2.7 Facilities for SWM

2.7.1 Facilities for Operation

(1) Final Disposal Site in Thilafushi

a. Location

It lies 7 km west of Male' Island

b. History of Landfill

Initially Thilafushi was a submerged reef flat with an average depth of 0.5 m below the low water level. On December 5 in 1991, the first landfill operation was commenced and about six and a half years have passed when the study team commenced this study.

c. Facilities Provided

(a) Ferry berth

(b) Pier for small boats to unload garbage

(c) Temporary storage of resort waste beside the pier stated above

(d) Stockyard of can, PET bottle, scrap iron and abolished refrigerator

(e) Administration office with garage

(f) Kitchen and accommodation for workers

(g) Diesel generator house and rainwater tank

(h) Chicken cage, pigeon hut and goat feeding lot

(2) Male'

a. Transport and Sweeping Facilities under MCPW

i) Waste Management Section

- Transfer station (200×400 ft)
- Ferry berth at new port
- Workshop (200×200 ft) sharing with Road Construction Section
- Garage for Lorry (200×185 ft)

ii) Harbor Administration Section

- Garage for tractor trailer (200×200 ft)

b. Facility under Male' Municipality

- Workshop (200×100 ft) sharing with Road Maintenance Section

c. Assessment of Present Situation

i) Transfer Station

- Wastes coming into transfer station are classified into five categories: scrap iron, demolition debris (sand and broken concrete with the size less than 20cm), bulky concrete debris, sawdust and other wastes.
- Residential waste and business waste are partly covered with soil as the control measure to prevent blown out and odor emission.
- There remains only the space for vehicle mobilization in the site and the volume of stored garbage has come to a maximum extent; it seems difficult to accumulate additional waste to the present situation.
- Bulky concrete debris (accumulated about 1,200 cub.m) and scrap iron (accumulated about 5,000 cub.m) are piled up about five meter high and rarely taken away. These wastes seem to require considerably time for transport by lorries.
- Residential waste and business waste are remaining constantly at about 2,800 cub.m and small sized demolition debris are also remaining constantly at about 700 cub.m.
- Due to the accumulation of residential waste, neighboring residents are complaining of offensive odor. Dispersion of waste is another fear of complaints.
- There are ten to twenty scavengers collecting copper wire, coconut shell or other re-usable materials.

ii) Ferry Berth

- There is a parking space next to the berth and the lorries with full of garbage are waiting there for boarding. Offensive odor from lorries is causing complaints of neighbors and passengers for Villingli because of smell.

iii) Workshop

- Workshops of MCPW and Male' Municipality do not have enough space for the repair of heavy equipment because the facility is mainly utilized for other section.
- Those vehicles which are already abandoned or under repair occupy a considerable space.
- The lack of professional mechanic may be one of the reasons of above mentioned congestion inside the workshop.

d. Items to be Improved

i) Transfer Station

- To solve the problem of offensive odor, perishable waste should be taken away in the same day or contained in the building.
- Bulky concrete debris and scrap iron needs processing to reduce the size, which makes loading and transport by lorries easier.
- Introduction of on demand collection system especially for bulky concrete debris and scrap iron. Those wastes are collected on designated date and transported directly to Thilafushi or recycling facility without bringing them to the transfer station. This method contributes to reduction of storage space.

ii) Ferry Berth

- It is necessary to shorten the waiting time of lorries before boarding so as to mitigate the nuisance by smell.

iii) Workshop

- Workshop function such as facility, equipment, human resources should be reinforced to meet the demand of quick inspection, repair and maintenance.

(3) Adjacent Islands to Male'

- Temporary waste storage alone is the SWM facility and is located in the harbor for the convenience of loading on dhoni for Thilafushi.

(4) Resort Island

- Every resort is obliged to install incinerator and incinerate combustible waste and dispose all the waste within the resort, except those in the capital region. The incinerator stipulated in the sixth provision of the Tourism Law, has been installed in most resorts

(5) Inhabited Islands

- Final disposal site is only the SWM facility and is located on the beach.

2.7.2 Facilities for Maintenance

(1) Responsible Section for Maintenance

a. Male' Municipality

Male' Municipality has a maintenance section for vehicles utilized for SWM. The section lies in Male' in a bloc sized 200ft×108ft, which is shared with foreign workers' accommodations. The section serves for both road maintenance section and the community services section.

b. MCPW

MCPW does not have a maintenance section but has a subsidiary company for maintenance. The name of the company is Building, Construction and Mechanical Works (BCMW). It was established on August 15, 1985 to answer the internal demand of MCPW on small scale construction and maintenance of government buildings and facilities as well as mechanical works for vehicle maintenance. Annual sales reaches approximately seven million rufiyaa in the last two years and the share of construction and mechanical works is almost equal, sharing 50% of total sales each other. The clients of mechanical works are:

- Road Construction Section, MCPW
- Waste Management Section, MCPW
- Harbor Section, MCPW
- Hulhumale Project, MCPW
- Male' Municipality

Among these clients in MCPW, the Road Construction Section alone has one Philippine mechanic and three Bangladeshi helpers in its organization therefore they order major repair of vehicles and heavy equipment to BCMW. The clients usually undertake only minor repair and daily checking with hand tools by themselves. Regarding the maintenance of ferry, MCPW can undertake the repair and maintenance of exterior by the workers of the Waste Management Section.

(2) Capacity of Maintenance Section

a. Male' Municipality

The Maintenance Section has neither machining tool installed nor expert mechanics assigned. Major repair works of heavy equipment and collection vehicles are commissioned to BCMW except minor repair made by hand tools.

b. MCPW

BCMW occupies a block beside the South-West Harbor with a size of 200ft × 200ft. The block is shared by BCMW and the Public Works Section. Public Works Section keeps construction material and fuel in six shipping containers placed along the masonry fence. The staff for vehicle maintenance is assigned as shown below.

• Mechanic Section:	Assistant mechanical engineer	1 (Egyptian)
	Mechanic	3 (Sri Lankan)
• Electric Section :	Electrician	1 (Maldivian)

They have the following machines and tools that can be used for vehicle maintenance. However, most of them are usually used for manufacturing materials as part of construction they are commissioned.

- Crank shaft grinder
- Lathe
- Drill press
- Hydraulic press
- Roller bender
- Electric welder (3 units)
- Gas welder/cutter (2 units)
- Hack saw machine
- Grindstone cutter (2 units)
- Air compressor
- Grinder

Among the equipment, a crank shaft grinder looked being rarely used though it was installed seven years ago. It is impossible for BCMW to undertake overhaul of engines either gasoline fired or diesel with the list of equipment mentioned above. It is considered that the acceptable repair works for them are the repair of other parts than engine such as chassis, transmission, tire, body, electric circuit and hydraulic system.

2.8 Public Awareness of Solid Waste Management

2.8.1 Objectives and Scope of the Survey

The objectives of the public awareness survey in connection with the Study is;

- To research sanitary condition level in the town,
- To research into the needs of better collection services,
- To research possibility of introduction of separate collection system,
- To research willingness to pay for improved collection services

2.8.2 Conditions of Public Awareness Survey

In order to improve the existing SWM system, it is important to know the awareness of the people who have been involved of waste discharge to the near-by Microbins or to the Transfer Station every day. Public awareness survey was conducted to understand the key issues among the people & society for consideration in planning based on the conditions indicated as follows.

(1) Scope of Survey

The survey was conducted through interview survey for 166 samples in total consist of 94 residential houses in Male', 10 residential houses in Villingili and Thulusdhoo respectively and 52 business establishment in Male'.

(2) Contents of Questionnaires

Prior to the survey, the JICA Study Team and Ministry of Planning and Human Resources held a meeting over the questionnaires and consented, each other to have 54 items for residential house and 30 items for business establishment as categorised below.

a. General

- a.1 : Number of People per House, a.2 : House Style, Income, a.3 : Public Services Charge,

b. Waste Discharge

- b.1 : Sanitation, b.2 : Type of Container, b.3 : Means of Waste Discharge, b.4 : Frequency of Discharging

c. Collection Service

- c.1 : Frequency of Collection, c.2 : Collection Fee, c.3 : Service Provider

d. Source Separation

- d.1 : Hazardous Wastes, d.2 : Recyclable Items, d.3 : Awareness of Separation

e. Public Awareness

- e.1 : Awareness of SWM

f. Improvement of Collection Services

- f.1 : Collection Frequency, f.2 : Items to be Separated , f.3 : Willingness to Pay, f.4 : Waste Charge Rate

(3) Selection of Samples

a. Residential House

Male' City is divided into 4 Wards and the wards are subdivided into 405 Blocks. Out of 405 blocks, 337 blocks are allotted for residential areas. Numbers of samples in Male' were determined based on the size of population in wards and the residential blocks as listed in Table 2-22.

Table 2-22 Number of Samples in Male' Municipality

Inhabited Island	Wards	Population	Percentage	No. of Samples
Male'	Mafannu	20,005	33.3%	30
	Macangoli	11,857	19.8%	18
	Galolhu	12,241	20.4%	23
	Henveiru	15,867	26.5%	23
Total				94

Ten samples were added to Villingili and Thulusdhoo Island respectively, and the interview survey was conducted for 114 samples in total for residential houses.

b. Business Establishment

The survey team carried out interview survey for the commercial, business and institutional waste generators in Male'. Fifty two (52) samples were selected for the waste generation sources including hotels, restaurants, hospitals, clinics, workshops, schools, offices, and general stores.

(4) Implementation

The interview survey was conducted from 17 June to 28 June 1998 in the period of the first field survey. Prior to commencement of the public awareness survey, it was publicised on TV, Radio, and Newspaper in order to urge cooperation of the residents to the interview survey.

2.8.3 Summary of Public Awareness Survey

Results of public awareness survey are summarised in the following tables for the key issues closely related with improvement of SWM services in future.

Preferable Type of Waste Container

Plastic bags, plastic buckets or sacks are used for storing and discharging waste at present. The residents in Male, Villingili and Thulusdhoo islands chose the plastic buckets for the most preferable type for waste containers. It is worth to note that plastic bucket was chosen by more than 80 % of the resident in Male'.

Types of Waste Container

Inhabited Island	Current Container	Ratio	Preferable Container	Ratio
Male' City	Plastic Bag	36.8 %	Plastic Bucket	82.4 %
	Plastic Bucket	44.7 %		
Villingili Island	Plastic Bag	42.9 %	Plastic Bucket	69.2 %
	Plastic Bucket	35.7 %		
Thulusdhoo Island	Sack	70 %	Plastic Bucket	58.3 %
			Sack	41.7 %

Types of Collection Services

Door to door collection services in Male' is provided by the Municipality, two private companies and about 30 hand carts. The coverage ratio of door to door at present is estimated less than 20 % and most of the residents carry waste and discharge wastes at the micro bins or at the Transfer Station. However, more than 87 % of the residents in Male' wish to have door to door collection services in future. Also the door to door collection services is expected by more than 60 % of the residents in Villingili and Thulusdhoo.

Types of Collection Services

Inhabited Island	Preferable Collection Service	Ratio
Male' City	Door to Door	87.1 %
	Stationary Collection	12.9 %
Villingili Island	Door to Door	61.5 %
	Stationary Collection	38.5 %
Thulusdhoo Island	Door to Door	69.2 %
	Stationary Collection	30.8 %

Recycling of Solid Wastes

The terms of recycling, reuse or materials recovery were not clearly defined in the questionnaire survey but it shows that the residents are interested about recycling of waste. Almost all of the respondents in three islands agreed support for separation of wastes at generation sources.

Recycling and Separation of Waste

Inhabited Island	Interest to Recycling	Participation in Waste Separation
Male' City	81.9 %	97.9 %
Villingili Island	80 %	100 %
Thulusdhoo Island	20 %	100 %

Waste Collection Time

Currently, two time zones are observed for discharging waste in the morning and the evening times. With reflection to the opinion of the residents, the current waste discharging time is split into two time zones: in the morning and evening. However, each time zone is a little higher than 20 % and it is not so remarkable in percentage.

Collection Time

Inhabited Island	Current Waste Discharge Time	Ratio	Preferable Collection Time	Ratio
Male' City	9-12	17.3 %	9-11	23.4 %
	18-21	23.6 %	19-21	22.3 %
	21-24	29.1 %		
Villingili Island	6-9	42.9 %	7-9	40 %
	9-12	21.4 %	17-18	30 %
	15-18	21.4 %		
Thulusdhoo Island	6-9	26.7 %	15-17	50 %
	12-15	26.7 %		
	15-18	33.3 %		

Frequency of Waste Collection Services

More than 85 % of the houses in Male discharge waste every day. Meanwhile, most of the residents, more than 70 %, in Villingili and Thulusdhoo discharge waste twice in a day. The respondents hope to have daily collection services for food waste and 4-5 times collection for other types of wastes.

Frequency of Waste Collection Services

Inhabited Island	Type of Wastes	Answer	Effective Count	Respondent	Ratio
Male' City	Food Waste	Everyday	91	88	96.7
	Other Waste	Everyday	91	40	43.9
	Recyclable Waste	Once in a Week	37	28	75.7
Villingili Island	Food Waste	Everyday	10	10	-
	Other Waste	Everyday	7	4	-
	Recyclable Waste	Once in a Week	9	6	-
Thulusdhoo	Food Waste	Everyday	9	6	-
	Other Waste	5 times/week	8	3	-
		Everyday		3	
	Recyclable Waste	Once in a Week	8	5	-

Income and Waste Collection Fee

The monthly income of the residents in Male' is a little higher than 11,000 Rufiyaas and bearing about 164 Rufiyaas in average. The ratio of waste collection charge to total income is accounted for about 1.5 %. The average income of the residents in Villingili and Thulusdhoo amounted to 7,500 and 5,200 Rufiyaas respectively.

Current Income and Collection Service Charge

	Income (Rf/month)	Collection Fee (% of total income)
Male' City	11,152	164 (1.5%)
Villingili Island	7,500	-
Thulusdhoo Island	5,200	-

Willingness to Pay and Waste Charge

Most of the residents in three islands agree to pay waste charge for the improved collection services in future. About 95 % of the residents in Male' approved for payment of the waste charge as enforced. Willingness to pay given by the residents in Male' amounted to 149 Rufiyaas which is about 1.3 % against total income of the house. Meanwhile, the residents in Villingili and Thulusdhoo agreed to pay 43 and 86 Rufiyaas per month respectively for waste collection services when implemented.

Willingness to Pay for Improved Services

	Participation to Community Collection	Agreed to Pay (% of agreed)	Waste Charge (Rf/month) (% to income)
Male' City	93.5%	94.7%	149 (1.3%)
Villingili Island	100%	90%	43 (0.5%)
Thulusdhoo Island	100%	77.8%	86 (1.6%)

2.8.4 Collection of Solid Wastes and Public Education

Involvement of government sectors and non-governmental organisations to the activities on solid waste management and/or public education is reported in the following subsections.

(1) Male' Municipality

Male' Municipality installed 22 units of micro bins at 9 stations to receive wastes generated from the neighbouring houses and carry to the Transfer Stations for emptying 3 times in a day. In addition, Male' Municipality provides door to door waste collection services to 417 residential and/or office buildings, stores, workshops and other waste generation sources on the base of charging service fee, which is accounted for about 6 % of buildings in Male' Municipality. Meanwhile, by-law of Male Municipality prescribes responsibility of the resident to clean street in front of the building. The by-law also states that the man who violate the regulation to be punished severely.

(2) Ministry of Trade, Industry and Labours

Almost all workers engaged in solid waste collection and disposal operation are expatriates from Bangladesh and/or Sri Lanka who are permitted to stay and work in Maldives through obtaining work permits from the Ministry of Trade, Industry and Labours (MTIL). According to the Ministry, about 9,000 expatriates are working in Male' out of total 17,000 foreigners working in the whole country. In the field of solid waste management, about 50 foreign workers are working for waste collection, disposal and related works. The information says that there is not an air of discrimination to the workers engaged in solid waste management work.

(3) Ministry of Education

a. School Education

The Ministry of Education (MOE) is conducting environmental education actively at schools. The environment class is learned from 1st to 5th grades focusing about variety of the subjects such as health, sanitation, science, food hygiene, population problems, and tourism. The 5th grade student have a class to visit the field work sites at Waste Management Section, Transfer Station and Thilafushi Disposal site to learn actual operation of solid waste management. The grade 6th and 7th students learn more detail about environment through sociology and science. Moreover, the 8th grade students learn about oceanographic environment, coral reef environment and fisheries around Maldives in the fisheries science class.

It is prohibited to bring plastic bags to the school for practising waste reduction activities at all the schools. There is no class to learn about waste recycling at schools. However, waste recycling is practised individually by the activities of environmental club in each school. PTA of the school opens the market for reusable items from time to time in the occasion of school holiday.

b. Public Education

Non-formal Education Center (NFEC), MOE is responsible for raising awareness of the people and for public education. Workshops are opened, although irregularly, to educate how to discharge waste and keep sanitation of the living places by means of the leaflets distributed free of charge by the NFEC. In addition, NFEC have a weekly radio program for the public information including environmental sanitation and solid waste management.

(4) Non-Governmental Organisation (NGO)

The three groups, Blue Peace, VESHI and FASHAN are known as NGOs in Male'. According to Blue Peace, the environmental NGO, was established less than 10 years ago and they consider that their activities have not yet permeated into the society. However, they are working actively by such a way to participate in formulation of the National Environment Action Plan. They are working on the activities such as cleaning seaside, raising public awareness through the radio and TV programs, and opening waste recycling market at schools from time to time. They consider that the NGO's are not supported well enough by the society and the government bodies. They consider that materials recovery by the resident and forming market in Maldives will be difficult. Although the situation is hard but Blue Peace hope to promote the activities of waste reduction and recycling from now on by raising awareness of the residents and public education.

2.9 Market of Recycled Materials

2.9.1 Recycling Activity in Operation

(1) Recycling Market in Male

a. Scavengers

About 15 to 20 person are working to pick up recyclable materials at the Transfer Station. Among them, 3 to 4 person are working at the break of dawn to around 7 to 8 a.m. for picking up the waste discharged from midnight to early morning. The other group of about 10 to 15 people are working daytime until 5 p.m.

The major materials recovered from the Transfer Station are coconut shells, electric wire (copper), broken electric appliances and machines, steel cans, bottles, sacks, clothes and toys. Their earnings amount to Rf 200 to 300 in average. Selling price of the major materials recovered by them are;

Coconut Shells (Firewood)	Rf 15 per sack about 20 kg.
Copper	Rf 10 per kg
Bottle	Rf 25 per 100 bottles
Brass	Rf 10 -15 per kg
Steel	About Rf 10 per kg
Woven sacks	Rf 50 per 400 sacks
Others	Depend on negotiation

b. Buyers of Recovered Materials

Four (4) buyers are identified at the Transfer Station. The first man is scavenging materials at the Transfer Station and buys coconut shells from the other scavengers at the rate of Rf 15 per sack and sells it to hotels as firewood to bake "Bokiba". The other buyer buys about 1,500 bottles per month to sell at Rf 1 per bottle after washing. Two buyers are working with two assistants to collect brass, zinc and ferrous metal. The buyer dealt 2 tons of brass in a month to sell at the price Rf 15,000 per ton.

c. Exporter of Recovered Materials

Three (3) exporters were identified during the survey period. Two men are working together with 4 to 6 men to deal with iron scraps but their activities is irregular. One exporter or merchant from India visit Maldives every week by air together with 2 to 3 accompanies to bring fruits and vegetable to the Male

market. On his return trip to India, he takes copper and zinc collected from the buyers. Copper is sold at 13,000 Rfs per ton.

d. Reusable Goods Bazaar

Reusable goods bazaar is open at schools in the term of school holiday organised by PTA. The bazaar is opened for 5 days to sell many types of second hand reusable items including books, clothes, toys, etc. brought in by the PTA to sell it to the public. The bazaar is opened once in a year at 4 primary schools and the bazaar is crowded with many interesting residents. In other activities, the Society for Health and Education open stalls once in a year to sell old books in the period of festival.

(2) Amount of Recyclable Materials

The survey was conducted for 15 days to measure weight of the recovered materials of the daytime scavengers working at the Transfer Station. The result of the survey was summarised in Table 2-23. During the survey period, the total weight of recovered materials amounted to 2,848 kg by about 10 to 15 scavengers collected everyday. In an average, the scavengers collect the reusable and recyclable materials amounted to about 190 kgs daily or about 0.1 % counted from the solid waste amount carried-in to the Transfer Station. Recovery of coconut shells is the most active work among the scavengers collecting about 110 kg or 58 % of the total weight every day followed by bottles, textile, waste electric appliance, and electric wire.

Table 2-23 Amount of Materials Recovered by Scavengers

Survey Period : 22 August - 7 September, 1998

Recovered Materials	Weight (kg)	Average per day (kg/d)	Ratio (%)
Coconut Shells	1,656	110	58.13
Electric Wire	126	8	4.42
Electric Appliances	193	13	6.78
5 Gals. Steel Cans	52	3	1.83
Other Metals	69	5	2.42
Bottles	454	30	15.92
Textiles	222	15	7.79
Others	77	5	2.72
Total (kg)	2,848	190	100.00

2.9.2 Material Flow Related to Waste Generation

The Study Team collected the records of import goods in 1995 from the Customs. The aim of collection of this data is to make a material flow of the goods until the goods are consumed to estimate broadly the generation amount of solid waste in Male. However, due to difficulties to convert all the goods into weight or because of no records of out-going flow of the goods to resort islands and/or to the local inhabited islands, the maternal flow work was abandoned. The import records were attached in Table 1-14 (1/3) to (3/3), "Solid Waste amount, Composition and Recycling" Supporting Report E. for a reference.

2.10 Treatment of Special Wastes

2.10.1 Waste from Individual Sources

The major industrial activities here in the Maldives are construction work and commercial activities in Male' and beverage, fish canning and garment factories in the local islands. Followings are the brief report to present situation of treatment and disposal of typical wastes generally categorised as non-municipal waste but observed typically in Transfer Station, Thilafushi and in Male.

(1) Construction Waste

Solid wastes originated from construction work consist of concrete debris, excess sand, demolition and waste woods, waste sand bags, leftover of pipe, fittings and steel bars. Generation amount of construction waste is huge at present comparing with general municipal wastes discharged from daily livelihood. Normally, the construction waste is transported to the Transfer Station by the contractors and by individual person to dispose at Thilafushi through landfill. Sometimes the contractor of large scale construction work request co-operation to MCPW to designate the site for disposal of concrete debris and excess soil. Most of the case, the reclaimed area in the north-east of the island, Nasandhula is designated by MCPW for temporary disposal site until transportation to Thilafushi. However, most of the construction waste is carried to the Thilafushi through Transfer Station. Daily generation amount of construction waste fluctuate owing to the progress of the construction work and the amount is estimated in the range between 80 and 150 tons per day.

(2) Commercial Waste

Packaging of wastes consists of carton box and bamboo basket is the major waste from distribution and consumption of commodities. Carton box is not recovered in Male' at present and transported to the Transfer Station for disposal at Thilafushi.

(3) Saw Dust from Carpentry

Twenty two (22) carpentry factories are operated in Male. Waste wood and saw dust are carried-in to the Transfer Station by means of their private vehicles. Saw dust is separated at Thilafushi from other waste to make use for composting. Test composting is set to work soon to use food waste from hotels and restaurants to mix with saw dust for adjustment of moisture and nutrient elements. About 4 to 5 tons is estimated as the daily generation amount of saw dust.

(4) Waste Oil

There are two sources of waste oil generation. The first source is from automobiles and the second source is from boats. Waste oil, lubricants, is stored at the Transfer Station in drum cans until the numbers of drum cans loading operation at the Transfer Station. Waste oil was burnt before mixed with general waste and saw dust. In January, 1998, 2,400 litres of waste oil was transported to Thilafushi. Sixteen drum cans are stored at the Transfer Station at present.

(5) Waste from Markets

a. Fish Market

Currently in Male', waste from fish market is stored in plastic containers until evening and carried-out to off shore of Male' for disposal in the sea and the fish waste is not carried into the SWM system operated by the Municipality and MCPW. Amount of fish waste from the market recorded by the Municipality amount to 3 tons in average with fluctuation in the range of 1 and 6 tons per day. Environmental pollution occurs sometimes caused by floating back of fish waste on to the shore. A study is being conducted by FAO to develop fish industries and for recycling of fish waste. The final proposal will be made to make use of the waste in Male' fish market by the end of 1998. Whatever the contents of the proposal is, the fish waste from the market will not be considered to be treated or disposed of in SWM system for Male' except for using it for raw material of composting by mixing together with saw dust or other types of organic matters.

b. Fruits Market

Waste from fruits market is collected by the Municipality together with dust bins placed on main streets. One tractor is operated for collection work in early morning to load about 300 to 500 kgs every day. Composition of the waste is a mixture of refuse normally observed in municipal wastes and packaging wastes.

(6) Medical Waste

Generation sources of medical waste in Male' are categorised by the sources from 2 hospitals and 27 clinics. IGMH treat infectious medical waste by incinerator installed in the compound of the hospital. Other medical waste of IGMH is transported to the Transfer Station in black plastic bags to burn it in drum cans. ADK hospital plan to install two types of incinerators. One type is designed for high heat furnace and the other type is low heat furnace. MCPW receive medical waste from ADK and clinics on request and carry it to Thilafushi for incineration treatment in drum cans. Currently, the amount of medical waste is estimated more or less 1 ton per day but the

waste shall be properly treated and disposed because of the infectious nature of the waste.

(7) Hazardous Waste

Hazardous waste such as batteries, insecticides, pesticides, waste chemicals are not collected separately and commingled with general municipal waste. Accordingly, there is no practical measures be taken to prevent it from causing of possible environmental pollution. Although the hazardous materials in municipal wastes is not a crucial problem at this moment, however, it will be required to take some practical measures to prevent the environment from probable pollution caused by the hazardous wastes.

2.10.2 Waste from Public Spaces

(1) Public Space on the Ground

Public space on the ground is kept clean by MM in cooperation with residents along the street. The following pubic spaces are maintained by the Community Services Section of MM and the other streets are decided to be cleaned by the residents in front.

a. Specific road:	exterior surrounding road
	in front of government's building
	specific commercial zone in Maafannu Ward (beside North Harbor)
b. Park	all parks
c. Cemetery	4 ordinary and 1 special for suicides

Public space cleaning is conducted by a crew of MM with one tractor, which carries the waste collected in the spaces mentioned above. The frequency of cleaning is eight times on every weekday. Collected waste is dumped at the transfer station in Male'. Cleaning activities by both residents and MM achieves a tidy appearance of the capital.

(2) Port Area

There are three ports in Male', namely North harbor, South-west Harbor and South Harbor. The port areas including water surface are kept clean regularly by the Harbor Section of MCPW. Besides the cleaning activity of MCPW, the coast guards of NSS also contributes port cleaning on voluntary basis. Their voluntary activity is usually conducted on every Friday, sometimes increased to once in two weeks and takes about half a year to go around the whole port area in Male'.

a. Cleaning Activity of MCPW

The Harbour Section has two crews for port cleaning and one crew for waste collection and haulage out of port area. The crews are organized and equipped under the supervision of one of 10 supervisors assigned to the Section as shown in Table 2.24.

Table 2.24 Organization of Port Area Cleaning

Personnel	Number	Role	Equipment
Supervisor	1	supervision	
Row boat crew for North harbor	4	water surface cleaning	
	2	rower	boccora (row boat)
	1	waste collector	scoop net
	1	cox	
Row boat crew for North harbor	4	water surface cleaning	
	2	rower	boccora (row boat)
	1	waste collector	scoop net
	1	cox	
Tractor crew	12	collection and haulage & port area cleaning	
	1	driver	tractor
	11	worker	scoop net, wooden rod, rake

The ordinary working hours begins 8:30 in the morning and ends at 12:00 midnight. The cleaning crews work even on Friday though the working hours is shortened for prayer. Collected waste is also dumped at the transfer station in Male'.

b. Cleaning Activity of NSS

NSS organizes about 50 out of 1,000 coast guards for each voluntary cleaning activity. Out of 50 volunteers, about 20 people are assigned as divers to collect submerged waste in the port. The others are assigned to support divers by providing them plastic bags to contain collected waste from the seabed and draw up heavy waste by dragging with rope in the similar manner to beach. MCPW supports the activity in removing waste taken out of the seabed by dispatching the port cleaning crew. Conspicuous kinds of waste from the seabed are tire of vehicles, coconut shell, can for food and drinks and vinyl sheet. There is a case an engine, screw and fly wheel of dohni are taken out of the water.

3 ENVIRONMENTAL CONDITION

3.1 Natural Condition on Thilafushi Island

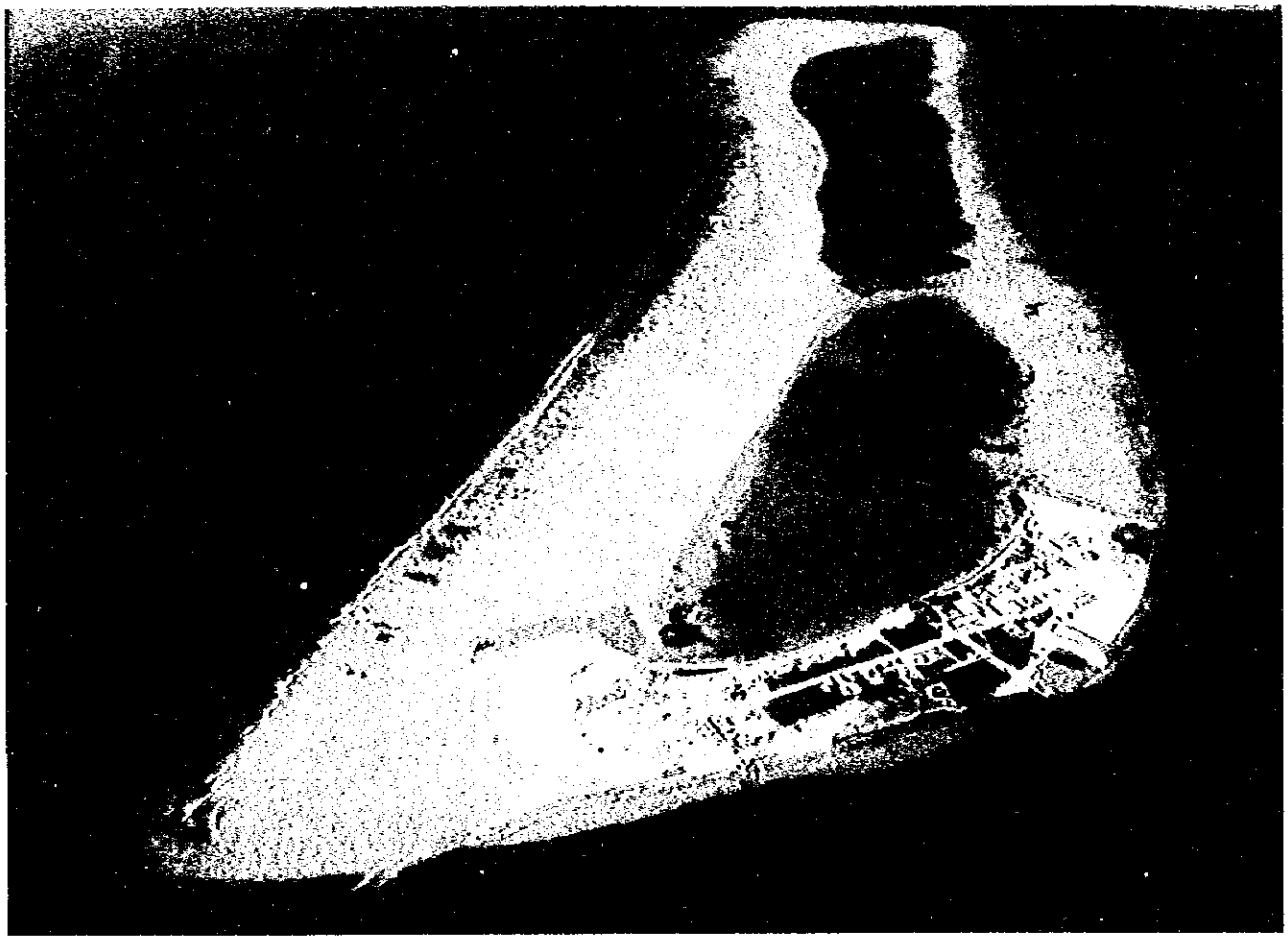
3.1.1 Topographic / Hydrographic Survey

Topographic and hydrographic survey in Thilafushi were conducted by the Study Team from July 19 to August 30, 1998. The results were drawn up in a scale of 1:6000 for Thilafushi Island and its surrounding as shown in Figure 3-1. However the configuration of the island has been changing day by day due to rapid sand reclamation by a suction dredger and solid waste filling. In addition to above survey, various informations have been obtained from aerial photographs as shown in Photo 3-1. Thilafushi reef lies on the south west fringe of North Male' Atoll and stretches from west to east in length of about 5,000 m and in width of 800 to 1,000 m. The northern reef flat (water depth :0.5 ~ 1.5 m) facing to inner atoll is in width of 150 to 200 m and the southern reef flat facing to Vadhoo channel is in width of 250 to 350 m. Inner lagoon having water depth of about 6 m is in width of 300 to 400 m.

3.1.2 Geology and Subsoil Condition

Thilafushi reef consists of live coral, coral fragments and coral fine sand. *Thila* is a coral reef usually a few meters below the water surface, while *fushi* is a big island usually on the outside reef of the atoll. Coral growth occurs in the warm shallow waters as the volcanic base rock subsides. In due course this coral dies and forms coral rock, with new corals growing from this dead coral mass. Wave and current action produces coral sand from the coral rock formation. This sand is deposited in calmer locations, either in deep water, or, in the case of sufficiently large coral masses, at the center of the formation to produce coral islands. Where rock formations are not exposed to mechanical weathering such as in deeper water, or where coral rock is overlain by coral sand, disintegration by chemical weathering can occur, forming softer silt/clay layers. Coral atolls are one of the most complex and variable environments in which carbonate material is encountered. Coral line deposits can contain materials of vastly differing properties, from loose sand, weathered clay/silt lenses, soft and hard coral rock to large cavities in the formations. Boreholes, only meters apart, can indicate vastly different properties. Several borings were conducted in Thilafushi Island for the STO Bulk Cement Import Terminal Project, the characteristics of subsoil conditions can be classified as in Table 3-1.

Photo 3-1. Aerial Photo of Thilafushi Island and Reef (April 15, 1998)



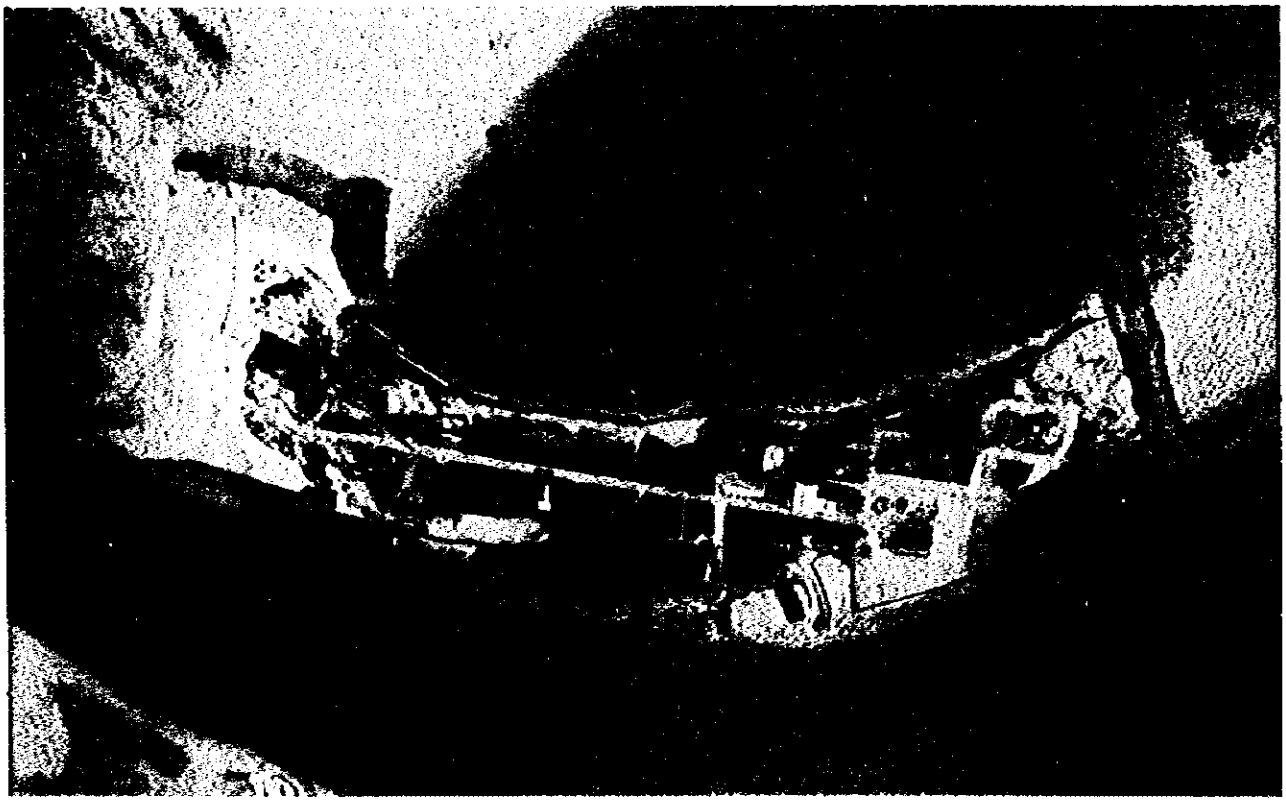


Photo 3-2 Aerial of Thilafushi Island (July 23, 1998)

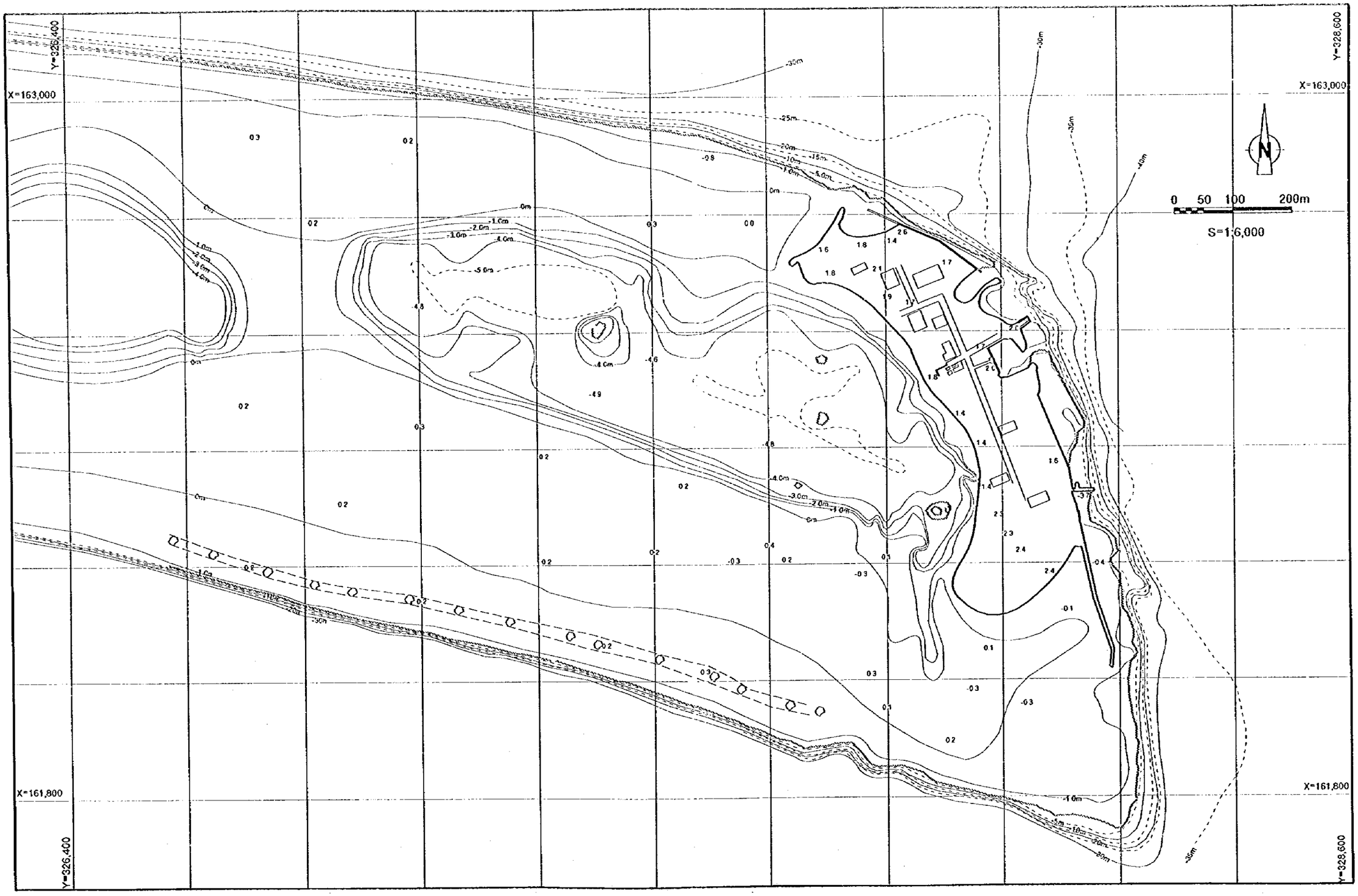


Figure 3-1 Topographic Survey Map (July – August, 1998)

Table 3-1. Subsoil Condition on Thilafushi Island

Boring No.1			Boring No.2			Boring No.3			Boring No.4 (a)			Boring No.5 (a)		
Depth	Description	SPT	Depth	Description	SPT	Depth	Description	SPT	Depth	Description	SPT	Depth	Description	SPT
0 - 0.2m	Rubbish & Fill Material		0 - 1 m	Fill Material with plastic & coral debris & sand	10	0 - 1 m	Rubbish / Fill Material	16	0 - 1 m	Coral Debris / Sand	10	0 - 1 m	Hardfill / Rubbish / Concrete etc.	
0.2 - 1m	Sand & Fill Material	14	1 - 2 m	Sand Material (Fill)	20	1 - 2 m	Fill & Rubbish	30	1 - 2 m	Sand & Coral Debris	17	1 - 2 m	Hardfill / Rubbish / Concrete etc.	21
1 - 2 m	Sand	14	2 - 3 m	Sandy Fill Material	17	2 - 2.6 m	Fill & Rubbish		2 - 3 m	Sand & Coral Debris	25	2 - 3 m	Sand Rock @ 2.8 m	22
2 - 3m	Sand	13	3 - 4 m	Sand & Coral Fragments	14	2.6 - 3 m	Sand	8	3 - 4 m	Sand & Coral Debris	13	3 - 4 m	Coral Debris & Sand	7
3 - 4 m	Fine Sand	11	4 - 5 m	Sand & Coral Fragments	7	3 -4 m	Sand	7	4 - 5 m	Coral Debris	16	4 - 5 m	Sand & Shell Fragments	8
4 - 5 m	Fine Sand	10	5 - 6 m	Sand & Coral Fragments	5	4 - 5 m	Sand & Shell Fragments	9	5 - 6.5 m	Coral Debris & Sand	4	5 - 6 m	Sand & Shell Fragments	3
5 - 6 m	Fine Sand	14	6 - 7 m	Sand & Coral Fragments	7	5 - 6 m	Sand & Some Coral Debris	17	6.5 - 7 m	Sand & Coral Debris	29	6 - 7 m	Sand & Shell Fragments	5
6 - 7.3 m	Casing dropped under own weight while SPT rods were being with drawn from 6 m test.	43	7 - 8 m	Sand & Coral Fragments	12	6 - 7 m	Coral Debris & Shell Fragments Rock @ 6.5m	16	7 - 8 m	Coral Debris	4	7 - 8 m	Shell & Sand	1/45cm
7.3 - 8.3m	Sand	9	8 - 9.5 m	Sand & Coral Debris		7 - 8 m	Sand Coral Debris Rock @ 7.5 m	1/43 cm	8 - 9.5 m	Sand	2	8 - 9.5 m	Sand & Shell Fragments	
8.3 - 9.5m	Sand	9	9.5 - 12.4 m	Sand & Coral Debris		8 - 9.5 m	Fine Sand	1/30cm	9.5 - 12.4 m	Coral Debris & Sand		9.5 - 12.8 m	Sand with occasional lumps of Coral Debris	
9.5 - 12.8 m	Sand & Fragments shell material - strong odour with return water		12.4 m	Hard Lump of Coral Debris		9.5 - 11.8 m	Sand & Coral Debris		12.4 - 12.8 m	Sand		12.8- 17 m	Color change @14.4 m to dark brown ,return back to light brown @16 m	
12.8 - 15.4 m	Sand & Fragment shell		12.5 - 15.4 m	Coral Debris & Sand		11.8 - 12.8 m	Sand & Some Coral Debris		12.8 - 14.4 m	Hard Layer Coral Debris		17 - 19 m	Sand & Coral Debris	
15.4 - 15.6m	Sand & Coral Debris		15.4 - 17 m	Sand & Coral Debris		12.8 - 15.4 m	Sand & Coral Debris		14.4 - 15.4 m	Coral Debris Minor Sand		19 - 22 m	Hard Coral Debris & Sand	
15.6 - 15.7m	Fragment shell & coral boulder		17 - 21.6 m	Sand & a few Coral fragments		15.4 - 17 m	Coral Debris & Shell		15.4 - 17 m	Coral Debris Minor Sand				
15.7 - 16.4 m	Sand & Coral Debris					17 - 21 m	Sand with Coral Debris		17 - 19 m	Coral Debris Minor Sand				
16.4 - 17.4 m	Hard Coral Rock					21 - 22 m	Hard layer Coral Debris		19 - 19.2 m	Coral Rock				
17.4 - 20 m	Sand & Shell fragments/coral debris								19.2 - 20 m	Coral Debris				
20 - 21 m	Sand & Shell fragments								20 - 20.6 m	Coral Rock				
21 - 21.2 m	Coral Boulder								20.6 - 22 m	Coral Debris				
21.2 - 21. 6m	Hard Coral Rock													
21.6 -22 m	Sand & coral fragments													

Source : STO Bulk Cement Import Terminal Project, conducted by Mc CONNEL DOWELL in October 1997

3.1.3 Meteorological Condition

(1) Wind

Maldives is in the Monsoon Belt in the north Indian Ocean and the climate of the Maldives is divided into two periods, northeast monsoon season from December to March and south west monsoon season from May to October. Wind data recorded at Hulhule airport during the period between 1993 and 1997 is summarized in Table 3-2.

Slightly stronger winds are associated with winds from the west typical of the southwest monsoon season. Strong winds and gales are relatively rare, because cyclones (hurricanes) are absent in the low latitudes where occupies the archipelago. During the SW monsoon, wind speeds are typically below 12 knots for 75 % of the time, and less than 28 knots for over 99 % of the time. During the NE monsoon, 88 % of wind speeds are below 12 knots, and over 99 % are less than 22 knots. The stormiest months are typically May, June and July. Storms and squalls producing wind gusts of 50 ~ 60 knots have been recorded in Male'.

(2) Rainfall

Rainfall record during the period of 1993 to 1997 obtained at the Hulhule airport is summarized in Table 3-3. Average yearly rainfall was 1969 mm ranging between 1407 mm and 2397 mm. Maximum monthly record was 588 mm in October 1994 and minimum monthly record was 0.4 mm in February 1993. Average monthly rainfall more than 200 mm was recorded in May, September, October and November and average monthly rainfall less than 100 mm were recorded in January, February and March.

(3) Temperature, Sunshine and Humidity

Temperature, Sunshine and Humidity record during the period of 1993 to 1997 obtained at the Hulhule airport are summarized in Table 3-4, 3-5 and 3-6 respectively.

3.1.4 Oceanographic Condition

(1) Tide and Datum Line

Tides are twice daily (semidiurnal), and typical spring and neap tidal ranges are approximately 1.0 m and 0.3 m respectively. Tidal condition on Thilafushi island can be considered the same as the one of Male' island. Therefore, the following tidal conditions can be adopted for the design of coastal facilities of the Thilafushi project in accordance with the Report of the Development Study on the Seawall Construction Project for Male' island prepared by JICA in 1992.

Design High Water Level for Outer Reef:	+1.64 m (considering wave set-up)
Design High Water Level for Inner Reef:	+1.34 m
Mean High Water Level at Spring Tide:	+1.34 m
Mean Sea Level:	+0.64 m
Lowest Astronomical Tide (LAT):	+0.00 m

(2) Wave Condition

There are two kinds of waves approaching Thilafushi. One is swells propagated from south Indian Ocean in SW monsoon season, another is wind-waves generated by northern and eastern winds blowing in the waters in North Male' Atoll in NE monsoon. In considering the design waves adopted for the Seawall Construction Project for Male' Island, the following significant wave conditions will be employed for the design of coastal facilities for Thilafushi as indicated in Figure 3-2.

	Height	Period
South Outer Reef:	3.0 m	16 sec.
North Inner Reef:	0.7 m	6 sec.
North Outer Reef:	1.2 m	4.6 sec.

(3) Current Condition

Several currents affect the Maldives islands. These currents are divided mainly into ocean currents and tidal currents, with the ocean currents being stronger than tidal currents.

The ocean currents flowing by the Maldives islands are driven by the monsoon winds. In the northern part of the Maldives, constant currents flow westward during the northeast monsoon period from December to April and eastward during the southwest monsoon period from May to August.

Generally, the tidal currents are eastward in flood, and westward in ebb. The velocity, however, varies by island area. The current patterns result from reef forms.

The study team conducted 12 hours current observation at 8 points around Thilafushi. Observations were made in every 2 meters water depth up to -20 m and every hour. The predominant currents are indicated in Figure 3-3. Since observations were conducted in August of Southwest Monsoon Period, observed currents may be much influenced by the ocean currents.

Table 3-2. Wind (1993-97)

	1993		1994		1995		1996		1997	Average		
	Dir	Kts	Dir	Kts	Dir	Kts	Dir	Kts	Dir	Kts	Dir	Kts
Jan	ENE	13.0	ENE	12.7	ENE	10.3	ENE	13.8	ENE	12.3		12.4
Feb	ENE	10.4	NE	8.9	ENE	9.1	NE	12.0	NE	8.9		9.9
Mar	NNW	7.3	ENE	8.0	ENE	7.5	NE	8.8	VRB	7.6		7.8
Apr	VRB	5.8	WNW	6.7	VRB	5.8	W	9.3	WNW	5.4		6.6
May	W	11.9	W	10.8	W	13.2	WNW	8.9	W	10.6		11.1
Jun	W	12.4	W	11.1	W	14.9	W	11.7	W	8.0		11.6
Jul	WNW	14.3	VRB	7.5	W	11.9	W	11.4	W	10.0		11.0
Aug	WNW	11.5	VRB	7.9	WNW	11.3	WNW	11.3	W	8.6		10.1
Sep	WNW	11.1	NW	8.9	WNW	12.3	WNW	12.6	W	9.0		10.8
Oct	WNW	11.5	VRB	8.1	W	12.4	WNW	13.0	VRB	7.0		10.4
Nov	W	12.0	VRB	7.2	WNW	11.0	WNW	8.2	VRB	8.0		9.3
Dec	ENE	7.4	ENE	11.9	ENE	14.3	VRB	10.3	E	9.3		10.6
Average		10.7		9.1		11.2		10.9		8.7		10.1

Table 3-3. Rainfall (1993-97)

	1993		1994		1995		1996		1997		Average	
	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
Jan	23.6	6	70.9	7	32.3	8	158.0	6	3.2	1	57.6	6
Feb	0.4	1	1.2	2	65.4	8	47.0	6	35.3	6	29.9	5
Mar	36.1	5	99.7	6	10.8	2	51.0	5	30.2	6	45.6	5
Apr	88.7	6	78.2	14	73.9	13	324.2	15	96.2	11	132.2	12
May	453.0	18	306.4	23	240.7	21	172.8	13	227.4	20	280.1	19
Jun	138.1	14	120.8	17	69.9	14	258.5	17	76.1	14	132.7	15
Jul	358.6	20	84.4	13	162.7	11	173.0	20	178.4	15	191.4	16
Aug	145.8	13	167.8	15	171.9	18	154.1	12	226.3	15	173.2	15
Sep	322.3	21	213.3	15	126.4	13	250.4	15	194.1	17	221.3	16
Oct	196.9	16	587.6	22	271.4	21	135.1	18	147.0	18	267.6	19
Nov	428.9	21	353.0	20	107.7	8	161.3	15	316.0	22	273.4	17
Dec	204.5	14	57.8	12	73.9	11	65.1	8	419.9	27	164.2	14
Total	2396.9	155	2141.1	166	1407.0	148	1950.5	150	1950.1	172	1969.1	158

(Days with 0.3 mm or more)

Table 3-4. Temperature (1993-97)

℃

	1993		1994		1995		1996		1997		Average	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Jan	30.1	25.4	30.3	25.7	30.9	26.3	30.2	25.7	30.6	26.3	30.4	25.9
Feb	30.5	25.7	30.9	26.4	30.2	25.9	30.7	26.1	31.0	26.1	30.7	26.0
Mar	31.0	26.1	31.2	26.3	31.7	27.1	31.0	26.4	31.8	26.5	31.3	26.5
Apr	31.8	26.9	32.0	26.7	31.9	26.7	31.0	26.1	31.9	27.1	31.7	26.7
May	30.8	25.6	31.0	25.6	31.0	26.4	31.3	27.1	30.8	26.1	31.0	26.2
Jun	30.7	26.1	31.0	25.9	30.5	26.6	30.4	26.0	31.6	26.8	30.8	26.3
Jul	29.9	24.7	31.3	26.2	30.7	26.4	30.2	25.2	30.8	26.0	30.6	25.7
Aug	30.2	25.3	30.7	25.6	30.3	25.6	30.1	25.9	31.0	26.0	30.5	25.7
Sep	29.8	24.2	30.6	25.6	30.2	26.1	30.0	25.8	30.4	25.4	30.2	25.4
Oct	30.2	24.9	30.0	24.8	29.8	25.3	29.3	25.2	30.7	25.5	30.0	25.1
Nov	29.3	24.4	30.0	25.1	29.9	26.0	29.9	25.4	30.7	25.7	30.0	25.3
Dec	29.7	25.0	30.5	26.0	30.3	25.7	30.3	25.9	30.6	25.2	30.3	25.6
Ave.	30.3	25.3	30.8	25.8	30.6	26.2	30.4	25.9	31.0	26.1	30.6	25.9

Table 3-5. Sunshine (1993-97)

Hours

	1993	1994	1995	1996	1997	Ave.
Jan	223	266	245	252	297	257
Feb	288	253	233	269	245	258
Mar	283	257	301	289	303	286
Apr	279	257	252	227	277	258
May	209	139	204	263	207	204
Jun	218	189	186	160	247	200
Jul	195	232	230	172	191	204
Aug	283	199	220	259	259	244
Sep	216	196	242	211	194	212
Oct	269	167	232	231	222	224
Nov	158	174	244	240	202	204
Dec	205	209	246	287	175	224
Total	2826	2537	2834	2858	2820	2775
Ave.	7.7	7.0	7.8	7.8	7.7	7.6

Table 3-6. Humidity (1993-97)

%

	1993	1994	1995	1996	1997	
Jan	74	75	76	79	78	76
Feb	70	75	77	78	77	75
Mar	74	74	73	75	76	74
Apr	74	75	79	81	78	77
May	81	78	83	78	82	80
Jun	78	79	81	82	81	80
Jul	80	76	80	80	79	79
Aug	77	76	80	79	79	78
Sep	79	76	78	81	82	79
Oct	78	79	82	83	81	81
Nov	82	80	79	79	82	80
Dec	79	77	78	77	83	79
Ave.	77	77	79	79	80	78

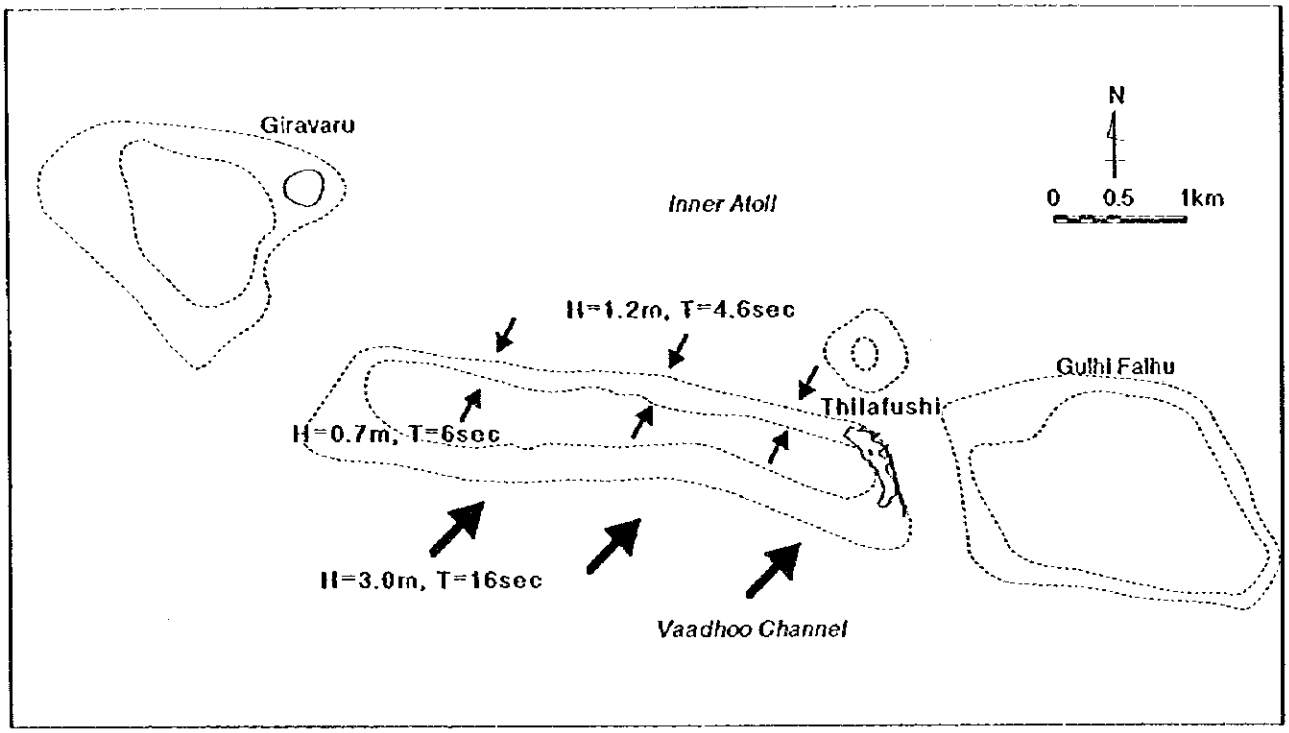


Figure 3-2. Waves Approaching to Thilafushi

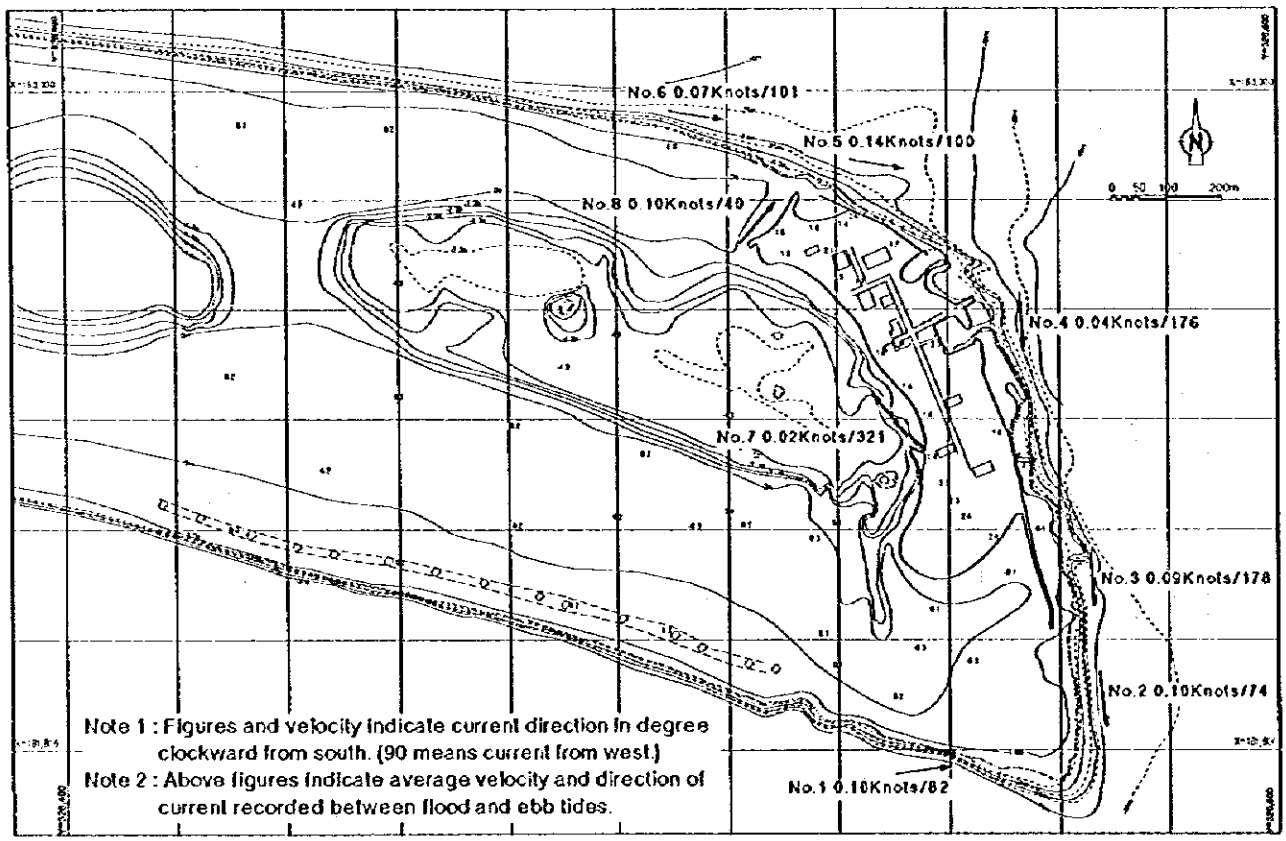


Figure 3-3. Current Records (August 1998)

3.2 Coral Ecology

3.2.1 Introduction

The ecological status of coral life in Thilafushi reef, including the Marine Protected Area (MPA)-Lions Head, and Gulhifalhu, including the MPA - Hans Hass Place (Kiki Reef),.were studied using both Manta Tow Survey and detailed Line Intercept Transect (LIT) survey.

Thilafushi comprises a submerged ring reef known locally as a *Faro*. This type of reef structure is unique to the Maldives. It is located in North Male' Atoll to the west of the capital island Male' on the southern perimeter of the atoll barrier reef, facing the 4.5 km width Vaadu channel which separates North Male' and South Male' Atolls. To the east of Thilafushi is another faro - Gulhifalhu which is separated by a narrow channel called Medhu Falhu Kandu (refer to Figure 3-4).

The coral reef community structure is strongly influenced by the physical environment such as wave energy, exposure, currents, sea-water temperature, salinity and tidal influence. In the Maldives, sites situated on the outer atoll reef have different community structure to those on the inner atoll reef and those lining the channels. The survey design concentrated on a limited number of sites near the landfill area at Thilafushi and Gulhifalhu with appropriate reference locations.

3.2.2 Survey Methodology

(1) Manta Tow Survey

The observer was towed using a manta board and rope behind a Dhoni (traditional boat). The tows were carried out parallel to the reef crest for 2 minutes at a constant speed, the boat stopped to allow the observer to record the data. GPS (global positioning system) was used to determine the locations of survey points.

Purpose: The Manta Tow technique was used to conduct a broad-scale assessment of large areas of the reef system at Thilafushi and Gulhifalhu. This technique provided information on the following:

a) the spread of garbage from the landfill site

b) percent cover of live, dead and soft coral

c) selection of representative sites for the Line Intercept Transect (LIT) survey

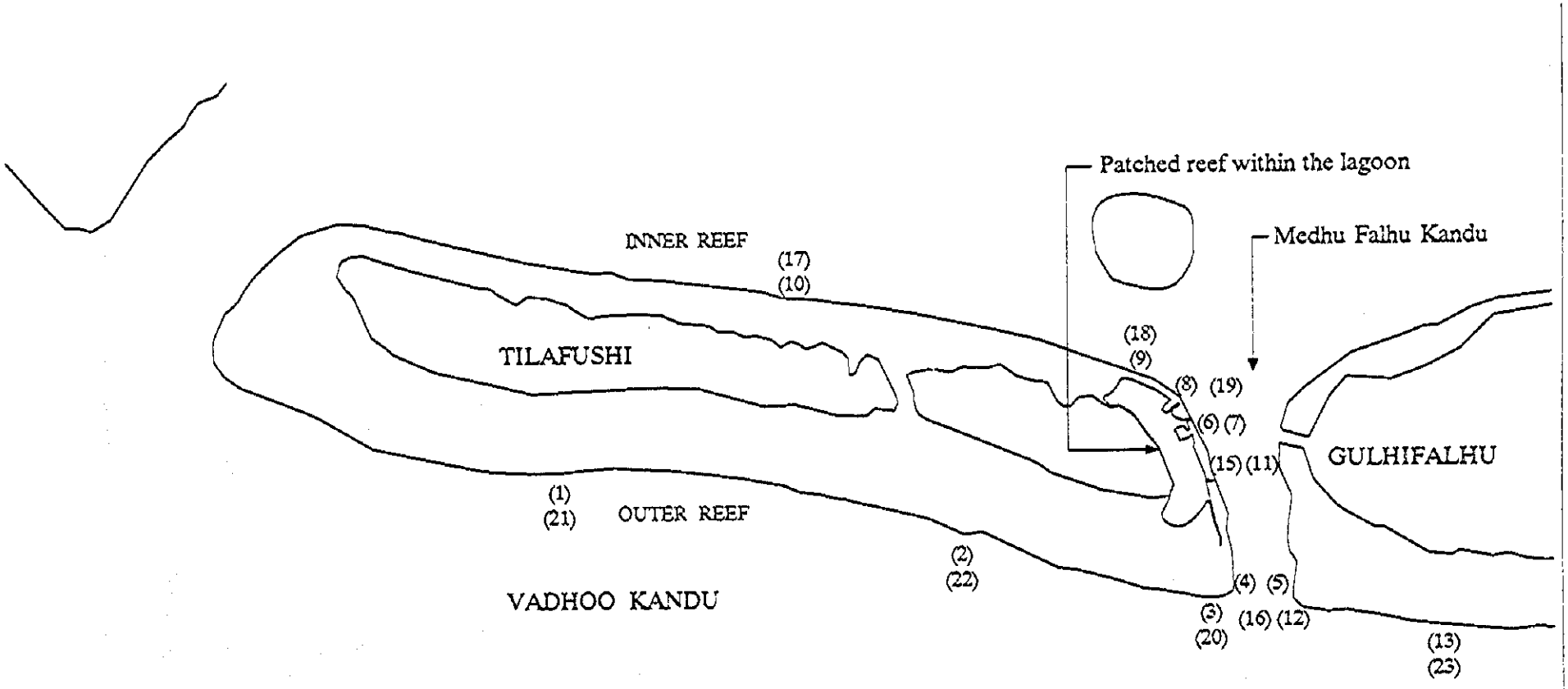


Figure 3-4. Locations of Line Transect Coral Survey - Tilafushi and Gulhifalhu

(2) Line Intercept Transect (LIT)

The selected representative locations of LIT survey are shown in Figure 3-4, which basically targeted the existing solid waste reclaimed Thilafushi Island and its vicinity. These stations are classified according to their reef locations as shown below (RF-Reef-flat, RS-Reef-slope, MPA-Marine Protected Area).

Outer atoll reefs		Inner atoll reefs		Channel reefs	
Site Ref.	Reef location/name	Site Ref.	Reef location/name	Site Ref.	Reef location/name
1=RF 21=RS	Thilafushi - south Lions Head (MPA)	9=RF 18=RS	Thilafushi - north	4=RF 5=RS	Thilafushi - east face (south)
2=RF 22=RS	Thilafushi - south	10=RF 17=RS	Thilafushi - north	6=RF 7=RS	Thilafushi - east face (north)
3=RF 20=RS	Thilafushi - south-west point	8=RF 19=RS	Thilafushi - north-east point	11=RF 15=RS	Gulhifalhu - west face (north)
13=RF 23=RS	Gulhifalhu - south Kiki reef (MPA)			12=RF 16=RS	Gulhifalhu - west (south)

A 20 m transect line was laid along the specified contour by the dive buddy pair. For the shallow reef-flat station the transect was positioned approximately 5 m from the reef crest. The depth varied between 1-3 m and was generally deeper on the outer atoll reefs. The reef-slope transect was located at 10 m at all stations.

Purpose: The Line Transect was used to assess the condition and health of reefs at the selected stations. The method provides information on the following key community parameters:

a) Species number per transect

b) Number of coral colonies per transect

c) Live/Dead coral coverage per transect

d) Coral health (i.e. bleaching)

(3) Fish Census - Belt Transect Method

The fish belt transect was the first survey completed after the transect line was deployed. The census was started after a minimum 5 minutes period during which no divers were allowed to disturb the area. The recorder swam slowly along the transect counting all fish encountered within a belt 2.5 m of each side of the transect line.

Purpose: The fish census was used to collect information on the reef fish community including:

a) Coral reef fish abundance

b) Coral fish diversity

3.2.3 Findings of the Survey

(1) Manta Tow Survey

a. Thilafushi reef

i) Coral Reef Assessment

Live coral cover varied between 10-40 % for the inner atoll reef, 0-20 % for eastern (channel) reef and 15-20 % for the outer atoll reef. Generally, live coral cover was low adjacent to the landfill, channels and harbour areas as a result of physical coastal alteration.

A manta tows was also conducted at the west side of Thilafushi to act as a reference area. Live coral cover varied between 20-60 % at the reef-slope.

ii) Garbage

The highest density of scattering domestic garbage was observed along the east face of the reef-flat from the main harbour to the small jetty towards the south. This comprised cans, glass -bottles and plastics. Construction waste was generally observed in those areas which had been modified for channels and harbours. The reef area at the north-east point towards the inner atoll reef also had a large volume of construction waste, which was probably associated with the construction of the sea wall. There was less garbage at the outer atoll reef.

b. Gulhifalhu

i) Coral Reef Assessment

Live coral cover on the outer atoll reef-slope varied from 20-60 %. However, bleaching was highly uniform at around 80 %. Moving along the south reef towards the entrance of the channel live coral cover was reduced to 10-15 %. Visibility at the south-west point was reduced due to sedinent plumes that originated at the south-east point of Thilafushi. Along the west face of the reef the amount of live coral cover was patchy, generally between 10-20 %. In the vicinity of the boat channel to the lagoon, coral cover had been reduced to zero

by dynamite blasting and dredging. Coral bleaching was around 60 %, being lower than that estimated for the outer atoll reef.

A manta tow was also conducted at the east side of Gulhifalhu. Live coral cover was low (between 2-15 %) and large amounts of coral rubble and sand shutes indicated that this area had been impacted in the past.

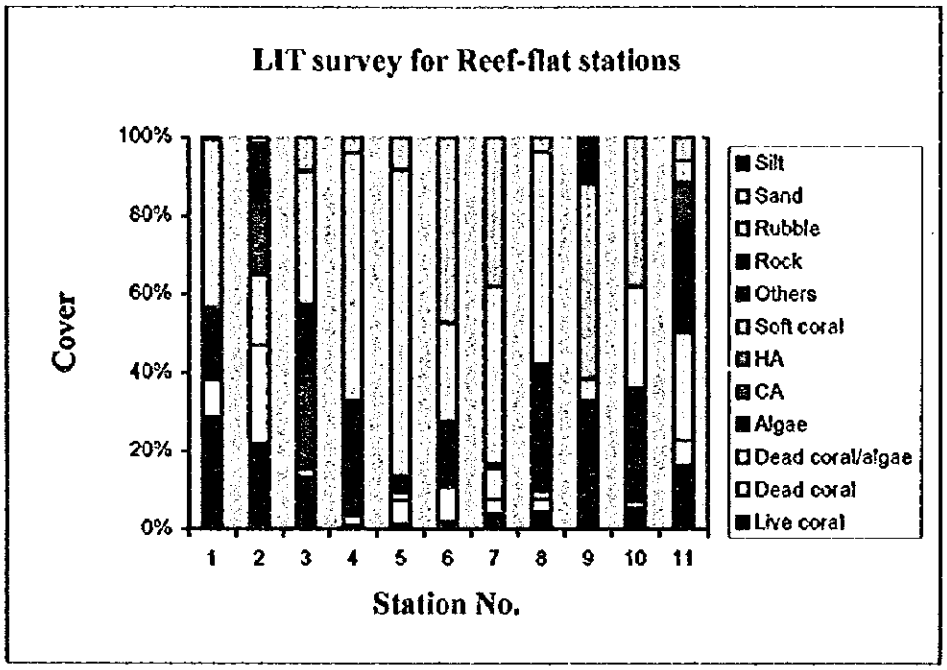
ii) Garbage

Both domestic and construction waste was randomly distributed along the entire west face of the reef adjacent to the channel. Higher densities of construction waste were associated with reef-flat area close to the channel entrance to the lagoon. Overall there was virtually no garbage at the outer and inner atoll reefs. At the eastern side of Gulhifalhu, there were large amounts of garbage distributed randomly. It is possible that this reef area has been used as a dump site during the redevelopment of Villingili.

(2) LIT Survey

The results of the line intercept transect (LIT) survey are shown in Figure 3-5 distinguished between reef-flat stations and reef-slope stations. The percentage of live coral cover also distinguished between reef-flat and reef-slope stations is shown in Figure 3-6.

All sites showed high levels of variation in the percent cover of benthic reef organisms and substrate types. Overall, the ratio of non-living substrate (NLS) cover to living cover was significantly greater in the reef-flat stations with the exception of reference areas located away from the landfill site at outer atoll reefs - Kiki reef, Gulhifalhu (#13) and Thilafushi-south (#2) (refer to Figure 3-4 for the location of stations).



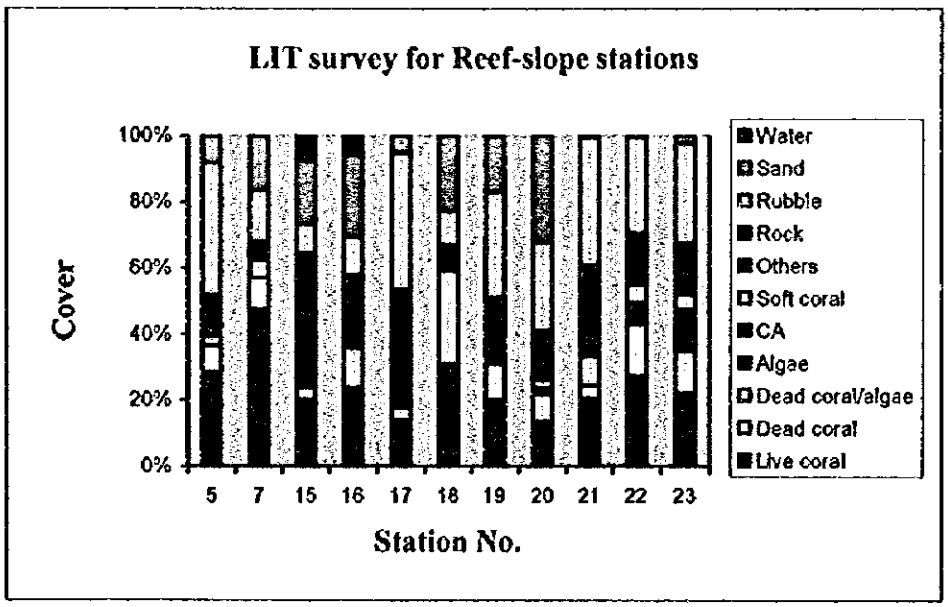
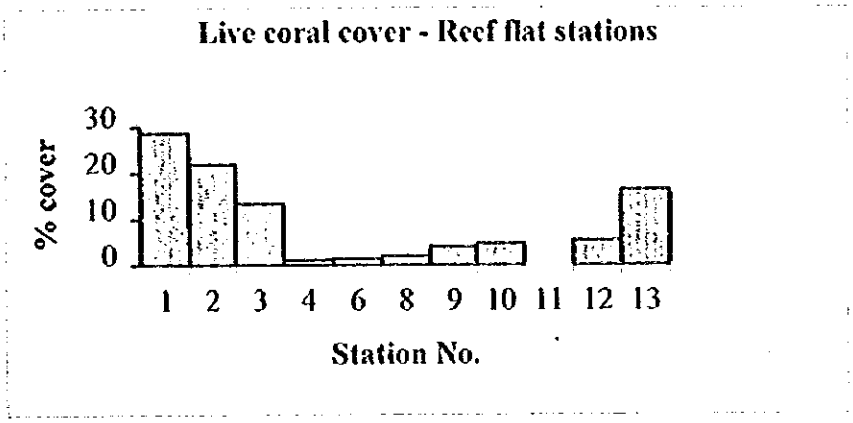


Figure 3-5. Life form Benthic Categories and Non-living Substrate at Reef-flat and Reef-slope Stations at Thilafushi and Gulhifalhu.

Note : HA-Halimeda algae, CA-Calcareous algae



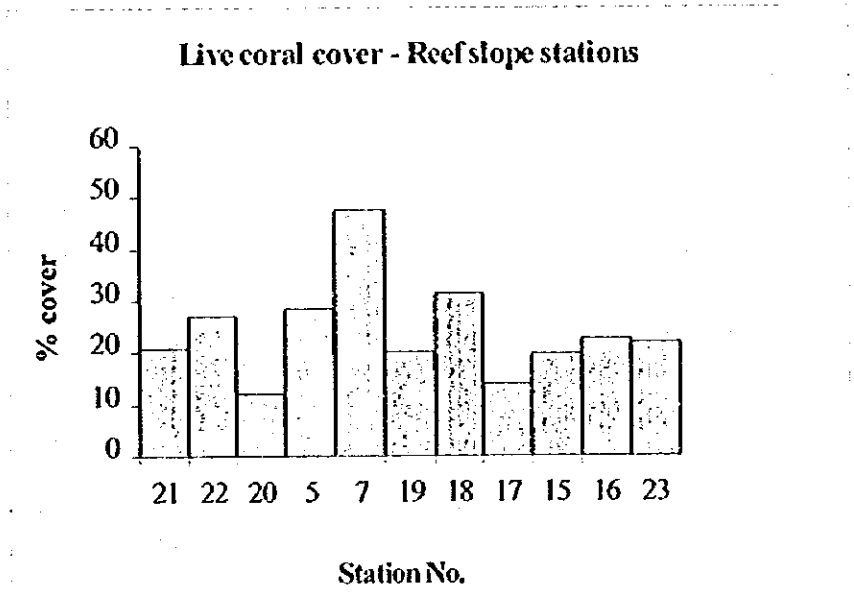


Figure 3-6. Percent Live Coral Cover for All Reef-flat and Reef-slope Stations.

i) **Reef-flat**

Live coral cover in the reference stations (outer atoll reefs) adjacent to the Vaadu Channel varied from 13-29 %. The Marine Protected Area (MPA) - Lions Head (#1) had the highest live coral cover. All remaining reference sites supported high calcareous and coralline algae cover (10-22 %) which is typical of wave exposed reef sites. Live coral cover at Kiki reef (#13 MPA at Gulhifalhu) was only 16 %, however, recently dead coral accounted for 28 % cover. The high value for this category was associated with the recent bleaching event.

All inner atoll reef stations supported low live coral cover (2-4 %) and had a high ratio of NLS. Similar values were recorded for the channel reef stations at Thilafushi and Gulhifalhu (0-5 % live coral cover). The non-living substrate categories in these stations varied considerably but overall coral rubble and sand were dominant in most stations.

Based on these observations, the inner reef-flat of Thilafushi would be the preferred location for future expansion of solid waste landfill development, since this choice at-least would minimise the inevitable and irreversible loss of coral life inherent to landfill development.

ii) **Reef-slope**

Live coral cover for the outer atoll stations varied from 12-27 % and was similar to values recorded for the corresponding reef-flat stations. In contrast, both the inner atoll and channel stations showed a considerable increase in percent live coral cover compared to their corresponding reef-flat stations. Live coral cover varied from 14-31 % for inner atoll reefs and from 20-48 % for channel reefs. The highest live coral cover (48%) was recorded at Thilafushi at the northern channel (#7) where the reef-flat cover was only 1 %. A similar situation was noted also at the station on the inner atoll reef towards the north-east point (#18), live coral cover was 31% for the reef-slope compared to 4 % for the reef-flat.

Based on these observations, it could be concluded that the existing solid waste reclaimed Thilafushi Island virtually caused no significant adverse effect on the coral life of reef-slope in the channel (Medhu Falhu Kandu) reef though the inevitable loss of reef-flat coral life was caused due to ecological alteration of the very reclaimed land environment from aquatic to terrestrial and other physical alterations,.

iii) Patch Reefs in Thilafushi Lagoon

Due to the topography and reef contour it was not appropriate to use the LIT method for assessing cover by benthic organisms and NLS. A semi-quantitative assessment was adopted which involved making a visual estimate of % live cover and dead cover and the dominant substrate type. Visibility at the eastern area of the lagoon close to the landfill was reduced to less than 3m.

Live coral varied between 5-15 %, dead coral accounted for up to 80 % and the dominant NLS was sand (5-10 %). Large portions of the dead coral were colonised by dense growths of dark red filamentous mats of algae. This algae belongs to phylum Cyanophyta (Blue-green algae) which often form fuzzy masses of filaments. They generally prefer high temperatures and sunlit areas with elevated nutrients. These algae were not observed in patch reefs distant from the landfill areas. The conditions responsible for the dense growth of blue-green algae may involve a combination of factors such as nutrient enrichment and elevated sea water temperatures. At the same patch reef the coral diseases known as *black band disease* and *black spot disease* were observed on some coral colonies.

The elevated nutrient level and its perceived adverse effect on coral life due to progressing eutrophication in the lagoon could be attributed to insufficient dilution of dispersed leachate into the lagoon from the Thilafushi landfill site.

iv) Transfer Station in Male'

The Male' transfer station is situated within the south-west harbour at the north towards the entrance. The shallow area adjacent to the transfer station was inspected by snorkelling to assess the condition and the status of garbage. The sea-bed in this area was composed of sand and fine rubble and the only coral communities were those growing on the concrete sea-walls and breakwaters. Overall the nature and level of garbage is similar to that observed in other parts of the south-west harbour. Accordingly, it is concluded that there was no significant adverse effect on the marine environment due to the activities associated with the transfer station.

v) Evaluation of Bleaching

At the beginning of the present survey, sea surface temperatures were returning to 29 - 31 °C from the previous high values of 32 - 34 °C recorded in May 1998. Evidence of bleaching was clearly visible from the surface, with large expanses of pale coloured reef communities. Over the survey period, large number of reef organisms, particularly hard and soft coral colonies regained their pigmentation. However, certain species of hard coral appeared to be more susceptible to

bleaching and hence suffered high mortality and were rapidly colonised by filamentous algae.

All reef organisms may be stressed for a long period as a result of this bleaching event. It is therefore imperative to reduce other sources of stress to promote conditions that would allow natural recovery processes. In areas, such as Thilafushi, where coral reef organisms are subject to high sedimentation the ability of the organisms to remove the sediment may be reduced. Hence it is imperative to mitigate the dispersal of dredged material due to landfill management in Thilafushi to surrounding marine environment.

vi) Fish Census

All stations showed similar trends in terms of the abundance of fish in the major fish families encountered, namely, Triggerfish, Surgeonfish, Parrotfish, Wrasses, Damselfish, Butterflyfish, and Groupers. Degraded reef-flat areas tended to be dominated by wrasse and parrotfish. Damselfish were abundant at all reef-flat stations with the exception of the inner atoll sites.

Reef-slope stations were characterised by high densities of damselfish, particularly juveniles. Groupers and butterflyfish distinguished reef-slope stations from their corresponding reef-flat stations. Overall the number of species within the different reef areas was very similar, with the exception of physically degraded areas.

vii) Protected or Endangered Species at or Close to the Landfill Site

A small number of protected species were observed at the outer atoll reef stations at Thilafushi and Gulhifalhu adjacent to the Vaadu Channel. These included the hawksbill turtle, the grey reef shark and black coral. In all cases observations were at 10 m depth or lower and hence not at reef-flat areas.

3.2.4 Conclusion

It is recognised that some damage to the coral reef system in the vicinity of the landfill operations is inevitable. However, this must be weighed against the benefits arising from the improvement to public health and the environmental pollution in Male' as a result of the solid waste collection and disposal system now in place. It is however, important to ensure that any damage to the coral reefs in the immediate vicinity of the landfill are minimised and that all possible control measures are adopted to protect the adjoining reefs.

High level of sedimentation and silt from dredging activities is considered as the major cause of reef degradation associated with the Thilafushi solid waste reclamation site. The results of the LIT surveys indicate that reef-flat areas opposite the impacted site on

site on Gulhifalhu are also affected by the high concentration of fine suspended particles. Hence it is imperative to mitigate the dispersal of dredged material (sediment) into the surrounding marine environment.

Overall the impacts from garbage are highly localised and directly associated with the Thilafushi landfill site. No significant distribution of garbage on to the adjoining reefs was noted. Despite the large volumes of loose garbage at the landfill and in the shallow back-reef areas, the amount of garbage observed underwater was fairly low. Nevertheless, from the very basic view point of aesthetics of marine environment and technically sound means of final solid waste disposal, it is imperative to prevent dispersal of garbage into surrounding marine water environment.

3.3 Water and Sediment Quality

The water and sediment (sea bed material) quality in Male' Island, the major solid waste generation and transfer area, and Thilafushi Island, the area where the solid waste is transported and dumped resulting in reclamation of the very island from the submerged reef, is studied in this section.

This study is made both based on available water quality monitoring data with the Public Health Laboratory (PHL) of the Ministry of Health (MOH) and also with water and sediment sampling and analysis conducted by the Study Team, principally in and around Thilafushi Island and as well in Male' Island.

Relevant waters of concern to solid waste management activity of both at present and in past are groundwater in Male', sea water both around Thilafushi and Male' and leachate generated in the already reclaimed (existing) Thilafushi Island. It is noted that until recent past solid waste was used in combination with other materials for the reclamation of southern part of Male' Island from sea. This is perceived as a cause of poor groundwater (well water) quality with high hydrogen sulfide (H_2S) levels, as monitored by the PHL.

Concerning sea-bed material quality either around Thilafushi Island or Male' Island there is no available data, since no such sediment sampling and analysis was conducted in the past. As such analysis results by the Study Team will only be used to define the status of sea bed material and effects, if any, due to solid waste reclamation of Thilafushi Island.

3.3.1 Water Quality

(1) Available Data

a. Groundwater in Male'

The groundwater in Male' is saline with chloride level mostly exceeding 1000 mg/l and hence unfit for potable use from the view point of this very basic drinking water quality requirement. As widely reported, the recent range of chloride level (1996-1998 data, as available in PHL) in groundwater is from 1000 to 3000 mg/l, at times even up to 15,000 mg/l which is almost the same as that of sea water (chloride level in Male' coastal sea water is around 20,000 mg/l). It is also noted that the chloride level in Male' groundwater as determined by the previous JICA study for the Seawall Construction Project in 1991 also exceeded 1000 mg/l in all five (5) wells measured.

Still, the available data, in PHL on groundwater quality a decade ago in Male' (1988) indicated a chloride level of around 100 mg/l only, which was even less than the chloride level of around 250 mg/l in the desalinated potable water presently supplied by the Maldives Water and Sanitation Authority (MWSA). Hence the present high groundwater chloride level in Male' could be attributed to salinity intrusion of sea water, which might also be aided by sea reclamation of land, due to the obvious cause of over exploitation of groundwater by recent high increase in population.

Moreover, the recent (1997-1998) groundwater quality data of PHL indicates widespread contamination with Hydrogen Sulfide (H_2S) distributed to all over the Male' island, with H_2S level exceeding 3 mg/l.

This effect also could be attributed to the past land reclamation in the southern part of the island with solid waste which results in lechate generation. In addition, the over exploitation of groundwater contributed to the dispersion of lechate to the entire underground of the island, thereby affecting the groundwater quality even worse than those parts of the natural (non-reclaimed) island.

Based on the above aspects it could be concluded that the groundwater in Male' island is both saline and polluted and not suited for most beneficial uses, in particular potable use.

b. Leachate in Thilafushi

Monitoring of the lechate quality generated in the Thilafushi solid waste landfill (sea reclamation) site was initiated in October 1993, with the provision of four (4) leachate monitoring wells within the already reclaimed area. Simultaneously, sea water quality monitoring around the sea area of the entire Thilafushi reef, including the near-by reefs of Gulhifalhu and Bodugiri, at seven (7) monitoring stations, were also initiated (refer to the subsequent section on sea water).

However, with time not only this leachate cum sea water monitoring frequency has become infrequent, but also the leachate monitoring wells (bore-holes) were gradually demolished to only one single remaining well at present (1998). No monitoring data is available for the entire year of 1995 and also no monitoring was conducted in this year (1998).

Of the leachate quality parameters monitored, though comprised of 25 items, that could be regarded as primary pollution level indicators due to decaying solid waste represented by leachate are only three (3), namely, Ammonia, Hydrogen Sulfide and DO (dissolved oxygen).

As could be expected of leachate quality rather wide range of ammonia and H_2S and consistently almost nil (0) DO were noted, typical for high strength wastewater. The most recent data of July, 1997 indicated an ammonia level around 115 mg/l and varying H_2S level of about 2 and 18 mg/l measured in 2 monitoring wells remained at that time. However since COD (chemical oxygen demand), the most representative parameter to determine the pollution load of a high strength waste like leachate was never measured, due to lack of laboratory capability, no quantitative estimation of the strength of leachate is possible, based on the available data.

c. Sea Water

There are seven (7) sea water quality monitoring stations established in October 1993, simultaneously with the above mentioned leachate monitoring programme in Thilafushi, around the entire reef of Thilafushi, including its surrounding reefs of Gulhifalhu and Bodugiri. (refer to Figure 3-9 for locations). This is the only consistent long term (1993–1997) sea water quality monitoring data available in the vicinity of the Study Area including Male' and Villingilli islands.

All sea water quality monitoring were conducted almost simultaneously (on the same day or in 2 days time) with the leachate quality monitoring delineated above, since this is an integrated leachate cum seawater quality monitoring programme in and around the Thilafushi reef. Also other than for the addition of Transparency (Visibility) all parameters monitored are the same as that of leachate monitoring, and hence the total parameters monitored were 26.

This integrated monitoring programme on leachate cum seawater quality could be considered to be intended at monitoring the effect of dispersion of leachate from the Thilafushi landfill to the surrounding marine environment on a macro basis. Since all the 6 stations are located away from the immediate vicinity of Thilafushi except for one (1) remaining monitoring station located at jetty where solid waste transportation barge unload the vehicles containing solid waste on to the island.

Anyhow the available sea water quality monitoring results (1993-1997) indicate the marine water quality remains typical to that of sea water with no discernable effect attributable to dispersion of leachate to marine environment.

Still it should be noted that this monitoring programme does not target adequately the immediate vicinity of Thilafushi reef, in particular the inner lagoon of the reef. Moreover, marine water quality is only a broad (macro) means of assessing the health of marine water environment and it alone would

not be sufficient, though necessary, to guarantee that the ongoing solid waste filling and the related activities of dredging of reef and the resultant dispersal of sediment (dredged material) and over carriage of garbage to Thilafushi Island do not in fact affect the marine ecosystem.

(2) Sampling by the Study Team

Water quality sampling by the JICA Study Team targeting ground water in Male' (4 locations), leachate in Thilafushi (4 locations) and sea water around Thilafushi, including its immediate vicinity and the seven (7) established monitoring stations of PHL (19 locations), and Male' (2 locations) were conducted in the beginning of September 1998.

The water quality parameters measured were basically the ones to determine the pollution effects including heavy metals and same for all three (3) types of water (groundwater, leachate and sea water). Significant parameters measured are, namely, temperature, pH, DO (dissolved oxygen), COD (chemical oxygen demand), sulfide, sulfate, ammonia, nitrite, nitrate, phosphate, total coliform (TC), fecal coliform (FC) and the metals of iron (total), copper, chromium (total), lead and mercury.

The locations of water quality sampling are shown in Figure 3-7 (groundwater and seawater cum sediment sampling locations of Male'), Figure 3-8 (leachate sampling locations in Thilafushi), Figure 3-9 (seawater sampling locations in the 7 monitoring stations of the PHL around Thilafushi reef) and Figure 3-10 (seawater cum sediment sampling locations in the vicinity of Thilafushi).

The following code system was used to distinguish the types of sampling locations;

- The four (4) groundwater sampling locations of Male' coded as G1 to G4 (Figure 3-7)
- The four (4) leachate sampling locations of Thilafushi coded as L1 to L4 (Figure 3-8)
- The seven (7) seawater sampling locations of the PHL monitoring stations around Thilafushi coded as S1 to S7 (Figure 3-9)
- The fourteen (14) seawater cum sediment (sea-bed material) sampling locations in vicinity of Thilafushi and Male' coded as SW1 to SW14 (Figure 3-10 for SW1-SW12 of Thilafushi and Figure 3-7 for SW13-SW14 of Male')

It is noted that the location SW13 at south-east coast of Male' was selected as a representative station for background quality, while the location SW14 at the south-west harbour of Male' is selected as it is the loading area for solid waste transportation barge from Male' to Thilafushi landfill island (ref. Figure 3-7).

Also all the remaining 12 locations of SW1-SW12 were selected in and around the immediate vicinity of the existing solid waste reclaimed Thilafushi island, but still to encompass the possible areas of the Thilafushi reef that could be subjected to future solid waste land-filling by this master plan including the inner lagoon of the reef adjacent to the existing solid waste reclaimed Thilafushi Island (ref. Figure 3-10).

The sediment (sea-bed material) sampling results of these 14 locations (SW1-SW14) is dealt with in the subsequent section on Sediment Quality.

The results of water quality analysis for groundwater in Male' (G1-G4 of Figure 3-7) is summarised in Table 3-7, that of leachate in Thilafushi Island (L1-L4 of Figure 3-8) in Table 3-8, that of the 7 seawater quality monitoring stations of PHL (Public Health Laboratory of the Ministry of Health) around Thilafushi reef (S1-S7 of Fig.3-9) in Table 3-9, and finally that of the 14 seawater and sediment quality sampling locations in the vicinity of Thilafushi Island (SW1-SW12 of Fig.3-10) and the south-east and south-west coast of Male' (SW13 and SW14 of Fig.3-7) in Table 3-10.

Based on the results of analysis the following observations are made on the quality of each type of water (groundwater, leachate and seawater).

a. Groundwater in Male'

The all four (4) wells sampled are located in Mosques of Male'. Heavy rainfall was experienced in the week prior to the sampling. Moreover the well G2 of Masjidul Furugan Mosque, located near the solid waste transfer station, is injected with rainwater collected on the roof-top of the Mosque in order to improve the well water quality. Still the other 3 wells do not have such artificial introduction of rainwater.

The COD results, that ranged from 7 to 20 mg/l (ref. Table 3-7), indicates significant pollution of groundwater for all 4 locations. In fact the lowest COD of 7 mg/l is measured in well G2 with artificial rainwater introduction. Disregarding G2 all the remaining wells recorded COD level in the range of about 15-20 mg/l, clearly indicating significant organic pollution for groundwater, since COD level of unpolluted groundwater normally does not exceed 5 mg/l. The cause could be the dispersion of landfill leachate generated at the solid waste reclaimed southern part of Male', as also pointed out in the foregone section.

Still nil (0) total and fecal coliform levels recorded in all 4 wells indicate no bacterial pollution attributable to human waste contamination thereby basically ensuring the public health safety of the groundwaters. Relatively low chloride level in the range of only about 250-1000 mg/l (against the typical range of 1000-3000 mg/l as per the available monitoring data of PHL) in the wells could

be attributed to dilution effect due to heavy rainfall. It is also noted the lowest chloride level of 250 mg/l was recorded at the well G2 with artificial rainwater introduction.

No significant metallic contamination, including heavy metals, is noted.

Finally considering the relatively high pollution level and chloride level of Male' groundwater artificial introduction of rainwater to wells leads to inherent beneficial effect of overall groundwater quality improvement, which needs to be encouraged.

b. Leachate in Thilafushi

It is noted that of the four (4) leachate sampling locations of L1-L4, L1 is the only remaining leachate monitoring well (bore-hole) of PHL established in October 1993 as noted in the foregone section (ref. Figure 3-8), hence be representative to longest age of leachate generation since the commencement of the landfill operation in Thilafushi in December 1992.

All other 3 locations (L2-L4) are leachate ponds that remained at the time of sampling. Though surface ponds, they are not directly linked to the surrounding seawater. Still L3 and L4 are located adjacent to sea coast.

The COD level measured in all 4 locations was in the range of about 200-750 mg/l (ref. Table 3-8), indicating relatively low pollution load typical to leachate. Still considering the specific environmental condition of the island that reclaimed from sea with solid waste, this would simply mean dilution and dispersion of leachate to surrounding sea environment due to active exchange with seawater. Accordingly it could be presumed that seawater assists in active treatment of leachate, though inefficient dispersion of leachate may affect the surrounding marine environment.

The lowest COD level of 220 mg/l in combination with high ammonia and hydrogen sulfide levels as noted in L1, the leachate monitoring well, indicates the long age of leachate generation and effective waste stabilisation.

The concentration level of metals measured, including the heavy metals, is very low for a typical leachate. Accordingly it could be concluded that the metallic accumulation in the landfill leachate is insignificant.

c. Seawater around Thilafushi and Male'

The results of analysis of sea water quality in all of the 21 locations, the seven (7) monitoring stations of PHL around Thilafushi reef (ref. Figure 3-9) and the 14 seawater cum sediment sampling locations in the vicinity of solid waste

reclaimed Thilafushi island as well as Male' (ref. Figure 3-10 and Figure 3-7) clearly indicates no significant deterioration of seawater quality that could be attributed to any of the on-going waste disposal means either in Thilafushi or Male'. It is noted that sewage generated in Male' also disposed via sea out-falls located around Male' island.

In particular near saturation DO level exceeding 7 mg/l in most locations (ref. Table 3-9 and Table 3-10), still exceeding 6 mg/l in all locations, typical for unpolluted water environment, points to the cleanness of seawater. Moreover mostly nil (0) total and fecal coliform level indicates no significant lingering effect that could be attributed to human waste pollution as well.

Most metallic parameters measured are also basically at near zero (0) detection limit (DL) level of analytical measurement for all the 21 sea water samples analysed.

The fine seawater quality around Thilafushi could be interpreted as effective dilution and dispersion of leachate in the surrounding marine environment to undetectable pollution level, due to sea waves, tides and current. In other words, in an overall sense, under the current rate of solid waste land-filling and subsequent leachate generation, the surrounding marine environment posses the required assimilative capacity to naturally render the pollution due to leachate insignificant, as far as the sea water quality is concerned. This is despite the fact that the on-going landfill operation in Thilafushi has many environmental concerns including the over-carriage (dispersal) of floating garbage to surrounding marine water environment.

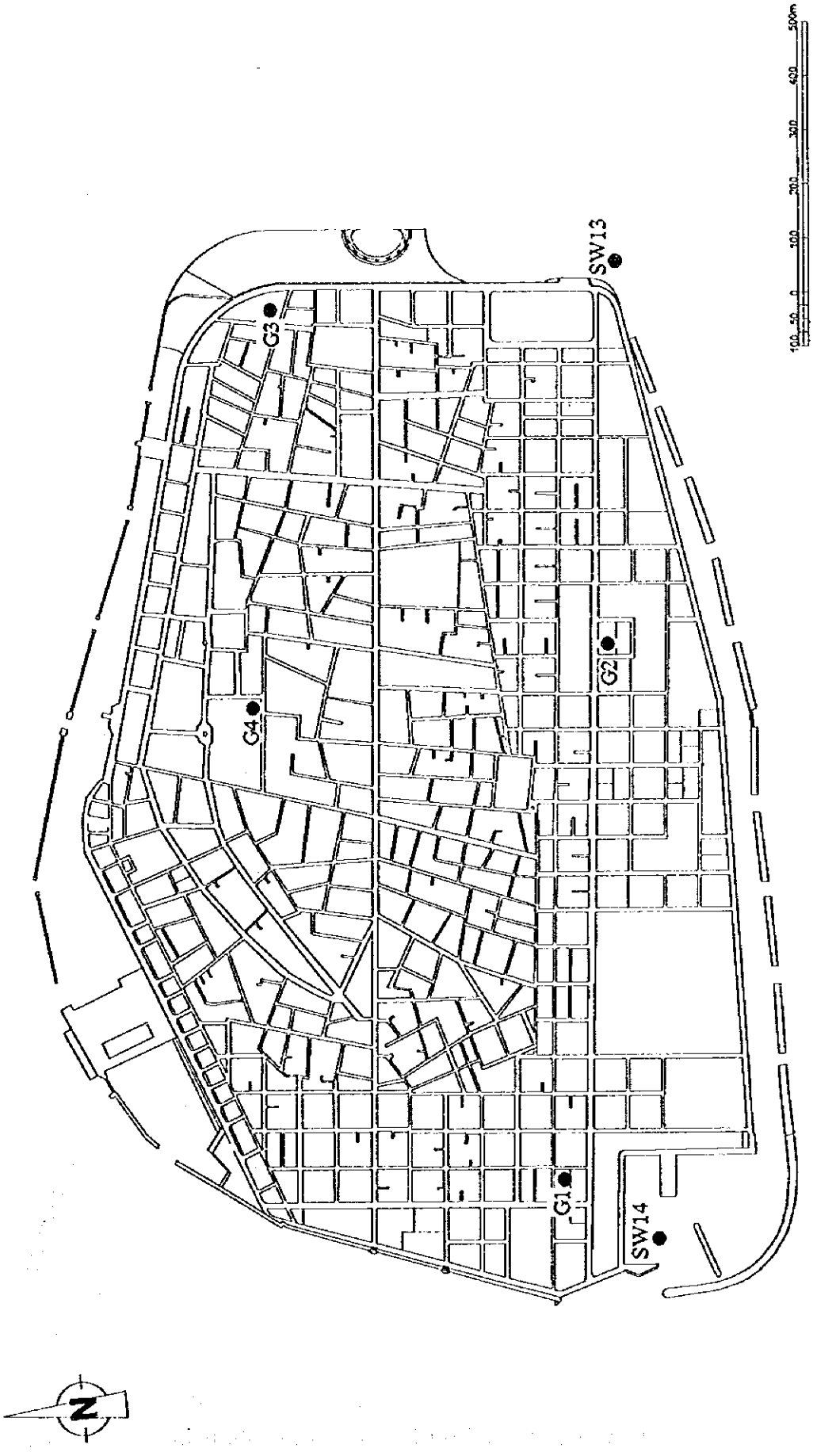


Figure 3-7. Ground Water and Sea Water cum Sediment Sampling Locations in Male

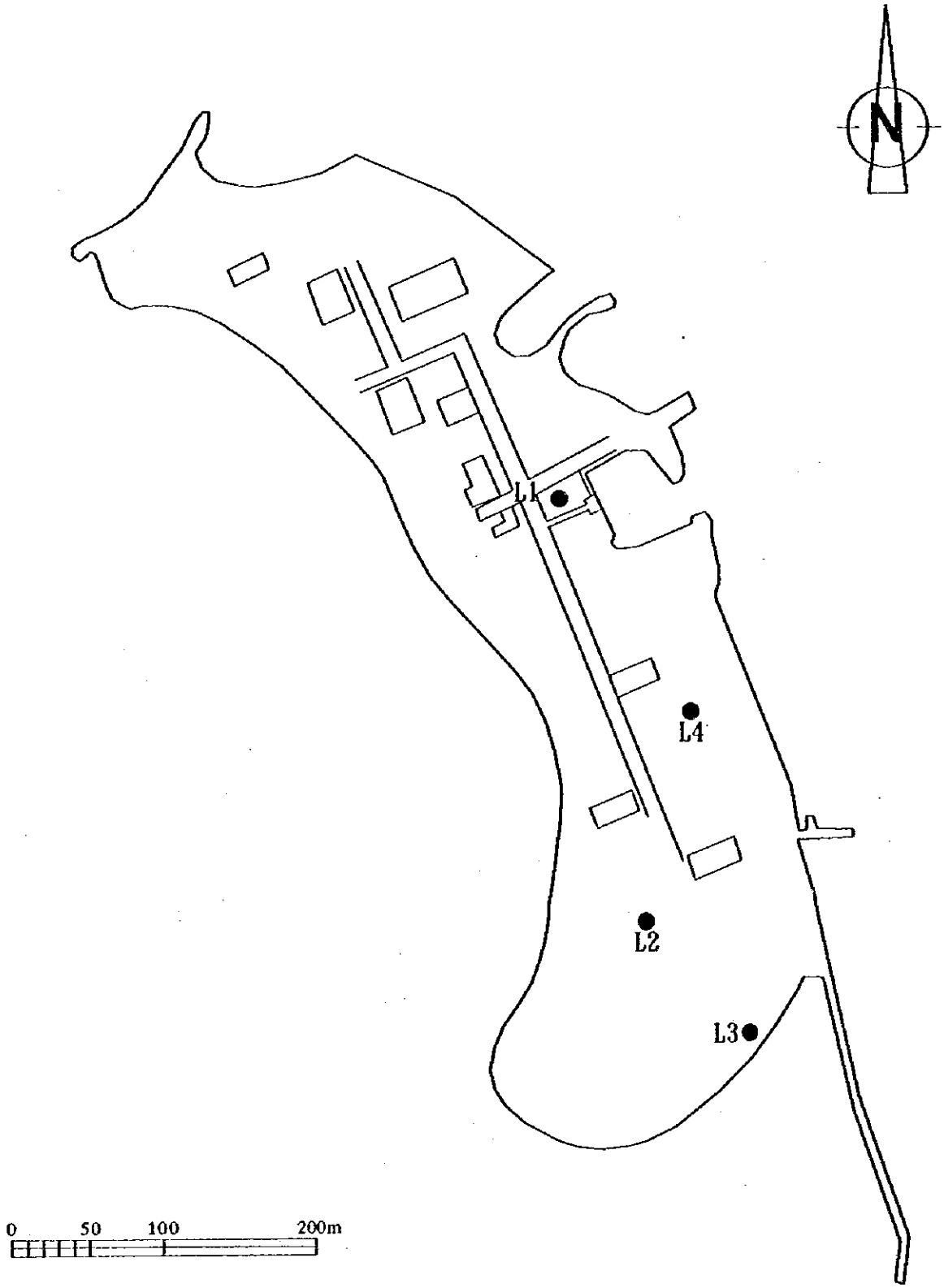


Figure 3-8 Leachate Sampling Locations in Tilafushi

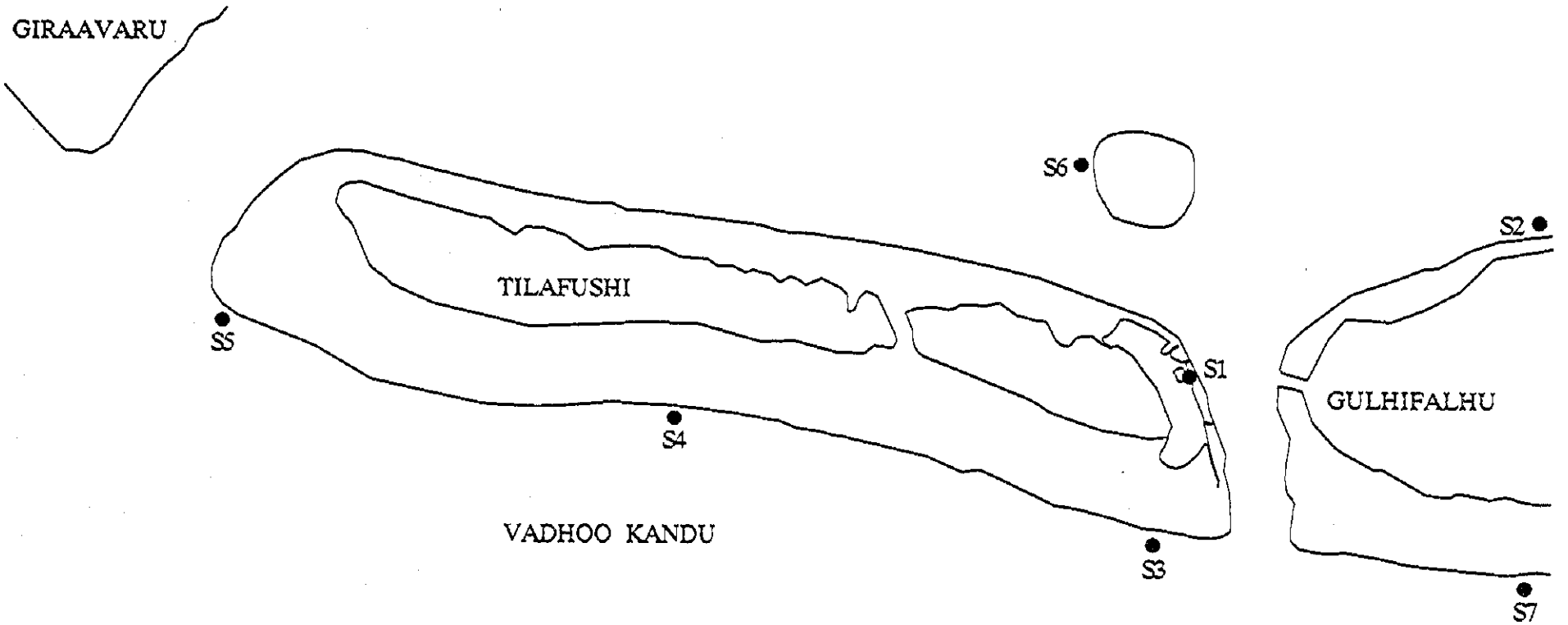


Figure 3-9. Sampling Locations around Tilafushi - Sea Water Monitoring Stations

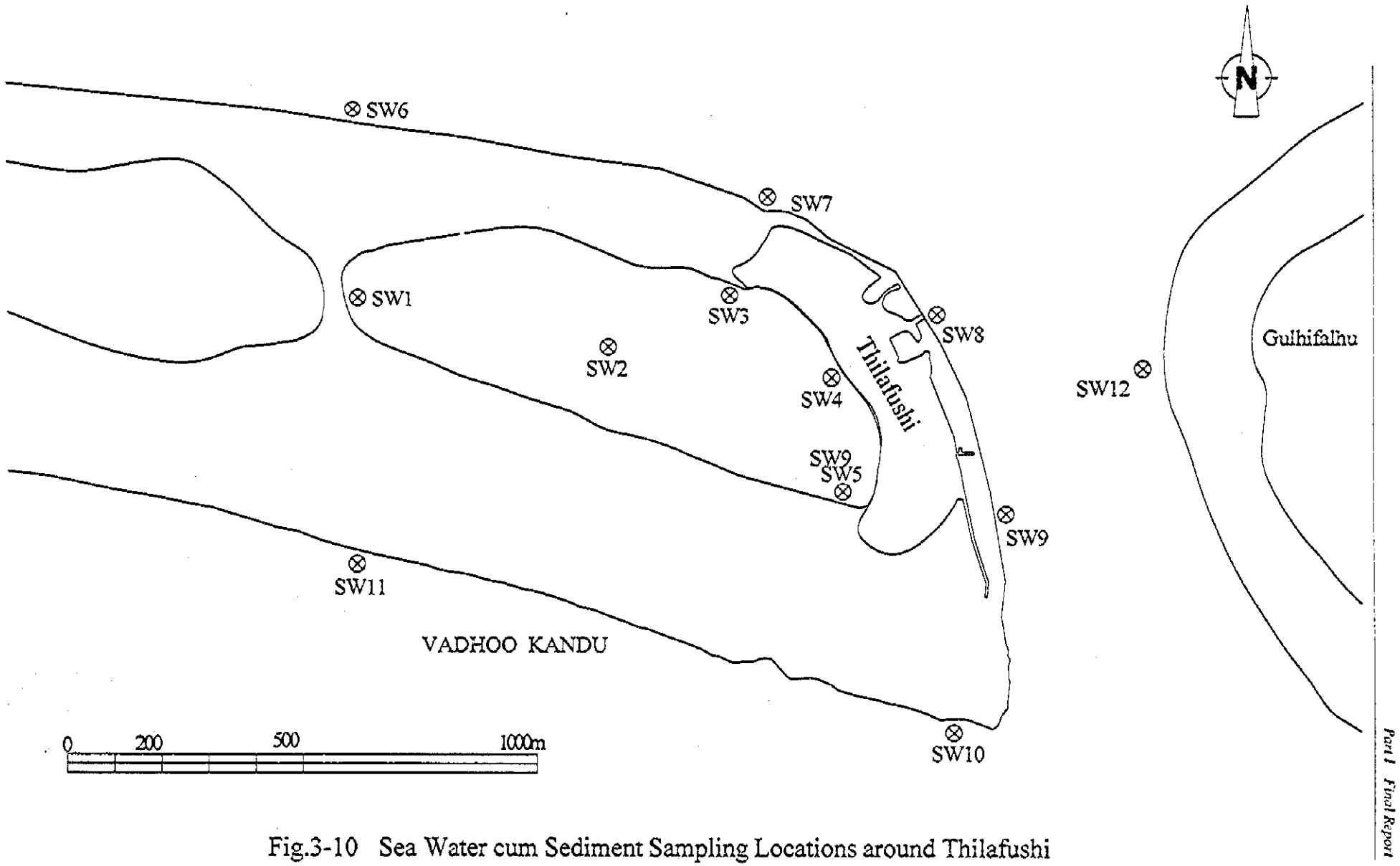


Fig.3-10 Sea Water cum Sediment Sampling Locations around Thilafushi

Note : Refer to Fig.3.7 for the sampling locations of Male

Table 3-7. Groundwater Quality Sampling Results-Male

Parameter	Unit	G_1	G_2	G_3	G_4
Physical Appearance		Clear & Colourless	Clear & Colourless	Clear & Colourless	Clear & Colourless
Temperature	°C	28.6	27.7	28.4	28.7
pH		7.7	7.6	7.6	7.3
Conductivity	ms/cm	3.000	1.061	1.460	3.870
Total Dissolved Solids	g/l	1.480	0.532	0.732	2.060
Dissolved Oxygen	mg/l	0.4	5.4	4.0	2.2
Chemical Oxygen Demand	mg/l	16.5	7.0	19.0	22.0
Hydrogen Sulphide	mg/l	0.1-0.3	0.0	0.0	0.0
Sulphide	mg/l	0.001	0.001	0.002	0.001
Ammonia	mg/l	0.54	0.23	0.06	0.01
Nitrate	mg/l	0.9	0.6	1.1	0.8
Nitrite	mg/l	0.004	0.005	0.003	0.00
Phosphate	mg/l	0.04	0.05	0.06	1.43
Sulphate	mg/l	75	32	75	75
Chloride	mg/l	777	250	262	1024
Chromium	mg/l	< 0.06	< 0.06	< 0.06	< 0.06
Lead	mg/l	< 0.10	< 0.10	< 0.10	< 0.10
Mercury	mg/l	< 0.002	< 0.002	< 0.002	< 0.002
Copper	mg/l	< 0.05	< 0.05	< 0.05	< 0.05
Iron	mg/l	< 0.06	< 0.06	0.1	< 0.06
Faecal Coliforms	/100ml	NIL	NIL	NIL	NIL
Total Coliforms	/100ml	NIL	NIL	NIL	NIL

Remarks

G_1 Masjidul Salaam (Maafannu)
G_2 Masjidul Furuqan (Galolhu)
G_3 Masjidul Noor (Henveiru)
G_4 Kalhuvakaru Miskiiy (Galolhu)

Table 3-8. Leachate Quality Sampling Results-Tilafushi Island

Parameter	Unit	L_1	L_2	L_3	L_4
Physical Appearance		Pale Brown	Brown	Brown	Pale Brown
Temperature	°C	30.5	30.9	32.5	31.0
pH		7.8	7.7	8.7	8.0
Conductivity	ms/cm	17.24	29.04	58.72	58.16
Total Dissolved Solids	mg/l	9.39	14.52	29.36	29.20
Dissolved Oxygen	mg/l	0.2	0.0	-	1.9
Chemical Oxygen Demand	mg/l	220	755	520	300
Hydrogen Sulphide	mg/l	>5	1.0	2.0	4.0
Sulphide	mg/l	2.45	0.20	0.45	0.80
Ammonia	mg/l	30.0	30.0	9.5	3.0
Nitrate	mg/l	16	7	14	15
Nitrite	mg/l	0.02	0.01	0.12	0.03
Phosphate	mg/l	10.8	34.2	5.2	1.0
Sulphate	mg/l	124	120	300	300
Chloride	mg/l	8137	8292	18392	18279
Chromium	mg/l	< 0.06	0.06	0.08	0.09
Lead	mg/l	< 0.10	< 0.10	< 0.10	< 0.10
Mercury	mg/l	< 0.002	< 0.002	< 0.002	< 0.002
Copper	mg/l	< 0.05	< 0.05	< 0.05	< 0.05
Iron	mg/l	0.3	3	0.4	2
Faecal Coliforms	/100ml	NIL	NIL	NIL	NIL
Total Coliforms	/100ml	NIL	NIL	NIL	NIL

Remarks : L_1 is the only remaining leachte monitoring well (bore-hole) in Tilafushi
L_2~L_4 are leachate ponds existed at the time of sampling in Tilafushi

Table 3-9. Sea Water Quality Sampling Results-PHL Monitoring Stations

Parameter	Unit	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Physical Appearance		Clear & Colourless	Clear & Colourless	Clear & Colourless	Clear & Colourless	Clear & Colourless	Clear & Colourless	Clear & Colourless
Temperature	°C	29.2	28.9	29.2	29.2	28.9	28.0	28.9
Conductivity	ms/cm	64	60.0	60.9	61.05	60.85	61.6	60.7
Total Dissolved Solids	g/l	30.3	30.1	30.5	30.6	30.45	30.85	30.4
Dissolved Oxygen	mg/l	6.2	7.6	7.4	7.6	7.5	7.7	7.6
Chemical Oxygen Demand	mg/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5
pH		8.2	7.3	8.2	8.1	8.3	8.2	7.7
Sulphide	mg/l	0.003	0.002	0	0.001	0.001	0.002	0.001
Ammonia	mg/l	0.24	0.00	0.00	0.00	0.00	0.03	0.01
Nitrate	mg/l	1.6	2.0	2.7	2.8	2.0	3.0	2.0
Nitrite	mg/l	0.009	0.003	0.003	0.003	0.002	0.002	0.006
Phosphate	mg/l	0.07	0.02	0.06	0.17	0.07	0.09	0.03
Sulphate	mg/l	2150	2050	1800	2300	2200	2000	2100
Chloride	mg/l	19354	18114	19419	18904	18399	19264	19312
Chromium	mg/l	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Lead	mg/l	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Mercury	mg/l	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Copper	mg/l	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Iron	mg/l	0.09	< 0.06	0.06	< 0.06	0.1	< 0.06	< 0.06
Faecal Coliforms	/100ml	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total Coliforms	/100ml	NIL	NIL	NIL	NIL	NIL	NIL	NIL

Remarks : $S_1 \sim S_7$ are the 7 monitoring stations around the entire Tilafushi reef and its vicinity established in October 1993.

Table 3-10: Sea Water Quality Sampling Results-Tilafushi and Male

Parameter	Unit	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	SW_{14}
Physical Appearance		Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Temperature	°C	29.2	29.4	29.6	29.7	29.5	29.2	28.6	29.3	29.0	28.9	28.9	29.2	28.1	27.0
Conductivity	ms/cm	73.90	75.45	71.75	73.40	72.45	70.05	69.40	72.25	72.30	69.75	74.50	71.50	71.40	71.80
Total Dissolved Solids	g/l	37.00	37.85	35.85	36.85	36.25	35.20	34.75	36.15	35.35	34.90	37.20	35.80	35.60	36.10
Dissolved Oxygen	mg/l	7.1	7.2	7.3	7.0	6.3	7.6	7.3	6.6	7.4	7.4	7.6	7.6	7.5	7.0
Chemical Oxygen Demand	mg/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
pH		8.20	8.20	8.20	8.20	8.20	7.60	9.01	7.85	8.74	7.39	7.31	8.20	8.24	8.20
Sulphide	mg/l	0.75	3.00	2.50	3.50	0.75	6.75	1.25	1.50	3.00	5.25	3.00	2.50	2.60	1.50
Ammonia	mg/l	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.600	0.000	0.001	0.000	0.000	0.010	0.000
Nitrate	mg/l	1.8	1.4	1.2	1.3	1.3	1.1	1.3	1.5	1.2	1.3	1.2	1.0	0.9	1.1
Nitrite	mg/l	0.007	0.006	0.011	0.006	0.008	0.004	0.003	0.003	0.002	0.003	0.003	0.003	0.001	0.002
Phosphate	mg/l	0.04	0.02	0.01	0.02	0.01	0.02	0.02	0.07	0.03	0.02	0.02	0.01	0.04	0.27
Sulphate	mg/l	1800	2150	2200	2200	2350	2250	2450	2300	2100	2000	2200	2250	1300	2400
Chloride	mg/l	21133	20203	18404	20156	21285	17984	20541	19309	21356	21551	19621	19836	19122	19911
Chromium	mg/l	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Lead	mg/l	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Mercury	mg/l	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Copper	mg/l	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Iron	mg/l	< 0.06	< 0.06	0.4	0.3	< 0.06	< 0.06	< 0.06	0.1	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Faecal Coliforms	/100ml	NIL	NIL	NIL	NIL	7	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	24
Total Coliforms	/100ml	NIL	NIL	NIL	NIL	13	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	37

Remarks

SW1~SW12 are sea water and sediment sampling locations in the vicinity of Tilafushi Island.
SW13~SW14 are sea water and sediment sampling locations in Male.
SW13~South -east coast of Male
SW14~Male South -west harbour (solid waste barge loading area for Tilafushi)

3.3.2 Sediment Quality

No data is available on the sediment (seabed material) quality in and around Male' or any other island of Maldives. This could be attributed to the very specialized nature of the analytical work involved, in particular the pre-treatment of the sample to facilitate the elution of the constituent measured. This requires elaborate laboratory facilities and technical skill that is lacking in Maldives.

The sediment (seabed material) sampling by the Study Team was also conducted in the beginning of September 1998 in tandem with the water quality sampling as mentioned in the foregone section. The sampling locations are the immediate vicinity of the Thilafushi Island (12 locations) and that of Male' Island (2 locations) with a total of 14 locations, the sea-beds of the same seawater quality sampling locations of SW1-SW14 shown in Figure 3-10 and Figure 3-7. Nevertheless in order to distinguish the seabed sampling locations from the corresponding sea water sampling locations, the sea bed locations are referred to as SE1-SE14.

The sediment quality parameters analysed are those representative to accumulation of pollution including heavy metals to bed materials of water bodies, namely, total nitrogen, total phosphorus, total sulfur and the metals of total iron, copper, total chromium, lead and mercury.

The results of seabed material quality analysis are shown in Table 3-11. Based on the results the sediment quality is assessed as clean with no significant contamination and hence representative to natural background seabed material.

Table 3-11. Sediment (sea-bed) Quality Sampling Results - Thilafushi and Male

Parameter	Unit	SE_1	SE_2	SE_3	SE_4	SE_5	SE_6	SE_7	SE_8	SE_9	SE_{10}	SE_{11}	SE_{12}	SE_{13}	SE_{14}
Total Nitrogen	mg/kg	10	<5	7	<5	16	212	82	112	95	<5	<5	5	44	64
Total Phosphorus	mg/kg	9	10	36	45	70	30	41	20	15	49	13	39	30	16
Total Sulfur	g/kg	1.0	1.0	1.0	1.0	1.0	2.0	1.0	2.0	2.0	2.0	1.0	1.0	1.0	3.0
Total Chromium	mg/kg	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12
Lead	mg/kg	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Total Mercury	mg/kg	<0.1	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Copper	mg/kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total Iron	mg/kg	21	80	26	69	55	36	35	43	69	43	44	45	68	607

Remarks

SE_1 ~SE_{12} are sediment sampling locations in the vicinity of Thilafushi Island.
SE_{13}~SE_{14} are sediment sampling locations in Male.
SE_{13}~South - east coast of Male
SE_{14}~Male South - west harbour (solid waste barge loading area for Thilafushi)

3.4 Environmental Institution, Laws, Regulations and Standards

3.4.1 Environmental Institution

The principal responsible institution for environmental affairs of the Republic of Maldives, until very recently up to October 1998, was the Ministry of Planning, Human Resources and Environment (MPHRE). From November 1998 the Environment Section of MPHRE has been transferred to the Ministry of Home Affairs and amalgamated reorganised new ministry is being referred to as the Ministry of Home Affairs, Housing and Environment (MHAHE).

The Environmental Section of MPHRE (since November 1998 MHAHE) has practical jurisdiction to ensure the relevant environmental laws and regulations, including the environmental impact assessment (EIA) for development projects, are adhered to by potential polluters and project initiators. Essentially the Environment Section of MPHRE is the basic planning and executing agency on a national basis, the environmental management, preservation and protection measures.

According to the Fifth National Development Plan of Maldives (1997) the overall responsibility of MPHRE is summarised as "monitoring the activities of the public and private sector to ensure that the activities and their management are consistent with public policies and a developed set of guidelines and procedures".

It is to be noted that the National Commission for the Protection of the Environment (NCPE), established in 1989 under the president office, as an advisory organ on environmental planning, management and environmental impact assessment to the MPHRE, is also a very important national environmental institution.

Other institutions with very significant involvement in environmental affairs of the country are the Ministry of Health, which also has the sole water quality analytical laboratory, and the Ministry of Fisheries, Agriculture and Marine Resources, which is responsible for the protection of marine environment by promoting sustainable utilisation of marine resources and their conservation, including coral ecology, and to the maintenance of uninhabited islands and wooded areas, including tree plantation (forestation), hence to the protection of terrestrial environment as well.

Accordingly, the Ministry of Fisheries and Agriculture (MOFA) has a very high stake in the management and conservation of natural (renewable) environmental resources of the nation. It is also noted that the ongoing "Million Tree Plantation Campaign in Maldives" is under the responsibility of the MOFA and MOFA manages a plant nursery to facilitate tree plantation in general.

3.4.2 Environmental Laws, Regulations and Standards

The Environment Protection and Preservation Act of Maldives enacted in 1993, known as Law No. 4/93, formed the basis of national environmental law. According to this law environmental guidance could be issued by any concerned ministry of the government. Moreover, the MPHRE (since November 1998 MHAHE) has been given the authority to identify and declare protected nature reserve areas and also to formulate the required regulations concerning the activities allowed in such protected areas, including audit of such allowed activities.

This Law No. 4/93 also stipulates the formulation of EIA for all development projects having potential impact on environment and its submission to the MPHRE for evaluation and approval. The MPHRE is also authorized to terminate any project causing undesirable environmental impact with no compensation.

This law essentially stipulates environmental conservation in a very general terms without any specific environmental regulations and standards. In this respect this Law No. 4/93 is only the basic law of environment and the relevant environmental regulations and standards, including that of ambient air quality standards and coastal sea water(swimming and recreational water) quality standards, are yet to be instituted.

It is also noted that there is no national standards, instituted by law, for potable (drinking) water quality, even tough the Maldives Water and Sanitation Authority (MWSA) has a drinking water quality criteria which is more stringent than the WHO (World Health Organisation) drinking water quality criteria. The rational for the adoption of more stringent criteria than that of WHO by MWSA is not clear, nevertheless, in practice, both these criteria are used as reference by the Public Health Laboratory (PHL) of the Ministry of Health in reporting drinking water quality analysis results. This Public Health Laboratory is the sole basic environmental laboratory in Maldives with capability to analyze water quality parameters.

3.4.3 EIA Regulation

As pointed out in the foregone section, the Law No. 4/93 clearly defines the requirement of EIA for development projects and the relevant supervisory institution (MPHRE, since November 1998-MHAHE). In accordance with this vested authority by law, the MPHRE has formulated a draft document as a guidance to carry out environmental impact assessment by project initiators, known as "An Information Handbook on EIA for proponents and government agencies in the Republic of Maldives", in December 1997.

This draft EIA Guidelines document is intended to become the EIA Regulation of the Law No.4/93, after being debated and modified/updated by the national parliament. However, it is yet to become a part of the Law No. 4/93. This EIA Guidelines defines the administrative procedure to be undertaken by a project initiator with MPHRE (since November 1998, MHAHE) on the necessity of carrying out an EIA or a less stringent procedure like IEA (initial environmental assessment) and/or an Environment Management and Monitoring Programme. Decision concerning the required depth of EIA study is proposed to be made by the Environment Section of MHAHE based on the degree of significance of the anticipated impacts by the proposed project and is up to the jurisdiction of the MHAHE.

It is noted that the Environment Section of the MHAHE is yet to demonstrate its competence to undertake such an EIA screening procedure based on anticipated significance of the perceived environmental impact in a fair and equitable manner, since such a formal procedure is yet to be attempted. Hence what is required urgently is the approval of the proposed draft EIA guidelines with necessary modifications so that it could become a part of Law No. 4/93 and its enforcement by MHAHE. Any shortcomings of the proposed EIA procedure could best be identified and improved with its implementation on a trial and error basis.

3.5 Environmental Management

The environmental management measures practised in Maldives at present, principally in Male' Island, including that of environmental monitoring programmes undertaken and environmental impact assessment process being conducted are illustrated in this section. It is noted that there are seven (7) sea water quality monitoring stations around Thilafushi Island, the present solid waste dump site, spanning the entire reef of Thilafushi, Gulhifalhu and Bodugiri as illustrated under foregone section on Water and Sediment Quality.

3.5.1 Present Environmental Management and Monitoring Status

(1) Water Environmental Monitoring

Water quality monitoring is the most significant environmental monitoring programme carried out on a rather regular basis by the Public Health Laboratory (PHL) of the Ministry of Health. PHL inherited the task of water quality monitoring/analysis from the Maldives Water and Sanitation Authority (MWSA) since February, 1998. MWSA is the organisation, also under the Ministry of Health, that supplies piped drinking water for the entire capital, Male' Island. Desalinated sea water is the source of potable water for MWSA.

It is noted that PHL has 5 laboratory units of which water analytical section is just one of them. The other units conduct human health and disease related analytical work which account for most staff and activity of the overall laboratory.

The water quality monitoring/analytical work undertaken spans basically piped water supply, including the potable water supplied in Male' by the MWSA, groundwater (dug well) resources and coastal and sea (reef) waters. The water quality parameters mostly analyzed are the basic ones suited for unpolluted clean waters, such as turbidity, pH, TDS (total dissolved solids), chloride, hardness, alkalinity, including bacterial parameters of total and fecal coliform. Accordingly the current analytical practice of PHL, as far as the water quality analysis is concerned, is basically adequate to confirm purity of unpolluted water resources including public health safety of drinking water only.

Based on the analytical results of piped water supplied by MWSA in Male', the supplied water consistently meets the bacteriological standards with nil (0) total and fecal coliforms, the basic public health requirement. However, with respect to TDS and chloride levels, though it basically meets the WHO Criteria, it exceeds the criteria set up by MWSA itself, which is more stringent than the WHO Criteria. Concerning the groundwater quality of wells in Male', the chloride level mostly exceeds 1000 mg/l,

typically ranging from 1000 to 3000 mg/l, and hence the groundwater is saline and not suited for potable use (The recommended chloride limit for potable water by WHO Criteria is 250 mg/l).

It is noted that the lack of pollution level indicator parameter monitoring, including the basic parameters such as BOD (biochemical oxygen demand) or COD (chemical oxygen demand), makes the present analytical capability of PHL inadequate for the determination of pollution level of potentially polluted waters and wastewater, including solid waste landfill leachate of Thilafushi Island.

Accordingly, the water analytical section of PHL in its present form is just a water analytical laboratory and its technical facilities including human resource need to be improved so that it could become a comprehensive water and wastewater environmental analytical laboratory.

(2) Ambient Air Environmental Monitoring

There exists no significant ambient air quality monitoring in Maldives. No published air quality data is available. Still due to the lack of any significant industrial development, vehicular traffic and diesel electric power generators are identified as the significant air pollution sources of Male' Island. Nevertheless, small land area surrounded by relatively vast sea (ocean/sea lagoon) environment, typical to the entire country, and the resultant active exchange of air between land and sea helps in dispersion of air pollutants. Accordingly ambient air quality is considered as satisfactory, even in Male' Island with high vehicular traffic.

Still, monitoring of ambient air quality in Male' is recommended to be initiated by the relevant institution (MPHRE). The recommended air quality parameters of analysis are the conventional ones, namely, SPM (suspended particulate matter), HC (hydro-carbon), CO (carbon monoxide), NOx (nitrogen oxides) and SOx (sulfur oxides).

(3) Marine Environmental Monitoring

The marine environment and its resources, principally fishery is a very important economic resource, of Maldives encompass a vast sea area and hence require effective monitoring to ensure their sustainability including tourism. Coral life forms the basis to sustain the marine resources of the nation including tourism.

The marine environmental (ecological) monitoring is under the jurisdiction of the Ministry of Fisheries and Agriculture (MOFA) and MHAHE. In particular, the MOFA manages and monitors the living marine environmental resources. MOFA has a Marine Research Section (MRS), which basically conducts monitoring the overall status of coral life on reefs in the atolls of the country. However, MRS has limited facilities and capability, including human resources, to conduct comprehensive marine ecological

monitoring. In particular the capability to conduct sampling, identification and analysis of basic marine biota (phytoplankton, zooplankton and benthic organisms) accounting for primary production and consumption in marine waters, which is necessary for comprehensive assessment of the ecological status of marine environment, needs to be instituted in the MRS.

3.5.2 Present Environmental Impact Assessment (EIA) Status

Most of the recent EIA studies are conducted for new resort developments on uninhabited islands, since only uninhabited islands are earmarked for resort developments. It is understandable as resort development is a major project activity having significant environmental effects on a previously uninhabited island and also such new resort developments rank high in new project initiations in the country.

A significant exception on major new project initiation is the ongoing land (reef) reclamation in Hulhumale for residential development, on the same reef of the Hulhule Airport Island. An Initial Environmental Evaluation (IEE) report for this new land reclamation, prepared in 1996 by MPHRE itself, is also available. This reclamation project is ongoing, since it is considered as a national urgency due to the shortage of land area in Male' for further residential development, without conducting any detailed EIA study. However, the MCPW will undertake a detailed EIA for the subsequent phases of the project.

As far as the EIA studies for new resort developments are concerned the islands are earmarked by the government as per the 2-nd Tourism Master Plan. The 2-nd Tourism Master Plan was developed through a wide consultative process in which suitable uninhabited islands for resort development are selected based on socio-economic factors and other surveys results conforming to predefined criteria. Hence the developer is in no need to consider alternative sites (islands) for the location of the resort. It is noted that there is a lack of available baseline environmental data in and around these islands, since they are uninhabited and generally remote. Accordingly, the EIA report formulation requires considerable effort in defining the baseline environment with primary data collection. As such EIA report of a resort essentially becomes a baseline environment report, without any significant alternative investigation on the location of project facilities such as jetties, orientation of hotel rooms and other amenities so as to minimise potential adverse environmental effects and also to enhance any beneficial effects.

4 FACT FINDINGS OF CURRENT SWM

4.1 Saturated Capacity of Waste Removal Measure in the Capital

Waste collection and transport system is adopted only in the capital region. Collection is conducted under the initiative of Male' Municipality allowing private companies and hand cart operators service for specific clients. Collected wastes are all dumped at the transfer station in Male' and reloaded on dump trucks to transport to Thilafushi Island. Reloading and transport is undertaken by MCPW.

Collection service is spread in the whole Male' island, however, the volume of waste collected is mere a quarter of the total volume brought into the transfer station. The rest of total is brought directly by the waste generators themselves. Male' Municipality places garbage containers at eight locations in peripheral area for neighbors to throw their garbage into free of charge. Because the capacity of carriers called Micro-bin is insufficient, removal of full containers and replacement with empty ones take long hours, from 5:00 in the morning to 10:00 at night. During the interval of replacement, overflowing or scattering garbage and offensive odor happen, which is a cause of complaint of neighbors. It is not easy to keep Micro-bin well maintained because the spare parts are very expensive and hard to repair due to old age and specially designed structure.

Transfer station is another seed of complaint of neighbors by smell and dispersion of light component of garbage. On the occasion of flood, garbage is drifting out of the site. Dump trucks for haulage have no rear bed panel except one unit and no top cover so that they scatter garbage and diffuse smell on the way to west harbor then to Thilafushi. Reloading and transport are sometimes delayed by mechanical trouble of trucks and heavy equipment, that results in growth of waste pile at the transfer station. MCPW has a problem with vehicles and heavy equipment, particularly the latter are all of old age and shared the use with the other construction project. Waste management section of MCPW needs its own maintenance facility and staff to keep steady operation.

Present style of waste discharge at generation sources allows mixture of every kind of waste in every part of the country. Exceptional style of discharge is adopted in specific types of waste, namely sawdust, scrap iron and demolition waste. Those waste are brought directly into transfer station by generators or their subcontractors

Among three types of waste above, scrap iron and demolition waste have a troublesome nature for loading to lorries to Thilafushi because each piece of them are too heavy or bulky and irregular in shape for loading equipment to handle.

To solve the problem, a certain preliminary treatments are required to facilitate loading operation and reuse or packing for reuse. Garbage dump sites is usually accompanied

by a certain criteria of acceptance that describes the requirement of waste brought there. The requirements in most cases derive from technical reasons such as workability with equipment, stability in the ground and limited function of facility. Transfer station in Male' has a restriction by neighbors of the site not to give them such nuisances as dispersion of waste and dust, emission of bad smell and loud noise. Other items to be segregated at discharging source are identified in view of separate treatment and material recycling.

4.2 Unstable and Environmentally Adverse Final Disposal in Thilafushi

Final disposal in Thilafushi is still going on and the land area above sea level is expanding day by day. Land use plan for urbanized facilities is also implemented in parallel with landfill operation. Because of inadequate stability, the peripheral coral bank has been partially encroached by sea waves and the risks of garbage drifting and collapse of the developing lots are taking place simultaneously. This situation threatens not only environmentally sound disposal but stable use of the land, however, no definite actions for protection has been taken so far. There is an urgent need to improve the existing landfill site to rescue from collapse as an emergent measure to escape the crisis.

Another problem with Thilafushi is degradation of coral community on the surrounding reef edge and subsequent slope. They are badly damaged mainly by the sediment of silt falling from the plume generated at the long lasting dredging here and there in the island. Cohesive fine particle of seabed material tends to stick to projecting coral and suffocate it to death. Other material like plastic sheets, and sand bags are observed affecting coral in the similar way to silt. Those thin, flexible and broad materials might be the content of solid waste once dumped and drifted or blown out of the island. Dying coral symbolizes decaying of the land. Reduction of sand provision by the coral is a lethal risk to keep the island permanently. It is recommended to take necessary measures to prevent further killing of coral from now.

4.3 Uneven but Totally Low Sanitary Level of Final Disposal in Local Islands

Open air public facilities as well as waste disposal site are built commonly in the peripheral area of island which undergoes direct influences of sea waves more severely than the core area of the same island. The scarcity of land pushes low productive facilities into flood-prone area, however, final disposal sites of solid waste is particularly fragile facility that tends to cause the drift of waste when encroached in the edge. There needs a special attention to protect the area against erosion. Proposed technical measure for final disposal will be elaborated by taking this point into

consideration and given for capital region and local islands respectively. The target level should be set to secure no direct exposure of garbage to open sea and to hold the site permanently. This must be disseminated to all the local islands under the initiative of the government. Number of local islands is so large that it takes long time to up grade the sanitary level of final disposal site once through the country.

4.4 Parallel Structure of Implementing Bodies for SWM

There is no law in Maldives which deals with SWM comprehensively. Practice of SWM is therefore undertaken separately by various government authorities. Individual efforts are achieving a considerable effect, however, there still exists a room of reform to enlarge the effect by integrating those efforts dedicated by relevant authorities. Proposed solution of this matter will be initiated by the enactment of comprehensive SWM law which at least stipulates the following items as its part or derivative regulations.

- objectives of SWM
- category of solid waste by its nature and by generator
- main responsible body and concerning bodies
- duties of concerning bodies including citizens and tourists
- obligation of waste generators
- private sector involvement
- basis of fee charging and collection
- designation of hazardous waste with handling rule

4.5 Small Administrative Section of SWM and Large Foreign Worker

SWM in urbanized area has a demand of long hour operation at the place where wastes are collected from people of waste generator. The nature resembles the other pubic services like electricity, water supply and security service which are inevitably adopting a special working shift exceeding regular hours from 7:30 to 14:30 at offices. As a matter of fact, most of workers engaged in this special shift and other dirty job in SWM are immigrants from Bangladesh. Apart from the extraordinary situation a public service is dependent on foreign work force, it is apparent that the dirty work in SWM is recognized as a commodity which can be bought with money. Foreign workers are not a part of administrative organization but a tool procured by the administrative agencies and applied to execute their tasks.

Maldivian government has a lot of vacant position in its organization for long time and has little prospect the prescribed position is entirely filled because of small and sparsely distributed population. The size of government organization is strictly controlled and

expansion of a specific section must face a grave difficulty in relation to the other section and the other ministries. In this situation, the demand of enhancement of the section in charge of SWM may force the government to take the course to the privatization of possible parts of tasks assigned. Labor intensive tasks and equipment maintenance are suitably transferred to private sector because of its flexible system of personnel acquisition and labor management. The partial transfer of waste management tasks is expected to provide the government with an advantage which enables the officer in charge to concentrate on supervising the activities in his hand. The officer in charge acquires the scope for consideration on better management and future vision.

On the other hand, capacity building of responsible bodies and personnel is a key factor to make the SWM system reliable and sustainable. It is entirely dependent on the capability of implementing bodies if the SWM system works well. Sufficient number and quality of personnel in due position is quite vital for Maldivian government with sparsely assigned organization. This is to be pursued through training and recruiting from internal and external sources in accordance with the assigned tasks to each position of personnel.

4.6 Undeveloped Recognition on Cost for Cleanliness

Maldivian people often complains of disagreeable effect of SWM near them, however, they rarely mention what they can do for the solution. The most negative effect of solid waste is generated by food waste every people discharge every day. Everybody who discharges food waste or other waste is responsible for the consequences of their waste. This point are mostly excluded out of their mind. When they are protesting government about the problem of waste, they do not consider the request needs money and they are paying no money for that or very few.

SWM is a kind of public service of which beneficiaries are clearly identified. This kind of service has a possibility that the service can be provided at the cost of beneficiaries as well as electricity and tap water. In analogy to the other public nuisances like air pollution and water pollution, the beneficiary of SWM is regarded as "polluter" of environment because they would pollute their surroundings by discharging solid waste there unless government provide the service for waste disposal. Then the concept that the cost for cleaning should be borne by waste generators is called as "polluter's pay principle".

If the government, as supplier of service, can charge a fee on people who enjoy the service depends on the affordability and willingness to pay of the people in principle. Even in the case a general tax is imposed on people, this principle is taken into consideration for additional charging on SWM besides tax. In Maldives, general

taxation is not imposed on people and the service for waste disposal is exclusively provided to the capital region. The government is suffering from chronic shortage of fund to achieve its priority projects. This situation indicates the necessity of charging for SWM on residents of capital region. To force an extra expense to the residents may compensate the regional disparity in living standard and somewhat contribute to retardation of migration to capital region.

4.7 Uneven Cleanliness between Street and Port

Solid waste management is originally one of the communal tasks to be undertaken equally by the members of local community. The prototype of management is still alive in small islands in this country where all the residents are involved in public space cleaning and dump site maintenance. They seldom receive the assistance in waste management from outside community and conduct it at their own cost and voluntary works. They are well aware of that they are responsible for maintaining the environment clean and they must contribute to their community through participation in cleaning activity.

The rule that frontage of residence and private lot is kept clean and swept by private persons is steadily conducted in every part of the country. Special public space such as park and harbor in Male' is swept by government authorities as their routine. Cleaning of public space on the ground is carried out adequately, but it is inadequate in the sea. Inside harbor in Male' is somehow swept every day by MCPW crew and once a month by NSS crew on the sea bed. These efforts have not satisfactorily achieved the port area always clean, in other word the pace of sweeping can not catch up with the frequent littering of garbage by people. One of the fundamental solutions to keep the sea clean is to prevent people from throwing waste in the sea.

4.8 Conflict between Final Disposal and Land Creation

Final disposal in this country usually ends when the top of garbage layer comes to a ground level, one meter above sea at most. It is quite difficult for them to imagine the garbage should be piled up higher than stature of people even though it is economically feasible. Landfill is commonly considered as a measure of land creation as was realized in Male' several years ago. In landfill operation, they are hurrying expansion of working face as much as possible. They have little scope to care for protection of the land and ecology. They could neither wait the time of completion of landfill operation in Thilafushi nor the time when the ground has settled enough to bear the buildings.

As a matter of fact, land creation may be the main interest of the government. Hence the improvement of existing landfill site can hardly be the target of national fund investment because no more land is expected as output of the project. Much less possible is to introduce a control measure to the site that may invade into the land acquired already. There will happen a severe conflict between land creation and environmental protection in design phase of improvement measures.

5 NATIONAL POLICY ON SWM

5.1 Scope of National Policy

It is widely recognized that environmental issues are crucial subjects in this country that depends greatly on the natural resources. The government of the Maldives duly places emphases on environmental conservation in fundamental policy and inscribes various activities required to keep the sound environment in every turn of the national development plan. This policy is a consequence of the long lasting economic growth that has been likely to affect the quality of natural environment and health condition.

As the results of the efforts of competent government authorities materializing the output of a series of studies elaborated under the scheme of international cooperation, solid waste in capital island Male' has been managed or disposed of properly, in general. However, the rapid growth of economic activities concentrated in the capital is getting the capacity of facilities for solid waste management exhausted very soon. The purpose of this study is to propose a comprehensive plan of solid waste management in line with above mentioned national policy.

5.1.1 Objectives of the Policy

The objectives of solid waste management are determined as a part of overall environmental policy to be achieved specially in this field of solid waste management. The efforts intending to clean the consequences of human activity is exerted with the following effect:

a. Healthy and Comfortable Life
b. Sound Natural Environment
c. Aesthetic Value of Domain

These three items are, at the same time, considered as the objectives of the policy on solid waste management.

(1) Healthy and Comfortable Life

Though the solid waste is initially a necessary thing itself or to keep the other commodities of use clean, safe and fresh, it becomes of no use once the things of main interest are consumed and discharged out of household or wherever the things are delivered. To discharge waste is to keep the inside of the house clean and to avoid any adverse consequences against health and comfort. The storage of solid waste particularly perishable food waste threatens the health condition inside. So does it outside the houses.

Solid waste management is conducted primarily to remove the waste from both private space and public space, then to dispose it properly. Quick removal and proper disposal prevents breeding of vectors and germs and contributes much to healthy life of citizens and comfortable life as well.

(2) Sound Natural Environment

Maldives stands on low lying coral islands which has been created by marine life of coral and the activity of coral is still providing material of land continuously. The country sustains its domain at the present position and size on a subtle balance of biological and marine reaction to it. That means the policy on SWM, as well as any other field of policy, should also aim at conservation of the natural environment as much as possible.

This is quite a vital objectives of the SWM because the conventional disposal of solid waste in Maldives is commonly executed on the beach where every kind of waste is exposed to the sea directly. The policy is directed to set the course of SWM toward maintaining sound natural environment by overcoming difficulties commonly experienced in the country.

(3) Aesthetic Value of Domain

The aesthetic value of domain is the economic basis of existence of Maldives as the sound natural environment is the physical basis of existence. More than 300, 000 tourists are attracted to this country in a year to enjoy its unique coral originated island life. Tourism has grown up to the largest industry in respect of foreign currency income and is expected to support this country from now on.

To keep the present status of tourism industry, it is quite essential to maintain the aesthetic value of domain, not only resort spots but other areas tourists are possibly visiting during their stay in Maldives. Even if the resort spots are kept clean, negative image given on the harbor, sea route, inhabited islands like Male' and vicinity of resort islands and protected marine areas may affect their preference to Maldives. SWM is considered to have a responsibility to secure the cleanliness of the area in question, therefore the aesthetic value of domain should be an objective of the policy on SWM.

5.1.2 Strategy for Achievement of the Objectives

As the basic frame of policy execution, a strategy is proposed hereunder. Proposed components are (1) Dual system of SWM for capital region and local islands and (2) Centripetal administration of SWM by the government. These two components are originated from geographical singularity of this country and considerable achievement of SWM by individual implementing agencies. This means the strategy is proposing a

progress of a step ahead, hence it will be able to provide a prospective frame on which a series of policies and practices work effectively.

(1) Dual System of SWM for Capital Region and Local Islands

Maldives has about 200 inhabited islands besides 73 resort islands. The singular nature of inhabitation of this country is high population density and scattered distribution of population. Overall population density is 2,000 on average and maximum 50,000 of Kadholhudhoo in Raa Atoll. Most of the communities in individual islands are small: only four islands exceed 4,000 in the year 1994 and 162 islands have less population than 1,000.

Each island is so small and isolated from each other that it is difficult to cope with solid waste in larger scale with common facilities. Therefore the basic way of SWM is forced to adopt an entire cycle of treatment in individual islands. On the other hand, some specific areas like Male' and its vicinity have an advantage to adopt the collective and larger scale of SWM system due to a huge amount of waste in the limited range which allows a daily access by dhoni. Recognition on what should be preserved as it is and what be innovated varies by area of the country. Male' and its vicinity has a comparably advanced achievement in SWM and the fundamental direction for future is almost fixed. To the contrary, SWM in the other area stays mostly in primitive level which utilizes water front as disposal site without due consideration on the consequences that may happen in the long run.

From technical and economic points of view, it is less advantageous to adopt unified system in both Male' and its vicinity and other local islands. In most local islands a simplified system is considered more realistic than in Male' and its vicinity due to the size of community and isolated location from tourist's spots and their sea routes. Thus the dual system of SWM is recommended to apply to respective areas in the country according to the waste volume and spatial extent of respective areas where a single system be applied.

(2) Systematic Cooperation of Implementing Bodies for SWM

Present SWM system is functioning as the sum of efforts of implementing bodies which are sharing the tasks by type of solid waste as shown below:

Table 5-1 Implementing Bodies of SWM by Type of Waste

Category of Island	Type of Waste	Capital Region	Local Islands
Inhabited island	general waste	Municipality, MCPW	M. Atolls Admn.
	industrial waste	MCPW	M. Atolls Admn.
	public space waste	Municipality, MCPW, NSS	M. Atolls Admn.
	hospital waste	M. Health, MCPW	M. Health
Resort Island	general waste	M. Tourism, MCPW	M. Tourism

Every type of waste is more or less handled by two or more agencies in capital region at present and by single agency in local islands. As the volume of waste increases, the treatment requires the involvement of specific functions of each agency. The present assignment has been formed gradually in response to the growth of demand following the rapid expansion of economic scale in capital region. Further expansion of economic scale will impose a heavier burden on this sector related to SWM. On the other hand there is an apparent need to upgrade the level of SWM in local islands. These trends urge a reform of administrative structure for SWM in order to comply with larger tasks than ever.

The first step of reform of administrative structure is considered to introduce an centripetal order to the inter-ministerial cooperation and to upheave the presence of SWM to the level suitable for its role. This is pursued with the efforts to establish a special law for SWM, which prescribes the core authority, roles and required capability of relevant authorities and that like. Under the special law system, SWM has a firm base for all the concerning bodies to participate in preservation of environment clean and sound jointly and severally. National policy on SWM is prepared and adjusted at the highest level of the government decision. The role of each implementing body is duly appreciated and given appropriate resources of budget and personnel in accordance with the assignment defined as inseparable part of national policy.

The role of the core administrative body under the special law system is to prepare the national policy on SWM and execution of it in coordination with the other implementing agencies. In the process of policy making, all the necessary measures and the tasks of concerning bodies are elaborated so as to maximize the effect within the resources available. Local administrative bodies are duly given the instruction and

resources to plan and execute SWM at a designated level in their territories. The wider involvement of concerning bodies is also the matter of interest of the special law system. Those policy on public participation, special treatment of hazardous waste, charging cost to beneficiaries, waste reduction, private sector involvement and other necessary means are to be given the basis in the system.

5.1.3 Basic Policy on SWM

Expected contribution of SWM is so vital for existence of this country and people that a higher priority in national policy should be given to this field. Though the necessity of environmental protection has been declared in national development plan or action plan, no definite plan for SWM has ever followed in the nationwide policy. Maldives is destined to be more dependent on clean environment than any other countries. Before the steep economic growth emerged, people in Maldives managed to exist together with vulnerable natural environment by modest life style. They knew excessive exploitation of natural resources would not benefit them in the long run.

Nowadays the life style of people has been greatly changed into that of more consumption than ever. This means the risk of degrading natural resources has grown up to a critical level. One of the most conspicuous phenomena due to the change of life style must be the volume of solid waste generated every day. Consequently due consideration needs to be made in accordance with the activated present economic level and also planned future level. A proper SWM system must be one of the contemporary knowledge of survival for this country.

Basic policy is set up to spread the knowledge to the public and organize them effectively. The contents of basic policy are deduced from the fact findings which are indicating the necessity of advanced concept of management. Though some parts of proposed policy already adopted by implementing agencies individually or jointly, the practice seems still spontaneous or intermittent. The basic policy proposed hereunder is suggested to apply systematically and continuously.

(1) Advancement of Bottom Level of SWM in Local Islands
(2) Promotion of Polluter's Pay Principle
(3) Promotion of Public Awareness and Participation
(4) Promotion of Private Sector Involvement
(5) Capacity Building of Implementing Bodies

5.2 Definition of Solid Waste

The following waste categories are as summarized in Table 5-2 below.

- Municipal Solid Waste

Municipal waste is defined as solid waste that may be collected, disposed of and managed by ordinary methods, which belongs to the responsibility of the Male' Municipality and island offices. The types of municipal waste are as enumerated below.

Residential waste
Commercial waste of small amount
Institutional waste from schools, offices, etc.
Waste from public space cleaning: parks, harbours, etc.
Market waste from fish market and fruits market
Hospital waste that does not require special treatment
Other wastes accepted by municipality

- Non-Municipal Solid Waste

Non-municipal waste, i.e., designated waste is defined as those of which treatment does not belong to the responsibility of Male' Municipality and island offices but to the responsibility of waste generators.

Table 5-2 . Waste Category and Management Responsibility

Category of Waste	Management Responsibility	Remarks
1 Resort island's waste 2 Non-hazardous industrial waste and commercial waste of large amount 3 Construction and demolition waste 4 Discarded ships and vehicles 5 Hazardous waste including infectious hospital waste	Waste generators (Male' Municipality and Island Offices should monitor generators' management of non-municipal waste until they establish a proper management system for these waste.)	Ministry of Construction and Public Works (MCPW) accepts waste for item1, 2, 3 and 4 at its disposal site on full cost recovery basis. The central government should establish hazardous waste management (treatment) facilities for item 5.