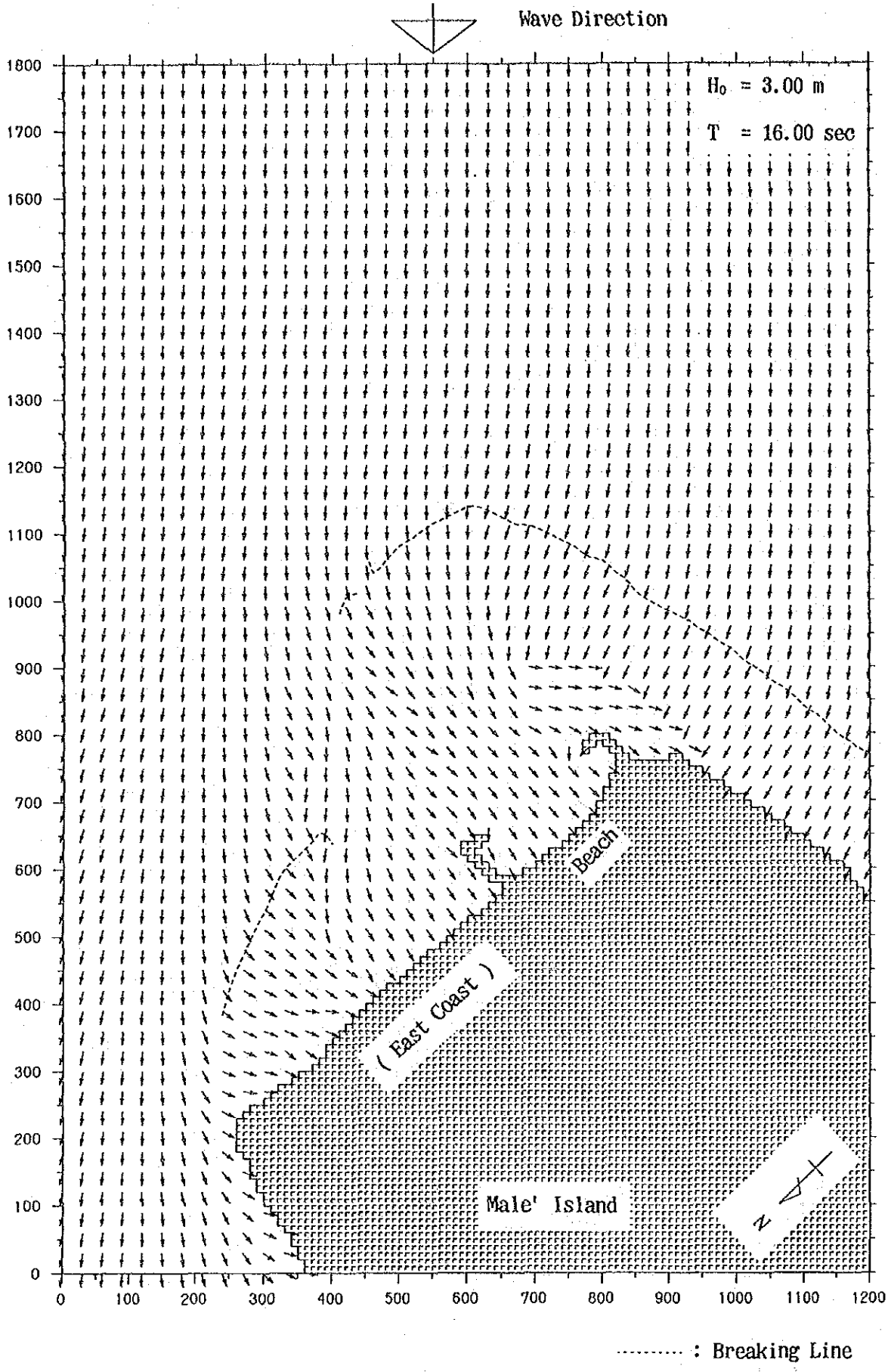


Figure 1.15 Wave Rays (East Coast : Plan-2)

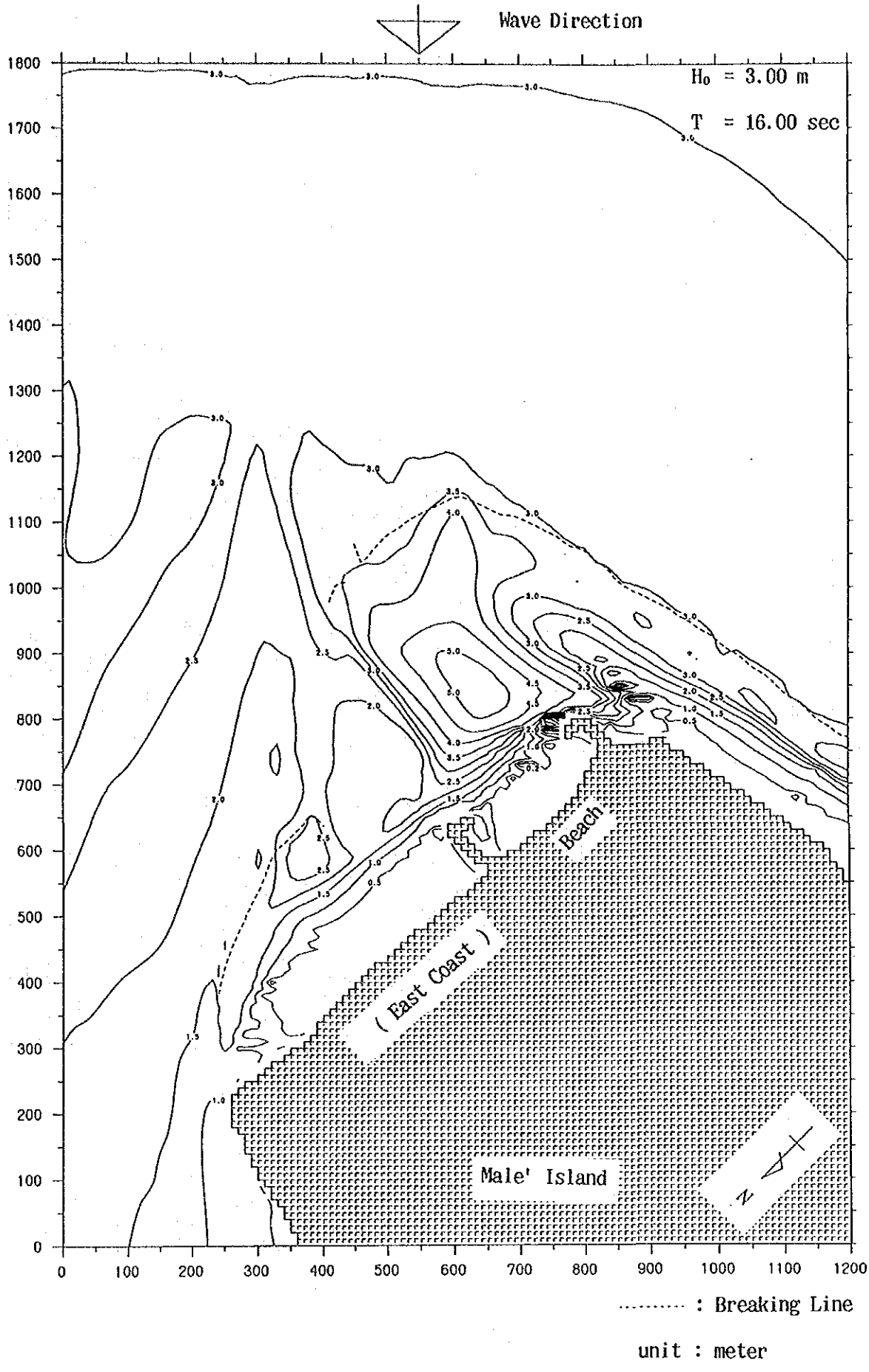


Figure 1.16 Wave Height Distribution (East Coast : Plan-2)

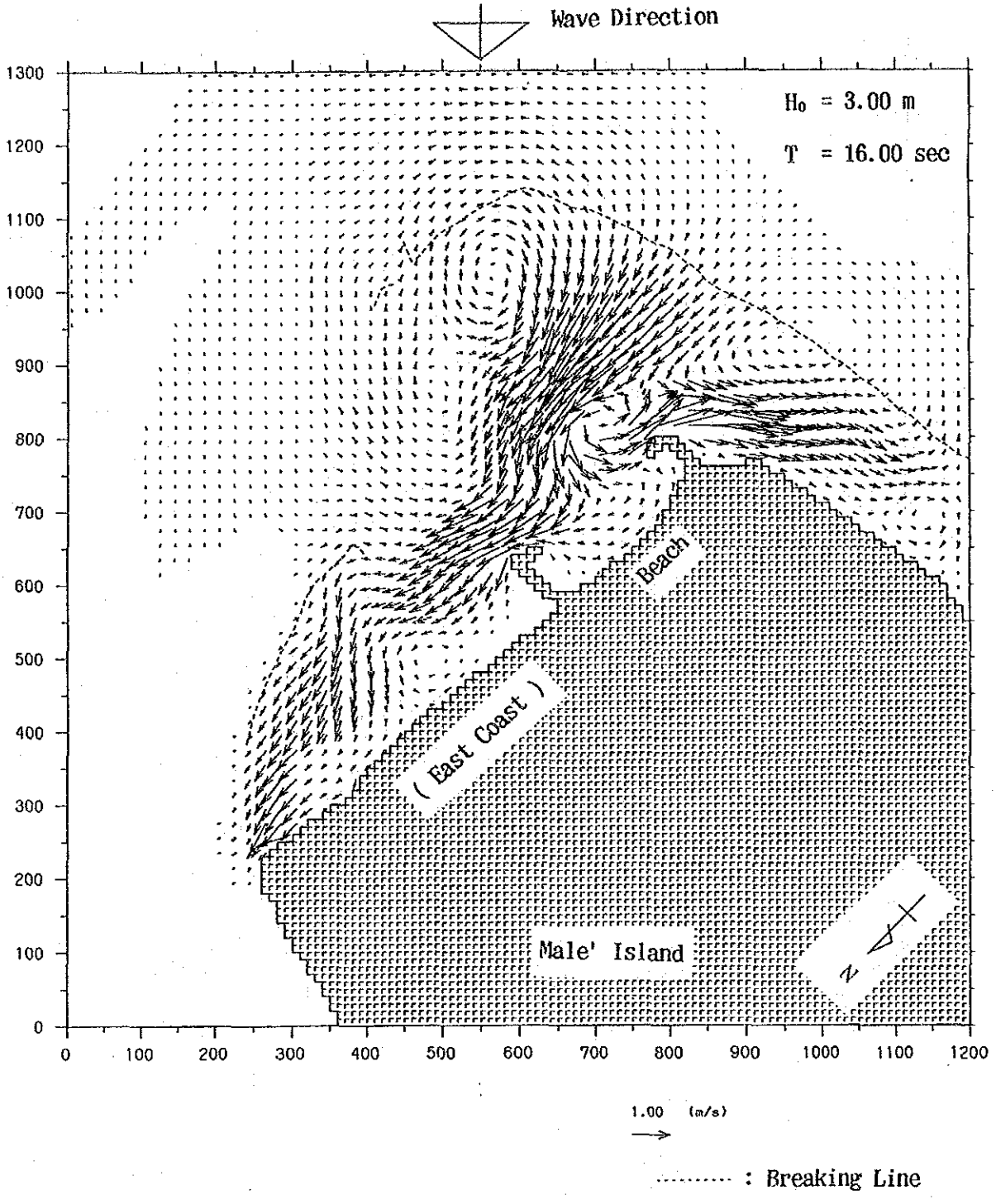


Figure 1.17 Nearshore Current Distribution (East Coast : Plan-2)

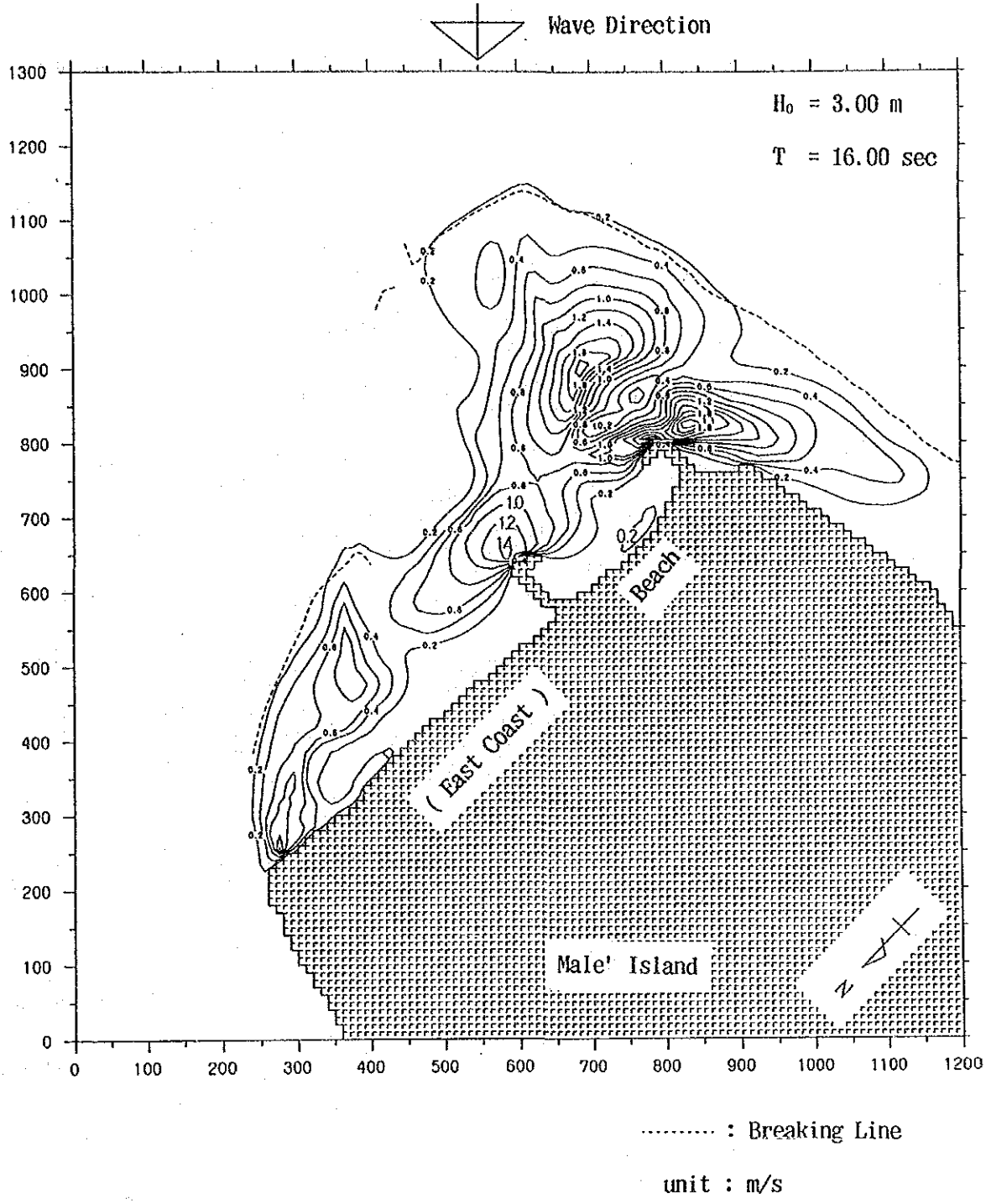
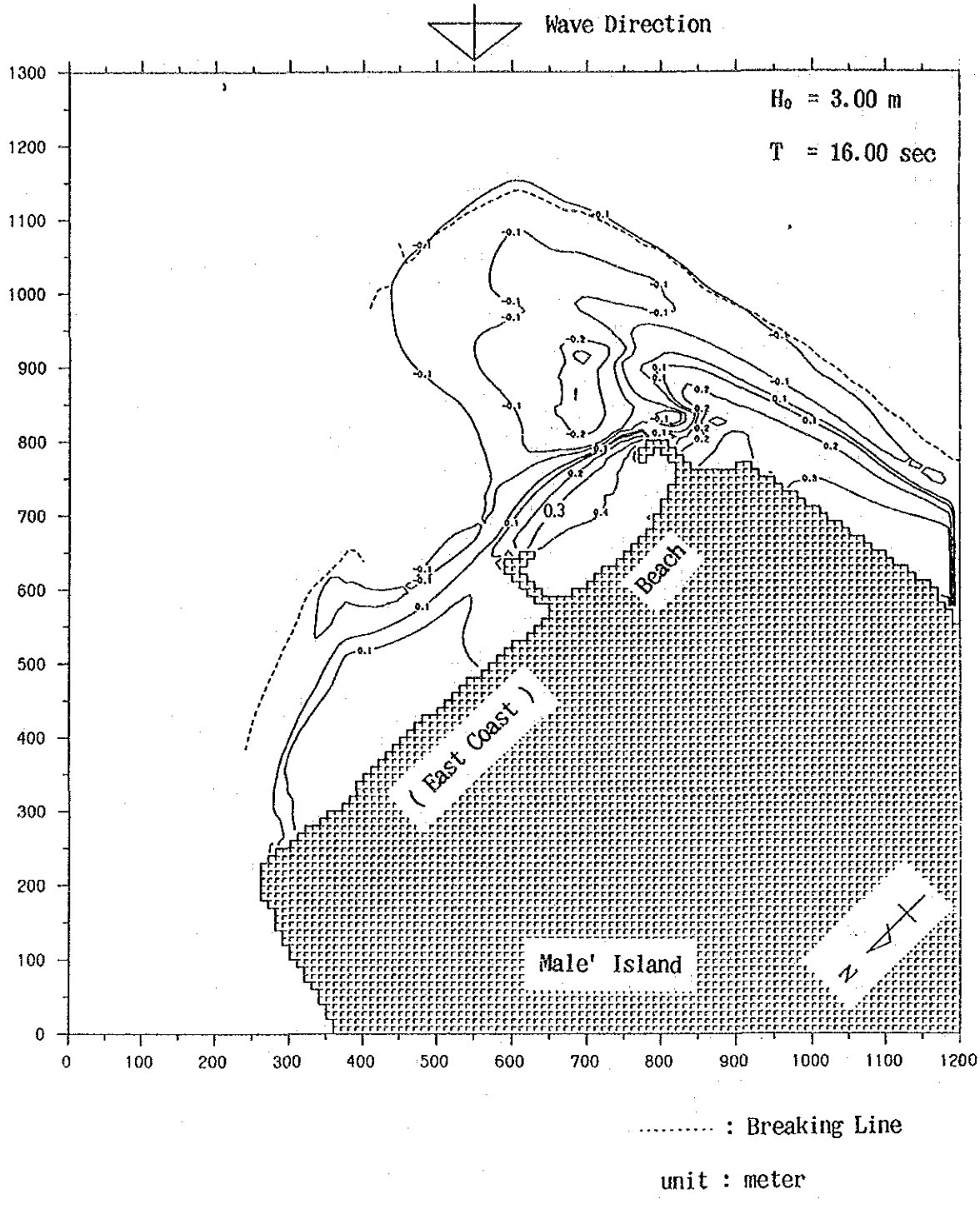


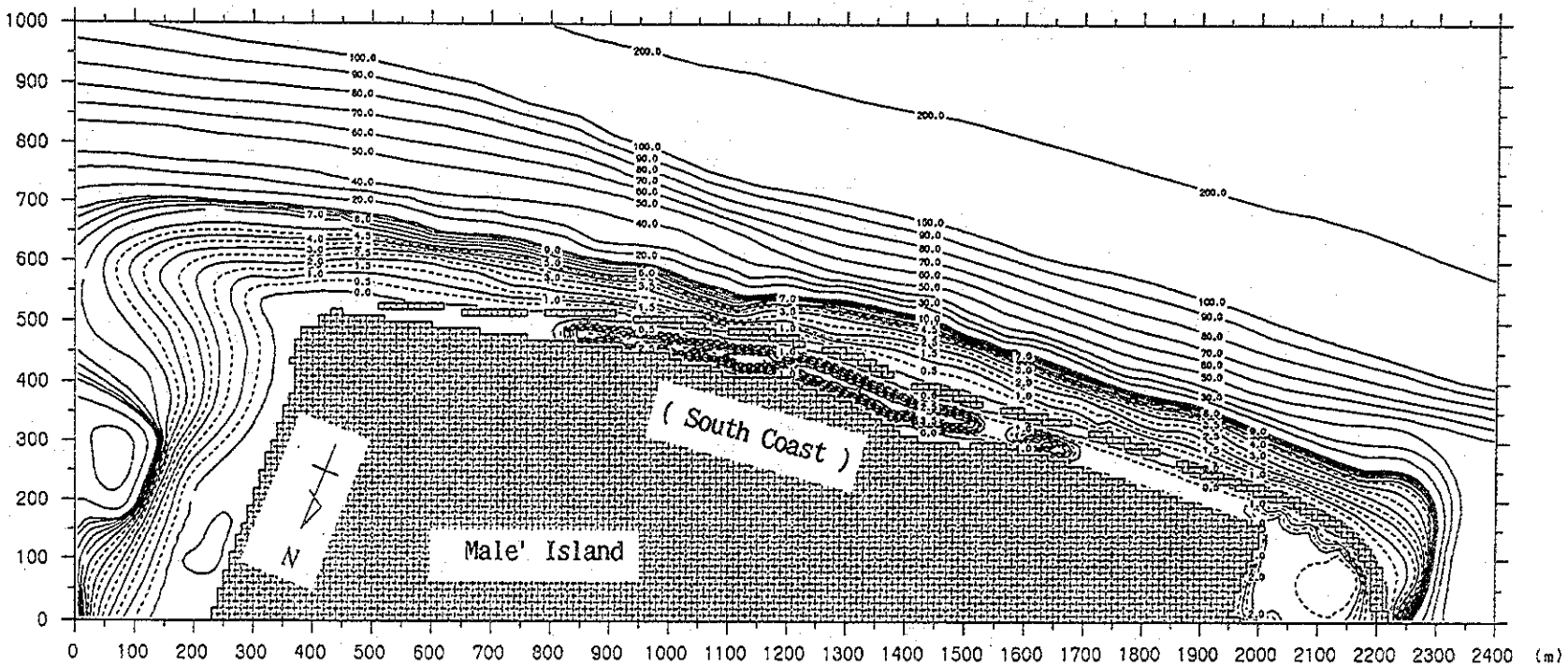
Figure 1.18 Current Velocity Distribution (East Coast : Plan-2)



..... : Breaking Line

unit : meter

Figure 1.19 Distribution of Mean Sea Level (East Coast : Plan-2)



unit : meter

Figure 2.1 Nearshore Topography (South Coast)

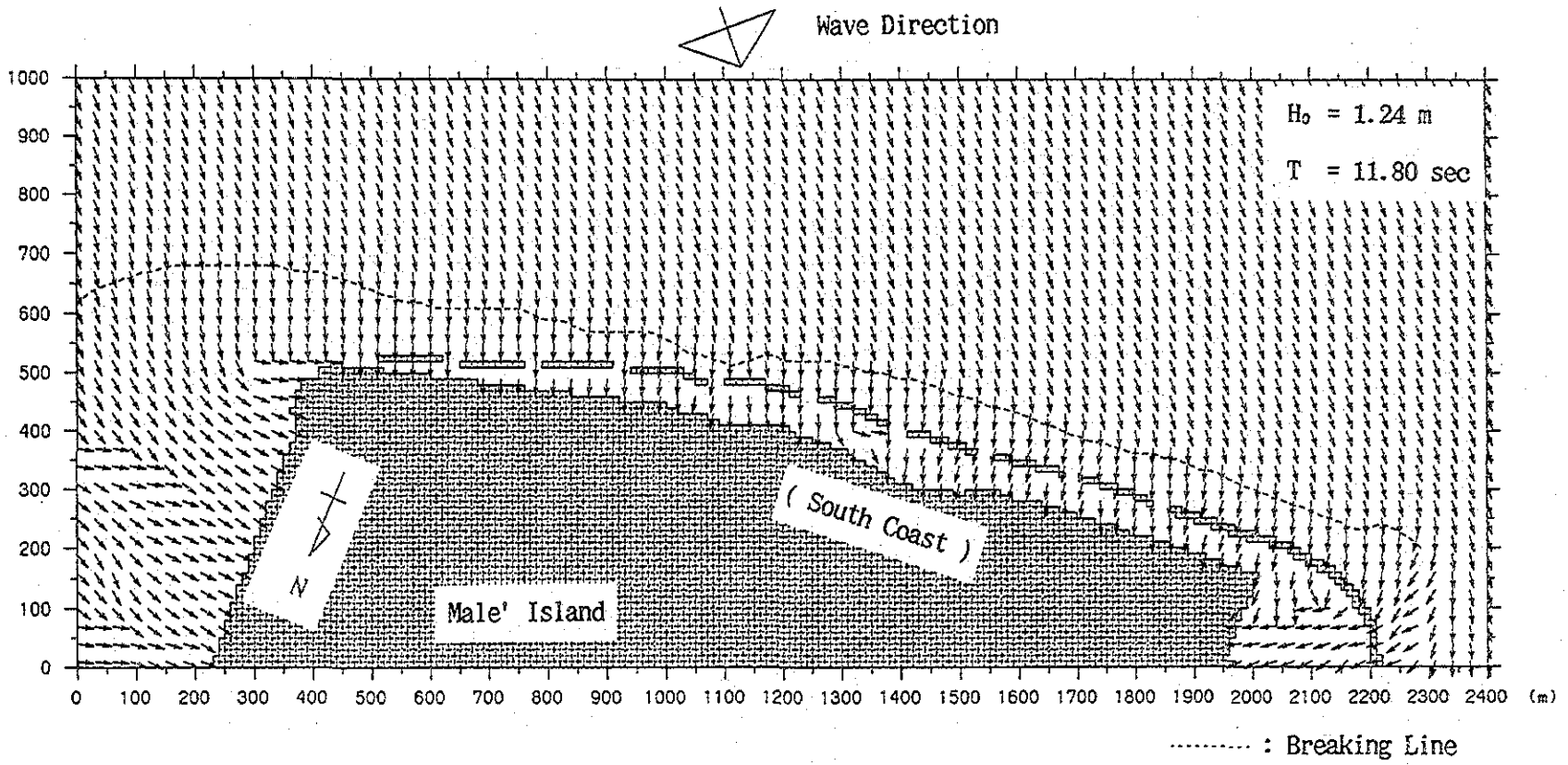


Figure 2.2 Wave Rays (South Coast : Verification)

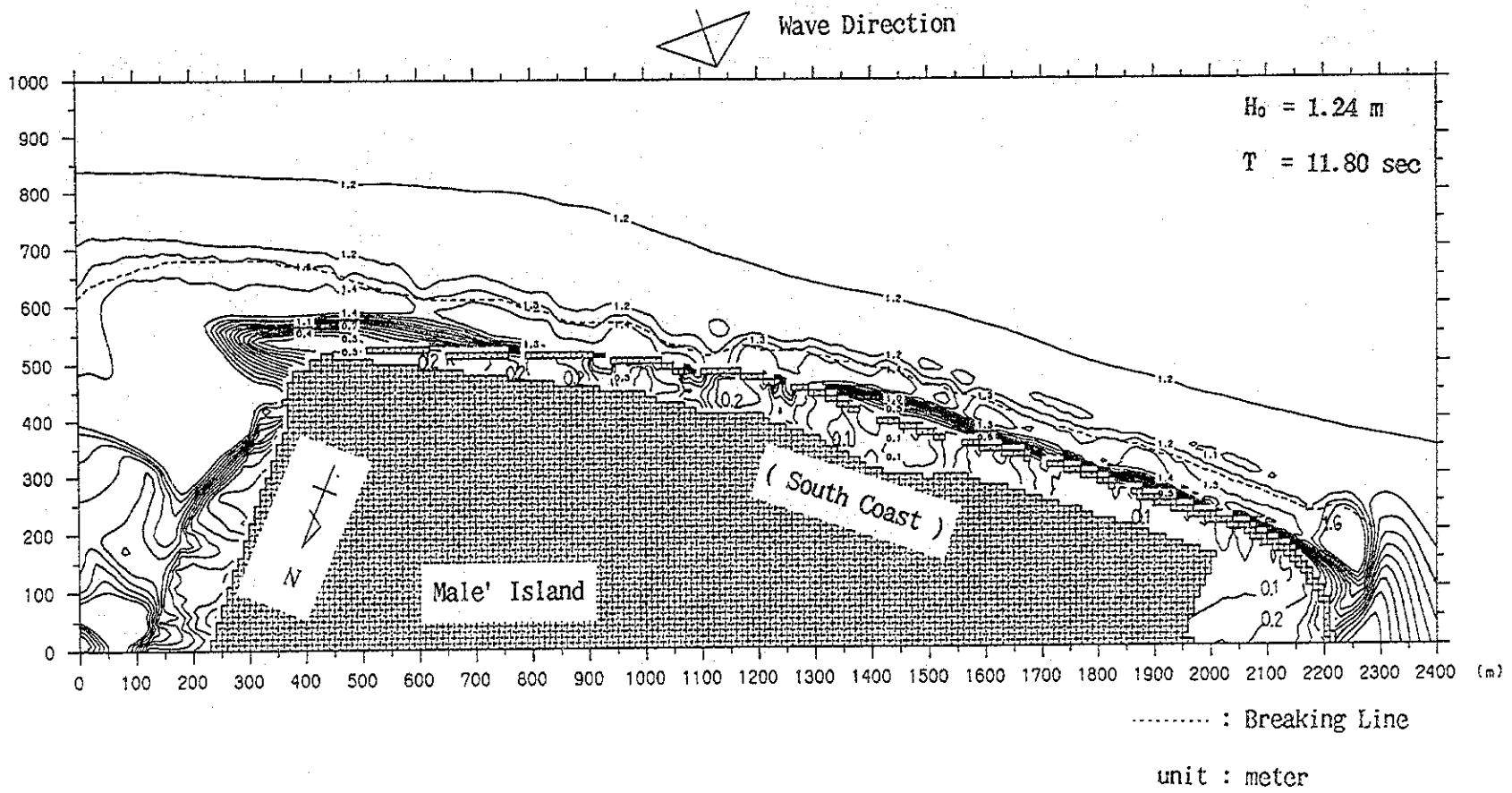


Figure 2.3 Wave Height Distribution (South Coast : Verification)

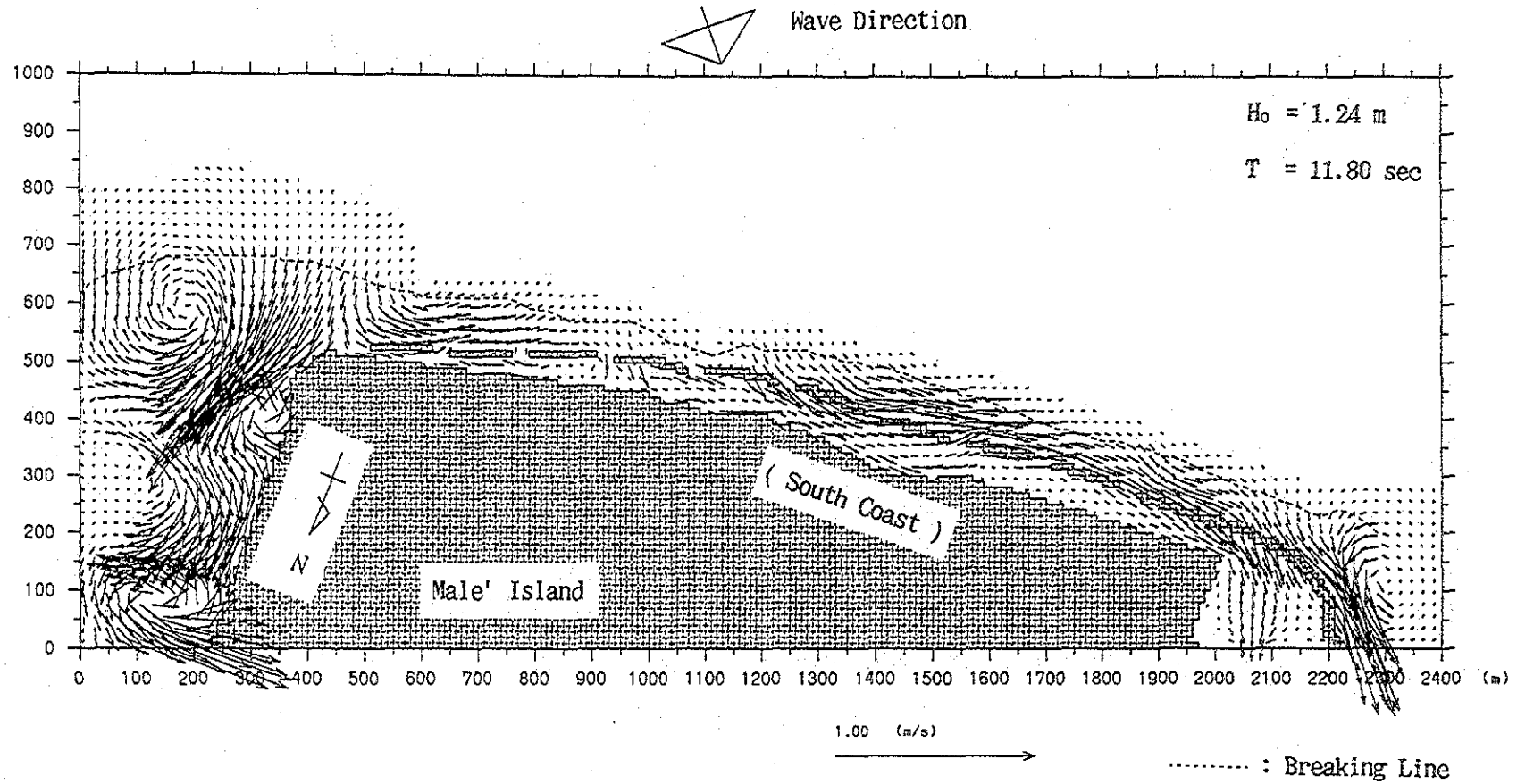


Figure 2.4 Nearshore Current Distribution (South Coast : Verification)

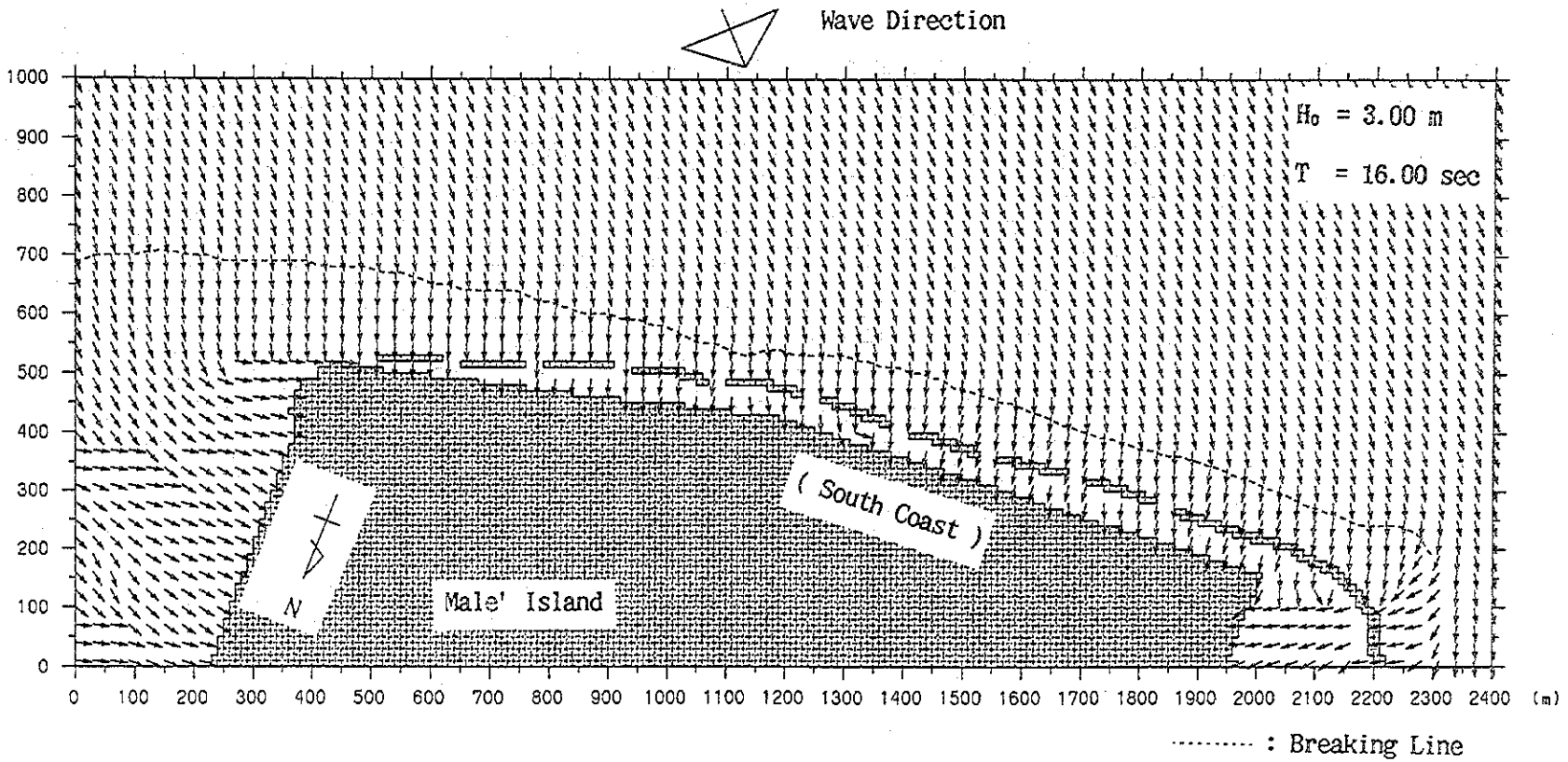


Figure 2.5 Wave Rays (South Coast : Prediction)

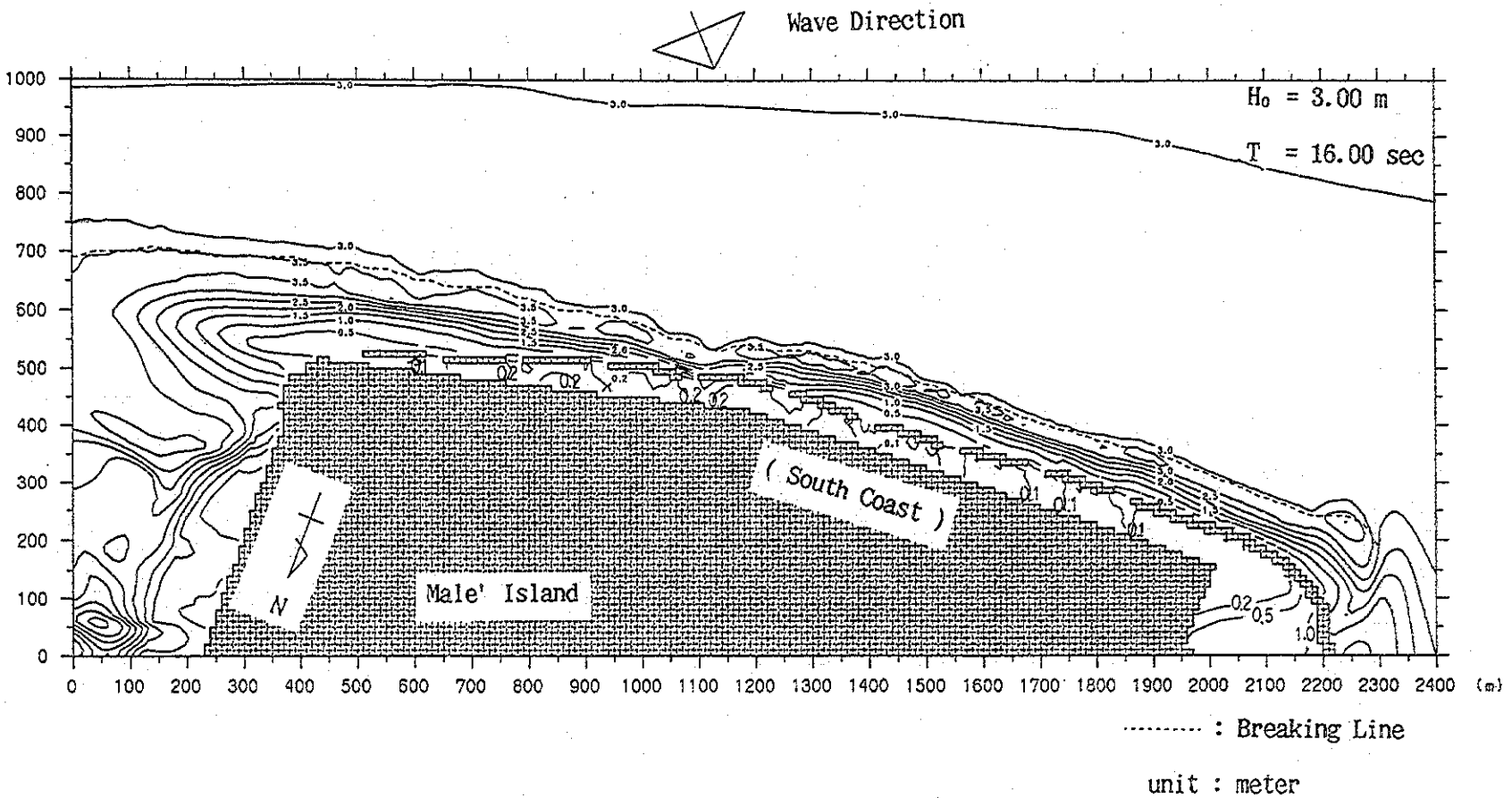


Figure 2.6 Wave Height Distribution (South Coast : Prediction)

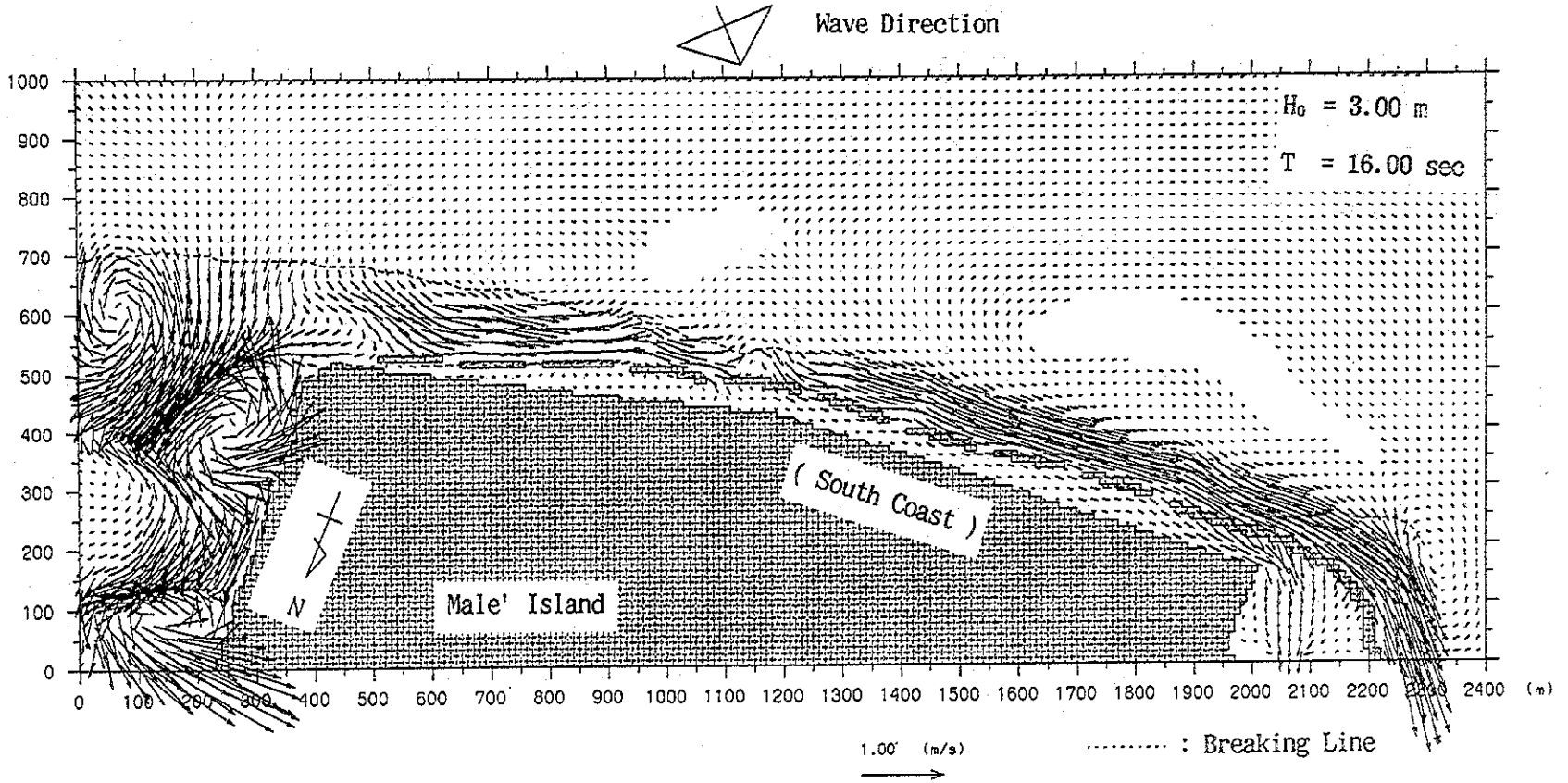


Figure 2.7 Nearshore Current Distribution (South Coast : Prediction)

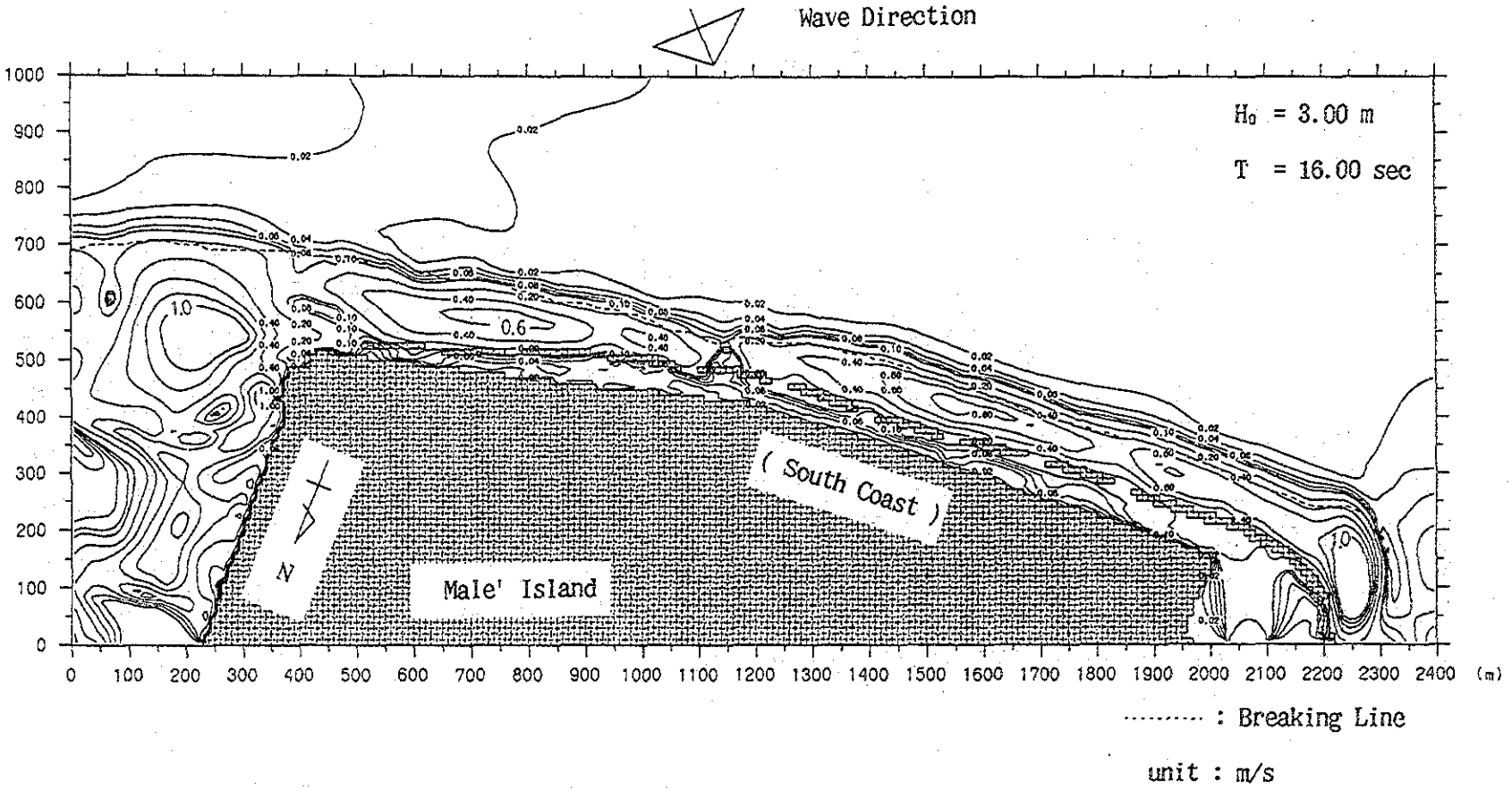


Figure 2.8 Current Velocity Distribution (South Coast : Prediction)

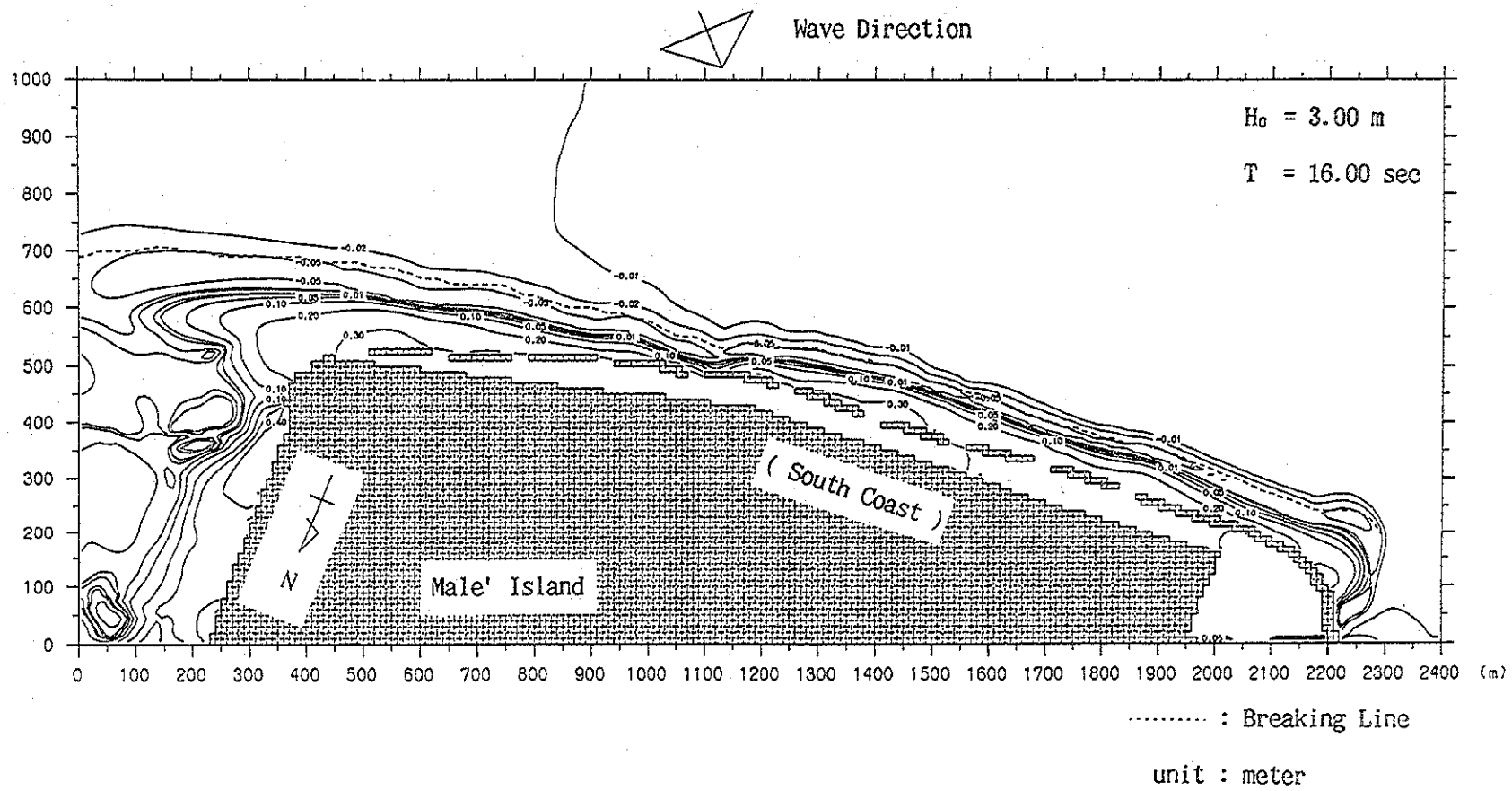


Figure 2.9 Distribution of Mean Sea Level (South Coast : Prediction)

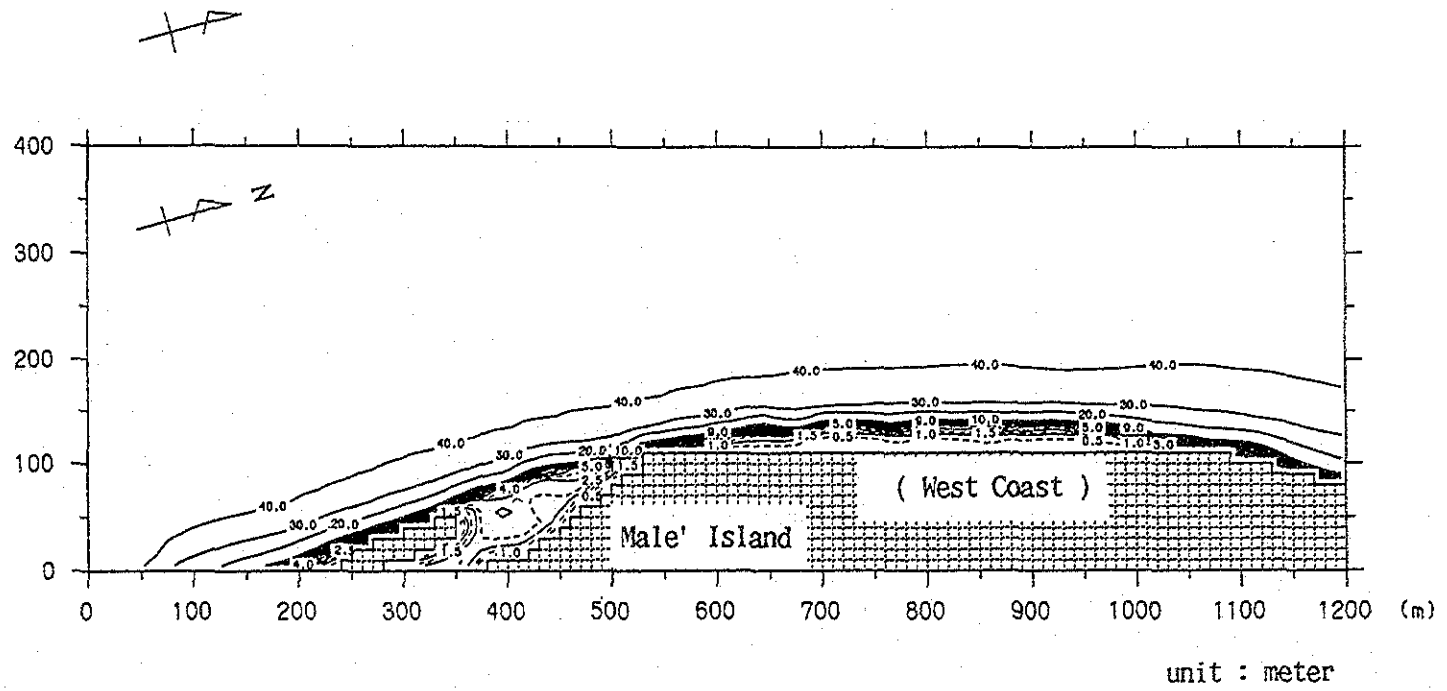


Figure 3.1 Nearshore Topography (West Coast)

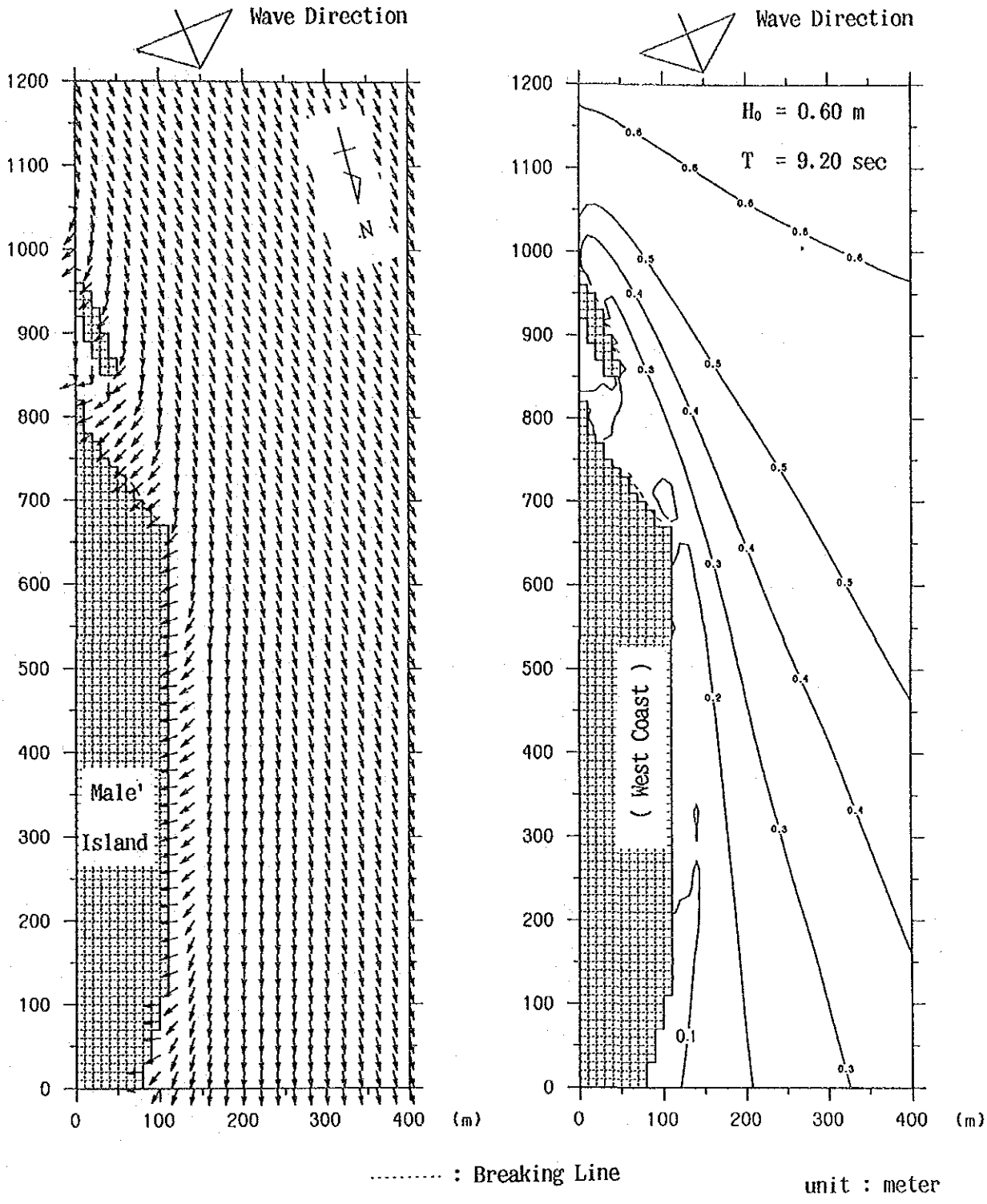
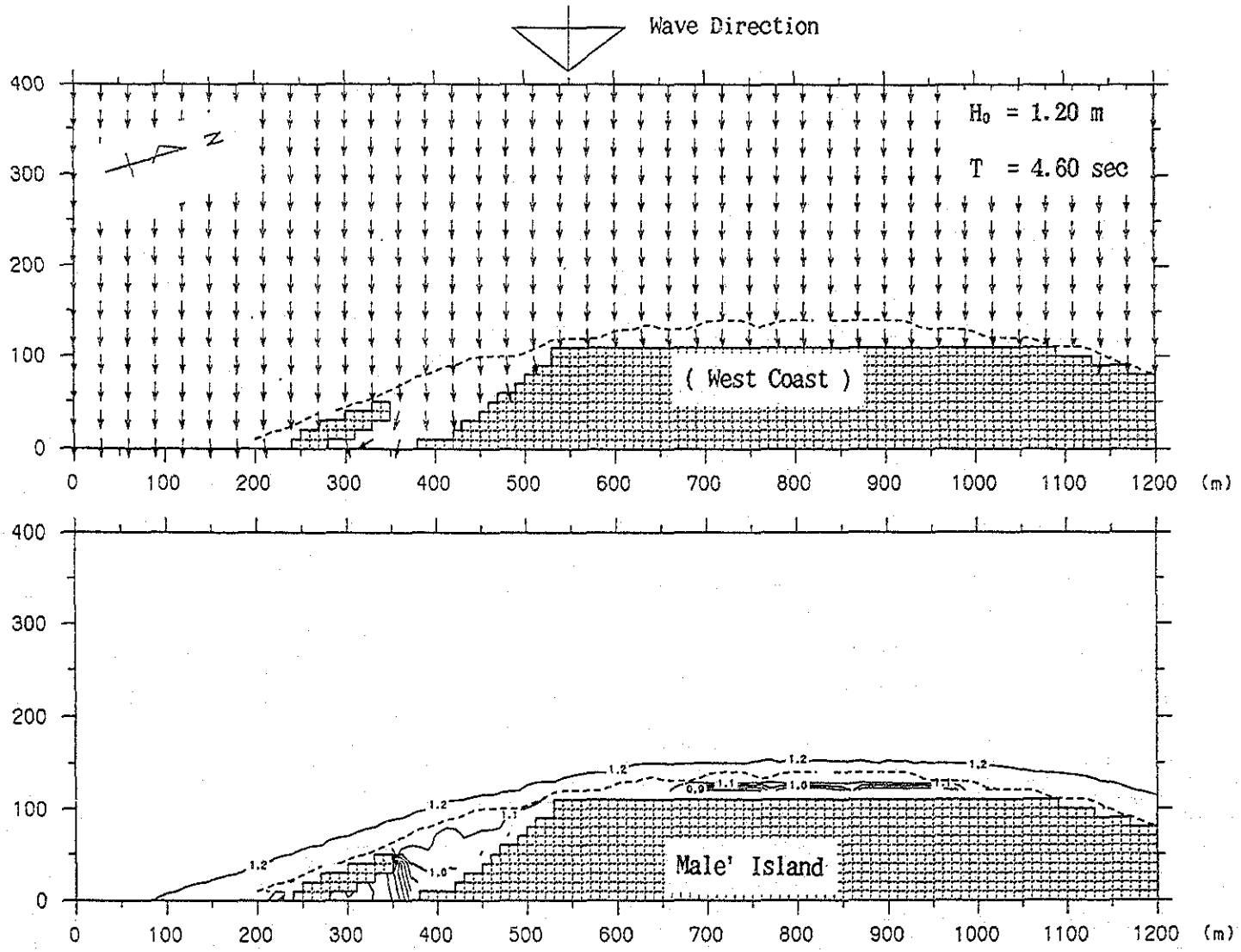


Figure 3.2 Wave Rays and Wave Height (West Coast : Verification)



..... : Breaking Line

Figure 3.3 Wave Rays and Wave Height (West Coast : Prediction)

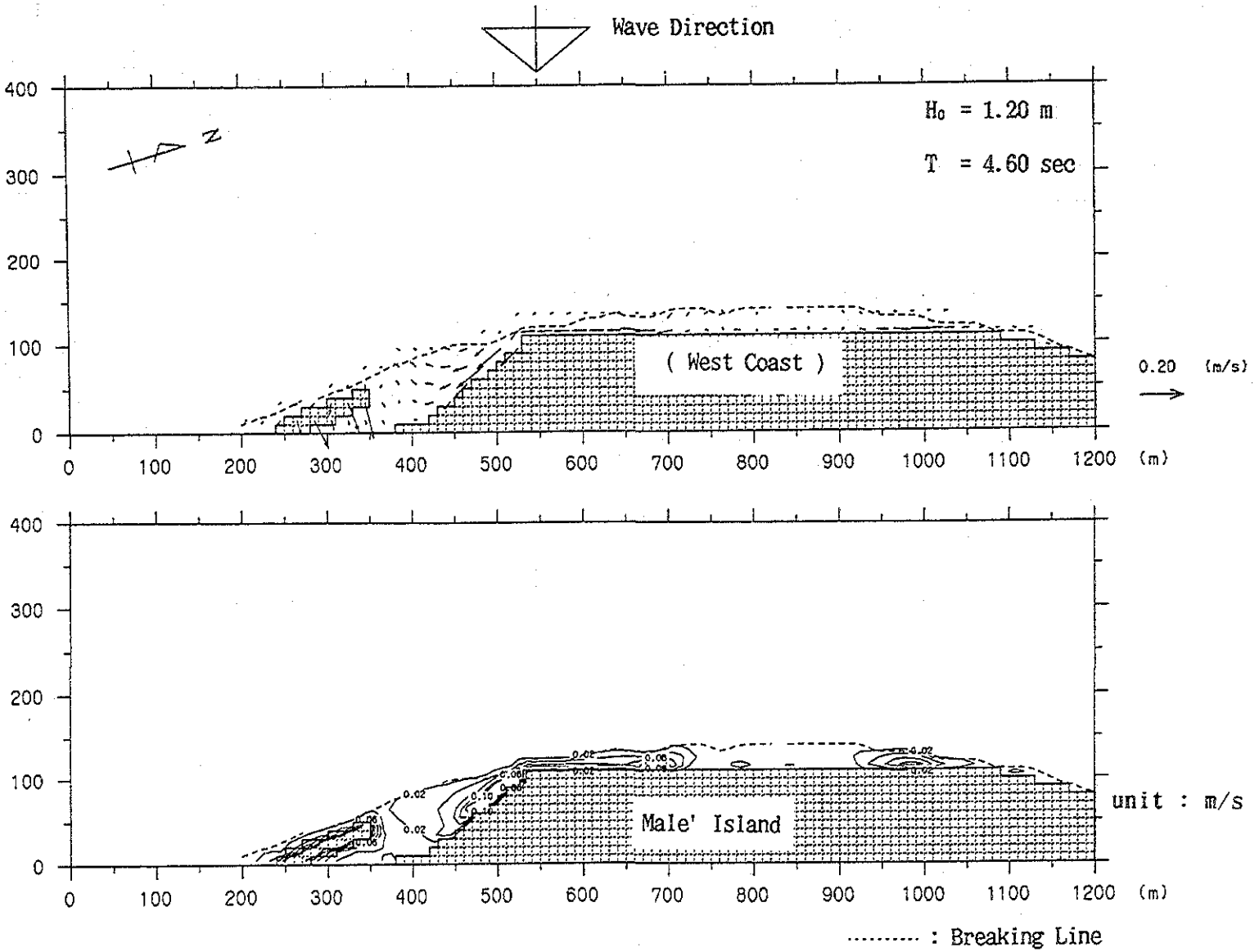


Figure 3.4 Nearshore Current and Velocity (West Coast : Prediction)

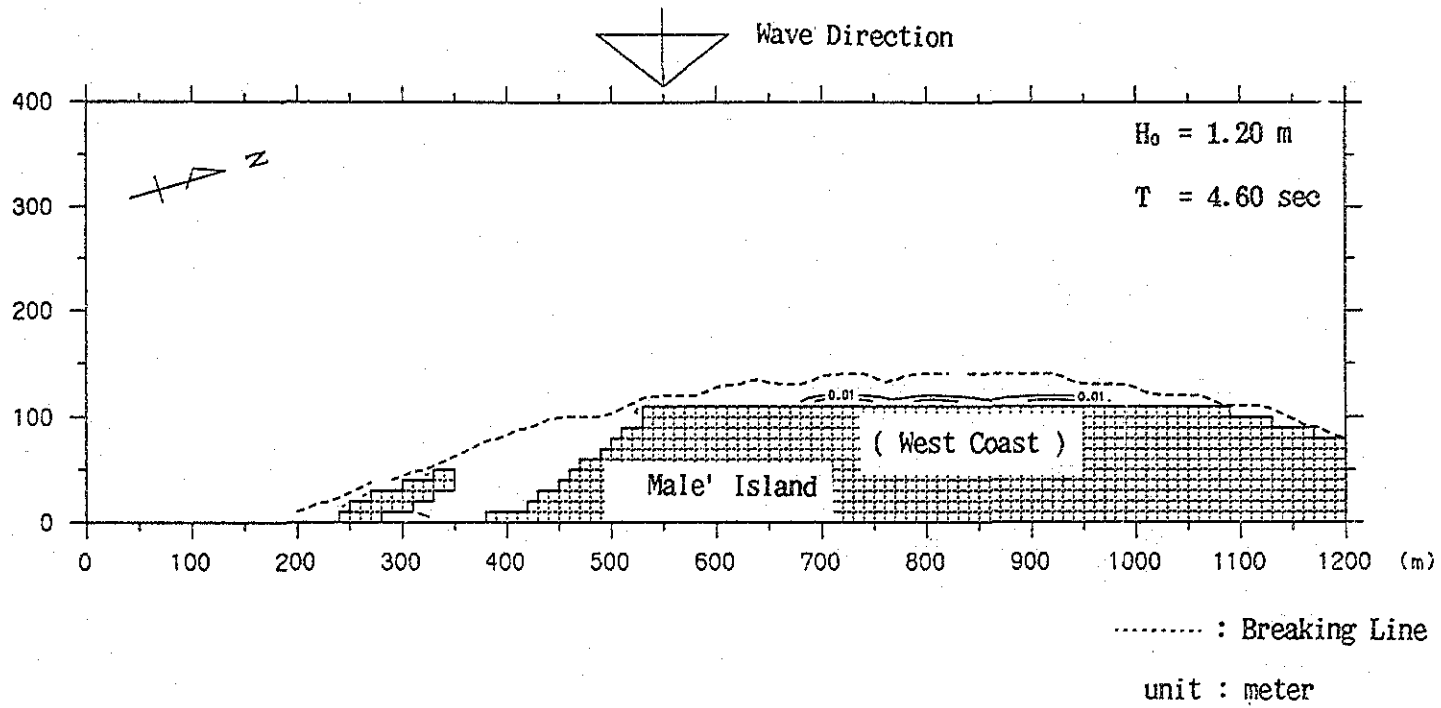


Figure 3.5 Distribution of Mean Sea Level (West Coast : Prediction)

Chapter 3. Environmental Conditions

3.1 Socio-economic Environment

(1) Population

According to "The Population and Housing Census of Maldives 1985, 1990" by Ministry of Planning and Environment, the total amount of population of the Maldives is 213,215 and the annual exponential population growth has been more than 3 % since 1965.

The population of Male' island accounts for 26 % of the total of the Maldives, or 55,130. The population of Male' is increasing 1 - 17 % in the annual exponential population growth rate since 1965. The population density in Male' is 30,627 people/km^2. The population growth is shown in Fig. 3.1.1.

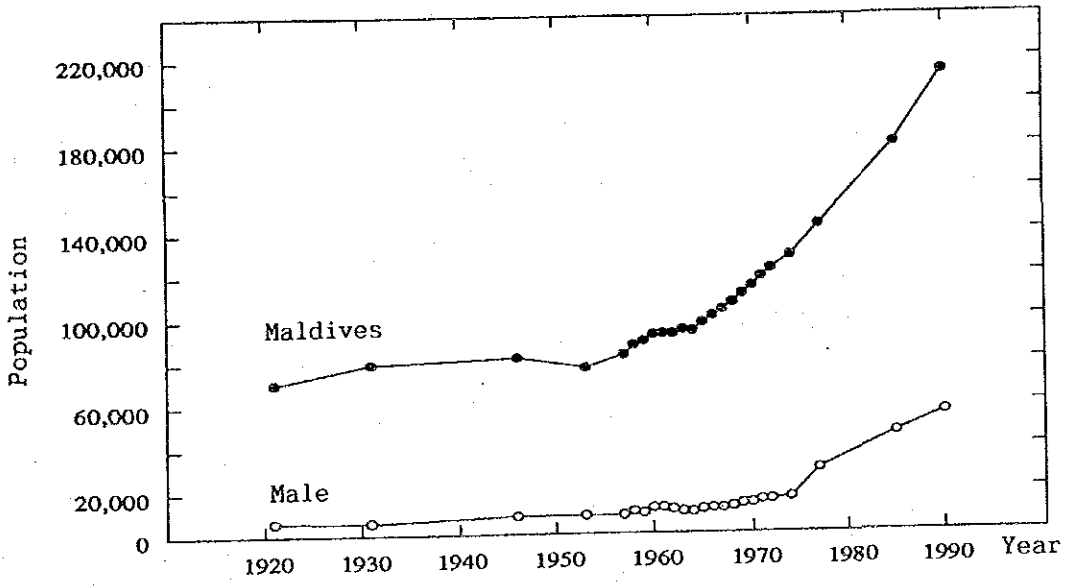


Figure 3.1.1 Growth of Population, 1920 - 1990
(by Ministry of Planning and Environment)

(2) Land Use

Land use on Male' island is shown in Table 3.1.1 and Fig. 3.1.2. Male' island has an area of approximately 1.754 km^2. Residential and small shop areas account for 57 % of total area of Male'. Most government warehouses and project sites are distributed in the south of Male'. There are commercial areas in the northwest and in the center of Male'.

Figure 3.1.2 Land Use Map

Table 3.1.1 Land Use in Male'

Area Category	Area (km^2)	(%)
Residential/Small Shops	1.000	57.0
Commercial Area	0.142	8.1
Government Office	0.059	3.4
Government Warehouse/Project Sites	0.284	16.2
Public Utilities	0.095	5.4
Educational Area	0.046	2.6
Recreation/Park	0.128	7.3
Total	1.754	100

(3) Coastal Use

a) Present Situation

The preventive structures of coastal disaster and coastal use map in Male' at present are shown in Fig. 3.1.3.

Male' island is surrounded by Seawalls and detached breakwater. The commercial Harbour (under construction) and the Inter-Island Harbour are in the north of Male'. The Inter-Island Harbour is used by many dhonis for anchorage. Southwest Harbour in the south is under construction.

The coast of Male' island is used for sewage discharge, for intake and outlet of desalination plants both DANIDA and French Plant, and for cooling water for power stations.

The southeast of Male' is also popular with young people, as it is area is the only place on Male' island where surfing is possible.

b) The Future Plans

Maldives government has some development plans for the future on Male'. These development plans are shown in Fig. 3.1.4 and as follows:

- Commercial Harbour Project (under construction)
- Southwest Harbour Project (under construction)
- Sports and Recreational Development Plan
- Indira Gandhi Memorial Hospital in the West of Male' sponsored by Indian Government (under construction)
- Widening of Marine Drive (under construction)
- Secondary Private School (Male' English School)

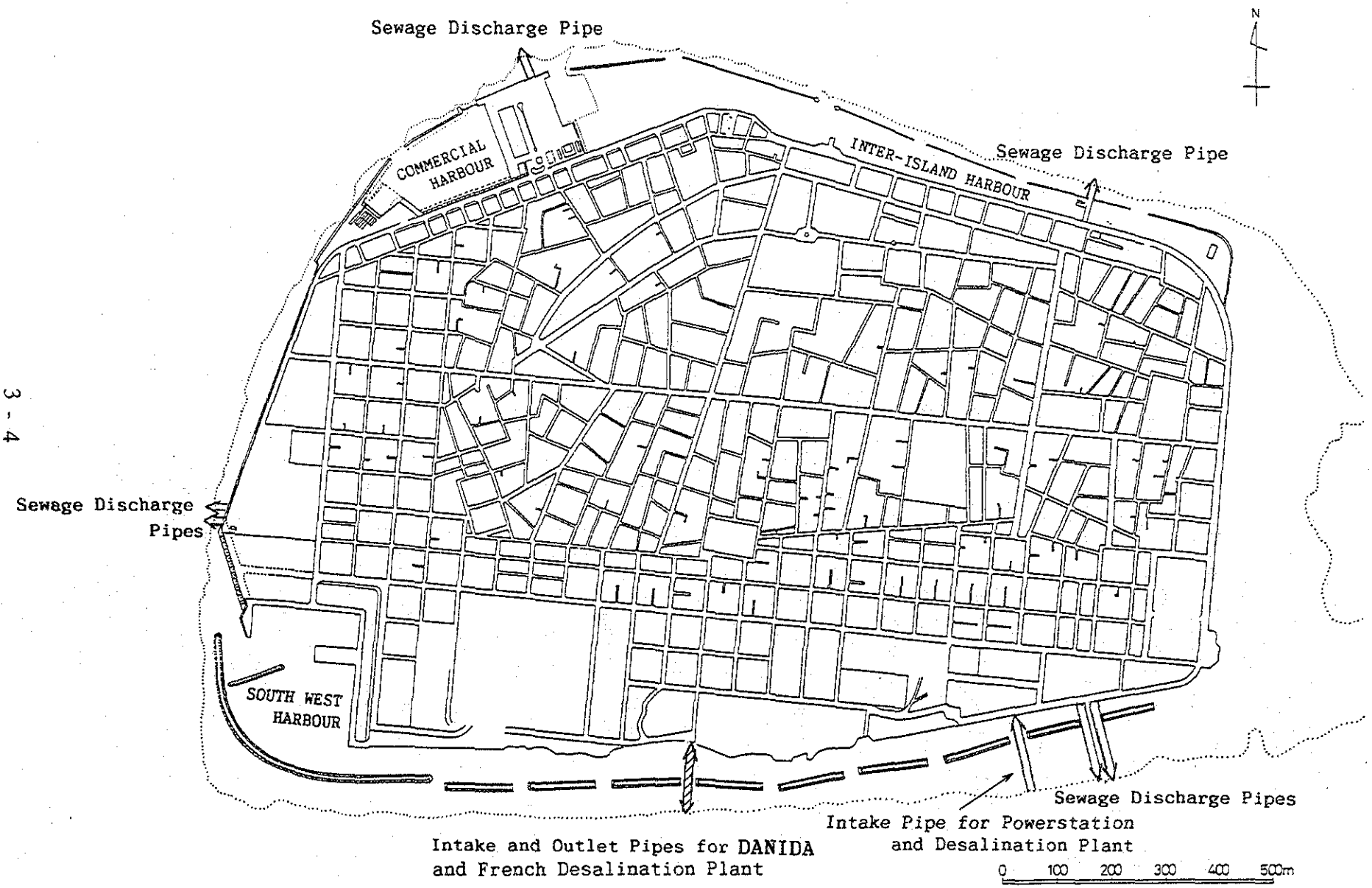


Figure 3.1.3 Coastal Use Map at Present

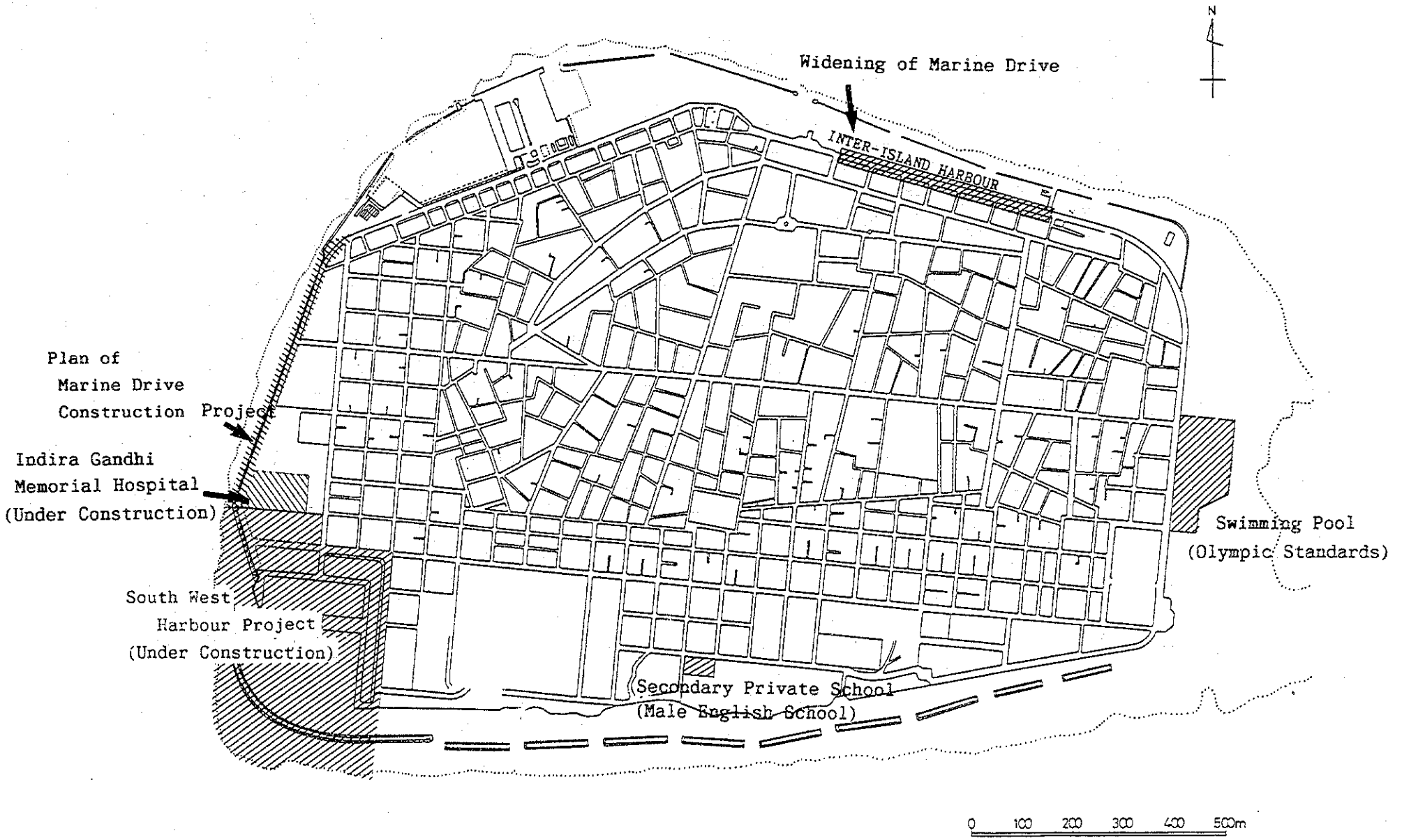


Figure 3.1.4 Coastal Use Map in Future

- Collection Site for Transport of Solid Waste
- Swimming pool (of Olympic standards)

(4) Economic Activities

a) Gross Domestic Product (GDP)

The GDP of the Maldives was estimated at 970 million Rufiyaa (calculated at 1985 prices) in 1990, which amounted to a per capita GDP of 4,555 Rufiyaa. The GDP is estimated to have grown at the average rate of approximately 8 % per year during 1985 to 1989 and of 15 % per year during from 1989 to 1990.

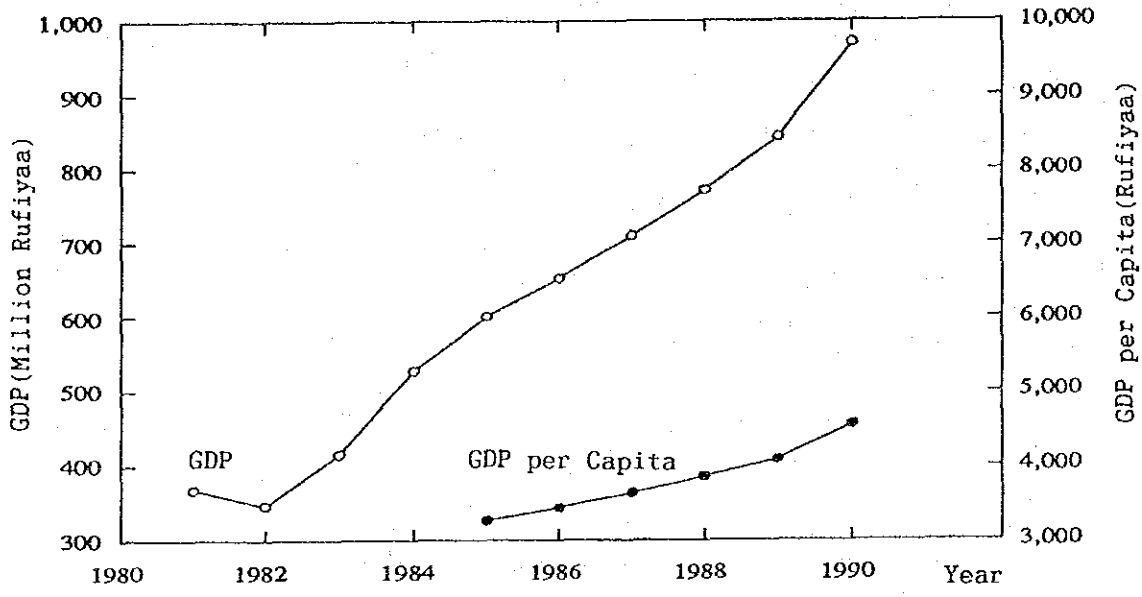


Figure 3.1.5 GDP of Maldives, 1990
(by Ministry of Planning and Environment)

b) Composition of the GDP

Composition of the GDP in 1990 is shown in Fig. 3.1.6, and Table 3.1.2.

Domestic product from the tertiary sector accounts for 60 % of the GDP. Looking closely at this sector, tourism accounts for about 18 % of the GDP. Tourism is increasing in importance as a source of domestic product since the establishment of the first resort in 1972. Fishing is also a very important industry in the Maldives.

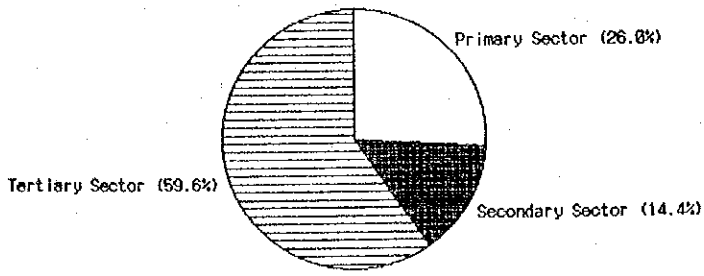


Figure 3.1.6 Composition of the GDP, 1990

Table 3.1.2 GDP of the Maldives, 1990

Sector		million Rufiyaa	share %
Primary Sector	Agriculture	87.130	8.98
(26.03 %)	Fisheries	147.554	15.21
	Coral and Sand mining	17.891	1.84
Secondary Sector	Construction	83.900	8.65
(14.38 %)	Manufacturing	55.625	5.73
Tertiary Sector	Distribution	166.829	17.19
(59.59 %)	Transport	56.958	5.87
	Tourism	177.797	18.32
	Real Estate	40.615	4.19
	Services	55.600	5.73
	Government Administration	80.420	8.29
Total		970.319	100.0

(by Ministry of Planning and Environment)

c) Economic Activities

The economy is based on three principal activities, tourism, shipping, and fishing.

1) Tourism

Tourism is the most important single activity in the Maldives. The first tourist resort was established in 1972. Since 1972, tourist resorts are increasing. There were 64 tourist resorts in 1990.

The number of tourists has been also increasing. Although the number dropped in 1989 on account of the Gulf War, it went up again in 1990 and 195,156 tourists arrived in Maldives that year.

Most tourists come from Europe, especially from Germany, Italy, and the UK. European tourists made up 78 % of the total in 1990.

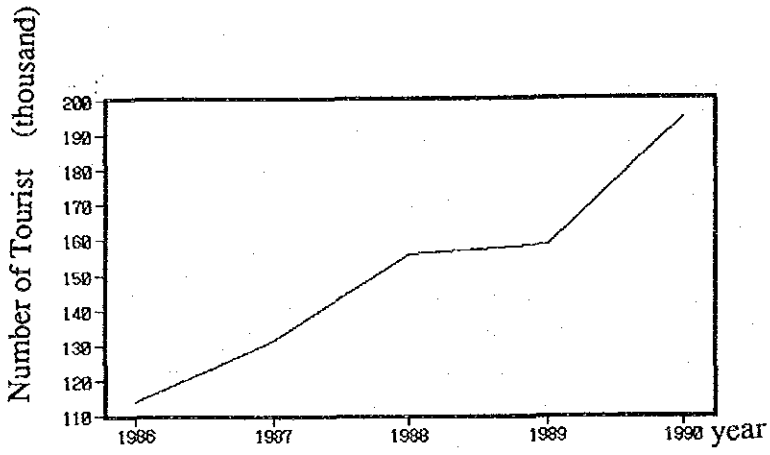


Figure 3.1.7 Number of Tourists, 1986 - 1990
(by Ministry of Planning and Environment)

2) Shipping

According to Department of Information and Broadcasting, the national shipping line which is operated by the Maldives National Ship Management Ltd. handles 85 % of the country's imports. Exports and imports of the Maldives in 1990 are as follows:

Exports	
Steel Scrap	0.462 million Rf.
Fisheries	363.249
Apparel and Clothing Accessories	138.941
Imports	
Consumer Goods	702.835 million Rf.
Petroleum Products	207.300
Intermediate and Capital Goods	405.271

3) Fisheries

Fisheries account for 72 % of export product value, approximately 363 million Rufiyaa. Fish production by types and utilization is shown in Table 3.1.3. Since 1988, fish production has been more than 70,000 tons a year. The main product is skipjack.

Fishery product for export accounts for more than 70 % of total fish caught in weight in 1989 and 1990, so the fishing industry is a very important source of foreign currency.

Table 3.1.3 Fish Production by Type and Utilization

unit: thousand metric tons

Items	1986	1987	1988	1989	1990
Export (excluding previous years stock)	32.0	36.0	35.2	50.0	56.7
Local consumption	23.8	19.1	28.8	15.5	15.9
Stock of Current years	3.5	1.8	7.5	5.7	3.8
Total catch	59.3	56.9	71.5	71.2	76.4
Skipjack	45.5	42.1	58.6	58.1	59.9
Yellowfin tuna	5.3	6.6	6.5	6.1	5.3
Other tuna related species	2.9	3.2	3.0	3.6	5.2
Other marine fishes	5.6	5.0	3.4	3.4	6.0

(by Ministry of Planning and Environment)

(5) Transportation

a) Land Transportation

The road network in Male' island is shown in Fig. 3.1.8. The main road is Majeedhee Magu which is located in the center. There is a ring road on the beach side named Marine Drive. Marine Drive passes through the north, the east, and a part of south Male'.

The total length of roads in Male' is about 48 km. Paved roads account for 14 % of total length.

b) Sea Transportation

The Maldives has a variety of vessels such as dhonis, mechanized yacht dhonis, baththeli and launches. However, the most popular sea transportation is the dhonis.

The dhonis is also used for inter-island transport. Many dhonis anchor in the Inter-island Harbour in north Male'.

Table 3.1.4 Vessels According to Registration in Male', 1990

Fishing Vessels	Mechanized yacht dhonis	Baththeli	Launches	Other vessels	Boats
1,128	29	52	558	310	234

(by Ministry of Planning and Environment)

c) Air Transport

There are four airports in the Maldives. One is for international use, three are for domestic use. The international airport is on Hulule island which is about 1.5 km from Male'.

The domestic airports are:

- Hanimaadhoo Island
- Khahdhoo Island
- Gan Island

Aircraft movement and other transport at Male' International Airport is shown in Table 3.1.5 and 3.1.6. The total number of flights was 1650 in 1990. International flights for passengers, freight, and mail transport to Male' have been increasing.

Table 3.1.5 International Transportation, 1990

Items			1989	1990
Aircraft movement		(flight)	1,476	1,650
Passenger arrivals		(population)	177,340	217,953
Freight	Inward	(kg)	4,360,880	5,241,713
	Outward	(kg)	290,364	1,799,873
Mail	Inward	(kg)	22,610	22,095
	Outward	(kg)	14,366	14,063

Figure 3.1.8 Road Networks Map

Table 3.1.6 Passenger Arrivals of International Flight

Year	1986	1987	1988	1989	1990
Number of Passengers	124,622	142,102	170,027	177,340	217,953

(by Ministry of Planning and Environment)

(6) Infrastructure

The infrastructure map is shown in Fig. 3.1.9. There are harbours, power stations, water supply system, hospitals, and roads in Male' island.

Harbours and roads are described in "(5) Transportation" and the solid waste disposal site is taken up in "(7) Health and Sanitation"

Harbours

There are two harbours which are located in north Male' at present. The commercial Harbour to be used by large scale vessels is being constructed at present. "Dhonis" for inter island transport is used in the Inter-Island Harbour. The third harbour which is named Southwest Harbour is being constructed in southwest Male'.

Shore Protection Facilities

Male' island is surrounded by seawall and detached breakwater. These structures are shown in Fig. in Main Report (1), and conditions of these structures are described in "Chapter 2, 2.7 Existing Shore Protection Facilities" in Main Report (1).

Electricity

There are two power stations in Male'. Both are diesel type generators. The old one is in the inner island, meanwhile the new one is located in the south side of Male'. Their generation of electricity are as follows:

Old Power Station	5,725 KVA (nominal capacity)
New Power Station	5,400 KVA (nominal capacity)

Hospitals

There are two hospitals. One is a general hospital and the other is a health center. At present, an additional hospital is being constructed by the Indian government in west Male'.

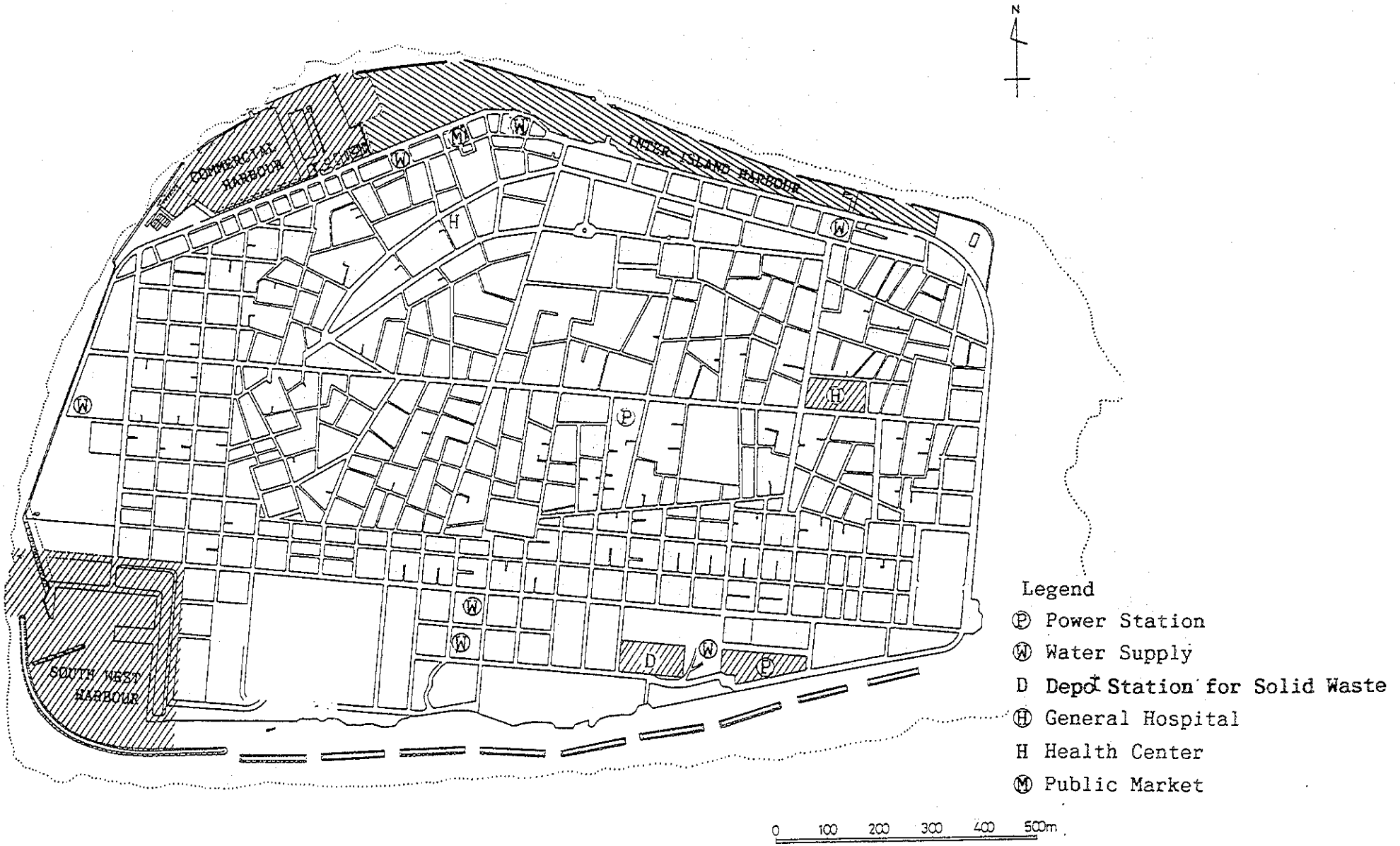


Figure 3.1.9 Infrastructures in Male'

(7) Health and Sanitation

a) Water Supply

In Male', public water supply system is operated and maintained by the Male' Water and Sanitation Authority (MWSA) which is under the Ministry of Health and Welfare. MWSA provides drinking water for residents.

1) Collection and Production of Public Water

The public water is produced in two methods as follows:

- Collection of rain water
- Produced from sea water by desalination plants

Collection of rain water

There are several large storage tanks, made of mild steel and concrete. The collected rain water is supplied to 30 standpipes. Storage tanks for the collected rain water are not only GOM's (Government of Maldives) but also in overhead tanks in mosques. These 15 tanks at the mosques with a capacity of 5 m^3 each (except one with 7 m^3). That collected water is also provided for public use. There are also 24 small fiberglass tanks (8 have been removed) in the yards of some mosques.

Table 3.1.7 The Volume of the GOM's Storage Tanks

Number of GOM	Volume	
GOM 1	520 m^3	
	260 m^3	
GOM 2	500 m^3	(close)
	500 m^3	(close)
GOM 3	530 m^3	
GOM 4	1,600 m^3	
	1,600 m^3	
GOM 5	1,600 m^3	
	1,600 m^3	
GOM 6	9,600 m^3	

(by the Male' Water and Sanitation Authority)

Desalination Plants

The MWSA operates three desalination plants for sea water as DANIDA I, II and French Plant. The amounts of water produced in each desalination plant are as follows:

	capacity	
DANIDA I	200 m^3/day	
DANIDA II	600 m^3/day	(2 unit)
French Plant	200 m^3/day	

The DANIDA I and II produce water with a volume of 3 m^3/hr, and running time of the plants is 4 hours per day. The French Plant produces 200 m^3/day.

Private Rain Water Collection

In Male', about 1,154 private households have rain water collection system and storage facilities. The average storage tank capacity is 3.6 m^3 per household, and total amount is 14,000 m^3.

2) Supply

There are 30 standpipes which receive water from the storage tanks in Male'. 27 standpipes are in mosque yards. Most standpipes are in the inner area of the island. Three standpipes have been installed in the public area in the southern reclamation area. The public water supply network is shown in Fig. 3.1.10. Service time of the standpipes is 11 hours per day: 8:30 - 17:30.

The MWSA analysed supplied water quality for bacteria and residual chlorine. The MWSA keeps 0.3 - 0.2 ppm of residual chlorine in overhead tanks.

3) Consumption Volume

Consumption volume in Male' is as follows:

Dry Season	600 m^3/day
Rainy Season	200 m^3/day

b) Sewage

In Male', there is no treatment of sewage. Sewage is directly discharged into the sea from 6 outfalls by 9 pumping stations. Location of discharge points are shown in Fig. 3.1.3.

c) Solid Waste

1) Collection

Solid waste is collected as follows:

- Disposal by the producer himself
- Collected individually on request using hand-carts or pick-ups
- Collected by the Maldives Transport and Contracting Company (MTCC)

The MTCC is a semi-government organization. The MTCC collects waste from 16 % of all the households or 700 households by compactor lorries (with 4 to 6 m^3 capacity) and open lorries.

The average composition of domestic waste is shown in Table 3.1.8.

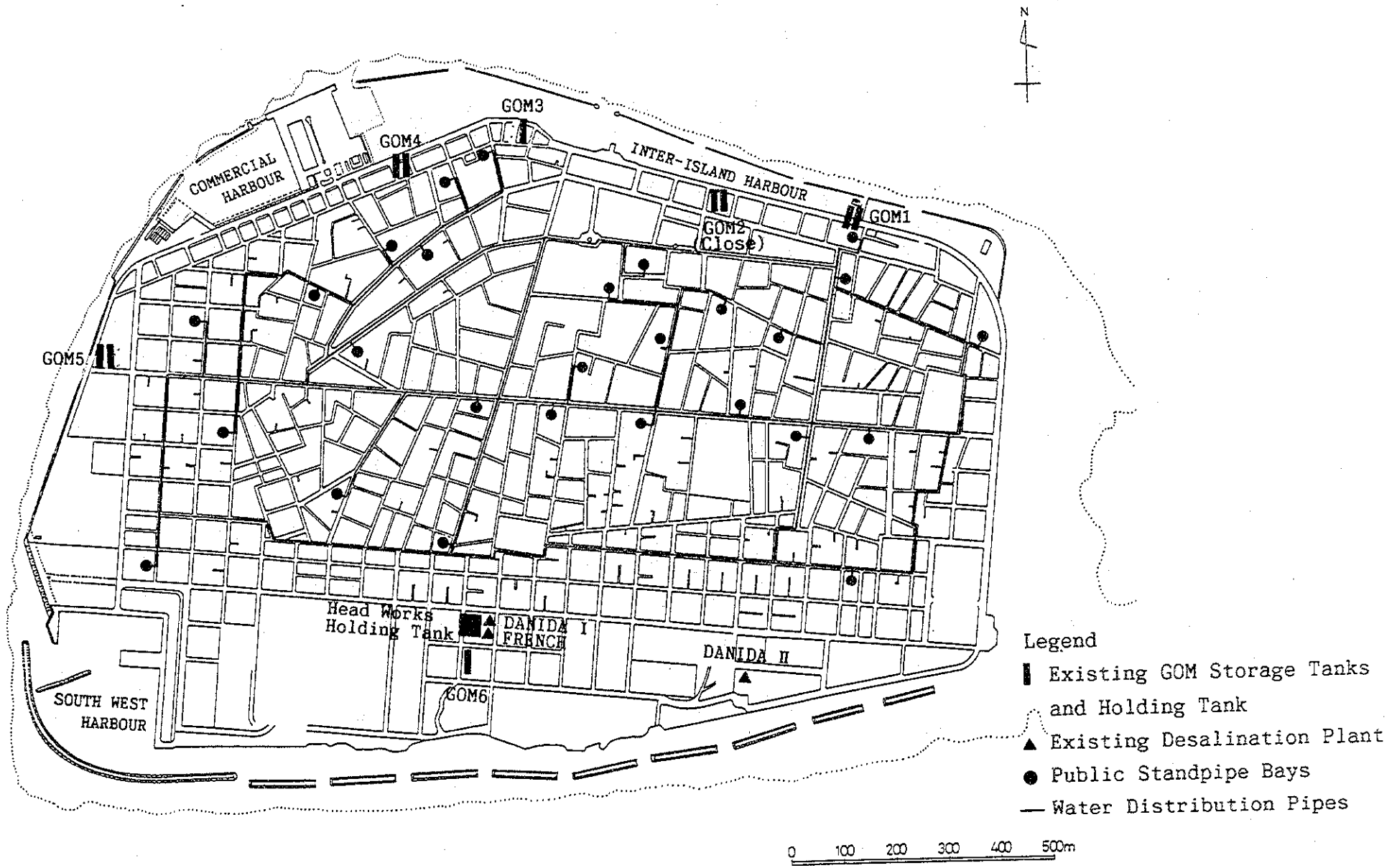


Figure 3.1.10 Water Supply System in Male'

Table 3.1.8 Composition of Domestic Waste in Male'

Items	Total Fraction(%)
Metal	3
Stone	1
Glass	2
Wood, Carton	3
Textile, Plastics	11
Leaves, Garden Waste	4
Paper	4
Kitchen Waste	19
Grit 50 - 10 mm	29
Grit 10 - 0 mm	24

(by Ministry of Health)

2) Disposal

The Maldives government carried out a land reclamation project in the south of Male'. In this project, coral and coral sand dredged from the Northern of Male', and solid waste were used as a material for reclamation. As the area is reclaimed it is covered with 30 cm of coral sand. Previously reclaimed area is mainly used for residences, sport facilities, warehouses, and public utilities. At present, solid waste is conveyed from the Southwest Harbour to a shallow lagoon named Uthuru Thilafalhu by ferry boat.

There was an incinerator plant in Male' with a capacity of 4 m^3/hour. However, this incinerator is not functioning now due to equipment failure.

(8) Cultural Facilities and Sites

Location of cultural facilities and sites in Male' is shown in Fig. 3.1.11 and Table 3.1.9. There are 26 mosques and 18 schools.

There are 8 private schools and 10 government schools. There is no university or college in the Maldives.

Table 3.1.9 Number of cultural Facilities and Sites

Items	Number
Mosque	26
School	
Private Primary School	1
Private Secondary School	7
Government Primary School	4
Government Secondary School	5
Government Pre-university	1
Cultural Site	3

There are many cultural sites in Male'. Main cultural sites are as follows:

- The Minaret
- Friday Mosque
- Muleeaage (The Presidential Palace)

(9) Landscape

a) East Side

Marine Drive passes through the east side of Male'. There is a seawall 0.9 m above the road. Reef edge and the horizon are seen from the road side. In the south of the east side, there is a public park, which is used as a recreation area for residents.

b) South Side

Residents can access to shore line only on the east of the south side. There is a seawall which is 0.8 m above the road. Detached breakwaters made up of tetrapods installed over the seawall. These tetrapods hinder visibility of the sea. However, the horizon can be seen between detached breakwaters from the road. And, it can be seen above detached breakwater from the seawall.

c) West Side

Marine Drive passes through the north of the west side, the sea can be seen from Marine Drive over the seawall that is 1.4 m high.

d) North Side

In the north side of Male', there are breakwaters over the seawall. The area between the breakwaters and the seawall is used by some vessels for anchorage.

In the center of the north side of Male', there is a park for residents and tourists where people come to relax in the evening.

Figure 3.1.11 Location of Cultural Facilities and Sites

3.2 Physical and Natural Environment

(1) Climate

The Climate of the Maldives can be divided into two periods as follows:

- Northeast Monsoon December - March
- Southwest Monsoon end of April - October

The Department of Meteorology observation of the weather on Hulule island which is about 1.5 km from Male' between 1986 and 1990 is shown in Fig. 3.2.1.

The mean monthly temperature of 31.7 °C is highest in April, and lowest in September at 25.1 °C. However, there is very little seasonal variation.

Monthly mean humidity ranges from about 75 to 80 %.

In Hulule, the average annual rainfall is approximately 1,900 mm. The maximum mean monthly rainfall is over 200 mm in June, from August to October, and in December.

The most frequent wind direction is northeastern in December through February and western in May through September as follows:

January and February
North to east northeast wind

May and June
West southwest to west northwest wind

July to September
West to northwest wind

December
Northeast to east

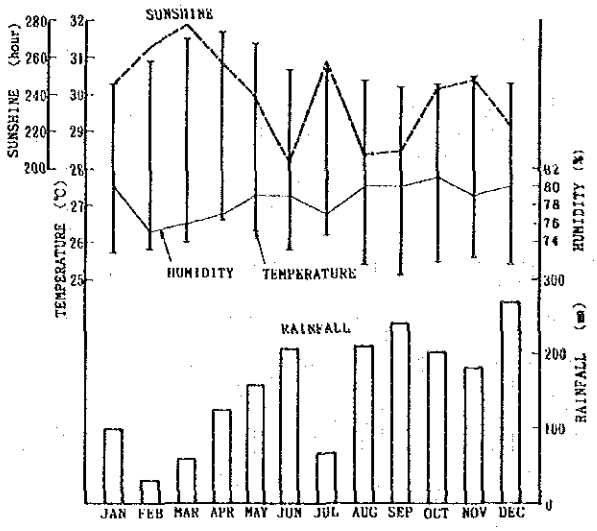


Figure 3.2.1 Monthly Average Climate in Hulule, 1986 - 1990

(2) Topography/Geology

The Republic of Maldives consists of 1,190 small coral islands out of which 200 are inhabited. The total area including lands and sea is approximately 9,000 km². The islands are formed in 26 natural atolls in the Indian Ocean. The island group of ring-shaped clusters, stretches for approximately 750 km from north to south and 120 km from east to west.

The capital of the Maldives is located on Male' Island. Male' Island is approximately 1.9 km wide and 1.2 km long. Topographical and geologic details on Male' is described in "2-3 Topographic and Hydrographic Survey" and "2-4 Soil Conditions" in Main Report (1).

At present, Male' island has an area of approximately 180 ha. However, originally the island was surrounded by coral reef and the area of the island was about 108 ha. Some parts of the reef were reclaimed to cope with increasing population in south and west. Changes of topography on Male' island are shown in Fig. 3.2.2, and the corresponding changes of area are as follows:

Year	Area
1950	107.64 ha (originally)
1978	123.02
1986	177.25

The ground level of Male' is 1.2 to 2 m high from sea level and reclamation area is more than 1 m high. Higher area is distributed in the center and the northeast of Male'.

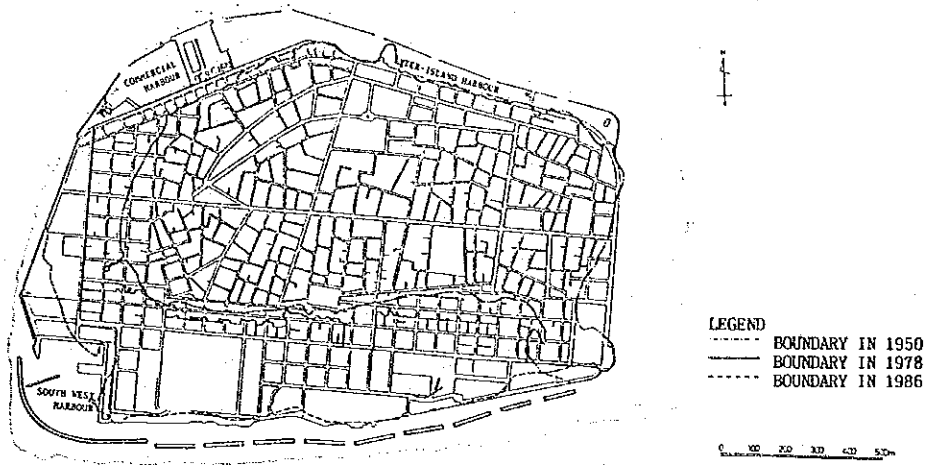


Figure 3.2.2 Changes of Topographic Conditions in Male' Island

(3) Ground Water

a) Conditions of Ground Water

The ground water is in the form of a fresh water lens as shown in Fig. 3.2.3. The conditions of ground water depends on the characteristics of porous coral rock, sea level and rainfall. Variation of ground water level is similar to the tidal level as shown in Fig. 3.2.4.

According to "The Implications of Sea Level Rise for the Republic of Maldives", it is predictable that mean ground water level in Male' is 0.4 m above mean sea level. And the thickness of ground water layer below mean sea level is 16 m.

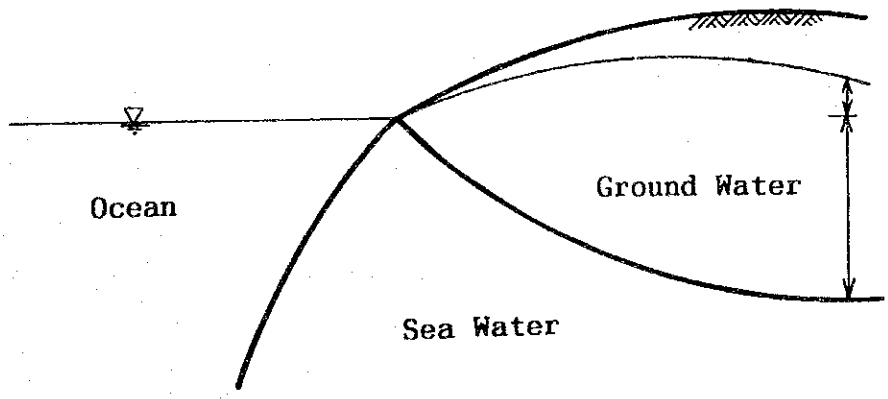


Figure 3.2.3 The Form of a Fresh Water Lens

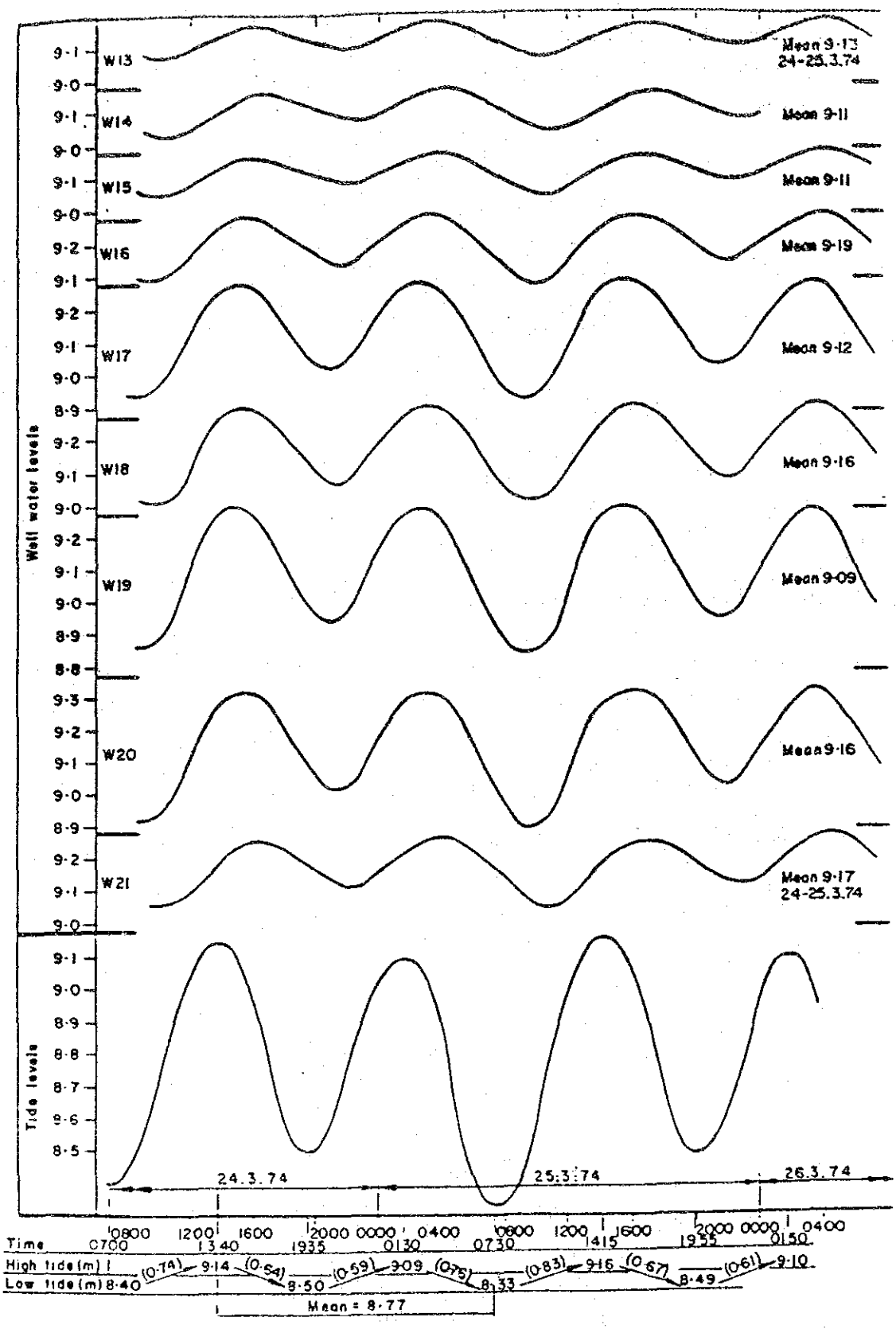


Figure 3.2.4 Relationship of Ground Water Level and Sea Water Level
(by Alasdair J. Edwards)

b) Quality of Ground Water

Male' Water Sanitation Project has surveyed the quality of ground water by monitoring wells. Distribution of chlorides is shown in Fig. 3.2.6. Concentration level of chlorides in ground water results from rainfall and sea level. Low concentration of chlorides is distributed in the center of Male'.

The JICA study team surveyed 5 wells in Male' on September 30, 1991. The result of the analysis is shown in Table 3.2.1, and the surveyed location map is shown in Fig. 3.2.5. The concentration of chlorine is lower in the center and higher near shore line wells except north of Male' (MG-2). Colibacillus was detected on M-5, which is in the south of Male'.

Table 3.2.1 Quality of Ground water in Male'

Date:Sep. 30, 1991

Station		MG-1	MG-2	MG-3	MG-4	MG-5
Water Temp.	(C)	28.6	29.1	28.7	28.8	27.8
Chlorine	(mg/l)	3,325	1,100	7,325	1,125	3,275
pH	(-)	7.2	8.1	7.4	7.4	7.5
Hardness	(mg/l)	1,675	550	2,675	775	1,325
Colibacillus		no	detected	no	no	no

(by JICA Study Team)

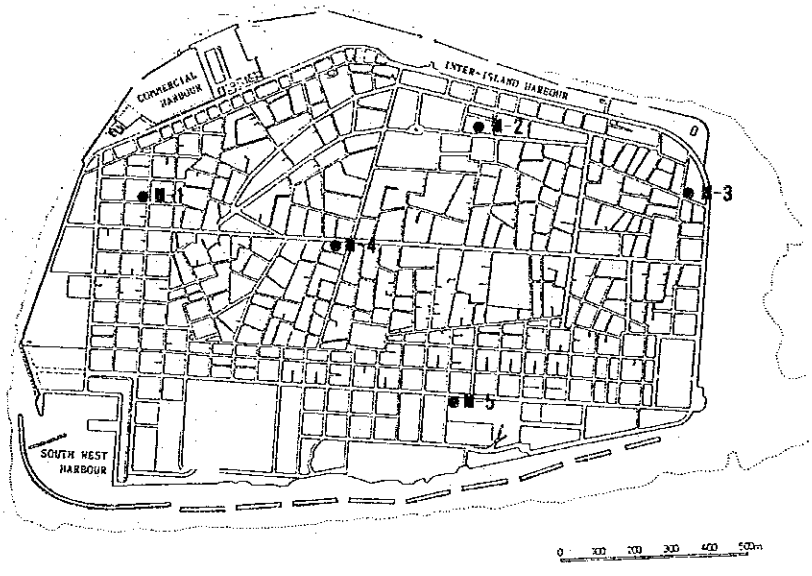
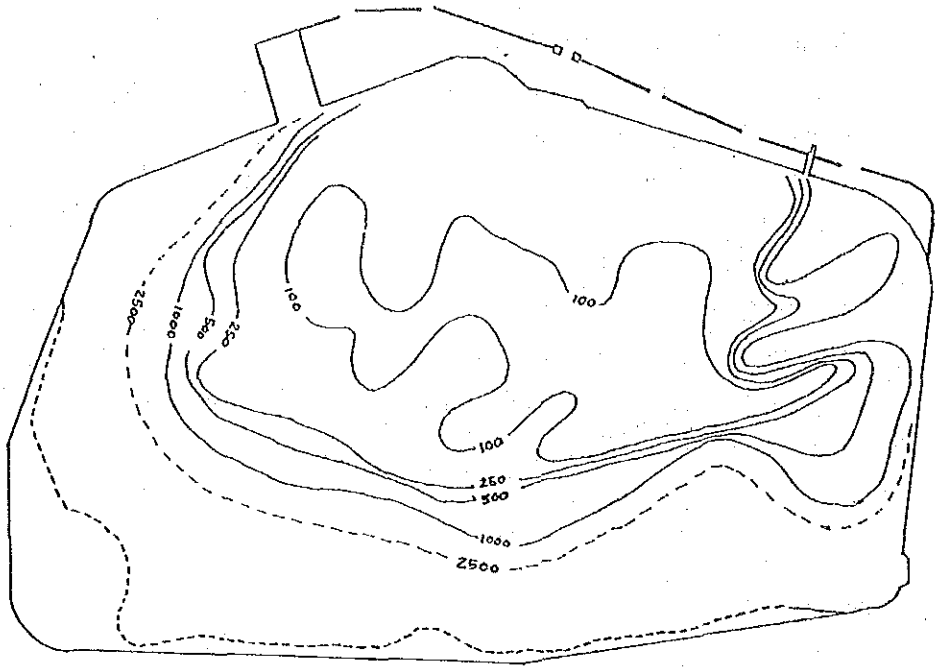


Figure 3.2.5 Location of Wells for Ground Water Survey
by JICA Study Team

October, 1989



March, 1990

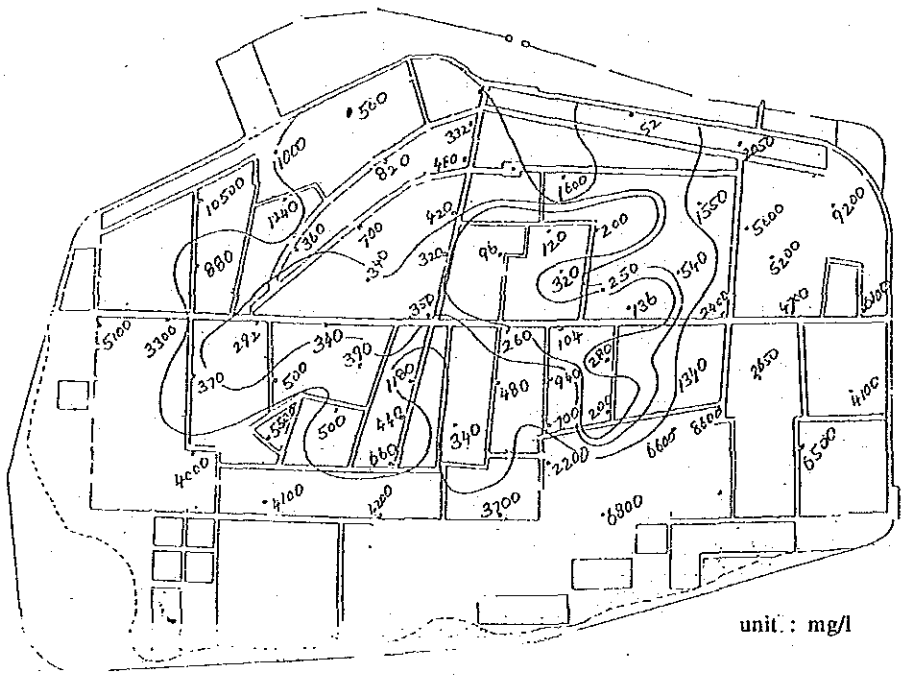
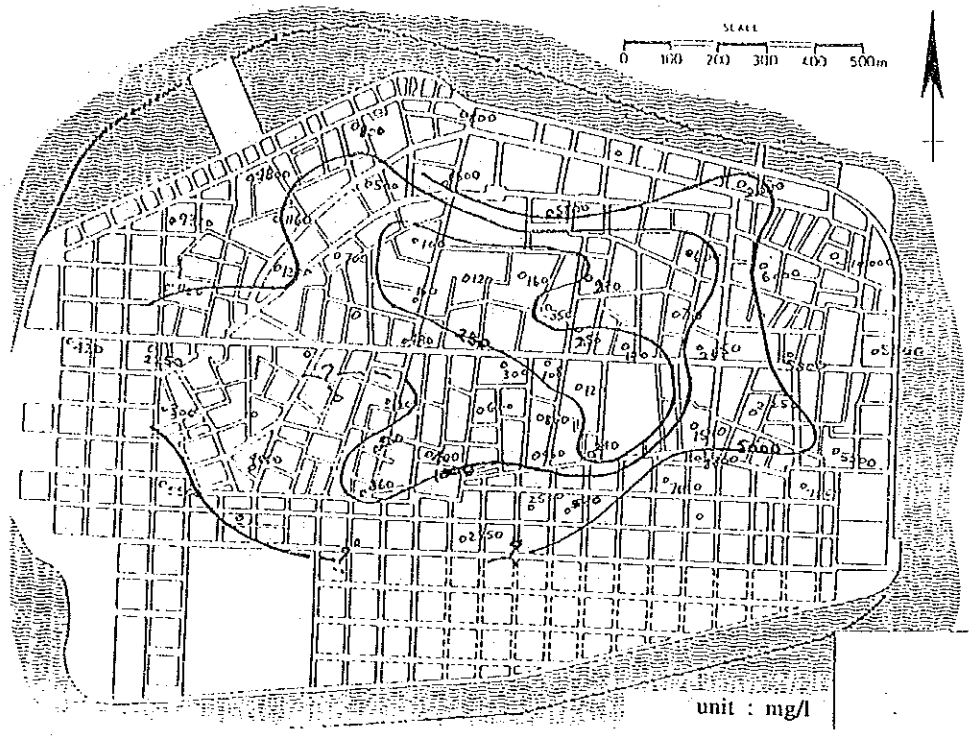


Figure 3.2.6 Distribution of Chloride in Male' Island (1)
(by Ministry of Health)

April, 1990



May, 1990

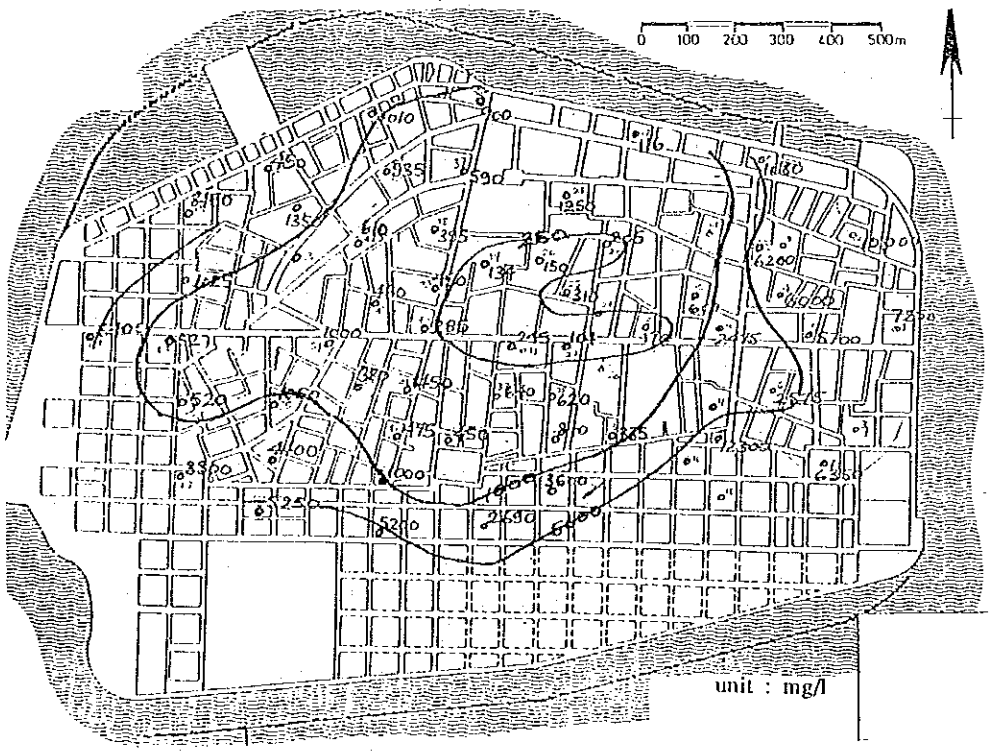


Figure 3.2.6 Distribution of Chloride in Male' Island (2)
(by Maldives Water and Sanitation Authority)

(4) Marine Hydrology

a) Currents

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 southeast monsoon period from May to August.

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

The currents flow westward during the northeast monsoon period, and they flow eastward during the southwest monsoon period. The seasonal patterns of currents are shown in Fig. 3.2.7.

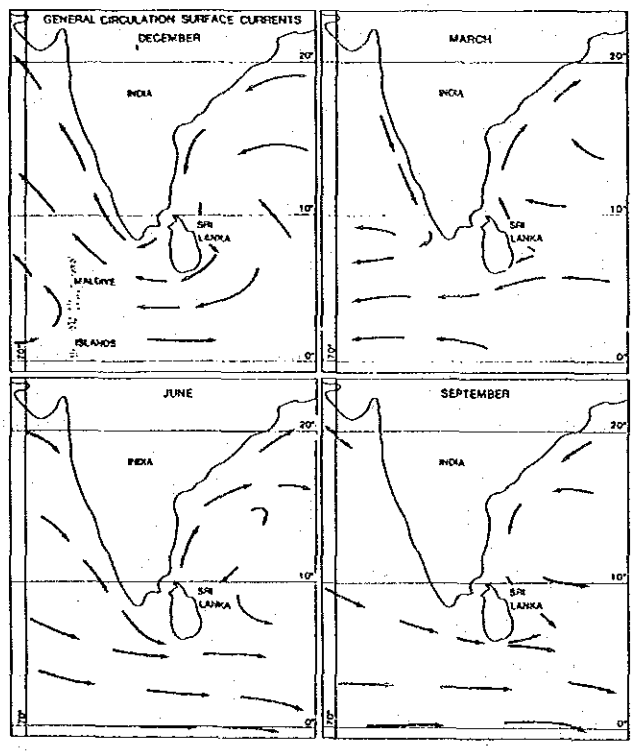


Figure 3.2.7 Surface Currents around Maldives (by Bernard Swan)

The JICA study team surveyed a trace of floats as they were moved by currents on the west of Male'. Results of this survey are shown in Fig. 3.2.9.

In the inner reef, there are northward currents. The speed of these currents are in the range of 0.3 - 0.4 m/s. In the outer reef, on the northern east side, there are low speed currents, which flow to the north. In the south of the east side, there are eastward currents. These currents are influenced by wind waves. Offshore from northeast side of Male', currents flow eastward at the speed of 0.3 - 0.4 m/s.

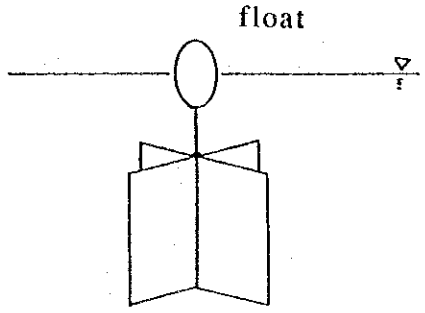


Figure 3.2.8 Equipment of Trace of Float Survey

b) Wave

Sources of waves on Maldives coasts can be divided into two types as follows:

- Waves generated by local winds and storms
  period 3 - 8 seconds
- Swells generated by distant storms
  period 14 - 18 seconds

Both types of waves are also conditioned by the monsoon wind and location islands. Detailed conditions of waves around Male' are explained in "2.6 Oceanographic Survey" in Main Report (I).

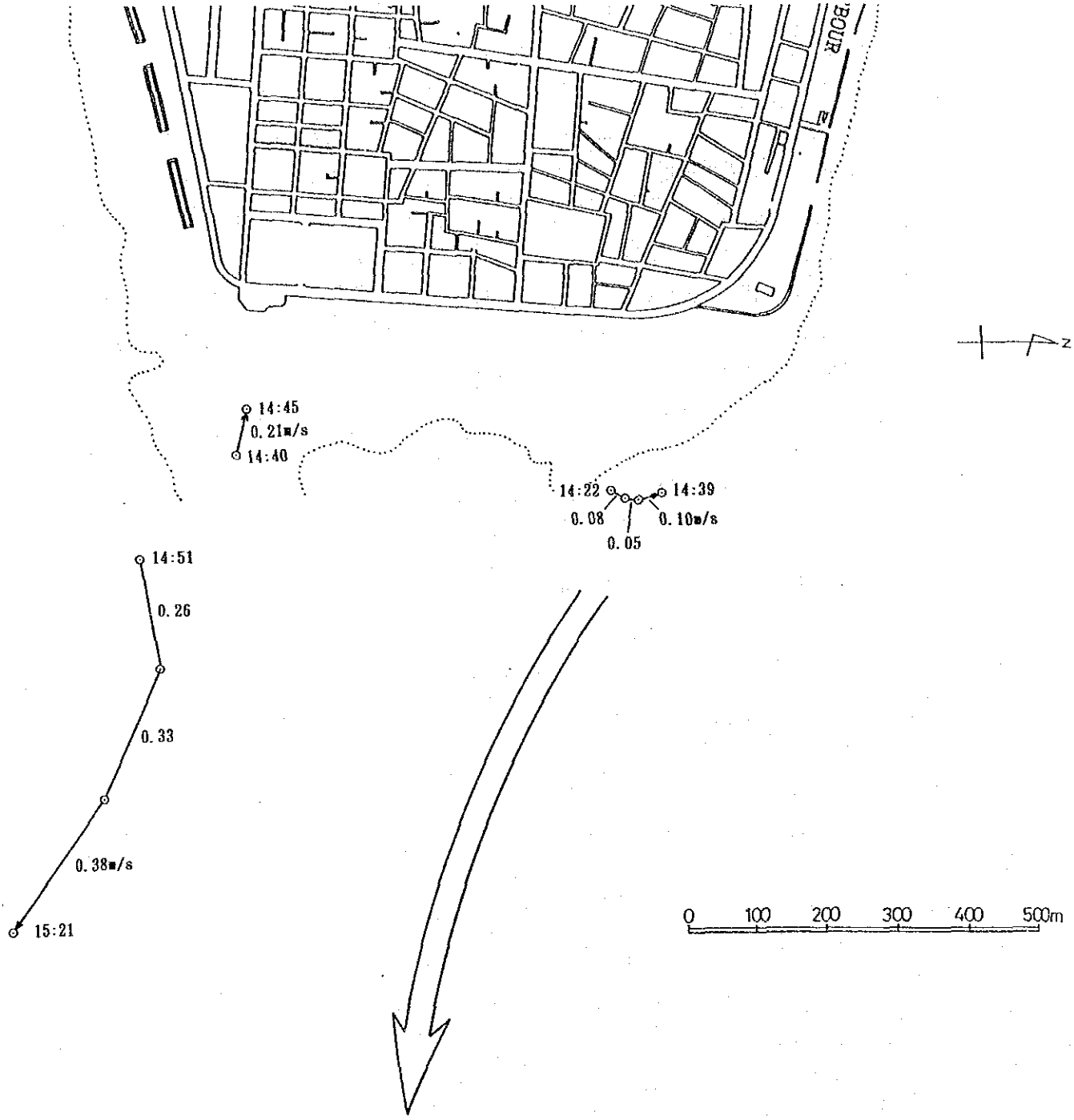
c) Tidal Level

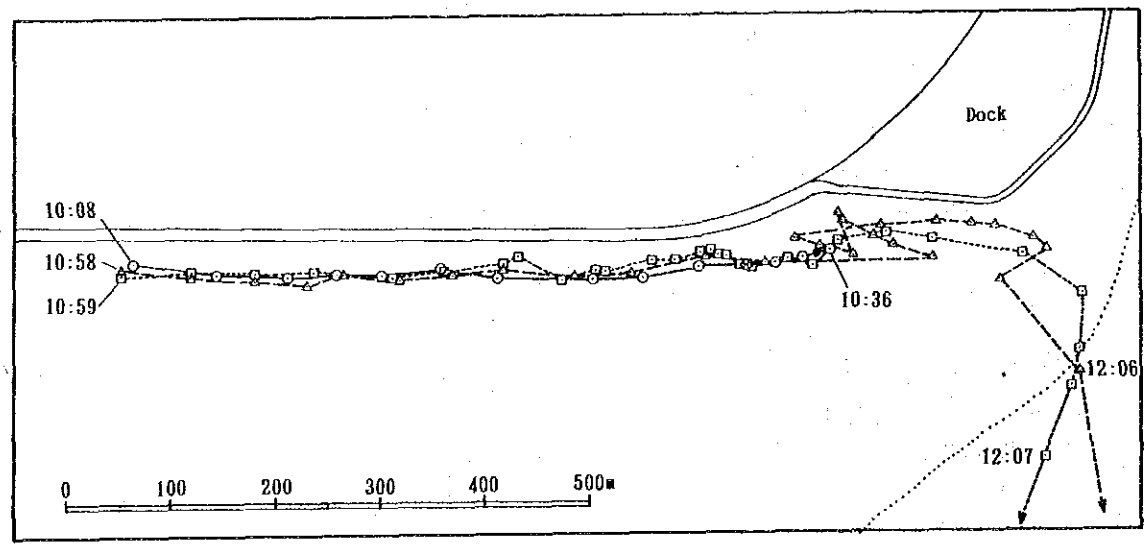
According to "Tide Tables Vol. 2, 1991" published by the Hydrographer of the Navy, the harmonic constants for Male' are as follows:

Constant of tide

Z_0	M_2	S_2	K_1	O_1	
0.56	0.24	0.14	0.12	0.06	m

High Water Level (HWL)	D.L. + 1.34 m
Mean Sea Level (MSL)	D.L. + 0.64 m
Chart Datum Line (MSL-Z)	D.L. + 0.08 m





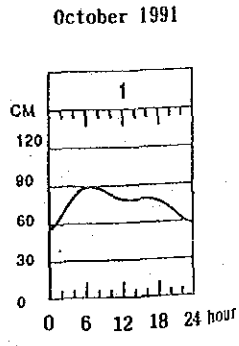


Table 3.2.9 Results of Trace of Floats

(5) Marine Water Quality

Characteristics of surface water in the Maldives are shown in Table 3.2.2. Since there are no large rivers, volumes of surface water reservoirs are determined by rainfall and evaporation.

Table 3.2.2 Characteristics of Surface Water in Maldives

Temperature	27.5	°C	in January
	28.9	°C	in May
Salinity	34.0	ppt	in February
	35.5	ppt	in August
Density	1,023	kg/m³	

(by the Ministry of Health)

The JICA study team surveyed water quality at 10 stations around Male' Island on October 3, 1991. The results of analysis and the location of the sampling points are shown in Table 3.2.3 and Fig. 3.2.10. The Marine Research Section, Ministry of Fisheries and Agriculture also surveyed water quality at 4 stations in the Inter-island Harbour on September 25, 1991. The data from the Marine Research Section in shown in Table 3.2.4.

According to these surveys, the Inter-island Harbour and the Inner harbour of the south Male' have a higher concentration of turbidness than that of around Male' island. However, other elements such as salinity and nutrient salt are varied among the stations.

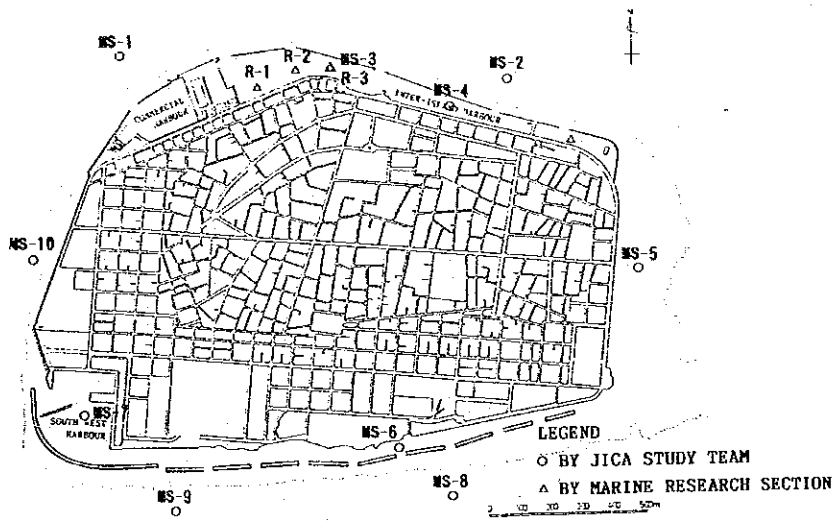


Figure 3.2.10 Location of Sampling Stations for Water Quality

Table 3.2.3 Water Quality in Male'

Date:Oct. 3, 1991

Station		MS-1	MS-2	MS-3	MS-4	MS-5
Transparency	(m)	10	9.0	2.0	Bot. (2.0)	Bot. (6.5)
Water Temp.	(°C)	28.6	28.8	28.9	29.1	28.8
Salinity	(ppt)	34	33	33	33	34
pH	(-)	8.2	8.2	8.2	8.2	8.3
DO	(mg/l)	6.1	4.6	6.0	5.0	-
COD	(mg/l)	< 1	< 1	< 1	< 1	< 1
PO_4-P	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02
NH_4-N	(mg/l)	<0.04	<0.04	<0.04	<0.04	<0.04
NO_2-N	(mg/l)	<0.03	<0.03	<0.03	<0.03	<0.03
NO_3-N	(mg/l)	<0.01	<0.01	0.01	<0.01	0.01

Station		MS-6	MS-7	MS-8	MS-9	MS-10
Transparency	(m)	2.9	1.5	12	Bot. (6.5)	12
Water Temp.	(°C)	28.9	28.9	28.6	28.6	28.6
Salinity	(ppt)	34	34	34	34	34
pH	(-)	8.2	8.2	8.3	8.3	8.3
DO	(mg/l)	5.5	-	-	6.0	-
COD	(mg/l)	< 1	< 1	< 1	< 1	1
PO_4-P	(mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02
NH_4-N	(mg/l)	<0.04	<0.04	<0.04	<0.04	<0.04
NO_2-N	(mg/l)	<0.03	<0.03	<0.03	<0.03	<0.03
NO_3-N	(mg/l)	0.01	<0.01	0.01	0.01	<0.01

( ):Depth

(by JICA Study Team)

Table 3.2.4 Water Quality Inter-Island Harbour by MRS

Date:Sep. 25, 1991

Station		R1	R2	R3	R4
Transparency	(°C)	29.0	29.0	29.0	29.0
Salinity	(ppt)	36.0	35.0	35.0	36.0
pH	(-)	8.2	8.2	8.2	8.2
Turbidity	(FTU)	5.0	2.0	3.0	1.0
Sulfide	(mg/l)	0.002	0.001	0.005	0.002
PO_4-P	(mg/l)	0.036	0.013	0.033	0.036
NH_4-N	(mg/l)	0.001	0.0003	0.001	0.003

(by Marine Research Section)

Pollution of harbours in Male' was researched by the Marine Research Section, Ministry of Fisheries and Agriculture. Inner Harbour has some problems as follows:

- Ship generates pollution from oil, bilge water, contamination from fish blood and dead fish bait.
- Discharging garbage and night soil from the residential boats due to lack of toilets on the boats

Other sources of pollution are:

- Six sewage discharge pipes without treatment
- Garbage dumping areas on shores

(6) Marine Fauna and Flora

There are more than 250 species of coral on Maldivian reefs. Corals built the reefs and islands of Maldives. Coral is used as building materials for houses and coastal protection structures.

The JICA Study Team surveyed coral reefs on the east, the west, and the south sides of Male' island using the Manta Tows method. Two 20 m long line-transects were set up on the south side. The results of survey are shown in Table 3.2.6.

a) East Side

This area experiences heavy wave action most of the year. The bottom had once an active reef of large massive corals, most of which are dead now and covered with turf algae. Sewage probably accounts for this since there is a large pumping station on the north side and the predominant current direction seems to be toward the east in channel.

The reef gently slopes away from shore to some distance towards the east. In the south of the east side, the bottom, which was 12 m deep, was mostly dead Porites with live Acropora hyacinthus and cytheria, and significant amounts of Pocillopora. Then the Acropora became rare and the community was dominated by *Pocillopora verucosa* on otherwise bare and gently undulating coral rock pavement. Cover in both cases was about 15-20 %. In the north of the east side, there are live coral thinned, and massive Porites alive and dead was common. There were some bug stands of Porites, much of which was in poor shape. Heavy turf algae was the dominant cover.

b) West Side

The reef top was narrow and sloped gradually to the edge at 2 m depth whence it plunged straight down to 20 m where there was a ledge (old sea level). On the shelf at 20 m were a lot of cans and coral boulders fallen from above. There was a second ledge at 22 m. The slope moderated a bit but remained very steep until 30 m where a sand/rubble slope of about 30 degrees began. At this point, there was an accumulation of dead coral boulders fallen from above.

About 50 % of the top was covered with medium size (0.5-0.8 m diameter) massive coral boulders resting on a flat coral rock base with coarse sand in between boulders. Live coral cover on top was about 99 % heavy algal turf growing on dead, mostly loose massive coral skeletons (mostly Porites but some other e.g.*Leptoria phrygia*). Live coral of all sorts on top was 1 % or less and consisted of: *Pocillopora verucosa* (dominant), with occasional Tubastrea, Dendrophyllia, Favia, *Acropora hyacinthus*, *A.Humilis*, Montipora, Astreopora, massive Porites, *Leptoria phrygia*, and encrusting soft coral. At all depths the massive atrophying and encrusting in form and the Acroporas were less than 10 cm in diameter. The only reef top invertebrate seen was *Diadema setosum*.

c) South Side

In the east of the south side, heavy turf algae on dead coral is the dominant life form. Live coral cover was estimated at 15 %. Small Acropora (humilis group, hyacinthus, cytheria) was dominant on the reef top. On the shoulder and upper slope Acropora was still dominant, but massive porites (about 75 cm diameter, with some 2 m head to the west) was important and occasionally locally dominant. *Pocillopora verucosa* was important, especially on top as was the encrusting soft coral (sinularia ?). There was a patch of broken coral normal on the reef top substrate to the reef edge. One large (about 5X10 cm) dying and fragmenting colony of *Pavona clavus* was seen, also with long axis normal to the reef edge. In general, the Acropora and Pocillopora seemed to be surviving well, while the massive corals seemed to be in worse condition.

Examination of massive corals showed that these are heavily parasitized and the live tissue area seemed to be generally receding. On the reef top, small burrowing urchins (Diadema) were common and one Heterocentrotus was seen. Covered live coral declined dramatically at about 30 m where sand was the

dominant substrate and soft coral was relatively abundant. Down deeper in the sea, encrusting (e.g. Favia) and foliose (e.g. Echinopora, Leptoceris) forms were observed more dominant among hard corals.

According to the line transect survey, although this quantitative measure is not conclusive, it is noteworthy that in both of the transects surveyed the percentage of covering coral declined as did the average intercepted size of coral colony (Table 3.2.5). The percentage of covering coral is about half of that seen elsewhere under similar conditions. The amount and luxuriousness of algal turf is much higher in the coast of Male' than elsewhere.

Table 3.2.5 Conditions of Coral in the South of Male'

		Hard Coral Coverage Ratio (%)	Average Intercepted Size (m)
No.1	Oct./1990*	15.15	0.12
	Oct./1991	13.50	0.10
No.2	Oct./1990*	7.75	0.05
	Oct./1991	7.05	0.04

*: surveyed by Bill Allison

It is noteworthy that on the top there is significant growth of Acroporas in the humilus group, which suggests that some sort of recovery is in progress despite the human stresses. However, the current breakwater construction and port dredging will have (and are having) a negative effect on the corals at the western end of the side.

In general although the Acroporas and Pocillopora veruccosa are doing well in the shallow waters, the massive corals, the main framework builders are atrophying in all locations on this reef, and the dominant cover is algal turf. The conclusion is that the reef is in poor condition and faces continued degradation.

Table 3.2.6 Results of Coral Survey in the South of Male' (1)

Transect 1 (Length of Transect : 20 m) Date : Oct. 7, 1991

Items	Total bottom cover %
Hard Coral	
Montastrea sp.	0.15
Montipora informis	3.25
Montipora sp.	1.90
Montipora venosa	0.40
Pavona sp.	0.75
Platygyra daedalea	0.15
Pocillopora sp.	0.05
Pocillopora verrucosa	0.10
Porites lobata	1.75
Porites massive	4.75
Psammocora sp.	0.25
Soft Coral	
Digitate Encrusting	0.40
Nephthea	1.45
Soft Coral Encrusting	13.65
Hydrozoa	
Millepora sp.	0.40
Algae	
Calcareous Algae	9.25
Dead Coral Algae	0.15
Heavy Turf Algae	30.75
Heavy Turf Algae Holding Sand	9.35
Lyngbia	0.20
Medium Turf Algae	0.90
Medium Turf Algae Holding Sand	0.45
Turf Algae Holding Sand	5.60
Turf/Calcareous Algae Mosaic	2.90
Other Organism	
Didemnum	0.40
Palythoa sp. (small polyp)	1.40
Substrate	
Rubble Loose	2.20
Sand	5.65
Sand/Rubble Matrix	1.30

Covering ratio of transect length and number of types

Hard Coral	:	13.50 %,	11 types
Soft Coral	:	15.50 %,	3 types
Hydrozoa	:	0.40 %,	1 type
Algae	:	59.55 %,	9 types
Other Organisms	:	1.80 %,	2 types
Substrate	:	9.15 %,	3 types

Hard Coral Colonies 29, Average Size 0.10 m

Table 3.2.6 Results of Coral survey in the South of Male' (2)

Transect 2 (Length of Transect : 20 m) Date : Oct. 8, 1991

Items	Total bottom cover %
Hard Coral	
Acropora Recruit	0.20
Acropora gemmifera	0.10
Acropora humilis	0.20
Echinopora lamellata	0.15
Favia pallida	0.90
Montipora millepora	0.45
Montipora sp.	0.80
Montipora venosa	0.15
Pavona sp.	0.15
Platygyra daedalea	0.10
Pocillopora verrucosa	0.95
Porites cylindrica	0.35
Porites massive	1.75
Psammocora profundacella	0.80
Soft Coral	
Gorgonians	0.10
Sinularia sp.	2.80
Sponge	
Sponge Encrust	0.55
Algae	
Calcareous Algae	21.50
Caulerpa sp.	4.00
Filamentous Red Algae	0.90
Heavy Turf Algae	24.95
Heavy Turf Algae Holding Sand	10.20
Medium Turf Algae	4.30
Turf Algae Holding Sand	17.50
Turf/Calcareous Algae Mosaic	2.00
Other Organism	0.60
Didemnum	1.00
Feather Hydroids	0.60
Palythoa sp. 2 (small polyp)	
Substrate	
Dead Coral	0.15
Sand on flat coral rock	1.85

Covering ratio of transect length and number of types

Hard Coral	:	7.05 %,	14 types
Soft Coral	:	2.90 %,	2 types
Sponge	:	0.55 %,	1 type
Algae Genera	:	85.35 %,	8 types
Other Organisms	:	2.20 %,	3 types
Substrate	:	2.00 %,	2 types

Hard Coral Colonies 34, Average Size 0.06 m

(7) Marine Fishery Resources

Fishery is one of the most important economic industrial sectors in the Maldives, and accounts for approximately 15 % of the GDP.

a) Method of Fishing

Zaha Waheed has surveyed the method of fishing in North Male' Atoll. Results of this survey are as follows:

As for day-time fishing, 2-5 fishermen work on one fishing boat, which goes far out in the atoll towards the outer rim and in the atoll rim channel. The men work with a single-hook handline, and use live bait fish such as Caesionidae, Apogonidae, and Pomacentridae.

As for early morning and night, Bokkuraa(s) (row boats) are operated with one or two fishermen during early morning and night as follows:

Full-time fishermen	from 8 p.m. to 3 a.m.
Part-time fishermen	from 8 p.m. to around midnight
	or
	from 3 a.m. to 4 a.m.

Sometimes, fisherman go out fishing twice a day. The main gear is a handline with a small sinker and a hook.

b) Fish Species Caught

In Male' the amount of fish landed was 4,953 tons in 1990 (Table 3.2.7). The main caught fish was skipjack. Skipjack was landed 4,084 tons or 82 % of the whole amount of fish caught with pole and line vessels (Table 3.2.8).

Table 3.2.7 The Amount of Fish Landing, 1990

Unit:tons

	Total	Skipjack	Yellowfin	Other tuna related Species	Other marine fishes
Total	76,373	59,898	5,279	5,185	6,011
Male' Atoll	5,278	4,622	402	137	117
Male'	4,953	4,084	373	322	174

(by the Ministry of Planning and Environment)

Table 3.2.8 Fish Catch by Fishing Method, 1990

Unit:tons

	Total	Skipjack	Yellowfin	Other tuna related Species	Other marine fishes
Total	76,373	59,898	5,279	5,185	6,011
Pole and Line Vessels	72,148	59,191	5,065	3,808	4,084
Trolling	3,877	703	213	1,362	1,599
Long Line	15	0	0	2	13
Hand Line	4	4	0	0	0
Fixed Gillnets	9	0	1	3	5
Miscellaneous	320	0	0	10	310

(by the Ministry of Planning and Environment)

The FAO (Food and Agriculture Organization of the United Nations) has surveyed fishery resources in North Male' Atoll. Composition of caught fish species by types of fishing is shown in Table 3.2.9. The most common fish caught with handline was L. gibbus. This species accounts for 25.6 % of the total in weight, and the second is L. bohar.

The species caught most in amount with longline is L. bohar (18.82 %) and A. virescens (18.75 %).

The species caught most with trap was L. elongatus. This species accounted for 15-69 % of the total in weight.

Table 3.2.9 Composition of Species by Types of Fishing in North Male' Atoll

Unit : %

Fish	Handline	longline	Trap
Lutjanus gibbus	25.6	0.07	4.34
Lutjanus bohar	12.46	18.82	10.63
Aprion virescens	4.27	18.75	2.28
Loxodon macrorhinus	1.36	14.05	-
Nebrius ferrugineus	11.17	3.34	-
Lethrinus elongatus		6.22	15.69
Lethrinus rubrioperculatus			11.66

(by FAO)

c) Seasonal Change of Handline Catch Rates

A test fishing with handline was operated in the North Male' Atoll by FAO during the period from March 1987 to March 1989. Catch rate with handline ranges from 2 to 4 /line/hr and from 2 to 5 kg/line/hr. However, there is no remarkable change in the trend of catch rates (see Fig. 3.2.11).

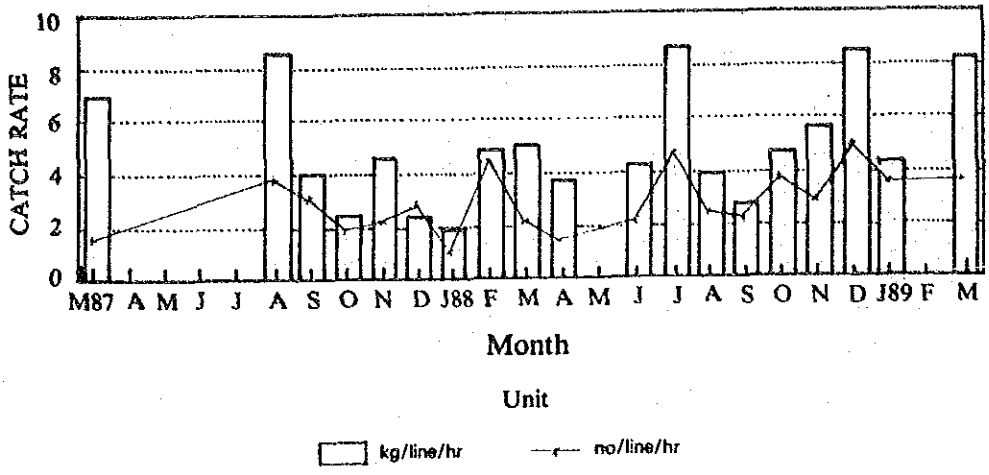


Figure 3.2.11 Catch Rates for Commercial Handline Fishery in the North Male' Atoll (by FAO)

d) Biomass

According to the estimation by FAO, biomass in North Male' Atoll was to be 2,600 - 3,500 tons. Biomass of the Snapper A. virescens was estimated between 488 and 656 tons, 572 tons on the average.

(8) Terrestrial Fauna and Flora

a) Fauna

In Male', colourful garden lizards, geckos, house mice and black rats can be found everywhere.

b) Flora

There are no native plants. Vegetation is very rare on Male' island. Some plants were put in house gardens, schools, and parks. The main plants are mango trees, casuarinas (Fithuronu) and wild hibiscus (Dhiggaa). However, the ratio of green cover is lower than in the other islands.

(9) Natural Disaster

In Male' island, there has not been any recent natural disasters as floods, droughts or land slides because of the climate and topography. Male' Island, however, has experienced following natural disasters in its history.

a) Freak Storms

- Oct. 26, 1962
- Dec. 1, 1965
- Apr. 29, 1971

  Winds were from the west at 41 miles per hour.
- May 1, 1977
- Dec. 15, 1980

  Strong gusts of wind were felt in Mafannu area.
- May 17, 1981

  Some boats in the inner harbour and 37 houses were damaged because of strong winds. At the height of this storm winds blew at 60 miles per hour.
- May 12, 1989

  Heavy rain and strong winds were experienced. Wind of 55 miles per hour.

refer to: Hassan Ahmed Maniku, 1990
Change in the Topography of the Maldives

b) Earth-tremors

- 1723*

  There was a report of some seismic activity from the atolls. Roofs seemed to have been trembled.
- Feb. 27, 1740
- 1753*

  Some seismic activity was reported from Male'
- Dec. 14, 1759
- 1810*

  It was reported that shock wave were felt throughout the Maldives.
- Dec. 13, 1921*

  Some shock waves were experienced on Male'
- Oct. 20, 1926*

  There was a reported of vibration lasting about 30 - 60 seconds, reported from Male'.
- Sep. 16, 1934*

  Some seismic activity was reported from Male'
- Apr., 1935 (no data)*

  Some seismic activity in Male', but no damage.
- Mar. 1, 1944*

  Shock waves, lasting about 2-3 minutes were experienced in Male'.
- Mar. 17, 1947 or 41* after mid-night
- Nov. 16, 1948*

  Roofs of houses on Male' trembled.
- Dec. 12* or 13, 1961

  Shock waves were experienced in Male'
- May 2* or 23, at 5:53 p.m., 1989

There was a few seconds of shock wave experienced in Male'.

refer to : Hassan Ahmed Maniku, 1990
Change in the Topography of the Maldives

* : V. S. Bhatt
Causes and consequences of Natural Disasters and the Protection and preservation of the Environment

c) Inundations

- Jul. 6, 1966
  High waves inundated the southern areas of Male' from 1 p.m. The previous day high waves battered the areas of Male'.
- May 31, 1968
  Rainfall for 24 hours was 145.3 mm.
- Oct. 12, 1977
  Rainfall for 24 hours was 148.8 mm.
- Dec. 24, 1977
  Male' received 175.9 mm of rain.
- Jun. 23, 1978
  The western and southern parts of Male' were flooded by waves between 3:30 and 4:30. In some areas waters were 2.5 feet deep.
- Dec. 6, 1980
  Reclaimed area in Mafannu was flooded by heavy rains.
- Jan. 20, 1987
  Parts of island were flooded due to heavy rain.
- Apr. 10, 1987
  Large part of the southern and eastern areas of Male' were flooded by high waves. 4 houses fell and extensive damage was caused to many others.
- Jun. 23, 1987
  Northwestern parts of the island were flooded.
- May 4, 1988
  The southern and western areas of the island were flooded by waves.
- Jun. 28, 1988
  The southern areas of the island were flooded by waves.

refer to : Hassan Ahmed Maniku, 1990
Change in the Topography of the Maldives

* : A. J. Edwards; The Implications of Sea-Level Rise for the Republic of Maldives, 1989

Chapter 4. Comparative Study on Alternative Plan

4.1 Comparison of Structures

Comparative study on the south coast and the north coast was carried out and summarized in Tables 4.1 and 2. As for the other coasts, there is no alternative structure from technical points of view as well as economical and environmental ones.

4.2 Comparison of Gravity Block Type and Steel Sheet Pile Type Quaywalls

Gravity block type and steel sheet pile type are compared as follows:

provided that steel sheet pile type is adopted on the south coast, leachate generated out of solid waste which is landfilled in the southern part of male' island cannot find its outlet into the sea and will end up stagnating the underground. Consequently, the leachate may possibly contaminate well water. Furthermore, noise and vibration will be generated by sheet pile work. Therefore, the gravity block type is regarded better than the sheet pile type from the environmental point of view.

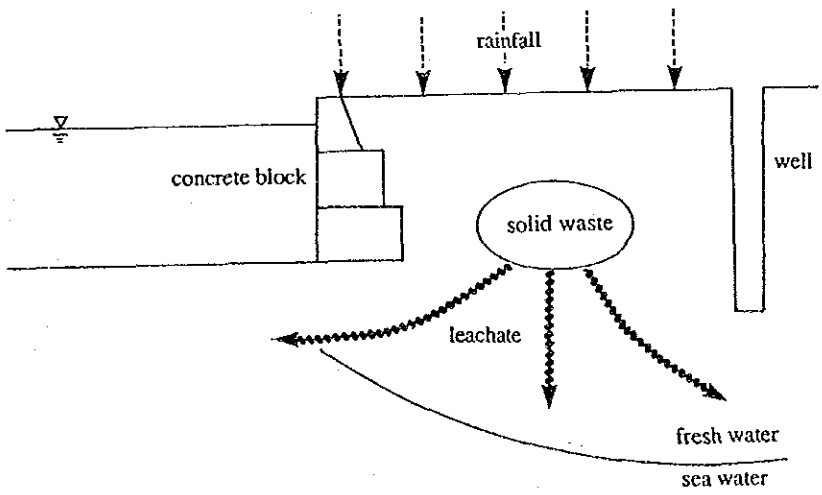


Figure 4.1 Gravity Block Type

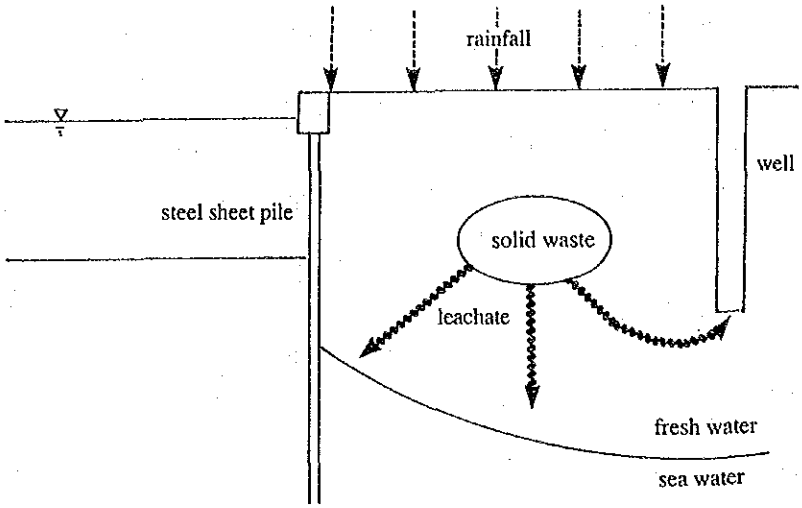


Figure 4.2 Steel Sheet Pile Type

Table 4.1 Comparison Table of Shore Protection Structure (1)

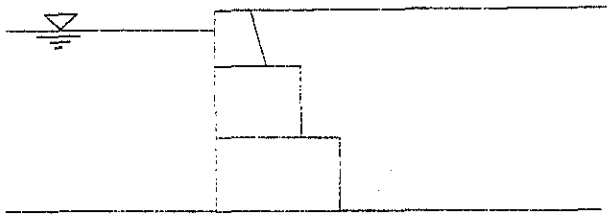
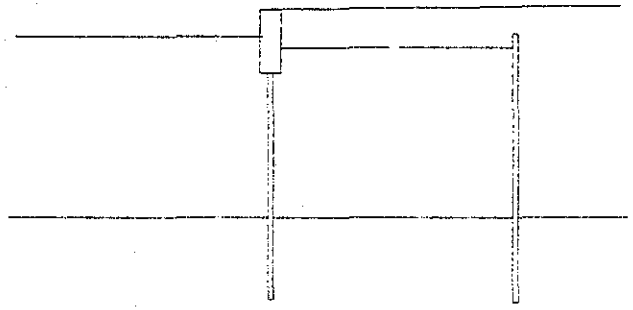
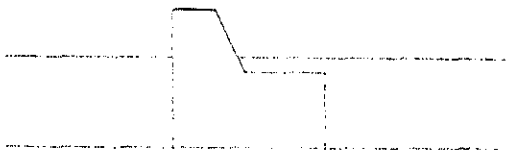
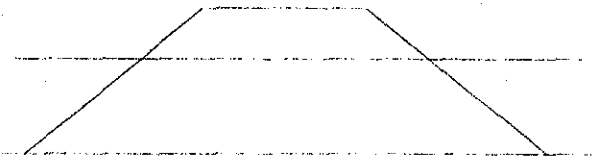
Type of Structure		Gravity Block Type	Steel Sheet Pile Type
TYPICAL CROSS SECTION			
COST INDICATOR		1	1.22
MERIT	Materials	- Long durability - -	- - -
	Construction	- Ease of construction - Construction equipment simple - Segmental construction	- Short construction period - -
	Environment	- - -	- - -
DEMERIT	Materials	- Almost all materials imported - -	- Cathodic protection needed - Almost all materials imported - Large quantity of stone for back-filling required
	Construction	- Fabrication yard area needed - Relatively long construction period -	- Construction method complicated - -
	Environment	- Turbid water during construction - -	- Noise and vibration during construction - -

Table 4.2 Comparison Table of Shore Protection Structure (2)

Type of Structure		Gravity Block Type	Armour Block Mound Type
TYPICAL CROSS SECTION			
COST INDICATOR		1	1.36
MERIT	Materials	- Long durability - -	- - -
	Construction	- Ease of construction - Construction equipment simple - Segmental construction	- Short construction period - -
	Environment	- - -	- Free water movement - -
DEMERIT	Materials	- Almost all materials imported - -	- Wide space needed - Almost all materials imported -
	Construction	- Fabrication yard area needed - Relatively long construction period -	- Fabrication yard area needed - Special form needed -
	Environment	- - -	- Aesthetically negative impression - -

Chapter 5. Typical Cross Section of Proposed Shore Protection Facilities

Figures 5.1 to 10 are typical cross sections of the proposed shore protection facilities for each coast. In addition to the above, alternative structural types for the south and west coasts are shown in Figures 5.11 and 12.

Weight (w) of armour concrete blocks for each coast are determined by using Hudson formula as follows;

$$w = \frac{\gamma_r H^3}{K_D(Sr-1)^3 \cot\alpha}$$

where
- w : Weight of Armour concrete Block (t)
- Sr: $\gamma_w/\gamma_r = 2.23$
- γ_r: Unit Weight of Concrete (2.3 t/m^3)
- γ_w: Unit Weight of Seawater (1.03 t/m^3)
- H: Design Wave (m)
- K_D: Coefficient Factor (8.3)
- α: Degree of Slope ($\cot\alpha = 4/3$)

Table 5-1 Calculation of Weight of Armour Concrete Block

Coast	H (m)	W(t)	Adopted Size of Block (t)
West	1.2	0.19	1.0
East	1.3	0.24	1.0
South	0.7	0.04	1.0
North	0.6	0.02	1.0

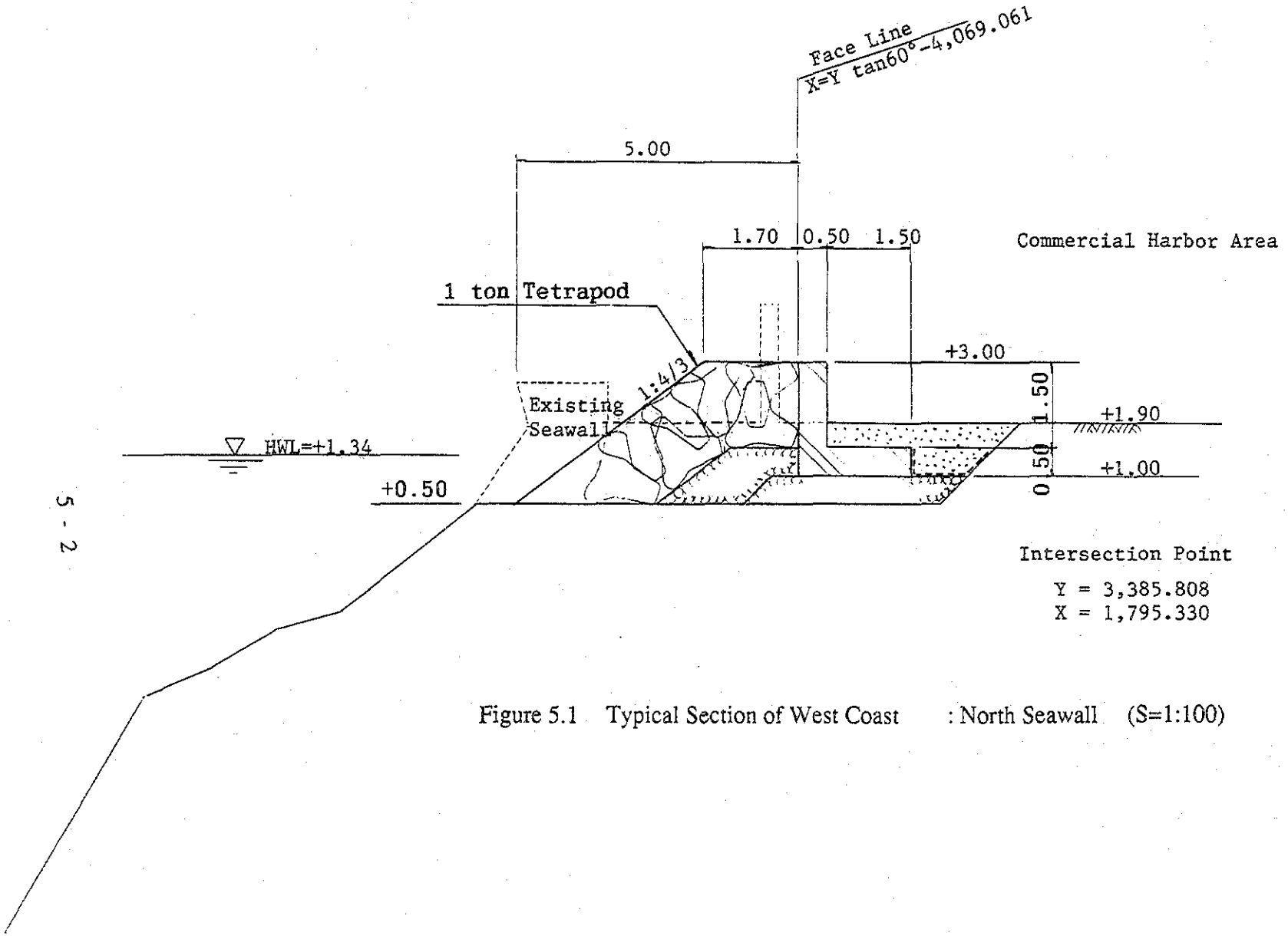


Figure 5.1 Typical Section of West Coast : North Seawall (S=1:100)

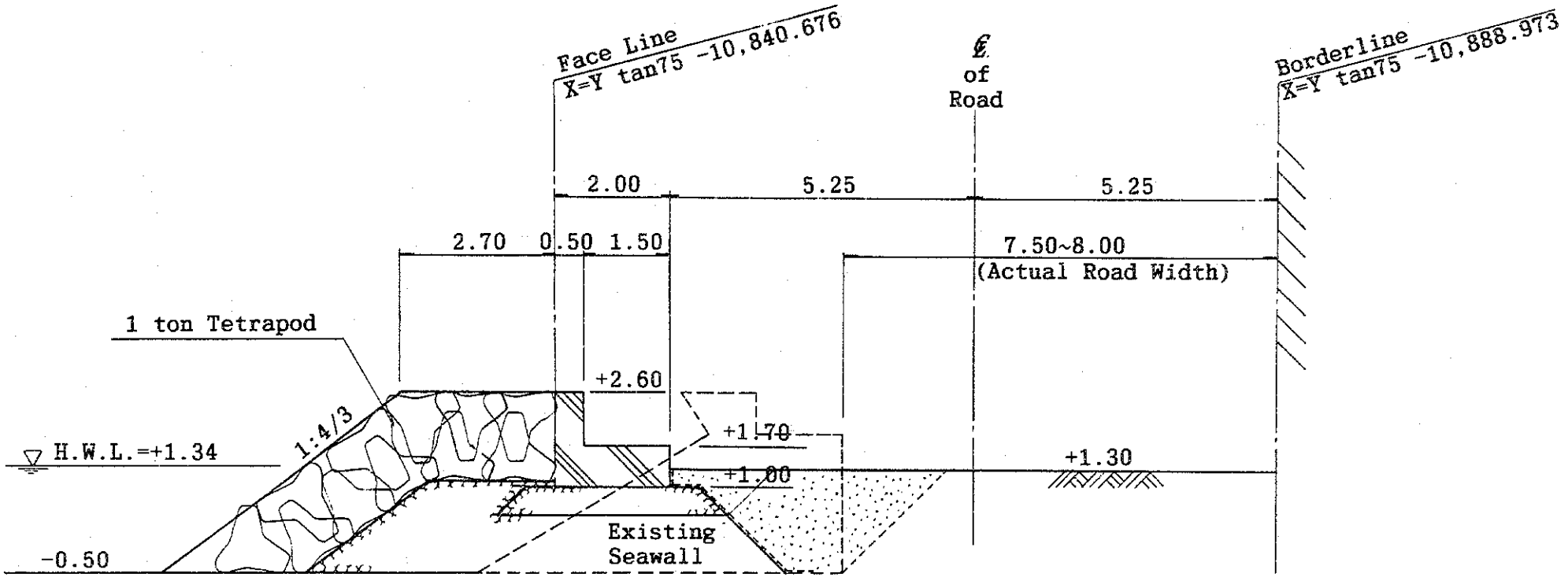


Figure 5.2 Typical Section of West Coast : South Seawall (S=1:100)

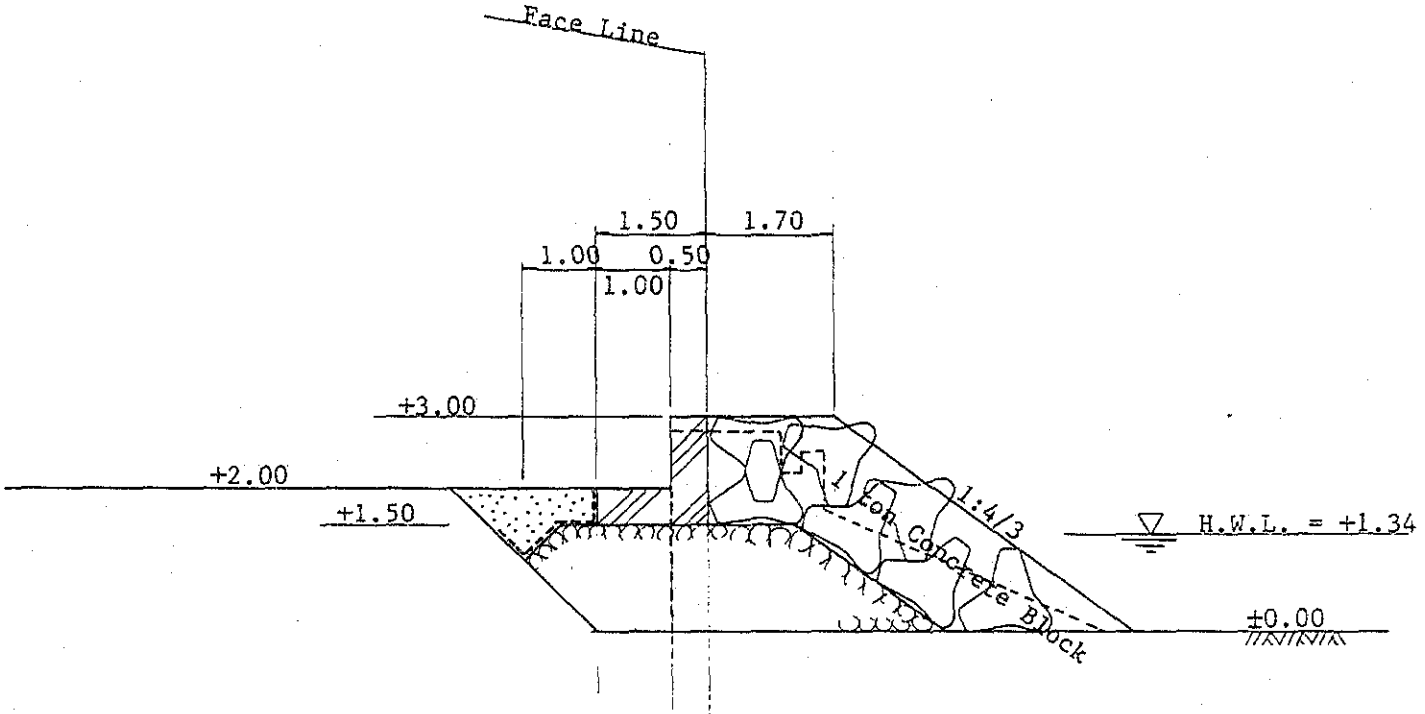


Figure 5.3 Typical Section of East Coast : South Seawall (S=1:100)

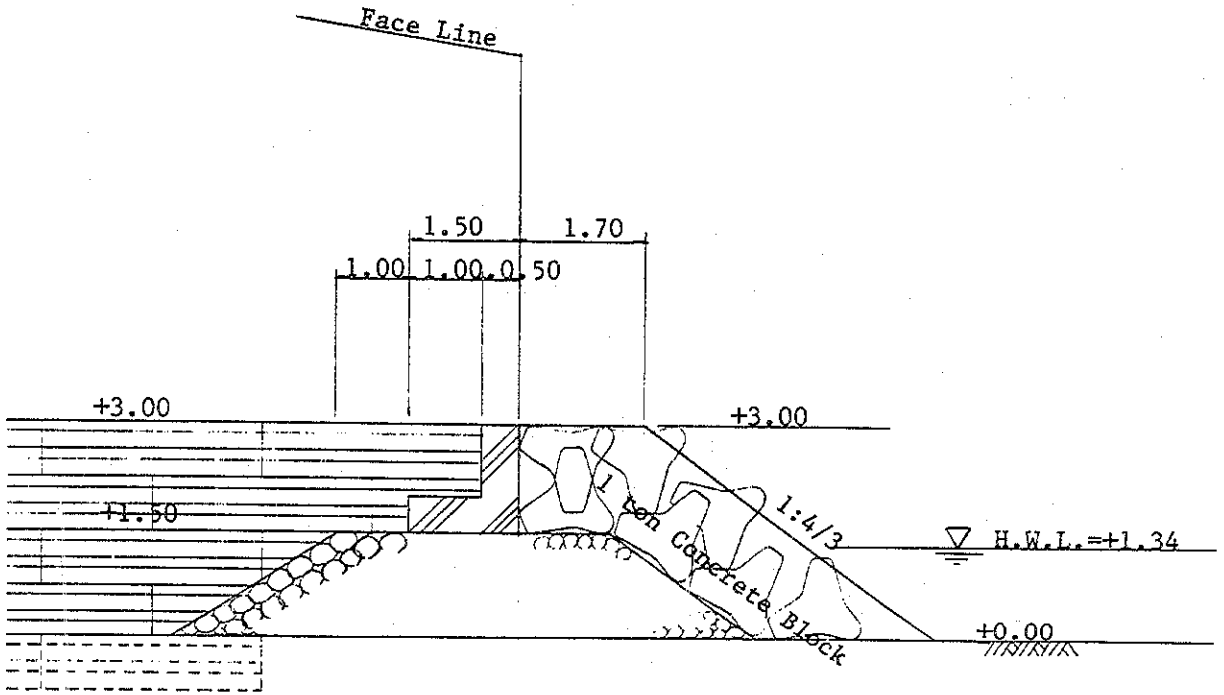


Figure 5.4 Typical Section of East Coast : Groin (S=1:100)

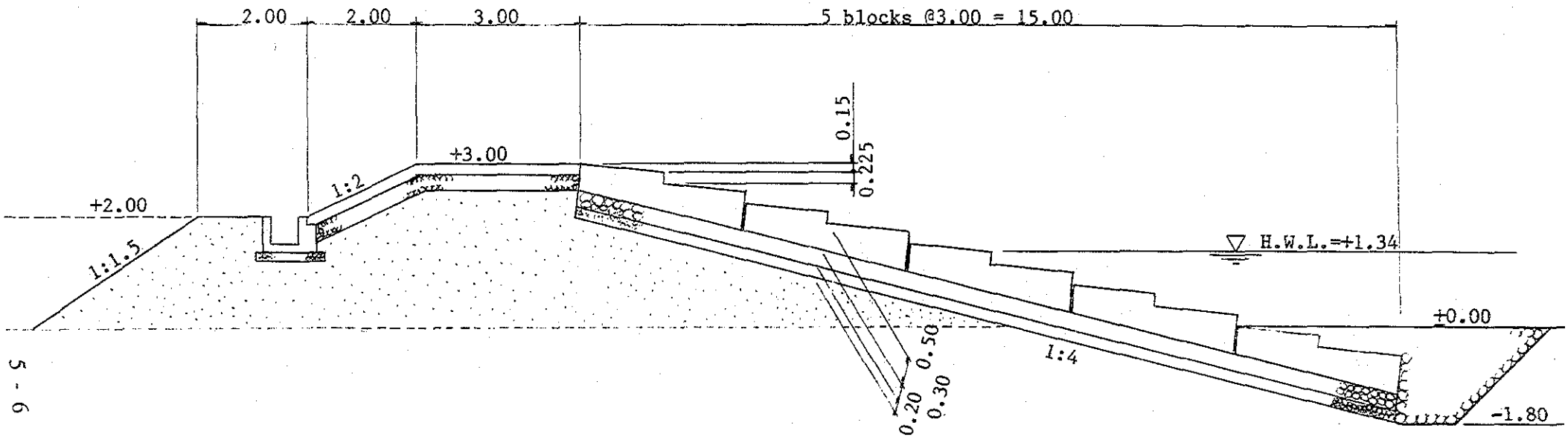


Figure 5.5 Typical Section of East Coast : Stepped Seawall (S=1:100)

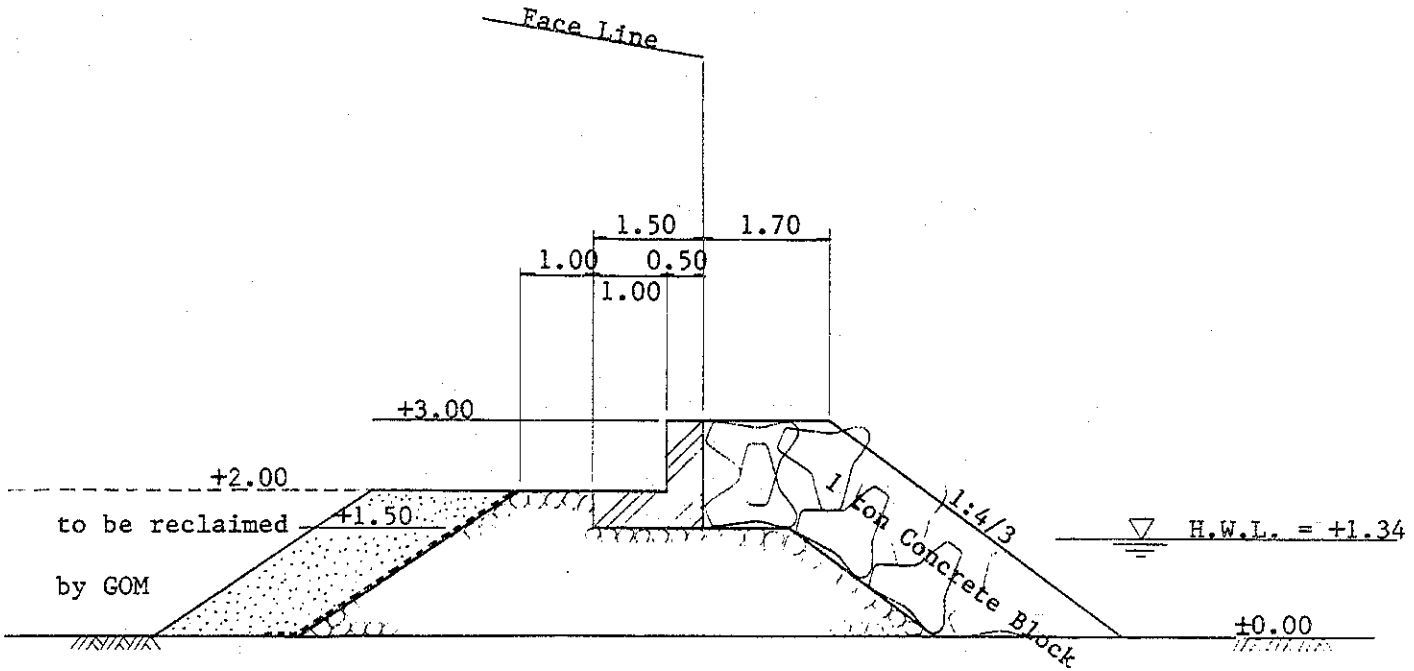


Figure 5.6 Typical Section of East Coast : North Seawall (S=1:100)

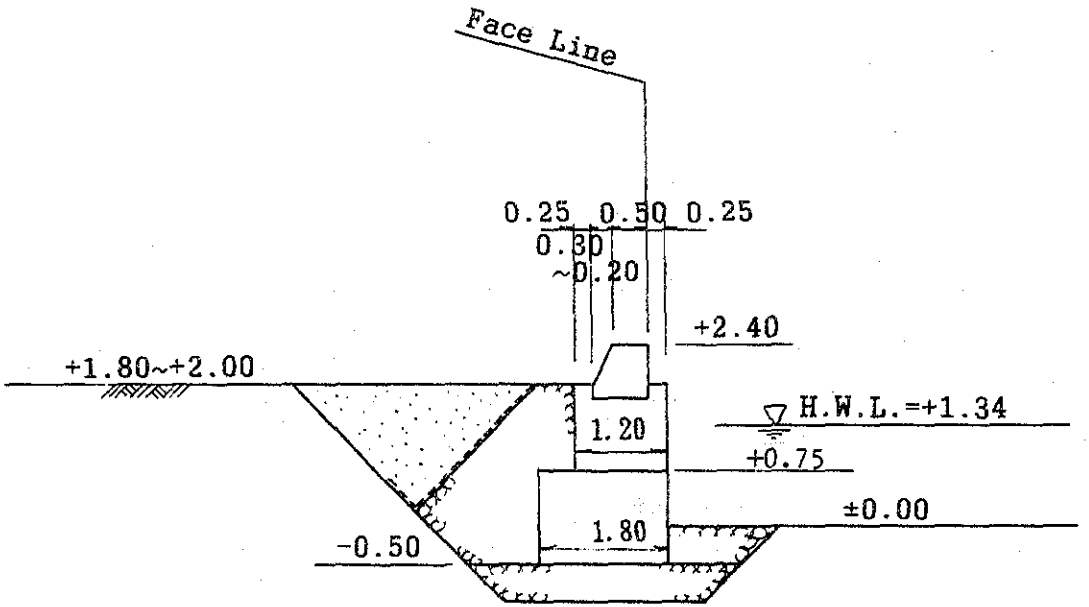


Figure 5.7 Typical Section of South Coast : East Seawall (S=1:100)

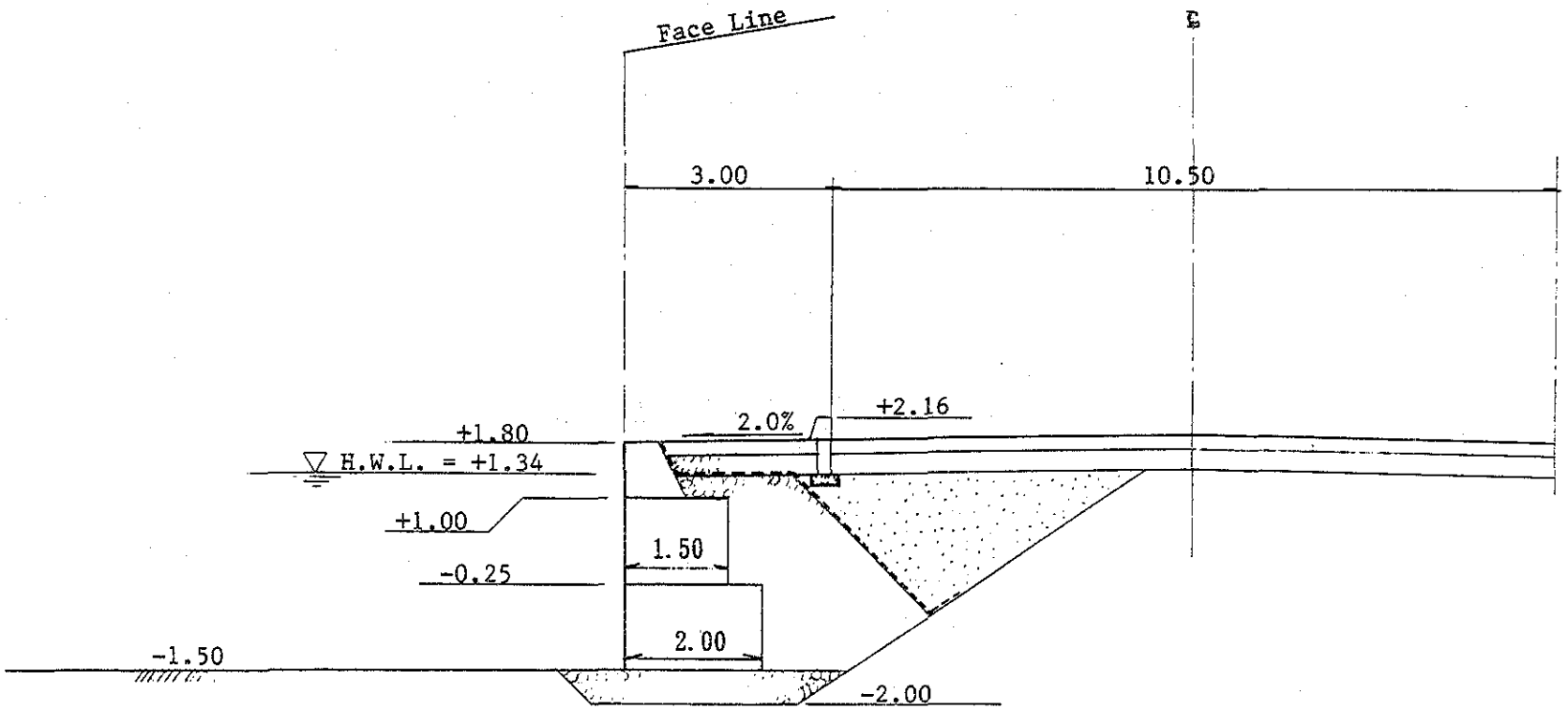


Figure 5.8 Typical Section of South Coast : Center Quaywall (S=1:100)

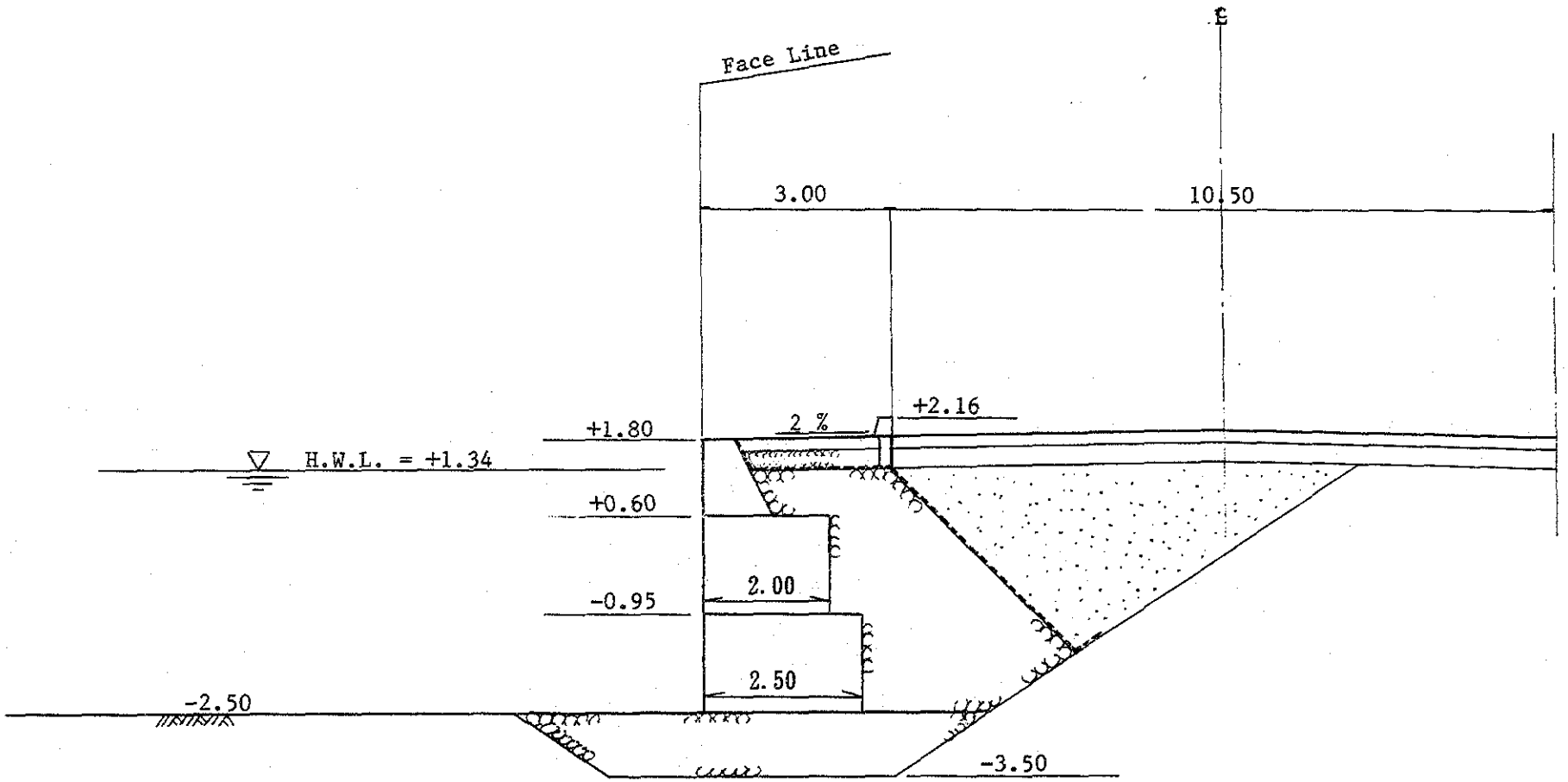


Figure 5.9 Typical Section of South Coast : West Quaywall (S=1:100)

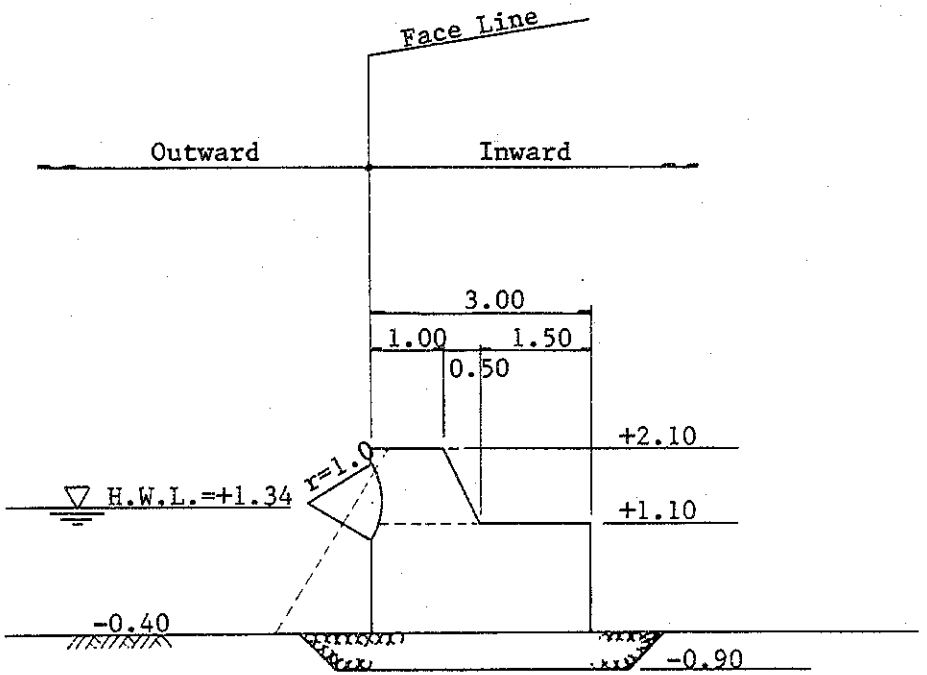


Figure 5.10 Typical Section of North Coast : Breakwater (S=1:100)

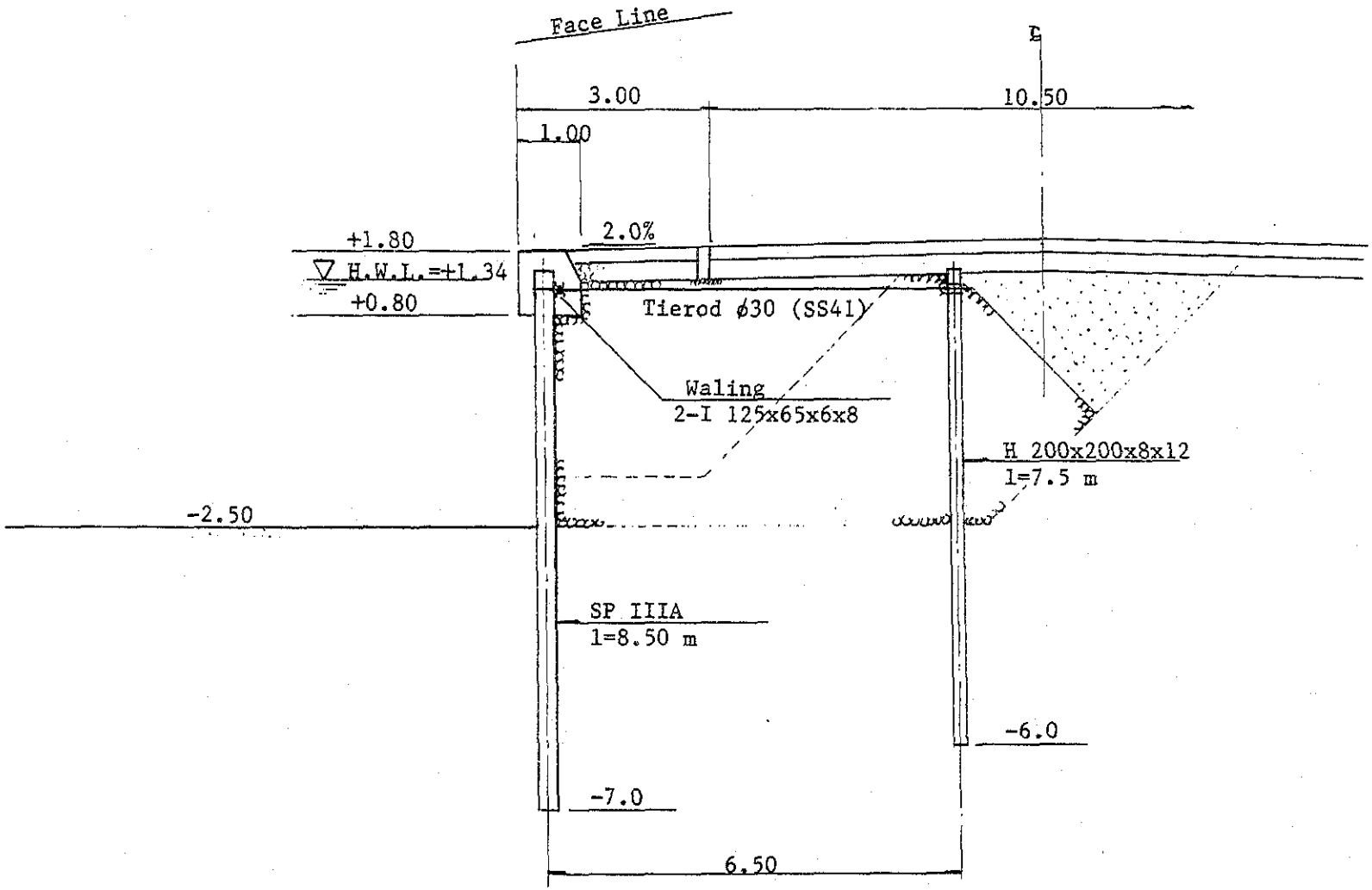


Figure 5.11 Typical Section of South Coast : Alternative Quaywall (S=1:100)

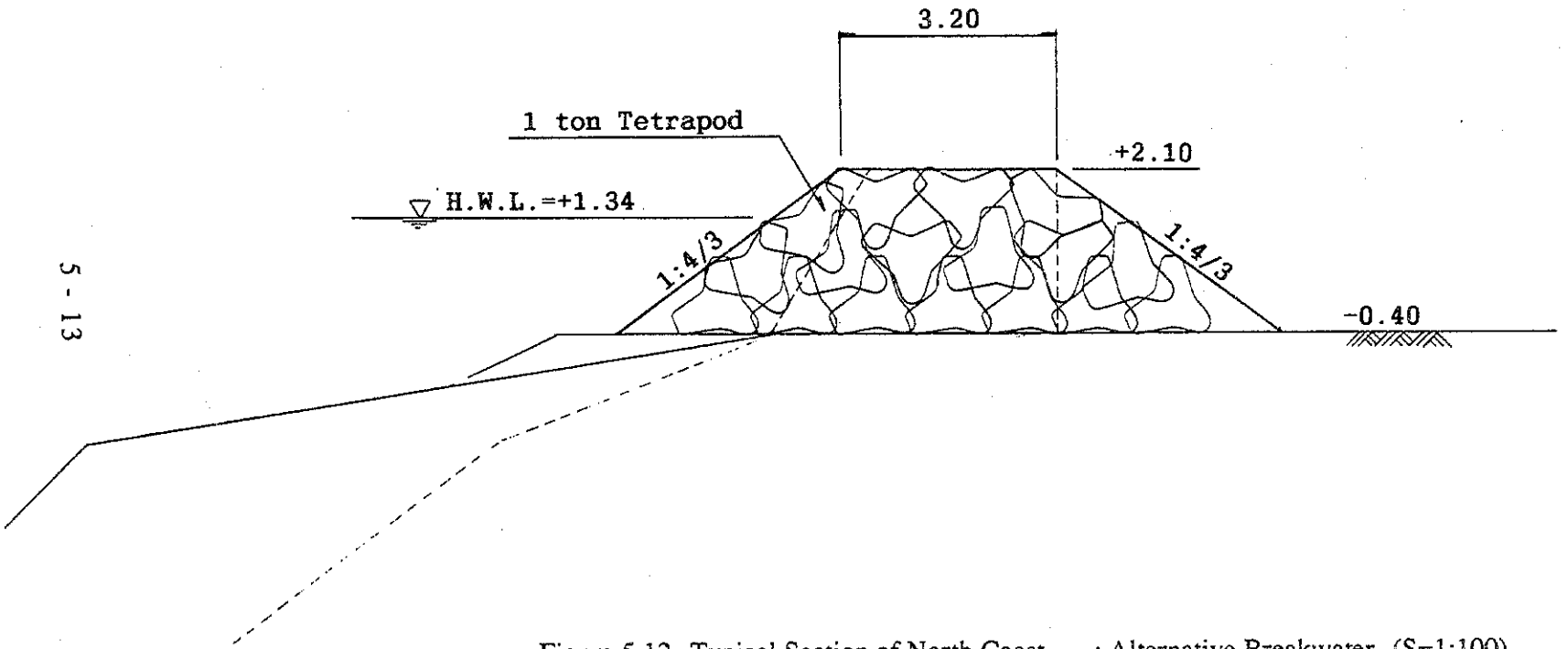


Figure 5.12 Typical Section of North Coast : Alternative Breakwater (S=1:100)

Chapter 6. Cost Study

The cost of each structural type is estimated based on unit price of construction materials, labour cost and equipment cost as shown in Table 6.1 to 12 including alternative structural types.

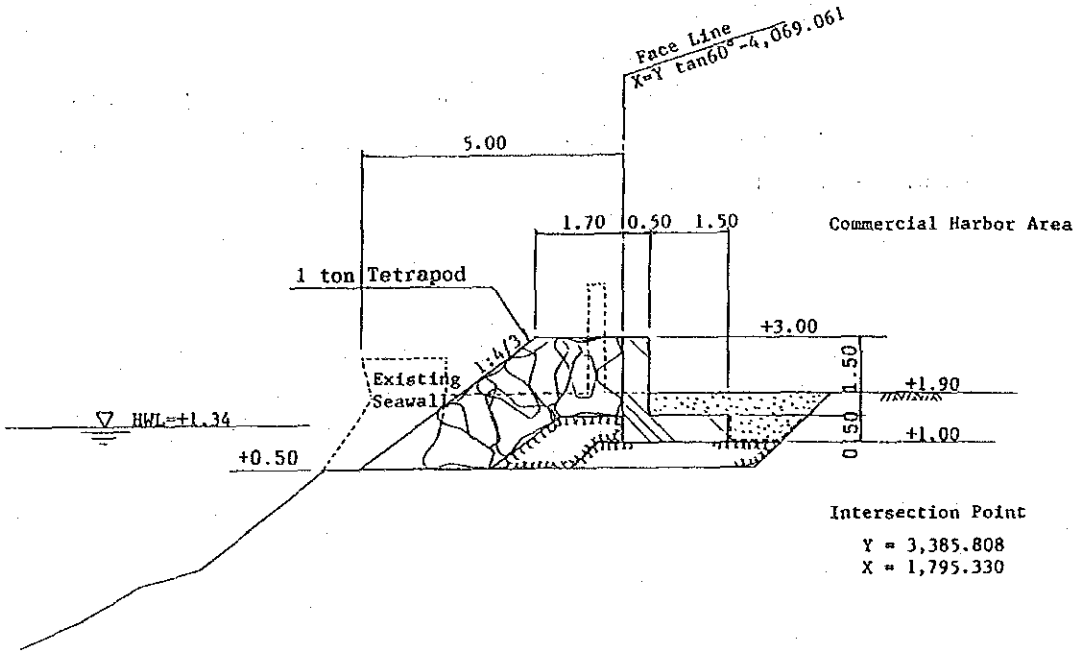


Table 6.1 Unit Cost of West Coast : North Seawall

DIRECT CONSTRUCTION COST (per linear meter)						
West-North Seawall				9V29V92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	1.75	45,707	79,987	Coping
Formwork		s.m.	4.35	2,837	12,341	
Re-bar		ton	0.09	99,810	8,733	
Joint Filling		s.m.	0.35	2,875	1,006	
Precast Concrete Block	1 ton Tetrapod	no.	8.20	41,492	340,234	
Rubble Stone		c.m.	3.24	23,400	75,816	
Levelling		s.m.	5.37	13,422	72,076	
Back Filling		c.m.	1.93	2,416	4,663	
Levelling		s.m.	3.50		0	
Reclamation		c.m.			0	
Geotextile Sheet		s.m.	2.00	2,291	4,582	
Excavation		c.m.	13.67	1,802	24,633	
Pavement		s.m.		0	0	
Demobilization of Exist. Structure		L.S.	1.00	21,446	21,446	
TOTAL					645,519	
		l.m.	254.00	645,519	163,961,721	

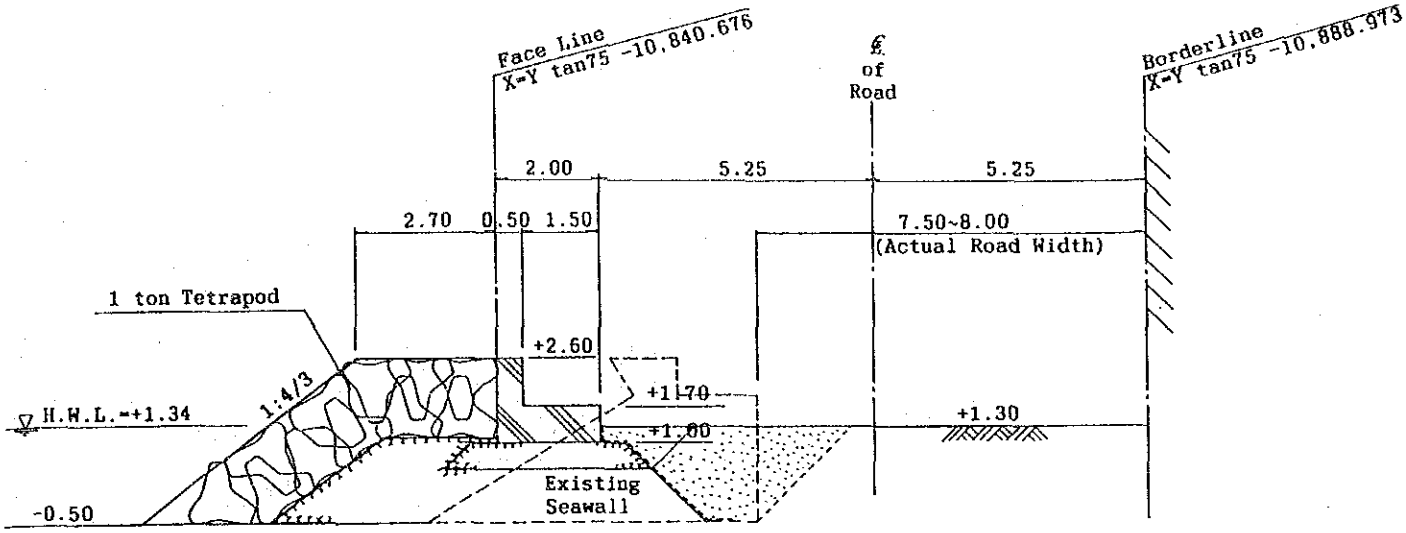


Table 6.2 Unit Cost of West Coast : South Seawall

DIRECT CONSTRUCTION COST (per linear meter)						
West-South Seawall				9/29/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	1.85	43,623	80,703	
Formwork		s.m.	3.57	2,837	10,128	
Re-bar		ton	0.09	99,810	9,232	
Joint Filling		s.m.	0.37	2,875	1,064	
Precast Concrete Block	1 ton Tetrapod	no.	10.10	41,492	419,069	
Rubble Stone		c.m.	9.77	21,893	213,895	
Levelling		s.m.	7.40	13,422	99,323	
Back Filling		c.m.	5.22	909	4,745	
Levelling		s.m.			0	
Reclamation		c.m.			0	
Geotextile Sheet		s.m.	3.50	2,291	8,019	
Excavation		c.m.	13.09	709	9,281	
Pavement		s.m.	0.00	0	0	
Demobilization of Exist. Structure		L.S.	1.00	16,451	16,451	
TOTAL					871,909	
		l.m.	520.00	871,909	453,392,532	

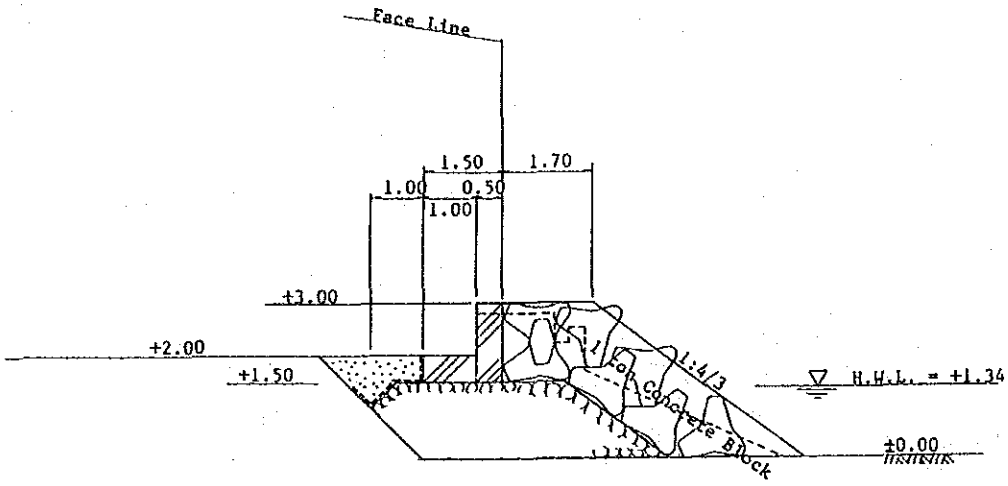


Table 6.3 Unit Cost of East Coast : South Seawall

DIRECT CONSTRUCTION COST (per linear meter)						
East-South Seawall				9/29/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	1.25	43,623	54,529	
Formwork		s.m.	3.25	2,837	9,220	
Re-bar		ton	0.06	99,810	6,238	
Joint Filling		s.m.	0.25	2,875	719	
Precast Concrete Block	1 ton Tetrapod	no.	9.75	32,573	317,587	
		c.m.	0.00	0	0	
		no.	0.00	0	0	
Rubble Stone		c.m.	6.38	21,893	139,568	
Levelling		s.m.	4.99	404	2,016	
Back Filling		c.m.	1.13	924	1,040	
Levelling		s.m.	2.00	404	808	
Reclamation		c.m.			0	
Geotextile Sheet		s.m.	2.21	2,285	5,050	
Excavation		c.m.		0	0	
Pavement		s.m.		0	0	
Demobilization of Exist. Structure		L.S.	1.00	16,451	16,451	
TOTAL		l.m.			553,225	
		l.m.	359.97	180,456	64,958,746	

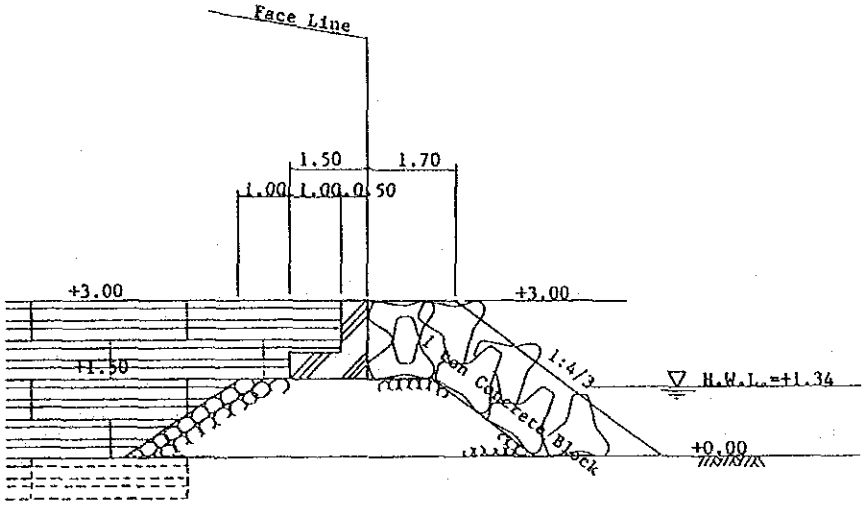


Table 6.4 Unit Cost of East Coast : Groin

DIRECT CONSTRUCTION COST (per linear meter)						
Groin				9/29/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	1.25	43,623	54,529	Coping
Formwork		s.m.	3.25	2,837	9,220	
Re-bar		ton	0.06	99,810	6,238	
Joint Filling		s.m.	0.25	2,875	719	
Precast Concrete Block	1 ton Tetrapod	no.	9.75	32,573	317,587	
		no.				
		no.				
Rubble Stone		c.m.	8.74	21,893	191,345	
Levelling		s.m.	4.99	404	2,016	
Back Filling		c.m.				
Levelling		s.m.				
Reclamation		c.m.				
Geotextile Sheet		s.m.				
Excavation		c.m.				
Pavement		s.m.				
Demobilization of Exist. Structure		L.S.				
TOTAL		l.m.			581,653	
		l.m.	61.00	581,653	35,480,858	

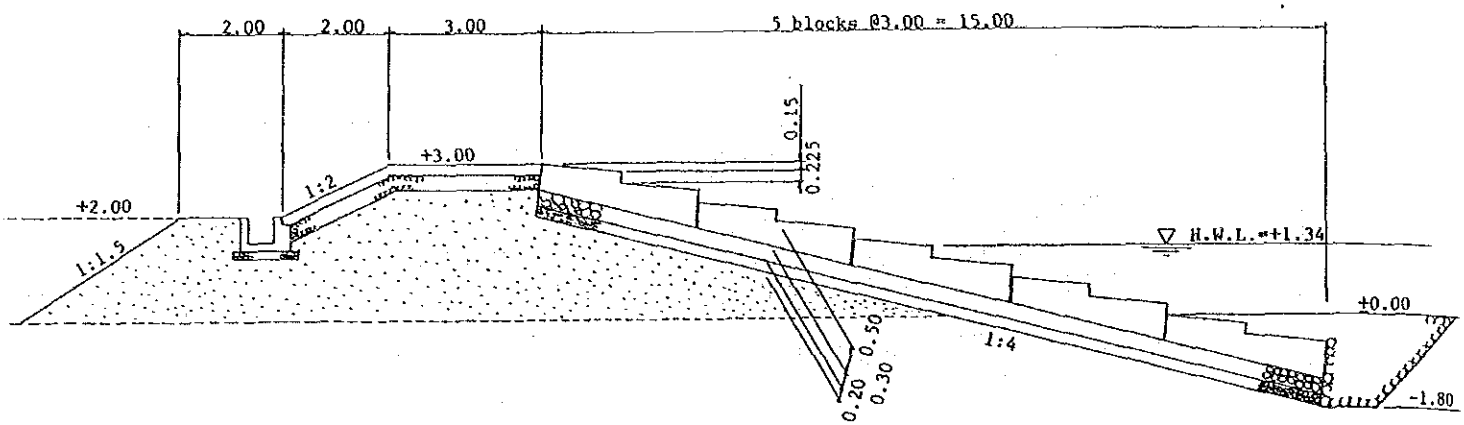


Table 6.5 Unit Cost of East Coast : Stepped Seawall

DIRECT CONSTRUCTION COST (per linear meter)						
East Stepped Seawall				9/30/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	0.19	43,623	8,288	Coping
Formwork		s.m.	2.00	2,837	5,674	
Joint Filling		s.m.	0.19	2,875	552	
Precast Concrete Block		no.	1.67	276,027	460,045	
	Transpo/Installation	no.	1.67	14,959	24,932	
Rubble Stone		c.m.	7.65	21,893	167,481	
Levelling		s.m.	36.80	6,913	254,398	
Back Filling		c.m.	25.82	924	23,858	
Levelling		s.m.			0	
Reclamation		c.m.	0.00	0	0	
Geotextile Sheet		s.m.	0.00	0	0	
Excavation		c.m.	1.62	1,530	2,479	
Pavement		s.m.	5.24	18,927	99,177	
Demobilization of Exist. Structure		L.S.	0.00	0	0	
TOTAL					1,046,885	
		l.m.	149.23	1,046,885	156,226,596	

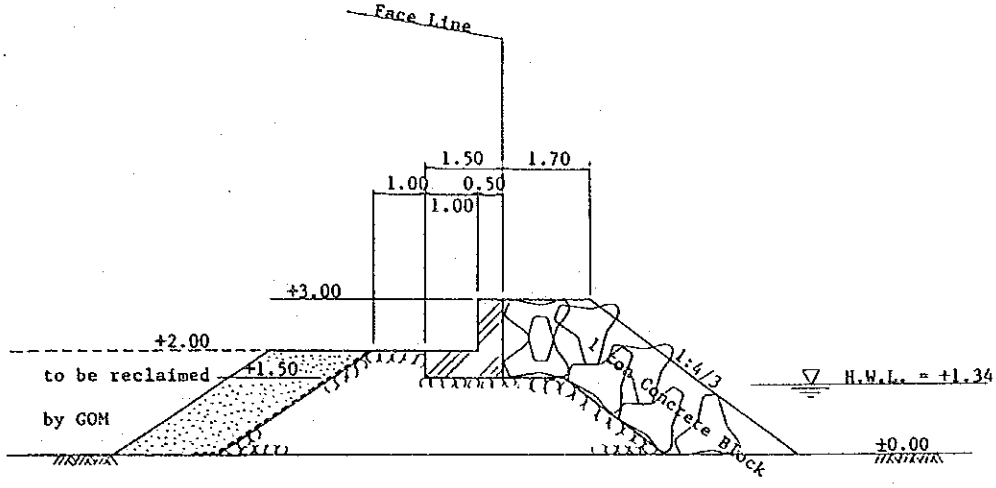


Table 6.6 Unit Cost of East Coast : North Seawall

DIRECT CONSTRUCTION COST (per linear meter)						
East-North Seawall				9/30/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	1.25	43,623	54,529	
Formwork		s.m.	3.25	2,837	9,220	
Re-bar		ton	0.06	99,810	6,238	
Joint Filling		s.m.	0.25	2,875	719	
Precast Concrete Block	1 ton Tetrapod	no.	9.75	32,573	317,587	
		c.m.	0.00	0	0	
		c.m.	0.00	0	0	
Rubble Stone		c.m.	10.55	21,893	230,971	
Levelling		s.m.	4.99	404	2,016	
Back Filling		c.m.	4.00	924	3,696	
Levelling		s.m.			0	
Reclamation		c.m.			0	
Geotextile Sheet		s.m.	4.97	2,285	11,356	
Excavation		c.m.		0	0	
Pavement		s.m.		0	0	
Demobilization of Exist. Stucture		L.S.		0	0	
TOTAL		l.m.	0	0	636,332	
		l.m.	579.25	636,332	368,595,418	

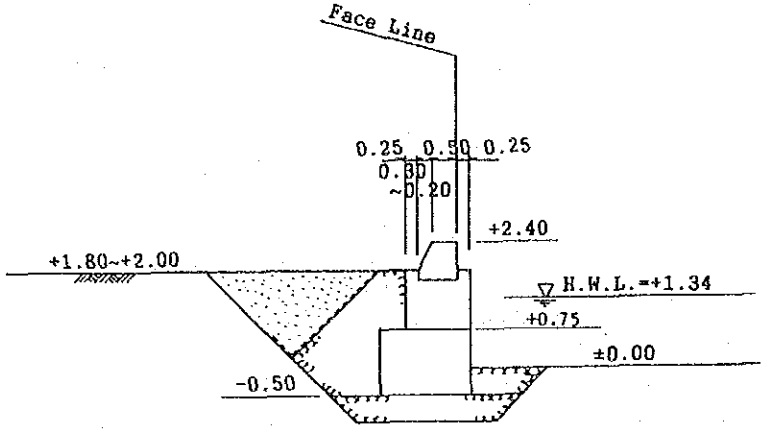


Table 6.7 Unit Cost of South Coast : East Seawall

DIRECT CONSTRUCTION COST (per linear meter)						
South-East Seawall				9/30/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	0.38	43,623	16,577	Coping
Formwork		s.m.	1.33	2,837	3,762	
Joint Filling		s.m.	0.08	2,875	219	
Precast Concrete Block		no.	0.00	0	0	
	2.0*1.25*2.0	no.	0.50	236,696	118,348	
		no.	0.50	22,733	11,367	
	1.5*1.25*2.0	no.	0.50	180,511	90,256	
		no.	0.50	22,733	11,367	
Rubble Stone		c.m.	2.38	21,893	52,105	
Levelling		s.m.	2.50	13,422	33,555	
Back Filling		c.m.	3.19	21,893	69,839	
Levelling		s.m.			0	
Reclamation		c.m.	3.06	909	2,782	
Geotextile Sheet		s.m.	2.97	2,291	6,804	
Excavation		c.m.	10.64	2,239	23,823	
Pavement		s.m.		0	0	
Demobilization of Exist. Structure		L.S.	1.00	16,451	16,451	
TOTAL					457,252	
		l.m.	287.00	457,252	131,231,434	

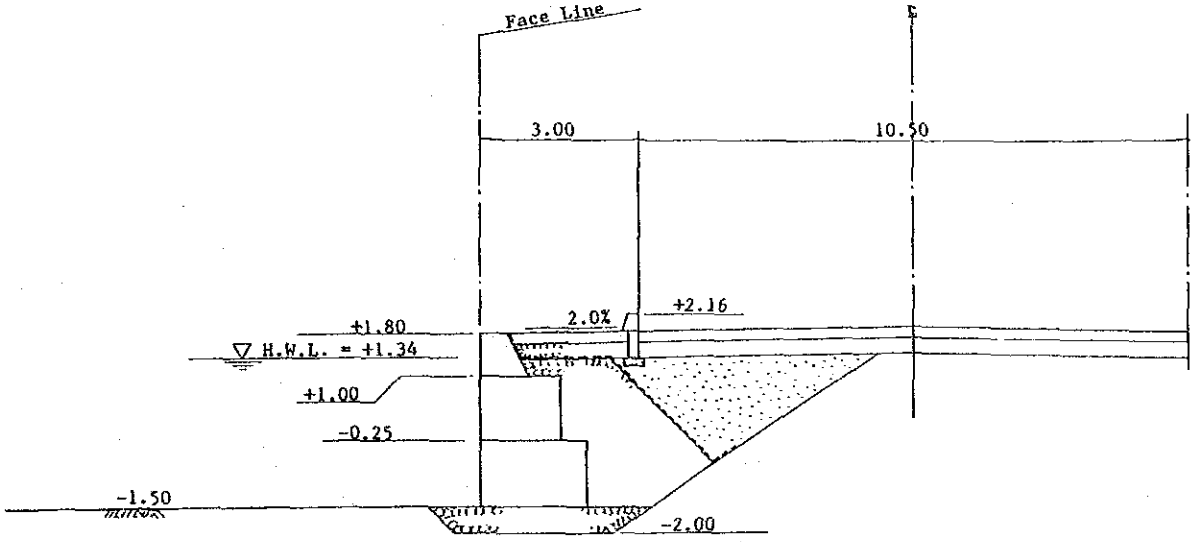


Table 6.8 Unit Cost of South Coast : Center Quaywall

DIRECT CONSTRUCTION COST (per linear meter)						
South Quaywall-2				9/30/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	0.96	43,623	41,878	Coping
Formwork		s.m.	2.73	2,837	7,751	
Joint Filling		s.m.	0.19	2,875	552	
Precast Concrete Block		no.	0.00	0	0	
Fabrication	1.5*1.25*2.0	no.	0.50	180,511	90,256	
Transportation/Installation		no.	0.50	22,733	11,367	
Fabrication	2.0*1.25*2.0	no.	0.50	236,696	118,348	
Transportation/Installation		no.	0.50	22,733	11,367	
Rubble Stone		c.m.	1.81	21,893	39,626	
Levelling		s.m.	2.50	13,422	33,555	
Back Filling		c.m.	5.48	21,893	119,974	
Levelling		s.m.			0	
Reclamation		c.m.	5.41	909	4,918	
Geotexile Sheet		s.m.	5.71	2,291	13,082	
Excavation		c.m.	3.90	2,239	8,732	
Pavement		s.m.	2.50	18,927	47,318	
Demobilization of Exist. Structure		L.S.	1.00	16,451	16,451	
TOTAL					565,172	
		l.m.	380.54	565,172	215,070,604	

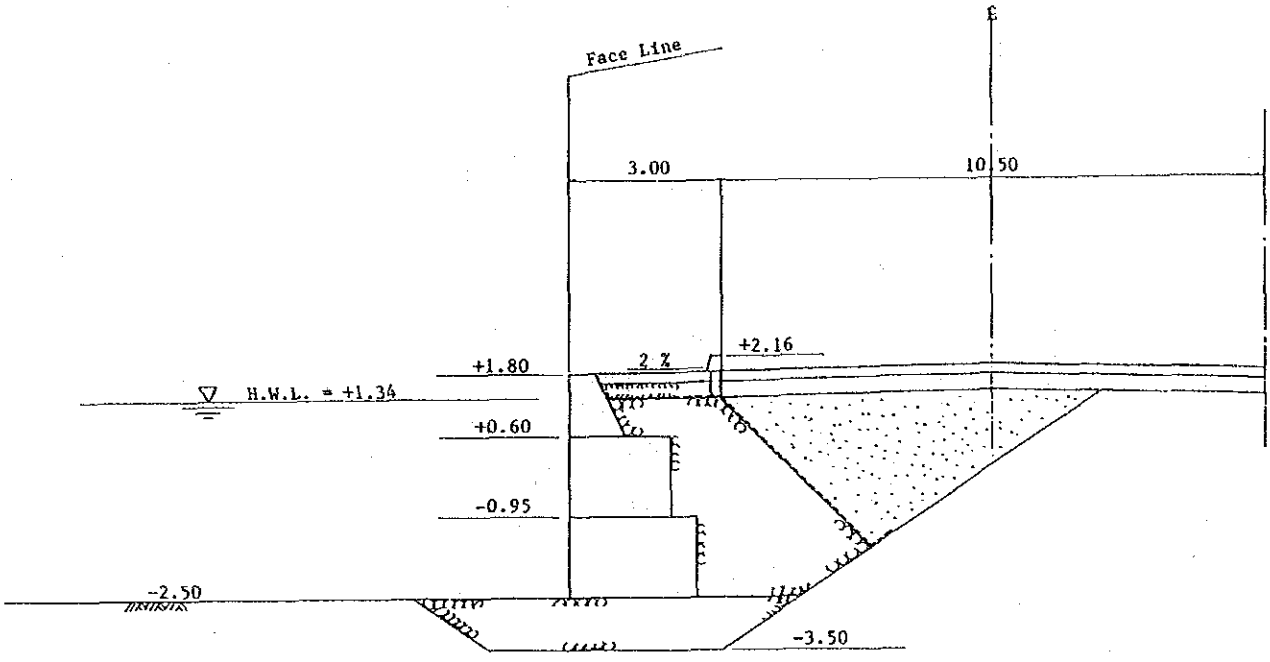


Table 6.9 Unit Cost of South Coast : West Quaywall

DIRECT CONSTRUCTION COST (per linear meter)						
South Quaywall				9/30/92	Unit : JPN Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	0.96	43,623	41,878	Coping
Formwork		s.m.	2.73	2,837	7,751	
Joint Filling		s.m.	0.19	2,875	552	
Precast Concrete Block		no.	0.00	0	0	
Fabrication	2.0*1.55*2.0	no.	0.50	292,615	146,308	
Transportation/Installation		no.	0.50	22,733	11,367	
Fabrication	2.5*1.55*2.0	no.	0.50	362,297	181,149	
Transportation/Installation		no.	0.50	22,733	11,367	
Rubble Stone		c.m.	6.00	21,893	131,358	
Levelling		s.m.	4.00	13,422	53,688	
Back Filling		c.m.	10.05	21,893	220,025	
Levelling		s.m.	0.00		0	
Reclamation		c.m.	11.25	909	10,226	
Geotextile Sheet		s.m.	7.51	2,291	17,205	
Excavation		c.m.	21.09	2,239	47,221	
Pavement		s.m.	2.50	18,927	47,318	
Demobilization of Exist. Structure		L.S.	1.00	16,451	16,451	
TOTAL					943,861	
		l.m.	841.29	943,861	794,060,891	
		l.m.	1,221.83	943,861	1,153,237,788	

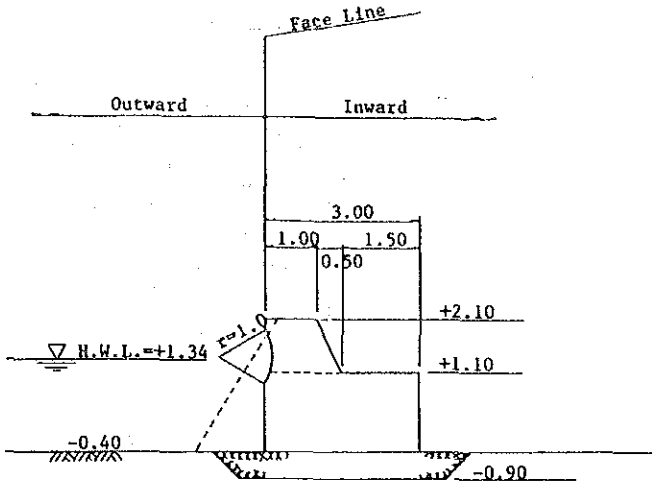


Table 6.10 Unit Cost of North Coast : Breakwater

DIRECT CONSTRUCTION COST (per linear meter)						
North Breakwater (Concrete Block Type)				9/30/92	Unit : JPN Yen	
WORK ITEM	*SIZE/SPEC.*	*UNIT*	*QUANTITY*	*UNIT PRICE*	*AMOUNT*	*REMARKS*
Cast-in-situ Concrete		c.m.	0.00	0	0	
Formwork		s.m.	0.00	0	0	
Joint Filling		s.m.	0.00	0	0	
Precast Concrete Block		no.	1.00	275,938	275,938	
	Transpo/Installation	no.	1.00	78,884	78,884	
Rubble Stone		c.m.	2.25	23,400	52,650	
Levelling		s.m.	5.00	13,422	67,110	
Back Filling		c.m.			0	
Levelling		s.m.			0	
Reclamation		c.m.			0	
Geotextile Sheet		s.m.			0	
Excavation		c.m.	2.25	3,074	6,917	
Pavement		s.m.			0	
Demobilization of Exist. Structure		L.S.	1.00	21,446	21,446	
TOTAL					502,945	
		l.m.	1,291.00	502,945	649,301,350	

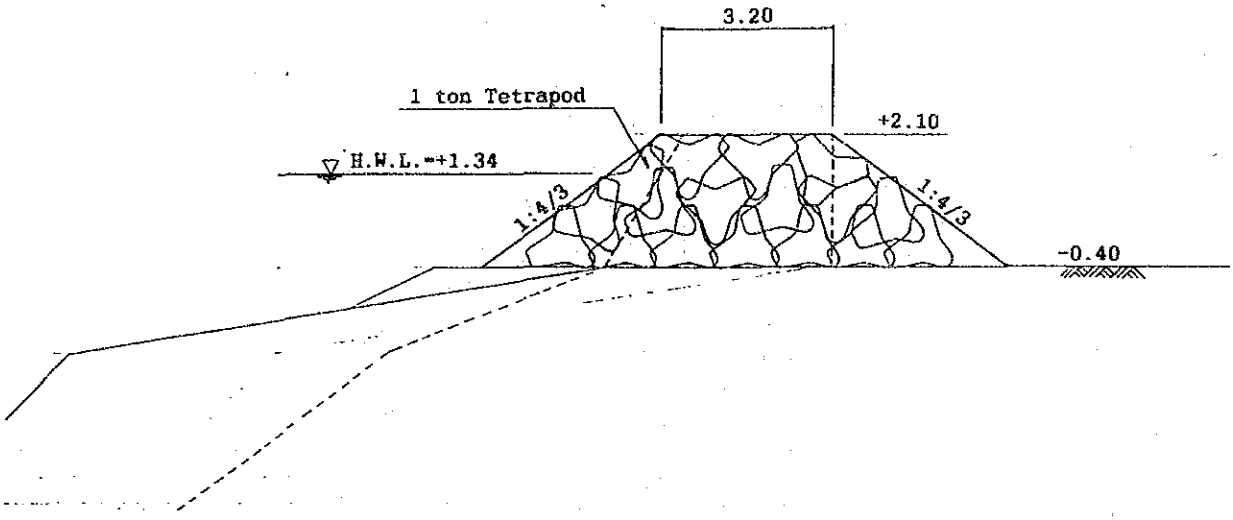


Table 6.11 Unit Cost of South Coast : Alternative Quaywall

DIRECT CONSTRUCTION COST (per linear meter)						
North Breakwater (Armour Block Mound Type)				9/30/92	Unit : Jpn Yen	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.			0	
Precast Concrete Block	1 ton Tetrapod	no.	20.40	32,573	664,489	
Rubble Stone		c.m.			0	
Levelling		s.m.			0	
Back Filling		c.m.			0	
Levelling		s.m.			0	
Reclamation		c.m.			0	
Geotextile Sheet		s.m.			0	
Excavation		c.m.			0	
Pavement		s.m.			0	
Demobilization of Exist. Structure		L.S.	1.00	21,446	21,446	
TOTAL					685,935	
		l.m.	833.00	685,935	571,384,022	

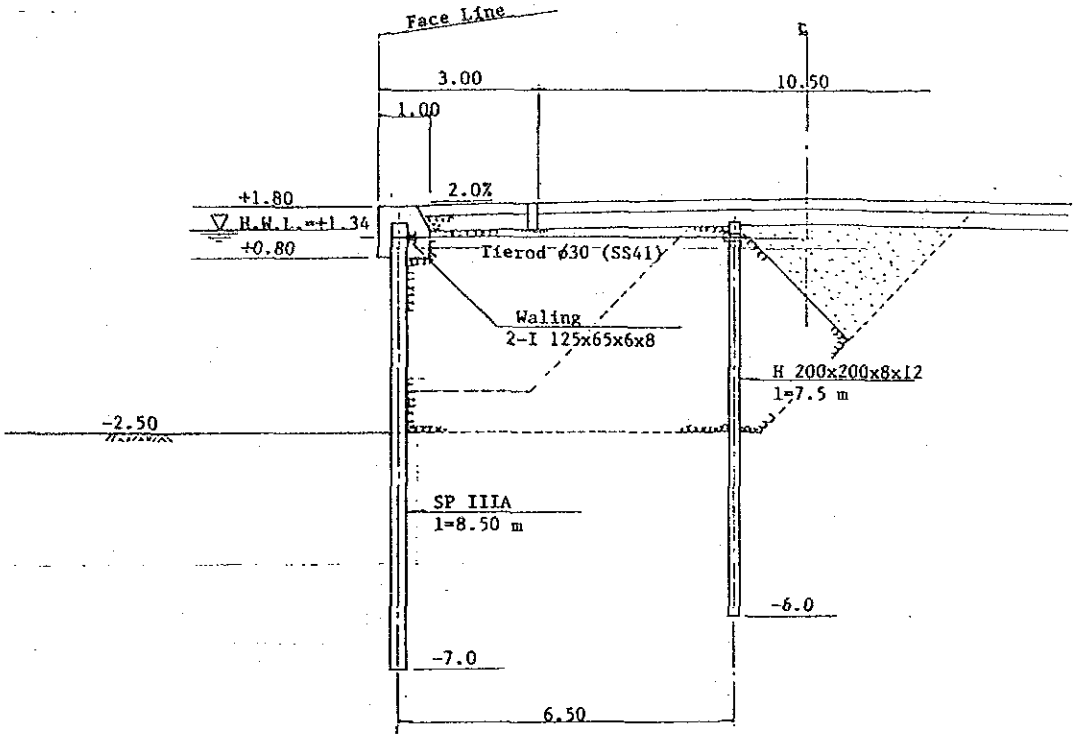


Table 6.12 Unit Cost of North Coast : Alternative Breakwater

DIRECT CONSTRUCTION COST (per linear meter)						
South Quaywall-SSP					Unit : US $	
WORK ITEM	SIZE/SPEC.	UNIT	QUANTITY	UNIT PRICE	AMOUNT	REMARKS
Cast-in-situ Concrete		c.m.	0.95	43,623	41,442	Coping
Formwork		s.m.	3.00	2,837	8,511	
Re-bar		ton	0.05	99,810	4,791	
Joint Filling		s.m.	0.19	2,875	546	
Steel Sheet Pile	SP IIIA l=8.5 m	t	1.24	0	0	
Pile Driving		no.	2.50	93,609	234,023	
Cathodic Protedtion		l.m.	1.00	83,603	83,603	
Waling	2[-125*65*6*8	t	0.03	0	0	
Installation		m	1.00	4,419	4,419	
Tie Rod	ø 30 (SS 41)	no.	0.63	36,107	22,567	
Installation		no.	0.63		0	
Anchor Pile	H-200*200*8*12	t	0.23	0	0	
Pile Driving	l=7.5 m	no.	0.63	54,130	33,831	
Rubble Stone		c.m.	0.00	0	0	
Levelling		s.m.	0.00	0	0	
Back Filling		c.m.	26.00	21,893	569,218	
Levelling		s.m.	4.00	404	1,616	
Reclamation		c.m.	11.25	909	10,226	
Geotextile Sheet		s.m.	0.00	0	0	
Excavation		c.m.	36.24	2,239	81,141	
Pavement		s.m.	2.00	18,927	37,854	
Demobilization of Exist. Structure		L.S.	1.00	16,451	16,451	
TOTAL					1,150,240	
		l.m.	841.29	1,150,240	967,685,065	
		l.m.	1,221.83	1,150,240	1,405,397,238	

Chapter 7. Organization and Management

7.1 Organization Charts

7.1.1 Government of the Republic of Maldives (GOM)

The organization chart of the Government of the Republic of Maldives as of September 1991 is shown in Fig. 7.1.

7.1.2 Ministry of Public Works and Labour (MPWL)

The organization chart of the Ministry of Public Works and Labour is shown in Fig. 7.2.

7.1.3 Ministry of Planning and Environment (MPE)

The organization chart of the Ministry of Planning and Environment is shown in Fig. 7.3.

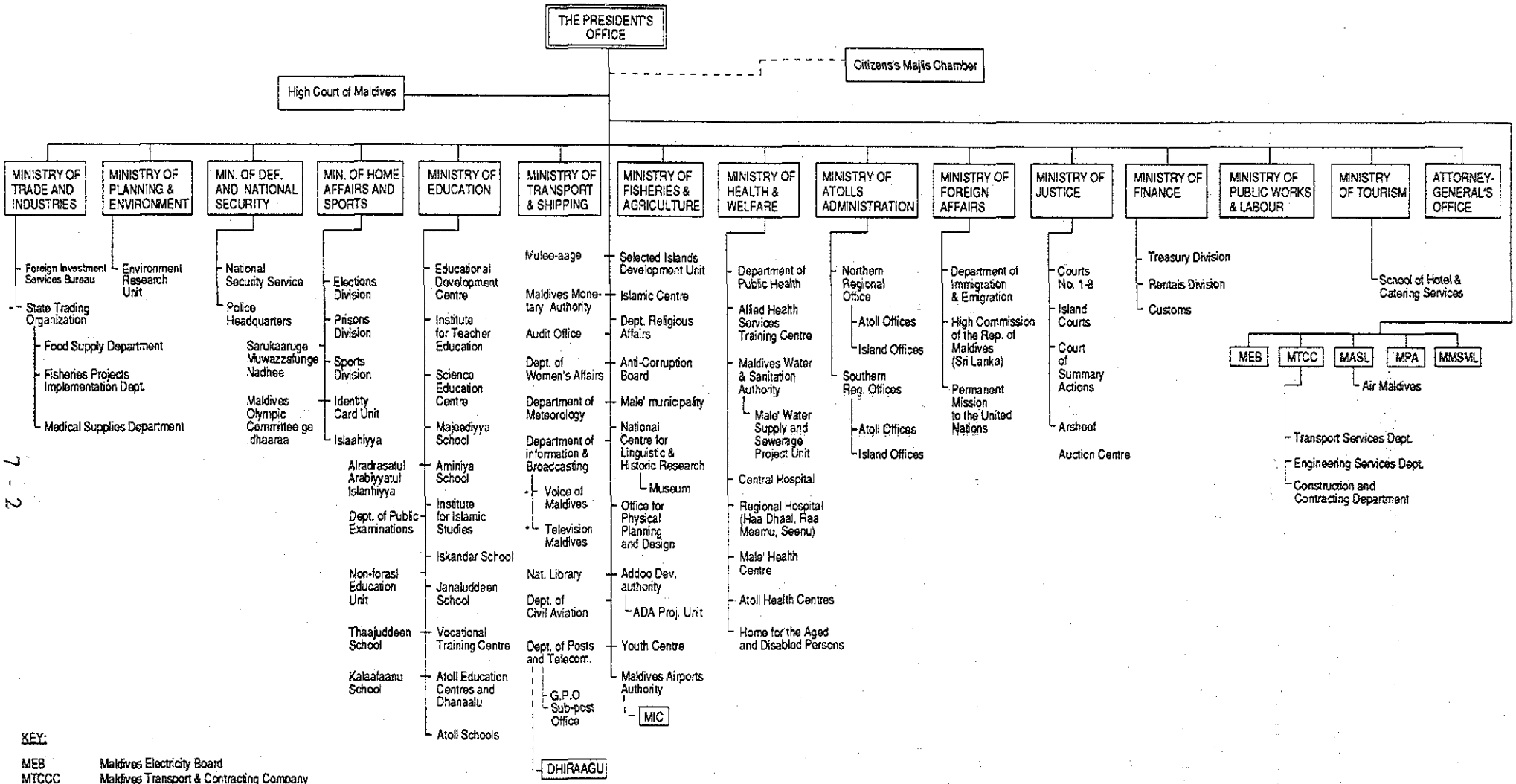


Figure 7.1 Government of the Republic of Maldives

Figure 7.2 Ministry of Public Works and Labour: MPWL

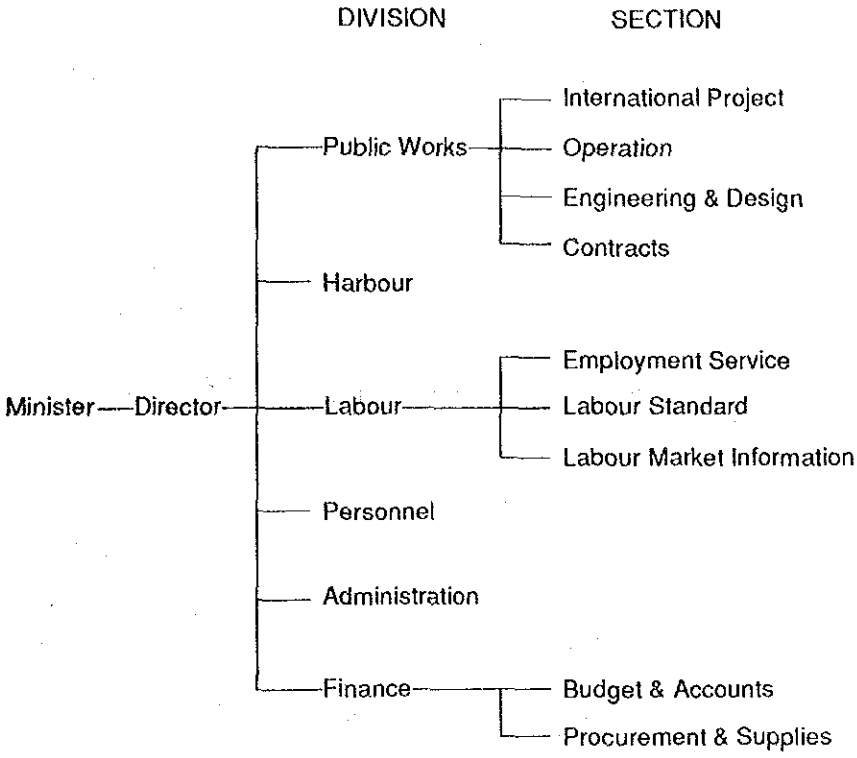
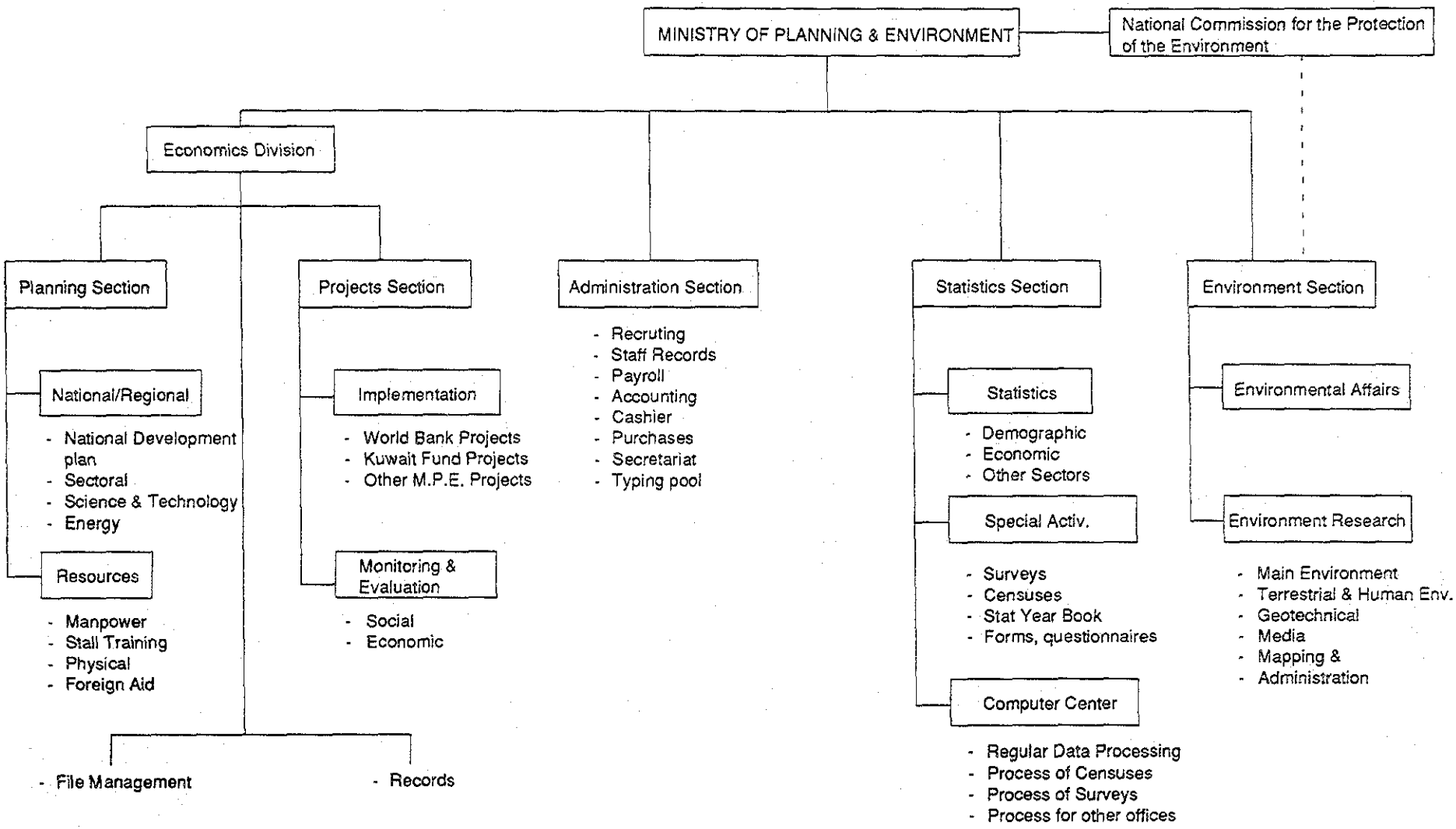


Figure 7.3 Ministry of Planning and Environment



7.2 Job Description of the MPWL

(1) Public Works Division (PWD)

a) Operations Section

1) Dredging of island harbours
2) Implementing all major civil works in Male'
3) Construction of Male' breakwater
4) Supervising the Public Works' workshop

b) Engineering and Design Section

1) Preparation of BOQ and structural calculations.
2) Designing and preparation of structural and architectural drawings.
3) Maintaining engineering standards.
4) Supervising structural aspects of civil works project which are implemented by the ministry.
5) preparing survey plans of islands (topographic, hydrographic, shore-line, harbour, etc.).
6) Collecting oceanographic data.

c) International Projects Section

1) Implementation of all international funded construction projects.
2) Handling of loans from international organizations for construction projects.

d) Contracts Section

1) Preparation of tender documents for government funded construction projects which exceed Rf. 50,000.
2) Announcement and invitation of tenders on behalf of the related government sectors.
3) Checking and forwarding of the completed tender documents submitted by the contractors to the Tender Evaluation Board (TEB).
4) Arranging and conducting meetings of the TEB.
5) Arranging for inspection by the members of TEB of the completed projects.

(2) Labour Division

a) Employment Services Section

1) Issuing work permits for expatriates to work in the Maldives.

b) Labour Standards Section

1) Drafting and implementing labour codes.
2) Investigating and solving employer-employee (expatriate) disputes.
3) Inspecting the violation of conditions of working visas.

c) Labour Market Information Section

1) Recording statistics of all expatriate workers in Maldives.
2) Collecting and analyzing labour market information.

(3) Harbour Division

a) Administration Section

1) Responsible for all administration works of the division.

b) Harbour Operation Section

1) Allocating space for mooring and dry-docking of vessels.

c) Harbour Maintenance Section

1) Repair and maintenance of seawall, harbour and dry-docking area of Male'.
2) Monitoring aggregate and sand mining operations around Male'.
3) Maintenance of law and order within Male' inner harbour.
4) Identifying and solving any problems regarding Male' inner harbour.

(4) Personnel Division

a) Carrying out all duties of the ministry regarding the staff.

5) Administration Division

a) Carrying out all administration duties of the ministry.

(6) Financial Division

a) Budget and Accounts Section

1) Maintaining and checking of budget expenditure.
2) Monitoring of the capital assets of the ministry.
3) Repair and maintenance of the ministry and its related buildings.

b) Procurement and Supplies Section

1) Acquisition of the necessary supplies and materials required for the ministry and projects.