**MINISTRY OF FOREIGN AFFAIRS,
ENVIRONMENT, TRADE, LABOUR
AND TOURISM,
GOVERNMENT OF TUVALU**

THE STUDY FOR ASSESSMENT OF ECOSYSTEM, COASTAL EROSION AND PROTECTION/REHABILITATION OF DAMAGED AREA IN TUVALU

FINAL REPORT
[Volume II : Main Report]

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JAPAN INTERNATIONAL COOPERATION AGENCY

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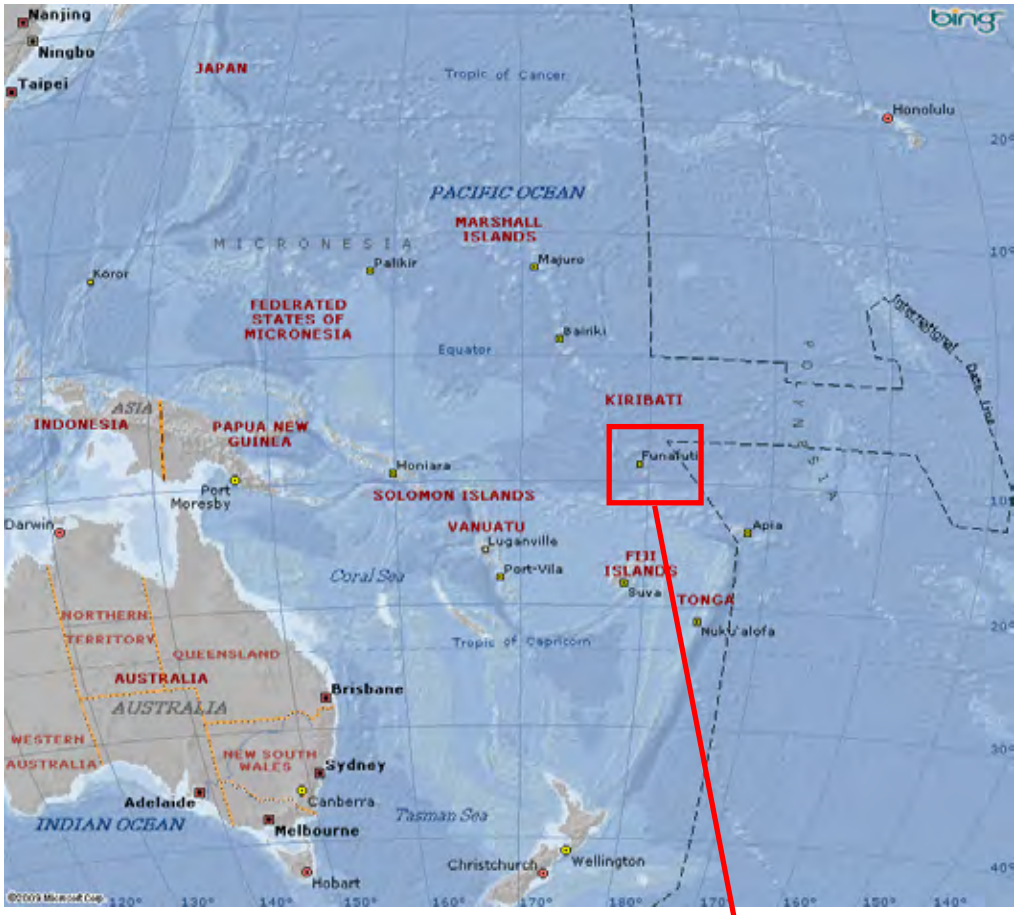
(As of November 2010)

ASSESSMENT OF ECOSYSTEM, COASTAL EROSION AND PROTECTION / REHABILITATION OF DAMAGED AREA IN TUVALU

Location Map of Study Area



Tuvalu

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF FOREIGN AFFAIRS, ENVIRONMENT, TRADE, LABOUR AND TOURISM, GOVERNMENT OF TUVALU

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Volume II: Main Report

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Abbreviations

ADB	Asian Development Bank
CBOs	Community Based Organizations
CDM	Clean Development Mechanism
DMO	Disaster Management Office
DOA	Department of Agriculture
DOE	Department of Environment
DOF	Department of Fisheries
DOLS	Department of Lands and Survey
EIA	Environment Impact Assessment
EU	European Union
F/S	Feasibility Study
GEF	Global Environment Facility
GIS	Geographic Information System
IEE	Initial Environment Examination
IGCI	International Global Change Institute
JICA	Japan International Cooperation Agency
O&M	Operation and Maintenance
PICCAP	Pacific Islands Climate Change Assistance Programme
PICs	Pacific island countries
PWD	Public Works Department
SOPAC	South Pacific Applied Geoscience Commission
SPREP	South Pacific Regional Environment Programme
STP	Sewage Treatment Plant
T-N	Total Nitrogen
T-P	Total Phosphorus
UNDP	United Nations Development Programme
USP	University of the South Pacific
NSDS	National Strategy for Sustainable Development
NAPA	National Adaptation Program of Action
AusAID	Australian Agency for International Development

CHAPTER 1 BACKGROUND OF THE STUDY

Tuvalu has been brought to international attention as a country in danger of submerging due to the impact of global warming, because most of its landmass is low-lying atoll only 1 to 3 meters above sea level. On the other hand, a study report says that the main cause of the existing coastal erosion and tidal surge impact is the increase of environmental load by population growth (sand supply decrease due to deterioration of water quality, and constructing barriers for accretion of sand) and sprawl of residential area (inhabitation in flood prone areas, and extracting earth and sand from coastal areas) rather than precipitation change or sea level rise due to global warming[1]. Therefore, a comprehensive study on the impact of human activities is needed for the island's long-term sustainability.

Previous studies have shown that coastal protection measures ignoring sand production/movement/deposition mechanisms of biologic origin, such as coral, run a high possibility of destroying the island's sustaining mechanisms in the long-term[2]. Therefore, the implementation of measures based on these mechanisms is required to protect the atoll island. Additionally, it is necessary to increase the island's permanence by mitigating negative effects on these mechanisms considering future sea level rises.

Long-term measures to increase the island's permanence must be considered. Nonetheless, the coast is already being eroded, with reports of residents' lives being affected. For these areas, urgent and short-term measures are required. Surveys on the impact of coastal erosion, and the planning of countermeasures to counter this, are particularly pressing in Fongafale Island, where the capital Funafuti is located, and 45% of Tuvalu's total population (9,652 persons: 2006, the secretariat of the pacific community) resides.

The then prime minister Fukuda promised the Japanese Government will support Tuvalu at a summit between Japan and Tuvalu in December, 2007. The then Minister of the Environment Kamoshita visited Tuvalu in January, 2008. The JICA project formation investigation team visited Tuvalu and conferred about a supportive content concretely with Tuvalu. Based on the result of the project formation investigation, first of all, the Tuvalu government requested international science and technology cooperation on global problems to clarify the mechanisms involved in the formation and sustainability of the island from a long-term perspective, which is

[1] Yamano, H., Kayanne, H., Yamaguchi, T., Kuwahara, Y., Yokoki, H., Shimazaki, H., and Chikamori, M.: Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale Islet, Funafuti Atoll, Tuvalu, Global and Planetary Change, 57, 407-416 (2006)

[2] Environment Research and Technology Development Fund by Ministry of the Environment, Japanese Government, Research on sustainable land management of atoll islands (2002-2007)

called the Project for Eco-technological Management of Tuvalu against Sea Level Rise (hereafter, Japanese science and technology cooperation). Moreover, in terms of short-term aspect, Tuvalu requested Japanese technical cooperation for a development planning study proposing short-term measures for the prevention of coastal erosion. This development planning study (the Study) aims to propose short-term coastal erosion countermeasures, working in coordination with the above Japanese science and technology cooperation, and based on the results of its long-term scientific research begun in April.

CHAPTER 2 OBJECTIVES OF THE STUDY AND STUDY AREA

2.1 Objectives of the Study

In recognition of the background mentioned above, the Objectives of the Study are set forth as follows:

(1) To assess ecosystem, coastal erosion and protection/rehabilitation of the damaged area
(2) To make a plan on sustainable measures for coastal protection/rehabilitation
(3) To strengthen capacity of institutions and communities for coastal management.

2.2 Study Area

The study covers the Fongafale Island and other islands of Funafuti atoll.

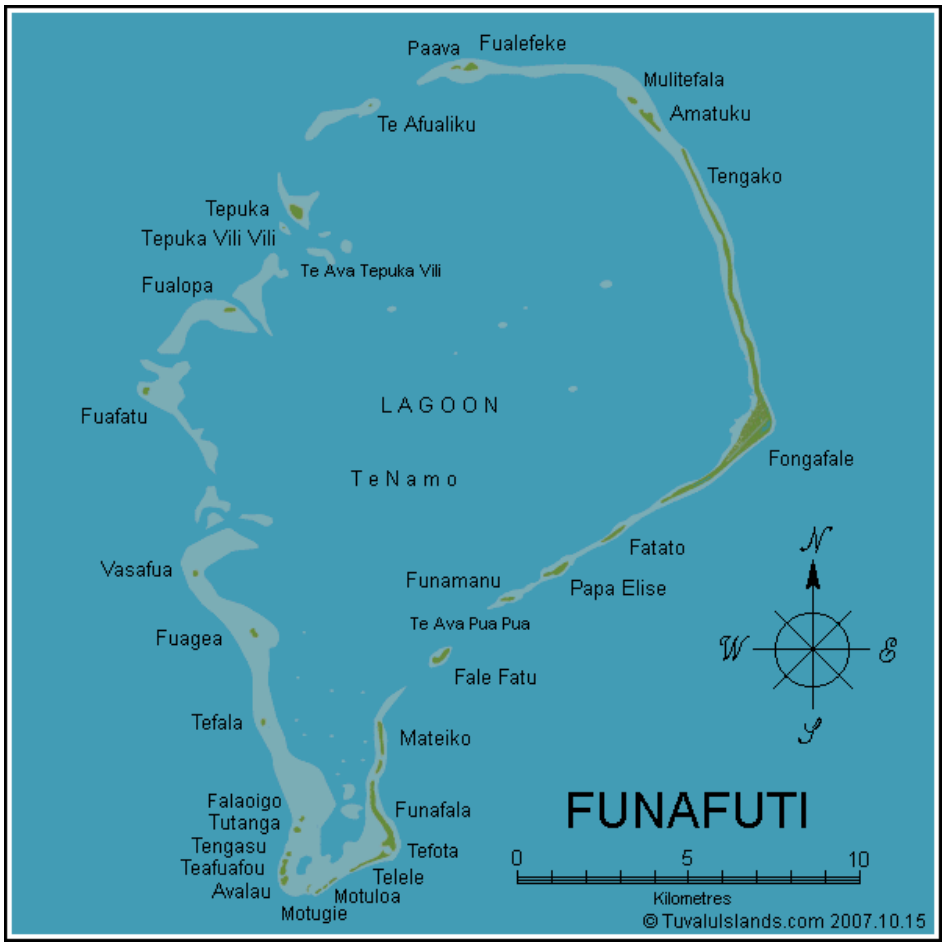


Figure 2.1 Study Area

CHAPTER 3 SOCIAL AND ECONOMIC CONDITIONS

3.1 Social Conditions

3.1.1 Laws and Acts in Coastal Zone

The basic law for coastal zone in Tuvalu is the Foreshore and Land Reclamation Ordinance. The ordinance provides that, "Subject to the public rights of (a) navigation and fishing, and (b) of passing over the foreshore, and to any private fights that may exist in or over the foreshore or the sea-bed, the ownership of the foreshore and sea-bed is vested in the Crown" ((1), 3 Declaration of ownership of foreshore and sea-bed), in which "foreshore" means the shore of the sea or of channels or creeks that is alternately covered and uncovered by the sea at the highest and lowest tides, and "sea-bed" means the bed of all territorial and inland tidal waters.

As the ownership of the foreshore and sea-bed is vested in the Crown, "any land reclaimed otherwise than under section 11 (1) shall be vested in the Crown" (9 Vesting of reclaimed land), subject to subsection (2). Subsection (2) provides that "Causeways and landing-places constructed by a local government council shall, subject to the right of the Minister to call for their surrender to the Crown at any time, vest in that council." And "Subject to section 11 (1) the Minister may, in accordance with this section, authorise the reclamation of land over and upon the foreshore or the sea-bed irrespective of the ownership of land bordering on or of whether any land borders on such foreshore or sea-bed" (4 Minister may authorise undertaking). However, "Without prejudice to any public or private rights that may be affected thereby, this Ordinance shall not apply to the filling by a landowner of the whole or any portion of the foreshore that borders on his land" (11 Landowner's liberty to fill foreshore not to constitute a right) .

3.1.2 Standards

As there is no provisions for specific industrial standards in Tuvalu, people generally refer to British Standards, and also there are no specific norms and standards for structural planning in Tuvalu, Australian standards are generally referred to in design. However, it is not mandatory to observe the standards but it is left to the responsibility of the main body of planning which norms and standards to adopt, so that structural planning for facilities to be built under foreign donors are planned in accordance with the donor country's standards.

3.1.3 Governance System

This section identifies the existing type of governance arrangement in Tuvalu, especially in the Funafuti community, as shown in **Figure 3.1**. Central government, parliament and Island Court have their bases in Fongafale islands but have own authorities over the whole country including the outer islands.

On the other hand, it seems a complicated local governance system in the context of developing a new administration system. The concept of local sovereignty highlighted the importance of localizing powers and authority, which documented in the FaleKaupule Act of 1997. The importance of the existing traditional leadership in major decision-making was recognized under the Act, a joint traditional and introduced governing system was formalized to locally address priority issues within each community. The new form of governance passed by the parliament of Tuvalu, devolved authority to the FaleKaupule and Kaupule (two separate bodies) to work together in addressing community affairs in order to promote decentralization. It also enables the island community to have a greater say in their development and to work out possibilities that suit their local needs.

The FaleKaupule is a traditional assembly in each island of Tuvalu that was composed in accordance with customs and tradition. The FaleKaupule is conferred greater control over the affairs and activities of the islands by vesting in them powers and functions once vested in the island councils. Basically, the FaleKaupule is the supreme decision-making body for all community matters that are of public interest or political importance, with the Kaupule as the executive arm within the community.
Funafuti is geographically divided into seven village areas, and a village leader is appointed for each area but without practical authority. The majority (75%) of the total population in Funafuti has moved from outer islands to Funafuti[1], and residents from each island have formulated their own community groups in Funafuti. There are eight Island Representatives in Funafuti who play an important role in coordinating among central government, island Kaupule and their own community.

[1] Basic Table of Population and Housing Census 2002

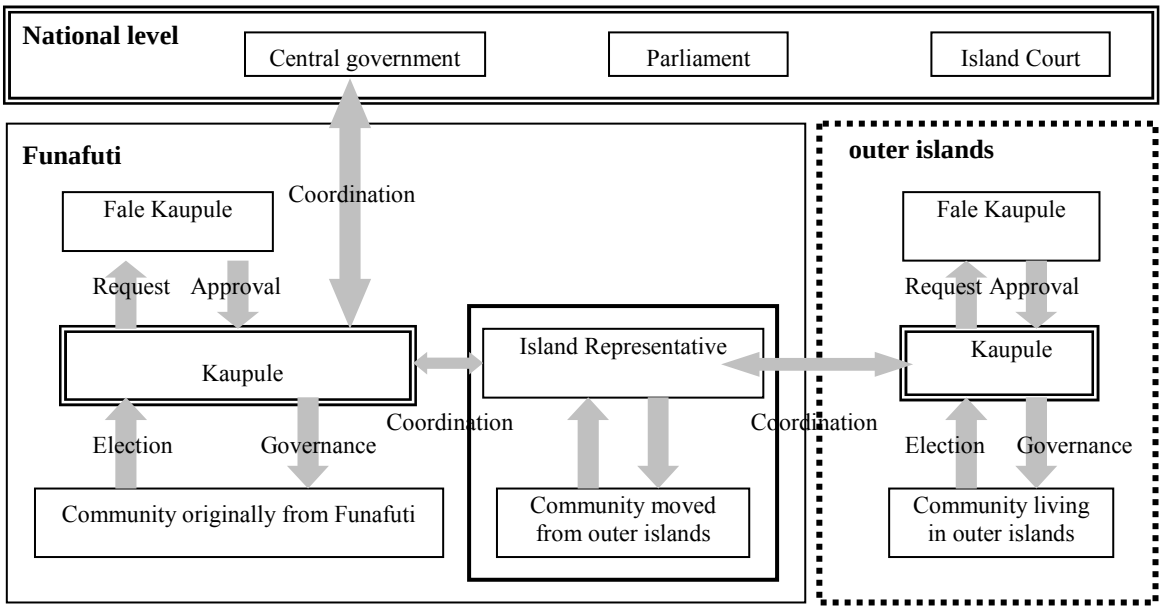


Figure 3.1 Governance System in Tuvalu

(1) Central Governments

The central government consists of the following ministries and departments (**Table 3.1**). In addition, several public corporations have provided public services. The central government pays for almost all education and health services with very little attempt at cost recovery, and heavily subsidizes basic facilities such inter-island shipping, the electricity system, and waste management.

Table 3.1 Ministries and Departments in Tuvalu

Ministry	Department	Ministry	Department
Office of the Prime Minister	Foreign Affairs	Finance & Economic Planning	Planning & Budget
	Tuvalu High Commission		Central Statistics Division
	Personnel & Training		Customs
	Labour		Postal
	Permanent Mission of Tuvalu to the UN		Treasury
	Meteorological		Inland Revenue
	Tuvalu Media		Aid Management
Communications, Transport & Tourism	Marine	Youth & Sports	Education
	Aviation		Primary Education
	Information, Communication & Technology		EFL Secondary Education
			Library
			Sports
	Tourism		Pre-service scholarships
			Youth
Natural Resources & Environment	Agriculture	Home Affairs & Rural Development	Rural Development
	Fisheries		Community Affairs
	Lands & Survey		Women Development
	Environment		Culture

Ministry	Department	Ministry	Department
Public Utilities & Industries	Energy	Health	Health Administration
	Public Works		PMH (Curative)
	Industries		Primary and Preventative Health Service

Source: Tuvalu Government. (2008) National Budget.

(2) Parliament

Tuvalu became independent from England in 1978 and an associate member of the Commonwealth thereafter. Tuvalu has a constitutional and parliamentary democracy system which gives authority to the Governor General as the head of state. The parliament has fifteen elected local members who are elected every four years from eight outer islands except Niilakita islands, and the present members won their seats in an election in August 2010. Even people not living on their island of birth, but living in Funafuti, can represent their island in parliament. The prime minister and deputy-prime minister are selected among these members of parliament, and there are basically no political parties.

(3) Governance System in Funafuti

Funafuti society is structured by two groups, FaleKaupule and Kaupule, as shown in **Figure 3.2**. The Falekaupule has the highest Authority in the Funafuti Community in terms of making final decisions. It is made up of the Island leader, the Deputy Island leader, and the FaleKaupule Funafuti. Almost all members of the Falekaupule are elderly males, which shows the absence of women and youths in this decision making body.

The Island councils, now afforded the title Kaupule a body elected by registered voters after the recognition of the Falekaupule Act in December 1997, function as the executive arm of the Falekaupule. The Funafuti Kaupule has six elected local members, whereby the Kaupule President and Kaupule Vice President are selected among them. The other four members represent different development sectors within the Kaupule. The Funafuti Kaupule is responsible for the basic management of island community, including maintaining local order through the island court and raising local revenues through various taxes and licenses. These services were previously provided for people born in Funafuti, however, have been currently expanded for people from outer islands due to a flow of population into Funafuti. In actuality, the Kaupule has faced difficulties to provide sufficient services for all residents due to its limitation in terms of staff numbers and budget.

Any external issue or development matter that the central government will implement and requires the community's support shall be channeled through the Kaupule before going to the Falekaupule for final deliberation and final decision. In other words, the Kaupule acts as the go-between in the project implementation.

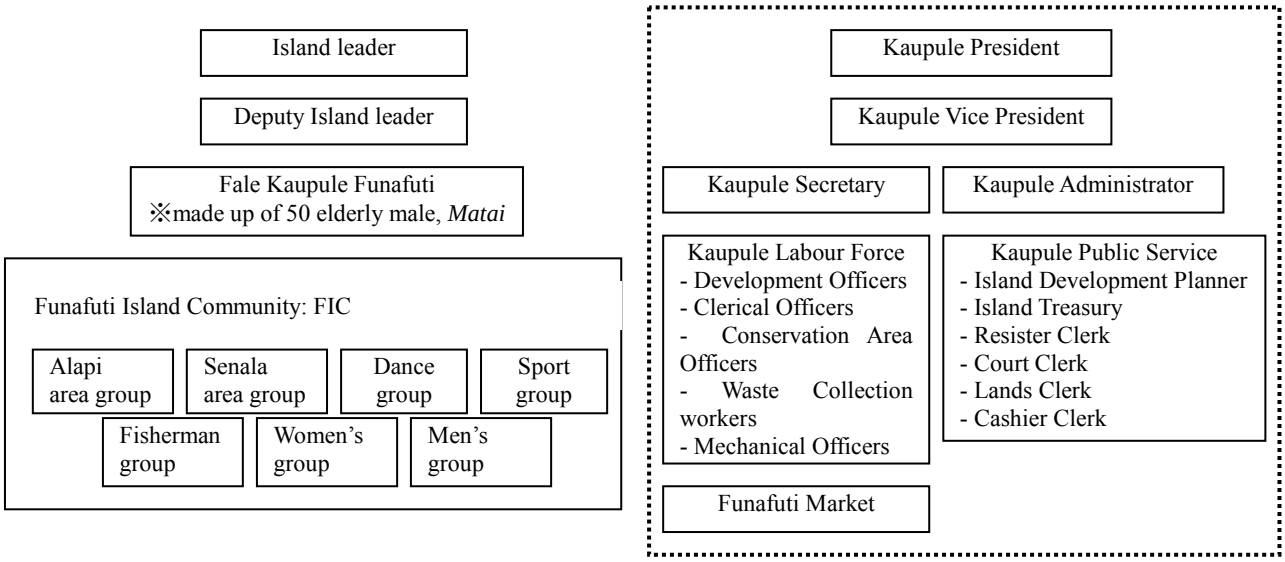


Figure 3.2 Governance System in Funafuti

3.1.4 Village Boundary

There are seven (7) villages in Fongafale Islet. Namely, from the north to the south, Asagatau Paka (Tengako Islet), Lofeagai, Fakai Fou, Senala, Alapi, Vaiaku, and Kavatoetoe.

Among these, the original villages of the islet are Senala and Alapi, whose elevation is slightly higher than other areas of the islet. Other villages are made later for incoming people mainly from other islands.

The ocean side of Fakai Fou and Vaiaku Vilages over the airstrip is used for the government and no residents are living in the section.

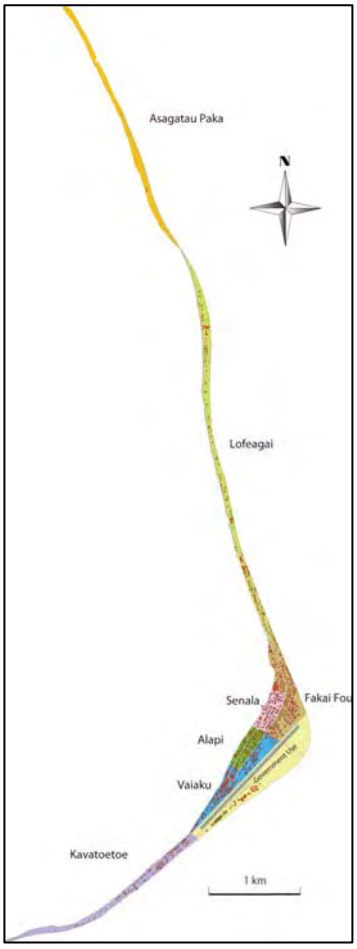


Figure 3.3 Village Boundary

3.1.5 Population Structure

The total enumerated population of 9,561 included 9,359 permanent residents. The total population in Tuvalu increased by 5.7% (518) during the intercensal period, 1991–2002 (**Table 3.2**).

Population trends are considerably different between the capital of Tuvalu, Funafuti, and the outer islands. The resident population increased from the previous census in 1991, rising from 8,750 usual residents living in Tuvalu in 1991, to 9,359 in 2002. This increase of 7% during the intercensal period equates to an average annual rate of growth of 0.6%. The resident population of Funafuti had increased by 10.8% during this period from 3,576 people in 1991 to 3,962 in 2002. The average resident population density of the outer islands was 236 people per square kilometer, while Funafuti had 1,420 people per square kilometer. In other words, more than 40% of total population is living in Funafuti which has a share of only 10% of total area, and Funafuti residents are surely living in a heavily populated area compared to the outer islands. The flow of population from the outer islands to Funafuti has remarkably increased since most opportunities such as higher education and employment are available in Funafuti.

Table 3.2 Population Changes in Tuvalu (1991-2001)

	Area (km^2)	Total population		Population distribution (%)	Population growth rate (%) (1991-2002)	Average annual growth rate (%)	Density (person per km^2)
		1991	2002			2002	
Total population	25.6	9,043	9,561	100	5.7	0.5	365
Resident population		8,750	9,359		7.0	0.6	
Funafuti	2.79	3,576	3,962	42.3	10.8	0.9	1,420
Outer Islands	22.84	5,174	5,397	57.7	4.3	0.4	236

Resident population: Total population excluding short-term visitors, tourists and temporary contract workers

Source: Basic Table of Population and Housing Census 2002

Table 3.3 shows the resident population in Tuvalu by island and the composition of Funafuti residents by island. One fourth of total population in Tuvalu are Funafuti residents by birth, while the rest of residents originally came from the outer islands.

Table 3.3 Resident Population in Tuvalu by Island, and the Composition of Funafuti Residents by Island of Birth

Tuvalu										
	Funafuti	Nanumea	Nanumaga	Niutao	Nui	Vaitupu	Nukufetau	Nukulaelae	Nutakita	N/A
9,359	1,004	1,560	1,063	1,453	835	1,694	1,149	461	2	138
100.0%	10.7%	16.7%	11.4%	15.5%	8.9%	18.1%	12.3%	4.9%	0.0%	1.5%
Funafuti										
3,962	991	662	360	634	232	476	475	120	25	132
103.7%	25.0%	16.7%	9.1%	16.0%	5.9%	12.0%	12.0%	3.0%	0.6%	3.3%

Source: Basic Table of Population and Housing Census 2002

Funafuti is geographically divided into seven villages as shown in **Figure 3.4**. **Table 3.4** shows the population of each village.

Table 3.4 Population in Each Village Tuvalu (1991-2001)

Village	Lofeagai	Teone	Fakaifou	Senala	Alapi	Vaiaku	Tekavatoetoe	Others	Funafuti Island
Population	399	540	1007	589	1024	516	343	74	4492

Source: Basic Table of Population and Housing Census 2002

Previously, most of the people on Fongafale Island used to live in Tingako Islands; however, they migrated to Funafuti, especially Senala, Alapi and Vaiaku areas at lagoon side after the Second World War. Therefore, Funafuti residents who were born on Fongafale Island are in the majority in these three areas. Residents who moved from the outer islands are mostly living in other areas like Lofeagai, Fakai Fou, Kavatoetoe, etc. These people have formulated own community groups by island and have organized community activities like community meetings and festivals.

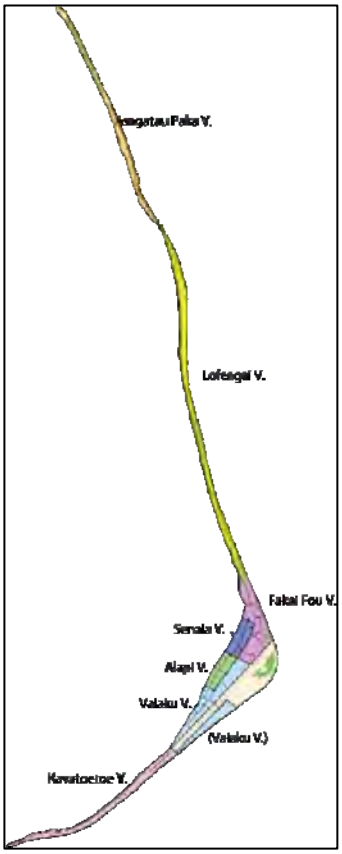


Figure 3.4 Village Areas in Funafuti

3.1.6 Gender

(1) International Conventions

Tuvalu government is party to the Convention on the Rights of the Child (September 1995) and the Convention on the Elimination of all forms of Discrimination Against Women (October 1999). According to most of the MDG indicators for gender equity, the status of women in Tuvalu is high and rising. Also, Tuvalu is rated first among 15 Pacific Island countries based on UNDP's gender development ratio (Te Kakeega II 2005-2015).

(2) Legislation

Section 27(2) of the Tuvalu Constitution lists the prohibited grounds of discrimination, however, the words 'sex' or 'gender' are not listed as prohibited grounds of discrimination[2]. Tuvalu National Gender Policy, which aims at achieving gender equality and elimination of discrimination against women, was developed.

(3) National Development Plan

Te Kakeega II, National Strategy for Sustainable Development (2005-2015), set the eight strategic areas (or sectors) directions the nation should take, based on the issues that are considered to be (and are) national priorities. A gender issue is included in 'Social Development' strategy which focuses on health and social welfare. The key gender policy objectives from 2005 to 2015 are to "Promote gender equity" and "Expand the role of women in development". According to Te Kakeega II, the following issues and challenges for women are:

- the burden of traditional chores,
- the lack of marketing facilities for their products,
- insufficient representation in community decision-making,
- inequitable laws governing the distribution of land, and
- unfair custodial rights.

In addition, it is suggested that in the outer islands gender equality is less robust than it is in Funafuti. To overcome the above matters, the gender priorities and strategies for better integrating the role of women in development and creating more economic opportunities for women are set out for development over the next ten years as follows:

- Integrate the role of women, and the issue of gender and development in implementing Te Kakeega II strategies.
- Review laws governing the distribution of land and the custodial rights of women.

[2] TUVALU NGO Submission to the United Nations Universal Periodic Review, [RE-SUBMITTED TO THE CEDAW PRE-SESSION WORKING GROUP OF THE 44th CEDAW SESSION], Submission of the Legal Literacy Project, Tuvalu National Council of Women, Tuvalu, Third Session of the Universal Periodic Review Working Group, 1-12 December 2008

- Provide women with small business and entrepreneurial training, and access to appropriate credit facilities.

(4) Relevant organizations

Governments and other organizations which are responsible for gender issues are: central government, Kaupule, NGOs and women's group in the community. The role and responsibility of each organization for gender issues are as shown in **Table 3.5**.

Table 3.5 Organizations Related to Gender Issues

Organization	Role and responsibility
[Central government] Department of Women Development (Ministry of Home Affairs and Rural Development)	・ Development of policy documents related to gender issues. ・ Enforcement of International Conventions (the Convention on the Rights of the Child, and the Convention on the Elimination of all forms of Discrimination Against Women. ・ Cooperation with other government departments for women empowerment. ex) Requested the personnel department to allow a quota of seats in parliament for women (The ratio of women to total government staff as of 2009: approximately 30%). ・ Development of an implementation plan (Corporate Plan (2007-2009) (to be amended to a new Plan (2010-2012)). ・ Responsible body for women's groups in Fongafale Islands and outer islands.
[Council] Funafuti Kaupule	・ Reinforcement of community activities in Funafuti including women's groups. ・ Coordination between central government and FaleKaupule.
[NGOs] TANGO	・ In the mangrove planting Project in Funafala and outer islands, they organized the Workshop to raise awareness of women on the importance of mangroves for coastal management.
[NGOs] Tuvalu National Council of Women	・ Operated as an umbrella NGO for women in Tuvalu since 1977, especially targeting sixteen women's group. ・ One of the members of TANGO. ・ Main counterparts for central government (Department of Women Development, Ministry of Home Affairs and Rural Development) ・ Implementation of the Project activities for better integrating the role of women in empowerment and creating more economic opportunities for women. ・ A committee consisting of representatives of each women's group has been formulated. Regular meetings have been organized for every two years (Next meeting to be held in 2010), and all gender matters like Domestic Violence (DV) and women's right are discussed in the meeting. ・ Proposal on Coastal erosion Project targeting outer islands was made and has been approved by GEF. The Project will be initiated in 2010 in cooperation with the UNDP Project, and focus on coastal management by planting mangroves, coconut trees and Giant trees *(Fetau)*. The Department of Environment and the Ministry of Agriculture are implementation bodies. Similar projects were undertaken targeting Nanumea Islands, Nukuraia Islands and Nui Islands with assistance of Canada and focused on raising awareness on mangrove, especially its ecological role and the need of protection, so that other islands besides these will be targeted in the GEF Project.

[In the Community] Women's groups	・ There are 16 women's groups; 8 groups in Fongafale islands by island of birth, 8 groups in outer islands. ・ Each church groups has its own women's group. ・ It is made up of a President, Secretary, Treasurer and committee members, and the President is selected from among committee members. ・ The meeting of Women's groups in Fongafale Islands have been held at *Fale* of FaleKaupule on a monthly basis, and discuss subjects such as the construction of playground, planning of sport festivals, church activities, etc.

(5) Matters to be considered

① Gender issues from socio-economic aspects

・ Historically, Tuvalu is a patriarchal society where women's roles are confined to the homes, and decisions of matters outside the family are left to the men.
・ The main sources of income for women are: handicraft, small business (including selling ice cubes, catering for school, selling homemade cakes and sewing)
・ Women have particularly limited choices for occupation, and there are few possibilities for women to get a job in higher social status fields like doctor and lawyer.
・ Women and youth have limited access to education, training and livelihood opportunities.
・ Despite the high incidence of domestic violence, there are many instances where cases of domestic violence, sexual assaults and rape against women are not reported due to lack of awareness of women's rights and traditional and cultural pressures on victims.
・ There is significant discrimination in the laws relating to inheritance of lands in Tuvalu. Land scarcity is a pressing problem in Tuvalu and the discriminatory land laws put women in a further disadvantaged position. Section 15 of the Native Lands Act (NLA) 1956 and section 9 of the Tuvalu Lands Code 1962, confer more advantages to the children of first spouses over second spouses, and allow for more lands to be given to the eldest son than the daughters in the distribution of lands.

② Gender issues in the decision making process

・ There is no participation of women in the parliament of Tuvalu as of October 2010. The laws of Tuvalu allow equal eligibility to men and women to enter parliament, however, since independence in 1978, Tuvalu has had only 1 female politician and that was in 2004. In the last general election 2006, 2 women contested in the election and neither of them won a seat[3].
・ There is a lack of will on the part of women to participate in decision-making forums beyond the home and a lack of support for the participation of women at all levels of decision-making, especially in the FaleKaupule meeting. Women and youth are often excluded from community decision-making as the following survey found. A survey in 2003 asked women and youth about their involvement in community decisions. On the other hand, women are inclined to speak out in meetings targeting women only.

[3] TUVALU NGO Submission to the United Nations Universal Periodic Review, [RE-SUBMITTED TO THE CEDAW PRE-SESSION WORKING GROUP OF THE 44th CEDAW SESSION], Submission of the Legal Literacy Project, Tuvalu National Council of Women, Tuvalu, Third Session of the Universal Periodic Review Working Group, 1-12 December 2008

- Almost all members of the Falekaupule, which is the highest authority in the Funafuti Community in terms of making final decision, consists of elderly males, which shows the absence of women and youths in this decision making body. Any matter or proposal made by women's group needs to receive approval from the FaleKaupule and have to be presented in the FaleKaupule meeting by the President or Secretary of the women's group, however, their proposals have often been turned down.
-

③ Gender issues in terms of coastal management[4]

- In the Planting Mangrove Project implemented by the Tuvalu National Council of Women, women have taken an important part in terms of implementation. In the outer islands, mangrove forests have been cut down by women for making handicraft, so that mangrove is the main income source for women. These handicraft goods are sold at Handicraft Center adjoining the airport, however, this has not been operated well. It seems difficult to ban cutting mangroves, and it is highly recommended to use mangroves appropriately. On the other hand, mangroves are seldom cut in Funafuti these days.
- In the field of climate change, it is recognized that women are especially vulnerable. If a coastal disaster caused by rising sea-levels or extraordinary weather occurs, women will be inferior to men physically, especially pregnant woman and the elderly.

3.1.7 Tourism

Tourism is under the jurisdiction of the Ministry of Trade, Tourism and Commerce in Tuvalu. In *Te Kakeega* II National Strategy for Sustainable Development 2005-2015, the eight strategic areas are defined, in which Tourism is included under the area of Natural Resources and listed as one of the strategic sectors for development.

In 2002, GDP of the Hotels and Restaurants was estimated at 3.7 million AU$, which accounted for 13.5% of the GDP of the country[5]. Nonetheless, arrival visitors including international tourists are rather small, 1,130 visitors in 2007, in which numbers of visitors whose purpose of visits are holiday and/or vacation, are less than 200 per annum.

[4] Based on the interview with Tuvalu National Council of Women (October 2008).
[5] Tuvalu Central Statistics Division

Table 3.6 Visitor Arrivals by Purpose of Visit

	Total Visitors	Purpose of visit				
		Holiday / Vocation	Business / Official	Friends / Relatives	Transit / Stopover	Other Purpose
2000	1,079	135	523	122	240	59
2001	1,140	104	486	318	165	67
2002	1,313	168	277	630	79	159
2003	1,377	184	343	582	79	189
2004	1,290	164	854	175	54	43
2005	1,085	178	566	199	69	73
2006	1,135	189	178	523	119	126
2007	1,130	135	523	122	240	59

Source: Tuvalu Central Statistics Division,

For tourism development, Te Kakeega II stress firstly to increase the number of tourist arrivals. Besides the fact that the most parts of the country remain pristine, Tuvalu does not have any special tourist attractions which neighboring countries in the region do not possess. It aims that the natural attraction of the Funafuti lagoon should be the basis for modest growth in the tourism industry, and that to support the development of an eco-tourism industry, and to support and develop new private sector tourism- related enterprises.

3.1.8 History

Topography of Fongafale Islet is closely related with its history. Fongafale Islet is used as a war front military base by the United States against the rapid southward progress of Japan. An airfield and a naval base and other related facilities were constructed in emergency in 1942. Prior to the construction, many of the residents were relocated to other islets. Tafua pond was partially filled in the construction of the Airbase. The lagoon side reef was also filled and a quay was made with wooden retaining wall; and a ship passage along the quay was made by excavating reefs. Those filling materials (rabbles of reefs) are obtained from the north and south part of the Fongafale island, including Tengako Islet.

Brief History of Tuvalu

1916 Gilbert (Kiribati) and Ellice Islands (Tuvalu) became British colonies

1942-45 U.S. Forces stationed in Tuvalu (Refer Table below)

1972 Hurricane *Bebe* strikes Funafuti

1978 Independence from U.K.

1981 Deep-water wharf opened at Funafuti

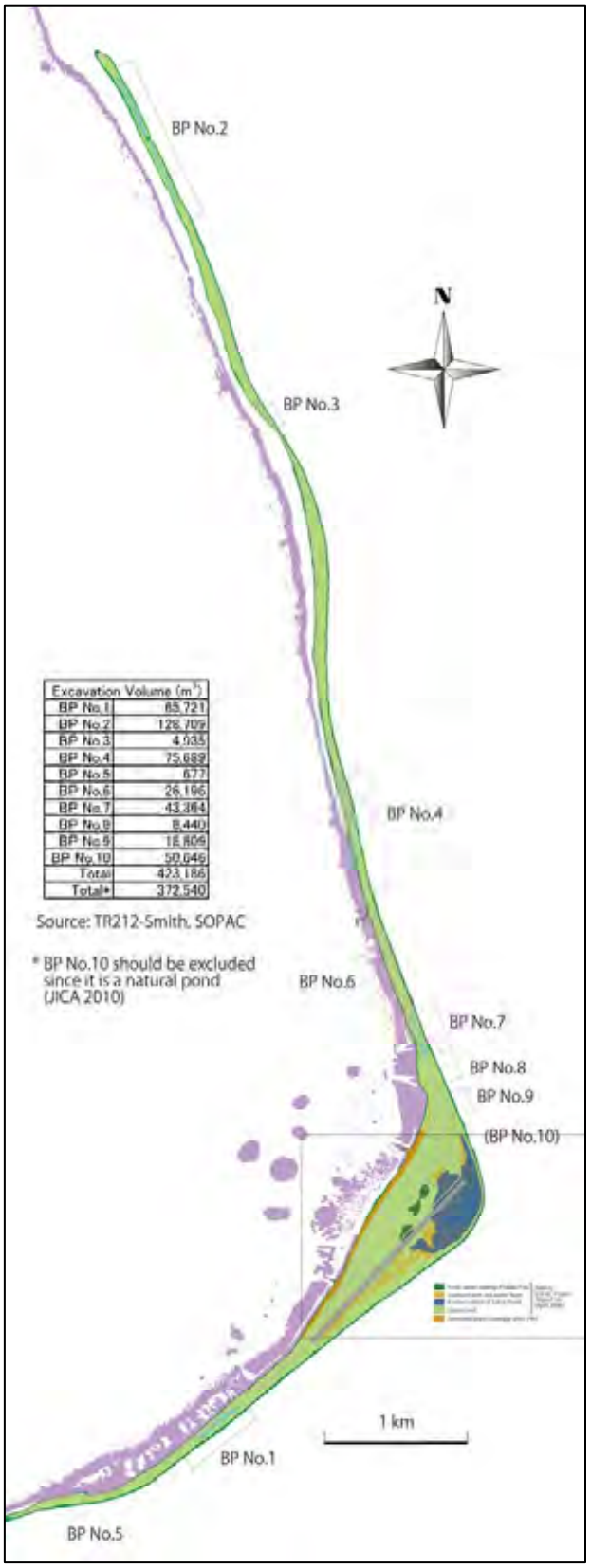
Table 3.7 History of Fongafale Islet during WW II

		Fongafale		Other Area in Pacific
1941	December			The Japanese attacked US Navy in Hawaii, and advanced up to Kiribati
1942		Residents in Fongafale was moved to Funafala, Papaelise, Amatuku, Fualefeke, Tepka, and Faatato		Battle of Midway
	October 2	Eleven warships arrived in Fongafale (Marines began to build airstrip, sea plane ramp and other facilities)		
1943	April	Fist strike from Tuvalu against the Japanese base in Nauru	The Japanese bombed Funafuti 9 times.	Battle of Tarawa
	October	43 ships entered the lagoon		
	November	131 ships anchored in the lagoon.		
	December	The number increased to 141. Over 6,000 Americans based in Tuvalu.		
1944	January	174 ships anchored in the lagoon		
	Mid 1944	The U.S. troops began withdrawing from Tuvalu, advancing toward the north		
1945	August	Entire U.S.troops had gone from Tuvalu by the end of war		Japan surrenders

Source: "*Tuvalu A History*", Institute of Pacific Studies and Extension Services, University of the South Pacific and Ministry of Social Services, Government of Tuvalu (1983) Fiji Times & Herald Limited

Locations of the borrow pits are shown in **Figure 3.5.** For construction of air field base, 370,000 m^3, approximately, of aggregates (rabbles of reef) were excavated from north and the south of the Islet ridges are excavated and carried in.

For carrying the fill materials from Tengako Islet to Fongafale Islet, causeway was constructed to connect the two islands.



Excavation Volume (m^3)	
BP No.1	65,721
BP No.2	126,709
BP No.3	4,035
BP No.4	75,689
BP No.5	677
BP No.6	26,196
BP No.7	43,364
BP No.8	8,440
BP No.9	18,809
BP No.10	50,046
Total	423,186
Total*	373,540

Figure 3.5 Locations of Borrow Pits

The central part of Fongafale Islet was used for the air and naval military base. Approximately 1.5 km of runway was constructed by filling half of Tafua Pond (Runway of **Figure 3.6** is the present runway). An access road was constructed to connect the air field and naval base. Another access road (20 m wide) was constructed by filling the lagoon along the quay. The quay is made by wooden retaining wall. Reef in front of the quay is excavated for free activities during low tide. The naval base was furnished with a seaplane jetty at the north, and moorings for rapid torpedo boats (T.P. boats) at the south.

Today, except the runway, all facilities are collapsed leaving rubbles of a retaining wall, which is said to be "erosion is in progress".

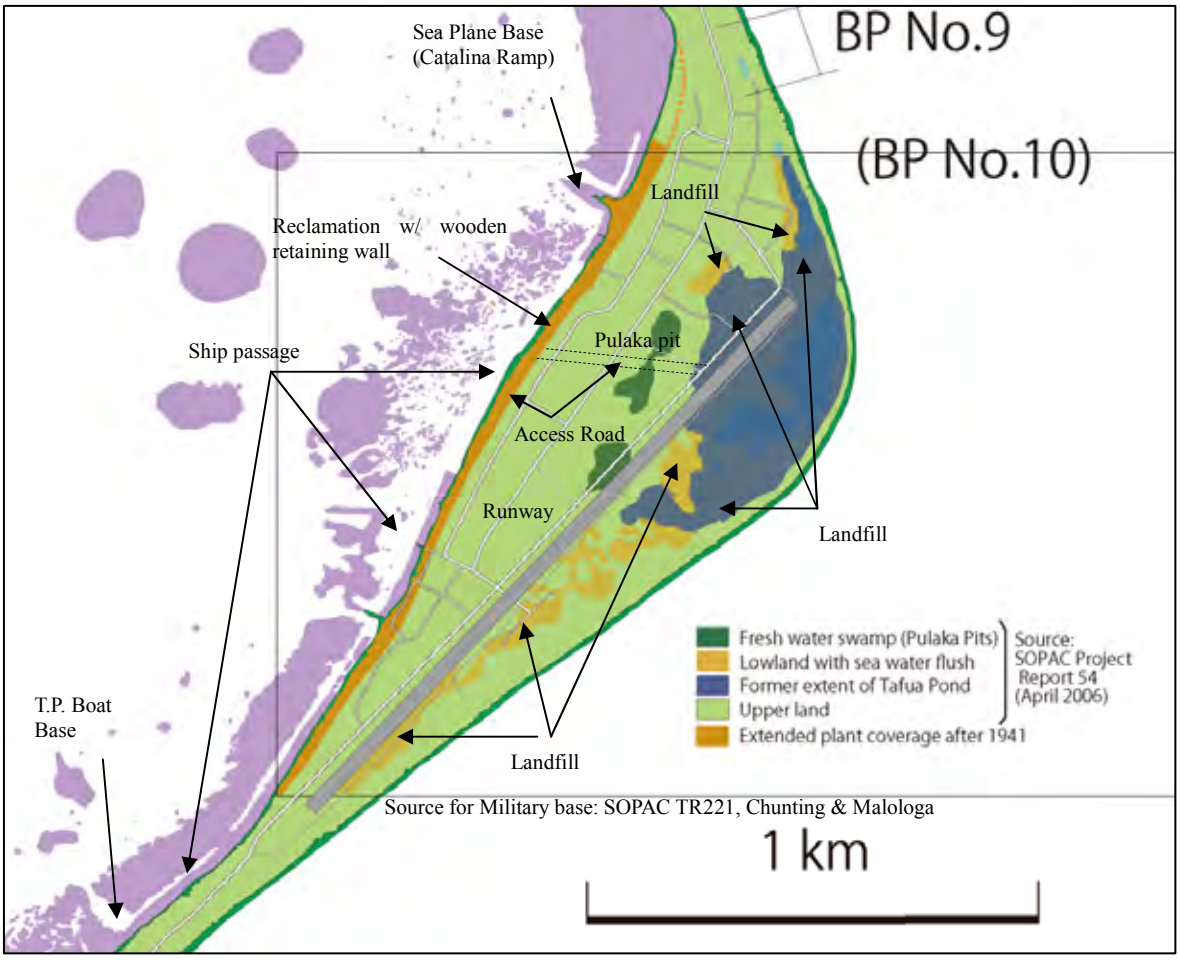


Figure 3.6 The Naval Base and Previous Landform

3.1.9 Development Plans related to Littoral Regions

The current National Development Plan in Tuvalu is Te Kakeega II, National Strategy for Sustainable Development 2005-2015[6]. Te Kakeega II raises following constraints, such as a

[6] Te KakeegaII, National Strategy for Sustainable Development 2005-2015

limited natural resource base, widely scattered and sparsely populated island geography, small domestic market with little potential for economies of scale, expensive access to international markets, limited business opportunities in the domestic economy, land and capital market development constrained by small size, social values and traditions, and poor absorptive capacity for major investment and so on.

And as structural weakness of the country: large and continuous trade imbalance, large public sector with a low productivity rate and lack of focus on customer services, pervasive government ownership of enterprise activities, many of which require fiscal concessions and (or) subsidies, small under-developed private sector which accounts for only one-quarter of GDP, underdeveloped financial system characterized with low domestic resource mobilization and so forth are listed.

Under these circumstances, it places the following as eight strategic areas:
1. Good Governance.
2. Macroeconomic Growth and Stability.
3. Social Development: Health, Welfare, Youth, Gender, Housing, and Poverty Alleviation.
4. Outer Island and Falekaupule Development.
5. Employment and Private Sector Development.
6. Human Resource Development.
7.Natural Resources: Agriculture, Fisheries, Tourism, and Environmental Management.
8. Infrastructure and Support Services.

As for the environmental management, which is included in the Natural Resources area, it is said that it has to confront two key challenges:

1) the numerous issues arising from the growing urbanization of Funafuti, and
2) the national impacts associated with climate change and sea level rise, specifically salt-water inundation of pulaka pits, coastal erosion and flooding, which are blamed either wholly or partly on global warning.

3.1.10 Tuvalu's Efforts on Climate Change and Donor Trends

a) Tuvalu's Efforts

The Seventh Conference of the Parties (COP7) of the United Nations Climate Change Conference decided on providing support to developing countries for the establishment of a National Adaptation Programme of Action (NAPA). In response, a NAPA was established in Tuvalu through discussions with stakeholders and approved in a cabinet meeting in May 2007. Afterward, the preparation for the implementation of the NAPA began with the support from the Global Environment Facility (GEF), with organizations such as UNDP, SPREP, and SOPAC providing follow-ups in a variety of fields. The NAPA of Tuvalu lists the following efforts as priority

projects:

Table 3.8 Priority Projects in Tuvalu National Adaptation Programme of Action (NAPA)

Priority	Field	Project	Principal agencies in charge	Required cost (US$)
1	Coastal area	Increasing resilience of coastal areas and settlement to climate change	DOLS, PWD, Kaupule	1,906,500
2	Agriculture	Increasing subsistence pit grown pulaka productivity through introduction of a salt-tolerant pulaka species	DOA, Kaupule	2,220,000
3	Water	Adaptation to frequent water shortages through increasing household water capacity, water collection accessories, and water conservation techniques	PWD, Kaupule	2,675,300
4	Health	Protecting community health through control of vector borne/climate sensitive diseases and promoting community access to quality potable water	DOH, PWD, CBOs, Kaupule	381,500
5	Fishery	Strengthening of community based conservation programmes on highly vulnerable near-shore marine ecosystems	DOF, DOE, Kaupule	636,500
6	Disasters	Strengthening community disaster preparedness and response potential	DMO, MET, DOE, Kaupule	462,000
7	Fishery	Adaptation to near-shore coastal shellfish fisheries resources and coral reef ecosystem productivity	DOF, DOE, Kaupule	388,000
			Total	8,669,800

b) Donor Trends

Major donors in relation to climate change include bilateral donor countries and the EU, as well as UNDP and GEF, multilateral assistance agencies which play major roles in financial assistance and technological support, and regional organizations in Oceania with recognized presence. **Figure 3.7** shows the donors related to climate change.

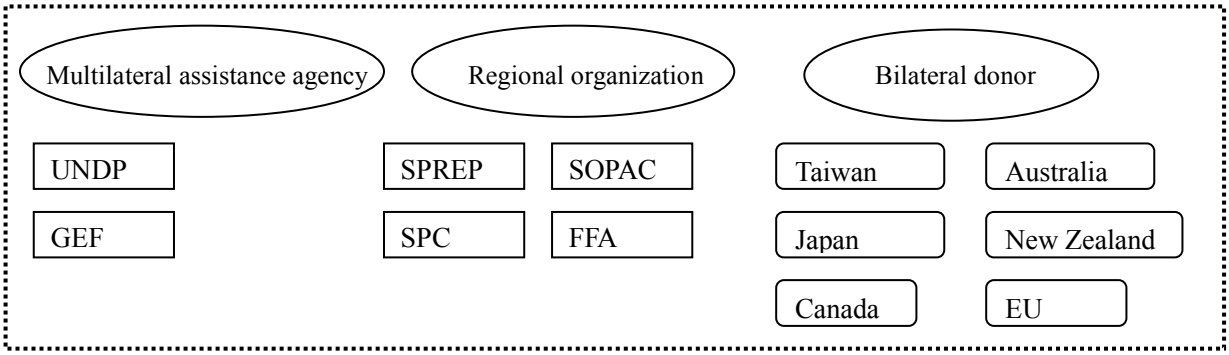


Figure 3.7 List of Donors That Provide Assistance Related to Climate Change

AusAID

The two major items in Australia's assistance to Tuvalu are (1) Respect for the regional initiative of Oceania and (2) Water and Health. AusAID, within which the Department of Climate Change has been founded recently, is expected to focus on assistance related to climate change. Having the perception that the project implementation capability of the Tuvaluan government needs improvement, AusAID is participating in administrative and financial reform through the Tuvalu Trust Fund (TTF), in an effort to address the climate change problems in an indirect way.

EU

The EU, under the National Indicative Programme (NIP)—a bilateral cooperation program—has been utilizing the European Development Fund (EDF) in various programs aimed at poverty reduction. So far, the EDF9 (2003-2007) has been completed, and the basic document of EDF10 that covers the years 2008 through 2013 was agreed upon in the latter half of 2007. EDF10 is aimed at sectors focusing on the water and health fields including waste management and sustainable energy, and the involvement of parties other than the government agencies, such as NGOs, was also agreed upon.

UNDP

UNDP's assistance related to climate change mainly consists of assistance in establishing a NAPA in collaboration with GEF (US$200 thousand), assistance for the National Capacity Self Assessment for Global Environment Management, and assistance such as the invitation to regional seminars and workshops. At present, UNDP is working with GEF to provide assistance in the creation of biodiversity strategies and action plans, sustainable land management, follow-up to the NAPA, and small-scale grant aid programs. UNDP is also providing assistance in the Integrated Water Resource Management (IWRM) and the Pacific Adaptation to Climate Change (PACC) in collaboration with GEF and SPREP.

Taiwan

Taiwan, having diplomatic relations with Tuvalu, is actively providing grant aid and technical cooperation programs to it. In 2008, the grant aid was mainly used for the repair of telecommunication systems, scholarships, medical services, electric power, other subsidies, purchase of equipment, assistance for participation in international conferences, salaries for foreign experts (such as ICT and doctors), and the repair of boats. As technical cooperation, experts in agriculture and stock raising have been dispatched to Tuvalu, providing assistance in organically grown kitchen gardens, pig farming, and aquaculture.

Regional organizations

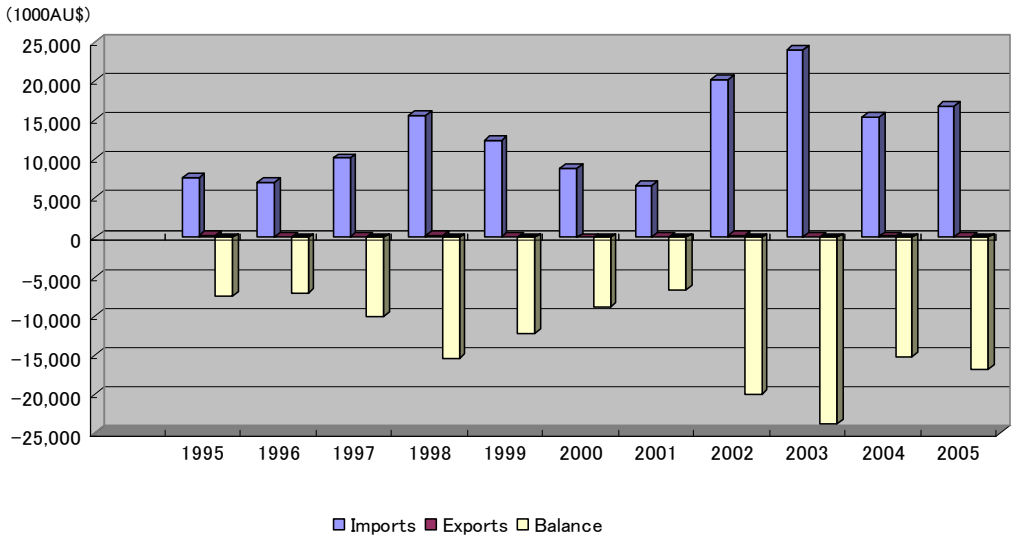
Donors often implement assistance programs in connection with the activities of research institutions of regional organizations. SOPAC and SPREP, in particular, have conducted many

surveys in South Pacific countries including Tuvalu and created reports on policies, strategies, action plans, management plans, and survey results while pursuing the development of capacities through workshops, seminars, etc.

3.2 Economic Conditions

3.2.1 Industrial Structure

Tuvalu's total population of about 10,000 is scattered over a wide area, which make it difficult to form a viable domestic market. As the coral reef islands, land resources are scarce and high productivities of agriculture and fisheries are not expected. Due to the scarcity of domestic resources, the population relies heavily on imports in terms of foodstuffs and other daily necessities, and as a result the trade deficits are immense. In 2005 the value of exports was only 0.47% of the value of imports. The purchase of imported goods per capita occupied 75% of the GDP per capita, or the value of import of AU$ 2,130 (2002).



Source: Tuvalu Central Statistics Division,

Figure 3.8 Trade Balance

About 40 % of the total population of Tuvalu lives in the Funafuti atoll. There are no outer islands of population over 900, except Vaitupu, which has a population of 1,300. Subsistence economy has remained dominant in the outer islands.

Tuvalu's GDP in 2002 had reached 1.7 times that of 1998, attributed to development of tertiary industries such as the transportation and telecommunication sectors and contributions of public expenditures. Contribution of the government sector to GDP was 26.1% in 2002, and state-run

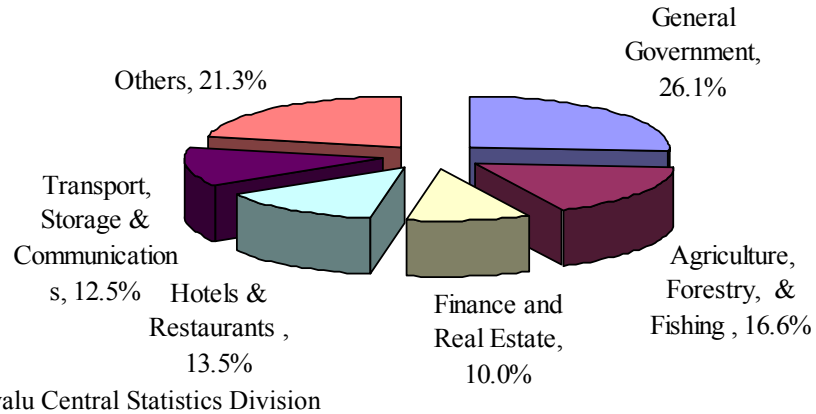
companies dominate in the other sectors. On the other hand, due to the decline of subsistence production in the outer islands, the ratio of the agriculture and fisheries in GDP has declined from 26% to 16.6% during the same period.

Table 3.9 Gross Domestic Product (GDP) (Current) Estimates

(Value: Thousand A$)

Sector	1996		2000		2002	
	Value	Ratio	Value	Ratio	Value	Ratio
Agriculture, Forestry, Hunting & Fishing	4,097	26.0%	4,322	18.0%	4,565	16.6%
Mining and Quarrying	82	0.5%	194	0.8%	237	0.9%
Manufacturing	578	3.7%	1,124	4.7%	1,433	5.2%
Electricity, Gas & Water Supply	585	3.7%	1,159	4.8%	1,370	5.0%
Construction	528	3.3%	793	3.3%	1,016	3.7%
Hotels & Restaurants	2,754	17.5%	3,166	13.2%	3,700	13.5%
Transport, Storage & Communications	1,361	8.6%	2,499	10.4%	3,429	12.5%
Finance and Real Estate	1,915	12.1%	3,586	14.9%	2,760	10.0%
General Government	3,235	20.5%	6,800	28.3%	7,188	26.1%
Other Community, Social & Personal Activities	1,182	7.5%	1,390	5.8%	1,794	6.5%
Less: Imputed Bank Charges	-555		-991		-1,295	
Total GDP (Current)	15,762		24,042		27,492	

Source: Tuvalu Central Statistics Division,



Source: Tuvalu Central Statistics Division

Figure 3.9 Components of GDP (2002)

3.2.2 Transportation

Tuvalu is a small island country much further from major international markets than other islands countries in the region. There are only two international flights a week by a middle range airplane with reciprocating engines between Suva in Fuji and Funafuti, and if busy an

extra flight a week may be arranged.

Funafuti Port is virtually the only international trade port in Tuvalu which can accept import cargos from foreign countries. During the peak year, in 1998, Funafuti Port handled 722 TEU import containers, and 2,652 m^3 of international bulk cargo. In 2002, it handled 400 TEU import containers and 1,220 m^3 import bulk cargo. As for the export cargos, the largest volume exported from the Funafuti Port in a year was only 193 m^3 in 1998. The number of international visitors by vessel is rather small, both incoming and outgoing passengers were around 50 in 2002. **Table 3.10** shows the volume handled and number of passengers by foreign vessels at Funafuti Port.

Table 3.10 Volume handled and Number of International Passengers at Funafuti Port

(Unit : Thousand AU$)	Container Cargo (TEU)		Bulk Cargo (m^3)		Passengers	
	Incoming	Outgoing	Incoming	Outgoing	Incoming	Outgoing
1997	622	569	1,972.59	83.21	43	27
1998	722	902	2,652.41	178.31	110	115
1999	663	707	2,003.54	192.77	77	83
2000	668	704	2,162.06	178.59	72	84
2001	546	505	1,485.57	100.76	59	65
2002	400	338	1,220.81	83.65	46	53

Source : Marine Department

After discharging at the Funafuti Port, imported goods are transferred to the inter-islands vessels for shipping to the outer islands. As an island country lacking domestic air flights, ocean transportation by vessels is a major means of transportation for Tuvalu and vital for supporting the lives of peoples in the outer islands. Vessels engaged in domestic shipping are the MV Nivaga II from the UK and the MV Manu Folau donated by the Japanese Government in 2004. These vessels handled 6,200 m^3 of cargo and carried 6,595 passengers in 2004.

Table 3.11 Domestic Cargo Handled at Funafuti Port

Year	2001	2002	2003	2004
Outgoing Volume	4,146.11	4,849.89	5,847.74	5,911.23
Incoming Volume	268.16	288.28	276.34	290.44
Total	4,414.27	5,138.17	6,124.08	6,201.67

(Unit : m3)

Source : Marine Department

Table 3.12 shows numbers of domestic inter-islands passengers.

Table 3.12 Number of Inter-islands Passengers

Year	2001	2002	2004
Inter-islands passengers	4,859	6,869	6,595

Source：Marine Department

3.2.3 Economic Indicators such as Income

The latest value of GDP estimated by the Government of Tuvalu is of 2002. GDP for 2002 was 27.5 million AU$ and GDP per capita was 2,814 AU$.

Table 3.13 Gross Domestic Product (GDP) - Summary

	1996	1999	2002
Gross Domestic Product (current prices) （value：thousand AU$）	15,762.6	21,213.7	27,490.2
Population	8,953	10,002	9,573
Gross Domestic Product (current prices) per capita （Value AU$）	1,760.5	2,135.7	2,814.5

Source: Tuvalu Central Statistics Division

The latest Economic Indicators of Tuvalu by ADB shows that Per capita GNI is US$ 2,972 in 2008. **Table 3.14** shows Tuvalu, Economic Indicators, 2004-2008 by ADB.

Table 3.14 Tuvalu, Economic Indicators, 2004-2008

Economic Indicators	2004	2005	2006	2007	2008
Per capita GNI, (Atlas method, US$)	2,223	2,353	2,401	2,725	2,927
GDP growth (% change per year)	4.0	2.0	1.0	2.0	1.5
CPI (% change per year)	2.8	3.2	3.8	2.2	5.3

Source: ADB, Asian Development Bank & Tuvalu, Dec. 2008

3.2.4 Land Use

Land use of Fongafale Islet is either residential area or governmental land (leased from private land owners). The following are the uses of the central part of the islet . All areas of Alapi Village, the oldest village on the islet, are residential; Fongafale's main institutions are located in Senala Village, such as the Funafuti Council (Kaupule), Conference Hall of the supreme decision making body (Fale Kaupule), a church, a hospital, and a primary school. Buildings of the Tuvalu Government are concentrated in Vaiaku Village, and also the Prime Minister’s house. The south-eastern side of the airstrip is designated as government land. There are no

residential houses, but a power plant, a prison, public works department, and meteorological bureau buildings. Numerous piggeries are built by the side of Tafua Pond; and there is a chicken battery.

There are not many agricultural fields except swamps (*pulaka* pits) on the airfield side of Alapi and Senala Village, in which the residents grow taro potatoes; and the other is a Taiwanese technical assistance experiment farm, located at the southern end of the government-use land.

There are many small fishing boats moored in the ship passages made by U.S. troops on the lagoon side of Alapi and Senala villages. Since there is no collective fish market system on the islet, and fishing is mainly for subsistence purposes, the fish are sold on a person to person basis. Therefore, there are no big boats on the islet. The boats are easily landed on the shore by fishermen who live nearby. Many boat ramps are found along the shore.

All solid waste is discharged into a borrow pit at the northern end of the Tengako Island (Asagatau Paka Village). There is another small dumping site at the south end of the islet (Kavatoetoe Village).

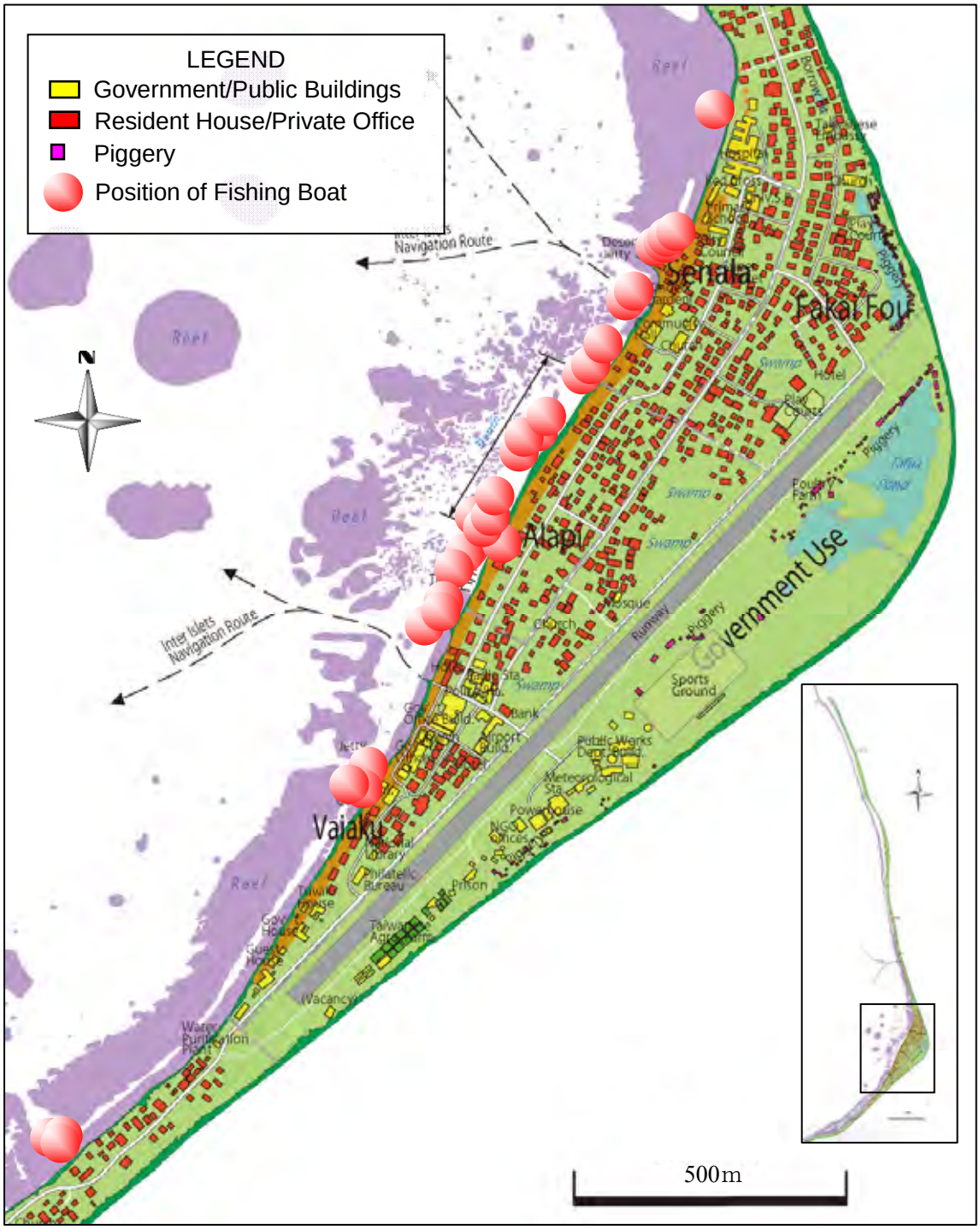


Figure 3.10 Central Part of Fongafale Islet

3.2.5 Land Tenure System

Subject to the provisions of the Native Lands Ordinance, native land shall not be alienated, whether by sale, gift, lease or otherwise, to a person who is not a native. (5 Restriction of alienation of native land, the Native Lands Ordinance)

There are several land tenure arrangements in Tuvalu: private land, government acquired land,

lased land, crown land, public land, communal land, village land, and Tuvalu Church land[7].

It appears that Tuvalu has retained its traditional land tenure system by merging its traditional setting into the Land Codes that govern the use of land today. The traditional land tenure system is primarily based on kinship. Land is being inherited from both their maternal and paternal sides.

Kaitasi: Lands owned by large extended families of up to third and fourth degrees of cousinship. Kaitasi means eating or sharing an interest in common. This interest is not to physically divide but rather a fractional part of one kaitasi interest. One is free to dispose his partial interest provided it does not contradict with the governing codes on the use of customary land.

Vaevae: Means divided. This usually takes place when land held under Kaitasi is divided among its members. Once land has been divided into smaller units then the owner to such unit is free to deal with his/her land.

Fakagamua: Communal land. More or less the same as the Kaitasi context, except for the fact that Fakagamua land cannot be divided. The sole supremacy for how it should be used is vested upon the chiefs and elders of the islands community.

Leasehold: Most land in Tuvalu is privately owned. Leasehold land makes up 5% of land area in the country. Large portions of lands in Funafuti are leased lands mainly by the national government. Terms of lease are limited to 25 years.

3.2.6 Rent of Land

The standard valuation of land is not applicable in Tuvalu. Rent is a matter of agreement between the land owner and the leaseholder, but the rent should be reviewed every 5 years. The Government is the largest leaseholder who can lease vast tracts of lands for development. The latest rent of the Government is 3,000 AU$ per acre, which was reviewed in 2010.

[7] L.M. Tausi, Land Tenure System: An obstacle to economic development in Tuvalu.

3.3 Other Data related to Environmental and Social Considerations

3.3.1 Water Supply and Sewerage

(1) Current Situation

1) Accessibility to Drinking Water

Official figures cite 97% of households as having access to safe drinking water[8].Almost all households on Funafuti have rain-water tanks or cisterns, most individually owned but some shared by the community, and are using for drinking water, cooking, flush toilets, bathing, washing, etc. These plastic tanks have a capacity of 10 m^3 and are manufactured in the factory located on the PWD premises, and are supplied with the financial assistance of international aid donors. Some also use concrete tanks, so the average number of water tanks each household has is one or two tanks. Cisterns are installed in the basements of major buildings such as the Princess Margaret Hospital and the Government Central Office. The water collected in these reserves is provided to the public by truck, especially as an emergency supply during droughts.

To maintain the water supply during droughts, two water desalinators were installed by Japanese donation. Sea water for the desalination process is taken from 100-200 meters off the lagoon side through pipe. Desalinated water is stored in water tanks and is supplied to households by truck. The cost of producing and supplying desalinated water is heavily subsidized by the government.

In some islands, groundwater was used for some domestic purposes before 1990, but this is rarely done on Funafuti now because of its effect on the freshwater lens, the increasing capacity of water tanks and the extent of groundwater pollution—other than for flushing toilets, bathing, or as an emergency supply during droughts. In addition, imports of bottled water have also risen and are used for drinking water.

2) Wastewater Treatment System

It is estimated that Funafuti residents annually generate about 475 tonnes of human waste[9], which is disposed of using one of several methods. According to the 2002 Census Report, 92 percent of the households use either flush toilets linked to septic tanks or pour toilets linked to pit toilets. Only less than ten percentages of households do not have access to an 'improved' sanitation system (**Table 3.15**). Most households have a basic sanitation system, unfortunately, the septic tank based system was introduced without regard to the geophysical characteristics of the atoll system, which is characterized by high groundwater level and it is subject to regular flooding, particularly in times of heavy rain and or king tides.

[8] Tuvalu 2006 Economic Report From Plan to Action, Ministry of Finance, Economic Planning and Industries, Government of Tuvalu and the Asian Development Bank, Draft Final Report, 31 March 2006

[9] SPREP. (2006) Economics of liquid waste management in Funafuti IWP-Pacific Technical Report (International Waters Project) no. 36.

Table 3.15 Distribution of Toilet Type in Funafuti (Number of Households)

	Toilet type (number of households)			Total
	Flush & septic toilets	Pour toilets	None	
Funafuti	424	163	43	639*

* Includes nine composting toilets on trial

Figure 3.11 shows a typical form of septic tank based system in Funafuti[10], which has three major components, a flush toilet, septic tank and a soak pit. The septic tanks are often poorly designed despite the presence of specific building codes and design specifications. And, septic tanks are not regularly cleaned of septage until the septic tank is blocked. Furthermore, there is no organized cleaning service available in the country and people have to rely on manual laborers to empty and reseal the tanks, which is undertaken by the Department of Public Works. Therefore, incompletely digested or untreated effluents seep out of the septic system and ultimately have resulted in high pollution of groundwater and the lagoon.

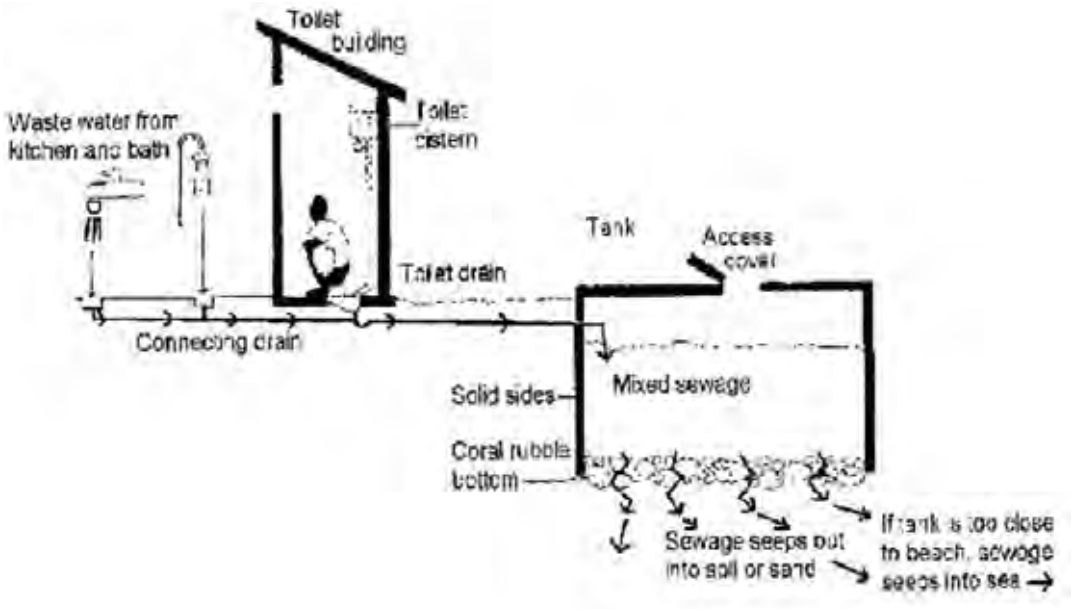


Figure 3.11 Typical Septic Tank System in Funafuti

In regard to animal waste, there are concentrations of piggeries near the sporting facility and also near the runway in the northern part of Fongafale Island. In both areas, animal waste is discharged to nearby ponds. The raising of pigs on residential premises is prohibited by a by-law and these two areas are designated areas. However, some piggeries are observed on residential premises and also along the coastline. Some of the abovementioned groundwater pollution is also caused by animal waste, particularly pig waste.

[10] Acquired from PWD presentation on composting toilets (October 2009)

3) Legislation

There are no national specific policies, strategy, plans and installation and maintenance standards for waste water treatment, especially for septic tanks and effluent infiltrates into the ground. The Waste Management Unit of Ministry of Home Affairs has been in change of water quality monitoring for groundwater and seawater, however, it has almost never been implemented.

4) Relevant Organizations

Each role and responsibility of relevant organizations for water supply and wastewater treatment is as below (**Table 3.16**).

Table 3.16 Relevant Organizations for Water Supply and Wastewater Treatment

Relevant Organization	Activity
Tuvalu Water and Sanitation Committee	• The committee is composed of 15 representatives from relevant organizations. The subordinate officer of Ministry of Public Utilities and Industries is a chairman of the committee. • It is playing an important role in the clarification of the ongoing situation of liquid waste management throughout the country, information sharing, and coordination among activities.
Public Works Department	• Organization responsible for water supply and waste water treatment. • Manufacturing, supply and cleaning of septic tanks. • Implementation body for promotion of compost toilet.
Department of Environment	• Development of environmental management plan, related legislation, and environmental standards for water management. • Implementation organization for Environmental Impact Assessment (EIA).
Department of Health	• Addressing human health issues. • Implementation body for water quality monitoring, especially drinking water. • Development of health standards for drinking water.
Waste Management Unit	• Implementation of environmental monitoring such as leachate generated from the final disposal site.
Kaupule Funafuti	• Enforcement of by-laws mandating that each household have a toilet facility and prescribing its actual location in the house

(Note) As of March 2010

5) Current Programs

Composting Toilets Promotion Project

The Department of Public Works has just commenced the Composting Toilets Promotion Program funded by GEF IW/EU Water Facility since 2009 on the recommendation of the report of Economic of liquid waste management in Funafuti, which was conducted by International Waters Project (IWP) in 2006. The program is aiming at promoting composting toilets as the preferred sanitation system for Tuvalu. The model of composting toilets to be introduced is plastic-made in relatively larger size that present flush toilets (approximately 1.0-1.5 m in diameter) as shown in **Figure 3.12**. The composting toilets introduced in the past are no longer in use, but the low social acceptability of composting toilets and inconvenient locations may have been contributory factors for their unpopularity. Based on the past experience, the program is focusing on awareness raising activities to convey the advantage of composting toilets.

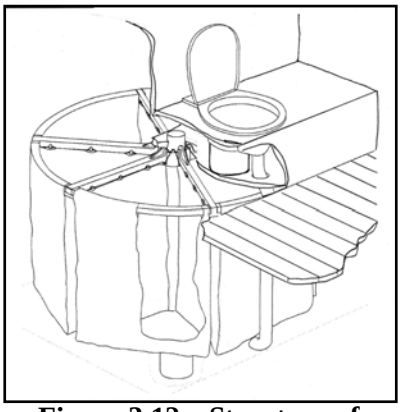


Figure 3.12 Structure of Composting Toilet to Be Installed in Funafuti

(2) Issues

a. Protection of the Facility for Water Resource

Tuvalu is poorly gifted with no surface water, so that it heavily depends on rainwater as its main water resource collected from roof of houses, and stored in water tanks most individually owned. On the other hand, the cisterns installed in the basements of major buildings like the Princess Margaret Hospital and the Government Central Office, and some common tanks shared by the community have significant roles as supplements for lack of water for households. In addition, two water desalinators are also important water resources to maintain the water supply during droughts and other emergency situations. The area where these important water resources are located shall be given priority to be protected against coastal disasters.

b. Introduction of Appropriate Wastewater Treatment Systems

Leachate from poorly managed septic tanks and pour latrines, wastewater from households and animal waste, especially from the piggeries, will directly or indirectly contribute to groundwater pollution and affect coral ecosystems and human health. It is concerned that these wastewaters will have a bad influence on ecosystem which plays an important role in coastal management. Several measures should be examined for the improvement of the existing wastewater treatment system in Tuvalu. These include the introduction of a low cost wastewater treatment system using locally available materials to good effect and enforcement of construction standards for septic tank structure, installation and maintenance. In addition, it is recommended that composting toilets should be strategically installed at specific locations considering the coral

habitat and densely populated areas. For this reason, it is desirable that the outcomes of the Study, such as the results of water quality and ecological surveys, should be shared with stakeholders who implement composting toilet programs.

3.3.2 Waste

(1) Current Situation

1) Current Situation of Waste Management

a. Waste Discharge (Amount and Characterization)

The Survey on Kaupule collection waste stream composition conducted in the year 2000[11], found that the community roughly produces approximately 258 tones of solid waste a year.

Table 3.17 Waste Classification of Household Collection Survey in Funafuti

Waste Type	Weight %
Biodegradable (kitchen waste, garden waste)	52.4
Paper	10.4
Metals	9.8
Glass	9.5
Plastics	9.3
Construction and demolition waste	3.2
Textiles	2.2
Potentially hazardous waste (batteries, cleaning fluids and pesticides)	0.6
Other	2.5
Total	100.0

Source: SPREP (2000) Solid Waste Characterisation Tuvalu

The above **Table 3.17** illustrates that green waste from gardens made up the bulk of the waste generated from households. The proportion of biodegradable waste is high, and the questionnaire survey with local residents conducted during February 2008 found that more than 90% of the respondents use their kitchen garbage (cooking waste and uneaten food) to feed their pigs[12]. The observation results of the contents of rubbish confirm that hardly any kitchen garbage is disposed of as solid waste. In Funafuti, the current rapid growth of population and changing lifestyle in recent years has intensified the tendency of Tuvaluan society to rely on imported products. There has been a distinctive change of the types of discharged waste towards plastics, glass and metals of which the treatment is difficult and such chemical solid waste as batteries, synthetic detergents and insecticides, all of which contain hazardous substances.

[11] Extracted from one of the three Waste Management Project Solid Waste Characterization Survey Reports（2000）.

[12] Report on Environmental Cooperation between Japan and Island Countries (Focus on Tuvalu), EX Corporation (March 2008)

b. Waste Collection

The Kaupule Funafuti is responsible for the collection of household waste throughout Fongafale Island. The frequency of collection services is supposed to be twice a week for household waste, and once a week for garden waste, however, these services have not been provided regularly. Therefore, many people take their waste to the disposal site by themselves without relying on the collection service.

c. Waste Minimization and Recycling Practices

Garden waste is collected by the Waste Management Unit and is shredded for composting at the Hanger. The compost made from garden waste is sold at the Hanger (where a composting facility is located), however, most garden waste is just discharged as general waste or taken to the disposal site.

Apart from garden waste chipping and composting, there were no active waste minimization and recycling efforts as of October 2009. Empty aluminium cans are discharged and stored separately with other waste by major business establishments like bars and restaurants, however, no purchases have been conducted due to lack of export route. There is no recycling system for waste home appliances and end-of-life vehicles. This abandoned waste is currently dumped in the final disposal site, or are kept in a building or on their premises or near a garage (along the coast), or simply left abandoned at home.

To strengthen sorting mechanism for domestic solid waste in order to reach the goals of reduction of waste and expansion of recycling, the Taiwanese government donated colored plastic-made bins for separate collection for metals, plastics and glass in 2009. However, it has not been realized yet.

d. Final Disposal

General solid waste (excluding aluminium cans for recycling and garden waste for composting) used to be disposed of at locations in the northern part of Fongafale Island that is under the jurisdiction of the Waste Management Unit (WMU) of Ministry of Home Affairs, or Kaupule designated dumpsites, anywhere suitable to household such as beaches, banana plantations etc. Kaupule dumpsites have been closed recently, so that the place for disposal in Fongafale Island is only the WMU one, as of October 2009. This disposal site does not have any partitions and is not monitored. As it can be easily accessed from the outside, illegal dumping constantly takes place, making the scattering of dumped waste unavoidable, and most of the waste is floating in the borrow pit located just next to the dumping area. There is one small excavator for landfilling work; however, it is not always available due to multipurpose use.

In 2009, the Taiwanese government donated an incinerator for general waste targeting dried leaves, wood, paper, nappies and cloth fiber. It has a capacity of 300 kg per hour to incinerate waste, and has been set up at the dumpsite area with signboard given instruction in Tuvaluan languages. It is planned to utilize the incinerator several times a week, however, there was no sign that is was being used frequently as of October 2009.

Furthermore, the implementation of Tuvalu Waste, Water and Sanitation Project (TWWSP) supported by the 10th European Development Fund will commence in mid-2010. As a part of project activities, it is planned to improve existing final disposal site in cooperation with the Taiwanese government as follows:

- Undertaken by contract and combined with recycling operations
- Contractor controls dumpsite as follows:
  - Dump site fenced and gated (limited public access)
  - Waste pushed and compacted each day
  - Litter control
- Shed to be constructed at dump site for equipment storage and recycling operations
- Incinerator for medical waste donated by Rotary Japan to be installed beside incinerator for general waste
- Secure two staff (2 plant operators + labourer)

2) Legislation and Relevant Organizations

a. Waste Operations & Services Act 2009 (WOSA)

Since the EU agreed to allow the progress of the EDF 10 Funding on condition that the enactment of Waste Management Legislation needed to be completed, the Waste Operations & Services Act 2009 (WOSA) was developed and came into effect in July 2009. One of the objectives of the Act is to define roles and responsibilities for waste management within Tuvalu as follows;

Under this Act, levies will be imposed in relation to the goods, substances and things, which can be prohibited or regulated where serious waste management issues arise. Obligations will also be imposed on certain businesses to ensure that they make adequate arrangements for the disposal of the wastes that arise from their business activities. Waste management operators in the private sector may be registered or licensed, and conditions will be imposed on their operations to ensure that they comply with Tuvalu's international obligations when waste is exported for disposal or recycling overseas.

Table 3.18 Role and Responsibility of Relevant Organizations Defined by WOSA 2009

Relevant organizations	Role and responsibilities
Department of Environment	・ A principle regulatory body as provided for in the Environment Protection Act 2008. ・ Waste management planning ・ Imposition of environmental standards on waste management operators. ・ The audit of waste generation and disposal from time to time.
Ministry of Health	・ Responsible for all aspects of managing medical wastes. ・ Imposition of health standards on waste management operators.
Kaupule	・ Responsible for the provision of regular and

Relevant organizations	Role and responsibilities
	compulsory residential and commercial garbage collection services, and disposal services
Waste Management Unit (Ministry of Home Affairs and Rural Development)	・ To be called as "Solid Wastes Agency". ・ Responsible for the formulation and application of a National waste Strategy ・ Implementation of waste management programs and projects on a nation-wide basis, ・ Responsible for waste management operations and for the provision of waste management services that are beyond the technical capacity of the Kaupule. ・ Responsible for dealing with hazardous wastes through proper storage, handling, transportation and disposal arrangements.

The Solid Waste Agency and Kaupule will be empowered to exercise controls over certain wastes by issuing notices requiring that they be dealt with in the proper manner. Power of enforcement is given to police officers, environment officers, public health officers, and the officers and contractors appointed by the Solid Waste Agency or designated waste management operators including Kaupule. One of the offences is trespassing in rubbish dumps and damaging property and signs in waste dumps and landfills.

b. Plans

During the period of the technical assistance project of the AusAID from 2004 to 2005, the Integrated Solid Waste Plan (ISWP) featuring Funafuti was prepared, and was adopted as a government plan in May 2005.

Under a technical assistance project (Effective Solid Waste Management and Recycling in Tuvalu) funded by ADB from 2004 to 2005, a draft by-law for waste management at the Kaupule level was prepared, but no progress has since been made.

(2) Matters to be considered

a. Consistency with the Existing Regulations related to Waste Management

The Waste Operations & Services Act 2009 (WOSA) prescribes that the allocation of regulatory roles under the Act should be consistent with the existing powers and roles of government agencies. The Marine Pollution Act 1991, which is one of the relevant regulations and is the responsibility of the Marine Department, prescribes the restrictions on dumping waste at sea. In addition, environmental standards relating to waste management practices and facilities will be formulated by the Department of Environment. The JICA Study Team has proposed an option of building a bank or levee using bulky waste, so this also needs to consider these regulations in cooperation with the relevant departments.

b. Impact on Coastal Environment caused by Landfill Project

As a part of EU Tuvalu Waste, Water and Sanitation Project (TWWSP) activities, it is planned

to improve the existing final disposal site. All the waste is currently dumped on the blind road, however, the new disposal operation is intend to dump the waste collected into the nearby borrow pit, and to reclaim by waste compressing to the side of borrow pit using heavy machines. There are some apprehensions for these landfilling procedures as follows:

1. Damage to storm ridge caused by the construction of access road,
2. Environmental impact on water quality and coral ecosystem caused by leachate from the landfill via the borrow pit, and
3. Impact on the coastal environment caused by the outflow of waste attendant to the breakdown of the storm ridge

1. Damage to Storm Ridge caused by the Construction of Access Road

For dumping into the deep space of borrow pit, an access road from the gate to the working space needs to be constructed for the movement of waste collection vehicles and heavy machines for landfilling. There is concern that the building of an access road may have a negative impact on the storm ridge which protects the vulnerable coast in Fongafale Islands. The interviews with relevant government officers as part of the field survey found that the EU Project would take into consideration the importance of a storm ridge for coastal management, and would construct the access road at the inside of borrow pit which was reclaimed by waste, not on the storm ridge itself. Discussions still need to take place between the JICA Study Team and the implementation body of EU Project, and the progress of landfill improvement work also needs to be monitored.

2. Environmental Impact on Water Quality and Coral Ecosystem caused by Leachate from the Landfill via the Borrow Pit

Under the above landfill improvement plan, the EU Project will not take any preventive measures against leachate such as a covering liner on the inside surface of borrow pit before dumping waste. It would not be a realistic measure to collect and treat leachate in Tuvalu in terms of topographical characteristics of atoll environment, limited capacity of government authorities and cost-benefit aspects. Instead of investing huge capital in the final disposal system, the waste minimization practices should take priority over all other matters for the Solid Waste Management in Tuvalu in order to avoid dumping organic waste which generates leachate as well as hazardous waste; including the promotion of organic waste composting and introduction of proper segregation system for hazardous waste. Community understanding and involvement are indispensable for the implementation of the above activities, so that the relevant organizations need to conduct continuous awareness raising activities. Concerning to leachate generated from final disposal site, careful consideration should be given to not only the current landfill site where the EU Project will be undertaken, but the previous dumpsite which has been closed in recent years.

3. Impact on Coastal Environment caused by the Outflow of Waste Attendant to the Breakdown

of the Storm Ridge

The field survey conducted in September 2009 found that the storm ridge located about 400 m north of present landfill site has been ruined, and some of the waste was floating near where the storm ridge was damaged and in the borrow pit which is connected to where all the waste is dumped. There is growing apprehension that the storm ridge will be ruined further by extraordinary events such as storm surge, which will bring the dumped waste into the lagoon side area and negatively impact the coastal environment. It is necessary to examine how the ruined area will be expanded, and also what kinds of countermeasures to be taken to block the flow of dumped waste.

In order to erase these apprehensions mentioned above, discussions needs to be held between the JICA Study Team and the implementation body of the EU Project. And, it is desirable to share the information and data gained from various studies which the JICA Study team has conducted.

3.3.3 Borrow Pits

(1) Background

The US military dug out substantial quantities of aggregate from the Fongafale and Tengako islands to build the base and airfield in the year of 1942 to 1943. The resulting ditches or "borrow pits" remain to this day.

The US military also dug out shallow water areas along the shoreline of the Fongafale island and artificially reclaimed the lagoon coastline by 25 to 30 meters to make new lands for military uses. Near-shore works have left a legacy of instability on this coast.

(2) Borrow Pits in 1990s

SOPAC's report describes that there were 10 (ten) borrow pits on Funafuti of the Fongafale and Tengako islands in early 1990s as shown in **Figure 3.13** and **Table 3.19.**

To fill all the borrow pits and other low lying areas on Fongafale, an estimated 644,700 cubic meters of sediment was required according to Gibb Australia (Tuvalu lagoon bed resources survey; Australian Development Assistance Bureau, 1985).

Table 3.19 Volume of Borrow Pits

Borrow Pit No.	Volume	Remarks
No. 1	128,709	Tengako
No. 2	4,935	
No. 3	75,689	Fongafale North
No. 4	28,198	
No. 5	43,364	
No. 6	8,440	
No. 7	16,809	Fongafale Central
No. 8	50,646	
No. 9	65,721	Fongafale South
No.10	677	
Total	423,188 m^3	

Source: SOPAC Technical Report 216 (Feb. 1995)

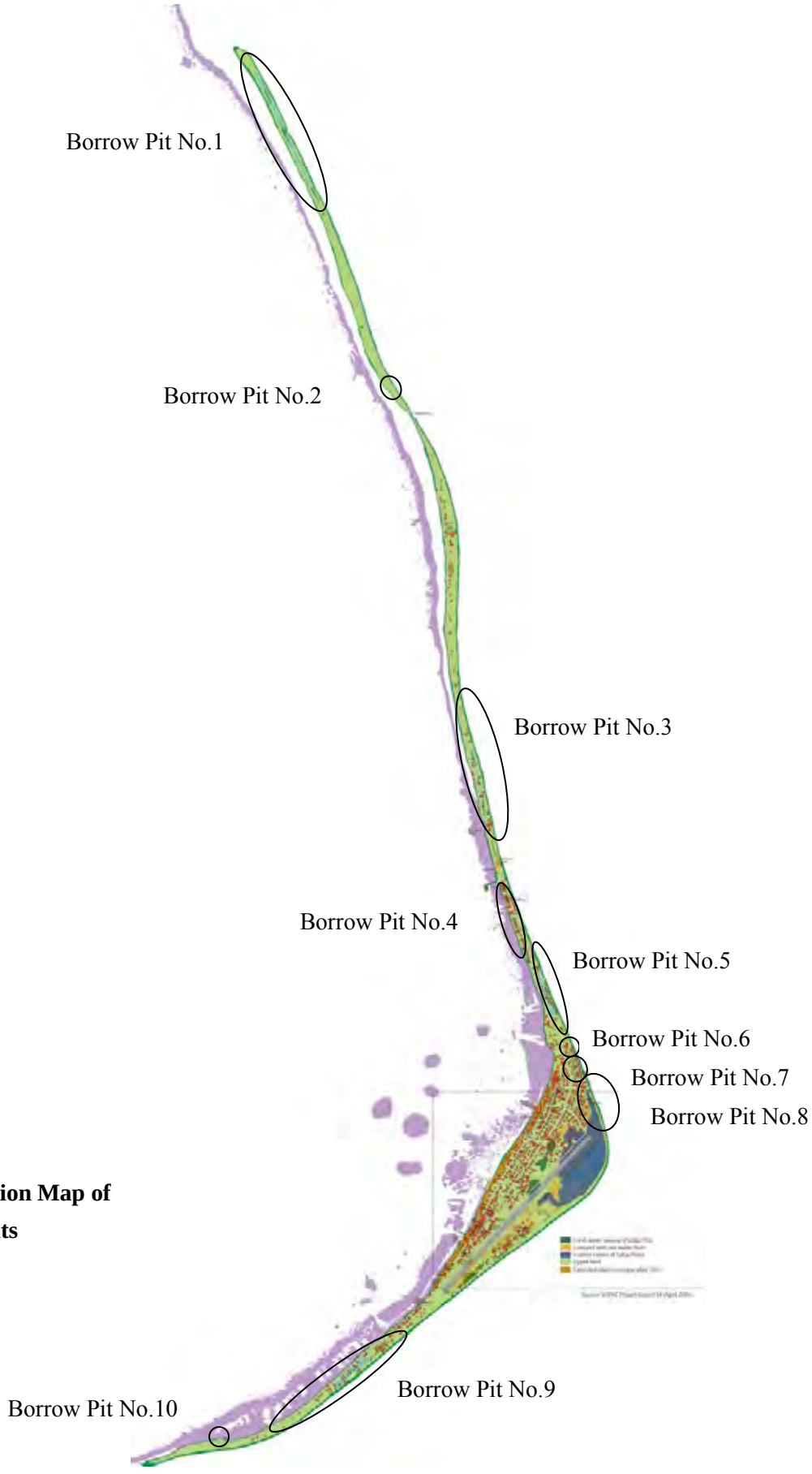


Figure 3.13 Location Map of Borrow Pits

(3) Present Situation of Borrow Pits

Existing borrow pits were checked during JICA Study and the result of the investigation is compiled as a photo album shown in Section 2 in Part I of Supporting Report. Some comments should be added that the field survey for the borrow pits was carried out in day time on January 18 to 20, 2010 when the tides were in the low water zone. This means that the volume of water as a whole was not so much.

The result of the borrow pit survey is summarized in Table 3.20 by comparing with existing data, referring SOPAC Technical Report 216 (Feb. 1995). The length of borrow pits listed in the second column in this table are the approximate lengths calculated from the figure of Technical Report No.216. The coordinates of present north and south ends of existing borrow pits were obtained using a precise GPS instrument, which implies an error of ±5 meters. The detailed survey results are as follows;

Borrow Pit No.1

This borrow pit is the largest one in the existing borrow pits with a length of more than 1,000 m and a volume of 128,709 m^3 located in the north part of Tengako Island. The southern part of this borrow pit is used as a waste disposal site at present.

It is emphasized that there is a wide breach in the storm ridge on the ocean side at S 08°27′11.2″, E 179°10′52.5″ in the north part of the borrow pit and the breaching materials together with inflowing materials from ocean side divide the borrow pit into two parts. The length of land area between borrow pits is measured as 21 meters.

Borrow Pit No.2

This small borrow pit in Tengako Island is located at the north of the causeway. This area is covered with jungle, therefore it is difficult to find the borrow pit. At present, this borrow pit looks like a small pond with a little water having the area of approximately 20 m^2.

Borrow Pit No.3

This borrow pit is the second largest one and many houses are built in and above the borrow pit at present. The north part of borrow pit was used as a waste disposal site in past times and the south part is reclaimed as houses and factories. Due to reclamation of the southern part, the length of the borrow pit is shorter than it was in the past. There is not so much water in borrow pit.

Table 3.20 Present Situation of Existing Borrow Pits

Borrow Pit No. (refer to Fig. 3.4--1)	SOPAC TR-216	Present Situation			
	Volume (Length)	North End	South End	Length	Comments
No. 1	128,709 m^3 (1,170 m)	S: 08°26′56.0″ E:179°10′44.0″	S: 08°27′28.1″ E:179°11′00.2″	1,099 m	Largest pit and southern part is used as a waste disposal site. Breaching site at north part divides borrow pit into two.
No. 2	4,935 m^3 (140 m)	S: 08°28′14.4″ E:179°11′18.5″		10 m	Very small pond in jungle (appr.20m^2)
No. 3	75,689 m^3 (830 m)	S: 08°29′35.5″ E:179°11′36.0″	S: 08°29′53.5″ E:179°11′40.7″	569 m	South part is reclaimed as houses/factories. North part was used as a waste disposal site in past times.
No. 4	28,198 m^3 (390 m)	S: 08°30′16.1″ E:179°11′46.8″	S: 08°30′27.2″ E:179°11′50.9″	361 m	Houses cover almost all of the borrow pit area. Water is seen only in a limited area.
No. 5	43,364 m^3 (390 m)	S: 08°30′30.1″ E:179°11′53.2″	S: 08°30′41.0″ E:179°11′57.1″	352 m	There are many houses around the borrow pit. Borrow pit is divided into 7 parts by small footpath.
No. 6	8,440 m^3 (140 m)		S: 08°30′45.6″ E:179°11′59.4″	20 m	Very small pond near Community Hall (appr.20m^2)
No. 7	16,809 m^3 (170 m)	S: 08°30′50.0″ E:179°12′01.3″	S: 08°30′52.5″ E:179°12′02.2″	81 m	Small borrow pit divided into two parts by a house (near Taiwan embassy)
No. 8	50,646 m^3 (280 m)	S: 08°30′57.0″ E:179°12′04.3″	S: 08°31′04.7″ E:179°12′06.4″	244 m	There are many pigpens around the borrow pit. Borrow pit is abundant in water and milky fishes.
No. 9	65,721 m^3 (610 m)	S: 08°31′59.1″ E:179°11′15.6″	S: 08°32′10.1″ E:179°11′01.9″	537 m	Central part is used as a timber factory. Southern part is littered with waste (mainly plastics).
No.10	677 m^3 (80 m)	S: 08°32′20.1″ E:179°10′39.1″		5 m	Exact position is not clear.

(Note) Length (SOPAC): Approximate length calculated from Figure of TR-216

Borrow Pit No.4

Almost the entire area of this borrow pit has been reclaimed for housing. Therefore, water is seen only in a limited area. There are pigpens in the northern part and along the lagoon side of the borrow pit.

Borrow Pit No.5

There are many houses around borrow pit and also pigpens in the southern part. This borrow pit is divided into 7 parts by small footpaths. The water in this borrow pit looks dirty because of highly land-use and pigpens.

Borrow Pit No.6

This small borrow pit is located near a community hall (Maneapa) near Teuaea road. At present, this borrow pit looks like a small pond with a little water having the area of approximate 20 m^2.

Borrow Pit No.7

This is a comparatively small borrow pit divided into two parts by a house with a pigpen, which is located next to the Taiwan embassy. The length of the borrow pit is shorter than in the past. This is thought to be due to reclamation of the southern part.

Borrow Pit No.8

This borrow pit is located next to the Tafua pond and the reclaimed area partly of this borrow pit is used as a tennis court. There are many pigpens along the borrow pit on the ocean side. The borrow pit is rather abundant in water and milky fishes.

Borrow Pit No.9

This borrow pit is the third largest one. Many houses, however, are built in and above the borrow pit and there are many pigpens along the borrow pit on the ocean side at present. There is not so much water in the borrow pit and it is dirty. The central part is used as a timber factory/warehouse. In the southern part, a lot of wastes composed mainly of plastics are deposited.

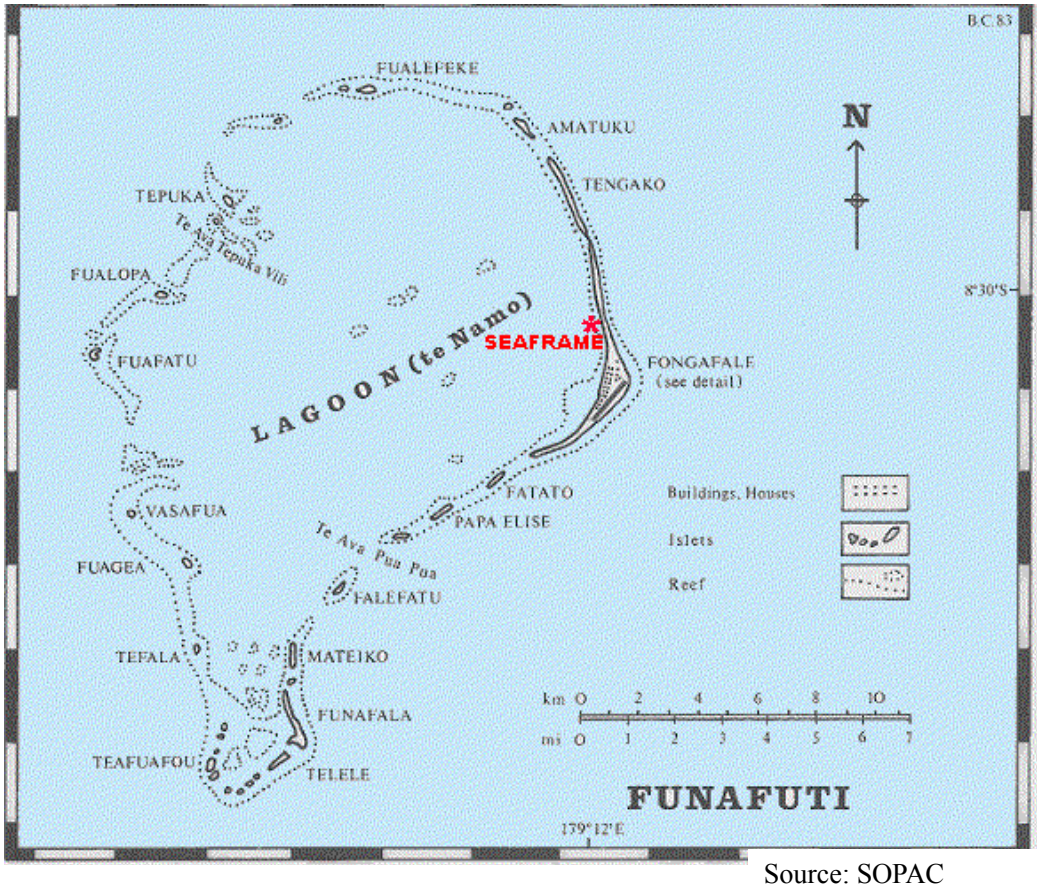
Borrow Pit No.10

This small borrow pit in the southern part of Fongafale Island is not clearly found because of its size and coverage with jungle. Evidence of an old borrow pit, however, was seen at the position shown in **Table 3.20**.

CHAPTER 4 PRESENT SITUATION OF NATURAL AND ENVIRONMENTAL CONDITIONS IN STUDY AREA

4.1 Meteorological Phenomena

As part of the AusAid-sponsored South Pacific Sea Level and Climate Monitoring Project for the south pacific region, a SEAFRAME (Sea Level Fine Resolution Acoustic Measuring Equipment) gauge was installed in Funafuti, Tuvalu, in March 1993. SEAFRAME gauges not only measure sea level, but also air and water temperature, wind speed, wind direction and atmospheric pressure. The time used for SEAFRAME is a Universal Time Coordinated (UTC), therefore the local time can be obtained by minus 12 hours.



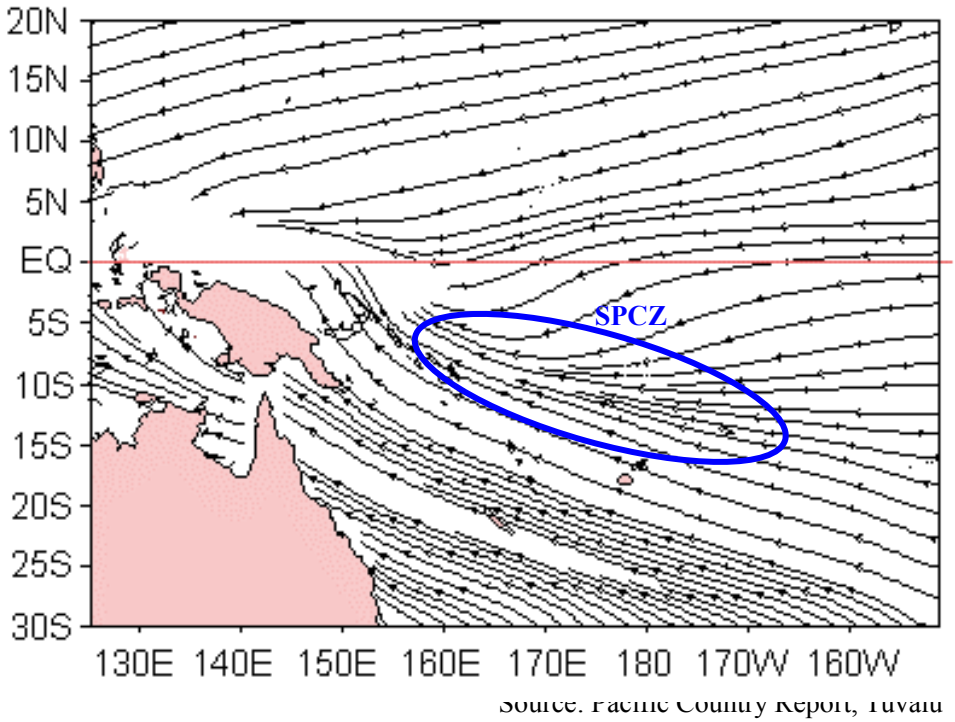
Source: SOPAC

Figure 4.1 Location Map of SEAFRAME at Funafuti, Tuvalu

4.1.1 Winds

(1) General Description

The streamlines of mean surface wind shown in **Figure 4.2** shows how the Tuvalu region is dominated by easterly trade winds. In the Southern Hemisphere the Trades blow to the northwest. The streamlines converge, or crowd together, along the "South Pacific Convergence Zone (SPCZ)".



Source: Pacific Country Report, Tuvalu

Figure 4.2 Streamlines of Mean Surface Wind

(2) Wind Speeds and Winds Directions

The annual wind data show the wind in Fongafale to be seasonal. We divided the wind conditions in the region into four (4) seasons, i.e. Summer/Wet Season from December to February, Winter/Dry Season from May to September, and two Transit Seasons from March to April and from October to November. The seasonal wind data are summarized in **Table 4.1** to **Table 4.3** as "Joint Frequency of Occurrence of Wind Speed and Wind Direction (1999- 2008)" and in **Figure 4.3** to **Figure 4.5** as "Wind Rose (1999- 2008)".

The annual frequency of occurrence of wind speed and direction during 1999 to 2008 shows that the wind speed less than 2.0 m/sec occurs at 32.0 % and the wind speed more than 8.0

m/sec at 2.2 %. Annual winds are predominant from easterly direction, i.e. 53.3 % from ENE to SE directions. Stronger winds than 14.0 m/sec are observed from westerly direction of SW to NW (refer to **Table 4.1** and **Figure 4.3**).

From December to February during the summer season, north-easterly winds from N to ENE are predominant with 45.5 % occurrence. The south-easterly and north-westerly winds compete with low occurrence percentages. Strong westerly winds reaching more than 15 m/sec are observed in this season including March (refer to

Table 4.2 and **Figure 4.4**).

From May to September during the winter season, the easterly to south-easterly winds not exceeding almost 6 m/sec are dominant, i.e. 52.0 % from ESE to SE directions. In this season, strong winds more than 10 m/sec are very rare cases, only 12 times during 10 years (refer to **Table 4.3** and **Figure 4.5**).

Wind characteristics in the transit seasons from March to April and from October to November show the intermediate conditions between the summer and winter seasons or the winter and summer seasons.

Table 4.1 Joint Frequency of Occurrence of Wind Speed and Wind Direction
Annual : January to December for 1999 – 2008

																	Regulation	87672	
Site	Funafuti																Observation	87428	(99.7)
Term	1999/ 1/ 1/ 0:00– 2008/ 12/ 31/ 23:00(Annual)																Error	244	(0.3)
(m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum	Accum. Sum
0.0 – 0.4	121 (0.1)	154 (0.2)	124 (0.1)	143 (0.2)	170 (0.2)	233 (0.3)	214 (0.2)	180 (0.2)	129 (0.1)	98 (0.1)	90 (0.1)	87 (0.1)	107 (0.1)	87 (0.1)	100 (0.1)	110 (0.1)	2147 (2.5)	2147 (2.5)
0.5 – 1.9	1210 (1.4)	2094 (2.4)	2461 (2.8)	3244 (3.7)	2855 (3.3)	5223 (6.0)	4087 (4.7)	1291 (1.5)	485 (0.6)	408 (0.5)	286 (0.3)	328 (0.4)	412 (0.5)	436 (0.5)	459 (0.5)	546 (0.6)	25825 (29.5)	27972 (32.0)
2.0 – 3.9	2700 (3.1)	3359 (3.8)	3343 (3.8)	6204 (7.1)	1803 (2.1)	6240 (7.1)	9251 (10.6)	2408 (2.8)	630 (0.7)	386 (0.4)	217 (0.2)	301 (0.3)	479 (0.5)	573 (0.7)	774 (0.9)	908 (1.0)	39576 (45.3)	67548 (77.3)
4.0 – 5.9	1582 (1.8)	702 (0.8)	1219 (1.4)	1414 (1.6)	255 (0.3)	1561 (1.8)	3174 (3.6)	1139 (1.3)	273 (0.3)	128 (0.1)	108 (0.1)	181 (0.2)	367 (0.4)	425 (0.5)	679 (0.8)	859 (1.0)	14066 (16.1)	81614 (93.3)
6.0 – 7.9	562 (0.6)	59 (0.1)	176 (0.2)	124 (0.1)	27 (0.0)	96 (0.1)	289 (0.3)	240 (0.3)	77 (0.1)	38 (0.0)	109 (0.1)	158 (0.2)	370 (0.4)	390 (0.4)	578 (0.7)	588 (0.7)	3881 (4.4)	85495 (97.8)
8.0 – 9.9	93 (0.1)	4 (0.0)	14 (0.0)	12 (0.0)	3 (0.0)	5 (0.0)	14 (0.0)	21 (0.0)	18 (0.0)	24 (0.0)	41 (0.0)	98 (0.1)	156 (0.2)	229 (0.3)	295 (0.3)	257 (0.3)	1284 (1.5)	86779 (99.3)
10.0 – 11.9	9 (0.0)		1 (0.0)	1 (0.0)			1 (0.0)	3 (0.0)	8 (0.0)	7 (0.0)	15 (0.0)	48 (0.1)	69 (0.1)	105 (0.1)	159 (0.2)	62 (0.1)	488 (0.6)	87267 (99.8)
12.0 – 13.9	1 (0.0)		1 (0.0)						2 (0.0)	1 (0.0)	2 (0.0)	8 (0.0)	20 (0.0)	31 (0.0)	49 (0.1)	15 (0.0)	130 (0.1)	87397 (100.0)
14.0 – 15.9											1 (0.0)	2 (0.0)	1 (0.0)	11 (0.0)	12 (0.0)		27 (0.0)	87424 (100.0)
16.0 – 17.9														1 (0.0)	2 (0.0)		3 (0.0)	87427 (100.0)
18.0 – 19.9													1 (0.0)				1 (0.0)	87428 (100.0)
20.0 ≦																		87428 (100.0)
Sum	6278 (7.2)	6372 (7.3)	7339 (8.4)	11142 (12.7)	5113 (5.8)	13358 (15.3)	17030 (19.5)	5282 (6.0)	1622 (1.9)	1090 (1.2)	869 (1.0)	1211 (1.4)	1982 (2.3)	2288 (2.6)	3107 (3.6)	3345 (3.8)	87428 (100.0)	* *

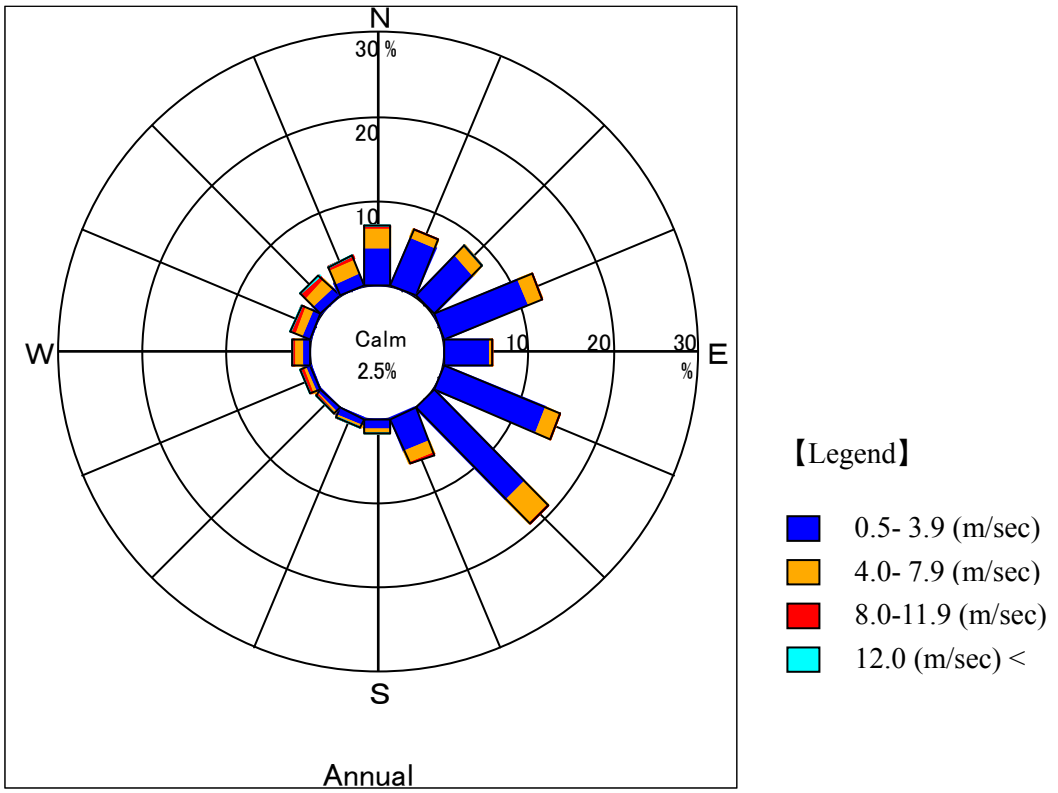


Figure 4.3 Wind Rose : Annual (1999 - 2008)

Table 4.2 Joint Frequency of Occurrence of Wind Speed and Wind Direction Summer/Wet Season : December to February for 1999 – 2008

Site	Funafuti																	Regulation	21672	
Term	1999/ 1/ 1/ 0:00– 2008/ 12/ 31/ 23:00[Summer(December to February)]																	Observation	21648	(99.9)
																		Error	24	(0.1)
(m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum		Accum. Sum	
0.0 – 0.4	28 (0.1)	42 (0.2)	34 (0.2)	37 (0.2)	36 (0.2)	53 (0.2)	53 (0.2)	51 (0.2)	38 (0.2)	31 (0.1)	22 (0.1)	26 (0.1)	32 (0.1)	28 (0.1)	25 (0.1)	28 (0.1)	564 (2.6)		564 (2.6)	
0.5 – 1.9	370 (1.7)	646 (3.0)	626 (2.9)	589 (2.7)	436 (2.0)	614 (2.8)	543 (2.5)	272 (1.3)	132 (0.6)	131 (0.6)	102 (0.5)	131 (0.6)	151 (0.7)	167 (0.8)	171 (0.8)	200 (0.9)	5281 (24.4)		5845 (27.0)	
2.0 – 3.9	1146 (5.3)	1267 (5.9)	1015 (4.7)	1126 (5.2)	330 (1.5)	373 (1.7)	646 (3.0)	334 (1.5)	147 (0.7)	106 (0.5)	87 (0.4)	155 (0.7)	251 (1.2)	288 (1.3)	357 (1.6)	381 (1.8)	8009 (37.0)		13854 (64.0)	
4.0 – 5.9	863 (4.0)	378 (1.7)	620 (2.9)	406 (1.9)	69 (0.3)	48 (0.2)	59 (0.3)	74 (0.3)	54 (0.2)	44 (0.2)	60 (0.3)	137 (0.6)	261 (1.2)	265 (1.2)	387 (1.8)	455 (2.1)	4180 (19.3)		18034 (83.3)	
6.0 – 7.9	407 (1.9)	34 (0.2)	98 (0.5)	37 (0.2)	4 (0.0)	4 (0.0)	2 (0.0)	10 (0.0)	19 (0.1)	16 (0.1)	76 (0.4)	139 (0.6)	314 (1.5)	294 (1.4)	392 (1.8)	400 (1.8)	2246 (10.4)		20280 (93.7)	
8.0 – 9.9	68 (0.3)	2 (0.0)	5 (0.0)	3 (0.0)	2 (0.0)			2 (0.0)	7 (0.0)	14 (0.1)	37 (0.2)	90 (0.4)	128 (0.6)	166 (0.8)	220 (1.0)	165 (0.8)	909 (4.2)		21189 (97.9)	
10.0 – 11.9	4 (0.0)		1 (0.0)					1 (0.0)	1 (0.0)	5 (0.0)	14 (0.1)	42 (0.2)	54 (0.2)	74 (0.3)	101 (0.5)	45 (0.2)	342 (1.6)		21531 (99.5)	
12.0 – 13.9									1 (0.0)		2 (0.0)	4 (0.0)	14 (0.1)	24 (0.1)	41 (0.2)	6 (0.0)	92 (0.4)		21623 (99.9)	
14.0 – 15.9												2 (0.0)		8 (0.0)	12 (0.1)		22 (0.1)		21645 (100.0)	
16.0 – 17.9														1 (0.0)	2 (0.0)		3 (0.0)		21648 (100.0)	
18.0 – 19.9																			21648 (100.0)	
20.0 ≦																			21648 (100.0)	
Sum	2886 (13.3)	2369 (10.9)	2399 (11.1)	2198 (10.2)	877 (4.1)	1092 (5.0)	1303 (6.0)	744 (3.4)	399 (1.8)	347 (1.6)	400 (1.8)	726 (3.4)	1205 (5.6)	1315 (6.1)	1708 (7.9)	1680 (7.8)	21648 (100.0)		* *	

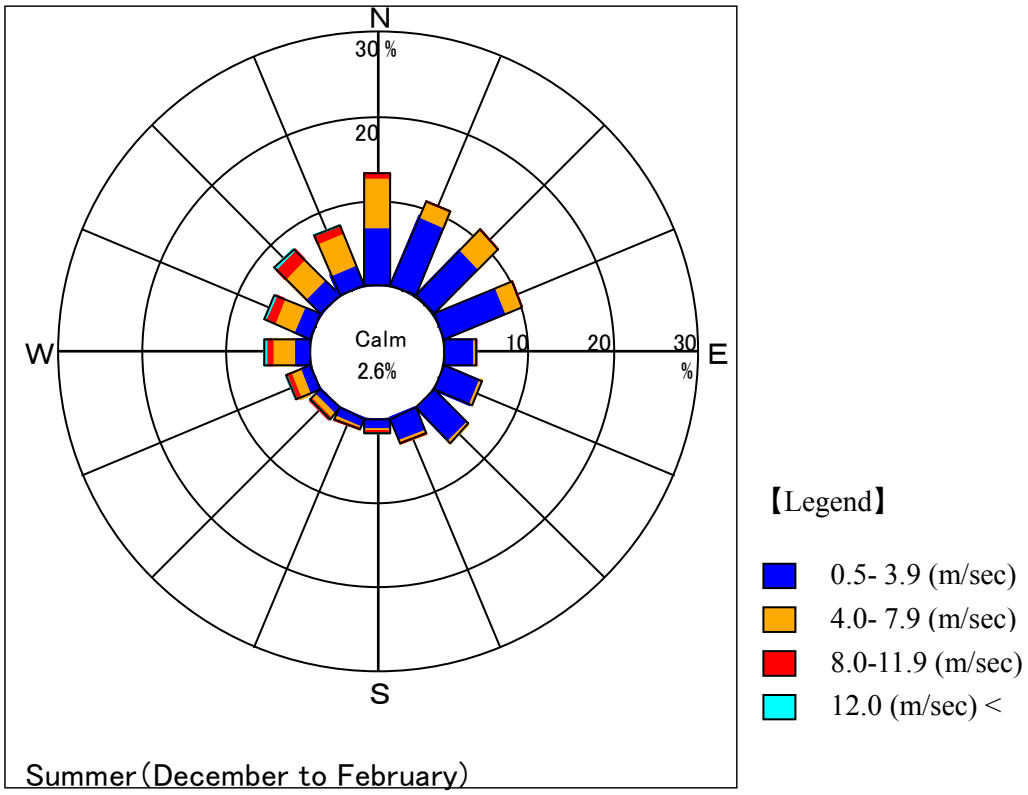


Figure 4.4 Wind Rose : Summer Season (December to February)

Table 4.3 Joint Frequency of Occurrence of Wind Speed and Wind Direction Winter/Dry Season : May to September for 1999 – 2008

Site	Funafuti																Regulation	36720	
Term	1999/ 1/ 1/ 0:00- 2008/ 12/ 31/ 23:00[Winter(May to September)]																Observation	36554	(99.5)
																	Error	166	(0.5)
(m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum		Accum. Sum
0.0 – 0.4	41 (0.1)	45 (0.1)	45 (0.1)	47 (0.1)	68 (0.2)	86 (0.2)	66 (0.2)	52 (0.1)	26 (0.1)	26 (0.1)	26 (0.1)	24 (0.1)	39 (0.1)	25 (0.1)	33 (0.1)	32 (0.1)	681 (1.9)		681 (1.9)
0.5 – 1.9	321 (0.9)	607 (1.7)	858 (2.3)	1340 (3.7)	1379 (3.8)	2804 (7.7)	2003 (5.5)	534 (1.5)	172 (0.5)	114 (0.3)	87 (0.2)	85 (0.2)	101 (0.3)	127 (0.3)	108 (0.3)	128 (0.4)	10768 (29.5)		11449 (31.3)
2.0 – 3.9	442 (1.2)	642 (1.8)	999 (2.7)	2795 (7.6)	939 (2.6)	4154 (11.4)	5797 (15.9)	1292 (3.5)	288 (0.8)	136 (0.4)	79 (0.2)	56 (0.2)	70 (0.2)	105 (0.3)	134 (0.4)	159 (0.4)	18087 (49.5)		29536 (80.8)
4.0 – 5.9	131 (0.4)	90 (0.2)	240 (0.7)	615 (1.7)	106 (0.3)	1275 (3.5)	2454 (6.7)	743 (2.0)	141 (0.4)	43 (0.1)	26 (0.1)	18 (0.0)	26 (0.1)	41 (0.1)	76 (0.2)	112 (0.3)	6137 (16.8)		35673 (97.6)
6.0 – 7.9	28 (0.1)	7 (0.0)	22 (0.1)	51 (0.1)	19 (0.1)	76 (0.2)	256 (0.7)	191 (0.5)	39 (0.1)	10 (0.0)	14 (0.0)	11 (0.0)	8 (0.0)	11 (0.0)	25 (0.1)	32 (0.1)	800 (2.2)		36473 (99.8)
8.0 – 9.9	2 (0.0)		3 (0.0)	5 (0.0)		4 (0.0)	11 (0.0)	17 (0.0)	6 (0.0)	2 (0.0)	1 (0.0)		4 (0.0)		5 (0.0)	9 (0.0)	69 (0.2)		36542 (100.0)
10.0 – 11.9				1 (0.0)					5 (0.0)	2 (0.0)					2 (0.0)		10 (0.0)		36552 (100.0)
12.0 – 13.9			1 (0.0)							1 (0.0)							2 (0.0)		36554 (100.0)
14.0 – 15.9																			36554 (100.0)
16.0 – 17.9																			36554 (100.0)
18.0 – 19.9																			36554 (100.0)
20.0 ≦																			36554 (100.0)
Sum	965 (2.6)	1391 (3.8)	2168 (5.9)	4854 (13.3)	2511 (6.9)	8399 (23.0)	10587 (29.0)	2829 (7.7)	677 (1.9)	334 (0.9)	233 (0.6)	194 (0.5)	248 (0.7)	309 (0.8)	383 (1.0)	472 (1.3)	36554 (100.0)		* *

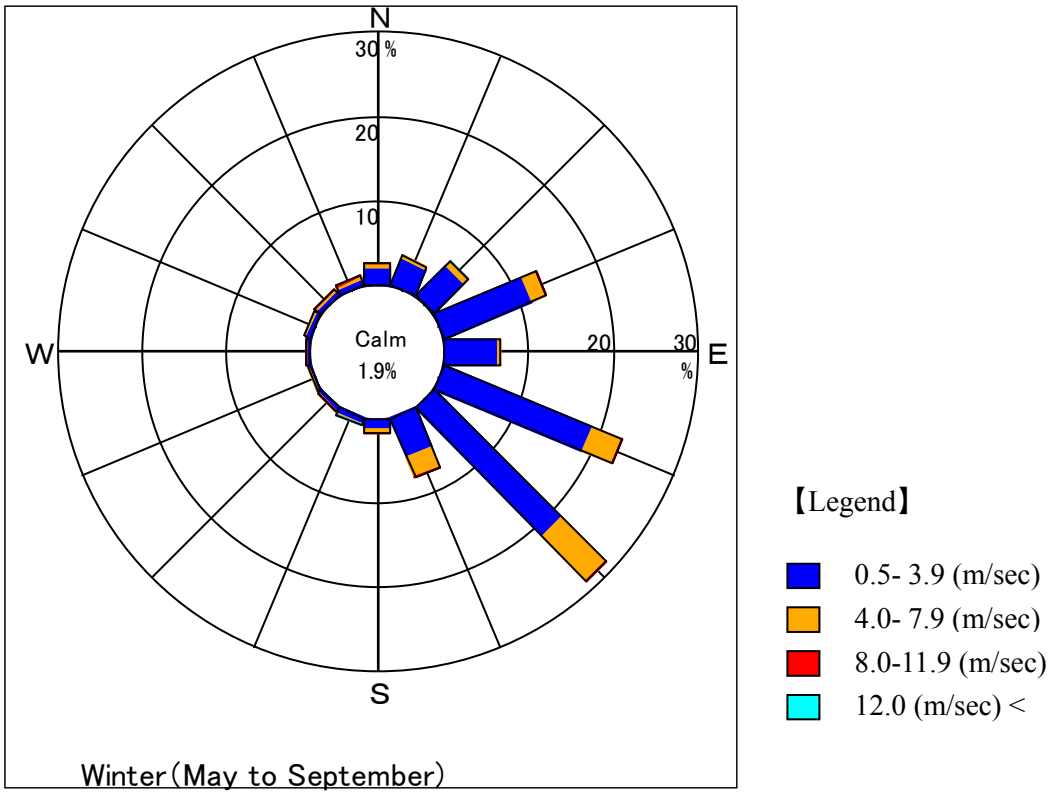


Figure 4.5 Wind Rose : Winter Season (May to September)

(3) Strong Wind Speeds

Table 4.4 shows the monthly strongest wind speeds obtained wind data recorded at the SEAFRAME station during 1994 to 2009. Strong winds occur in December to March of the summer season, while comparatively weak winds in May to September of the winter season.

Seeing the yearly occurrence frequency of strong wind speeds, it is specially noted that the strong winds blow in 1997 which is coincident with the El Niño event.

As a whole, the percentage occurrences of strong winds more than 10 m/sec and 14 m/sec were 0.7% and 0.06%, respectively.

Table 4.4 Monthly Strongest Wind Speed (1994 - 2009)

Month	Strongest Wind Speed (m/sec)	Remarks
January	16.5	2007
February	16.2	2002
March	19.2	1997
April	15.4	2004
May	12.0	2005
June	13.6	2002
July	9.8	1998/2005
August	11.3	2006
September	9.5	1994
October	13.3	2002
November	13.8	2007
December	19.7	1994

The strongest wind speed is recorded to be 19.7 m/sec on December 14, 1994 followed by 19.2 m/sec March 15, 1997, when the Tropical Cyclone Hina passed nearby. Most of strong winds recorded during 1994 to 2009 were affected by the Tropical Cyclone Hina.

4.1.2 Precipitations

Tuvalu Meteorological Service (Station: J64800) at Funafuti observes the daily climatology such as rainfall, air temperature, atmospheric pressure, and wind speed and direction at 9:00 o'clock every day. Regarding to precipitation, the observation was started from January 1st, 1933.

The monthly precipitation data recorded are summarized in **Table 4.5** and **Figure 4.6**. The precipitation at Funafuti shows a seasonal change in the monthly means, which is typically divided into two seasons, the rainy season from December to March and the dry season from April to November.

The annual mean precipitation over the duration of the recorded is 3,493.2 mm. The annual maximum and minimum precipitations was reached to 6,771.1 mm in 1940 and 2,226.0 in 1971, respectively.

Table 4.5 Monthly Precipitation (1933 – 2008)

Month	Precipitation (mm)			Remarks
	Maximum (year)	Mean	Minimum (year)	(Mean)
January	1,141.5 (1955)	399.7	163.7 (1978)	1945 - 2008
February	1,138.9 (1957)	347.3	93.4 (1979)	ditto
March	1,293.1 (1939)	347.7	81.8 (1941)	1945 - 2007
April	618.2 (1939)	265.7	58.8 (2006)	ditto
May	615.2 (1969)	249.6	46.0 (1971)	ditto
June	566.4 (1949)	226.3	67.6 (1955)	ditto
July	617.2 (1941)	259.0	72.2 (1999)	ditto
August	1,196.3 (1940)	265.3	40.9 (1950)	ditto
September	879.1 (1940)	209.5	47.0 (1950)	ditto
October	556.3 (1958)	263.2	55.1 (1999)	ditto
November	702.8 (1940)	268.3	56.3 (1976)	ditto
December	836.9 (1970)	391.7	129.8 (1933)	ditto
Annual	6,771.1 (1940)	3,493.2 mm	2,226.0 (1971)	

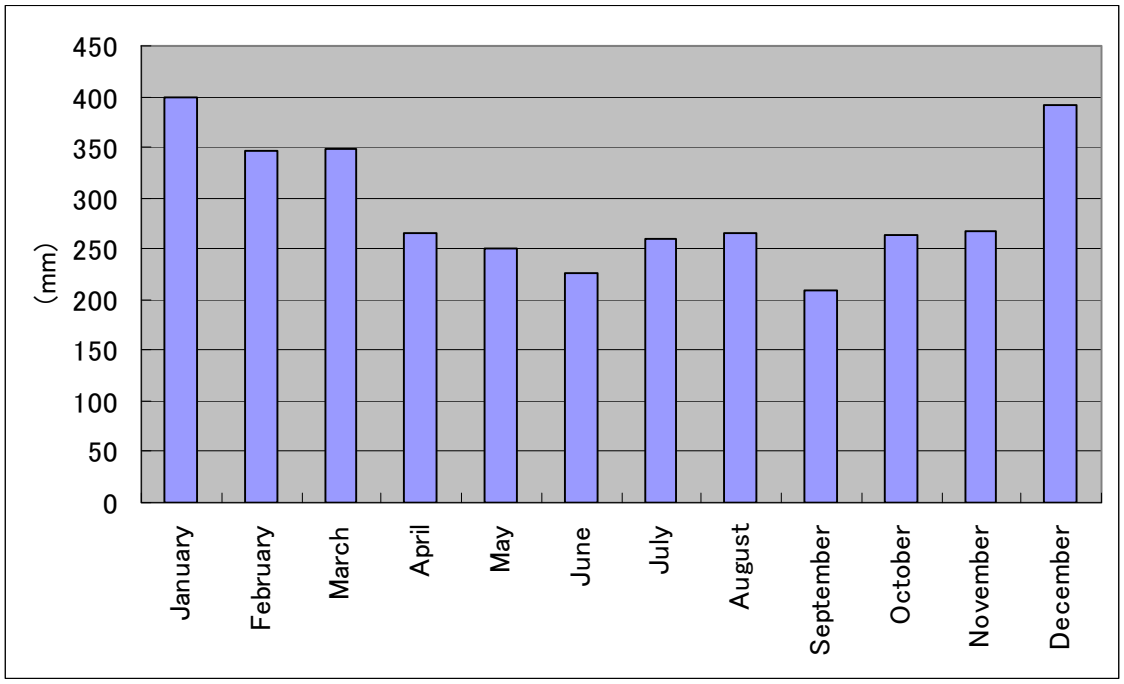


Figure 4.6 Monthly Mean Precipitation at Funafuti (1945 – 2008)

4.1.3 Air and Water Temperatures, and Atmospheric Pressures

(1) Air Temperatures

The air temperature data recorded from 1994 at Funafuti are summarized in **Figure 4.7**. The middle curve (red) represents the monthly mean temperature. The upper and lower curves show the highest and lowest values recorded each month.

The air temperature at Funafuti shows a slight downward trend in the monthly means from installation until 1999, followed by a slight upward trend. From 1999–2000, air temperature maxima were relatively low. Compared to high latitudes, air temperatures in the tropics vary little throughout the year. Funafuti recorded the lowest air temperature, 22.8℃, on 14th of January 1999 and the highest air temperature, 33.7℃, on 19th of November 2005. The mean air temperature over the duration of the recorded is 28.5℃.

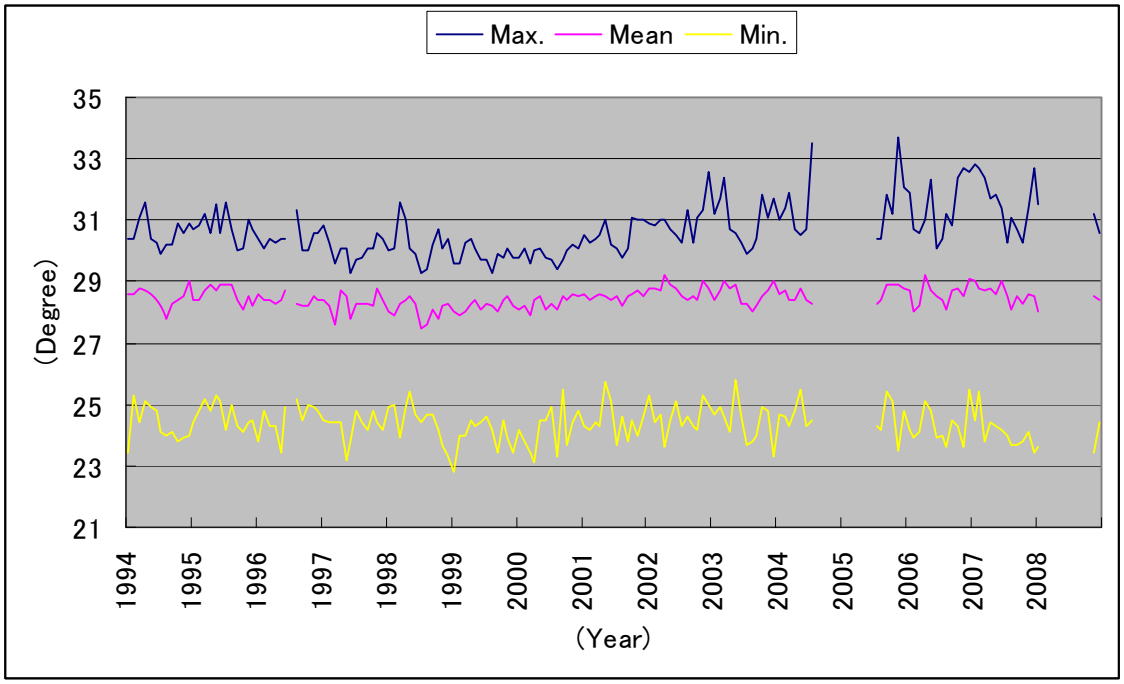


Figure 4.7 Monthly Air Temperature at Funafuti (1994 – 2008)

(2) Water Temperatures

Since installation of the SEAFRAME in 1993 a decadal fluctuation in water temperature has been observed. The water temperature data recorded from 1994 are summarized in **Figure 4.8**. The middle curve (red) represents the monthly mean temperature. The upper and lower curves show the highest and lowest values recorded each month.

The annual maximum temperatures typically occur in November each year, although during El Niño the seasonal cycle of sea level and water temperature are interrupted. The mean water temperature over the duration of the recorded is 29.5℃. The maximum water temperature was 32.7℃ on 26th of November 2001, and a new minimum of 27.3℃ was recently recorded on 30th January 2008.

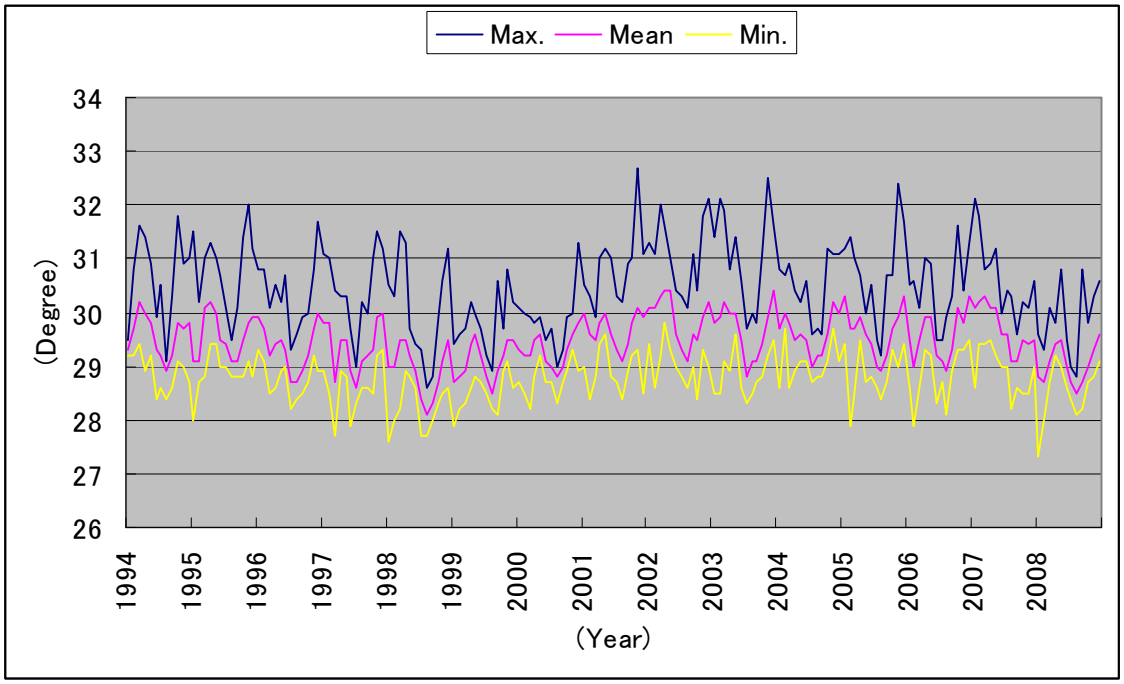


Figure 4.8 Monthly Water Temperature at Funafuti (1994 – 2008)

(3) Atmospheric Pressures

Atmospheric pressure is one of the parameters that can potentially influence relative sea level rise. The monthly barometric pressure data recorded from 1994 are summarized in **Figure 4.9**. The middle curve (red) represents the monthly mean pressure. The upper and lower curves show the highest and lowest values recorded each month.

Barometric pressures vary little throughout the year. The monthly atmospheric pressure at Funafuti shows a decline over the years after the El Niño of 1998. The mean barometric pressure over the duration on the recorded is 1008.5hPa. Funafuti recorded the highest barometric pressure, 1016.4hPa on 2nd of July 1998 and the lowest barometric pressure, 995.4hPa on 5th of March 1997, which coincides with the passage of Tropical Cyclone Gavin.

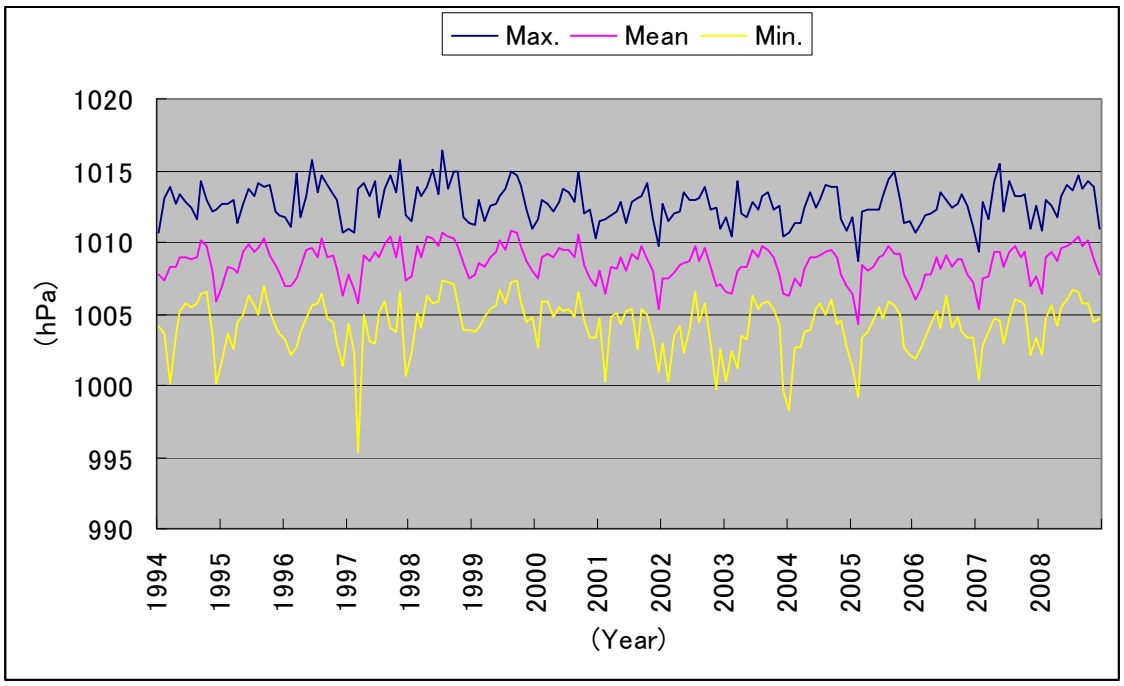


Figure 4.9 Monthly Atmospheric Pressure at Funafuti (1994 – 2008)

Table 4.6 Monthly Maximum and Minimum Air Temperature, Water Temperature and Atmospheric Pressure (All Year: 1994 - 2009)

Month	Air Temperature (˚C)		Water Temperature (˚C)		Atmospheric Pressure (hPa)	
	Max.	Min.	Max.	Min.	Max.	Min.
January	32.8	22.8	32.1	27.3	1012.6	998.3
February	32.7	23.8	32.1	27.9	1013.9	999.2
March	32.4	23.4	32.0	27.7	1014.8	995.4
April	31.7	23.1	31.6	28.6	1014.2	1003.5
May	32.3	23.2	31.4	28.7	1015.5	1002.2
June	31.4	23.8	31.0	28.3	1015.7	1002.9
July	33.5	23.7	30.5	27.7	1016.4	1004.6
August	31.3	23.3	30.2	27.7	1014.9	1002.5
September	31.8	23.4	31.1	28.0	1015.0	1004.0
October	32.4	23.7	31.8	28.3	1014.3	1003.0
November	33.7	23.4	32.7	28.5	1015.7	999.8
December	32.7	23.3	32.1	28.5	1012.5	999.6
Max. & Min. (Date of Occur.)	33.7˚C Nov.19, 05	22.8˚C Jan.14, 99	32.7˚C Nov.26, 01	27.3˚C Jan.30, 08	1016.4 hPa July 2, 98	995.4 hPa Mar.5, 97

4.1.4 Tropical Cyclones and El Niño - Southern Oscillation

(1) Tropical Cyclones

Tropical cyclones, which are fueled by heat stored in the upper ocean, tend to occur in the hottest months. They do not occur within 5° of the equator due to the weakness of the "Corioli's Force", a rather subtle effect of the earth's rotation.

Tuvalu is situated in the southwest Pacific in an area that experiences tropical cyclones. The main Tropical Cyclones affected to Tuvalu are listed in **Table 4.7**.

Table 4.7 Records of Tropical Cyclone Effected to Tuvalu

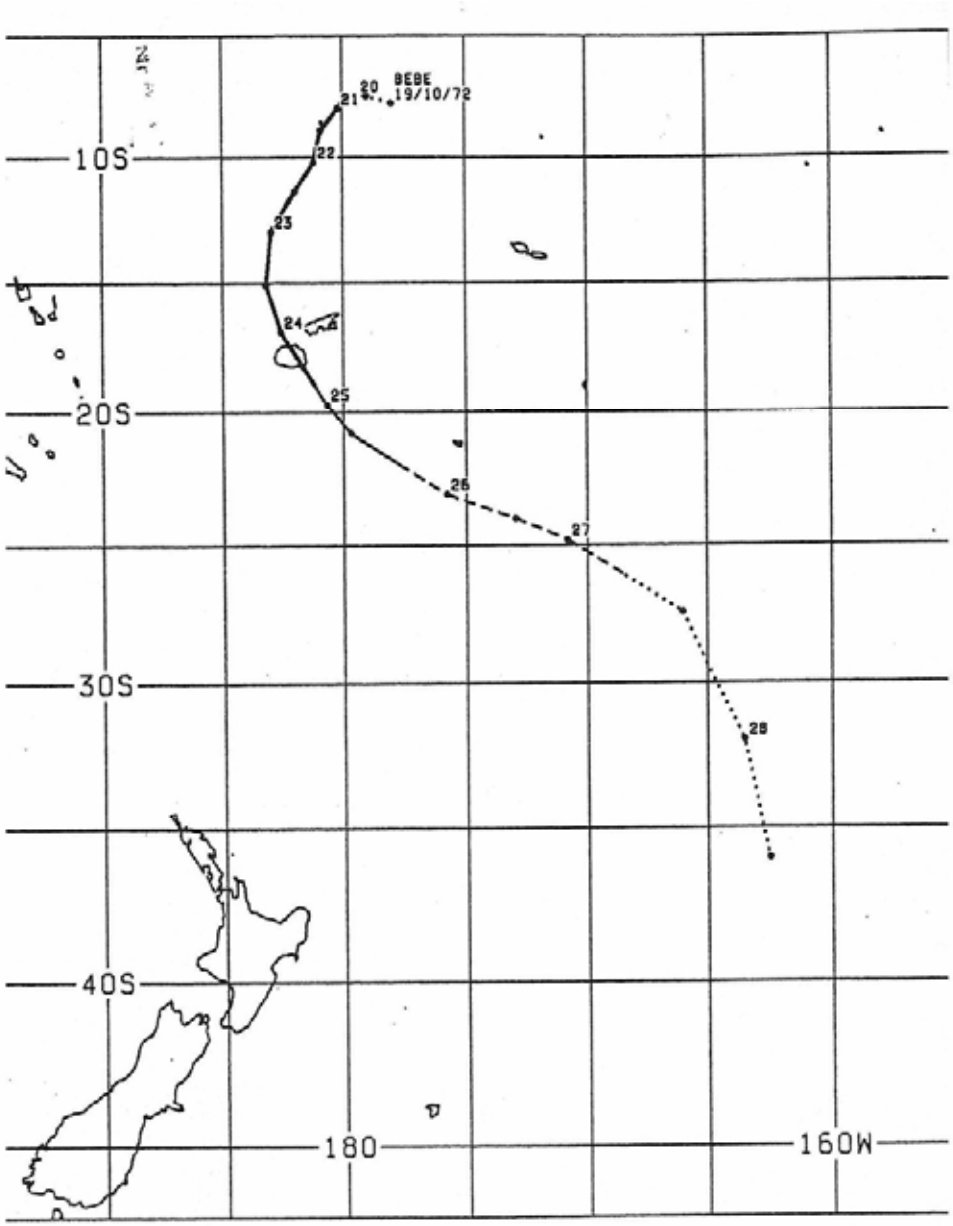
No.	Name of Cyclone	Date of Occurrence	Remarks
1	Unnamed	Feb. 18, 1891	
2	Unnamed	Jan. 02, 1958	
3	Bebe	Oct. 21, 1972	
4	Ofa	1990	
5	Sina	Nov. 1990	
6	Val	Dec. 1991	Dec. 4-5
7	Kina	1993	
8	Nina	1993	
9	Gavin	Mar. 1997	Mar. 5-7
10	Hina	Mar. 1997	Mar. 10-13
11	Keli	June 10, 1997	June 10-13
12	Ami	Jan. 11, 2003	Jan. 11-14
13	Heta	Jan. 02, 2004	Jan. 2-4

(Note) Date : UTC Time

In recorded history, there were three tropical cyclones which had a major impact on Tuvalu (formerly the Ellice Islands). They were unnamed and occurred on February 18, 1891 and January 2, 1958. Another was Cyclone Bebe occurred on October 21, 1972 (refer to **Figure 4.10**) with the lowest recorded mean sea level pressure 954 hPa at Funafuti and with a maximum 10-minute average wind speed of 80 knots and a maximum 3-second gust of about 110 knots. The storm surge was reported to be about 4 meters above the mean high level water mark.

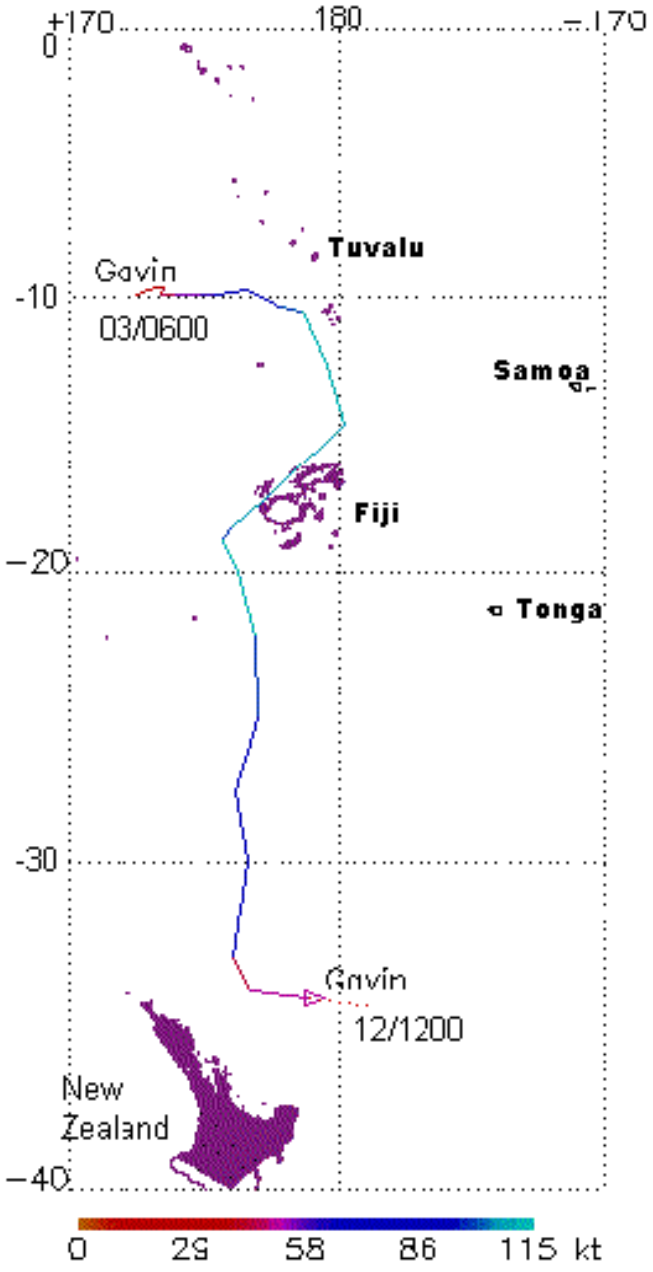
Only one tropical cyclone has passed close to the SEAFRAME at Funafuti since its installation in 1993. Tropical Cyclone Gavin originated close to the southwest of Funafuti on the 3rd March 1997 (see **Figure 4.11**). The storm surge, the non-tidal part of the recorded sea level,

generated by Gavin reached a peak of 0.3 meters on the 5th of March, but since this was at a time of Neap tides it did not cause as much damage as it might have at Spring tides. Gavin did cause considerable erosion through wave action reaching into the lagoon.



Source: Tuvalu Government

Figure 4.10 Track of Tropical Cyclone (Bebe)



Source: SOPAC

Figure 4.11 Track of Tropical Cyclone (Gavin and Hina)

(2) El Niño - Southern Oscillation

The El Niño- Southern Oscillation (ENSO) refers to the periodic change in atmospheric and oceanic patterns in the tropical Pacific Ocean. The warm phase of the ENSO cycle is often simply referred to as El Niño, whilst the cool phase is termed La Niña. ENSO events have a return period of between four to seven years and typically last for around 12 to 18 months. They are a natural part of the climate system and have been affecting the Pacific Basin for thousands of years.

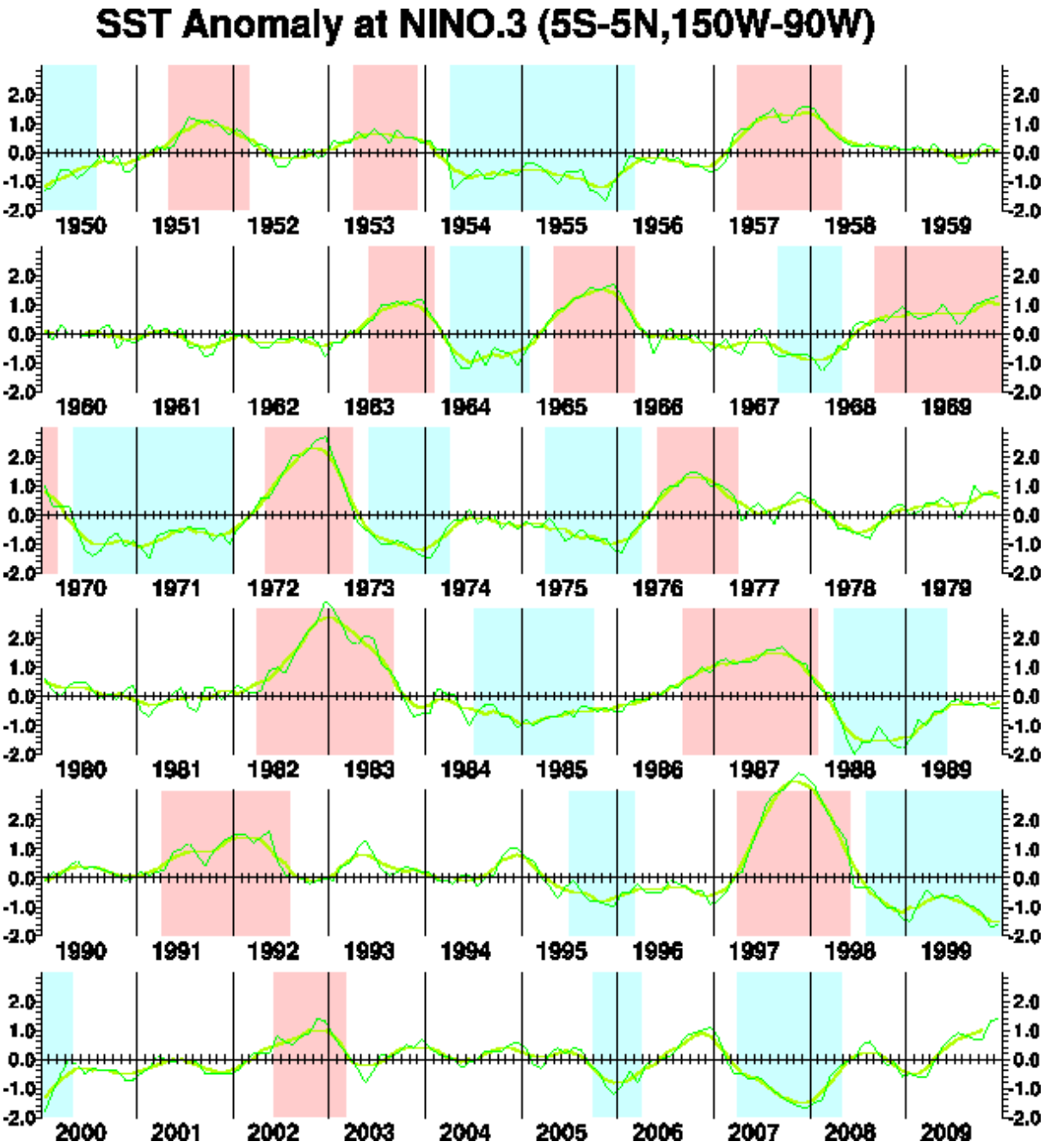
During neutral conditions (non- El Niño or La Niña phases), the easterly trade winds blow across the tropical Pacific. These winds pile up warm surface water in the west Pacific, so that the sea surface is about 50cm higher at Indonesia than at Ecuador. The sea surface temperature is about 8℃ higher in the west, with cool temperatures off South America, due to an upwelling of cold water from deeper levels. Rainfall is found in rising air over the warmer western waters and the east Pacific is relatively dry.

During El Niño events, the trade winds relax in the central and western Pacific. This reduction in the winds causes a reduction in the upwelling along the equator, leading to a depression of the ocean thermocline. The result is a rise in sea surface temperature and a drastic decline in primary productivity. Impacts of this shift eastwards in the circulation over the tropical Pacific may include increased cyclone activity in the central Pacific.

The opposite phase of El Niño is called La Niña. La Niña is characterized by unusually cold temperatures in the equatorial Pacific, as compared to El Niño, which is characterized by unusually warm ocean temperatures in the equatorial Pacific. Global climate anomalies associated with La Niña tend to be opposite those of El Niño.

Climate conditions during 1950- 2009 year at El Niño monitoring area NINO.3 (5°S-5°N, 150° W-90°W) were shown in **Figure 4.12**, in which the period of El Niño phenomena is shown with red and La Niña with blue in terms of the El Niño- Southern Oscillation.

In these 20 years, El Niño was observed three times in the Pacific climate, from March 1991 through to July 1992, from March 1997 to May 1998 and from May 2002 to February 2003. Whilst La Niña were observed four times from June 1995 through to February 1996, from July 1998 to May 1999, September 2005 to March 2006 and from March 2007 to April 2008.



Source: Japan Meteorological Agency

Figure 4.12 Occurrence Period of El Niño and La Niña Phenomena

4.2 Oceanographic Phenomena

4.2.1 Sea Levels and Tides

(1) Sea Levels

The sea levels in the Pacific Islands are controlled by many factors, some periodic like the tides, some brief but violent like cyclones, and some prolonged like El Niño. El Niño's impact on the sea level is mostly felt along the "South Pacific Convergence Zone (SPCZ)", because of changes in the strength and position of the Trade Winds, which have a direct bearing on sea level, and along the equator, due to related changes in ocean currents.

The sea level data recorded since installation at the SEAFRAME gauge at Funafuti is summarized in **Figure 4.13**. The middle curve (red) represents the monthly mean sea level. The upper and lower curves show the highest and lowest values recorded each month. The most notable features of the monthly means are the annual peaks, which appear every year around February or March except in 1998, when a large drop in sea level was recorded during the 1997/1998 El Niño.

The mean sea level over the duration of the recorded is 2.01 m. The lowest sea level over the duration of the recorded is 0.53 m on 27th of February 1998 during the El Niño. Sea levels reached 3.30 m in March 1997 as a result of Tropical Cyclone Gavin, but the highest sea level recorded over the duration of the recorded is 3.42 m on 28th of February 2006. This was not caused by a tropical cyclone, but was due to the highest predicted astronomical tide 3.24m, which is the highest predicted level over the period 1990 to 2016, combined with a sea level anomaly of 0.18m due to the enhanced trade wind activity.

Table 4.8 summarizes the monthly highest sea level during 16 years from 1994 to 2009 at Funafuti and shows that the high sea level period is January to March and the low level period June to November.

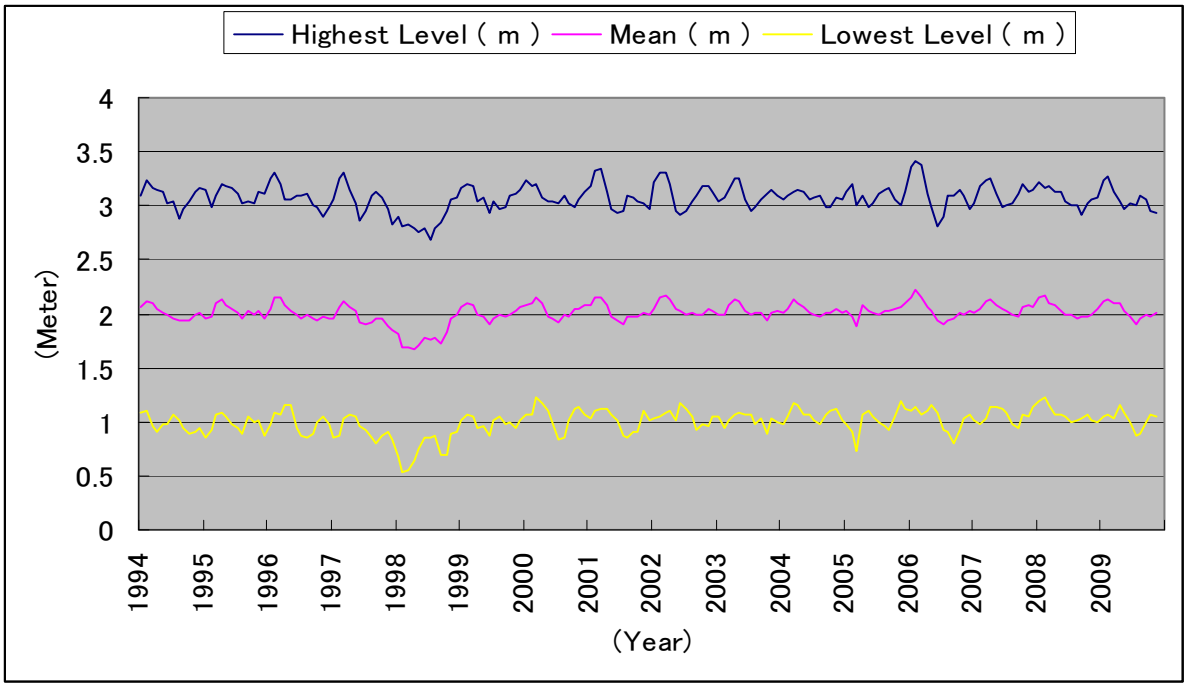


Figure 4.13 Monthly Sea Level at Funafuti

Table 4.8 Monthly Highest Sea Level (All Year: 1994 - 2009)

Month	Highest Sea Level (m)	Remarks
January	3.358	2006
February	3.415	2006
March	3.370	2006
April	3.262	2007
May	3.246	2003
June	3.159	1995
July	3.115	2005
August	3.154	2005
September	3.163	2005
October	3.193	2007
November	3.151	2003
December	3.172	1994

(2) Sea Level Rise due to Climate Change

As discussed in detail by the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (IPCC AR4, 2007), sea level change is an important consequence of climate change, both for communities and environment.

IPCC AR4, 2007 estimates that global average eustatic sea level rise over the last century was 1.7±0.5 mm/year. From 1961 to 2003, the average rate of sea level rise is estimated as 1.8± 0.5 mm/year. IPCC AR4, 2007 also recognizes that sea level records contain a considerable amount of inter-annual and decadal variability. For instance, the average rate of sea level rise for the decadal period 1993- 2003 based on satellite altimetry is 3.1±0.7 mm/year. Studies have shown that comparably large rates of average sea level rise have been observed in previous decades.

Using these ten years' mean sea level data during 1999 to 2008, we calculated the sea level rise at a SEAFRAME station in Funafuti as shown in **Figure 4.14**. The average rate of sea level rise was obtained to be 2.3 mm/year, which is in the range of IPCC (AR4) estimation 3.1±0.7 mm/year for the decadal period 1993- 2003.

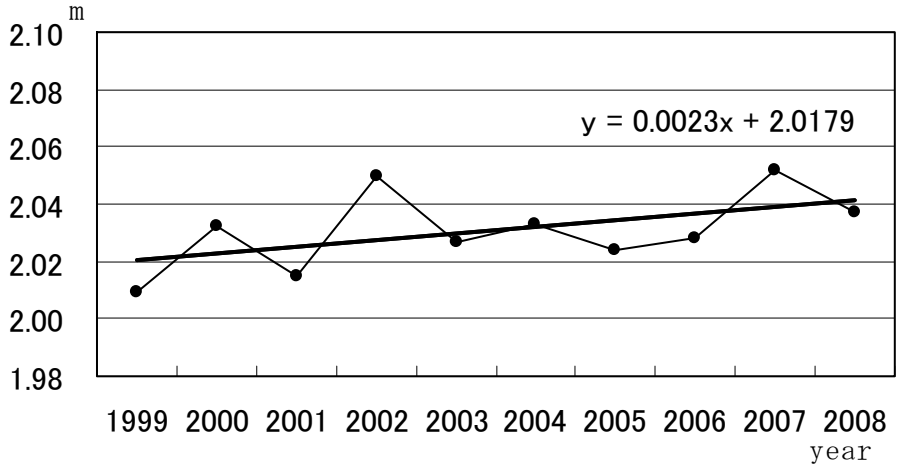


Figure 4.14 Yearly Mean Sea Levels during 1999 to 2008 at Funafuti

(3) Tidal Diagram

Some of the more important water levels, datum and the relation among Bench Marks (BM-22 etc.) for vertical control are shown in **Figure 4.15** as "Tidal Diagram" considering existing tidal information at Funafuti.

Chart Datum Level / Zero of SEAFRAME Gauge

Chart Datum Level (CDL) is the level to which soundings on a published chart are reduced, and above which tidal predictions and tidal levels are given in the tidal tables. Chart Datum Level

in Fongafale is determined 4.0123 meters below Deep Bench Mark: BM-22 at present. The zero of SEAFRAME tide gauge was also set to be the same as the Chart Datum Level by National Tidal Centre, Australian Bureau of Meteorology.

Chart Datum Level (CDL) = Deep Bench Mark: BM-22 − 4.0123 meters
Zero of Tide Gauge = Chart Datum Level (CDL) ± 0.000 meter

Mean Sea Level

The reliability of a value for Mean Sea Level will depend on the length of the period of observation taken to determine it. On this report, Mean Sea Level was newly calculated using observed data over 15 years period from 1994 to 2008 at the SEAFRAME station (1993 year was omitted from the calculation because of many lack of data). This value calculated is 2.1cm higher than the existing Mean Sea Level (CDL + 1.985 meters) for the period of 1993 to 1994.

Mean Sea Level (MSL) = Chart Datum Level (CDL) + 2.0067 meters

Highest High Water and Lowest Low Water

Highest High Water (HHW) was recorded as 3.415 meters on February 28, 2006, while Lowest Low Water (LLW) was recorded as 0.531 meters on February 27, 1998 since installation at Funafuti. As a reference, predicted values of highest and lowest heights in the year of 2009 in Tide Table at Funafuti by Australian Bureau of Meteorology are 3.20 meters and 0.88 meters, respectively.

Highest High Water (HHW) = Chart Datum Level (CDL) + 3.415 meters
Lowest Low Water (LLW) = Chart Datum Level (CDL) + 0.531 meters

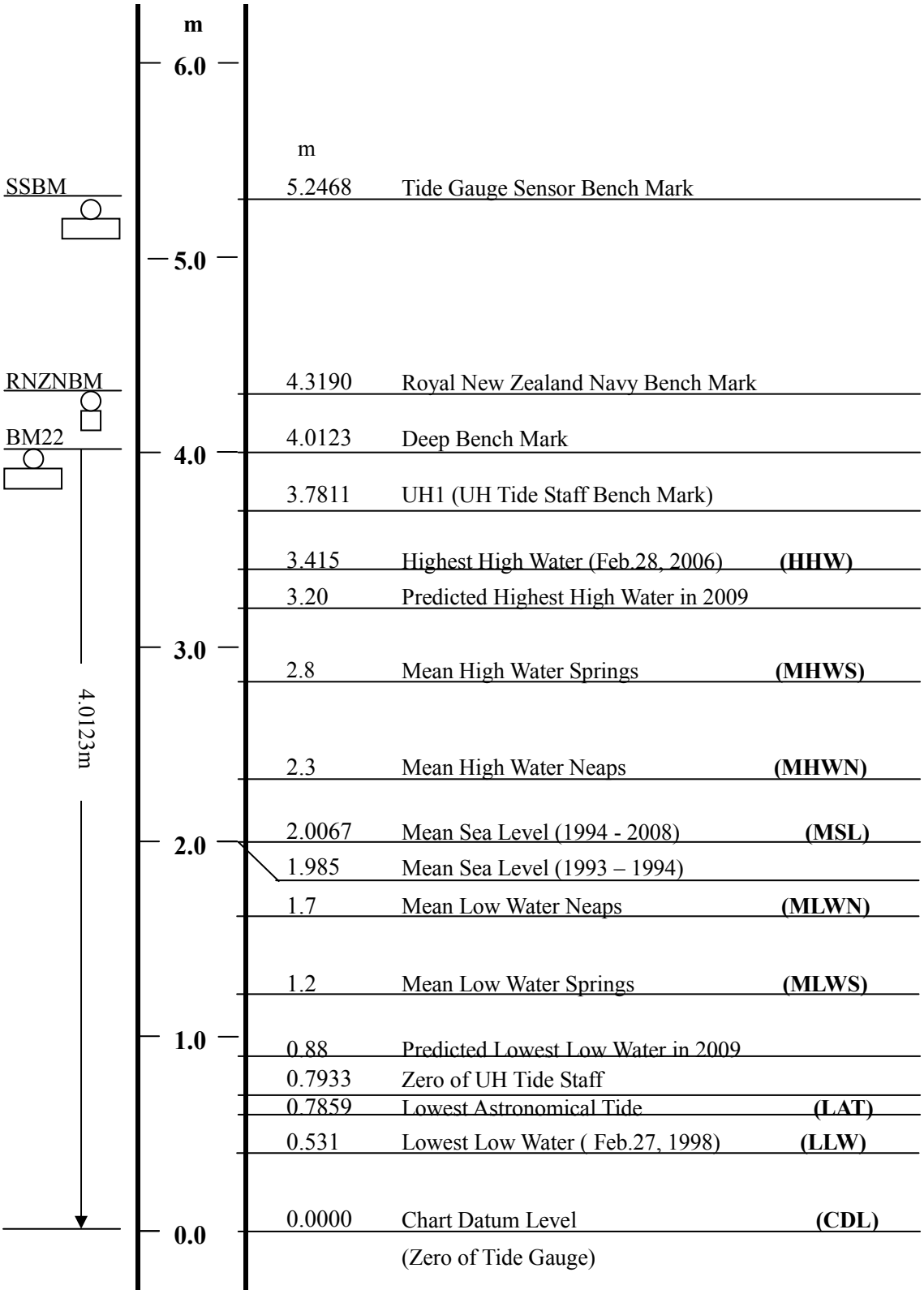


Figure 4.15 Tidal Diagram at Funafuti

(4) Tides

Tidal curve during February 27 to March 1, 2006, when the highest high water 3.415 meters since installation was recorded, at SEAFRAME station in Funafuti is shown in **Figure 4.16**.

This graph clearly shows that the type of tides in this area is a semi-diurnal tide, which has two high waters and two low waters in a day, and the each heights of successive high waters and low waters are almost equal.

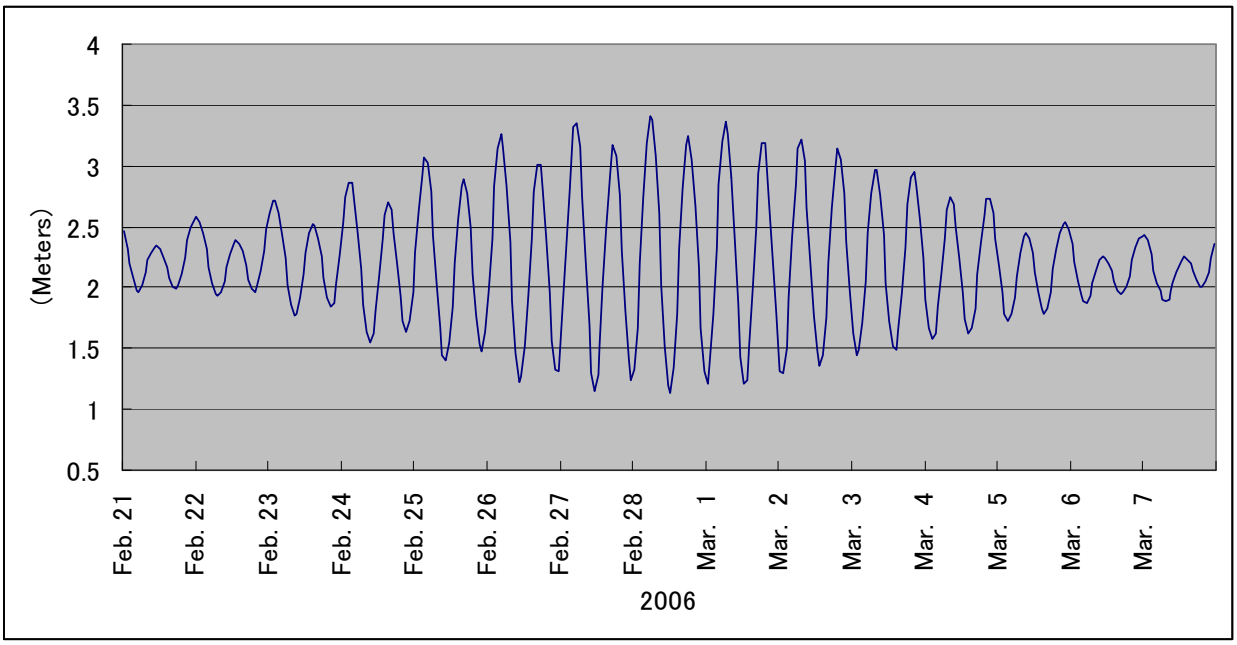


Figure 4.16 Tidal Curve during February 21 to March 7, 2006 at Funafuti

4.2.2 Waves

(1) Ocean Side

Wave measurements with a Waverider Buoy were carried out off the eastern coast of Funafuti Atoll between May 8th, 1990 and April 7th, 1992 with sampling interval of every 3 hours by Oceanographic Company of Norway AS (OCEANOR) as part of the Wave Measurement Program funded by the Norwegian Government Agency. **Figure 4.17** shows the measurement location (Position: 08°3l.5'S, 179°12.9'E. Water depth: 585 m).

The monthly maximum and average significant wave heights (H1/3) with wave period (Tm) recorded for 1990 to 1992 are shown in **Table 4.9**.

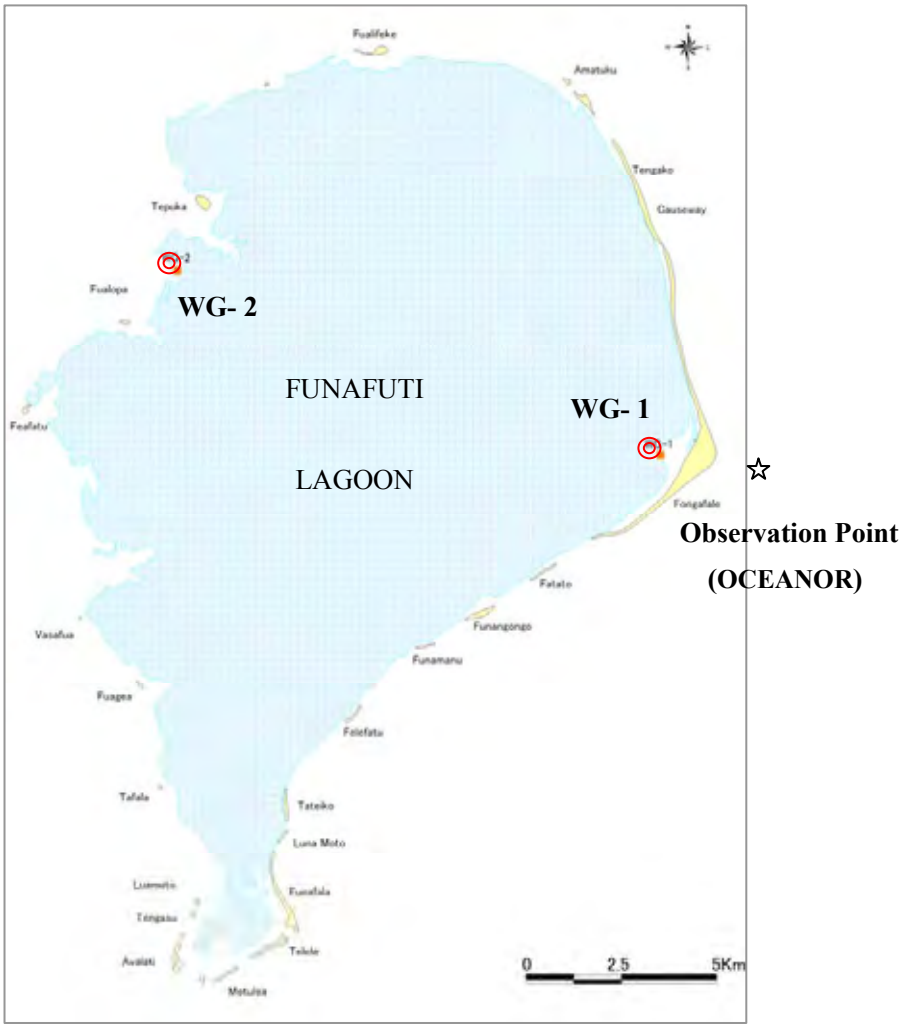


Figure 4.17 Location Map of Wave Observation

The significant wave heights (H1/3) is remarkably constant throughout the year with an average of 1.8 m. The average wave period is 9.2 sec, in the main dominated by local wind seas.

Although the wave climate is steady offshore, it is not necessarily the case on the coast due to a strong seasonality in wind direction in this region.

The highest measured sea state occurred in November 1990 when the H1/3 reached 3.4 m with a peak period (Tp) of 16.7 sec, partly as a result of swell arriving from Tropical Cyclone Sina to the south. Due to the fact that tropical cyclones tend to be in their early stages in the area of Tuvalu, high winds and waves are uncommon. We refer the following comments. Although average wave heights are remarkably steady in Tuvalu, the directional character of the waves is extremely variable through the year. Swell are relatively common from the north during summer, whilst swells from south occur all year but tend to be more frequent in winter.

Table 4.9 Monthly Maximum and Average Values of Wave Records for 1990 to 1992

Month	Maximum Values		Mean Values	
	H1/3 (m)	Tm (sec)	H1/3 (m)	Tm (sec)
January	2.80	13.3	1.7	10.0
February	2.37	13.3	1.7	10.0
March	2.50	13.8	1.8	10.2
April	2.51	11.1	1.8	9.7
May	2.61	14.2	1.8	9.1
June	2.66	10.5	1.8	8.1
July	2.56	10.5	1.8	8.1
August	3.34	11.1	2.1	8.2
September	3.04	10.5	1.7	8.2
October	2.82	11.8	1.6	8.8
November	3.40	13.8	1.7	9.6
December	3.10	12.9	1.9	9.8
Annual	3.40 m	14.2 sec	1.8 m	9.2 sec

Source: SOPAC TR 186

(2) Funafuti Lagoon

Wave observation was conducted at two points: the frontage of Vaiaku Lagi Hotel on Fongafale Islet (WG-1) and the sea area to the south of Tepuka Islet (WG-2) shown in **Figure 4.17**, during field surveys by JICA Study, using one set of Sontek Acoustic Doppler Profilers (Mini-ADP) and one set of I.O-Technic Wave Gauge (Wave Hunter WH403).

Data sampling was made on wave height, period, wave direction and drift for 10 minutes before and after every hour on the hour (for 20 minutes) at intervals of 2 hours and recorded at intervals of 0.5 sec. The details of the deployments of wave gauges and the observation period of waves are shown in **Table 4.10**.

Table 4.10 Deployment of Wave Gauges and Observation Period of Waves

St. No.	WG – 1	WG – 2
Location	Vaiaku	Tepuka
Instrument	Wave Hunter	Mini-ADP
Longitude	179.18957˚E	179.07383˚E
Latitude	8.51972˚S	8.47738˚S
Water Depth	approx. 10 m	approx. 15 m
Height above Seabed	0.4 m	0.4 m
Observation Period		
First Deployment	Nov. 1 to Nov. 21, 2009 (20 days)	Nov. 17 to Jan. 8, 2010 (51 days)
Second Deployment	Feb. 2 to Feb. 19, 2010 (16 days)	Jan. 9 to Feb. 20, 2010 (41 days)
Third Deployment	Feb. 20 to Mar. 19, 2010 (27 days)	---

a) Frontage of Vaiaku Lagi Hotel (WG-1)

Regarding the wave characteristics at the frontage of Vaiaku Lagi Hotel (WG-1) obtained from the first, the second and the third deployments, **Table 4.11** shows the statistics for wave observations. The range of significant wave height, wave period and wave direction (traveling direction) obtained from the first observation were respectively 0.2 to 0.3 meters (average: 0.2 m), 2 to 4 seconds (average: 2.5 sec) and 49 to 83 degrees with hydrographical convention (average: 70.7°). The range of wave height, wave period and wave direction obtained from the second and third observations were respectively 0.2 to 1.4 meters (average: 0.4 m), 2.1 to 4.5 seconds (average: 3.1-3.6 sec) and 51 to 99 degrees (average: 76-80°).

Comparing the results of the second and third observations with those of the first observation, it was indicated that the wave characteristics from the second and third observations were influenced more strongly by western wind or roar.

Table 4.11 Statistics for Wave Observations (WG-1)

Wave Dimension		First Deployment (Nov.1 to 21, 2009)	Second Deployment (Feb.2 to 19, 2010)	Third Deployment (Feb.20 to Mar.19, 2010)
Wave Height :	Maximum	0.3 m	0.9 m	1.4 m
	Mean	0.2 m	0.4 m	0.4 m
	Minimum	0.2 m	0.2 m	0.2 m
Wave Period :	Maximum	4.0 sec	4.5 sec	4.5 sec
	Mean	2.5 sec	3.6 sec	3.1 sec
	Minimum	2.0 sec	2.5 sec	2.1 sec
Wave Direction:	Maximum	83.0°	89.0°	99.0°
	Mean	70.7°	79.8°	76.8°
	Minimum	49.0°	67.0°	51.0°

(Note) Wave Height : significant wave height, Wave Period : significant wave period
Wave Direction : mean wave direction

b) Sea Area to the South of Tepuka Islet (WG-2)

Regarding the wave characteristics in the sea area to the south of Tepuka Islet (WG-2) obtained from the first and the second observations, **Table 4.12** shows the statistics for wave observations.

The range of significant wave height, wave period and wave direction (traveling direction) obtained from the first observation were respectively 0.2 to 1.1 meters (average: 0.3 m), 5.3 to 14.9 seconds (average: 8.9 sec) and 22.4 to 310.1 degrees with hydrographical convention (average: 193.9°). It was indicated that the wave characteristics from the first observation were influenced strongly by northern swell. The range of wave height, wave period and wave direction obtained from the second observation were respectively 0.2 to 1.1 meters (average: 0.5 m), 5.3 to 14.0 seconds (average: 8.9 sec) and 204.5 to 225.0 degrees (average: 219.3°).

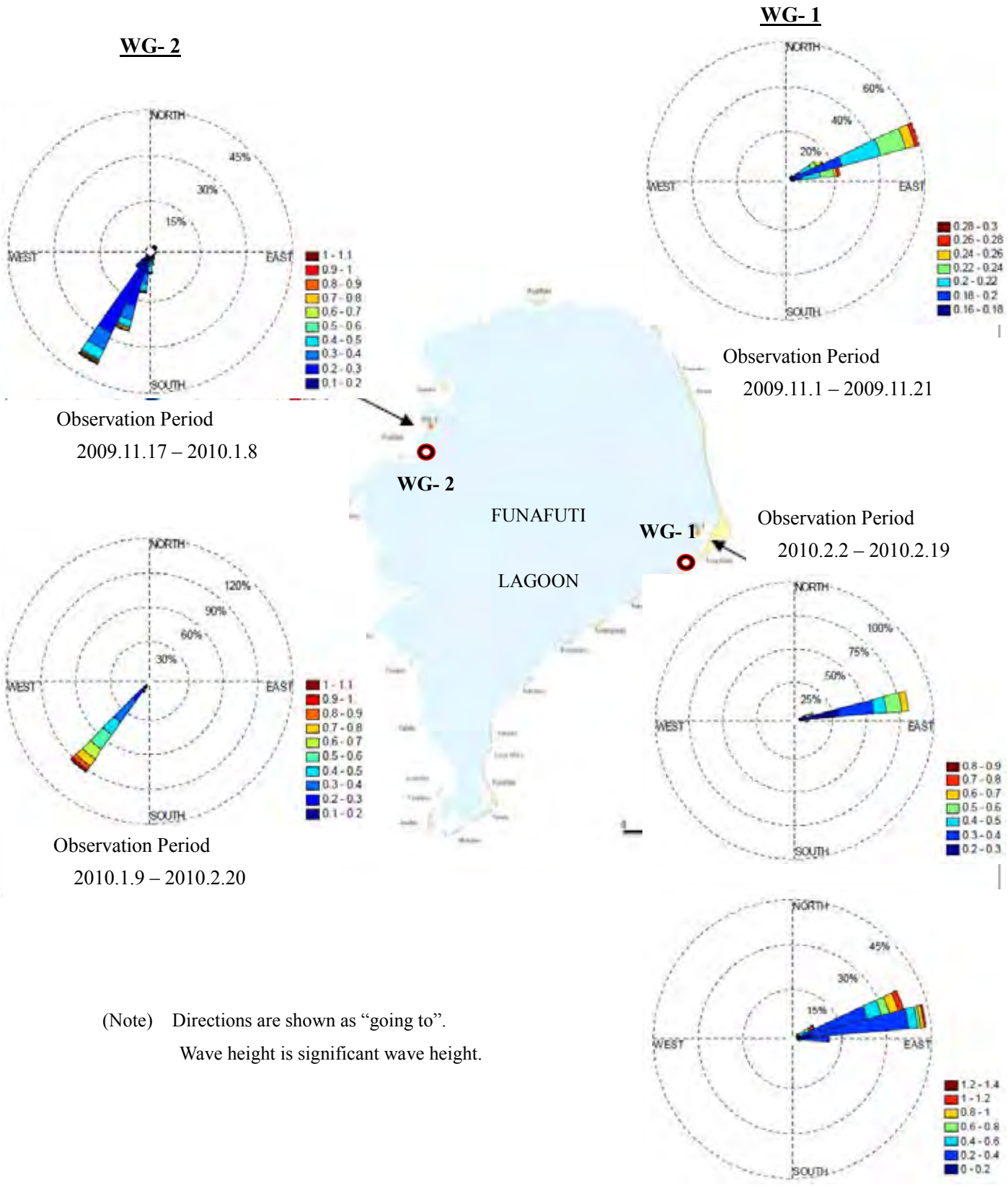
Comparing the results of the second observation with those of the first observation, a marked difference in the wave height and wave period was not found. Regarding the wave direction, the occurrence frequency for significant wave with 220 degrees predominated. However, it was indicated that the wave characteristics from the second observation were influenced more strongly by northeastern wind or swell.

Table 4.12 Statistics for Wave Observations (WG-2)

Wave Dimension		First Deployment (Nov.17. 2009 to Jan.8, 2010)	Second Deployment (Jan.9, 2010 to Feb.20, 2010)
Wave Height :	Maximum	1.1 m	1.1 m
	Mean	0.3 m	0.5 m
	Minimum	0.2 m	0.2 m
Wave Period :	Maximum	14.9 sec	14.0 sec
	Mean	8.9 sec	8.9 sec
	Minimum	5.3 sec	5.3 sec
Wave Direction:	Maximum	310.1°	225.0°
	Mean	193.9°	219.3°
	Minimum	22.4°	204.5°

(Note) Wave Height : significant wave height, Wave Period : significant wave period
Wave Direction : mean wave direction

Figure 4.18 shows the frequency occurrence diagram by wave direction at two observation points for each deployment period. On this diagram, the wave directions are shown as "going to", which means the hydrographical convention.



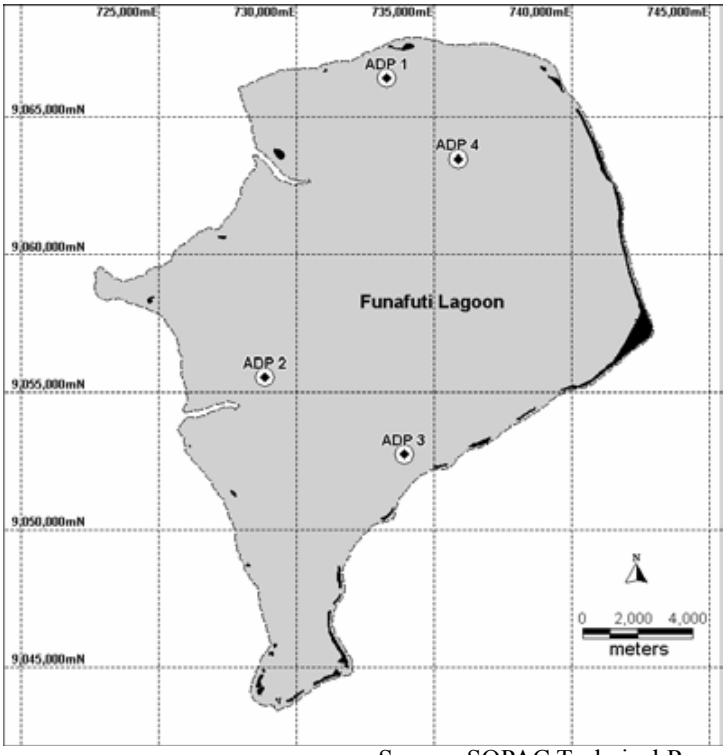
(Note) Directions are shown as "going to".
Wave height is significant wave height.

Figure 4.18 Frequency Diagram by Wave Direction

4.2.3 Currents

(1) Existing Data

Current observations in the Funafuti Lagoon were recently carried out using Sontek Acoustic Doppler Profilers (ADP), which were settled at 0.63 m above seabed, at four points shown in **Figure 4.19**. ADPs are capable to measure horizontal and vertical currents throughout the water column from near bottom to near surface as well as water pressure. The detailed deployment of current observation are summarized in **Table 4.13**.



Source: SOPAC Technical Report 50

Figure 4.19 Location Map of Current Observation (SOPAC)

Table 4.13 Deployment of Acoustic Doppler Profiler (September to October, 2004)

Station No.	Location	Water Depth	Observation Period	Duration
ADP-1	Pa'ava	30 m	Sep.18 (15:00) to Oct.22 (07:00), 2004	33 days
ADP-2	Te Ava Fuagea	27 m	Sep.18 (15:00) to Oct.04 (11:20), 2004	15 days
ADP-3	Payne Rock	24 m	Sep.18 (15:00) to Oct.22 (10:40), 2004	32 days
ADP-4	Te Atau Loa	31 m	Oct.04 (13:30) to Oct.22 (09:50), 2004	17 days

Results of this current observation are shown in **Figure 4.20** as "Current Rose Diagram" and maximum current speeds, mean speeds, mean directions and main current directions recorded at

each observation station are summarized in **Table 4.14**.

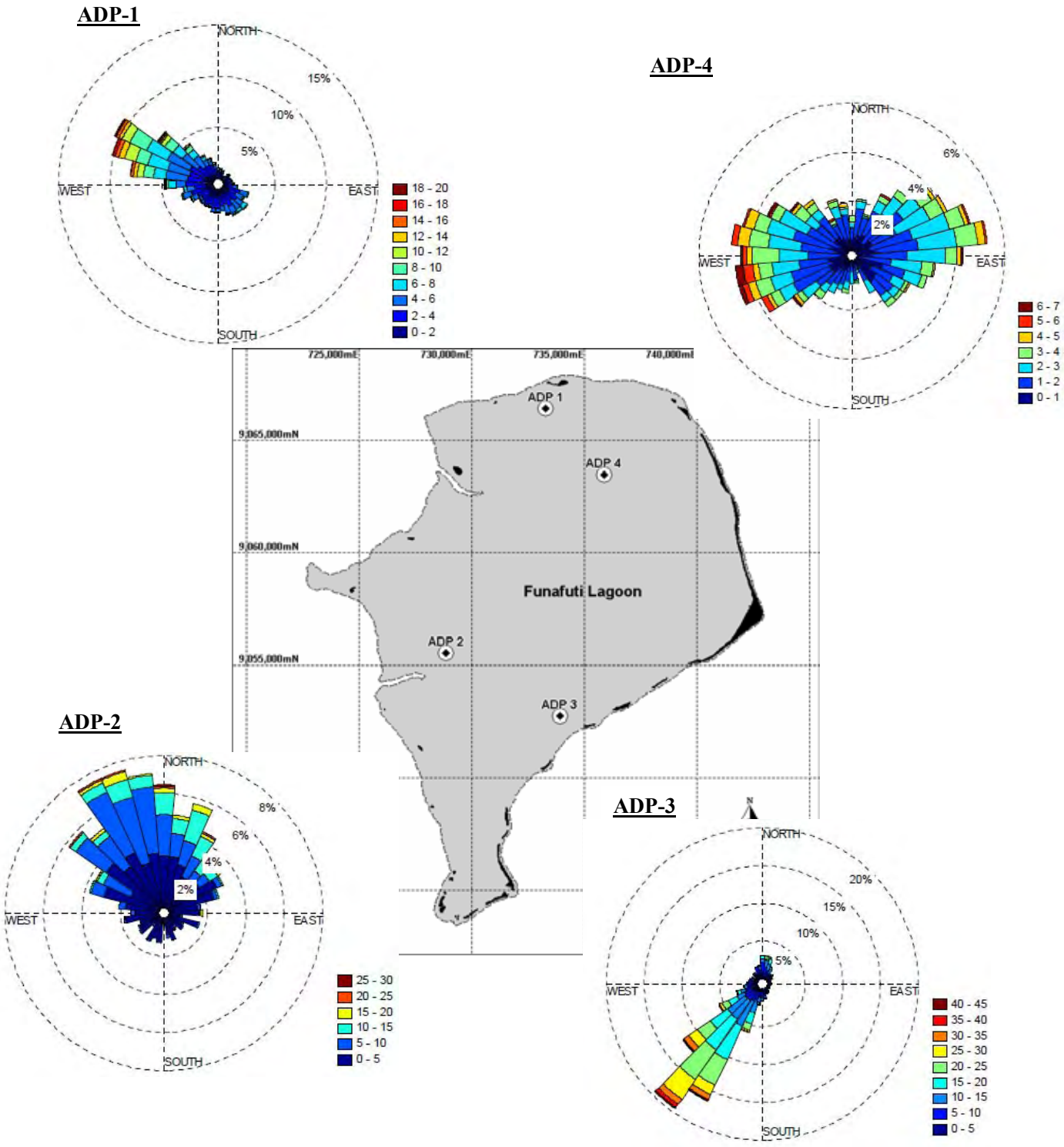
At Station No.1 (ADP-1), the maximum speed was 20cm/sec and direction was prevailed around 300° which means "going to outer ocean from lagoon" through the channel between Paava islet and Te Afualiku islet. At Station No.2 (ADP-2), the maximum speed was 27cm/sec and direction was prevailed around 340° which means "going to north-northwest".

The maximum speed of 44cm/sec during the observation was recorded at Station No.3 (ADP-3) with direction of 220°which means "going to outer ocean from lagoon" through the channel between Funamanu islet and Falefatu islet. Whilst an alternative motion to direction of 80°-260° was observed at Station No.4 (ADP-4) with weak current speeds.

Table 4.14 Results of Current Observation by ADPs
(Statistics for Depth Averaged Velocity)

Station No.	Max. Speed	Mean Speed	Mean Dir.	Main Dir.	Remarks
ADP-1	20 cm/sec	5 cm/sec	232°	300°	going to ocean
ADP-2	27 cm/sec	5 cm/sec	200°	340°	going to north
ADP-3	44 cm/sec	14 cm/sec	200°	220°	going to ocean
ADP-4	7 cm/sec	2 cm/sec	179°	80°- 260°	alternative motion

(Note) Directions are given in "going to".



(Note) Directions are shown as "going to".

Figure 4.20 Current Rose Diagram (SOPAC)

(2) JICA Study

Water flow velocities, current speeds and directions, were measured using two Sontek Acoustic Doppler Profilers (ADP) and one JFE-ALEC Electro-magnetic current meter (Infinity-EM AEM-USB) during the baseline data collection phase on the JICA Study. The current meters were deployed on the lagoon floor at three locations shown in **Figure 4.21**.

The ADPs at CM- 2 and CM- 3 stations were set on the seabed in an upward configuration and the AEM-USB at CM- 1 station measured current speed and direction at the sensor head, 0.7 meters above seabed, for 30 seconds at 10 minutes intervals. The detailed deployment of current observation are summarized in **Table 4.15**.

Table 4.15 Deployment of Current Meters (ADPs and AEM-USB)

Station No.	Location	Water Depth	Observation Period	Duration
CM- 1	Vaiaku	10 m	Nov.7 (12:00) to Nov.23 (12:10), 2004	16 days
CM- 2	Tepuka Vili Vili	15 m	Nov.1 (12:00) to Nov.23 (09:00), 2004	21 days
CM- 3	Causeway	10 m	Nov.8 (12:00) to Nov.23 (10:00), 2004	15 days

Figure 4.21 Location Map of Current Observation (JICA Study)

Results of the current observation are shown in **Figure 4.22** as Current Rose Diagram" and maximum current speeds, mean speeds and main current directions recorded at each observation station are summarized in **Table 4.16**. The current speeds and directions shown in these figures and table are statistics of depth averaged velocity for ADPs at Tepuka Vili Vili and Causeway stations and time averaged current velocity at the sensor head for AEM-USB at Vaiaku station.

The current speed at Vaiaku Station CM- 1 was weak as a whole with maximum speed of 12cm/sec and mean speed of 2cm/sec, and an alternative motion to the direction of 90˚- 270˚ was observed at this point.

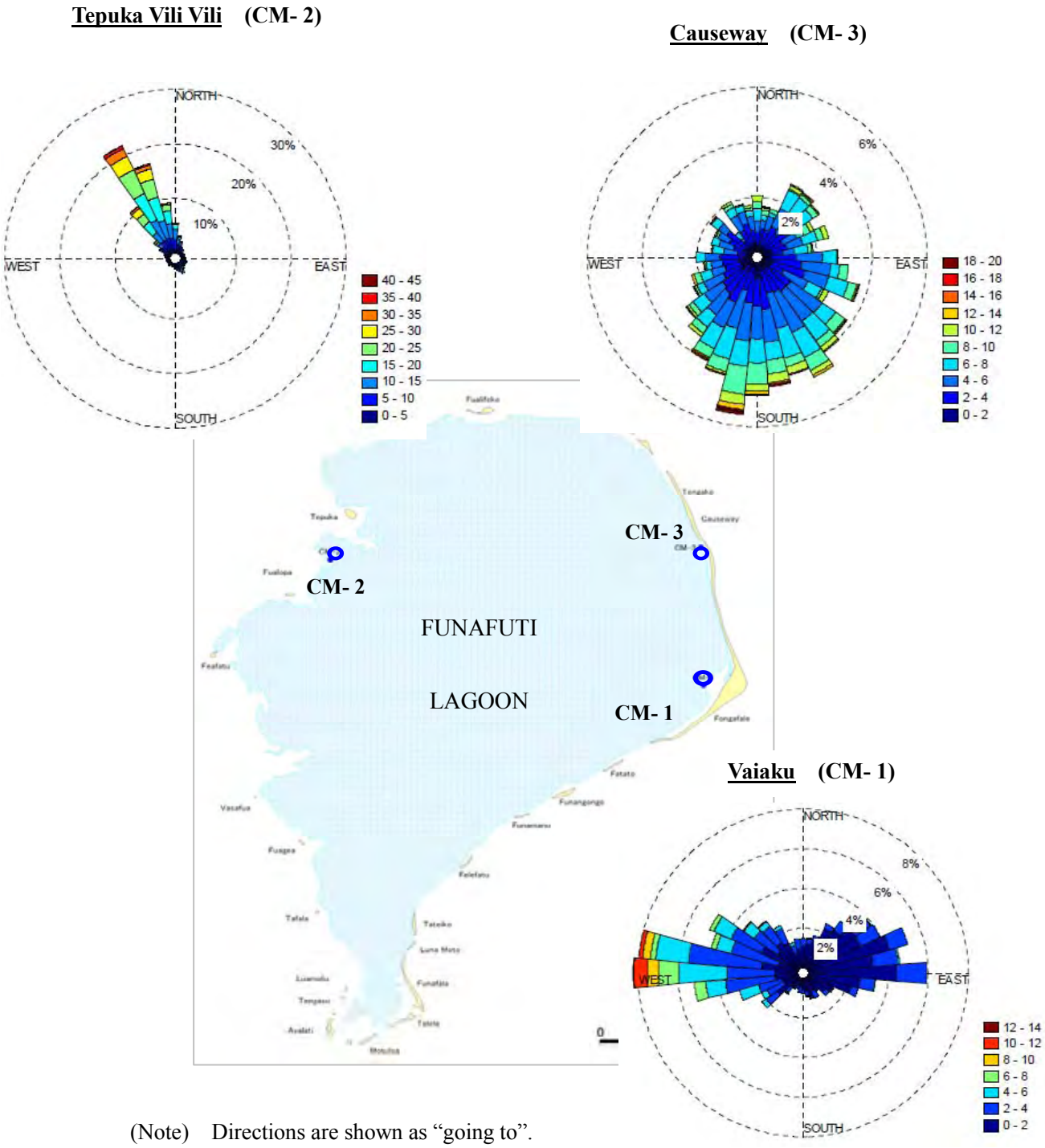
The maximum speed of 45cm/sec during the observation period was recorded at Tepuka Vili Vili Station CM- 2 with direction of 320˚ which means "going to outer ocean from lagoon" through the channel between Tepuka Vili Vili and Fualopa islet. The mean speed was also comparatively strong as 14cm/sec.

At Causeway Station CM- 3, the maximum speed was 18cm/sec and direction was prevailed around 175˚ which means "going to inner lagoon side" along the coastal line. The mean speed was comparatively week as 5cm/sec.

Table 4.16 Results of Current Observation by JICA Study

Location	Max. Speed	Mean Speed	Mean Dir.	Main Dir.	Remarks
Vaiaku	12 cm/sec	2 cm/sec	188˚	90˚- 270˚	alternative motion
Tepuka Vili Vili	45 cm/sec	14 cm/sec	264˚	320˚	going to ocean
Causeway	18 cm/sec	5 cm/sec	169˚	175˚	going to south

(Note) Directions are given in "going to".



(Note) Directions are shown as “going to”.

Figure 4.22 Current Rose Diagram (JICA Study)

4.3 Topographic and Geological Characteristics

Funafuti atoll consists of about thirty islets. Fongafale located on the eastern side of the atoll is the main islet of Funafuti atoll. It is 1.42 km^2 in area and has functions of a capital city of Tuvalu with an international airport and seaport.

4.3.1 Topographic Feature

(1) Land Topography

Fongafale islet is a long and narrow strip of extremely low elevation with a broad "V" shaped outline. Rabbles of dead coral are piled up at ocean-side fringe of the islet up to 3 m above mean sea level, making the highest points of the islet. Other areas are below 2 m above mean sea level in large portion of the islet.

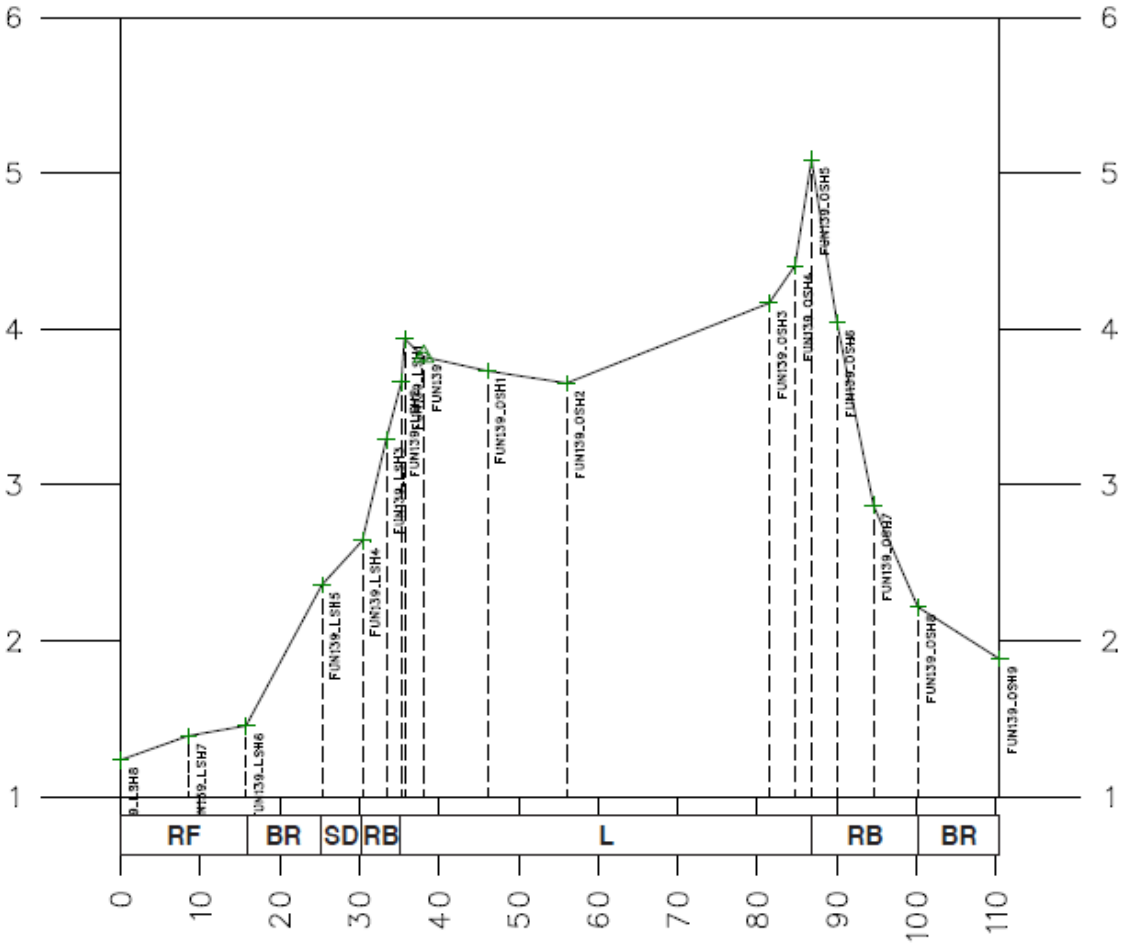
Fongafale islet can be divided into three geographical areas, namely ①the south part (or arm) extending southwestward approximately 2.5 km from the south end of the runway, ②the central area from the south end of the runway north approximately 2 km to Teuaea road and ③ the north part (arm) extending north northwestward approximately 4.5 km from Teuaea road.

When the US forces arrived in Funafuti in October 1942 during the Second World War (WW Ⅱ), there was a lake with surrounding mangroves in the north part of the central area of Fongafale. In order to build a long runway, a large volume of gravel had to be dug from the land area to fill in the lake and mangroves. Sand dug from the lagoon was used for paving the runway, and area 2 km long and 25-40 meters wide was reclaimed along the lagoon shore to provide an access road (SOPAC TR 221).

As the results of the airport construction, ten borrow pits in the islet including one in Tengako islet exist at present. There are persistent sea water intrusions in every day basis; and the water levels of the borrow pits fluctuate according to the tidal movement. During spring tides called King Tide, both sides of the airstrip are inundated by sea water coming through coral rabbles.

The topographic survey on JICA Study was conducted on October 2009 to March 2010 during the baseline survey in the Funafuti atoll. The survey was composed mainly of the control point survey and the cross sectional survey from ocean side to lagoon side. **Figure 4.23** to **Figure 4.25** show the representative cross-sectional profiles in the north part, central part and south part of Fongafale Islet.

North of BP-Oil (FUN-139)

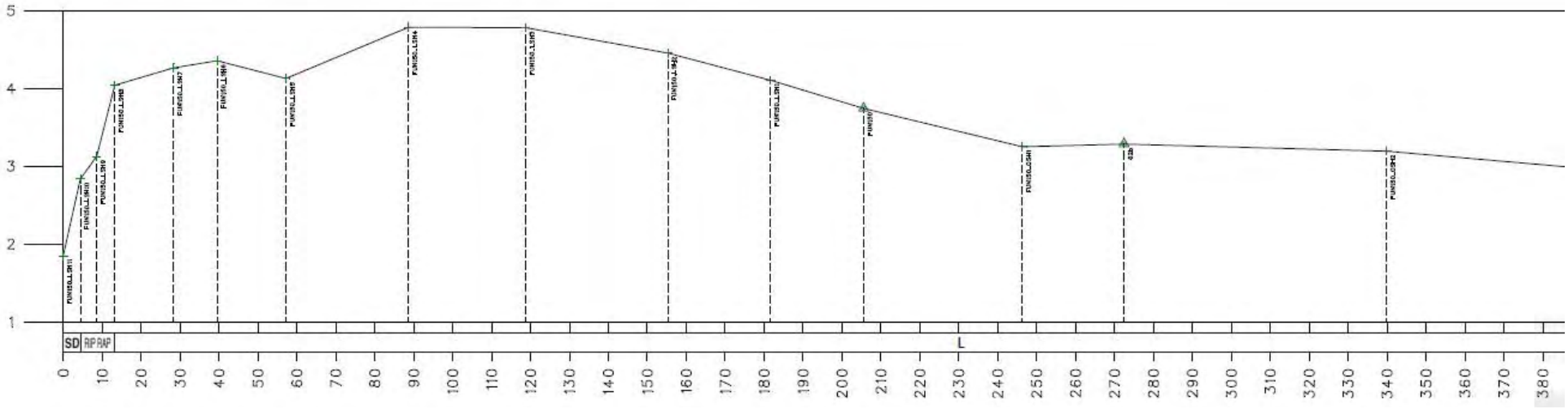


SOPAC

Abbreviation Codes for Funafuti Transect-Sketches

VL	– VEGETATION LINE	BRB	– BEACH ROCK BOULDERS
BF	– BEACH FACE	BRP	– BEACH ROCK PEBBLES
SD	– SAND	BRG	– BEACH ROCK GRAVEL
CR	– CORAL RUBBLE	RB	– RUBBLES
BR	– BEACH ROCK	L	– LAND
CP	– CORAL PATCHES	SP	– SAND PIT
RF	– REEF FLAT	BP	– BORROW PIT

Figure 4.23 Cross Section in North Part of Fongafale Islet (Control Point: FUN-139)



North End of Runway (FUN-150 & FUN-151)

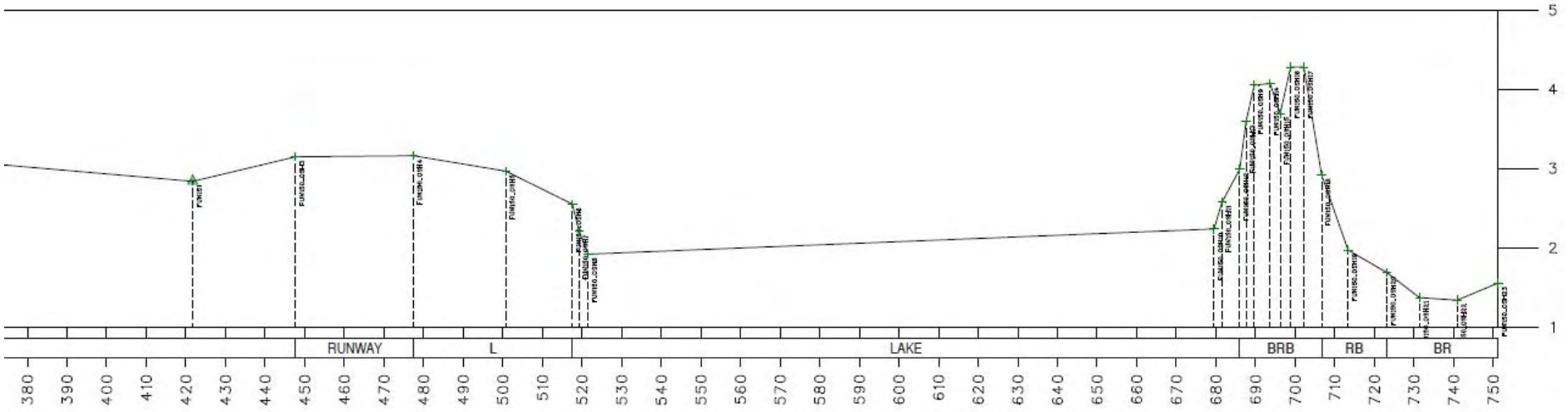


Figure 4.24 Cross Section in Central Part of Fongafale Islet (Control Point: FUN-150 & FUN-151))

South of South End of Runway (FUN-157)

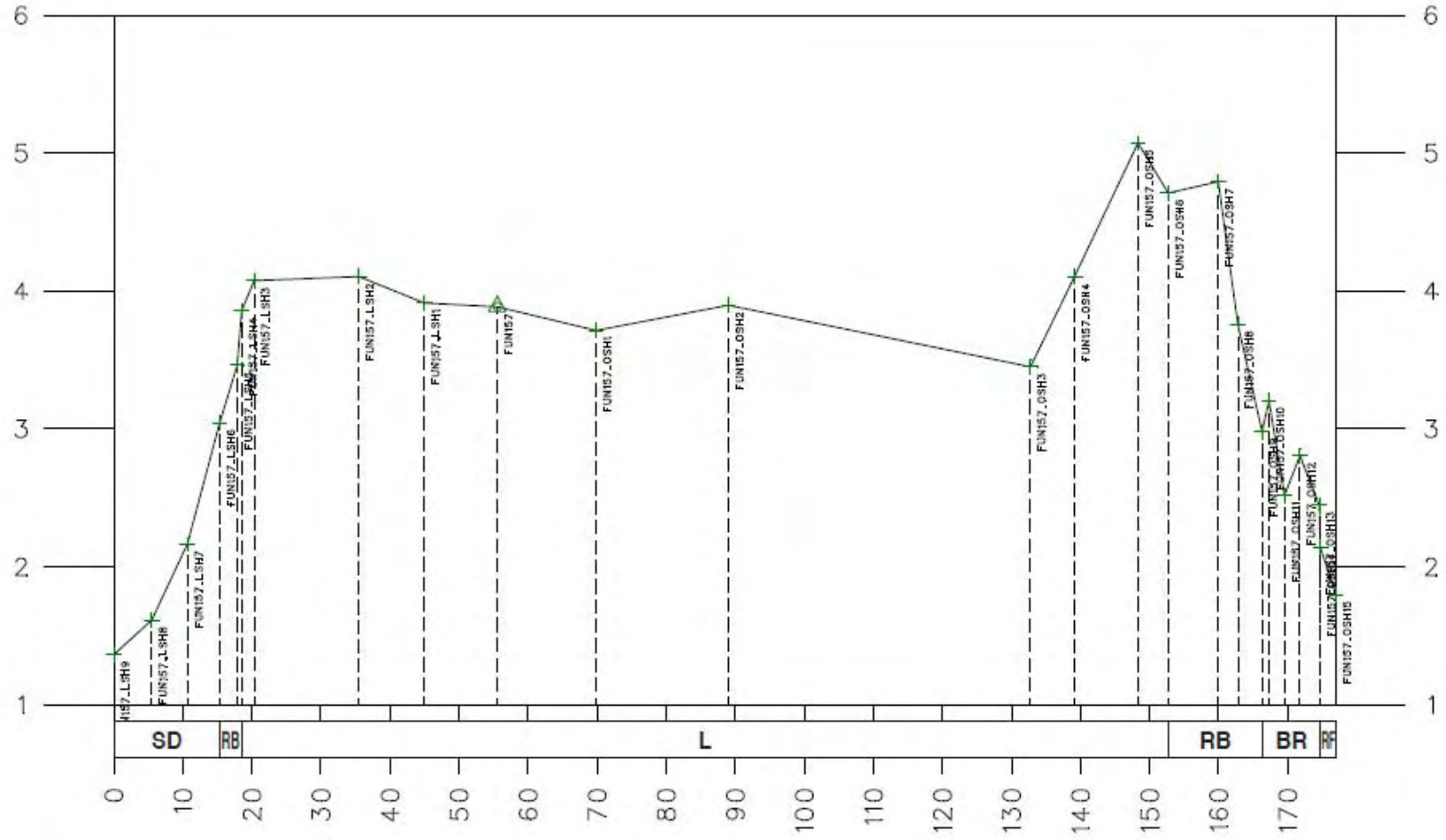


Figure 4.25 Cross Section in South Part of Fongafale Islet (Control Point: FUN-157)

(2) Coastal Line

Senior residents remember that there was a long, low-gradient, sandy beach prior to the WW Ⅱ. Modifications of the lagoon side of Fongafale islet during WW Ⅱ include a 2.3 km long piece of reclamation with coral rock seawall, a long borrow pit (often called channel) beside the seawall, and other channels normal or parallel to the seashore.

The Catalina Ramp was the seaplane base and there was a borrow pit beside and in front of the ramp. A shore-normal channel 35 m wide was dredged 450 m southwest of the south end of the present runway for a petrol torpedo (P.T.) boat base. In the north area, two other channels normal to the shore and one 125 m long channel parallel to the shore near the present Tuvalu Co-operative Wholesale Society were also dug.

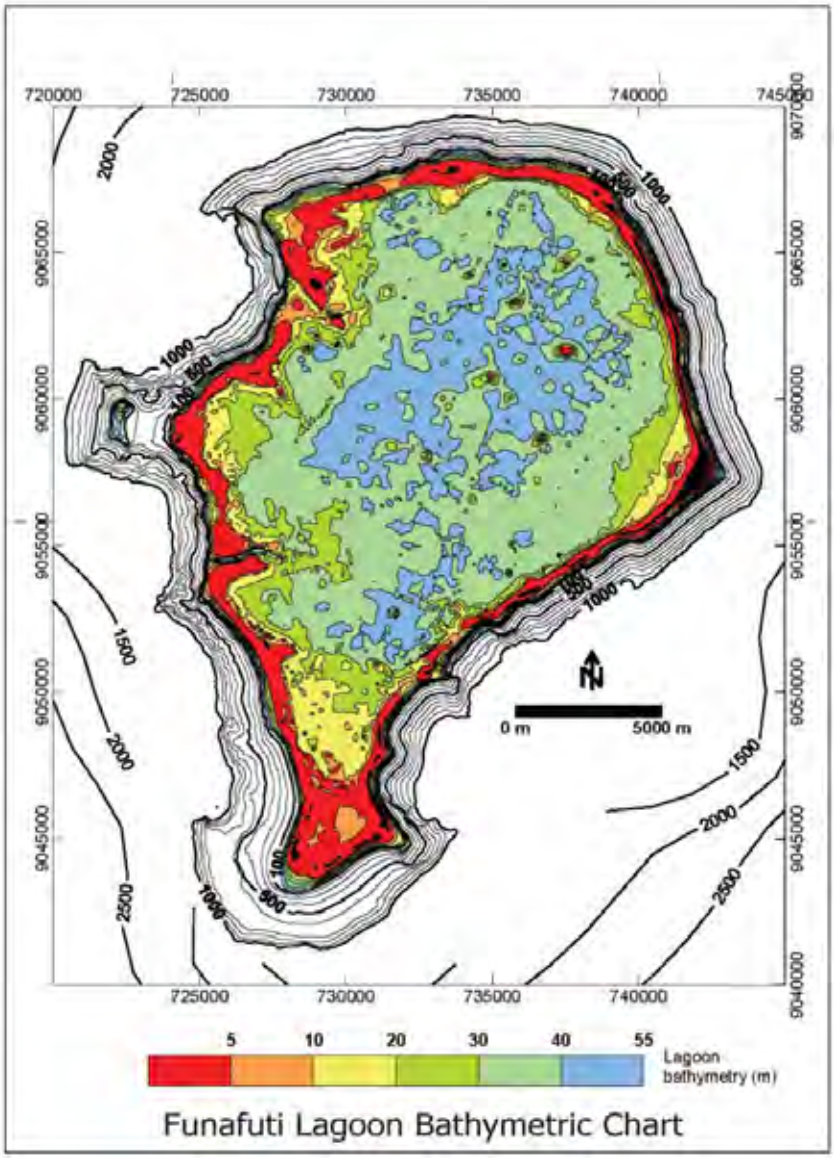
These developments changed the shoreline and sedimentation patterns. The seawall was placed at about the former low tide line and suffered erosion after it was built. The borrow pits (or channels) have been filled with sand transported by wave and long-shore currents and with sand and/or gravel eroded from the reclaimed land. The natural trend is to fill the borrow pits and erode the reclaimed land, as nature attempts to recover the natural beach gradient (SOPAC TR 221).

Observing the present state of the coastline along lagoon side in the central area of Fongafale islet, most of the beach is covered by beach rocks and the sandy beach extends with only 500 m length from the north of Vaiaku Lagi Hotel to the south of Catalina Ramp.

4.3.2 Bathymetric Feature

(1) Ocean Side

Figure 4.26 shows the bathymetry in the Funafuti atoll by SOPAC. The reef flat on the ocean side is about 100 m wide in front of storm ridge. Outside of reef edge increases rapidly depth and is over 1,000 m depth.



Source: SOPAC

Figure 4.26 Bathymetric Map of Funafuti Atoll

(2) Lagoon Side

The lagoon side reef flat is 55- 350 m wide including a 15- 25 m wide beach. Chungting Xue (1995) divided the reef flat in the lagoon into three provinces of the south province southward from Vaiaku Wharf, the central province from Vaiaku Wharf to Catalina Ramp, and the north province northward from Catalina Ramp. He also classified the coral flat into two types, such as Type 1: coral reef pavement with beachrock and/or loose sediments, and Type 2: sand and patch coral with sandy beach.
Type 1 coral flat occurs in the south and north provinces. The coral reef flat pavement is composed of coral reef in the outer western part (lagoon-ward) and beach-rock partly covered with sediments or loose sediments in the inner part. Type 2 coral flat occurs in the central province. It consists of sand and patch coral reef in the outside of the beach.

Inside of lagoon, shallow places (Te Akaue) such as Te Akaue Fasua Kaupa, Loa, Pukeu, Tuluaga, Pusa, Fasua and Asano are scattered about. The water depth in the central part of lagoon is range from 40 to 50 meters and the maximum depth can be read as 49 meters on the existing chart (Funafuti Atoll, Chart No.83094).

On the other hand, main channels (Te Ava) from the ocean side into the lagoon are Te Ava I Te Lape in the north part of the atoll; Te Ava Tepuka, Tepuka Vili Vili, Kumkum and Fuagea in the west part of the atoll; and Te Ava Puapua and Mateika in the southeast part of the atoll.

(3) JICA Study

a) Bathymetric Survey in Lagoon Area of Fongafale Islet

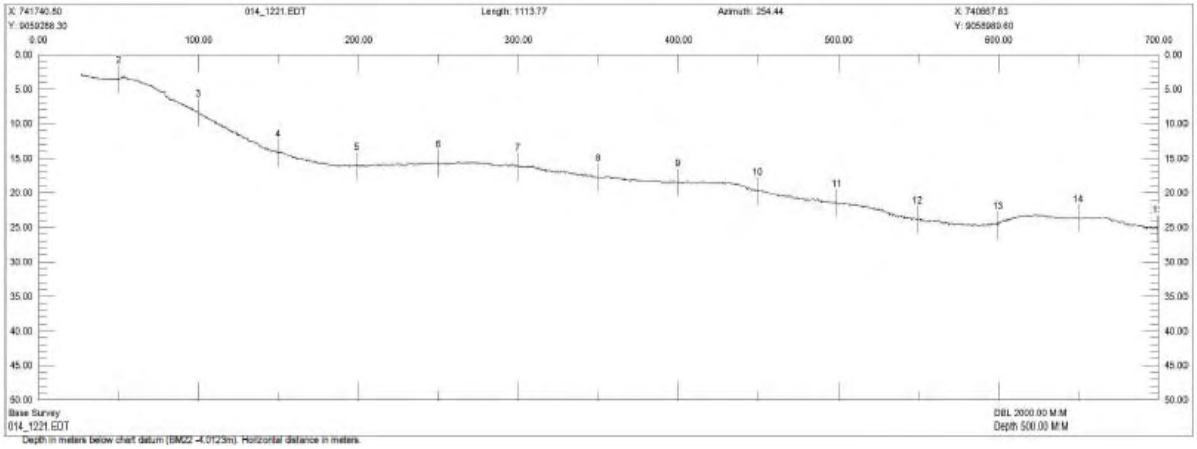
The results of the bathymetric survey in the lagoon area were compiled as a set of cross sections more than 200 lines and a bathymetric chart. **Figure 4.27** shows representative samples of cross sections in front of the Fisheries Department (the north part of Fongafale), the south of Catalina Ramp (the central part of Fongafale) and the Water Boy: seawater desalination station (the south part of Fongafale).

b) Detailed Bathymetric Survey in Target Zone for Coastal Protection Measures

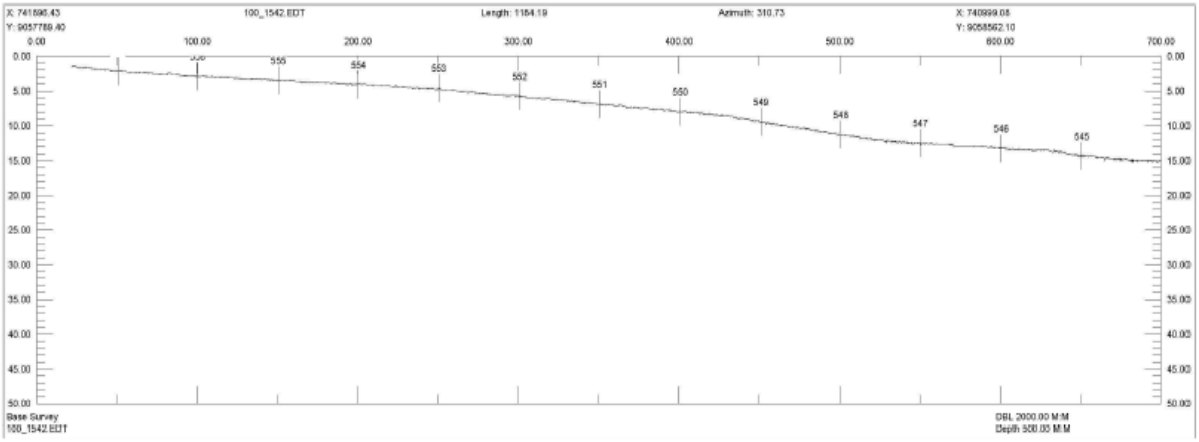
The result of the detailed bathymetric survey in the target zone for coastal protection measures, which was performed on the end of June 2010 during the feasibility study, was compiled as a bathymetric map as shown in **Figure 4.28** and a set of cross sections for each survey line for the calculation of required volume for gravel nourishment.

The dialed bathymetric maps in the target zone for coastal protection measures are shown in **Figure 4.29** to **Figure 4.32** for each zone.

North Part (Line N-14: Fisheries Dep.)



Central Part (Line S-100: Catalina Ramp)



South Part (Line S-85: Water Boy)

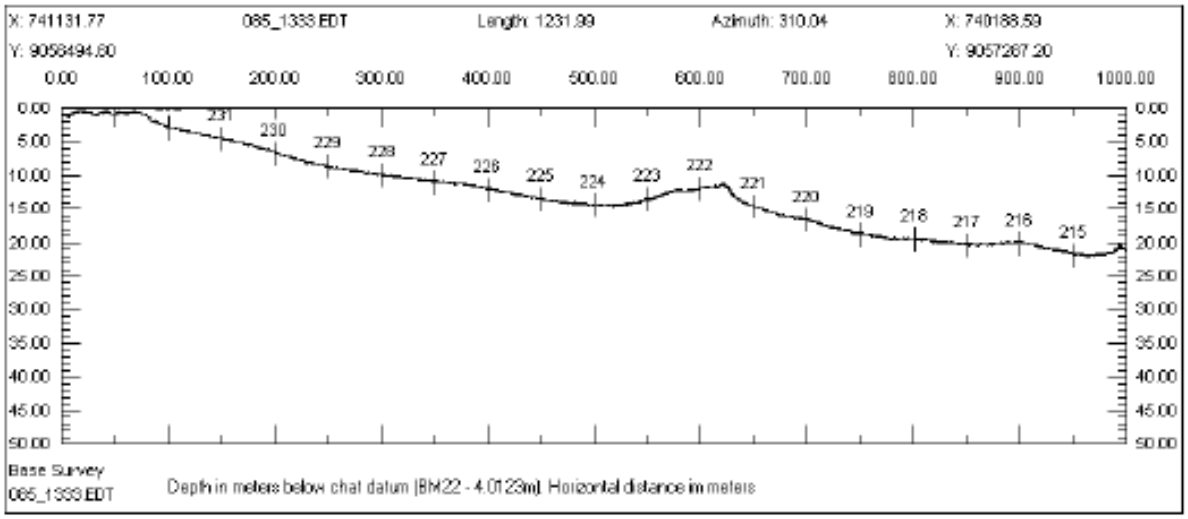


Figure 4.27 Representative Cross Sections in Funafuti Lagoon

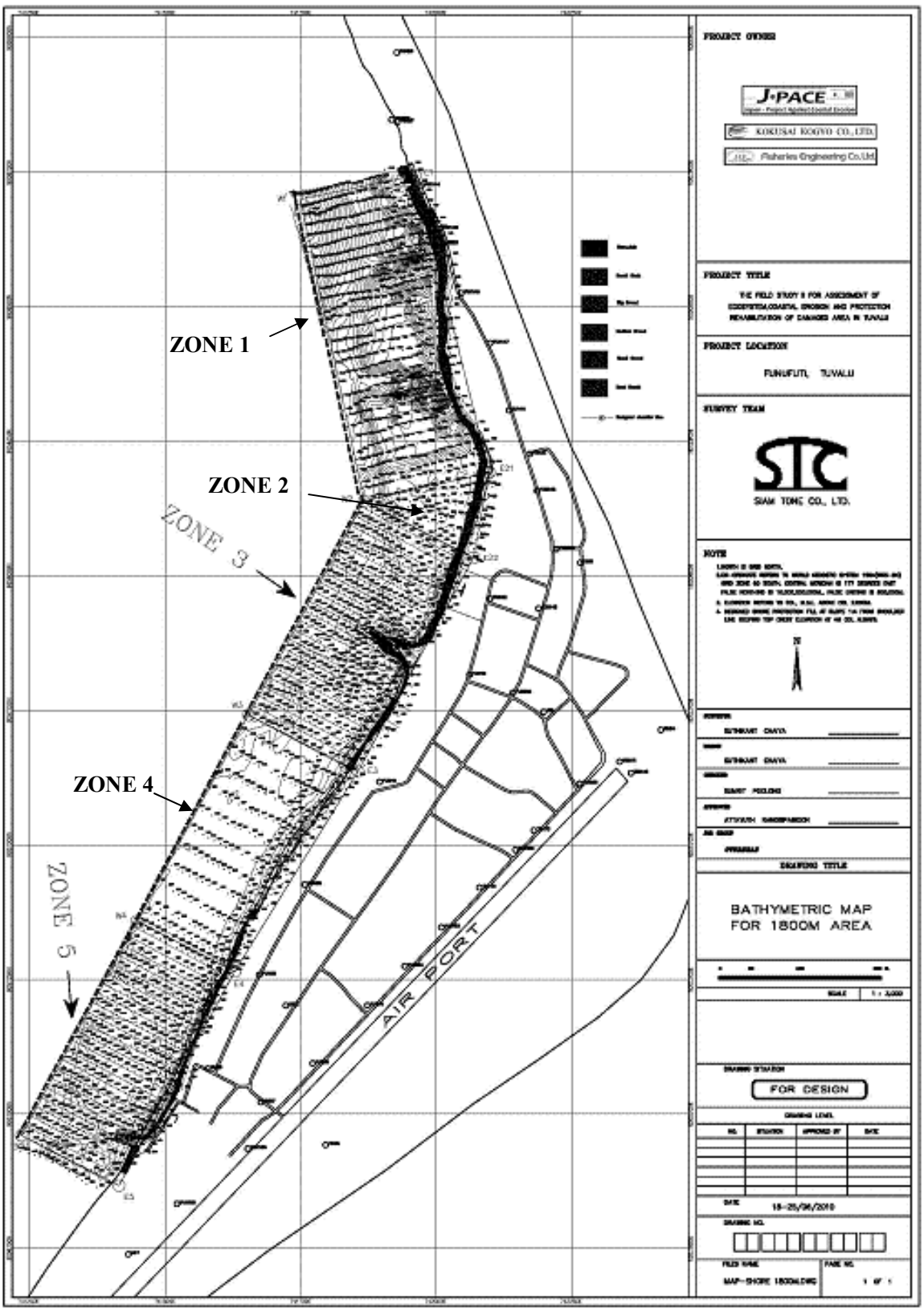


Figure 4.28 Bathymetric Map in Target Zone for Coastal Protection Measures

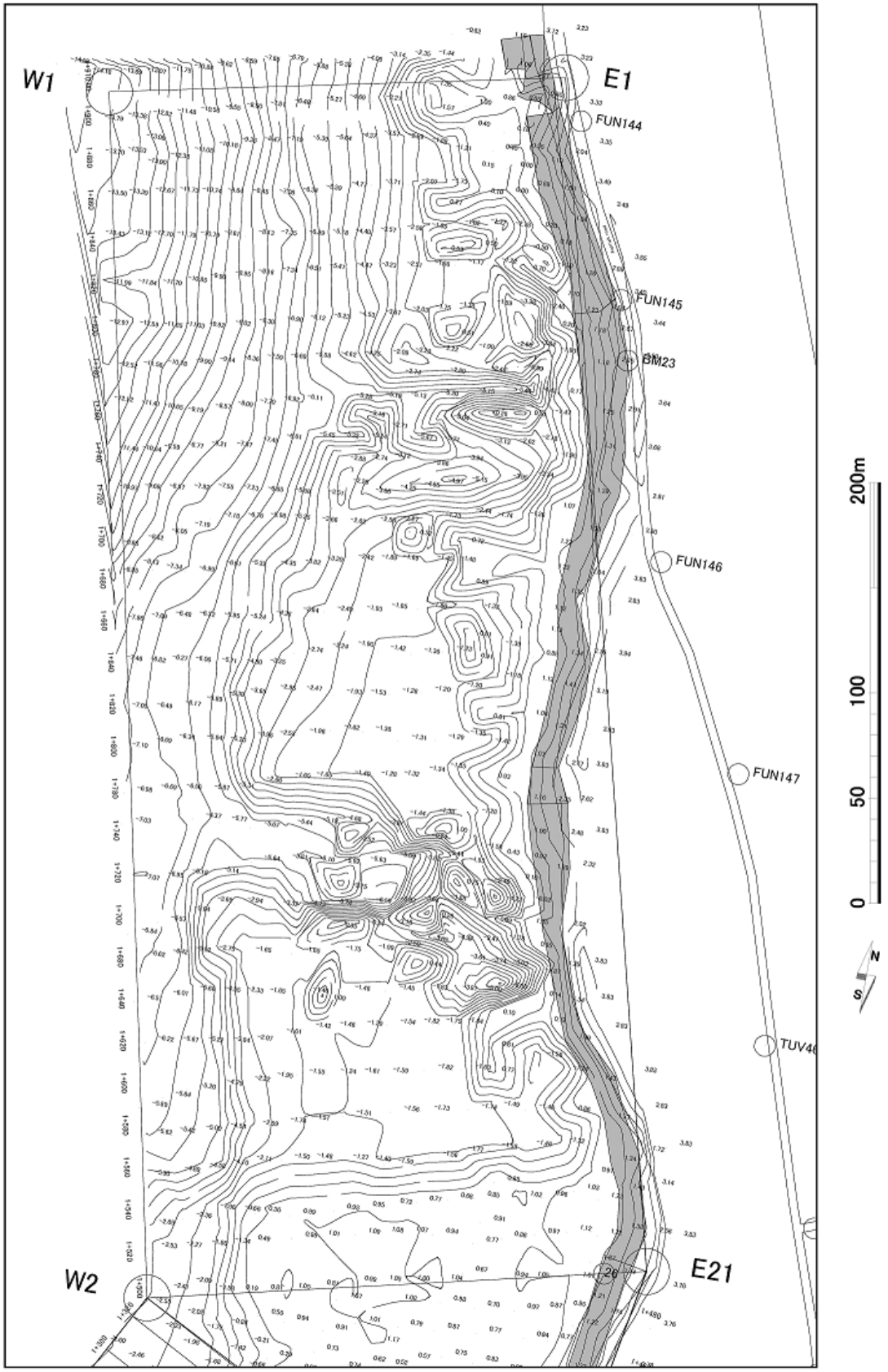


Figure 4.29 Detailed Bathymetric Map in Target Zone for Coastal Protection Measures (Zone - 1)

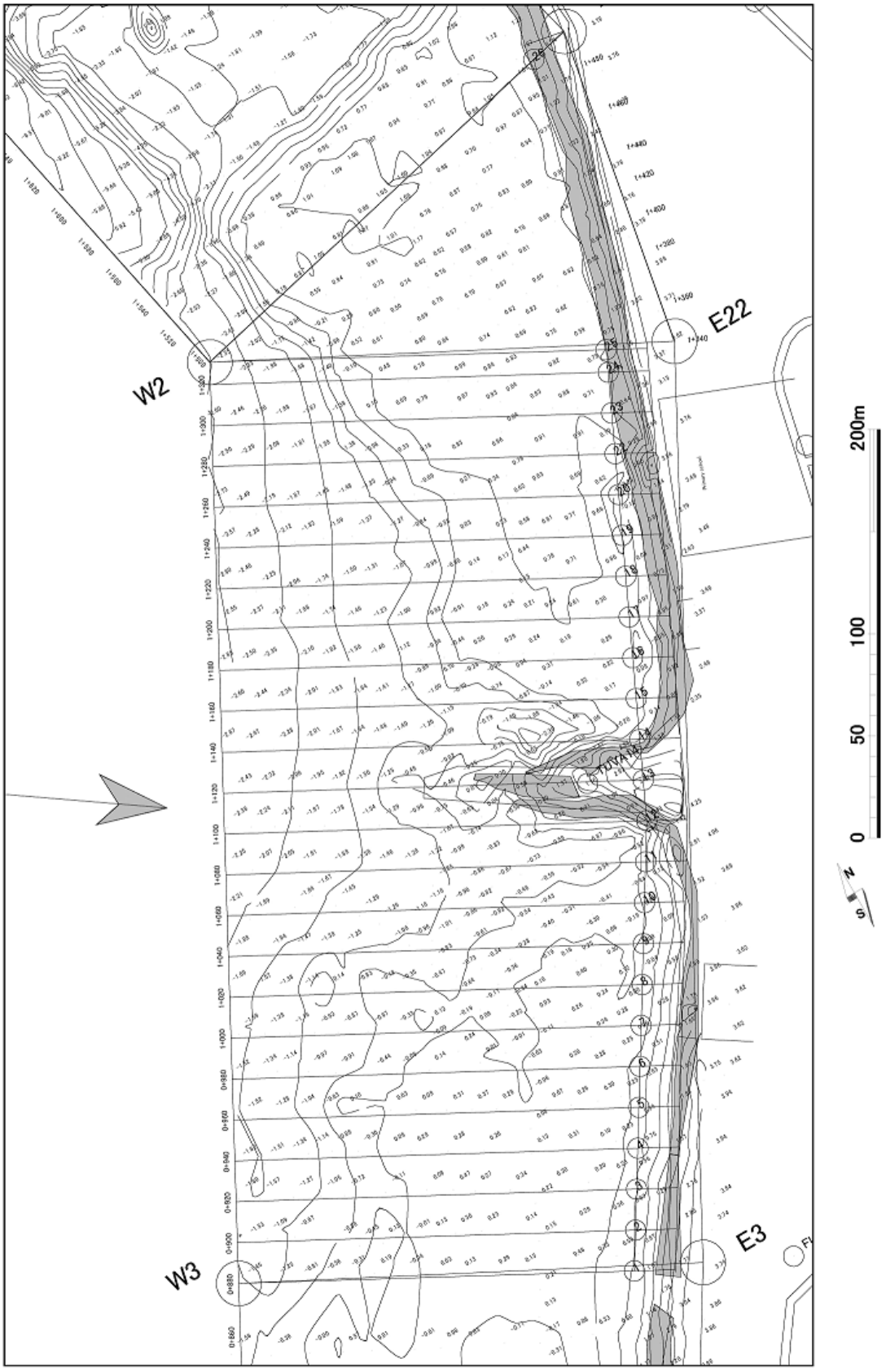


Figure 4.30 Detailed Bathymetric Map in Target Zone for Coastal Protection Measures (Zone – 2 & Zone - 3)

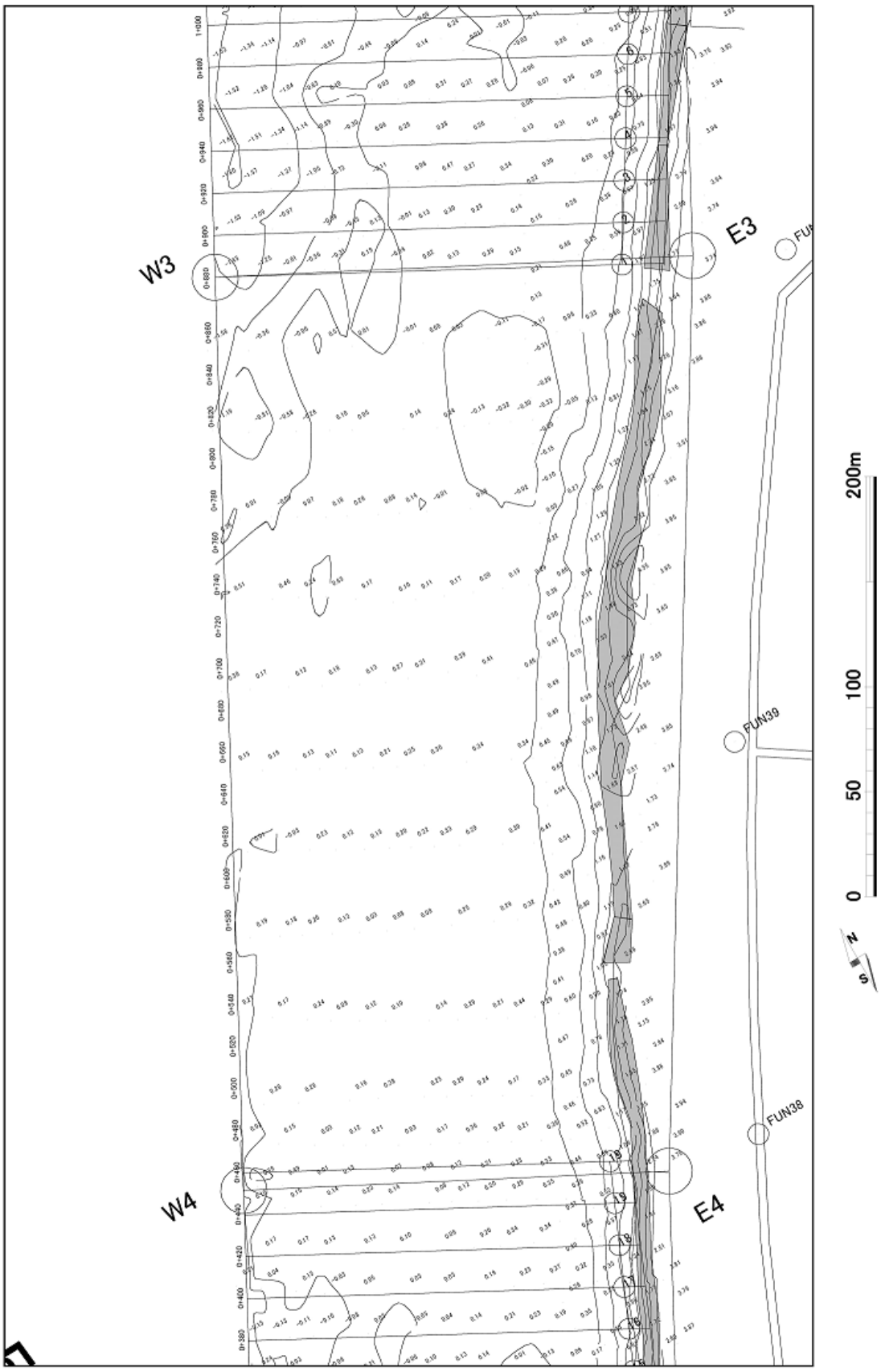


Figure 4.31 Detailed Bathymetric Map in Target Zone for Coastal Protection Measures (Zone - 4)

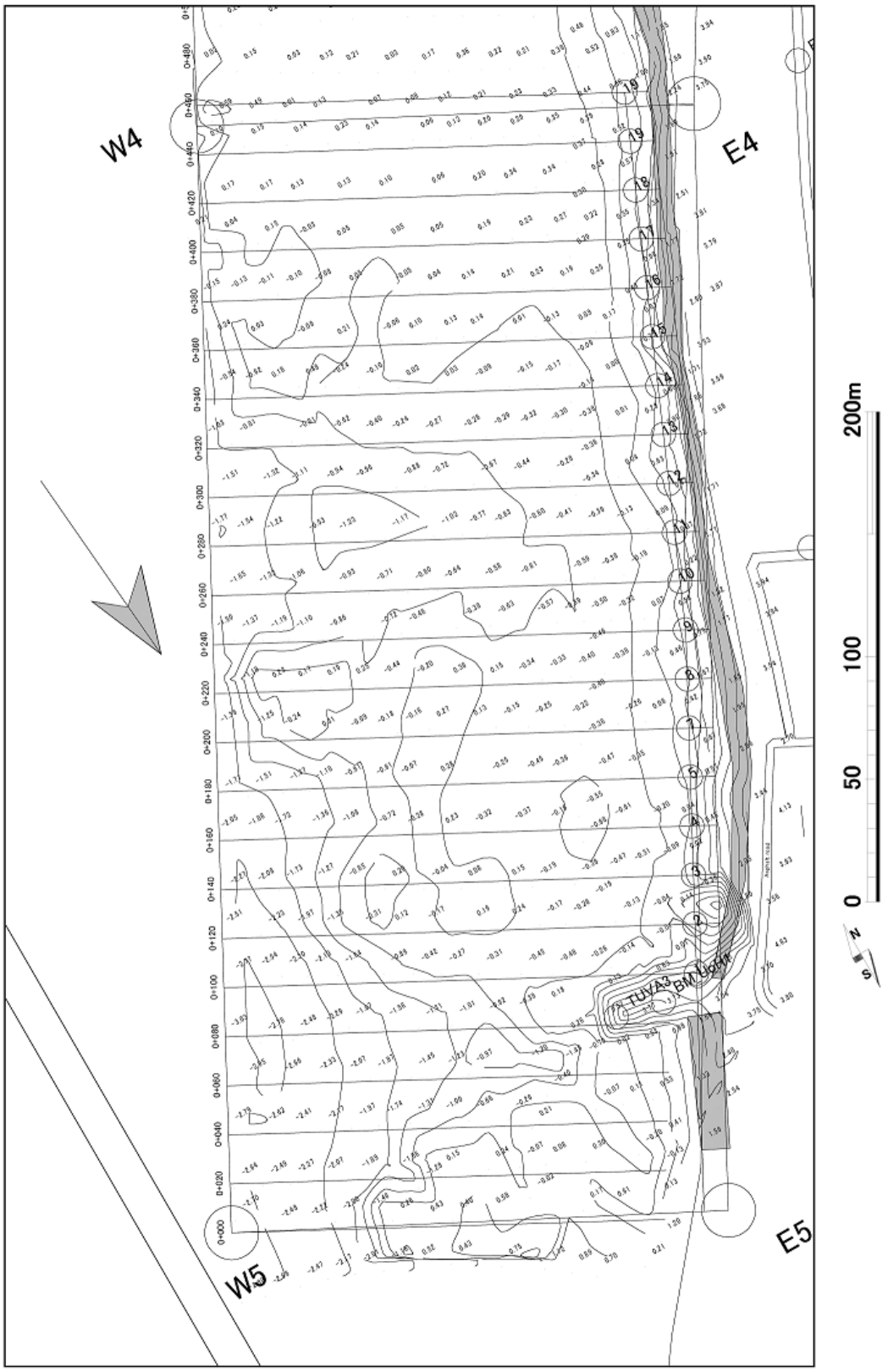


Figure 4.32 Detailed Bathymetric Map in Target Zone for Coastal Protection Measures (Zone - 5)

4.3.3 Geological Characteristics

Early geological investigations of the Tuvalu were driven by the debate over concepts relating to the long-term development of mid-ocean coral atolls and Dawin's subsidence theory (Darwin, 1842). Drilling exploration at Funafuti from 1896 to 1898 resulted in 340 m long cores comprising shallow-water carbonates without encountering basement volcanic (David & Sweet, 1904).

Additional studies on the deep structure of Funafuti comprised a magnetic survey (Creak, 1904) and a single seismic refraction survey inside the lagoon (Gaskell & Swallow, 1953). These two data sets are interpreted to show a minimum of 500 meters of limestone below the lagoon floor, with presumed underlying volcanic (Locke, 1991).

No volcanic basement was reached during the drilling campaign in Funafuti in the late 19th century, and the boundary depth was estimated at approximately 1,000 meters from data provided by seismic experiments.

"Tuvalu Lagoon Bed Resources Survey" carried out by Gibb Australia in May 1983 estimates the thickness of unconsolidated sediments beneath the lagoon bed and compiles the spatial distribution of lagoon bed materials (Gibb, 1985). Details of the seismic survey is shown in **Figure 4.33**, which shows an isopach map of the depth to the inferred coral surface, in other wards, an isopach map of the thickness of unconsolidated sediments. Seeing the map, the maximum thickness of unconsolidated sediments is around 25 meters at offshore area approximately 3 km long from Vaiaku area.

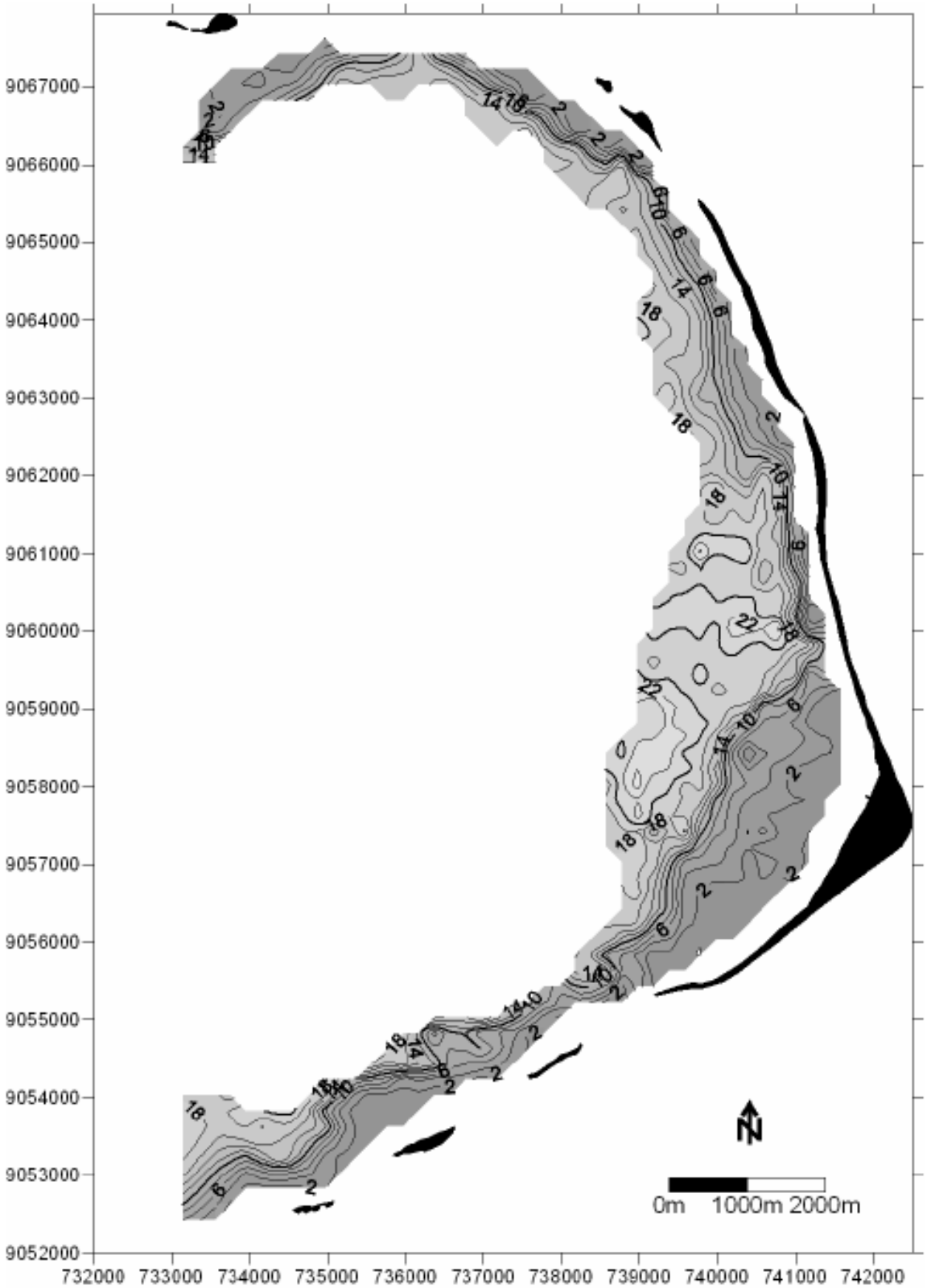


Figure 4.33 Isopach Map for Thickness of Unconsolidated Sediments