaded by the *Nivaga II*. Under such a scenario, two work boats are lashed together to provide a pontoon arrangement for transshipment to shore.

2.3.2 Passenger Transfers

For safety reasons, passengers are not ordinarily transferred between the ship and the shore after dark. The only exception to this occurs at Nukufetau (at the discretion of the ship's Captain). This is normally permitted because the inter-island vessels are able to enter the sheltered waters of the Nukufetau central lagoon and the transfers undertaken without the risks associated with waves.

The unloading and loading of passengers into the work boats differs on each of the inter-island vessels. However on either vessel, life-jackets are not issued nor ordinarily requested by passengers.

On the *Manu Folau*, passengers embark and disembark through a gateway on a lower deck directly into the work boats. Under calm seas (which should be acknowledged is a rare event) the gunwale of the work boats is about 0.3m below the deck level from which passengers alight. There is a further 0.6m to 0.8m drop from the gunwale of the boat down onto its floor. In other words, passengers are endeavoring to move between two platforms that are some 1m difference in height and are moving independently of each other as the work boat and ship pitch and heave in response to the prevailing sea conditions.

The dangers associated with this during even mild sea conditions can be very considerable indeed - particularly as there are infants, young children, sick, elderly and infirm people all endeavoring to accomplish the transfer into or out of the work boats.

On the *Nivaga II*, passengers walk down a gangway slung over and along the side of the vessel. They board the gangway from the upper front deck of the ship then walk down its steps onto a small landing platform at its end. Passengers then step off the gangway onto the gunwale or transom of the work boats. This is even a more perilous undertaking than on the *Manu Folau*. The gangway platform is by necessity located considerably higher than the gunwale of the work boats since it is suspended out over the water and needs to be above where it could be washed by waves.

During most sea conditions, the work boats need to keep away from the gangway platform to avoid being caught under it whilst surging in the waves (in rough seas this could swamp the boat, or seriously injure anyone caught between the two). This therefore requires passengers to step both out and down into the work boats. However the location at which they land is either the narrow gunwale or the flat transom at the back of the boat. There is a further drop of some 0.7m to 1.1m onto the floor of these larger work boats.

Whilst passengers are not ordinarily carried in work boats that are also carrying general cargo, sometimes this is not always the case. Indeed the personnel effects and small cargo items carried by passengers when boarding the work boats can account for a considerable amount of space within each boat. This further inhibits the ability of following passengers to board with assurance and safety.

When sick, injured or elderly people need to be transferred between shore, they can be transferred into or out of the work boats on board the ship. That is, the work boat itself is lifted by the ships crane/derrick onto or alongside of the deck of the ship where the person can negotiate the transfer in less hazardous circumstances.

The transfer of passengers and cargo into the work boats is difficult even under mild sea conditions. The main ship, the work boats and the slung cargo are all moving independently of each other. Even during quite mild sea conditions this transfer can be extremely perilous and unsafe. At those times when conditions are particularly rough, some passengers (particularly those who are elderly or with young children) will not transfer into the work boats, electing instead to return to Funafuti on the ship without going onto their island destination.

When seas become rough and transfers too perilous, the captain of the inter-island ship will abandon further operations.

When the *Manu Folau* was originally supplied to Tuvalu, the work boats also came with landing gangways that were specifically designed to fit to the sides of the boats and enable passengers to transfer more easily between the work boat and the ship. These were used quite effectively until such time as the work boats needed replacement. Their replacements were not of the same design (different freeboard, size, etc) and the gangways were not as effective. Consequently they fell into disuse. Nevertheless in any future work boat replacement program, this issue of purpose built gangways should certainly be considered in an attempt to provide improvements to the safe transfer of passengers between the ship and the work boats.

2.4 Transit Voyage

Once loaded with passengers or cargo, the work boats embark on the transit voyage to shore (or alternatively back to the main ship). This entails passage in deep water up to the sea approaches to the reef channels, entering the reef channels so as to cross the reef edge, negotiating the passage through the channels and maneuvering to land at the shore. It relies considerably on the skills of the work boat operator for it to be completed safely.

As is the case with the ocean-side operations, this process must be undertaken across a broad range of tide levels; weather and sea conditions; channel widths and depths; currents; and is sometimes undertaken at night. The most hazardous aspect is the navigation into and through the reef channels.

The sea conditions are generally such that waves are shoaling and breaking on the outer edge of the reef. During heavy seas the entrance to the channels can be awash with waves and the currents emerging from the channel can lead to a confused sea state. Not only can the entrance channel be difficult to negotiate at such times, but it can be difficult to identify during the sea approach. Likewise, once in the channel it can be difficult to discern its limits.

Work boat operators use a system of “counting waves” to assist in their decision as to when and how they enter the channels during rough conditions. This entails timing the average duration between waves so that they can time their passage accordingly and are not unexpectedly caught by a wave.

Most of the reef channels are relatively narrow and are quite shallow - particularly during low tides. Consequently care is required once in the channels to ensure that the work boats don’t strike the bottom or sides. On those islands that have a narrow fringing lagoon, the reef channels can be short and wave activity still quite considerable where they end at the island. At such locations it is necessary to quickly turn the boat around and face its bow into the waves. Ideally this should be done under power, but there is usually insufficient depth of water to effect this maneuver and one of the work boat crew needs to alight and manhandle the boat so as to face it back into the waves.

Work boats have been swamped and passengers and cargo spilled into the ocean on several occasions. The occurrence of such accidents has diminished somewhat since the reef channels have been built. Nevertheless, the unpredictable and often severe nature of ocean conditions means that the passage through the reef channels will always be fraught with risk.

2.5 Island-side Operations

The means by which passengers and cargo are offloaded and loaded at the various islands depends upon many aspects. At almost all locations, the transfer of cargo between the shore and the work boats is undertaken primarily by hand, with little or no assistance from crane trucks, tractors or other such mechanical means. One of the reasons being that these vehicles cannot negotiate the sandy beach between the upper foreshore and the landing point.

During high tides, the work boats can usually approach the beach or concrete ramps and offload directly onto the shore. From here the cargo is typically carried up onto the foreshore (or in the case of a concrete ramp, can be loaded onto tractor/trailers or trucks). However at low tides the work boats generally cannot approach close enough to shore and the offloaded cargo must be carried across the intertidal reef flat. This might mean having to wade ashore in the shallows during neap tides, or walk across the dry reef flat during spring tides. This unloading can be an arduous exercise as the quantities and weight of cargo delivered to the islands can be significant.

One of the most difficult exercises is that of lifting the heavy 200 litre steel drums in the work boat and then tipping them over the side into the shallows on the platform reef (or in the reef channel itself if a low tide means a dry reef flat). As is the case for most of the island-side cargo handling, this is normally done by paid members of the island community. The drums are then floated the short way to the bottom of the beach slope, rolled up the foreshore and then often rolled for considerable distances along the unsealed roadways of the island to their final destination.

2.6 Problems & Constraints

2.6.1 Tides

At the present time, the constraints imposed by varying tidal conditions on the transshipment of cargo and passengers between the ships and the island shores is considerable. Tides significantly affect both the transit voyage of the work boats and the island-side operations.

The tide level affects the transit voyage primarily because the existing reef channels are too shallow and there is insufficient depth to allow the passage of a laden work boat during many low tides (or in the case of a few islands, low tides prevent any access whatsoever). Consequently as the tide drops during the transshipment operations, entry into the reef channels and the passage through them becomes somewhat uncertain, with increasing risk of a grounding and subsequent swamping by waves. The transfers have to be undertaken with greater caution, or even abandoned.

The only exception to this is at Nanumea where the work boats can navigate the deep wide reef channel into the sheltered waters of the central lagoon. Cargo and passengers are then offloaded at a small wharf via multi-tide landing platforms and a crane truck. Nevertheless, even this transfer process is affected somewhat by tides since very strong currents flow out of the reef channel during ebbing tides and can contribute to a hazardous passage of the channel.

Channel improvement works proposed under this TSSTP are aimed at alleviating the various problems associated with inadequate depths in the channels. Indeed this is an achievable objective for all of the outer islands - with the exception of Nukulaelae, for which operations at low tide will always be unworkable.

The effect of tides on the island-side operations of transferring passengers and cargo imposes a significant constraint that affects the viability of the crane truck / beach access / work boat operational process. It is vital to the successful implementation of any arrangements proposed for the TSSTP that the influence of tides is well understood and accommodated.

It is perhaps appropriate to consider the effects and problems currently experienced across the entire range of tides that occur at the island landings. This requires consideration of the effects on island-side operations during the following tidal conditions:

- High Spring Tides
- Low Spring Tides
- High Neap Tides
- Low Neap Tides

High Spring Tides

In most cases this particular tidal condition poses the least problem to the transit voyage and the island-side operations. During spring high tides the work boats can navigate into and through the existing reef channels with little risk because there is typically adequate depth of water.

insert figure

Figure 2-4 : Island-side Landing at High Spring Tides

When wave conditions in the channel and at the shore landing are mild, the work boats typically come abeam to shore and offload passengers and cargo over their side. This would either be directly onto a sandy beach or a concrete ramp. On occasions when there is wave activity propagating over the reef crest and/or along the reef channel, the work boats turn so that they have their bows facing into the waves and then discharge passengers and cargo over the stern.

The high tide levels enable larger waves to propagate over the reef edge and along the channel to reach shore. At those islands having a narrow fringing reef there can be quite a problem with wave-induced fluctuations of water levels on the beach face (ie. due to surf beat, wave setup, and the waves themselves). These can cause the work boats to surge up the shore and to range considerably along it. Even mild occurrences of these effects would present a challenge to any crane truck attempting to safely unload cargo onto the beach or ramp.

Low Spring Tides

During spring low tides the work boats cannot access the shores of Nukulaelae, Nui or Nukufetau because of the inadequate depth of water in their reef channels. The typically shallow water in the reef channels at other islands can also significantly restrict their navigation at low spring tides.

insert figure

Figure 2-5 : Island-side Landing at Low Spring Tides

At those other islands, the distance between the landward end of the channel and the shore is such that once vehicles have traversed the beach slope they would then have to drive down onto the reef flat and across it to reach the work boat.

At the moment there are no opportunities on any of the islands for a crane truck to do this, they cannot negotiate access across the beach to the reef flat. Those islands with concrete beach ramps find the surface at their ends far too slippery to drive on, or the ends of the ramps are buried beneath sand, or there is a step off the end of the ramp - all of which prevent crane trucks from moving beyond the concrete surface of the ramp.

Nonetheless, discussions with the various island Kaupule and crane truck drivers indicate that even if an appropriate beach access system could provide a trafficable surface across the beach, there is a strong aversion to the notion of the crane truck venturing onto the reef platform beyond. This is understandable since the crane trucks are not robust heavy duty vehicles, and the irregular and rough surface of the reef platform (with various shallow saltwater pools) is a particularly adverse working environment for such vehicles. This would be particularly the case when they are loaded with cargo. Saltwater splash, damage to tyres by the rough surface and damage to the light chassis by the undulating nature of the surface are very real concerns.

Consequently even if a reliable and easy beach access system could be provided, it is most unlikely that crane trucks would venture out onto the reef platform to unload the work boats at low spring tides. Tractors with trailers might do so, however this would entail manually unloading the work boats and lifting cargo up onto the trailer. Heavy cargo and fuel drums would likely still be manhandled ashore.

High Neap Tides

For many of the islands, it is the neap tides (whether high or low) that pose the greatest problem with regard to the efficient transfer of cargo and passengers between the ship and shore.

This is because the depth of water over the reef platform between the end of the channel and the shore is limited. During high tide this is generally such that it is not possible to fully load the work boats - otherwise their draft is too great and they cannot pass beyond the end of the channel to shore. In which case, the boats have to be unloaded at the end of the channel and the cargo transported ashore through the water between the channel and the shore.

insert figure

Figure 2-6 : Island-side Landing at High Neap Tides

By only partially loading the work boats it is sometimes possible to bring them up to the shore where they can be unloaded directly onto the beach or concrete ramp (by a crane truck if appropriate beach access could be effected). However this prolongs the entire cargo unloading process. This in itself presents problems since it is really only for a period of about three hours that boats can access the shore directly during neap high tides. After that, the scenario of neap low tides comes into effect. This can prevent any further work at some islands and significantly restricts efficiency at others.

If all the cargo cannot be discharged at neap high tide then this frequently means that the inter-island vessel has to moor offshore overnight so that it can complete unloading operations on the neap high tide of the next day. This can disrupt the shipping schedule and contribute to access problems at those other islands to be subsequently visited on the same voyage. Additional sailing costs and inconvenience to passengers and communities on subsequently visited islands is incurred.

Wherever possible such constraints are incorporated into the planning of the shipping schedule, but most islands are affected by neap tides and there will always be some uncertainty in schedules during neap tides.

Low Neap Tides

During low neap tides the work boats cannot access the shores of Nukulaelae or Nui (and Nukufetau most times) because of the inadequate depth of water in the reef channels.

insert figure

Figure 2-7 : Island-side Landing at Low Neap Tides

At other islands, the width of reef platform between the landward end of the channel and the shore is underwater and there is insufficient depth of water to enable the work boats to access the shore. Consequently passengers have to disembark and wade through the shallows to shore. Likewise cargo has to be manhandled ashore through the shallows. Even if there was adequate access across the beach for a crane truck or other vehicles, they would not be taken through the shallows to load / unload the work boats further offshore.

Summary

A major focus of previous studies and projects associated with the transfer of cargo to outer islands has focused on providing a trafficable access across the beach so that mechanical plant can then offload cargo from the work boats and transport it safely across the foreshore and onto the island.

Various means of providing the beach access have been either implemented (the concrete beach ramps funded by Canada Fund), or advocated as a more appropriate alternative (Kaly, 1999). Indeed this Pre-design Report nominates another possible means of providing such access (Section 3.5.3).

A basic premise to the concept of a trafficable access across the beach to the reef platform is that there will be vehicles on the various islands that will use this access to facilitate the easier handling of cargo between the work boats and shore. The crane trucks that have been provided under Japanese aid to many of the island Kaupules have been considered a fundamental element in this assisted unloading / loading operation. The island tractors and their trailers are also an important component, although these need to be loaded manually, or worked in combination with the crane trucks since they have no cargo lifting capability.

The constraints imposed on the use of these vehicles by the tides mean that in reality such unloading is likely to only ever be undertaken during high tides. At some islands where the fringing reef is relatively narrow (Nui, Niutao and Nanumaga) even this unloading could be restricted during spring tides due to surging and ranging of the work boats against the shore. Operations during neap high tides would also be restricted somewhat because of the short time that there is sufficient depth of water for the work boats to come within the operational range of the crane trucks.

It is important to consider these issues when evaluating the benefits and costs of potential TSSTP components such as the beach access system; cargo handling equipment and procedures; and reef channel improvements.

2.6.2 Reef Channels

The main problems currently associated with the reef channels are as follows:

- The sea approaches to the channels are often awash with waves and the entrance can be difficult to identify.
- Likewise once in the channel, its edges and therefore the limits of safe navigation can be difficult to identify.
- Most reef channels and their sea approaches are currently not deep enough, wide enough, or straight enough to enable them to be navigated with confidence by work boats or island fishing boats at all stages of the tide.
- There is frequently insufficient depth or area at their landward ends to undertake the turning maneuvers necessary to land the work boats on shore, particularly during low tides.
- In those locations where there is a concrete ramp across the beach that ends close to the end of the channel, sand is being washed from the foreshore into the channel. this not only causes some filling of the channel, but also represents a permanent loss of sand from the island and the mechanism for much of the erosion evident at ramp sites.

2.6.3 Cargo Handling

The main problems currently associated with the current system of cargo handling are as follows:

- Many items are presented for shipping inadequately packaged or bound. This poses problems and risk of damage to these and other items when trying to offload and transport the items to shore.
- During the loading of the work boats at the ship, cargo can be spoiled or damaged by crushing, rain, or splash.

- Given that much of the unloading of cargo and fuel at the island is undertaken manually, there is significant risk of cargo damage and spoilage - as well as injuries to the people undertaking the unloading.

3 Options for Improving Cargo Transshipment

3.1 Work Boat Designs

Section 2.2.2 presented some discussion of the work boats currently being utilised by the Marine Department. One of the main reasons that timber work boats have been preferred to the present time is that they can be readily repaired in Tuvalu.

Only quite recently both the PWD and the TMTI have acquired the skills and the equipment to carry out welding of aluminium. This offers the opportunity to re-assess the overall design of work boats for both of the inter-island vessels. Advice received by the Pre-design Team with respect to boat designs suggest that there could be alternative designs in aluminium which offer greater stability (and therefore safety).

The Pre-design Team is of the opinion that this recently acquired capability to undertake repairs and welding of aluminium in Tuvalu warrants a reassessment of work boat designs. Consequently it is recommended that Technical Assistance be provided to the Marine Department to investigate feasible designs for work boats operating with the *Manu Folau* and the *Nivaga II* and recommend an appropriate design.

The scope of such design investigations should not just be focused on improving the transit voyage of the work boats to and from the shore, but also consider the entire process of transferring passengers and cargo safely and efficiently between the work boats and the inter-island ships; and between the work boats and the shore.

3.2 Shipping Boxes

Bags of rice, flour, sugar and cement are particularly prone to spoilage and they are carried in large quantities to the outer islands. These items are usually carried in 20kg or 25kg bags, except for sugar which is usually supplied in 50kg bags. Other cargo is typically packed in cardboard boxes and is therefore also often damaged by wetting or by crushing during loading / unloading operations. Indeed cargo can be damaged at any stage throughout the entire transshipment process.

Robust watertight shipping boxes could be used to protect general cargo and personal items that are prone to damage. Ideally the boxes could be packed at the wharf in Funafuti, or alternatively packed by the crew of the inter-island ships in the hold of the ship prior to dispatch to each island visited on the voyage.

Given that much of the rice, flour, sugar and other such bulk items are dispatched by the TCS to the outer island *fusi*s, the packing could even be undertaken at the TCS warehouse facility in Funafuti then delivered to the wharf ready for shipment. Similarly cement is usually shipped in bulk and a similar arrangement implemented.

Being of 1 tonne capacity, the boxes could be lifted by the crane trucks on shore when conditions allowed such vehicles to be used. In the event that the crane truck is unable to lift the boxes from the work boat (due to adverse tide conditions or general non-availability) the boxes could be opened and the contents taken ashore manually as is the current practice. Alternatively the offloading of the boxes at each island could be scheduled into the unloading operations so as to occur during tidal conditions more favourable to the utilisation of the crane truck.

On board the inter-island ships, there would be a need to move the loaded shipping containers around in the ship's hold. The cranes on the *Manu Folau* would enable each box to be positioned in the general vicinity of their preferred location, but not necessarily in a stacked arrangement. This might prove adequate during any initial trial of the shipping boxes, but if fully implemented across all outer islands the number of shipping boxes is likely to require them to be stacked so as to provide for adequate operations in the hold.

The *Nivaga II* operates a union purchase arrangement and positioning is not easily achieved. Some pushing and dragging by the derricks and the crew in the hold can achieve some greater control over positioning, however this entails rough treatment of the boxes and would therefore not be a preferred method of handling. Stacking of shipping boxes in the hold of the vessel could not be practically achieved given the union purchase arrangements.

Consequently it is recommended that a small hand operated forklift be procured for the *Nivaga II* . This would enable the shipping box system to be trialed on both vessels. another such forklift would be required for the *Manu Folau* should a successful trial see the shipping boxes implemented across all islands.

It would be necessary to also provide lifting chains for each of the crane trucks to better facilitate the offloading of shipping boxes at each of the island landings. Consideration should be given to incorporating a spreader bar arrangement into the chains.

It is recommended that Technical Assistance be provided to design and facilitate the manufacture and supply of appropriate shipping boxes for use throughout Tuvalu. It is envisaged that this would entail a trial of the system, not only to refine the design of the boxes themselves, but to also examine the operational aspects of their implementation.

It is envisaged that the trial would be island specific, with one or possibly two islands participating in the trial. Given that it is the shipping boxes / crane truck collaboration that actually requires assessment, this would best be undertaken on either Nui or Nanumaga since the crane truck at both locations is currently used to offload cargo from the work boats at high tide.

The following performance specifications should apply to any shipping boxes for general cargo:

- Robust durable construction
- 1 tonne laden capacity
- Sized to accommodate 1 tonne of stacked bags of rice, flour or sugar
- Easily and cheaply repaired using methods readily available in Tuvalu
- Lifting effected by chain hooks
- Robust recessed lifting attachments located at or near top of the box
- Can be picked up and lifted by a forklift
- Boxes seal when closed so as to be watertight, not just waterproof
- Lid and box as single unit
- Stackable when empty
- Stack / interlock when full
- Float when empty and lid is open
- Highly visible colour
- Fit into current work boats

- Inert material that does not deteriorate in saltwater or high UV environments
- Cheap to manufacture

3.3 Fuel Drums

Diesel, kerosene and petrol are currently transported to the outer islands in 200 litre steel drums. They are relatively easily handled by the ships lifting gear and can therefore be readily offloaded into the work boats. However once delivered to the island, their unloading and subsequent transport across the shore and onto the island itself is typically done by hand. This difficult exercise often results in damage to the drums by them being rolled along the reef platform and the beach, injuries to those having to manhandle them and contamination of the fuel.

A system of containerising fuel drums was considered by the Pre-design Team in an attempt to solve many of the problems associated with the island-side handling of fuel drums. This basically evolved into a system of shallow cargo baskets holding four or five 200 litre drums that could be delivered into the work boats by the ships' cranes and derricks. The provision of an access for the crane truck to cross the beach to directly assist in the unloading of fuel drums from the work boats at the island is discussed in the subsequent Section 3.5.

However a significant disadvantage of a cargo basket for fuel drums is that in the event the crane truck at the island was not available to lift the cargo baskets out of the work boat, then it would be extremely difficult to manhandle them out of baskets.

Consequently whilst the existing process of individually unloading each drum from the work boat and transporting it ashore is not ideal, it is better than any bulk handling system that could be devised by the Pre-design Team. Nevertheless, there is significant scope to make this process of individual handling more efficient and potentially less damaging to cargo and less injurious to people.

The most hazardous exercise is that of lifting the heavy full 200 litre steel drums in the work boat and then tipping them over the side into the shallows on the platform reef (or in the reef channel itself if a low tide means a dry reef flat). This is normally carried out by island labourers. This process could be improved by installing a cradle arrangement in the work boats that hinged over the side. Fuel drums could be maneuvered into the cradle, then the cradle lifted and tipped overboard. This assisted tipping would require less physical effort and offer less risk to those unloading drums from the work boat. The drums could then be floated close to shore within reach of the crane truck.

The crane trucks would need to carry lifting chains to pick up the drums. There are two types of lifting attachments that can be fitted on chains for 200 litre drums, ones that lift the drums from their top (ie. with the drum's longest axis vertical) and those that attach and lift on each end (ie. with the drum's axis horizontal). Both types would need to be carried by the crane trucks since the lifting arrangements on the *Manu Folau* and the *Nivaga II* differ. This means that the work boats from the *Manu Folau* typically carry the fuel drums standing up, whereas those from the *Nivaga II* carry them lying on their side.

Through careful design, these lifting chains and their end hooks used to unload fuel drums could be the same as those used to lift the shipping boxes.

In summary, it is recommended that a hinged cradle arrangement to lift and tip fuel drums out of the work boats be designed and fabricated for each boat and that all crane trucks on the outer islands be issued with lifting chains that can be used for fuel drums as well for the shipping boxes.

3.4 Packing Standards

Often cargo is presented for shipping that is inappropriately packaged. This is typically building materials that are to be sent to outer islands on behalf of private individuals, families or groups. Items such as timber, plywood sheeting, roofing, etc. are often delivered to the Marine Department for shipping loosely bound or even in some instances not packaged or bound at all. This presents problems with regard to crew safety and cargo damage when trying to lift these items from the ship into the work boats and subsequently transporting them ashore.

The Marine Department's Bills of Lading and Cargo Receipts contain the requirement that all cargo is to be "appropriately" packaged or will not be accepted for consignment. However the reality is that this is rarely enforced because there is no real standard for the Department to offer as a benchmark. Nor is there apparently any wide spread understanding across the general community with respect to the requirements for shipping such items.

There would be considerable benefit in providing Technical Assistance to the Marine Department for the development of appropriate packing standards and the appropriate dissemination of those requirements through a public awareness campaign throughout Tuvalu.

3.5 Beach Access

3.5.1 General Requirements

A trafficable access for island vehicles (and the crane trucks in particular) across the shore and down to where the work boats land would assist significantly in the offloading of cargo. The implementation of a system of shipping boxes would result in cargo normally prone to damage coming ashore with less risk, however this containerisation also offers the opportunity of implementing a system of bulk cargo handling that offsets the need to manhandle individual items ashore.

Clearly if the crane trucks can collect the boxes from the work boats and deliver them to their final destination - or at least to an onshore area where the contents can then be unpacked and released to the consignees - there are further benefits with respect to efficiency and safety of cargo delivery.

It was primarily with this objective in mind that the construction of the concrete beach ramps was instigated. An unfortunate environmental impact of these ramps was their adverse effects on natural beach processes and the foreshore erosion that they initiated. These effects have been such that there are firm recommendations for the ramps to be removed. Nevertheless, there is still a genuine need to provide for an access across the beach.

However, as discussed in the preceding Section 2.6.1 it is important to appreciate that such beach access system will really only enable the current crane trucks to access the work boats during high tides - and even then conditions at the boat landing site might impede the ability of the crane trucks to unload.

As determined by Kaly (1999), from an environmental perspective any beach access system must have the following characteristics:

- it must be transparent to the lunar and seasonal sand movement cycles - i.e. sand must be able to move up and down the beach and along the beach without piling up against the structure;
- it must be temporarily moveable so that they can be taken out of the way of large storms or cyclones;
- its construction must not require large amounts of natural materials (such as stones) that are important to the ecological integrity of the island, and
- it must be immune to damage by storms and cyclones.

The following sections offer some discussion of options for the provision of beach access for island vehicles.

3.5.2 Enviro-Ramps

The concept of an "*enviro-ramp*" to replace the concrete beach ramps has been developed by Kaly (1999) and advocated by the Review Team for application at a number of appropriate locations on outer islands. The system is a variation on the board and chain roadways that are used at locations worldwide for managing pedestrian and vehicle access across dunes and sandy foreshores.

The enviro-ramp concept entails robust timber planks bound together by rope to form a ladder-type arrangement that is laid out on the surface of the beach. This then provides a trafficable surface. The top of the structure is permanently anchored onshore at the crest of the beach slope, whereas the bottom is tethered to the reef platform at the bottom of the beach.

The system is well documented in the earlier reports associated with the reef channels and the environmental assessment of the effects of the concrete ramps. It relies on neutral buoyancy and negligible interaction with the swash processes that move sediment alongshore so as to have little impact on longshore sediment transport rates.

The intent is to construct enviro-ramps at each beach landing and to effectively leave them in place. During storms or heavy seas, the seaward end of the enviro-ramp would be released from its tethers, connected to a tractor or crane truck, then folded back on itself, up off the beach beyond the reach of the waves. This prevents damage to the enviro-ramp itself and allows the foreshore to respond to storm induced processes. Once the storm waves abate, the enviro-ramp would be redeployed on the beach face.

Experience has shown on similar cross-shore board and chain beach accesses that they can become buried during accretion cycles on beaches and need to be lifted out of the sand from time to time. This would likely be the case for those enviro-ramps deployed on outer island foreshores, since many of the locations experience seasonal changes to beach profiles. This requirement of lifting is due to the fact that it is very difficult to make hardwood timber structures positively buoyant, and even if they are near neutral buoyancy the small scale processes at the timber / sand interface appear to cause sand to accumulate against or on top of the timbers.

The enviro-ramps are expected to require on-going maintenance - particularly with regard to the attachment of the rope to the timbers. The timbers themselves are likely to be very robust and provided they are supported by sand along their entire lengths (as opposed to having to span across gaps or rocks in the supporting surface) would accommodate the loads imparted by a loaded vehicle passing over them. The selection of appropriate ropes and fixtures would be required to ensure that they were durable under the harsh coastal environment and did not wear excessively. Chains in lieu of ropes would not be appropriate due to their expected rapid rate of corrosion.

Nevertheless the enviro-ramp concept offers a reliable system of beach access for vehicles.

3.5.3 Mobi-Mats

The French company DESCHAMPS has developed and patented a monofilament matting system called "*mobi-mats*". They have a wide application, since they can be deployed quickly to create trafficable pathways across uneven, infirm and sloping ground - in either sand, mud, or snow.

The mobi-mats can be purchased as proprietary items and there is a specific product range for military applications. These are used by a number of defense forces around the world to enable over-the-shore deployment of military equipment such as armoured personnel carriers, tanks, excavators and other such heavy machinery. Basically the mats are rolled out on the beach slope, in wave environments their edges are pegged through reinforced eyelets into the ground (using pegs not unlike those used for securing tents), then the equipment drives up the mats and onto the foreshore. Once all equipment is onshore, the mats are then rolled up and taken away.

Their main advantages for that type of military application is that they are very robust, can be reused many times, are relatively lightweight and portable, quickly installed, weatherproof, and are inert to seawater and fuel spills. These same advantages would apply for any application to provide an access for crane trucks and tractors across the beach on the outer islands in Tuvalu. Furthermore, since the mobi-mats only need to be deployed for the duration of the unloading operations, they do not interfere with beach processes. The beach is left in its natural state between unloading operations.

The standard lengths of mobi-mats are 10m, 20m and 40m. Typically these are supplied in widths of 4.2m. It is envisaged that a standard 20m long mobi-mat would suit most beach access applications on the outer islands. The exception being at the Muli Channel site on Niutao where the eroded foreshore and upper beach area have resulted in an overall beach width of some 30m.

The 20m long mat rolls up to a diameter of approximately 0.6m and weighs around 150kg. It can therefore be easily handled by a crane truck, or even manhandled by two or three people. Mobi-mats can be rolled out on the beach manually, and likewise can be rolled back up manually. If required, straps to assist in the rolling up processes can be used.

If provided to an island Kaupule, the mobi-mat would be deployed prior to the arrival of the work boats onto the island. Then on completion of unloading operations, it would be rolled up the beach slope by hand. It could perhaps be rolled into and out of a purpose-built box at the top of the beach, and left on the foreshore until the arrival of the next ship. Because they are transportable, the same mobi-mat could also be used to provide beach access at an alternative channel site when conditions prevent a landing via the main channel.

Alternatively, a mobi-mat could be carried on each of the inter-island vessels. The first work boat ashore would bring the mat for deployment on the beach; the last work boat to leave the island following completion of offloading operations would bring the mat back to the ship. Therefore instead of providing each island with a mat for each main channel and each alternative channel location (as would be required for an enviro-ramp), only one mobi-mat for each of the two inter-island vessels (plus probably a spare one) would be required.

4 Channel Improvements

4.1 Channel Excavation

4.1.1 Required Dimensions for Main Channels

Most of the existing reef channels on the outer islands are either too shallow or too narrow (or both) to allow boats to enter and navigate through them at all tides with the confidence that they will not encounter any obstructions. It is difficult enough to confront the challenge of negotiating the waves and currents on the seaward approach into most of the channels without the added uncertainty of a channel and entrance that is narrow and shallow.

There would be significant enhancement to the safety of this undertaking if the reef channels themselves were wider, deeper and in some cases straighter.

Given the size of work boats and island fishing craft currently using the channels, the minimum cross sectional requirements to enable safe navigation are considered to be:

- minimum width at low tide (say, at Mean Low Water Springs) = 8 metres
- minimum depth at low tide (say, below Mean Low Water Springs) = 1.5 metres

4.1.2 Alternative Channels

During the westerly season in Tuvalu, the sea conditions on the usually sheltered side of the islands can become quite rough, with large waves propagating towards and breaking on the western fringing reef. Alternate landings are typically made on the eastern side of the islands, however there are few formal reef channels that have been constructed at such locations. To provide for safer landings on islands during adverse westerly conditions, alternative channels can be constructed.

However the reef platform on the eastern side of many islands is quite wide (e.g. some 470m at Nanumea and 250m at Nui). Given the infrequency of their use, there seems little to justify the effort, expenditure and environmental impacts of constructing very long alternative channels of similar physical dimensions as that of the main channels.

Nevertheless, the passage they offer across the reef edge needs to comply with the minimum requirements of 8m width and 1.5m depth (below Mean Low Water Springs) in order to be safe. Rather than excavate such a channel all the way to shore, it would instead be appropriate to terminate it a sufficient distance landward of the reef edge to ensure that the wave conditions sweeping across the adjacent reef platform or penetrating down the channel itself will not compromise safe island-side operations. Depending on the location and the structure of the fringing reef, this distance can vary from only some tens of metres to a hundred metres or more.

The way in which this shorter alternative eastern access channel would operate is perhaps best described according to what tide phase might be prevailing at the time.

Duringhigh spring tides, the work boats would cross the reef edge, navigate through the channel and across the shallower reef flat to shore. Consequently cargo and passengers would be transferred all the way to the shoreline in the work boats. During low tides however, the work boats could only navigate as far as the end of the channel.

Passengers would then need to disembark / embark and walk across the dry (or near dry) reef flat from the end of the channel to shore. Cargo would either not be dispatched from the ship in work boats at low tides, or only such cargo as could be manually carried ashore would be dispatched. Access across the shore and the reef flat might be effected by the island crane trucks and/or tractor/trailers to facilitate transfer of more bulky cargo, however there is a general reluctance across all islands for such machinery to travel on the reef flat.

During neap tides, its is likely to still be possible to land passengers and cargo directly on the beach at high tides. However the reduced water depths over the reef platform between the end of the channel and shore may restrict the amount of cargo carried by the work boats (to minimise the laden draft of the boats). However at low tides, work boats laden with passengers and cargo are unlikely to be able to traverse the shallow water over the reef platform between the end of the channel and the shore.

Consequently passengers would have to disembark / embark and walk through the shallows on reef flat so as to reach shore. The management of cargo handling would be similar to those under low spring tides. Consequently the philosophy applied to the development of design criteria for the alternate channels at the various island sites is that as a minimum they will enable:

- safe delivery of passengers at all tides;

- the landing of cargo on shore other than around low tides.

4.1.3 Turning Basins

When the work boats arrive at the end of the reef channel, it is not practical to simply land with their bow to the beach. They need to turn so as to discharge passengers and cargo, either over the stern or over the side. The actual maneuver required depends very much on the state of the tide, the sea conditions, currents and depths that prevail at the time. For instance, it is often necessary to quickly turn the boats around so that their bows are facing into waves that propagate down the channels and across the fringing reef. The work boats are then more stable and can ride the sea conditions much better when discharging passengers and cargo.

The ideal scenario is to undertake this turning maneuver under power - that is, by using the outboard motor to steer the boat around. The alternative of having one of the work boat crew or passengers jump out of the boat and physically manhandle it around can be fraught with difficulties and risk.

In most cases this turning maneuver can be undertaken with some confidence at high tides, but with far less certainty at lower states of the tide. Consequently there is significant benefit to the safety and convenience of the boat landings to have an area at the end of the reef channels that enable the work boats to maneuver freely. Consequently it is recommended that turning basins be provided at all reef channels that end at an island foreshore.

To avoid or minimise any possible impacts of these basins, it is necessary that they comply with the general guidelines associated with channel works (Kaly, 1999). In particular they should not be constructed any closer to shore than the landward end of the existing channel - ideally a minimum of 30m from the toe of the beach slope.

Their general shape should be roughly rectangular with the longer side parallel to the beach (ie. T-shaped) but with the entry being tapered not angular (refer attached concept sketch). Discussions with the work boat operators suggests that a T-shape is preferable to an L-shape since it gives them a choice as to how the turning maneuver is undertaken under the conditions that prevail at the time.

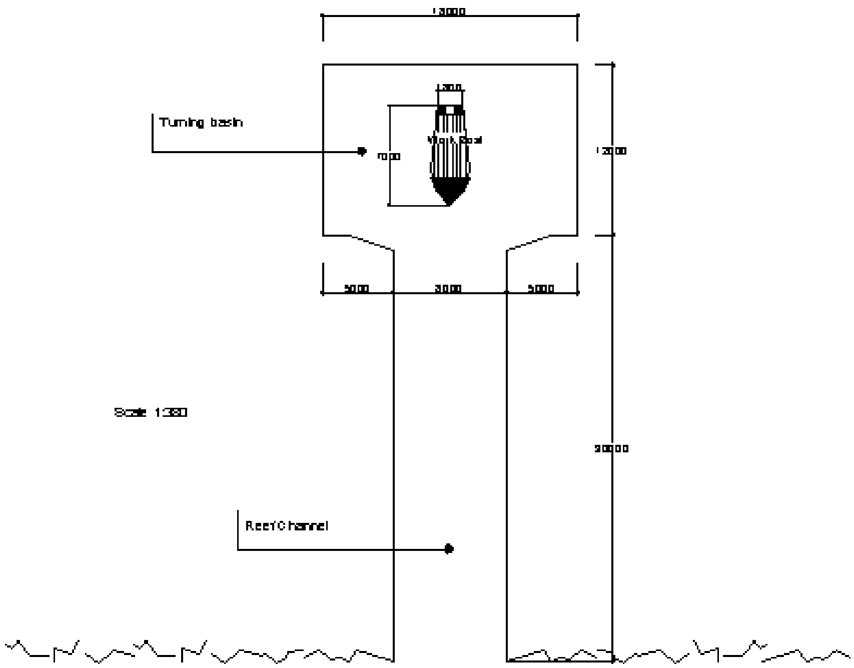

Figure 4-1 : Conceptual Arrangement for Turning Basin

The size of the turning basin required depends upon the characteristics of the work boats as well as the conditions under which the turning maneuver is to be made. Ideally the basins should be around 18m (longshore dimension) x 12m (cross shore dimension). However on some of the islands the reef platform is quite narrow - and therefore the length of the channel quite short - consequently a turning basin of this size is not always practical. Under such circumstances the minimum size would be around 15m x 10m.

Whilst it is essential to ensure adequate depth in the turning basin to enable the work boats to maneuver freely at low tide, it is also important that the turning basin not be too deep. In many circumstances it is necessary for one of the work boat crew to stand at the bow and hold it into the waves during the unloading / loading operation. If the turning basin was more than about 1m deep during the low tides when it is being used, it could compromise the ability of the boat crew to stand firmly in the basin and hold the bow. Therefore it is recommended that the turning basins be excavated no deeper than 1m below Mean Low Water Springs at each island.

4.1.4 Excavation Methodology

The technique by which they are excavated is vitally important to the successful attainment of wider and deeper channels. In all cases material that is removed to form the channels must be taken away from the vicinity of the works, and placed where it cannot be returned by the prevailing coastal processes to fill the hole.

Unfortunately this has not been undertaken in most of the past reef channel works on the outer islands of Tuvalu. It is apparent from inspections undertaken by the Pre-design Team (and the Review Team) that some of the reef channels have simply filled as a consequence of the material that was originally removed to create them being placed on the adjacent reef platform to form bunds along the flanks of the channels.

This original construction methodology has also been confirmed by island residents who witnessed the works being effected. Waves and currents have subsequently washed the material back into the channel - leaving only the larger rocks in the bunds. This is particularly evident in the Nui and Nukufetau channels.

Also it seems that the earlier work undertaken by the Reef Blasting Team was directed primarily towards blasting channels rather than on the subsequent removal of material. Some removal was reputedly undertaken, but this seems to have been quite limited and relied significantly on island labour to take the material from the blasted area by hand.

Blasting is but one activity in reef channel excavation, and its primary purpose is to make hard areas of the reef easier to dig and remove. The most effective means of creating wider and deeper channels is to use a conventional hydraulic excavator operating on the reef platform at low tide to mechanically dig the material out of the channel, and to then place it into a truck or trailer which is hauled away for placement onshore. This removed material could be used to nourish eroded foreshores, as general fill, or for construction aggregates in island building works. The excavation methodology is illustrated below.

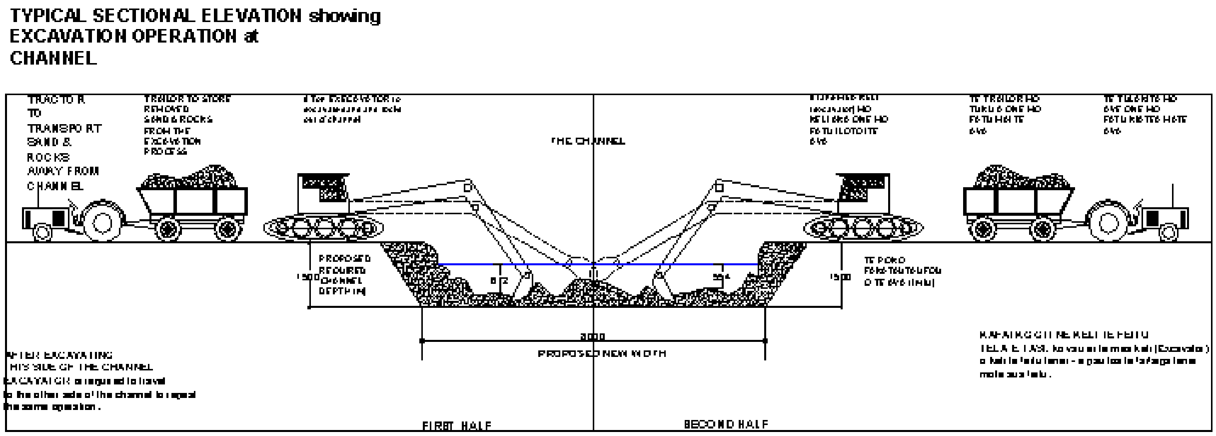

Figure 4-2 : Methodology for the Excavation of Reef Channels

Experience has shown that some blasting could be required to break up the capping on the surface of reef platforms, but once this has occurred the excavator can then “peel off” the capping to expose the less consolidated material beneath. Given that most of the channel improvement works are associated with deepening existing channels (ie. extending previous excavations) and that most of the material to be removed is already exposed reef matrix, there is not expected to be too great a reliance on blasting to assist the channel improvement works.

Nevertheless, the extent of blasting required to assist in this excavation process not only depends upon the solidity of the reef matrix to be removed, but also on the size and power of the excavator used. A small excavator (of some 8t-10t say) is likely to rely on explosives to loosen some material for subsequent digging and removal. Whereas a larger excavator (of say around 25t-30t) could effect the works with minimal or no blasting.

Where a new channel is to be created in an undisturbed reef platform, there is likely to be explosives required to enable an excavator of any size to commence digging the material below the hard capping and to peel back the capping itself. The entrance to reef channels on the outer reef edge typically consists of quite extensive very hard areas. They also tend to be largely inaccessible to excavators even during low tides. Consequently these entrance areas generally rely on blasting alone to form a channel profile.

Given that most channel excavation work needs to be undertaken by equipment working on the reef platform at low tide, it will be necessary to work during the night-time low tides to take advantage of these opportunities. This is particularly the case during low spring tides when the opportunities are most beneficial.

4.1.5 Rock Bags

Whilst the use of “rock bags” does not perhaps constitute works that are associated with channel excavation works, a discussion of their use is perhaps warranted as they can be used to facilitate some of the works recommended in later sections of this Pre-design Report.

Rock bags are really fabricated rocks or rough blocks that can be used for marine construction works in remote locations. They do not require skilled labour to fabricate or to place. As will be discussed in later sections, they are recommended to form low level permanent bunds on the reef platform at Niulakita, and could also be used to reduce the strong ebb currents in the American Channel on Nanumea.

Rock bags comprise of bags filled with sand, coral fragments and cement. Hessian bags especially procured for the purpose could be used, alternatively empty 20 kg rice or flour bags can be utilised. Rice and flour are shipped in significant quantities to the outer islands and the empty bags could be accumulated by the island communities for subsequent use.

Sand and broken coral fragments from the foreshore (or alternatively from channel excavation) is mixed with cement within a conventional concrete mixer in appropriate proportions, but without the addition of water. Each bag is filled with the dry mix to around ¾ of its full capacity, then sewn closed.

Once placed underwater or into the intertidal area, the gradual infiltration of seawater causes the dry mix in the bags to set hard like concrete. After a period of time, the outer bags deteriorate and wear away. Alternatively the bags could be cut and pulled away from the underlying hardened concrete.

4.2 Plant and Equipment Requirements

Marine construction involving reef excavation and blasting primarily involves specialised heavy earthmoving activities undertaken in a physical environment that is particularly harsh and aggressive on mechanised plant and equipment. It is significantly constrained by tides, wave and weather conditions. The selection of appropriate equipment and its subsequent care through a rigorous preventative maintenance strategy is vital to an effective and successful construction campaign.

In order to undertake the channel improvement works proposed under the TSSTP, the following are considered to be the major plant items required.

4.2.1 Hydraulic Excavator

A large excavator of some 25 to 30 tonnes weight would be well suited to the excavation works envisaged for the channel improvement works. However as discussed in Section 2.2.1, the *Nivaga II* has the highest rated lifting capacity of the two inter-island vessels, with a rating of 7 tonnes on a single derrick at 14m extension. Consequently this limits the size of the excavator that can be transported to the outer islands.

This means that a 7 to 8 tonne excavator would have to undertake the channel works. The working range of such an excavator is sufficient to achieve the necessary channel dimensions. As indicated in the preceding Section 4.1.4, such a machine is expected to be able to effect the necessary channel excavation but would need to rely on some blasting to loosen the harder material for subsequent digging.

In addition to a normal bucket, a rock bucket and a ripping tyne should accompany the excavator so as to assist with any hard digging. A quick-hitch should also be fitted to the boom to facilitate an easy exchange of these various bucket attachements when working.

A larger more powerful excavator could possibly be used, whereby its boom was removed when shipping on the *Nivaga II*. Then the main unit and the boom could be brought ashore separately. The excavator could then be re-assembled onshore. In this way, a 10 to 12 tonne excavator could be used. However the removal and reattachment of the boom on most modern excavators is not a procedure that is usually undertaken. It is a complex and specialised process that (whenever it is undertaken) is performed by specialised mechanics from the manufacturer and under controlled conditions in a well resourced workshop. There is otherwise a very real risk of inappropriately reattaching the boom and damaging the machine during subsequent operations.

Consequently it is recommended that an excavator of some 7 to 8 tonnes maximum weight be applied to the task of channel excavation, and that its operation be assisted with explosives where necessary.

4.2.2 Rock Trailers

It is critical to the efficiency of the channel excavation works that the excavator keeps operating and loading material into a rock trailer for subsequent haulage onshore. The excavation work must not stop while the excavator stands idle waiting for the return of the trailer. The window of opportunity for operating this machinery on the platform reef at low tide is narrow and needs to be fully exploited.

The excavation work required at some locations entails quite long haulage routes between the work location and the site for the delivery of the excavated spoil. This is particularly the case for the work on the main channels at Nui, Nukufetau and Nukulaelae - as well as for most of the proposed alternative channels on the various islands. It is envisaged that two robust 15 tonne capacity rock trailers would be required. These are similar to that which was available to the Reef Blasting Team (but was not apparently used very effectively). That trailer is currently in Funafuti but is beyond repair.

A 15 tonne rock trailer typically has an unladen weight of some 3.5 to 4 tonnes. It could therefore be loaded and offloaded by the derricks on the *Nivaga II*.

4.2.3 Tractor

A tractor would be required to haul the rock trailers across the reef platform between the working excavator and the island-side spoil placement site. Tractors are used extensively by the island communities. Most of the island Kaupule have at least one tractor (the exception being Niulakita) which are in various operational conditions.
They are owned and operated by the island Kaupule who hire them out to individuals and groups. All Kaupule have indicated their willingness to hire their tractor to TSSTP for channel improvement works.

The ROC embassy in Funafuti has proposed funding for the procurement of 4WD Massey Ferguson tractors (Model MF5355) and tipping trailers for outer islands. Should these be provided to the outer island Kaupules, they would prove to be of considerable value to the activities of a TSSTP construction team.

Nevertheless, a critical component of the construction works is the haulage of material removed during channel excavation and placed in rock trailers for subsequent disposal onshore. Given the importance of this intense activity to the overall operation, it would be prudent to not rely on the Kaupule tractor to be available for hire. Its high utilisation by the community, in conjunction with the unpredictability of its operation, may prove to be problematic to TSSTP construction activities.

It is therefore recommended that a 4WD Massey Ferguson tractor (Model MF5355) be procured for the TSSTP construction team. This compatibility with those being considered for supply to the outer islands under the ROC assistance will maximise mechanical support during construction activities.

4.2.4 Barge

The flat-bottom dumb barge used previously by the Reef Blasting Team is currently lying in disrepair on the foreshores of Niutao near the Kulia Channel. A recent inspection by the Pre-design Team indicates that this barge could possibly be restored. However the bottom of the hull could not be inspected since it is lying on the sand. It is recommended that the barge be inspected by the PWD Mechanical Engineer to ascertain whether it can be rehabilitated, and the cost of such works.

A barge would be necessary to safely transport the large equipment items to shore from the *Nivaga II* (ie. the excavator, rock trailers, and a tractor for Niulakita). It would also be used to transport the other project equipment across the reef to the excavation site during high tides so as to better exploit available working opportunities at low tide.

4.2.5 Sand Dredge

Much of the channel clearance work entails the removal of unconsolidated sediments that have been deposited into the channel. Rather than remove this material by an excavator working with a rock trailer, a small 4” - 6” suction dredge or air-lift arrangement would provide a more efficient removal technique. These are typically mounted on pontoons or barges to clear sediments from canal estates and marinas. It is envisaged that such a mobile arrangement would be established so as to operate when necessary on the construction team's barge.

4.2.6 Other Items

Clearly there would be a need to utilise other minor plant items to supplement and support the large equipment and the operations of the construction team on the outer islands. Such items would consist of high pressure water cleaners, welding equipment, rock drills and compressor, a comprehensive store of spare parts, mobi-mat, VHF radios, etc.

Other items that could be hired on the outer islands to assist the construction activities might comprise boats, vehicles (including a crane truck), fuel handling and workshop facilities.

4.3 Navigation Aids

The use of solar powered beacons to assist in the navigation of the reef channels would significantly improve the safety and efficiency of the transit voyage of work boats to the islands. Basically there are three types of navigation aids that could be utilised for this purpose, namely

- lighted channel markers
- light lead beacons
- reflectorised daymarks & lead beacons.

4.3.1 Lighted Channel Markers

These basically consist of solar powered lights mounted on poles erected along the sides of channels to indicate their boundaries. They are conventionally lit as red for port (left) and green for starboard (right) when entering a channel or harbour. There are such lights already mounted on the head of each breakwater at the Vaitupu harbour. These are the navigation aid types suggested by the Review Team for marking the entrance to reef channels on the outer islands.

Perhaps one of main disadvantages of such arrangements is that they would need to be installed at the seaward entrance to the reef channels on the outer reef edge. This is an area of very considerable wave activity and consequently a very aggressive environment in which to locate structures. The continuous heavy wave loadings, corrosion potential, and restricted access for construction and maintenance present significant challenges to overcome. Not only that, but once boats had negotiated the entrance and passed beyond the entrance beacons there are no further aids to assist with defining a route within the channel. Another set of beacons would be required to mark the channel boundaries at its landward end - resulting in a minimum of four beacons for each channel.

Given the appreciably aggressive environment in which lit channel markers would need to operate, particularly the front markers, this type of installation is not favoured by the Pre-design Team.

However, there is a shallow reef in the lagoon at Nukufetau which requires marking (refer discussions in Section 5.7.2). The inter-island ships need to navigate quite close to this feature when entering and leaving the central lagoon and it represents a risk to the safe passage of the *Manu Folau* and the *Nivaga II*.

Many years ago, the earlier inter-island vessel *Nivaga I* reputedly ran aground whilst attempting to avoid this obstacle. A beacon placed on a properly designed and constructed pole or tower would provide assistance to ships' crews to safely navigate the lagoon entrance at Nukufetau. Given the ongoing maintenance required of a moored buoy, such a system is not considered sustainable for an outer island setting. Alternatively the shoal could be removed or the water depth over it increased by explosives.

4.3.2 Lighted Lead Beacons

This is the preferred means of defining a navigable route through the reef channels. This consist of two lights located onshore. They are mounted on poles with the rear light located some distance behind the front light which is typically the lower of the two, but this is not critical to their function.

The lights work as leads into and through the channel on the basis of an approaching boat maintaining their transect, that is by ensuring that both lights line up one above/behind the other. Should an approaching vessel deviate from the safe alignment of the channel, the parallax of the two lights means that they are no longer seen as being one above the other. Corrective action can then be taken which would then bring the vessel back onto the safe route.

The benefits of this system is that the boat operator has a clearly defined route for a sea approach into the channel entrance as well as through the channel itself whilst looking forward. They are also located on land which offers a far less aggressive working environment and one that ensures that they can be readily accessed for any maintenance.

The lead beacon lights can be purchased as proprietary units in a range of light colours, generally red, green, yellow, blue or white. They are typically self contained robust and water tight single units that incorporate all of the solar modules, batteries and operating circuitry. Battery life is typically around three to five years and the high intensity LED lights normally operate for some 100,000 hours before requiring replacement.

Each beacon can be set to either flash to one of 256 No. IALA flash patterns (and two can be set in a synchronised flash pattern) or they can be set as continuous steady lights. A range of light intensities can be acquired, however lights with a two nautical mile rating (ie. some ??kms) would be sufficient for most lead beacon applications envisaged. The exception being at Nanumea where a 5 nautical mile rating would be required (refer discussions in Section 5.2.2).

In addition to the lights, it is recommended that the poles on which they are mounted also be fitted with daymarks so that they can be readily sighted during the day. These daymarks should be fitted with reflective material so that in the unlikely event that the solar lights are not working the marks can be seen in torchlight at night. As a further back up, the poles should also be fitted with hooks or similar fittings so that pressure lanterns could be hung to serve as the lead lights if necessary.

During the development of the lead beacon concept by the Pre-design Team, some consideration was given to the possibility of somehow using the lights that are mounted on columns to currently illuminate the existing beach ramp landings as the front beacon. However these lights are operate on electricity and on many of the outer islands the generators are switched off around 10pm or midnight, even when unloading operations at the ramp could still occur. Consequently it was deemed more appropriate that an independent system of lighted navigation aids be adopted.

4.3.3 Reflectorised Daymarks & Lead Beacons.

There is a need to mark the safe passage through the protected waters of some fringing lagoons and to also provide lead beacons on the alternative channels at Motufuoa on Vaitupu and at Kulia Channel on Niutao. However these navigation aids do not need to be lit.

For instance, at Nukulaelae there is a wide fringing reef that must be negotiated by the work boats once they have safely crossed the reef edge (using the lights of the lead beacons). However this fringing reef area is shallow and contains many rocks and shoals that represent hazards that the work boats need to negotiate. By placing poles with reflective material attached (so they can be seen under torchlight at night) to define the boundaries of a navigable channel would be most beneficial.

Similar poles placed to form the lead beacons for the passage into and through the alternative channels at Motufuoa on the eastern shores of Vaitupu and the Kulia Channel on Niutao would also prove most useful for those times when those landings were required. Given that these channels are not often used, installation of lights is not warranted.

In the case of reflectorised daymarks, it is envisaged that a lower section of pole be firmly fixed to the seabed (by way of tremmie-poured concrete foundations or pre-cast mass concrete footings). A non-corrosive pole of timber, PVC, or HDPE construction would suit best. An upper length of similar pole would be fixed at the junction (at a level somewhere above Mean High Water Springs) to which a standard port / starboard mark would be fixed.

This mark would have appropriately coloured reflective material (red or green) fixed to provide the illumination required under torch light at night. Experience has shown that reflective tape does not last in such applications and therefore the reflective material needs to be robust and firmly fixed by screws and a mounting plate. The upper section of the post can be readily removed for repair or replacement as required.

The reflective lead beacons would be of similar construction, but have white reflectors instead of the red and green reflectors indicating port and starboard. These lead beacon poles should have fixtures that enable pressure lanterns to be attached when necessary to further enhance their function.

5 Site Visits and Proposed Works

5.1 Background to Site Visits

The Pre-design Team was of the strong opinion that in order to properly appraise the ship to shore transport process it was vital to undertake a site visit to each of the islands; and furthermore that the inspections be undertaken whilst travelling on scheduled voyages of both inter-island vessels, the *Nivaga II* and the *Manu Folau*.

The following presents the findings of the Engineering Analysis, along with comments and observations as a consequence of the site inspections.

5.2 Nanumea

5.2.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report. The works recommended by the Review Team for Nanumea were as follows:

1. *Remove Explosives from Kaupule workshop* - Explosives were left on the island by the reef blasting team.
2. *American Channel* – Undertake numerical modeling to identify feasibility of reducing the current velocity in the channel by placing constriction at it's lagoon end.
3. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo.
4. *Fixed Crane* - install a crane or derrick at the wharf to facilitate the use of dry boxes and larger items..
5. *Beacons* - Install navigation beacons for the main American channel and also the route between Nanumea and Lakena.
6. *Forklift* - Provide a forklift to facilitate cargo transport between the wharf and the fusi.
7. *Alternative Channel* - Construct a channel on the eastern side of the island, some 8m wide x 20m long to facilitate access to shore when westerly conditions prevent the use of the main American Channel.

5.2.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Nanumea community and the Kaupule during the scheduled visit by the *Nivaga II* on 16th March 2006. The prevailing sea conditions at the time were regarded by the island community and the crew of the work boats as being quite calm and certainly much milder than average.

Tides were very close to springs - with the peak of the spring cycle occurring on only the previous day. Consequently it was possible to view the flow in the American Channel at a time when it was close to the maximum that can occur under astronomical tide conditions. The tides on the day of inspection were:

Time	Level above MSL
0530 hrs	+0.82m
1115 hrs	-0.81m
1730 hrs	+0.83m
2345 hrs	-0.85m

Unlike other islands, Nanumea has a wharf against which small boats (including the work boats of the inter-island vessels) can berth. The wharf is located in the sheltered waters of the southern-most of Nanumea's two ponding lagoons, which is referred to in earlier reports as First Lagoon. Sea access to First Lagoon is via the American Channel which was constructed during WWII to link the lagoon directly to the ocean. The environmental consequences of that connection is documented elsewhere, but it is perhaps appropriate to point out that it has resulted in very high flow velocities during ebb tide as the ponding lagoon drains to the ocean through the channel.

Explosives

The Pre-design Team were informed during discussions with the Kaupule that the explosives which had been left on the island by the Reef Blasting team were removed some time in 2004 by New Zealand defense personnel.

American Channel

The high flow velocity in the American Channel during the ebbing spring tide presents significant hazards. It is not just the flow itself, but particularly its interaction with the high wave energy environment at the edge of the reef. As waves approach the reef edge they begin to shoal prior to breaking. This shoaling process is significantly pronounced when waves encounter a strong current along the axis of wave propagation. Consequently this shoaling and subsequent wave breaking process make conditions at the seaward approach and at the entrance to the American Channel particularly hazardous.

As is the case for most reef channels, the work boat operators need to time their approach and entry into the channel so that they are not swamped by waves approaching from astern. This requires that they power the boats sufficiently to stay in front of the frequently large waves that propagate towards the reef edge and the channel.

During an ebbing tide in the American Channel, this ability to stay ahead of incoming waves can be significantly compromised by the strong out-flowing current. Work boats have been swamped by large breaking waves on the approaches to American Channel on several occasions - with passengers and cargo being spilled into the sea in this area of high breaking waves and very strong offshore flowing currents. clearly this represents a significant risk.

Once inside the channel, the strong ebbing current does not present too great a challenge to the work boat operators, since the wave energy has been significantly diminished by breaking at the entrance and they no longer need to contend with that risk. The current alone is not sufficient to require abandonment of ship to shore movements as the work boats have sufficient power to transit through the channel - even when fully laden. This is reputedly the case for almost all of the island fishing boats as well.

The “New Zealand Channel” (which was created in the 1980’s) runs parallel to the main American Channel for a short length before it connects into it. This channel is never used by the work boats nor island boats as it is considered far too hazardous.

The Review Team has suggested that numerical hydrodynamic modeling could be undertaken to determine whether constricting the width of the American Channel at its lagoon end might reduce the strong currents in the channel. In the process of developing a strategy as to how this constriction might actually be built, the Pre-design Team devised a method by which the linkage between the southern-most of the ponding lagoons be removed. This would in effect be re-establishing the situation prior to the construction of the American Channel during WWII.

This would entail the manufacture of 20kg “rock bags” - consisting of a dry mix of sand, coral gravel and cement sewn into empty flour/rice bags (or hessian bags procured especially for the purpose). These could be made on Nanumea using non-skilled labour. The dry bag mix would then be placed/dumped under controlled conditions at a site that has been identified by a site inspection so as to form a wide berm that extended up to the level of the fringing reef platform. This berm across the entrance would prevent the channel from draining the lagoon.

The cross section of the channel at the proposed site of the berm has the floor some 4.5m below Mean Low Water Springs and approximately 40m to 50m wide. It is acknowledged that there would be a considerable number of rock bags required to effect the closure of the American Channel at this site, nevertheless it could be completed in only a few months at relatively low cost.

The implications would be to increase the water level in the ponding lagoon system by approximately 30-40 cm (Kaly, 2000); and to effectively prevent boats from transiting from the ocean into the ponding lagoon (and the village of Nanumea) at low tide. The implications of such a rise in lagoon levels on the lagoon ecosystem, foreshore infrastructure, foreshore erosion, ground water levels, *puluka* pits and the like would need to be further investigated. However, during discussions there was considerable opposition from both the Kaupule and the Marine Department to complete closure of the channel. This was focused on the adverse effects that it would have on the passage of boats through the channel.

The Kaupule maintain that it is vital for the island community to have all-tide access between the village and the ocean. The Marine Department see such a closure as inhibiting the present ability to transport cargo and passengers from the ship to shore at all stages of the tide. When it was suggested by the Pre-design Team that complete closure could well result in improved wave and current conditions at the sea entrance to American Channel, both the Kaupule and the Marine Department expressed the strong view that the present hazards would be preferable to not being able to use the channel for a period of time during low tides.

The Pre-design Team has considerable reservations about the effectiveness of any method of constricting the ebb tide flow in the American Channel (either by locally reducing its width or depth) as a means of inhibiting flow velocities without compromising the ability to navigate the channel at all stages of the tide. The changes induced to the flow regime are unlikely to assist the passage of small boats into the lagoon during ebb tides - and indeed may make it even more difficult to do so.

Consequently it is recommended that no further works be undertaken with respect to modifying the existing American Channel.

However this does not make the passage of the channel safer during the strong out flowing ebb tides. The risk to safe navigation arises primarily from the difficulty that the work boats have in being able to keep ahead of waves when there is a strong current flowing against their passage into the channel. Consequently, if the work boats were to be fitted with more powerful outboard motors for transfers to Nanumea, then this constraint on safe operations would be significantly diminished. It is envisaged that 60hp outboard motors would provide the necessary power to overcome the risk represented by the strong current.

The passage through the American Channel and the subsequent passage through the fringing lagoon to the landing area on Nanumea is deep and does not require the work boat operators to lift the engines. Consequently the fitting of the larger 60hp motors offers a viable solution to the difficulties in negotiating the transfer of passengers and cargo to shore.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. That system relies on a crane truck to lift the boxes from the work boats. On Nanumea there is presently a 3 Tonne capacity crane truck that assists with the unloading and loading cargo from the wharf at Nanumea. Consequently this cargo handling system could be implemented for Nanumea. Lifting chains for the boxes that also enable fuel drums to be lifted by the crane truck could also be provided.

Fixed Crane

When the Review Team made the recommendation for a 3-tonne capacity fixed crane to be installed, the crane truck had not been delivered to Nanumea. At that time, the Review Team was under the impression that the restricted space in the wharf precinct would preclude any crane truck from working effectively. Whilst maneuvering the truck that has now been delivered around the wharf area is somewhat restricted, it can nevertheless be driven alongside the berthing face and used to lift loads out of the work boats.

The wharf precinct at Nanumea is about to be reconfigured, with several sheds and small buildings to be removed, and larger ones to be refurbished. This is expected to ease the present constraint placed on the 3-tonne crane truck. Consequently it is recommended that a fixed crane not be procured for Nanumea wharf.

Beacons

Discussion with several of the work boat operators has indicated that of all the outer islands, it is at Nanumea that the need for navigation beacons is the greatest. The severe and very confused sea state in the sea approach to the entrance and in the entrance itself means that it is not always possible to clearly identify the channel. Furthermore, the technique that is usually applied by the work boat operators of relying on distinct onshore features as references to guide their approach to the channel entrance cannot be applied to the American Channel.

The channel alignment is such that it exits into the large ponding lagoon, some 1km from the shoreline on the other side. The undeveloped foreshores and considerable vegetation and tree canopy on the distant shoreline opposite means that there are no distinct features available for reference.

The Review Team made recommendations for the installation of solar powered navigation aids at the seaward entrance into the American Channel. It is the view of the Pre-design Team that land based lead beacons are more appropriate for marking channels on the outer islands. A discussion of the relative merits and disadvantages of channel beacons and lead beacons is presented in Section 4.3.

Consequently it is recommended that solar powered lead beacons and large lead marks be placed on Temotufoliki island to assist in the safe navigation of the American

Channel. Yachts reputedly also visit the lagoon and this would also assist in the safe passage of these vessels.

The issue of markers for the route taken by island boats as they navigate through the ponding lagoons between the main village of Nanumea and Lakena was raised by the island Kaupule in discussions with the Pre-design Team. The provision of such navigation aids was recommended by the Review Team. Whilst there is a genuine and understandable need for such navigation aids, there is no direct benefit to the ship to shore transport of cargo or passengers. It is therefore difficult for the Pre-design Team to recommend funding of such works under the project.

Forklift

When the Review Team made the recommendation of a forklift at the Nanumea wharf it was to complement the use of a fixed crane. Since that time a crane truck has been delivered and is currently serving the purpose of a fixed crane working with a forklift. Consequently a forklift is not required.

Alternative Channel

The site of an alternative channel on the eastern side of the atoll was inspected by some members of the Pre-design Team near spring low tide. The fringing reef platform is some 470m wide at this location. The proposed channel site was identified by a local resident who had accompanied earlier inspections by members of the Review Team. The reef edge was reputedly blasted when the reef blasting team was undertaking work elsewhere on Nanumea, however it was apparently abandoned after only a short campaign. There was no evidence of any blasting, certainly there is no evidence of any effective channel construction.

The Review Team recommended that a 20m long, 8m wide channel be created at the site. The reef edge is somewhat lower that the reef platform behind it. The transition slope is some 80m-100m wide. Therefore in order to offer an significant benefit as a sheltered passage during low tides, the channel would need to extend at least to the higher reef platform area. This would entail the construction of a channel some 100m long, not 20m. The width would be 8m and the depth such that there was no more than 1m at Mean Low Water Springs.

5.2.3 Recommended Works

Following an engineering review of those works initially proposed by the Review Team for Nanumea, the recommended works are as follows:

Beacons

- Solar powered lead beacons and large lead marks be placed on Temotufoliki island to assist in the safe navigation of the American Channel.

Alternative Channel

- Excavate an alternative channel on the north-eastern tip of the Nanumea islet (near Matangi) at the location previously assessed by the Review Team.
- It is recommended that this channel should be no more than 100m in length, 8m wide with a minimum depth of 1.5m at Mean Low Water Springs.

Shipping Boxes

- Following a successful outcome of a trial of the system, implement the proposed cargo handling using shipping boxes.
- Provide lifting chains for the boxes that also enable fuel drums to be lifted by the islands crane truck.

5.3 Nanumaga

5.3.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report prior to our visit. The works recommended by the Review Team for Nanumaga were as follows:

1. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo.
2. *Beacons* - Install navigation beacons for the main American channel and also the route between Nanumea and Lakena.
3. *Modify Beach Ramp* - Modify the existing ramp to facilitate use by vehicles and create a larger gap to the channel.
4. *Main Channel* – Remove rocks in the channel and improve turning circle.

5. *Alternative Channel* - Construct a channel 8 m wide x 20 m long to facilitate shore access on the south-eastern side of the atoll.

5.3.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Nanumaga community and the Kaupule during the scheduled visit by the *Nivaga II* on 15th March 2006. The prevailing sea conditions at the time were regarded by the island community and the crew of the work boats as being quite calm in comparison to that which typically exists.

Tides were at the peak of springs. Consequently it was possible to view a wide range of water levels that prevail at the landing site. The tides on the day of inspection were:

Time	Level above MSL
0515 hrs	+0.76m
1115 hrs	-0.77m
1715 hrs	+0.85m
2315 hrs	-0.85m

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. That system relies on a crane truck to lift the boxes from the work boats. On Nanumaga there is presently a 3 Tonne capacity crane truck that very effectively assists with the unloading and loading cargo at the existing beach ramp. Consequently this cargo handling system could be first trialled at Nanumaga. Lifting chains for the boxes that also enable fuel drums to be lifted by the crane truck could also be provided.

Beacons

The Review Team made recommendations for the installation of solar powered navigation aids at the seaward entrance into the reef channel. It is the view of the Pre-design Team that land based lead beacons are more appropriate for marking channels on the outer islands. A discussion of the relative merits and disadvantages of channel beacons and lead beacons is presented in Section 4.3.

Consequently lead beacons are recommended to mark the sea approach into the Nanumaga reef channel.

Beach Ramp

The existing beach ramp at the landing site extends beyond the beach out onto the reef platform, ending only some 3.3m from the end of the channel. The beach itself consists of coral fragments (referred to locally as *coral gravel*) rather than sand. This, in conjunction with the prevailing wave climate, has resulted in a very steep beach at site with a high storm berm along the top of the beach slope. The existing ramp profile is therefore above that of the beach face. It was because of the difficulty in moving people and cargo up the steep beach that the ramp was presumably built.

The Pre-design Team inspected the site towards the end of the westerly season and observed the accretion of the coral beach sediments against the northern side of the beach ramp - indicating a north to south net longshore transport. Given the orientation of the island and the foreshore at the landing site, this accumulation is somewhat unexpected - as a first assessment based on westerly wave approaches and shoreline orientation would suggest a net movement from south towards north.

However various discussions with the island community confirmed that there is always a wider beach to the north of the ramp. Whilst not clear from the photos taken by the Review Team in mid-July 2003, this also appears to be the case during the easterly season.

The main problem associated with the concrete ramp that the Kaupule highlighted (and was confirmed by inspection and discussion with other community members) is that the end of the ramp is very slippery. The crane truck finds it difficult to work on the slippery surface and tends not to operate so as to have the rear drive wheels on the lower slippery slope. The slippery surface has also caused accidents, with people slipping whilst carrying cargo and children to and from the work boats. The community have cleaned the marine growth from it in the past, but this only offers a temporary reprieve from the problem. Requests were made to see if something more permanent could be done to alleviate this risk.

Nevertheless, of all the island-side operations inspected by the Pre-design Team, it was the crane truck / beach ramp combination at Nanumaga that worked most effectively. There was consequently considerable and very strong resistance expressed by the Kaupule when they became aware of the recommendation of the Review Team to modify the ramp by shortening it.

The adverse impacts of the beach ramp was explained to the Kaupule members, nevertheless their view was that whilst there may be some erosion occurring (and some members of the Kaupule expressed doubts as to that actually occurring), the erosion buffer on the southern side of the ramp was wide and adequate. The Kaupule felt very strongly that the adverse effects of the existing beach ramp did not warrant the operational problems that a shorter ramp would bring about.

In relation to the beach ramp, the Pre-design Team are of the following opinions:

- Due to the relative dynamic stability of the beach and the location of the ramp, the loss of coral beach sediments at this site appears to be small. Kaly (1998) stated that this is likely to be due in part to a transverse rock ledge at the seaward entrance to the reef channel inhibiting the currents that sweep out of the channel. Contrary to the recommendations of that environmental assessment, some blasting of this ledge was nonetheless undertaken by the Reef Blasting Team.

  The extent of that modification to the transverse ledge could not be determined by the Pre-design Team due to adverse tide and wave conditions at the reef edge at the time of our visit, however there was a strong offshore current flowing in the channel. The loss of coral beach sediment is nevertheless still likely to be small.
- There is evidence of some beach material in the turning basin, although the quantities are not large. This could however be due to the currents removing the material soon after its deposition. The accumulation was observed to be primarily in the north-eastern corner of the basin, consistent with deposition by a north to south transport of beach sediments encountering the beach ramp obstruction.
- Should a subsequent inspection of the area of the submerged transverse ledge at the channel entrance indicate that the extent of blasting has in fact substantially removed the ledge, then it could be artificially reinstated by the controlled placement of “rock bags” (refer discussions in Section 4.1.5).
- The proposed shortening and steepening of the existing beach ramp will require either an enviro-ramp or mobi-mat to be placed at the end of the ramp to enable a

crane truck to access the reef flat. Neither option is feasible due to the steep beach slope and the inability of a vehicle to negotiate the steep beach slope.

- There appears to be some merit in retaining the existing beach ramp at Nanumaga. Particularly as how the adverse effects on the southern downdrift foreshore appear minimal and acceptable to the island community. However a means of capturing beach sediment washed into the end of the channel; and its subsequent placement on the downdrift side of the ramp would be beneficial. The Pre-design Team suggest that this could be achieved through the excavation of a "sand trap" as a northern extension of the existing turning basin. The concept is illustrated and described below.
- If implemented, then the performance of the beach ramp and the sand trap should be monitored.
- There is currently a step off the end of the existing ramp of some 25cm down onto the reef platform. There is no benefit in modifying the end of the ramp to make it end level with the reef flat since no vehicle would be able to go onto the reef platform here as there is only a 3.3m width available between the end of the ramp and the turning basin.
- To facilitate traversing of the slippery lower surface of the ramp by people and vehicles, it is recommended that expanded aluminium sheeting each approximately 0.6m wide be bolted to the surface along the tyre lines of the crane trucks. Two such lines located approximately 0.5m from each ramp edge, along with a 1.2m wide strip down the centreline of the ramp would enable the truck to work on either side of the 5m wide ramp. Sand blasting of the concrete surface to create a rougher surface has not proven a satisfactory solution elsewhere.

The sand trap entails excavating an extension of the existing turning basin towards the north. This would be no closer to the beach than the present basin, and be some 15m alongshore and 12m cross shore in size. The trap would best be excavated to a depth greater than the adjoining basin, some 2m to 2.5m below Mean Low Water Springs is suggested. The material removed during this initial excavation should be placed in the upper beach profile on the southern side of the ramp so as to provide for an increased erosion buffer on this downdrift foreshore.

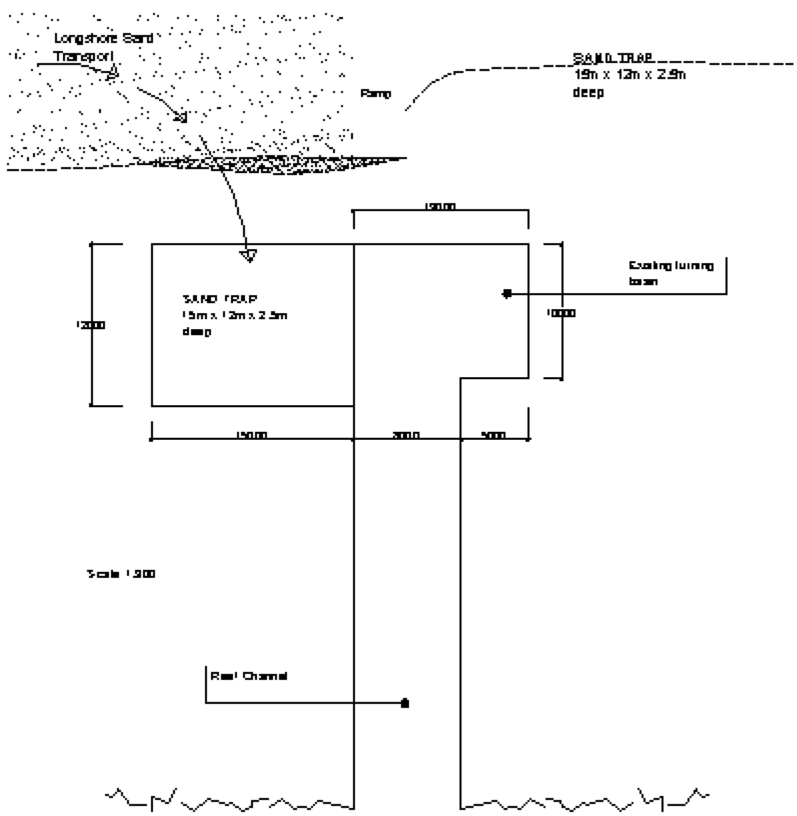

Figure 5-1 : Concept of Sand Trap at Nanumaga Ramp

Should the subsequent interaction of the existing ramp and the prevailing longshore transport of coral beach material wash into this basin extension, it will not be so readily washed offshore through the reef channel. At an appropriate time, the trap could be "emptied" by deploying mobile sand/coral dredging equipment that would be procured for the implementation of reef channel works under the TSSTP project (refer discussions in Section 4.2.5). This same deployment would present the opportunity to also clear any accumulated sediments within the existing basin and reef channel if necessary.

The removed material would be placed on the downdrift side of the ramp within the active beach system. The operation and management of this sand trap (which entails the subsequent removal and relocation of littoral material) constitutes mechanical bypassing of the ramp. Such a process is frequently used on a much larger scale to manage coastal processes and maintain navigable entrances to harbours and rivers.

In summary, it is recommended that the existing beach ramp at Nanumaga be retained but that any potential adverse implications to local foreshores be managed through the provision and operation of a sand trap as an extension to the existing turning basin.

Main Channel

There are a number of isolated rocks within the reef channel and the turning basin which present a hazard to their safe navigation by work boats and island fishing boats. These should be removed. The landward edge of the turning basin also needs to be better defined and cut more steeply to provide a near-vertical face. This would enable the work boats to come alongside the adjacent reef platform more readily at low tides, without the risk of damage and thereby facilitate the safer transfer of passengers into the boats.

Alternative Channel

Two sites for a possible alternative channel were assessed on environmental issues by Kaly (1998). One was on the north eastern side of the island near Mulifenua, whereas the other was on the south eastern side at Teone Ngaonga. Of these, the south eastern site was determined to be the most appropriate. During discussions with the Kaupule (who were unaware of this earlier recommendation) requested that another side mid-way between the two previously assessed locations. The rationale being that when conditions are too rough to land at the main channel on the western side, the conditions are frequently too rough at one or other of the two nominated sites. A location mid-way between the two would therefore offer greater chance of a landing during rough westerly conditions. However following a site inspection, this third site was determined by the Pre-design Team as being inappropriate due to environmental concerns.

The south eastern site therefore offers the most appropriate alternative channel site for Nanumaga. A channel some 8m wide, 20m long and a depth of 1.0m at Mean Low Water Springs could be excavated by a hydraulic excavator working on the reef flat at low tides in conjunction with tractor-hauled rock trailers. Given the apparent dense, hard nature of the capping on the reef platform, some initial blasting is likely to be required to expose the less consolidated material beneath.

Once formed, the channel would serve as the alternative landing site during most rough westerly conditions. The beach at the rear of the reef platform consists of small coral boulders and is very steep. The island crane truck could not negotiate this beach face so as to access the work boats, either at low tide in the reef channel or on the beach during high tides. Consequently the work boats (including the contents of any shipping boxes) would need to be unloaded / loaded by hand, as is the present practice.

5.3.3 Recommended Works

Following an engineering review of those works initially proposed by the Review Team for Nanumaga, the recommended works are as follows:

Beach Ramp

- Leave the current ramp in place with no major modifications.
- To mitigate any adverse effects on the southern downdrift foreshore, and to prevent the permanent loss of foreshore sediments from the active beach system, excavate a 15m x 12m “sand trap” as a northward extension of the existing turning basin. This basin should be some 2m to 2.5m deep at Mean Low Water Springs.
- Any accumulated sediments in the sand trap should be removed periodically using the projects sand/coral dredging equipment and subsequently placed on the downdrift foreshore.
- Monitor the performance of the ramp and sand trap with respect to impacts on coastal processes.
- Install tracks of expanded aluminium sheeting on the lower intertidal section of the ramp to provide a non-slip trafficable surface.

Main Channel

- Remove isolated rocks from entrance channel and turning basin.

Beacons

- A solar powered lead beacons be provided to mark the navigable reef channel.

Alternative Channel

- Excavate the alternative channel on the south eastern side of Nanumaga at the site assessed by the Review Team .
- It is recommended that this channel be 20m in length, 8m wide, with a minimum depth of 1.5m at Mean Low Water Springs.

Shipping Boxes

- It is recommended that the shipping boxes be trialed at Nanumaga prior to it being implemented throughout the other outer islands.
- Provide lifting chains for the boxes that also enable fuel drums to be lifted by the islands crane truck.

5.4 Niutao

5.4.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report. The works recommended by the Review Team for Niutao were as follows:

1. *Concrete Ramp at Muli Channel* - Remove the concrete beach ramp and thereby remove the primary cause of foreshore erosion at the site.
2. *Muli Channel* - Remove rocks, widen, deepen the reef channel to improve the safety and utilisation of the channel.
3. *Beacons at Muli Channel* - To mark the sea approach to the reef channel thereby improving the safety of access at night.
4. *New beach access for the Muli Channel* – An enviro-ramp was recommended.
5. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo.
6. *Kulia Channel* - Remove rocks, widen and deepen the channel; and improve the turning basin.
7. *Beacons at Kulia Channel* - To mark the sea approach to the reef channel thereby improving the safety of access at night.

5.4.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Niutao community and the Kaupule during the scheduled visit by the *Nivaga II* on

17th March 2006. As was the case for the visits to the other islands in the northern group on this voyage, the prevailing sea conditions at the time were regarded by the island community and the crew of the work boats as being quite calm in comparison to that which typically exists.

Tides were one day after the peak of springs. It was therefore possible to view a wide range of water levels that prevail at the Niutao landing sites. The tides on the day of inspection were:

Time	Level above MSL
0545 hrs	+0.82m
1145 hrs	-0.79m
1800 hrs	+0.76m
2400 hrs	-0.78m

Niutao is characterised by consistently rough seas. The transfer of cargo and passengers between the inter-island vessels and the shore is always difficult. Several work boat drivers nominated this island as being the hardest of all outer islands on which to land. There are two well established but incomplete reef channels, one to the north of the main village (the Muli Channel) and the other to the west of the village (the Kulia Channel). Since the visit by the Review Team in mid-July 2003 there have been two changes of particular relevance, namely:

- the demolition and removal of the concrete beach ramp at the Muli Channel; and
- the construction of a new concrete beach ramp at the Kulia Channel.

These works are discussed below.

Concrete Ramp at Muli Channel

The concrete beach ramp at this site was contributing to the significant erosion of the local foreshore. Consequently the reef blasting team was to remove approximately 19m from the seaward end of the ramp as a matter of urgency during their visit to undertake channel improvement works in 1999. Only a short length was actually removed at that time and erosion continued.

Consequently the island community undertook the removal of the concrete beach ramp themselves. The work was commenced in late 2005 and completed in January 2006. It was achieved by lighting fires beneath the ramp, which initiated cracking in the thick concrete slab. These cracks were then used to break apart the slab with wedges, heavy sledgehammers and bars. A short length still remains on the landward end of the ramp behind the line of terrestrial vegetation which is used as a hardstand area during the unloading and loading of the work boats.

The work has effectively removed the ramp from the active beach system and will enable coastal processes to begin re-establishing the upper beach and the foreshore, although recovery is likely to be slow.

An adverse effect of the works is that the foreshore in the immediate vicinity of the old ramp is now strewn with steel reinforcing bars recovered during the demolition. Most of the concrete rubble has been removed away from the area, but the twisted and corroding steel reinforcement has been placed into a number of piles. This has placed a constraint on the use of this much utilised foreshore. Coastal vegetation is now starting to cover the piles from view and they therefore represent a significant risk to people using the foreshore precinct at Muli. It is recommended that the steel reinforcement be removed from the foreshore by TSSTP equipment and disposed of appropriately.

Improvements to the Muli Channel

The recommendations of the Review Team with regard to the channel improvement works are endorsed by the Pre-design Team. The seaward entrance to the existing reef channel should be widened to around 18m, with the remainder of the length widened to 12m. The entire channel should be excavated to a minimum depth of 1.5m at Mean Low Water Springs.

A turning basin should be constructed at the landward end of the channel (but no closer to the beach) with a longshore length of 18m and a width of 12m. The basin should not be excavated any deeper than 1.0m below Mean Low Water Springs to enable the crew of the work boats to stand at the bow and hold the boats into the approaching waves.

There are also a number of isolated rocks between the toe of the beach and the end of the channel that present a hazard to work boats and island fishing boats approaching the beach at high tide. These need to be removed.

Beacons at the entrance to Muli Channel

The Review Team made recommendations for the installation of solar powered navigation aids at the seaward entrance into the reef channel. It is the view of the Pre-design Team that land based lead beacons are more appropriate for marking channels on the outer islands. A discussion of the relative merits and disadvantages of channel beacons and lead beacons is presented in Section 4.3.

Consequently lead beacons are recommended to mark the sea approach into the Muli reef channel.

New Beach Access at the Muli Channel

The community on Niutao have removed the concrete ramp in response to previous advice that it was inappropriate at this site and now require a replacement that will enable access to work boats by the crane truck and the island's tractor and trailer.
The Review Team recommended that the existing concrete beach ramp at Niutao be replaced by an Enviro-ramp. Earlier in this report there is a discussion about the Mobi-mat proprietary system as another alternative to concrete beach ramps in Tuvalu . The Pre-design Team is of the opinion that the Mobi-mat system is more appropriate at Niutao and indeed the system should also be trialed at Niutao.

Based on the observations and measurements of the beach profile by the Pre-design Team, it is estimated that the longest length of Mobi-mat required to provide a trafficable access across the beach would be some 30m. This entails the provision of two standard 20m long Mobi-mats. For the trial period of the mobi-mats, only one mat is envisaged, meaning that the trial would only be undertaken on high tides at Niutao.

Improvements to the Kulia Channel

The recommendations of the Review Team with regard to the channel improvement works are endorsed by the Pre-design Team. The existing reef channel should be widened to around 9m and excavated to a minimum depth of 1.5m at Mean Low Water Springs. This would also entail removing a number of isolated rocks from within the channel.

A turning basin should be constructed at the landward end of the channel (but no closer to the beach) with a longshore length of 15m and a width of 10m. The basin should not be excavated any deeper than 1.0m below Mean Low Water Springs to enable the crew of the work boats to stand at the bow and hold the boats into the approaching waves.

Beacons at the entrance to Kulia Channel

It is recommended that lead beacons to mark the sea approach into the Kulia reef channel be installed. There are already two long PVC pipes concreted vertically into the upper beach area providing this role. However from discussions with some of the island fishermen it appears that these are too close together and could be better positioned. There would also be benefit in having reflective marks placed on new relocated poles to enable them to be seen at night. Permanent fixtures on the poles to accommodate kerosene pressure lanterns should also be provided. Given the low utilisation of this channel by work boats, providing lit beacons is not warranted.

New Ramp at Kulia Channel

The Review Team recommended that an enviro-ramp be deployed to service the Kulia Channel. However since that time a concrete beach ramp has been constructed. It is unfortunate that the Review Team's final report and recommendations were not conveyed to the island community. Particularly as the end of the newly constructed ramp is only some 13m from the end of the reef channel - much less than the 30m strongly advocated by the Review Team and by Kaly (1999) for such structures.

There is little doubt that the ramp will adversely affect beach processes due to its proximity and location opposite the Kulia Channel. The ramp's cross shore profile is not a constant slope, but appears to have been formed to follow the beach profile at the time of its construction. The beach profile has changed in response to the ever-changing conditions that prevail on such foreshores, and sand now covers a long portion of the ramp. Consequently it cannot now be used by the island crane truck to gain access to work boats.

It is recommended that the new concrete beach ramp be removed from the active beach - this would entail demolishing approximately 20m from its seaward end which would also then comply with the requirement for a minimum of 30m to the end of the channel.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. The early implementation of such a system to the ship to shore operations at Niutao would be of significant benefit since, of all of the outer islands Niutao has the greatest amount of cargo lost or spoiled.

The shipping box system relies on a crane truck to lift the boxes from the work boats. On Niutao there is presently a 3 Tonne capacity crane truck that could be used to assist with the unloading and loading of cargo. However to do so requires that it have access to the work boat across the sandy beach. Given that the Mobi-mat system is recommended for trial at Niutao, this also offers the opportunity to trial the shipping box system at this island as well. Lifting chains for the boxes that also enable fuel drums to be lifted by the crane truck should also be provided.

5.4.3 Recommended Works

Following an engineering review of those works initially proposed by the Review Team for Niutao, the recommended works for Niutao are as follows:

Muli Channel

- Widen the entrance to the channel to 18m and the remainder of its length to 12m. The channel should be excavated to a minimum depth of 1.5m below Mean Low Water Springs.
- A turning basin to be excavated to a depth no greater than 1.0m below Mean Low Water Springs. The basin should have a minimum longshore dimension of 18m and a cross-shore width of 12m. It shall be located as a longshore extension on either side of the end of the main channel to form a T-shaped plan profile. The landward edge must be no closer to the beach than the present channel.
- Remove isolated rocks from the reef flat between the toe of the beach and the turning basin.

- All of the channel and turning basin excavation would need to be undertaken by mechanical means and the removed unconsolidated material taken out of the channel so that it is not transported back by waves and currents.
- Remove debris of previously demolished ramp from foreshore precinct.

Beacons for Muli Channel

- The existing electrical light and tower currently used to illuminate the beach ramp at night be relocated slightly so as to also function as the front lead beacon for defining the sea approach to Muli Channel.
- A solar powered rear lead beacon be provided on a timber pole erected further inland.

Beach Ramp at Muli

- Provide a 20m standard length of Mobi-mat to enable the island's crane truck to traffic across the beach and gain access to the work boats and the reef flat during low tides.
- The Mobi-mat beach access system should have its initial trial at the Muli Channel, with a view to implementing it at other outer island locations.

Kulia Channel

- Widen the channel to uniform width of 9m and remove isolated rocks. The channel should be excavated to a minimum depth of 1.5m below Mean Low Water Springs.
- A turning basin to be excavated to a depth no greater than 1.0m below Mean Low Water Springs. The basin should have a minimum longshore dimension of 15m and a cross-shore width of 10m. It shall be located as a longshore extension of the end of the main channel and no closer to the beach than the present channel.

New Ramp at Kulia Channel

- Remove the new ramp for a distance of 20m where it transits through the active beach profile, then following a successful outcome to the Mobi-mat system at the Muli Channel, adopt the same system at Kulia Channel by relocating the 20m long mat as required.

Beacons at the entrance to Kulia Channel

- Remove the existing PVC pipes acting as lead beacons and replace them by more robust and appropriately positioned lead poles.

- Place reflective marks on the new lead poles so that they can be seen at night.

Shipping Boxes

- Following a successful outcome of a trial of the system, implement the proposed cargo handling using shipping boxes.
- Provide lifting chains for the boxes that also enable fuel drums to be lifted by the islands crane truck.

5.5 Nui

5.5.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report. The works recommended by the Review Team for Nui were as follows:

1. *Main Channel* - Deepen the channel and improve the turning basin. Shorten the channel at the landward end.
2. *Ramp* - Modify the existing ramp by shortening and integrating it to the level of the reef platform.
3. *Beacons* - Provide beacons to mark the main channel.
4. *Boat Passage in the lagoon* - Mark a safe boat passage to the other side of the lagoon using reflective markers.
5. *Alternative Channel* - Construct a minimum channel 8 m wide x 20 m long to facilitate shore access on the eastern side of the atoll.
6. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo.

5.5.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Nui community and the Kaupule during the scheduled visit by the *Manu Folau* on 23rd March 2006. Wave conditions on the fringing reef were quite mild at the time.

The tides on the day of inspection were:

Time	Level above MSL
0445 hrs	-0.20m
1145 hrs	+0.41m
1845 hrs	-0.40m

Main Channel

The main reef channel at Nui was first constructed in 1978, but has now filled in to such an extent that it is too shallow to use at low tides - particularly during springs. Discussions with some of the Nui community who recall its initial construction reveals the material was simply placed in spoil bunds on either side of the channel some 15m away from the channel and parallel to it. Whilst there is still some evidence of these bunds, they are really just rubble mounds now - consisting entirely of large rocks. All of the finer material has since been swept away or washed back into the excavated channel. Indeed it would seem that this has been the primary source of the material that has since filled much of the channel.

As discussed in Section 4.1, it is a basic requirement of reef channel construction to remove the excavated material from the vicinity of the works to ensure that the channel remains clear. The current problem of inadequate depths in the channel can be significantly attributed to this not having been undertaken when the channel was first constructed. During high tides and periods of significant wave activity, strong currents reputedly occur that sweep across the alignment of the channel from south to north. These currents would provide the sediment transport mechanism by which fine material placed in the southern spoil bund could be readily washed back into the channel. Likewise, during ebb tides the reef top currents sweep into the channel from both sides of the channel alignment and would have been another mechanism of transporting fine material from the spoil bunds into the channel.

The Pre-design Team is of the opinion that if the existing channel was properly cleared of sediments and all of this material placed onshore, then the channel depth could be maintained without any significant future maintenance commitment.

The channel is not straight, it has a slight bend of a few degrees occurring about half-way along its length (to starboard/right when navigating shoreward). At about this location the channel becomes slightly wider. However with the siltation that has occurred, the actual width of useable channel is not much greater than the offshore section.

It is recommended that the channel be widened at the bend and seaward of it. This would also serve to straighten it's alignment. It should also be cleared of built up sediments and further excavated where necessary to provide a minimum depth of 1.5m at Mean Low Water Springs along its entire length and width. Soundings undertaken on the day of the inspection indicates that some 1.3m to 1.5m depth of material needs to be removed from within most of the channel. This could be achieved by a hydraulic excavator working on the reef at low tide in conjunction with tractor-hauled rock trailers to then remove the excavated material to shore.

Given that it is unconsolidated sediments washed into the channel from the initial spoil bunds which now need to be removed from the channel to deepen it, it is possible that the clearance work could be successfully completed by the sand dredging equipment proposed for the project (refer Section 4.2). This would be quicker than having to rely on an excavator working to load tractor-hauled rock trailers.

Should this be the case, then the sand material could be pumped ashore to nourish the foreshores immediately north of the beach landing area. Because the channel is very long, it is likely that the pumping distance would be too far for the sand dredging equipment to transport the material removed from the seaward end to be delivered to shore. Clearance of this outer length of the channel may require the pump to deliver the sand slurry into the rock trailers for subsequent haulage to shore once it has drained, or alternatively to utilise the excavator and rock trailers.

The Pre-design Team was unable to undertake a snorkel survey of the outer reef edge however, from spot soundings and general observation through the water column, it appears that seaward of the reef crest the reef platform slopes away initially at quite a shallow slope for some 20m - 50m near the spur-and-groove zone, at which point it drops into deeper water. Consequently the width over which incoming waves shoal and break is quite wide.

This represents quite a risk to the work boats as they make their sea approach to the channel, particularly during low tides. There are a number of large rocks and shoals within this area immediately offshore of the channel entrance. However it appears as though it would be necessary to not just remove these isolated features to create a safe and deep navigable approach into the channel, but to cut through the submerged sloping reef platform.

Because there is no low tide access available for an excavator, this could really only be achieved by blasting so as to create a submerged channel some 1m to 1.5m deeper than the surrounding reef over a minimum width of some 12m and a length of 20m to 50m. This could be quite difficult to achieve given the volume to be removed, in which case little can apparently be done to alleviate the problems of the sea approach to the main Nui reef channel.

However it is possible that this could be overstating the problem since the nature and extent of the seabed approaches to the reef channel could not be properly inspected and assessed by the Pre-design Team. When preparing the scope of works required for Nui it would be prudent to allow for some blasting of the entrance area to improve the approaches into the reef channel.

Because the landward end of the channel is too close to the toe of the beach slope, the Review Team has recommended that the channel be shortened. This could be readily achieved through the placement of “rock bags” (refer discussions in Section 4.1.5) across the channel at the required location up to the seabed level of the adjacent fringing reef. The section of the channel landward (between the rock bag bund and the beach) could then be filled with material from the channel clearance work.

The shortening of the channel would need to be undertaken at the same time as the channel clearance work in order to provide the material necessary to fill the end of the channel.

It is further recommended that a turning basin be excavated at the shoreward end of the shortened channel. The basin should be excavated to a depth no greater than 1.0m below Mean Low Water Springs and have a minimum longshore dimension of 18m and a cross-shore width of 12m. It should be located as a longshore extension on either side of the main channel to form a T-shaped plan profile. The landward edge must be no closer than 30m to the toe of the beach slope.

Ramp

The existing beach ramp has acted as a groyne by intercepting the longshore transport of sand and coral fragments on the foreshore. There is a greater accumulation of this material on the southern side of the ramp, and the line of terrestrial vegetation at the rear of the beach is located further offshore on its southern side. This indicates that there is a net south-to-north littoral movement of sand at this location.

The ramp has become “full” in terms of its trapping potential, and there is evidence that littoral sand is moving across its lower sections and around the toe onto the downdrift foreshores. The position and plan orientation of the up-drift foreshore is now such that most of the northward moving sediment transport is transported passed the ramp, with little impact on the down-drift foreshore.

Some of the material moving alongshore beyond the toe of the ramp is finding its way into the nearby channel end. However on the day of the inspection by the Pre-design Team, there did not appear to be a significant accumulation in the channel at this location. This could very likely be because the ebb tide currents and wave action has carried it seaward in the channel. There is little doubt that during strong wave activity when cross-shore sediment transport processes are actively re-profiling the beach, there is a definite mechanism for transporting beach sand into the nearby end of the channel.

It is the Pre-design Team’s view that provided the end of the channel is moved a minimum distance of 30m from the bottom of the existing beach slope (which is just seaward of the toe of the ramp), then the concrete ramp may not require removal. Nevertheless, the performance of this ramp / beach interface should be monitored.

The ramp currently enables the crane truck to unload the work boats at low tide. However during strong wave activity, the surging and ranging of the boats on the ramp frequently prevents the effective use of the crane truck for unloading operations. This would also occur on an enviro-ramp or mobi-mat.

Beacons

The Review Team made recommendations for the installation of solar powered navigation aids at the seaward entrance into the reef channel. It is the view of the Pre-design Team that land based lead beacons are more appropriate for marking channels on the outer islands. A discussion of the relative merits and disadvantages of channel beacons and lead beacons is presented in Section 4.3.

Consequently lead beacons are recommended to mark the sea approach into the Nui reef channel.

Boat Passage in the Lagoon

The Review Team recommended that a safe boat passage for fishing boats across the central lagoon be marked by reflective beacons. Kaly (1998) mapped a route using a hand held GPS and also noted that this would entail the blasting of some five coral heads (*lakai*). Whilst acknowledging the need for such a marked access for fishermen, the Pre-design Team regard this request by the Kaupule as beyond the scope of the TSSTP.

Alternative Channel

The Review Team recommended that an alternative channel be constructed on the eastern side of the atoll where inter-island vessels had landed work boats previously. The recommendation was for it to be a minimum width of 8m although the length is somewhat unclear. Kaly (1998) recommended that the site of this eastern channel be near Tutupe at a low depression between two rocky spur ridges that run across much of the width of the intertidal platform just south of the natural passage between the islets of Motupuakaka and Fenua Tapu. That assessment also stated that the channel should not end any closer than halfway between the beach and the outer reef edge. This would entail a maximum length of around 120m, much of which is a natural depression across the reef platform at roughly Mean Sea Level.

The Pre-design Team were shown another potential site for an alternative channel near Telaeleke which has not previously been assessed for environmental impacts. The site was reputedly used the last time that a landing needed to be made on the eastern side of Nui because of adverse westerly conditions. At that time it was assessed by the work boat operators and the captain of the inter-island vessel to be safer to use than any other site.

Whilst acknowledging that the decision as to the most appropriate location for an eastern landing must be made by the captain of the inter-island vessel, the Kaupule indicated a preference to the initially selected site near Tutupe. It is easier to gain access onto the reef platform at this location. It is the Pre-design Team's opinion that a more formal alternative access channel at this location would provide for a better and safer channel during westerly conditions.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. That system relies on a crane truck to lift the boxes from the work boats. There is presently a 3 Tonne capacity crane truck on Nui that is currently used to assist with the unloading and loading cargo. Consequently this cargo handling system could be trialed at Nui prior to being implemented on other outer islands. Lifting chains for the boxes that also enable fuel drums to be lifted by the crane truck could also be provided.

Other issues

During discussions between the Kaupule and the Pre-design Team, a request was made by the Kaupule for a piled jetty to be constructed on the foreshore at the end of the main channel. It's purpose being to facilitate access by the crane truck to unload the work boats. Preliminary estimates of such a structure suggest that it's initial construction cost would be some NZD 300,000 to NZD 400,000, and have a significant on-going maintenance commitment. The facility is unlikely to offer any significant improvement to the ability to offload under the typically high sea conditions that currently prevail at the ramp. Given the notional budget allocation for the TSSTP, the Pre-design Team is unable to recommend such a structure for Nui.

5.5.3 Recommended Works

Following an engineering review of those works initially proposed by the Review Team for Nui, the recommended works for Nui are as follows:

Main Channel

- Remove (by blasting) obstructions to the safe navigation of the seaward entrance into the reef channel so as to provide a minimum 12m wide deep approach into the channel.
- Fill the seaward end of the existing channel so that it is no closer than 30m to the toe of the beach slope. This relocated end of the channel should be formed by placing “rock bags” across its width up to the level of the surrounding seabed, then filling the landward end with the material removed from other channel improvement works.
- Straighten the existing channel and provide for a minimum constant width of 8m along its entire length.
- Deepen the existing channel to a minimum depth of 1.5m at Mean Low Water Springs by removing the unconsolidated sediments that have washed into the channel.
- Construct a turning basin so as to form a 18m x 12m x 1m deep basin as a T-shaped extension at the end of the shortened channel.
- All of the straightening, widening, deepening and turning basin excavation would need to be undertaken by mechanical means and the removed unconsolidated material taken out of the channel so that it is not transported back by waves and currents.

Beach Ramp

- Leave the existing ramp in place, but monitor its influence on beach processes - particularly with regard to the natural bypassing of longshore sediment movement and potential for its deposition in the end of the main channel.

Beacons for Main Channel

- Solar powered lead beacons be erected onshore to define the sea approach to the main channel, and the safe route through the straitened channel.

Alternative Channel

- Excavate an alternative channel on the eastern side of the atoll near Tutupe where previous environmental assessments have determined this to be the most appropriate.
- The channel should be at least 8m wide, have a minimum depth of 1.5m at Mean Low Water Springs and extend to some 120m of the beach.

Shipping Boxes

- It is recommended that the shipping boxes be trialed at Nui prior to it being implemented throughout the other outer islands.
- Provide lifting chains for the boxes that also enable fuel drums to be lifted by the islands crane truck.

5.6 Vaitupu

5.6.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report. The works recommended by the Review Team for Vaitupu were as follows:

1. *Fixed crane and forklift* - Install a crane in the harbour to facilitate the lifting of cargo from the work boats. A forklift to move cargo from harbour or onto a tractor and trailer.
2. *Beacons* - Install solar powered beacons to replace the beacons which are currently not working.
3. *Winch* – Provide a winch to better facilitate hauling of fishing boats up the harbour slipway.
4. *Alternative Channel* - Completion of the alternative channel at Motofuoa
5. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo

5.6.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Vaitupu community and the Kaupule during the scheduled visit by the *Manu Folau* on 21st March 2006.

Tides were at neaps and on the day of inspection were:

Time	Level above MSL
0145 hrs	-0.46m
0815 hrs	+0.52m
1445 hrs	-0.37m
2045 hrs	+0.22m

Unlike other atolls and islands with reef channels on their western side, Vaitupu has a man-made harbour constructed at its shoreward end. Whilst providing some protection once inside the harbour basin, the breakwaters do not provide any protection whatsoever for the sea approach to the entrance channel nor in the vicinity of the reef edge where boats enter the seaward end of the channel itself.

The harbour entrance (ie. the gap between the heads of each breakwater) is located back from the reef edge and is orientated such that waves from the west can penetrate directly into the harbour basin. Therefore despite the harbour, the reef channel at Vaitupu is prone to the same boat access and transit problems as at other islands.

The island maintains a relatively large population (some 1,570 recorded in the 2002 census) which is the second highest island population after Funafuti - so cargo volumes tend to be high. There are quite a few large development projects that are either currently being implemented or are planned for Vaitupu. This includes construction of new classrooms and buildings for the Primary School, a new Government Guesthouse, TEC's upgrading of the electricity supply network, and improvements to the telephone system by TTC. All of these projects will require the importation of heavy and bulky items. Also the Motofoua Secondary School on Vaitupu is the largest by far of only two secondary schools in Tuvalu. As a result, there is a large number of boarding students returning or leaving Vaitupu at each end of the school year, which coincides with the season of rough westerly conditions.

As a consequence of these various aspects, there is a heavy reliance on the safe and efficient transfer of a considerable number of people, as well as a large and wide variety of cargo - with the likelihood of the quantities of each increasing in the future.

Fixed Crane and Forklift

Unlike most of the other islands, Vaitupu does not have a 3-tonne crane truck. The original suggestion made during earlier discussions with the Review Team of a fixed crane supported by a forklift has since been amended by the Kaupule. The Kaupule advised that there is currently a proposal under consideration by Japan for the supply of a mobile crane to facilitate cargo unloading in Vaitupu. Given the nature and volume of cargo that is currently discharged (and which is likely in the near future), such equipment is warranted. This is particularly so since the offloading could be done very effectively from the quay face along the internal wall of the northern breakwater.

Discussions with the *Grant Aid Researcher* from the Japanese Embassy in Fiji indicates that Japan is well advanced in the appraisal of this request and are currently investigating appropriate equipment within the AUD100,000 budget allocation.

Beacons

When the harbour was re-constructed in 1997 following extensive damage during a cyclone in 1993, solar powered port and starboard beacons were erected on the ends of the breakwaters. At the time of the inspection of the harbour precinct by the Review Team in late July 2003 these were not working. They were still not working when the Pre-design Team inspected the site in late March 2006. It appears that there is some dispute and considerable debate between the Kaupule and CFC as to which of the two agencies is responsible for their repair.

The provision of replacement navigation aids cannot be supported until such time as this long running issue is resolved. The Pre-design Team has made recommendations for the supply of navigation beacons at other outer islands throughout Tuvalu. The dispute as to who is responsible for their maintenance and upkeep on Vaitupu (with the result that there none have been working for several years) highlights the requirement to have a clear unambiguous understanding within the GOT as to responsibilities for implementation and management of any navigation aid assets provided under the TSSTP.

Winch

The request for a winch to haul island fishing boats out of the water is beyond the scope of the TSSTP. Consequently the Pre-design Team does not recommend that it be funded under the project.

Alternative Channel

The Motofoua Secondary School on Vaitupu is located on the south eastern foreshore of Vaitupu. It is the main school providing secondary education for children in Tuvalu. The school year both ends and starts during the westerly season when the reef channel into the harbour on the western side of Vaitupu is often too rough to use. This, in conjunction with the need to provision the large island community, means that there is a very real need to have an alternative landing site during adverse westerly conditions.

There are already the beginnings of a channel on the edge of the fringing reef quite near to the school on the south-eastern foreshore. Kaly (1998) has undertaken an environmental assessment of the site with respect to the construction of a reef channel and has determined that it would be appropriate for a channel to be constructed at this location. The Review Team recommended that the channel be constructed at Motofoua. Neither document made specific recommendations as to the preferred length of this channel - however the implied guidelines are the general recommendations for the construction of all channels determined previously by Kaly (1998).

The fringing reef is approximately 200m wide at the Motofoua site, and there is a 20m wide sandy beach behind this reef. Given the numbers of passengers and the quantity of cargo that would need to be transferred through the reef channel, it is recommended that the channel be at least 8m wide, have a minimum depth of 1.5m at Mean Low Water Springs and extend to some 30m to 40m offshore of the toe of the beach slope (ie. an approximate length of 160m).

It is further recommended that a turning basin be excavated at the shoreward end of the new channel. The basin should be excavated to a depth no greater than 1.0m below Mean Low Water Springs and have a minimum longshore dimension of 18m and a cross-shore width of 12m. It should be located as a longshore extension on either side of the end of the main channel to form a T-shaped plan profile. The landward edge must be no closer than 30m to the toe of the beach slope.

The fringing reef is substantially dry, even near low water neaps. Consequently access for construction equipment does not present any particular challenges. The channel could be constructed in the conventional way of a hydraulic excavator working in conjunction with tractor-hauled rock trailers to remove the material from the channel works to an onshore or foreshore site.

It is recommended that lead beacons be provided to mark this alternate channel at Motofoua. However these need not be lighted beacons, but reflective marks mounted onshore on poles to define the channel and its entrance.

The foreshore opposite this channel excavation work is within the confines of the school campus, negotiations will be required with the school's management with respect to appropriate site access, machinery operations and any work camp.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. The shipping box system relies on a crane truck to lift the boxes from the work boats. There is presently no crane truck on Vaitupu, however as discussed previously there is currently a procurement request under advanced consideration by Japan for a mobile crane to be supplied to the island. This would enable the implementation of the shipping box system to Vaitupu. Lifting chains for the boxes that also enable fuel drums to be lifted could also be provided.

Other Issues

During discussions between the Pre-design Team and the Kaupule a number of other issues arose, primarily as a consequence of further requests by the Kaupule.

The Kaupule reported that some filling in of the turning basin at the bottom of the concrete ramp within the harbour is reputedly causing some difficulties in the landing of island boats. However on further enquiry of the work boat operators, this does not appear to be adversely affecting their ship to shore transfer of passengers and cargo. Nevertheless, given that this deposition is likely to be by unconsolidated sediments, then it is possible that they could be readily removed by small sand dredging equipment that is proposed for the Marine Construction Team (refer Section 4.2.5). Consequently this clearance of the turning basin could be undertaken as a precautionary measure whilst the Team was on Vaitupu. Material removed could be placed as beach nourishment on the northern side of the harbour.

Within the harbour basin there is a multi-tide passenger landing built into the northern breakwater arm. This facility is rarely used, reputedly because it has a concrete surface that is very slippery. If this could be remedied then it could provide a very useful facility for safely and conveniently transferring passengers between the shore and the work boats. It is therefore recommended that appropriately sized expanded aluminium sheets be fixed onto the trafficable surfaces to provide a non-slip surface on which passengers can be landed. The design needs to incorporate sheets with rounded edges and corners to make their use less difficult.

A request was also made to extend the breakwaters on either side of the harbour to provide for improved access across the reef edge. Our advice on this issue is that extending the breakwaters on their current alignment and out to the outer edge of the reef platform would not provide any improved shelter to the boat passage across the reef edge. To provide such protection would require extending the breakwaters out beyond the reef edge into the very deep water beyond. Such an undertaking requires extremely large quantities of materials (given the offshore water depth) and the commissioning of specialised construction equipment. The environmental implications of such works would be significant and the cost would be very considerable. The Pre-design Team cannot recommend such works under the TSSTP.

5.6.3 Recommended Works

Following an engineering review of those works initially proposed by the Review Team for Niutao, the recommended works for Vaitupu are as follows:

Main Channel & Harbour

- Remove unconsolidated material from the turning basin using small dredging equipment utilised by the project’s construction team.
- Fix expanded aluminium sheeting on the trafficable surfaces of the multi-tide passenger landing in the harbour to provide a non-slip surface for passenger transfers to and from the work boats.

Alternative Channel at Motofoua

- § Construct a new channel on the south eastern fringing reef at the location where some channel improvement works have already been initiated. That channel should be excavated to a minimum width of 8m, minimum depth of 1.5m at Mean Low Water Springs and extend shoreward to end no closer than 30m from the toe of the existing beach slope (a length of approximately 160m).
- § A turning basin be excavated to a depth no greater than 1.0m below Mean Low Water Springs and have a minimum longshore dimension of 18m and a cross-shore width of 12m. It should be located as a longshore extension on either side of the end of the main channel to form a T-shaped plan profile. The landward edge must be no closer than 30m to the toe of the beach slope.
- § This excavation would need to be undertaken by mechanical means and the removed unconsolidated material taken out of the fringing lagoon so that it is not transported back into the hole by waves and currents.
- § Provide reflective lead beacons onshore to define the entrance and channel route.

Shipping Boxes

- § Following a successful outcome of a trial of the system, implement the proposed cargo handling using shipping boxes. This would be conditional on a mobile crane being provided to Vaitupu under Japanese aid funding.
- § Then provide lifting chains for the boxes that also enable fuel drums to be lifted by the islands crane.

5.7 Nukufetau

5.7.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report. The works recommended by the Review Team for Nukufetau were as follows:

1. *Main Channel* - Widening and deepening of the channel; relocation of coral heads; creation of a small fishing boat tie up and the removal of a breakwater and existing ramp.
2. *Construct a jetty* - Construction of a T-shaped jetty extending from the beach crest out to the edge of the turning basin.

3. *Beacons* - Provide beacons at each end of the channel.
4. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo
5. *Fixed Crane* - Install a crane at the jetty to facilitate the use of dry boxes and to handle large items.

5.7.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Nukufetau community and the Kaupule during the scheduled visit by the *Manu Folau* on 21st and 22nd March 2006.

The deep wide passage on the western side of the atoll provides a natural channel through which the inter-island vessels can pass. This permits these vessels to anchor within the sheltered waters of the central lagoon to facilitate the transfer of cargo and passengers ashore. Consequently the transfers between the inter-island ships and the shore are almost always undertaken in very mild wave conditions - a situation unique to Nukufetau. This safe operating environment enables cargo and passengers to be transferred at night.

There is a wide intertidal back reef on the edge of the central lagoon where the main settlement on Savave island is located. This has necessitated the construction of a channel some 540m long to provide a route for work boats and fishing boats between the lagoon and the foreshore. Despite the mild wave environment, the navigation of the channel requires some care at the present time, due to it being of insufficient depth at low tides to allow fast and confident passage by these small boats.

The tides were at neaps, and on each day of the inspection were as follows:

	Time	Level above MSL
21st March	0145 hrs	-0.41m
	0815 hrs	+0.52
	1445 hrs	-0.37m
	2045 hrs	+0.22m
22nd March	0245 hrs	-0.30m
	0930 hrs	+0.40m
	1645 hrs	-0.30m
	2300 hrs	+0.14m

Main Channel

The channel was first constructed in 1982 and reputedly filled with sand soon thereafter. Some improvement works were effected by the Reef Blasting Team in 1998, however this was primarily related to minor widening, with no effective deepening of the channel completed. The Review Team concluded that the shoaling of channel depths was primarily due to material that was removed during channel excavation not being removed from the general vicinity of the channel.

It was instead simply placed in spoil bunds on either side of the channel some 10m away from the channel and parallel to it. Whilst there is still some evidence of these bunds, they are really just rubble mounds now - consisting entirely of large rocks. All of the finer material has since been swept away or washed back into the excavated channel.

The Pre-design Team is of the same opinion after having undertaken a snorkel survey of the channel and the adjoining reef flat. Interviews with those in the island community who assisted with the earlier channel works confirmed the initial construction methodology. As discussed in Section 4.1, to ensure that the channel remains clear it is a basic requirement of reef channel construction to remove the excavated material from the vicinity of the works.

The current problem of inadequate depths in the channel can be attributed to this not having been undertaken. During periods of strong wave activity on the atoll’s western reef edge, strong currents are reported to occur that sweep across the alignment of the channel from west to east. These currents provide the sediment transport mechanism by which fine material placed in the western spoil bund were readily washed back into the channel.

The Review Team also concluded that if the existing channel was properly cleared of sediments and all of this material placed onshore, then the channel depth could be maintained without any significant future maintenance commitment. The Pre-design Team is of the same opinion.

In addition to channel deepening, the Review Team recommended creating a uniform 9m width of channel along its entire length and the Pre-design Team concurs that providing a constant width along the entire channel poses less risk to boats navigating the passage. This widening could be readily achieved by an excavator working off the adjacent reef flat to load tractor-hauled rock trailers.

A similar construction methodology can be applied to the completion of the turning basin at the landward end of the channel. As was agreed between the Review Team and the Kaupule, that this basin should form a T-shaped plan profile at the channel end, with a 25m alongshore dimension, 13m cross shore width and a minimum depth of 1.5m at Mean Low Water Springs.

Given that it is unconsolidated sediments washed into the channel from the initial spoil bunds which now need to be removed from the channel to deepen it, it is possible that the clearance work could be successfully completed by the sand dredging equipment proposed for the project (refer Section 4.2.5). This would be quicker than having to rely on an excavator working to load tractor-hauled rock trailers.

Should this be the case, then the sand material could be pumped ashore to a stockpile behind the eroded seawall immediately north of the beach landing area. Because the channel is some 540 metres long, it is likely that the pumping distance would be too far for the sand dredging equipment to transport the material removed from the seaward end to be delivered to shore. Clearance of this outer length of the channel may require the pump to deliver the sand slurry into the rock trailers for subsequent haulage to shore once it has drained.

It is also recommended that the partially demolished concrete beach ramp and the landing platform (constructed between the end of the channel and the beach by the Reef Blasting Team) be removed completely.

Construction of a Jetty

During discussions with the Pre-design Team, the Kaupule was strongly advocating for the construction of a “jetty”. In fact what was being suggested was a Boat Landing located adjacent to the turning basin. The intent being to then link this solid offshore structure to the foreshore by a piled jetty that would enable the crane truck to drive out to the landing area to load and unload work boats. A multi-tide passenger landing is also envisaged. The Kaupule had developed the concept with input from the PWD, including preliminary sketches and cost estimates. PWD's preliminary cost estimates are for some NZD 90,000 to NZD 100,000.

The Pre-design Team had the opportunity to review these preliminary concepts, and whilst having some reservations about the practical aspects of the arrangements and how the facility might best operate, we have no major objection to such a facility at this location. This view is conditional on the general size, dimensions and proximity to shore that are shown on the concept designs are maintained in any future development of the concept.

Provided the solid boat landing is connected to shore by an open piled structure, then the Pre-design Team can see no particularly adverse impacts on local coastal processes. As noted in the Review Team' report, ordinarily such a structure immediately offshore of an active beach system would have an impact on beach processes (being effectively an offshore breakwater), the sheltered nature of this site on the shores of the central lagoon means that such impacts are minimal.

It is recommended however that the detailed engineering design of any jetty and boat landing be undertaken by suitably qualified structural engineer with particular expertise and experience in maritime works. The rigors imposed by the extremely adverse environment requires special attention to structural detailing and a focus on being able to subsequently undertake repairs / maintenance easily and cheaply.

As an alternative to the piled jetty and boat landing, a 20m long standard mobi-mat would provide access for the island's crane truck to cross the beach to assist in unloading the work boats.

Beacons

There are currently two poles erected on either side of the entrance to the channel to mark its location and assist in the seaward approach. Neither pole carries any reflectors or lights. The Kaupule advise that in 1999, a solar powered flashing red beacon was placed on top of a pole mounted on the landing platform that was constructed by the Reef Blasting Team. It was located on the centerline of the channel. This served as a general beacon to vessels out in the central lagoon, and as guidance when navigating the channel once the entrance had been located. Unfortunately the light was broken some time in 2002 and the Kaupule was unable to locate replacement parts.

The Kaupule requested that solar powered lights be provided along the length of the channel to better define it at night. The Pre-design Team is of the opinion that properly constructed reflective daymarks would serve the purpose of marking the channel. Approximately four sets of starboard / port marks would be required.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. That system relies on a crane truck to lift the boxes from the work boats. There is presently a 3 Tonne capacity crane truck on Nukufetau that could assist with the unloading and loading cargo. Consequently this cargo handling system could be implemented for Nukufetau. Lifting chains for the boxes that also enable fuel drums to be lifted by the crane truck could also be provided.

Fixed Crane

The Review Team's recommendation for a 3 tonne capacity fixed crane on the jetty was made prior to the delivery of a similarly rated crane truck to Nukufetau. Provided that the proposed jetty and boat landing was designed to accommodate the loads and the unloading / loading operations of the crane truck, then there would be no need for a fixed crane.

Other Issues

During discussions between the Pre-design Team and the Kaupule a number of other issues arose, primarily as a consequence of further requests by the Kaupule. The Nukufetau Kaupule advised that they had developed a view that siltation of the channel could be prevented by the placement of 1.5m high, 1.5m long pre-cast mass concrete units along the western flank of the channel. These would be laid so as to reduce currents that sweep across the channel and deposit sand into it. As stated above, the Pre-design Team and the Review Team are both of the opinion that once the channel is cleared of sediment and this material is removed to shore, then the channel depth could be maintained without any significant future maintenance commitment. There would be no need for the concrete units.

In discussions with the Ship's Captain on the *Manu Folau*, the existence of a shoal or large rock only some 1m below the surface near the route where inter-island vessels must sail on entering the central lagoon was highlighted. It is located at 8º 00.978' South; 178º 19.582' East. Whilst the feature is indicated on admiralty charts (BA766), the Captain requested that the Pre-design Team give consideration to either properly and permanently beaconing this navigation hazard, or preferably have it removed by explosives.

The extent and nature of this obstacle could not be discerned fully, nevertheless it is recommended that the shoal should at least be appropriately beaconed. This would require a properly designed and constructed pole or tower on which to mount a solar powered lantern with a minimum rating of 5 nautical miles. This is considered a more sustainable option for this outer island location than a moored buoy due to the ongoing maintenance that would be required for the mooring. The most appropriate structure could only be determined following an underwater inspection of the shoal.

5.7.3 Recommended Works

Following an engineering review of those works initially proposed by the Review Team for Nukufetau, the recommended works are as follows:

Main Channel

- Widen the existing channel so as to provide for a constant width of 9m along its entire length.
- Deepen the existing channel to a minimum depth of 1.5m at Mean Low Water Springs by removing the unconsolidated sediments that have washed into the channel.
- Complete the turning basin as previously agreed so as to form a 25m x 13m x 1.5m deep basin as a T-shaped extension at the end of the channel. This excavation is not to be undertaken so as to reduce the current distance between the toe of the beach slope and the existing basin area.

- All of the widening, deepening and turning basin excavation would need to be undertaken by mechanical means and the removed unconsolidated material taken out of the channel so that it is not transported back by waves and currents.
- Complete the demolition of the existing concrete beach ramp, and remove the landing platform currently at the landward end of the channel.

Beacons

- Erect four sets of reflective daymarks (starboard / port) on poles either side of the entrance channel so as to define it at night.
- Design and construct a beacon to adequately mark the existence and position of a shoal near the passage into the main central lagoon.

Construction of a Jetty

- The preliminary design and costings for a Boat Landing has already been prepared by the PWD. However the structure itself and the piled jetty that links it to the foreshore has yet to be designed in detail.
- Subject to the piled structure being designed by a suitably qualified and experienced engineer, then the Boat Landing and jetty can be constructed at this location since they are not expected to have any significant adverse impacts on local beach processes.

Shipping Boxes

- Following a successful outcome of a trial of the system, implement the proposed cargo handling using shipping boxes.

5.8 Nukulaelae

5.8.1 Recommendations of Review Team

The Kaupule had not received a copy of the Review Team's previous report prior to our arrival. The works recommended by the Review Team for Nukulaelae were as follows:

1. *Improvements to the "New" Channel* - Widening at the mouth and extending its length 80m shoreward, but reducing in depth and width towards its landward end.

2. *Beacons* – provision of two solar powered beacons and three reflector beacons to improve the safe use of the channel during the night.
3. *Alternative Channel* – Create a 20 m long x 8 m wide x 1.5 m deep channel on eastern side of the atoll to provide a safer channel during the westerly season.
4. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo.
5. *Ramp or jetty* – provide enviro-ramp or jetty to facilitate the use of the crane truck for offloading of cargo from work boats.
6. *Search light* - Install a rotating, elevated searchlight on the western side of the island so as to provide fishermen with a reference point for the island in bad weather.

5.8.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection and meetings with various members of the Nukulaelae community and the Kaupule during the scheduled visit by the *Manu Folau* on 11th March 2006. As was the case for the visit to Niulakita on the preceding day, the prevailing sea conditions at the time were regarded by the island community and the crew of the *Manu Folau* work boats as being milder than average. Tides were increasing from neaps, with the lowest neap range being some three days earlier. Tidal predictions for Nukulaelae on this day were:

Time	Level above MSL
0330 hrs	+0.50m
0930 hrs	-0.48m
1530 hrs	+0.69m
2145 hrs	-0.74m

Improvements to the "New" Channel

In the process of further exploring the recommendations of the Review Team with respect to the development and completion of the "new" channel to the north of the existing channel, there was considerable debate between the various Kuapule members as to the merits of focusing on either the existing channel or the new channel. It was evident that none had seen a copy of the Review Team's earlier report. Agreement was reached that the works should focus on the improvements to the new channel - which was recommended by the Review Team.

This entails the widening of the seaward entrance into the channel and its extension for 80m shoreward on an alignment between the two *Acropora* storm banks reputedly formed during Tropical Cyclone Kina. The position and length of the new channel has been considered in detail by Kaly (1998); and the particular design characteristics required of the channel configuration re-emphasised by the Review Team. These important requirements have been incorporated into this engineering assessment of the proposed works.

Given the nature of the algal capping on the fringing reef along the proposed alignment of the channel extension, some blasting is likely to be necessary to break up the capping and to expose the underlying less consolidated reef matrix for removal.

The excavation for the channel extension would best be undertaken by mechanical means and the removed unconsolidated material taken away from the vicinity of the work so that it is not transported back by waves and currents to fill the newly excavated channel. The *Ecological Impact Assessment* (Kaly, 2000) strongly recommended that the removed material not be placed anywhere in the fringing lagoon, on the reef platform, nor dumped at sea, but should instead be placed above high tide or used for building construction on the island.

Excavation would be by a small hydraulic excavator working on the reef flat at low tide, using explosives as required to help break up the harder surface material. The excavator would load material directly into tractor-hauled rock trailers for subsequent removal to shore. However, this process of transporting material removed by the excavator away from the vicinity of the works presents a significant challenge unique to Nukulaelae.

Due to the exposed nature of these works, they will need to be undertaken primarily during low spring tides and relatively moderate wave conditions. Consequently there is only a narrow window of opportunity in which to utilise mechanical plant for creating the new channel. This is a constraint imposed at several of the outer island channel improvement works, however at Nukulaelae it is compounded by the additional problem of a very wide fringing lagoon which inhibits movement of mechanised plant between the elevated reef platform area and shore.

It is envisaged that the excavation equipment (namely the excavator, rock trailers and a tractor) would be delivered to the vicinity of the works on the elevated outer reef platform just prior to low tide by a self-powered barge. This could be at a location in the lee of the *Acropora* storm banks. When the barge grounded on the falling tide, the equipment would be off-loaded and commence working.

The excavator would load material into the rock barge which would then be hauled ashore by a tractor along the shallowest route through the deeper fringing lagoon. To minimise any environmental damage, only the one route would be utilised. It was not clear from the site inspection just what that route might be, nevertheless it appears that there is the opportunity to avoid deep sections of the lagoon, except for the naturally deep channel that is used by the work boats when navigating through the lagoon.

The alternative of using the barge to transport the tractor and rock trailers ashore might prove to be feasible. However, given that the work is to be undertaken at low tide, the required operating draft of the barge is likely to be too great for the available depth of water across the lagoon or within the existing work boat route.

When the tide began to rise, any equipment still working on the outer reef platform would have to be loaded back onto the barge for transport ashore once the barge re-floated.

It is important to appreciate that the ongoing operating integrity of all mechanical equipment engaged on the project is dependent on it not operating in saltwater - even quite shallow water - for any period of time. At Nukulaelae this will likely be an unrealistic expectation if material is to be brought ashore. It will certainly require an even more rigorous application of the corrosion prevention strategy routinely applied to all mechanical plant operated by the construction team.

The effect on any equipment that works in seawater is severe and should not be underrated. There are many examples throughout the Pacific region where marine construction projects have failed or have run well over budget due to inappropriate operation of mechanical plant. It is therefore recommended that the requirements of the earlier environmental assessments be reconsidered with respect to not having the excavated material placed on the platform reef at Nukulaelae. Compliance is expected to require hauling the material through the ponded fringing lagoon, with adverse implications to construction equipment.

An alternative strategy would be to haul the material across the elevated reef platform (offsetting the requirement to operate the tractor and rock trailers in deeper water of the fringing lagoon),and place it on the platform at a location well away from the new channel. This might be on the flanks of the existing *Acropora* storm banks. However guidance on environmental issues would be required so as to implement the most appropriate placement for any compromise strategy.

Whilst not specifically identified by the Review Team, there would be significant benefit in clearing isolated rocks from a defined route through the fringing lagoon. These would not be the large rocks that exist throughout the lagoon, but smaller rocks that present a hazard to the work boats as they negotiate the passage through the fringing lagoon at low phases of the tide. These rocks could be relocated nearby, but beyond the boundaries of the navigation route.

Larger rocks would need to be marked – preferably by reflective daymarks so that they could be readily identified by work boats at night, but these marks could also be used to better define an adjacent clear route through the fringing lagoon. The daymarks should be mounted on HDPE or timber poles firmly fixed to the seabed, with the ability to unbolt an upper length of the pole for removal so as to effect any repairs or maintenance to the daymark.

An extensive investigation of the best route and the extent of large rock hazards was not possible during the visit by the Pre-design Team. Nevertheless the passage by work boats through the lagoon on several occasions during the visit suggests that some 5 to 8 daymarks might be required to adequately mark a clear route.

Beacons

The Review Team made recommendations for the installation of solar powered navigation aids at the seaward entrance into the reef channel. It is the view of the Pre-design Team that land based lead beacons are more appropriate for marking channels on the outer islands. A discussion of the relative merits and disadvantages of channel beacons and lead beacons is presented in Section 4.3. Since both channels will be used by the work boats, it is recommended that lead beacons be installed at Nukulaelae to mark both the existing "old" channel and the new channel.

The front lead beacon opposite each channel would be located on top of a pole erected on the beach.

The vegetation along the shore line opposite these channels is quite substantial with a dense cover of mature trees resulting in a very high thick canopy extending to the shoreline, and in some locations actually overhanging the beach. A shore based rear lead beacon would need to be located within this quite substantial canopy. This would require clearing some of the trees in the general vicinity in order for the beacon to be seen from sea and the solar panels to be effective. Due to the limited time on the island, this issue of tree clearing could not be explored during the visit by the Pre-design Team.

Alternative Channel

The alternative channel (Channel 5 in Kaly, 2000) has previously been assessed. The channel should be created to the south of the area with live coral cover on the reef flat at the point where there is an existing natural channel in the outer reef (reputedly at 9º22.483'S; 179º50.842'E). The proposed channel site is located approximately 80m to the south of the southern tip of Tumiloto islet in an area without a fringing lagoon or direct drainage from the central lagoon during low tide.

Although access to the large central lagoon is possible during high tide, this channel would not be useable during low tide. The Review Team recommended that the channel should be no more than 8m wide and 20m long. However this seems to be inconsistent with the determination made by Kaly (1998) where an 80m long channel was determined to be acceptable. That earlier assessment indicated that a channel having its seaward entrance at a larger than average groove in the breaker zone could be constructed at the site providing that it did not pass the level of the reef crest. This particular location was suggested during the earlier assessment in 1998 because it would not result in drainage of the central lagoon and because there is a low diversity of organisms at the site.

The Pre-design Team inspected the site of this proposed channel about an hour before the neap tide high of +0.69m (to MSL datum) on 11 March 2006. The depth of water over the reef flat landward of the proposed channel location was some 1.0m to 1.2m deep for quite a considerable area. This indicates that the reef area virtually dries when tides approach Mean Low Water Springs. This was confirmed by the local boatman, who also advised that it is possible to walk across the reef platform between Olatanga on the southern tip of Tumiloto islet and Vaiafua Point on the northern tip of Niuoku islet.

He further advised that during such tides, the edge of the central lagoon was quite evident - being along an approximate south eastern alignment off the tip of Tumiloto islet. Soundings with a hand-held depth sounder confirmed that observation. This being the case, it appears that the raised platform reef between the central lagoon and the ocean is approximately 180m to 200m wide.

Consequently the Pre-design Team is of the view that the 80m long channel first mooted would not cut through the reef crest and would therefore not offer a drainage path from the central lagoon. It is therefore recommended that this channel should be no more than 80m in length, 8m wide with a minimum depth of 1.5m at Mean Low Water Springs.

This channel could be excavated quite readily by a small hydraulic excavator operating on the reef crest during low spring tides, loading the removed material into rock trailers which are hauled ashore by a tractor for disposal above high tide. The works would be undertaken on an islet of the Nukulaelae atoll that does not have any road or track access to the main Fangaua Island. It would therefore be necessary to establish a work camp with a very basic workshop facility near the site to support the project equipment, and keep it provisioned by boat from Fangaua Island.

The mechanical equipment could be delivered to the site by workboats entering the central lagoon from either the existing reef channel on Fangaua Island or the proposed channel location during high tides. The most appropriate would depend upon the conditions prevailing at the time. Removal of the equipment upon completion would have a similar choice.

The area in the vicinity of the proposed work camp at Olatanga has historical significance - with the nearby Elekana Memorial commemorating the arrival of Christianity in the Ellice Islands in 1861. Consequently appropriate operations in and around the work camp would need to be incorporated into the Environmental Management Plan established for the camp.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. That system relies on a crane truck to lift the boxes from the work boats. On Nukulaelae there is presently a 3 Tonne capacity crane truck on the island that could provide this offloading function. Consequently this cargo handling system could be implemented for Nukulaelae. Lifting chains for the boxes that also enable fuel drums to be lifted by the crane truck could also be provided.

Ramp or Jetty

Wave conditions are typically mild at the landing site, even when offshore sea conditions are rough. This is due to the protection afforded by the reef crest and the 450m wide fringing lagoon.

The existing ramp does not appear to be interfering with local beach processes - primarily due to it being substantially buried on a foreshore which does not experience significant longshore or cross-shore sediment transport. The ramp provides a convenient hardstand area at the rear of the beach landing site on which cargo can be temporarily stored during island-side operations. Consequently it is recommended that this beach ramp not be removed.

However the present ramp cannot provide any access for the island crane truck or other vehicles to the work boats, even at high tides. This is because most of the ramp is below the natural beach level. Earlier in this report there is a discussion about the Mobi-mat proprietary system as an alternative to concrete beach ramps in Tuvalu. The Pre-design Team is of the opinion that the Mobi-mat system would be appropriate at Nukulaelae and indeed the system should also be trialed at this location.

It is therefore recommended that access be provided by deployment of a standard 20m long mobi-mat across the beach during visits by the inter-island vessels, thereby providing a trafficable surface from the existing concrete beach ramp down to the work boats on the edge of the fringing lagoon.

Searchlight

There is currently an electrical light mounted on a tower which lights the landing area on Nukulaelae during night time operations. The lights could be distinguished at sea in the pre-dawn light or after dark from quite a considerable distance - in many cases well before the island itself could be discerned. Therefore they effectively act as “searchlights” for fishermen at sea.

Following discussions with the Nukulaelae community, it appears that the request for a search light relates to the need for fishermen working in the large central lagoon to identify the main village on Fangaua at night or in adverse weather conditions, rather than when returning from fishing in the open ocean.

The provision of a large search light (which is comparable to a lighthouse) to enable the main village on Fangaua to be identified from within the central lagoon represents a genuine and understandable need. Nevertheless there is doubt whether this could be justified under the present scope of the TSSTP.

5.8.3 Recommended Works

Following an engineering review of those works proposed initially proposed for by the Review Team for Nukulaelae, the recommended works are as follows:

Channel Improvements

- Widening at the mouth of the “new” channel and extending its length shoreward, reducing in depth and width towards its landward end. The design requirements for length, alignment, width and depth of the proposed channel extension works are provided in detail in the Review Team’s Final Report.
- It is recommended that the requirements of the earlier environmental assessments be reconsidered with respect to not having the excavated material placed on the platform reef. Compliance is expected to require hauling the material through the ponded fringing lagoon, with adverse implications to construction equipment.
- Relocate isolated rocks on the floor of the fringing lagoon along the alignment of the navigable route.

Beacons

- Provide solar powered lead beacons on shore to mark the existing and the new passages through the fringing reef.
- Provide reflective daymarks mounted on timber or HDPE posts to define the navigable route through the fringing lagoon and to mark larger rock hazards.

Alternative Channel

- Excavate an alternative channel on the eastern side of the atoll at the location previously assessed by the Review Team near the southern tip of Tumiloto islet in an area without a fringing lagoon or direct drainage from the central lagoon.
- It is recommended that this channel should be no more than 80m in length, 8m wide with a minimum depth of 1.5m at Mean Low Water Springs.

Shipping Boxes

- Following a successful outcome of a trial of the system, implement the proposed cargo handling using shipping boxes.

Beach Ramp

- Leave the existing concrete beach ramp in place to serve as a hardstand area at the rear of the beach landing area.
- Trial the mobi-mat beach access system to provide access for the crane truck to unload the work boats.

5.9 Niulakita

5.9.1 Recommendations of Review Team

The island community had not received a copy of the Review Team's report prior to our visit. The works previously recommended by the Review Team for Niulakita were as follows:

1. *Main Channel* - Remove rocks which are navigation hazards. Provide a turning circle. Reduce currents by building a bund wall at either side of the channel.

2. *Beach Ramp* - Modify existing ramp by shortening and interfacing it with a wooden roll-up ramp to the bottom of the beach. Requires a winch to roll up during bad weather.
3. *Alternative Channel* - Construct a minimum channel 8m wide x 20m long on the northern side of the island to facilitate shore access.
4. *Dry Boxes* - Use dry boxes to prevent damage to susceptible cargo.
5. *Tractor and Trailer* - Provide a tractor to allow cargo to be moved in difficult circumstances.

5.9.2 Engineering Assessment of Works & Proposed Methodology

The Pre-design Team undertook a site inspection of Niulakita during the scheduled visit by the *Manu Folau* on 10th March 2006. The prevailing sea conditions at the time were regarded by the island community and the crew of the *Manu Folau* work boats as being milder than average. Nevertheless there was still strong wave activity and surging within the reef channel and on the beach face immediately opposite. Tides were increasing from neaps, with the lowest of the neap range occurring some two days earlier. Tidal predictions for Niulakita on this day were:

Time	Level above MSL
0300 hrs	+0.41m
0845 hrs	-0.39m
1500 hrs	+0.60m
2130 hrs	-0.67m

Main Channel - Misimoa Channel

Niulakita's reputation as being one of the most difficult of all of Tuvalu's islands to access was clearly evident despite the comparatively mild wave conditions that prevailed during the site visit. It was noted that there are still some submerged rocks and ledges protruding from the sides of the entrance channel that should be removed to improve the safe navigation of the reef channel.

Clearly there is a need for the work boats to turn around quickly once they have negotiated the short reef channel so that they have their bow facing into the approaching waves. This turning maneuver can be achieved more readily under power during the higher stages of the tide when there is an adequate depth of water within the fringing lagoon. Nevertheless this is somewhat impeded by isolated rocks that lie on the bed of the lagoon between the toe of the beach and the landward end of the reef channel. The operators of the work boats need to avoid these rocks and consequently cannot turn freely or confidently except during the highest tides.

It is recommended that these rocks be removed and relocated to a position within the fringing lagoon where they will not represent a hazard to work boat maneuvers when approaching the beach face for unloading and loading.

These minor works will assist somewhat in improving the ability of the work boats to turn safely under power and face into the approaching waves during high stages of the tide. However at or near low tides, there is insufficient depth of water to attempt such a maneuver. There is undoubtedly a need for a deeper turning basin at the shoreward end of the reef channel, as recommended by the Review Team.

The overall basin should be some 15m x 12m (the longer dimension alongshore) and excavated to a depth of 1m below Mean Low Water Springs (MLWS). It is important that it be no deeper, as this could compromise the ability of the boat crew to stand at the bow and hold the boat into the waves during the unloading / loading operation.

New excavation to create the basin must be no closer to the toe of the beach than the end of the existing channel. This is a firm recommendation of the earlier Review Team and is strongly endorsed by the Pre-design Team.

This excavation would need to be undertaken by mechanical means and the removed unconsolidated material taken out of the fringing lagoon so that it is not transported back into the hole by waves and currents. The removed material could be used for beach nourishment purposes, or for the construction of low level bunds on each side of the landing area (refer later discussion).

This process of excavation and transport away from the area would best be undertaken by a small hydraulic excavator working in conjunction with tractor-hauled rock trailers. It is unlikely to require explosives.

The consistently high wave energy environment on the fringing reef appears to keep the lagoon behind it filled for much of the time. This presents difficulties in properly accessing and working the site of the proposed turning basin with mechanical plant. The site inspection was undertaken during neap tides and at times there was still up to 1m depth of water in the fringing lagoon during low tide.

It is unclear from a review of earlier reports pertaining to Niulakita's fringing lagoon whether or not the lagoon drains substantially during spring low tides and periods of relatively calm sea conditions. Nevertheless, it seems that access for a hydraulic excavator could be possible during some low spring tides. The proposed excavation of the turning basin and the channel improvement works will require careful planning and monitoring of tides and possible sea conditions prior to deployment of any construction equipment to Niulakita. These difficult works would best be undertaken following the enhancement of the day-to-day construction techniques that would evolve from the Construction Team having worked on other less challenging channel excavations on other islands.

Another recommendation of the Review Team was the construction of low-level bunds on either side of the boat landing area that would inhibit the flow of water from the fringing lagoon towards the reef channel. In fact this was one of five activities identified by the Team as requiring urgent attention.

This flow of water draining from the lagoon out through the reef channel can be quite substantial at times. These longshore currents flowing towards the channel deliver sand into the deeper reef channel, from where it cannot be returned to the beach system by natural processes. This represents an ongoing and permanent loss of sand from the local foreshore. The strong out-flowing current can also represent a hazard to the safe navigation of the channel by work boats.

It is recommended that the two bunds be constructed from rock bags (refer to discussions in Section 4.1.5). Hessian bags especially procured for the purpose could be used, alternatively empty 20 kg rice or flour bags could be utilised. Rice and flour are frequently supplied as cargo to Niulakita, nevertheless the numbers of empty bags could be supplemented through contributions from Nuitao – from which the community on Niulakita is derived.

Sand and broken coral fragments from the foreshore (or alternatively from the excavation of the turning basin) would be mixed with cement within a conventional concrete mixer in the appropriate proportions, but without the addition of water. Each bag would be filled with the dry mix to around ¾ of its full capacity, then sewn closed. The bags would then be individually placed and firmly tamped into layers of an interlocking paving pattern to create a wide low level bund extending from the beach across the fringing lagoon to the wide elevated algal ridge on the outer reef edge.

Once placed into the intertidal area, the gradual infiltration of seawater causes the dry mix in the bags to set hard like concrete. After a period of time, the outer bags deteriorate and wear away. Alternatively the bags could be cut and pulled away from the underlying hardened concrete.

It is estimated that the lowest layer of each bund might be approximately 5 or 6 bags wide, with some 4 or 5 progressively narrower overlying coarses raising the bund to a height of approximately 0.5 metres. Figure 2-1 illustrates the general concept of the construction. The precise locations for each of the two bunds needs to be finalised, however observations undertaken during the site visit suggests that the western bund would likely be 50m to 60m long and the eastern bund around 40m to 50m long. These works could be undertaken and completed quite readily by the Niulakita community itself - with appropriate supervision, particularly with regard to the size, extent and location of the bunds.

Figure 5-2 : Rock Bag Bunds for Reef Platform

If the bunds were to be created at the same time as the turning basin, then the material for their construction could be derived from the basin excavation. However, this excavation will require the deployment of plant and equipment which will take some time to put in place. Given the need to urgently implement measures to inhibit the draining of water from the surrounding fringing lagoon into the reef channel at Niulakita, this is unlikely to be an appropriate strategy.

The removal of sand and coral fragments from the foreshore area of Niulakita for building the bund does not represent sound coastal management practice. Mining the foreshores of atolls and islands for building materials is actively discouraged worldwide. However given Niulakita's particularly remote location, the difficulty in bringing materials across the fringing reef to the island, and the relatively small quantity required, there seems little point in bringing sand and aggregate from elsewhere in Tuvalu – particularly as how it would probably have to be mined from other island environments similar to Niulakita.

This, in conjunction with the fact that the primary purpose of the bunds is to arrest the ongoing permanent loss of sand from the fringing lagoon into the reef channel, leads to the conclusion that this local material represents the most viable source for constructing the bunds. The material removed from the fringing reef to form the turning basin in later construction activities could be placed back into the upper beach region to compensate for the permanent removal of sand and coral fragments to form the bunds.

It might also be possible to construct temporary bunds and an elevated working platform for the excavator to work from during excavation of the turning basin using this same method of low bund construction. Under such a scenario, the temporary construction bunds would be removed completely following completion of the turning basin.

Beach Ramp

It was evident that the beach at the ramp had accreted considerably since the visit by the Review Team in late July 2003 (refer Figure 5-3 for comparison, these photos were taken looking westward). This is likely reflecting the seasonal nature of the longshore sediment transport regime on the foreshores of Niulakita. At the time of the inspection by the Pre-design Team, the upper beach at the very western end of the island had eroded quite noticeably, suggesting that this area had been the source of the sand which has accumulated in the vicinity of the landing site. The build-up and depletion of the beach at the ramp is expected to be a seasonal cycle.

The Review Team observed the characteristics of the foreshores in late July, which is mid-way through the period of easterly conditions; whereas the Pre-design Team made the inspections in early March which is towards the end of the season when westerly conditions prevail.

Beach Ramp – 29 July 2003 *Beach Ramp – 10 March 2006*

Figure 5-3 : ***Erosion and Accretion Phases of the Niulakita Landing Site***

Discussions with the island community suggests that the recent accretion process has been progressive since about the time of the Review Team's visit in 2003. There was a general view that the beach ramp was not contributing to any erosion of the foreshore. However if this gradual accretion has occurred, it is likely to be in response to either stronger westerly seasons or milder easterly conditions than is typical (or both) over that timeframe. A return to a more depleted beach profile is expected in the future as the prevailing coastal process respond to the wider range of sea and weather conditions that prevail at Niulakita.

The removal of the existing beach ramp will enable the beach and foreshore at the landing site to better respond to these coastal processes without any adverse effects. However, given the need for the island community to have a hardstand area on which to store cargo for offloading and loading, it is recommended that a section at the landward end of the ramp be retained for this purpose. This should extend no further seaward than the approximate line of terrestrial vegetation at the top of the beach (refer Figure ??).

Figure 5-4 : ***Extent of Ramp Removal at Niulakita***

There is often a wide and steep sandy beach between the toe of the ramp and the fringing lagoon where the work boats load and unload (even when the beach profile is lower during easterly seasonal conditions).

The Review Team recommended that the existing concrete beach ramp at Niulakita be demolished and replaced by an enviro-ramp. The removal of the existing ramp will require the deployment of equipment and/or explosives specifically for that purpose.

The Pre-design Team believes that an enviro-ramp would not be viable at Niulakita because of the high wave energy environment of the beach face and the dynamic profile changes that consequently occur - not only on a seasonal basis, but also on timescales of days. The community on Niulakita have no mechanical means of rolling up and relaying an enviro-ramp; and the task would be extremely difficult to effect by manual means.

Earlier in this report there is a discussion about the Mobi-mat proprietary system as another alternative to concrete beach ramps. Based on the observations and measurements of the accreted beach profile by the Pre-design Team, it is estimated that the longest length of Mobi-mat required to provide a trafficable access across the beach would be some 35m to 40m. This entails the provision of two standard 20m long Mobi-mats.

Whilst such a system would be suited to the conditions of a dynamic sandy beach (only being in place for the duration of the inter-island ship's visit), the reality is that the time and effort required of the island community in laying out two of these mats is likely to be at least comparable to that required to simply carry the typically small amount of delivered cargo up the beach.

Consequently a mobi-mat system is not considered viable for Niulakita.

There really is no sheltered side to this small island since the open ocean swell (irrespective of the direction of propagation) sweeps around almost the entire perimeter of the outer reef edge. There are occasions when the conditions are too rough to land work boats via the main channel yet there is no safe access across the fringing reef anywhere on Niulakita. On such occasions, the visiting inter-island ship may wait for a short while to determine whether the situation will improve with a change in tidal conditions – but typically it departs without transferring any cargo or passengers. This reputedly occurs once or twice yearly.

The role of an alternative channel is therefore somewhat different for Niulakita than for other outer islands. An alternative channel at Niulakita is unlikely to result in a significant difference to the number of times that safe landings can be made, however it could offer a safer alternative to the Main Channel under some sea and weather conditions.

Previous investigations have focused on the utilisation of the Nanue Channel on the northwestern side of the island as an alternative access across the outer reef edge when conditions are too rough to use the Main (Misamosa) Channel. Nanue Channel is a natural feature and primarily consists of a short section of the reef crest that is lower than elsewhere. There really is no clearly defined “channel” as such – only a section of the fringing reef and nearshore area that is somewhat naturally deeper than the area surrounding it. Some blasting work was reputedly undertaken on this channel by the Reef Blasting Team before running out of explosives, however that work does not appear to have provided any useful purpose.

During the inspection of the site by the Pre-design Team, there were two swell trains arriving at Niulakita, the predominant one was from the west-south-west and the other from the north-west. Both of these combined to make for a very active, confused and hazardous sea state on the sea approaches to Nanue Channel - as well as within the channel itself. This made inspection of the channel on the day very difficult, indeed it was hard to even identify it because of the considerable wave activity.

However it was fortunate in many respects that these conditions were occurring during the site visit, as they were indicative of the sea conditions which would normally prevail during the westerly season - when the need for an alternative location is perhaps greatest.

Towards the end of the Pre-design Team's stay on Niulakita another alternative channel was nominated by the island's leaders. This is used by many of the fishermen throughout the year as an alternative to the Main Channel. The site is located several hundred metres south-east of the present channel. Like Nanue Channel, it too is a natural low point in the fringing reef. However unlike at the Main Channel, the raised crest along the seaward edge of the fringing reef in this general vicinity is not so pronounced – being lower and narrower. The fringing lagoon in this area is also wider and deeper than at the Main Channel; the beach face is not as steep (although this could be seasonal); and the foreshore is not as high.

Wave conditions at the reef edge were certainly milder than at the main channel site during the westerly swell conditions occurring at the time of the inspection. In fact the Marine Department representative on the Pre-design Team was of the view that under the prevailing conditions (indicative of the westerly season), the site offered better and safer access for work boats at high tide than the Main Channel.

The island fishermen report that unlike at the Main Channel site, the seabed drops away steeply from the seaward edge of the fringing reef. This means that the seaward approach to the channel entrance does not experience steeply shoaling or heavily breaking waves.

Certainly once the incoming waves encounter the sudden change in bathymetry as the seabed shoals rapidly up to the reef edge there is heavy breaking. But this reputedly occurs mainly on the reef edge to either side of the natural depression that forms the entrance to the natural channel. It appears from the anecdotal reports of the island's fishermen that local diffraction processes as waves propagate over the reef edge at this particular location are such that shoaling and breaking is not as pronounced as on nearby areas – including the Main Channel. This would not be the case for all sea conditions, but it was very evident on the day of inspection when westerly conditions predominated.

Due to the need to leave the island on the scheduled departure of the *Manu Folau*, it was not possible to inspect the alternate site during low tide. Consequently the potential implications to the fringing lagoon by modifying the natural channel through the reef edge to provide for an alternative access to shore could not be properly estimated. Nevertheless the Pre-design Team is of the view that this location warrants further investigation and environmental assessment as to its viability as an alternative channel at Niulakita during the westerly season.

Dry Cargo Boxes

A system of shipping boxes is discussed in Section 3.2 of this Assessment. That system relies on a crane truck to lift the boxes from the work boats. On Niulakita there is presently no crane truck on the island, nor any other mechanical means of removing the boxes from the boats.

The strong ranging and surging of the workboats on the beach face as a consequence of the very active and almost continuous wave action immediately opposite the reef channel would make unloading by a crane truck almost impossible. Nevertheless, the use of storage boxes could still be implemented since this will protect the cargo from damage during the ocean-side operations and the transfer to shore in the work boats. Under such arrangements the boxes would have to be emptied by hand at the island whilst the boxes remained in the work boats.

This is basically what happens now, with loose items instead being removed from the boats and individually carried ashore. However the retrieval of items stacked within a box may require additional time and effort than if they were simply loose in the work boats. Given the need for cargo and passengers to be quickly unloaded and loaded on shore so that the work boats can be dispatched back out to sea, the use of cargo boxes might compromise this requirement for a swift turnaround.

The quantity of cargo that goes ashore to Niulakita on each voyage of the inter-island vessels is relatively small. In fact most cargo is not transported by these vessels in their holds, but is instead simply stored loosely on deck or in small cargo closets adjacent to the open passenger decks. Consequently a strategy of only partially filling the shipping boxes for the transfer of cargo to shore at Niulakita might solve any problems associated with having to quickly access the items when unloading at the island.

If following a trial period the system was found to be problematic at Niulakita, then it could be abandoned for this particular island and the current system of manually unloading and loading of work boats be adopted.

There is only a small amount of diesel fuel delivered to the community on Niulakita. Nevertheless the delivery is made using a 200 litre drum which is very difficult for the island community to manhandle out of the strongly surging work boats; and to then transport up the steep high beach. There is often spillage or contamination of the fuel as a consequence of the rough handling of the drum which is an inevitable outcome of such a difficult exercise.

It is recommended that instead of being delivered in drums, the diesel be delivered in 20 litre containers similar to those currently used by the community for outboard motor fuel. These containers are easier to remove from the work boats and can be carried up the beach with less problems than fuel drums. The transfer from 200 litre drums to 20 litre containers can be done quite readily on board the inter-island vessel prior to their being dispatched to shore. Suitable fuel hand-pump are currently allocated permanently to each inter-island vessel.

Tractor and Trailer

There is currently a submission being considered by the Republic of China (ROC) for provision of 4-wheel drive tractors and tipping trailers for the outer islands. Should this eventuate at Niulakita, then the transfer of cargo up the steep high beach face could be effected quite readily.

Other Issues

There is an opportunity to improve on the design of the handcarts that are used extensively on the island. These are the same as those fabricated by the PWD in Funafuti and used on other outer islands. Special tracked wheel designs have been developed overseas, and these have found a useful application when fitted to wheelchairs to enable them traverse soft and wet sand. The concept is known as “Beach Trekker” wheels and they could be applied to wheels fitted to the Niulakita hand carts to enable them to carry cargo across the beach.

The central component of the wheel design used on the wheelchairs are two track wheels that are 160mm wide x 600mm in diameter with twelve stainless steel flexible spring spokes on each wheel. The entire track wheel is flexible and deforms (alters the shape of the wheel by pressure or stress) to the contour of the ground. The rim of the wheel is large and flat and effectively the wheel becomes like a track with the load distributed by the stainless steel flexible spokes.

The tracked wheels have very low energy losses in the deflection of stainless steel rims and spokes. This means that not much energy is lost when pushing the wheel because energy is recovered via the wheel deforming rather than the ground deforming (which occurs with conventional wheels). It springs back into shape. once the load is reduced.

The effort required to push the wheels is reputed to be about 1/5 of the weight of the load. It is recommended that the PWD manufacturers investigate the application of such wheels to the current hand cart design.

Other Issues

The issue of navigation aids was raised by the island community during discussions relating to the existing reef channel. There was a request made for the provision of navigation aids to enable the channel to be identified by the island's fishermen when returning to shore at night. Whilst this represents a genuine and understandable need, there is doubt whether this could be justified under the present scope of the TSSTP.

It would only be under extraordinarily rare calm conditions that the Marine Department would operate work boats to Niulakita at night from either the *Nivaga II* or the *Manu Folau*. This would only be undertaken to transfer cargo, as it is a policy of the Marine Department to not transfer passengers to any of the outer islands by work boat after dark.

The short channel and proximity of onshore features for reference enable experienced work boat operators to locate the reef channel during the day, even in bad weather. So there appears to be minimal benefit to the ship to shore operations of the Marine Department of providing navigation beacons.

Nevertheless there may be some merit in considering the placement of onshore leads to better assist in identifying the passage through the reef. These leads would incorporate reflective marks so that they could be seen by torchlight at night. Such a system could also incorporate hooks or other such fixtures on which kerosene pressure lanterns could be hung as lead beacons during the night when conditions warranted their use.

5.9.3 Recommended Works

Following an engineering review of those works proposed initially proposed for by the Review Team for Niulakita, the recommended works are as follows:

Main Channel Improvements

- Remove (by blasting) isolated rocks along the flanks of the main channel that are inhibiting safe navigation.
- Excavate a turning basin at the end of the existing channel. It should have a depth no greater than 1.0m below Mean Low Water Springs, have a minimum longshore dimension of 15m and a cross-shore width of 12m. It should be located as a longshore extension on either side of the end of the main channel to form a T-shaped plan profile. The basin must not extend any further landward than the end of the existing reef channel.
- This excavation would need to be undertaken by mechanical means and the removed unconsolidated material taken out of the fringing lagoon so that it is not transported back into the hole by waves and currents.
- Construct wide 0.5m high bunds across the fringing lagoon either side of the existing beach landing area so as to inhibit the flow of water draining from the lagoon into the reef channel. The location of these bunds requires closer inspection during spring low tides, but are expected to be some 50m to 60m long to the west and around 40m to 50m long to the east. The bunds are to be formed by the structured placement of empty rice/flour bags, each partially filled with a dry mix of sand, coral fragments and cement.
- Relocate isolated rocks on the floor of the fringing lagoon between the toe of the beach and the landward end of the reef channel / turning basin.

Beacons

- Provide two poles with reflective material to serve as lead beacons when required.

Beach Ramp

- Demolition and removal of the existing concrete beach ramp – leaving only a short length behind and above the beach slope as a hard stand area.
- Incorporate the deformable "Beach Trekker" tracked wheel concept into the fabrication of handcarts used on Niulakita.

Alternative Channel

- Undertake further engineering and environmental assessments of the alternative channel site to the east of the existing Main (Misimoa) Channel. This is at a different site to the Nanue Channel considered by the Review Team.
- Should this alternative site prove to be a more viable option than Nanue Channel, then prepare cost estimates and potential construction methodology and schedule for further consideration. Construction of any alternative channel would best be undertaken whilst specialised mechanical equipment was on Niulakita undertaking other channel improvement works.

Shipping Boxes

- Following the success of a trial, implement the proposed cargo handling system of shipping boxes. This will likely require a further period of trial on Niulakita since the boxes will need to be unpacked by the island community whilst still in the work boats. It is not clear at this point whether such a strategy will compromise the need for quick turnaround times for island-side operations.
- Implement a system of delivering fuel and kerosene in 20 litre containers rather than in 200 litre drums.

6 Recommended Works & Cost Estimates

6.1 Options Not Recommended

During the Pre-design Team's work, there were a number of potential solutions to the current problems of the ship to shore process that were offered for consideration by the various island communities, government officers, private individuals and groups. These have all proven vital to the Team's development of prospective solutions to what are difficult and complex issues.

Nevertheless, there are some that the Pre-design Team considers are inappropriate for implementation, or are beyond the scope of the present project. Some discussions of these is warranted.

6.1.1 Harbours

When going ashore from the inter-island ship in a work boat, there are two areas which present the greatest risk to passenger safety. These are, the sea approach into the channel (which typically requires negotiating shoaling and breaking waves); and transferring passengers and cargo from the work boat onto shore. For a harbour to improve the safety for passengers, it must alleviate the problems in both of these areas.

When undertaking consultations for this project, requests by a wide range of people for the provision of a reef top harbour like that at Vaitupu were frequently made to the Pre-design Team. Before commenting specifically on the Vaitupu harbour, it is perhaps appropriate to discuss how harbour design addresses the above problems - which after all are problems not uncommon in any harbour of any size anywhere in the world.

As waves approach a shoreline and begin to "feel" the seabed, they begin to increase in height and break. Vessels approaching the shoreline are at very considerable risk if they are caught up in this breaking process, particularly as how it is likely to be in water depths that are becoming gradually shallower. Consequently harbour design seeks to have the entrance into the basin located in depths as deep as possible. That way, as vessels enter they are not subjected to the considerable risks associated with shoaling and breaking waves. Often the basin is dredged or excavated for some distance into the harbour so as to provide the same depth of water as outside.

To further protect vessels from the effects of breaking waves, breakwaters (or the “arms” encircling the harbour) are built out to the deep water entrance. These are generally configured so that their ends overlap somewhat to prevent waves from coming straight through the gap formed between the ends. Rarely does the gap face directly out into the direction of the main wave approach.

Therefore as vessels approach a harbour, they should ideally be in deep water with no breaking waves to hinder their passage. The entrance into the harbour between the breakwaters should also be undertaken in deep water. Outside along the flanks of the breakwaters, the waves are shoaling and breaking as they approach the adjoining shore, but the excavated basin inside the harbour is protected. Waves cannot penetrate into the harbour and affect loading/unloading operations because the orientation of the encircling breakwaters is aimed at not offering a gap through which the worst waves can pass.

Unfortunately, the ends of the breakwater arms that form the harbour entrance at Vaitupu are set back from the edge of the reef. Consequently in order to enter this harbour, vessels must first negotiate the sea approach into the reef channel and then enter the channel itself - just as is required for the reef channels on all the other islands. The harbour breakwaters at Vaitupu offer no assistance whatsoever in this most hazardous part of the passage to shore.

Unless the harbour breakwaters extend out into the deep water beyond the reef edge, and the channel between them is deep and wide, they will not provide any assistance to the passage of vessels into the harbour basin. Thus, a harbour like that at Vaitupu does not improve the safety of the passage to shore. In fact, such a harbour can actually make this entrance area more difficult to enter. Strong currents flowing around the outside of the encircling harbour breakwaters can contribute to the formation of “*standing waves*” at the entrance. This can make entry into the harbour more hazardous in certain circumstances. Community members and work boat operators advised that the harbour at Vaitupu does have these currents and standing waves at times.

As stated above, one of the primary objectives of any harbour is to make the loading and unloading of passengers and cargo safe. At Vaitupu the steps on the northern side of the harbour are rarely used. The Pre-Design Team was advised that they were slippery and dangerous to use. Most passengers disembark into the water or onto the reef flat, and then walk to shore and up the beach. This is really no different to the unloading and loading of passengers at other islands that don't have a harbour. Except that at Vaitupu the concrete revetment over which they must walk is very slippery and unsafe.

The gap in the breakwaters that form the entrance to Vaitupu harbour faces directly out towards the direction that waves approach the western reef edge of Vaitupu. Consequently most waves can propagate straight through the harbour entrance and onto the ramp area where work boat operations are undertaken with minimal change in their energy. Thus, the harbour provides little protection to boats within it or to passengers disembarking at the times when it is most needed.

In the preceding Section 2.2.8 there was a discussion presented regarding the impacts of building obstructions to the natural movement of sand on foreshores. Just as is the case for concrete ramps, shorelines adjacent to harbours will erode. Erosion is quite evident adjacent to the harbour at Vaitupu.

In summary, harbours on reef platforms such as the one constructed at Vaitupu can cause serious long-term environmental problems. There is little additional benefit to the safety of passenger and cargo movements since they do not assist in the hazardous passage across the reef edge; they do not effectively stop waves from adversely affecting island-side operations; and in fact under some sea conditions can make both of these already difficult undertakings even worse.

The Pre-design Team is of the firm view that a harbour like that at Vaitupu offers little additional benefit to the safe and efficient transport of passengers and cargo than would a properly designed reef channel with appropriate and well managed island-side operations. This is particularly pertinent given that the cost to build the Vaitupu harbour was some USD4.5 million.

Harbours have therefore not been included in the options considered by the Pre-design Team.

6.1.2 Deepening channels and connecting to ponding lagoons

On many islands, the outer reef crest acts as a barrier that traps water on the reef platform between it and the island during low tide. This creates what is called a “ponding lagoon” on the fringing reef platform. This damming effect of the reef crest means that the level of water in this fringing lagoon at low tide is higher than it is in the ocean. However the reef crest is often an obstruction to boat passage at low tide, consequently navigation channels cut through reef crests have been requested.

Breaching the reef crest to form a channel will effectively remove the barrier wall. This has two broad impacts. The first is that during a falling tide, once the level of the sea is lower than the water level within the ponding lagoon, the water in the lagoon will endeavor to flow out to the lower sea level through this breach. This results in a strong seaward flowing current that can be so strong as to make the channel unusable and dangerous. An example of this is the American Channel on Nanumea.

This strong current is also likely to carry sand and other such natural materials offshore, leading to the permanent loss of this material from the island and its foreshores. This will result in on-going and log-term erosion.

The second impact is to lower the water level within the ponding lagoon over the lower part of the tidal cycle. Without this channel, the water level within the ponding lagoon will fall slowly with the tide, but will be effectively held at the height of the reef crest. In Tuvalu, this has been shown to be up to 0.8m higher the low water level (Kaly, 1989). Once there is a breach in the reef crest through which water can escape, the lagoon level will be lowered. Kaly (1998) estimated this had resulted in a 0.5m reduction in the water level of the central lagoon at Nanumea.

The lowering of the water level has an enormous impact on the lagoon environment. Those species which need to be covered by water become exposed at low tide and die. This reduces the biodiversity within the lagoon.

In summary, the breaching of reef crests on ponding lagoons is likely to produce a channel which is of less use than the present situation; however it will adversely impact the environment. Works which involve breaching ponding lagoons have therefore not been considered by the Pre-design Team.

6.1.3 Widening channel entrances

Widening channel entrances was proposed in a number of discussions with the Pre-design Team as a means of reducing currents or attenuating breaking waves. This was eliminated from options considered as it would not have significantly reduced currents unless it was a tremendously large widening. Increasing the channel entrance to the widths and depths required would then have allowed increased wave penetration onto the nearby island shoreline; in some cases would also have adverse environmental impacts; and the cost would far exceed the available funds. Widening of channel entrances has only been included where it is required to enable the safer passage of boats.

6.1.4 Jetties

A piled jetty that either extends out to the edge of the reef or out over the beach to the end of the reef channel was suggested in discussions with the Pre-design Team. Such facilities are inappropriate on open foreshores that are exposed to any significant wave conditions. Certainly the swell and seas that constitute the wave climate on the foreshores of Tuvalu's outer islands would not be an appropriate environment in which to operate a jetty.

The inshore wave conditions that typically occur during island-side operations significantly compromise the ability of work boats to berth against any jetty for the purpose of safely transferring passengers and cargo. Consequently the Pre-design Team has not considered this option as a solution to providing improved transfers to the shores of those islands with reef channels on their fringing reefs.

Such a structure, if appropriately designed, could be used for transferring cargo and passengers within the sheltered waters of a lagoon. Indeed such a facility is considered in this Pre-design phase of the TSSTP as a viable option for the lagoon shores of Nukufetau.

6.1.5 Low Profile Piled Ramp / Jetty

An option for beach access is that of a piled ramp of primarily aluminium construction. The rationale for this type of structure is that because it is on piles (and not a solid obstacle) it does not have a major impact on beach processes, nor does it require local natural materials for its construction. Nevertheless it is a fixed structure located over a dynamic beach system. Typically the elevated ocean levels associated with storm events (tides plus surge, wave setup and run-up) means that the structure would be subjected to wave influences during such events.

Not all structural components could be of aluminium, so the potential for accelerated corrosion by having differing metals in its construction is very real - despite the care that could be applied to their design. Apart from the exceptionally high cost of providing such ramps/jetties, there remains concern about the practicalities and sustainability of such marine structures on outer islands. Consequently the Pre-design Team has not considered this option as a solution to providing access for crane trucks over the reef.

6.1.6 Cranes and Derricks

<< MORE WORDS >>>>

6.2 Recommended Works - By Island

Based on the investigations undertaken during the site visits, the following works are recommended for inclusion in the Pre-design phase.

Nanumea

- Out-board motors - Use 60hp outboard motors on all work boats using the channel.
- Beacons - Solar powered lead beacons to mark the entrance to American Channel.
- Alternative Channel - Excavate 100m long x 8m wide x 1.5m deep eastern channel.
- Shipping Boxes - implement system of shipping boxes for cargo (after trials).

Nanumaga

- Main Channel - Clear isolated rocks to deepen channel & entrance.
- Turning Basin - Complete basin excavation by trimming sides.
- Sand trap - Excavate sand trapping basin as northward extension of turning basin.
- Ramp - Monitor impacts of ramp and sand trap on local beach processes
- Ramp - Install tracks of expanded aluminium sheeting as non-slip trafficable surface.
- Beacons - Solar powered lead beacons to mark the entrance.
- Alternative Channel - Excavate 20m long x 8m wide x 1.5m deep eastern channel.
- Shipping Boxes - initial trial for the cargo shipping boxes (with lifting chains).

Niutao

- Muli Channel - Widen entrance, deepen entire channel, remove rocks near beach.
- Turning Basin at Muli Channel - Excavate 18m long x 12m wide x 1m deep basin.
- Beacons for Muli Channel - Solar powered lead beacons to mark the entrance.
- Beach Access - Provide 20m standard mobi-mat for vehicles to access work boats.

- Kulia Channel - Widen & deepen entire channel, remove isolated rocks.
- Turning Basin at Kulia Channel - Excavate 15m long x 10m wide x 1m deep basin.
- Beacons for Kulia Channel - Reflective lead markers to define the entrance.
- Beach Ramp at Kulia Channel - Demolish 20m from end of the concrete ramp.
- Remove debris of previously demolished Muli ramp from foreshore precinct.
- Shipping Boxes - implement system of shipping boxes for cargo (after trials).

Nui

- Main Channel - Improve entrance by blasting; straighten, deepen & widen channel.
- Main Channel - fill end of channel to ensure minimum 30m distance from beach toe.
- Turning Basin - Excavate 18m long x 12m wide x 1m deep basin.
- Beacons - Solar powered lead beacons to mark the entrance.
- Alternative Channel - Excavate 120m long x 8m wide x 1.5m deep eastern channel.
- Shipping Boxes - initial trial for the cargo shipping boxes (with lifting chains).

Vaitupu

- Turning Basin - Clear accumulated sediments from the basin within the harbour.
- Passenger Landing - Fix expanded aluminium sheeting as non-slip surfaces.
- Alternative Channel - Excavate 160m long x 8m wide x 1.5m deep eastern channel.
- Shipping Boxes - implement system of shipping boxes for cargo (after trials).

Nukufetau

- Main Channel - Deepen & widen channel by removing accumulated sediments.
- Turning Basin - Complete 25m long x 13m wide x 1.5m deep basin & moorings.
- Beach Access - Demolish existing concrete ramp and boat landing.
- Jetty & Landing - Subject to appropriate design & cost, construct landing & jetty.
- Beach Access - Consider 20m mobi-mat for beach access in lieu of landing & jetty.
- Beacons - Erect 4No. sets of reflective daymarks along flanks to define the entrance.
- Beacon - Erect a towered & lighted beacon to mark a shoal in the central lagoon.
- Shipping Boxes - implement system of shipping boxes for cargo (after trials).

Nukulaelae

- Reef Channel - Complete works to create new access channel to north of existing.
- Main Lagoon Channel - Clear isolated rocks to provide a clear route through lagoon.
- Beach Access - Provide 20m standard mobi-mat for vehicles to access work boats.
- Alternative Channel - Excavate 80m long x 8m wide x 1.5m deep eastern channel.

- Beacons - Solar powered lead beacons to mark both ocean entrances to lagoon.
- Beacons - Erect approximately 5No. reflective daymarks to define lagoon channel.
- Shipping Boxes - implement system of shipping boxes for cargo (after trials).

Niulakita

- Main Channel - Clear entrance by blasting; remove isolated rocks near beach slope.
- Reef Bunds - Construct 2No. bunds using rock bags to inhibit currents on reef flat.
- Turning Basin - Excavate to form 15m long x 12m wide x 1m deep basin.
- Existing Beach Ramp - Remove the section of the ramp seaward of vegetation line.
- Alternative Channel - Further investigate new landing site to south of main channel.
- Beacons - Erect reflective lead beacons onshore to define entrance channel.
- Shipping Boxes - implement system of shipping boxes for cargo (after trials).
- Cargo Handling - Incorporate tracked wheel concept on the island's handcarts.
- Fuel Containers - Implement delivery of fuel in 20litre containers, not 200 litre drums.

6.3 Recommended Works - By Activity

Based on the investigations undertaken during the site visits, the following works are recommended for inclusion in the Pre-design phase.

Shipping Boxes

- Following a successful trial period at Nanumaga and Nui, implement the system of shipping boxes for cargo (with appropriate lifting chains) throughout all of the outer islands.

Work Boat Improvements

- Outboard motors - Use 60hp outboard motors for transfers at Nanumea (but these are likely to be used at other locations during high tides to facilitate quicker deliveries by the work boats - particularly at Vaitupu and possibly Nukufetau).

Improvements to Existing Channel

- Nanumaga - Clear isolated rocks to deepen and widen channel.
- Niutao (Muli) - Widen entrance, deepen entire channel, remove rocks near beach.
- Niutao (Kulia) - Widen & deepen entire channel, remove isolated rocks.
- Nui - Improve entrance by blasting; straighten, shorten, deepen & widen channel.
- Nukufetau - Deepen & widen channel by removing accumulated sediments.

- Nukulaelae - Complete works to create new access channel to north of existing one.
- Niulakita - Clear entrance by blasting; remove isolated rocks near beach slope.

Turning Basin

- Nanumaga - Complete basin excavation by trimming sides.
- Niutao (Muli) - Excavate 18m long x 12m wide x 1m deep basin.
- Niutao (Kulia) - Excavate 15m long x 10m wide x 1m deep basin.
- Nui - Excavate 18m long x 12m wide x 1m deep basin.
- Nukufetau - Complete 25m long x 13m wide x 1.5m deep basin & moorings area.
- Niulakita - Excavate to form 15m long x 12m wide x 1m deep basin.

Alternative Channel

- Nanumea - Create 100m long x 8m wide x 1.5m deep eastern channel near Matangi.
- Nanumaga - Create a 20m long x 8m wide x 1.5m deep channel at Teone Ngaonga.
- Nui - Create a 120m long x 8m wide x 1.5m deep eastern channel near Tutupe.
- Vaitupu - Create 160m long x 8m wide x 1.5m deep eastern channel at Motofoua.
- Nukulaelae - Create 80m long x 8m wide x 1.5m deep eastern channel at Olatanga.
- Niulakita - Further investigate new landing site to south of the existing channel.

Beacons - Solar Powered

- Nanumea - Solar powered lead beacons on Temotufoliki to mark American Channel.
- Nanumaga - Solar powered lead beacons to mark the entrance.
- Niutao (Muli Channel) - Solar powered lead beacons to mark the channel entrance.
- Nui - Solar powered lead beacons to mark the entrance.
- Nukufetau - Erect a towered & lighted beacon to mark a shoal in the central lagoon.
- Nukulaelae - Solar powered lead beacons to mark both ocean entrances to lagoon.

Beacons - Reflective Marks

- Vaitupu - Reflective lead beacons onshore to mark the Motufuoa channel.
- Niutao (Kulia Channel) - Reflective lead beacons onshore to mark the entrance.
- Niulakita - Erect reflective lead beacons onshore to define entrance channel.
- Nukufetau - Erect 4No. sets of reflective daymarks along channel alignment.
- Nukulaelae - Erect approximately 5No. reflective daymarks to define lagoon channel.

Modify or Remove Concrete Beach Ramps

- Niutao (Muli Channel) - Ramp is demolished, but remove the debris from foreshore.
- Niutao (Kulia Channel) - Demolish 20m from seaward end of ramp.
- Nukufetau - Demolish and remove ramp (as well as existing boat landing).
- Niulakita - Demolish the section of the ramp seaward of the terrestrial vegetation line.
- Nanumaga - Monitor impacts of ramp & sand trap arrangement on beach processes.
- Nanumaga - Install expanded aluminium tracks as non-slip trafficable surface.
- Vaitupu - On passenger landing fix expanded aluminium sheets as non-slip surfaces.

Beach Access

- Niutao - Trial mobi-mat system of beach access, using standard 20m long mat.
- Nukulaelae - Trial mobi-mat system of beach access, using standard 20m long mat.
- Nukufetau - Consider 20m mobi-mat for beach access in lieu of landing & jetty.
- Niulakita - Incorporate tracked wheel concept on the island's handcarts.

Miscellaneous

- Nanumaga - Excavate sand trapping basin as northward extension of turning basin.
- Nukufetau - Subject to appropriate design, construct landing & jetty access.
- Niulakita - Implement delivery of fuel in 20litre containers, not 200 litre drums.
- Niulakita - Construct 2No. bunds using rock bags to inhibit currents on reef flat.

Technical Assistance

Provide technical assistance to the Marine Department in regard to:

- Determining appropriate design for work boats.
- Determining appropriate design for shipping boxes.
- Establishing and implementing standards for packaging of cargo for shipment.

6.4 Cost Estimates for Recommended Works

6.4.1 Cargo Handling

Elsewhere in the Pre-design Report is the recommendation that the implementation of the cargo handling system be trialed. This will enable any unforeseen deficiencies in the design, fabrication or operation of the shipping boxes to be rectified prior to full implementation across all outer islands.

It is recommended that tenders for the fabrication of appropriate boxes for the trial period be sought from potential suppliers in New Zealand and Pacific Island countries. Based on the assumption that these will be of heavy-duty construction with approximate dimensions of 1.75m length x 1.5m width x 0.8m high and capable of accommodating 1 tonne of contents, it is estimated that each box would cost NZD1,000 to manufacture and be delivered to Funafuti. Subsequent orders for larger numbers are expected to be less, at approximately NZD 775 each.

In addition to the shipping boxes, four lifting chains incorporating spreader bars would be required (one for each inter-island vessel, and crane truck utilised in the trial) along with one small hand operated forklift for handling the boxes in the hold of the *Nivaga II* (and shared with the *Manu Folau* if found necessary).

It is estimated that some 50No. of these boxes would be required for the initial trial, with some 600No. likely to be required for implementation throughout the entire outer islands. This therefore results in the following estimate of cost for implementation of the Shipping box system:

for the initial trial period only

shipping boxes	: NZD 50,000
small forklift	: NZD 4,500
lifting chains	: NZD 2,500
subtotal of	*: NZD 57,000*

additional for full implementation

shipping boxes	: NZD 465,000
small forklift	: NZD 4,500 (for other ship)
lifting chains	: NZD 5,500
subtotal of	*: NZD 475,000*

6.4.2 Work Boat Improvements

It is recommended that 60hp outboard engines be utilised on all work boats for transfers of cargo and passengers between both inter-island vessels and the shore at Nanumea. Since Yamaha outboard motors are used very extensively throughout all of Tuvalu and the Marine Department have reliable and efficient purchasing arrangements with Yamaha dealers, it is recommended that 60hp Yamaha outboard motors be procured for each of the two workboats on each of the *Manu Folau* and the *Nivaga II*.

Given that they are also likely to be used on islands other than Nanumea to facilitate quick delivery of cargo and passengers when tides and sea conditions are favourable, it is recommended that a spare 60hp motor be available on each inter-island vessel (in addition to the ones allocated to each work boat). This would facilitate the current practice of rotating their use to regularly service the motors. That is, a total of 6No. outboard motors would be required to properly support their use on the work boats of both inter-island vessels.

It would be appropriate to also procure a store of spare parts for these engines, with the standard practice of having at least two spare propellers for each engine available on the ship at any time.

It is estimated that the cost of supplying 6No. 60hp Yamaha outboard motors (three for each inter-island vessel) with an appropriate store of spare parts is NZD 45,000.

6.4.3 Navigation Aids

There are basically three types of navigation aids recommended for implementation throughout the outer islands under the TSSTP, namely:

- solar powered lighted lead beacons;
- reflective lead beacons; and
- reflective daymarks.

Solar powered lighted lead beacons are required at Nanumea, Nanumaga, Niutao, Nui and Nukulaelae (at two channels). All except the lead beacons at Nanumea would be rated at 2nm (ie. two nautical miles), the special requirements of Nanumea are discussed below. The lights themselves, the solar equipment and the associated fixtures can all be purchased as proprietary items. The posts on which they would be mounted should be of aluminium construction with appropriate fixing arrangements for the equipment and for the foundations. There are presently a number of electrical lights mounted on columns which are lighting some landing areas on the islands. These are maintained by TEC. It is envisaged that the columns on which the lead beacons be mounted would be very similar to the ones used by TEC.

The Nanumea beacons would be located on the islet of Temotufoliki, some 1km across the central lagoon from the entrance into the American Channel. Consequently in order for these to be effective, it recommended that these beacons be rated at 5nm. It is further recommended that the Nanumea leads be fitted with large and visible daymarks to facilitate their use during daylight hours. It is likely that the leads will need to be mounted on a tower structure rather than a simple pole as the daymarks would be quite large and need to withstand wind loadings during storms.

Reflective onshore lead beacons are recommended to mark the alternative channel at Motufuoa on Vaitupu; the Kulia Channel on Niutao, and the main channel onto Niulakita. These would consist of appropriate marks (firmly fitted with reflective covering) mounted on top of corrosion resistant poles. Typically the front lead would be located on the beach above Mean High Water Springs, with the rear lead being as far behind the line of terrestrial vegetation as possible.

Reflective daymarks would be used to define the 540m long channel at Nukufetau, and also to define a navigable route through the fringing lagoon at Nukulaelae. These daymarks would consist of the appropriate starboard / port marks (fitted with correctly coloured reflective covering) mounted on corrosion resistant poles that were themselves firmly embedded in the seabed.

The following estimates of costs for these various application of navigation aids is as follows:

solar powered lighted lead beacons

Nanumea (American Channel):	NZD 45,000
Nanumaga (Main Channel):	NZD 10,000
Niutao (Muli Channel):	NZD 10,000
Nui (Main Channel):	NZD 10,000
Nukulaelae (2No. locations):	NZD 20,000

reflective lead beacons

Vaitupu (Motufuoa Channel):	NZD 4,500
Niutao (Kulia Channel):	NZD 4,500
Niutao (Muli Channel):	NZD 4,500
Niulakita (Main Channel):	NZD 4,500

reflective daymarks

Nukufetau (4 sets = 8No. total):	NZD 6,000
Nukulaelae (say, 5No.):	NZD 4,000

The total estimated cost for providing appropriate navigation aids to the outer islands is therefore NZD 115,000.

6.4.4 Mobi -mats

Elsewhere in this Pre-design Report there is a recommendation for a trial of the mobi-mat system to enable the island crane trucks and other vehicles to drive across the beach to assist in the unloading of the work boats. The trial involves one of the inter-island vessels carrying a standard 20m long mobi-mat on board and deploying it on the foreshores of various islands. Should the trial prove successful, then it is likely that three such mats might be procured - one for each of the two inter-island vessels and one as a spare. This therefore results in the following estimate of costs:

for the initial trial period (one mobi-mat only)	: NZD 32,000
for full implementation (2 additional mobi-mats)	: NZD 64,000

6.4.5 Reef Channel Improvements - Tuvaluan Marine Construction Team

The cost of undertaking the proposed improvements to existing reef channels and the construction of alternative channels on the various islands will depend significantly on the adopted implementation method. Section **Error! Reference source not found.** discusses several ways in which the works could be undertaken; either by the creation of a specialised Tuvaluan Marine Construction Team, by contracting an overseas based contractor, or by simply providing the necessary construction equipment to the PWD. This later option is not viable as the PWD does not have the capacity to undertake the specialised work without significant assistance by way of training and further staff recruitments (refer Section 7).

Consequently when preparing cost estimates for channel improvement works, both options of a Tuvaluan Marine Construction Team and an overseas based construction company are considered.

Tuvaluan Marine Construction Team

The equipment required to undertake the recommended reef channel work is discussed in Section 4.2. Almost all of this equipment is currently unavailable in Tuvalu. The only exception being the barge used by the previous Reef Blasting Team which is currently lying in disrepair on the foreshore near the Kulia Channel at Niutao - but could possibly be restored to working order.

Consequently, it would be necessary to procure the required equipment under the TSSTP and have it delivered to Funafuti when assembling resources for the Marine Construction Team. The estimated cost of properly resourcing a Tuvaluan Marine Construction Team is as follows:

Equipment

hydraulic excavator (8 tonne)	NZD 175,000 (including spares)	
extra buckets & ripping tyne	NZD 15,000	
2No.rock trailers (15 tonne)	NZD 110,000	
Tractor (4WD)	NZD 52,000	
barge (assume restored)	NZD 25,000	
sand dredging pump & hoses	NZD 28,000	
mobi-mat (20m standard)	NZD 34,000	
VHF radios	NZD 14,000	
computers (2)	NZD 6,500	
motor bikes (2)	NZD 5,500	
welding equipment	NZD 7,000	
mechanical tools, etc.	NZD 8,000	
Total for equipment		NZD 480,000

Staffing

Expatriate Project Manager	NZD 200,000 per annum
Tuvaluan staff	(provided as GOT contribution)

7 PWD Capability

7.1 Current Structure

The PWD is administered by the Director of Works and is responsible to the Secretary of Works and Energy. The Department consists of seven Sections, namely:

- Design and Supervision Unit (DSU)
- Building Section
- Mechanical Section
- Electrical Section
- Plumbing & Sewage
- Civil Engineering
- the Vaitupu Branch

The Design and Supervision Unit

The head of the DSU is the Deputy Director - who currently has a Diploma in Construction and a Diploma in Quantity Surveying from FIT - with experience in construction, estimating and building surveying. The DSU provides design, contract documentation, tender preparation / review, and construction supervision services for a wide range of government projects. It is also called upon at times to provide advice to the private sector (eg. banks, hotels, etc.) since the PWD is the only agency in Tuvalu that has all the skills required to facilitate civil works and building projects.

Most of the design, tendering and supervision undertaken by the DSU relates to Government Buildings throughout Tuvalu. These primarily include government quarters and schools, however they have also provided such services for the construction of seawalls, the upgrading of roads (primarily in Funafuti), and minor civil works associated with the airstrip on Funafuti.

The DSU consists of a number of sub-sections - including Architectural, Quantity Surveying, Civil Engineering and Housing Divisions. The Architectural Division is normally headed by the PWD Architect, however this position is currently vacant and the division therefore consists of two architectural draftsmen, one of whom is acting in the role. Likewise the role of PWD Quantity Surveyor is vacant and the division's two Estimators are providing the required quantity surveying services to the DSU.

The role of PWD Civil Engineer is also currently vacant while the appointed officer is studying for a Bachelor of Engineering in New Zealand. The role is currently filled by an employee who partially completed a Diploma in Civil Engineering from FIT. The current Director is the only employee with formal Bachelor of Engineering qualifications and therefore frequently undertakes structural engineering designs for the DSU.

There is also a Housing Division within the DSU. The role of this division being the letting and supervision of contracts for maintenance work associated with government assets. The PWD undertakes minor repairs and maintenance of government buildings, but it is the government's policy to contract most of the larger maintenance works to the private sector. Consequently the activities associated with the tendering, contract administration and supervision of maintenance activities is undertaken by the Housing Division.

Whilst there is a somewhat formal structure to the DSU, the reality is that much of the technical work is shared amongst the various staff. This is a consequence of a heavy workload and a need to draw on practical skills that have evolved across a relatively small number of employees through experience and innovation rather than formal education or training. Consequently many of the DSU staff have at least some proficiency in most activities undertaken by the group.

Building Section

The Section is managed by the PWD Asset Manager who reports directly to the PWD Director. Whilst it is generally Government policy to tender construction works to the private sector, in recent times the PWD has undertaken some construction work itself. This has evolved as a consequence of some private sector firms not being able to complete contracted works, and the PWD subsequently electing to complete the works using its own resources. Under such circumstances, the Building Section will take on the responsibility of managing the construction by utilising resources from the Civil Engineering Section, supplemented with contracted labour where necessary. The PWD will be substantially undertaking the planned upgrading of the infrastructure at the TMTI under ADB funding.

Ordinarily however the role of the four Supervisors in this section is to supervise construction work that is contracted by the PWD to the private sector. These staff members have no formal qualifications, but have sound experience in general building works. There is currently an unfilled vacancy for a fifth Supervisor. When undertaking projects on outer islands, these Supervisors are generally assigned to the construction site for the duration of the works. Such works typically include government buildings (with school buildings being a significant component) but also include seawalls and the concrete beach ramps funded by the Canada Fund. There is also a small sub-section of the Building Section that employs four carpenters who perform general joinery work.

The contracts awarded by PWD to private sector firms for the construction of government assets are typically for the supply of labour and equipment only, with the building materials supplied to the Contractor by PWD.

Mechanical Section

The Section is managed by the PWD Mechanical Engineer who reports directly to the PWD Director. The section consists of Automotive and Mechanical Divisions and operate from a mechanical workshop within the PWD compound at Funafuti.

The Automotive Division consists of a Chief Mechanic and four other mechanics who are responsible for the upkeep of the PWD's mechanised plant and vehicles, but are also often called upon to assist the private sector. The Division supported the Reef Blasting Team during its earlier activities in the outer islands. The main equipment owned by the PWD and maintained by the Mechanical Division include : **….. AMPOLOSA, I NEED THE ASSET REGISTER SHOWING LARGE ITEMS OF PWD MECHANICAL PLANT….**

The Mechanical Division undertakes general small steel fabrication - but also have the capacity to perform aluminium welding. The staff consists of a Chief Welder and two other welders.

Electrical Section

This consists of four qualified electricians who work in two Divisions; Electrical and Refrigeration. The Electrical Division consists of three of these electricians who undertake all works associated with the electrical wiring of government buildings. One of these electricians acts as the PWD Electrical Engineer, reporting directly to the PWD Director. They perform minor electrical repairs (including those on the new three-storey Government Offices building in Funafuti), however any major repairs are contracted out to the private sector. The electrician working as the Refrigeration Division also has relevant qualifications and is responsible for all air conditioning and refrigeration in government buildings. Typically the four electricians work as a team, with work being shared as necessary.

Plumbing and Sewerage Section

The Section is managed by the PWD Water Engineer who reports directly to the PWD Director. The Section consists of two Divisions, Plumbing and Water. The Plumbing Division consists of three plumbers, of which two have qualifications (from FIT). They undertake works associated with the maintenance of sewerage systems, solid waste disposal, electrical pumps and drainage (including guttering) for government buildings - including the new Government Offices in Funafuti.

The Water Division is responsible for the delivery of potable water to government buildings and therefore includes for all plumbing necessary to effect this outcome. There is no reticulated mains water in Tuvalu, with water being delivered from rainwater tanks. There are currently four staff employed in this role, none of whom have any formal plumbing qualifications.

Civil Engineering Section

The Section is managed by the PWD Civil Engineer who reports directly to the PWD Director. It consists primarily of 8 to 10 young unskilled labourers whose main tasks include road repairs in Funafuti, maintenance of the airstrip, collection and delivery of heavy cargo from the wharf and assisting the Building Section with any construction work.

Vaitupu Branch

The PWD maintains a small depot on the outer island of Vaitupu that is staffed by five officers. These being a plumber, electrician, carpenter, storeman, and a driver. The position of Supervisor is currently unfilled. Minor building repair works are undertaken by the depot, however any significant new construction or maintenance work is contracted to the private sector and is administered by Funafuti-based PWD staff.

7.2 Capacity for Works Under the TSSTP

Marine construction involving reef excavation and blasting primarily involves specialised heavy earthmoving activities undertaken in a physical environment that is particularly harsh and aggressive on mechanised plant and equipment. It is significantly constrained by tides, wave, weather conditions and often entails working at night to exploit favourable conditions.

In Tuvalu the extreme remoteness of the works and the scheduling of inter-island shipping imposes even further limitations. Consequently when undertaking such works it is vital that it incorporates careful logistical planning, close supervision and management. It relies significantly on engineering staff with experience of such a working environment.

The PWD does not have previous experience of these core activities associated with the implementation of the TSSTP. The earlier work undertaken by the Reef Blasting Team did not directly involve the PWD in any significant role - except to provide some support with regard to mechanical repairs on equipment. The PWD also does not have any of the major plant items necessary to undertake the proposed improvements to the outer island reef channels.

Nevertheless, the PWD offers opportunities with respect to the effective implementation of the engineering works proposed under the TSSTP. These are discussed below.

7.2.1 Staffing and Equipment

Whilst the PWD currently do not have any of the major plant items required to undertake the channel improvement works (except for a barge that is currently in disrepair on Niutao), a number of staff do have the skills to operate and provide mechanical support to such equipment.

It is worth noting that such skills are also available on the outer islands. Many Tuvaluan men have worked at the phosphate mines on Ocean Island **(Barnaba)** and Nauru where they were employed for many years on excavation activities using large mechanical plant. According to senior engineers in PWD, in addition to PWD's own skilled mechanics and operators, there are many people in the outer islands who have considerable ability to operate and service heavy earthmoving equipment. Perhaps as testimony to this skill are the number of quite old tractors, vehicles and other machinery that are still currently in active use on many of the outer islands.

In recent times there have been a number of relatively major construction activities completed on Funafuti, including the sealing of roads and the construction of the three-storey Government Offices Building. Whilst these were completed by overseas-based contractors, the PWD provided some support with regard to servicing of construction equipment. This informal exposure to such works was reputedly also of benefit to PWD staff.

Should the various items of plant and equipment required to undertake the channel improvement works be made available to the PWD, it is the opinion of the Pre-design Team that such equipment could be operated and maintained by PWD with minimal support and training from the equipment suppliers.

The area in which there is inadequate skills and experience is in relation to the use of explosives - particularly with regard to their use in underwater applications.

7.2.2 Project Management

Whilst the few senior managers / engineers in PWD have any direct experience of major marine excavation works, they are experienced with regard to managing construction activities in the outer islands. Consequently the difficulties and constraints associated with provisioning those works with labour and materials is well understood. It is the Pre-design Team's opinion that there are two or three of senior staff who could provide valuable support to the construction activities proposed under the TSSTP. However none have all of the specialised skills necessary to manage those activities efficiently or effectively on their own.

Such project management would need to be provided by an overseas-based MSC with experience in marine construction (particularly channel excavation) in remote island environments.

Given the opportunity that this specialised marine construction work offers to train a senior PWD officer in such works, the PWD Director is most keen that such an officer be appointed to assist with the management of the project. However this would require a fulltime commitment of that officer to the TSSTP for the duration of the construction activities - even if fulltime assistance was provided through the appointment of an overseas-based MSC.

Given the current workload of the few PWD senior engineers and managers, this would represent a depletion of PWD's ability to manage its day-to-day operations and to service its normal contractual commitments.

8 Implementation of Works

8.1 Trial of Mobi-mats

It is recommended that one standard 20m length mobi-mat be procured for the purposes of implementing a trial of this beach access system.

The intent is to not just test the performance of the mat itself, but the entire process of loading/unloading it into the work boats; bringing it to and from the shore; laying it out and rolling it up under a range of tide and sea conditions; and testing its ability to provide trafficable access for island vehicles (particularly the crane trucks).

The mat would be carried on one of the inter-island ships, but during the trial period also be used by the other ship - thereby identifying any problems specific to each vessel and their respective work boats. It is recommended that the trial be focused initially on Nukulaelae and then at Niutao. This provides for testing within a reasonably sheltered fringing lagoon and on a high wave energy foreshore respectively.

At Nukulaelae the mat would be deployed from the toe of the existing concrete ramp across the sand beach towards the landing point of the work boats. One of the anticipated immediate benefits of a successful operation of the trial at Nukulaelae is a quicker turn around of the work boats. Work boats can only access the shore during high tides, and this will remain the case even after implementation of the proposed channel improvements under TSSTP. At the present time, the quantities of cargo currently being delivered to Nukulaelae are just slightly too much to accomplish in one high tide. Consequently the inter-island ships often need to wait for a second high tide.

The peculiarities of the tides in Tuvalu are such that during neap tides, there is only one high tide during daylight hours. Therefore the inability to transship all cargo at Nukulaelae during one high neap tide means that the inter-island vessels often need to wait for another day - just to offload a small amount of cargo. A quick turnaround by work boats as a consequence of the mobi-mat providing the opportunity for the island crane truck and tractor/trailer to facilitate more efficient offloading therefore is of significant benefit to shipping schedules and the operating costs of the Marine Department.

At Niutao, the concrete beach ramp at Muli Channel has been removed by the island community because of the erosion it was causing. Whilst this ramp never really provided the opportunity to have the island-side cargo handling operations assisted by tractors/trailers or crane trucks, there is an expectation by the community that such a system can and will be implemented. Indeed, the community has been aware of the enviro-ramp concept (Kaly, 1999) and its suitability for quite some time.

As discussed in Section 5.4.2, the Pre-design Team is of the opinion that the mobi-mat system would be better suited to this location where every effort needs to be made to have a system that has minimal impact on the natural beach re-building processes. The beach and foreshore at Muli is currently about 30m wide - and a standard 20m long mobi-mat would not be useful at low tides. Should the system be successful during operations at higher tides and it be implemented across other islands, then a longer more versatile mat (or alternatively a second one to make up the 30m beach width at Niutao) could then be acquired.

Prior to the trail mobi-mat's initial deployment on each of the inter-island ships, it is strongly recommended that those of the ship's crew who will be responsible for the deployment of the mat first do some familiarisation of the deployment procedure before applying it to the outer islands. The mat should be offloaded from a ship's work boat and deployed onto the lagoon foreshore at Funafuti as a training / familiarisation exercise. This process of prior deployment and removal should be undertaken so as to refine the techniques necessary, before having to employ them for the first time in what could conceivably be adverse sea conditions.

8.2 Trial of Shipping Boxes

It is proposed to trial the shipping boxes before implementing them across all islands, this gives the opportunity to assess and refine their design and operation. It is again proposed to undertake the trial at Nukulaelae. There would be immediate and significant benefits to the Marine Department should the trial deliver quicker turn around of the work boats during island-side operations at Nukulaelae.

It would not be necessary to undertake the shipping box trial at the same time as that for the mobi-mat. Nor would it necessarily rely on the results of the mobi-mat trial.

However there would be some advantages if the opportunity to do so was available - or if the mobi-mat system had already been rolled out across all of the islands. It would offer the opportunity to test the box design and the operation of the containerisation system with regard to their handling by crane trucks and the island tractors / trailers. Nevertheless, the boxes could otherwise be unpacked manually, and the contents simply carried ashore as is currently done.

Most of the cargo prone to damage (bags of rice, sugar, flour, cartoons of food and household items) is shipped by TCS to stock the local *fusi*. The intent of the trial is therefore to firstly apply the containerisation system to all of the cargo consigned to Nukulaelae by TCS. If in this initial period of the trial, the shipping box system was found to be effective then it would be a simple matter to extend it to cover a greater range of consigners.

Based on the past and projected cargo figures for TCS and the general items shipped to the island by the Marine Department, it is estimated that some 50No. boxes would be required to facilitate the trial if they were to be offloaded by the crane truck and other mechanical means, that is if the mobi-mat system was already implemented or being trialed at the same time. However if the boxes were being brought to shore and then returned back to the ship following manual clearance, then only some 25No. would be required.

If the shipping box trial indicated that the system could be rolled out across all islands, then it is estimated that an additional 600 No. boxes would be required. The actual number necessary would become more evident during the trial itself - as would any refinements to the design of the boxes.

8.3 Implementation of Channel Improvement Works

8.3.1 Reef Channels

It is recommended that the major improvement works for each island be undertaken by the Marine Construction Team in the following order:

1. Nukufetau
2. Niutao
3. Vaitupu

4. Nanumaga
5. Nui
6. Niulakita
7. Nukulaelae
8. Nanumea

The rational being as follows:

- It would be prudent to undertake the initial works within a sheltered environment so that work practices can be tested and refined, prior to undertaking more challenging channel excavations in exposed reef platforms. Nukufetau offers the best opportunity for this exercise.

- Perhaps the most urgent need for channel improvements is at Niutao and Niulakita. However the challenge imposed by the very high wave energy environment and deep fringing reef at Niulakita would likewise best be undertaken once some experience of working on reef platforms on the open shoreline was well established by the construction team. Some time might also be required to further investigate the alternative channel site at Niulakita. Consequently it is considered appropriate to undertake the required works at Niutao first.

- The first three locations only require work on one channel - there is no second/alternate channel mooted for these islands.

- The order in which Vaitupu, Nanumaga and Nui is undertaken is not critical. It will be determined somewhat by the scheduling of the works for Vaitupu since these channel works need to be undertaken on the eastern side of the island during the westerly season of December through to March.

- The proposed works at Nukulaelae are really to provide for a supplementary channel to the main one that which already exists. Whilst it is acknowledged that this existing channel does require improvements to make it safer, the need for such works is greater on other islands.

- The proposed works at Nanumea are for an alternative channel only. The intent under the TSSTP is that existing American Channel will provide the necessary channel access until such time as the alternative one is built.

8.3.2 Navigation Aids

The installation of the navigation aids is somewhat reliant on the channel works. Nevertheless, some beacons can be placed at locations where the alignment of the navigable channel is unlikely to change as a consequence of the channel improvement works. These would be at Niulakita, Nanumea, Nanumaga, Niutao (Muli Channel only), Nukulaelae (the existing channel only) and the lagoon shoal at Nukufetau. At Nukufetau it would be prudent to delay the installation of the channel markers until such time as the channel excavation activities were completed.

The installation of navigation aids for Nui, Niutao (Kulia Channel), Nukulaelae (new channel) and Vaitupu (Motufuoa Channel) will first require the channels works to be completed and the final navigable route better defined.

9 References

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