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3rd Report

VOLUME FOUR : SUPPORTING REPORT-2

Third Report of
The Study on Tsunami Recovery, Rehabilitation
and Development of Islands in Maldives

February 2006

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The Study on Tsunami Recovery, Rehabilitation and Development of Islands in Maldives
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THE THIRD REPORT OF
THE STUDY ON TSUNAMI RECOVERY, REHABILITATION AND DEVELOPMENT OF ISLANDS IN THE MALDIVES

TABLE OF CONTENTS

3rd Report
The Study on Tsunami Recovery, Rehabilitation and Development of Islands in the Republic of Maldives

VOLUME ONE: SUMMARY REPORT

VOLUME TWO: MAIN REPORT

PART TWO: Project Descriptions

VOLUME TRHEE: SUPPORTING REPORT-1: Tender Documents for Short-term Projects

VOLUME FOUR: SUPPORTING REPORT-2: Miscellaneous

S2-1 : REFERENCE DATA ON MARINE TRANSPORT SECTOR

S2-1(1) : NATURAL CONDITIONS

1 Introduction

This section deals with the outline of natural conditions covering Laamu Atoll and Thaa Atoll where the 14 project sites are located. Major concern is the general marine, oceanographic and geotechnical conditions, since projects are covering Coastal Protection Works, Repairing Damaged Causeways and Repairing and/or Reconstruction of Island Harbours.

Thaa Atoll is about 200 km to the south from Male and Laamu Atoll is located in about 50 km further south. These two Atolls are located the south end of an Atoll group that Male is also belonging to. Thaa and Laamu Atolls are separated by about 20 km by Veymandhoo channel.

Thaa Atoll (population is 9,305, Capital Veymandhoo, inhabited islands are 13 out of 68 islands) is a massive circular reef embracing 700 km^2 of ocean. Maldivians sail cautiously in these waters. Entry and exit are only through a few narrow passages. The eastern rim of the reef is dotted with many deserted islands, sandbanks and local villages, some separates only by knee-deep lagoons. Laamu Atoll (population is 11,588, Capital Fonadhoo, inhabited islands are 12 out of 83 islands) is located 25 km beyond Veymandhoo Channel and is 40 km long and 25 km wide.

2 Climatic Conditions

(1) General Climate in Maldives

The general climatic conditions depend on the location of the site and surrounding atmosphere environment. It is no doubt that Maldives is governed more by oceanographic circumstances rather than the influence by the atmosphere of the nearby continent.

(2) Temperature

The daily temperatures vary little throughout the year with a mean annual temperature of 28 ℃. The mean daily minimum temperature recorded for Male' during 2003 was 25.4 ℃ and the daily mean maximum temperature for the same year was 31.1 ℃.

The highest temperature ever recorded in the Maldives was 36.8 ℃, recorded on 19 May 1991 at Kadhoo Meteorological Office. Likewise, the minimum temperature ever recorded in the Maldives was 17.2 ℃ recorded on 11 April 1978at the National Meteorological Center.

(3) Rainfall

Rainfall in Maldives varies from north to south with the amount of rainfall increasing towards the south. This difference in rainfall patterns is primarily due to the NE monsoon period and April being much drier in the north than in the south. Rainfall patterns are measured throughout the country by 8 rainfall stations and it is evident that there are variations in rainfall from north to south through the atoll chain, with the north being drier and the south wetter. Average monthly and annual rainfall for Male' are 162.4mm and 1,948.4mm respectively. There are considerable inter-annual variation in rainfall from 1,407mm to 2,707mm over the last 30 years.

(4) Humidity

The Maldives has a warm and humid tropical climate. The weather is dominated by two monsoon seasons: the north-east (dry) monsoon season from January to March and the south-west (rainy) monsoon season from May to November when winds blow predominantly from either of these two directions. The annual average relative humidity ranges from 73% to 85%.

(5) Wind Record and Data Sources

Wind directions in the area are seasonal and governed mainly by two monsoon seasons: the NE monsoon (December to March) and SW monsoon (June to September). Slightly stronger winds are associated with winds from the west, typical of the SW monsoon season. On average, wind speeds vary between 7-12 knots. The sever monsoon months are typically May, June and July during the early part of the SW monsoon, and September and October in the latter half. Squally gusty wind of 50-60 knots has been recorded at Male' (DoM, 2000).

Table 1.1 Monthly Average Wind in Hulhule

unit: Knots

Month	2000		2001		2002		2003		2004		Mean Speed
	Dir	knots	Dir	knots	Dir	knots	Dir	knots	Dir	knots	
Jan	NE	11	NE	10	ENE	11	ENE	12	ENE	12	11
Feb	VRB	6	VRB	6	ENE	11	ENE	9	ENE	8	8
Mar	VRB	6	ENE	6	ENE	8	E	7	N	7	7
Apr	W	10	W	7	VRB	5	VRB	5	W	6	7
May	W	10	W	11	W	10	W	10	W	14	11
Jun	W	12	W	11	WNW	12	W	9	W	10	11
Jul	WNW	10	WNW	11	WNW	11	WNW	7	W	10	10
Aug	W	10	WNW	10	W	10	W	10	W	8	10
Sep	W	10	W	10	W	8	W	9	W	9	9
Oct	WNW	10	W	12	W	11	W	10	W	6	10
Nov	VRB	8	W	8	W	7	VRB	7	E	7	7
Dec	ENE	9	ENE	11	ENE	9	ENE	10	ENE	11	10

Note: VRB means variable directions.
Source: Department of Meteorology

Table 1.2 Wind Observations in Kulhudhuffushi

unit: Knots

Month	Wind direction Percentage of observation from N	NE	E	SE	S	SW	W	NW	Calm	Mean wind speed
Jan	16	51	13	1	1	2	4	9	3	7
Feb	25	45	11	1	1	3	5	7	2	8
Mar	23	24	4	4	7	1	8	20	9	8
Apr	6	3	2	2	6	18	36	20	7	8
May	2	2	2	1	6	25	46	12	4	9
Jun	2	2	1	6	13	29	29	12	6	8
Jul	2	1	2	9	17	33	23	7	6	8
Aug	2	1	1	7	9	17	42	13	8	7
Sep	3	1	1	4	7	21	36	19	8	8
Oct	5	1	1	5	8	13	37	23	7	9
Nov	12	3	2	1	5	14	28	29	5	8
Dec	15	30	6	8	1	6	9	20	5	7
Average	9	14	4	4	7	15	25	16	6	8

Source: West Coast of India Pilot, 1975
Compiled 1945-1965, Male' (6 Years Only)

Table 1.3 Wind Observations in Hithadhoo

Unit: Knots

Month	Wind direction Percentage of observations from N	NE	E	SE	S	SW	W	NW	Calm	Mean wind speed
Jan	25	14	2	1	1	2	14	36	5	7
Feb	40	24	10	1	0	0	1	19	5	8
Mar	34	12	1	4	3	7	9	26	4	7
Apr	8	6	10	14	9	12	17	18	6	8
May	4	2	3	21	20	14	21	7	8	9
Jun	3	3	7	25	29	16	8	5	4	8
Jul	4	1	3	27	27	20	8	4	6	7
Aug	2	4	17	24	25	11	12	3	2	7
Sep	4	2	4	27	24	14	12	7	6	8
Oct	4	2	3	8	15	26	25	14	3	9
Nov	5	3	5	7	6	19	26	24	5	8
Dec	10	6	1	1	7	8	26	35	6	7
Ave.	12	7	6	13	14	12	15	16	5	8

Source: West Coast of India Pilot, 1975
Compiled 1945-1965, Gan (7 Years Only)

The Department of Meteorology indicates the monthly wind data at L.Kadhoo, which is located in Laamu Atoll and closest wind observation point. The data is shown in Table 1.4.

- High wind speed is experienced in May and September at the time of seasonal changes. Among these, the winds in May present the most sever situation. The maximum wind speed is from WSW and its intensity is 22 knots or 11m/ sec or more.
- The maximum wind speed recorded should be referred to for estimation of design wave

strength. According to the Maandhoo Fishing Port design, the wind speed is 23 m/sec (or 46 knots) for estimating the design wave. Maandhoo port is located at the same inner reef flat side, like Fonadhoo Island Harbour and Causeways. Refer to Table 6.5.6.

Table 1.4 Monthly Wind Data in Kadhoo

Month	Wind Speed (Knots)						Main Direction
	＞22	17-21	11-17	7-11	4-7	1-4	
Jan			NE	NE	NE		NE
Feb				NNE	NNE		NNE
Mar				W	W, NE		W
Apr			W, WSW	W, SW	SW, W		W, WSW
May	WSW	WSW	W				W
Jun			WSW	WSW, SW			WSW, SW
Jul			W	WSW, W	W		W
Aug			W		SW		W
Sep		W	WSW, W	SW, W			W
Oct			WSW	SW, W	W		W, SW
Nov			WNW	WNW, W	W		WNW, W
Dec			NE	NE	NE, N		NE, N

Source: Department of Meteorology

3 Oceanographic Condition

(1) General Oceanographic Conditions and Data Sources

The available data is mostly belong to the reports of previous projects, including MPA ports construction projects, Study Report of Male Sea Defense Works and Maandhoo Fisheries Port Study Report.

(2) Tide and Data Sources

1) Assumed Tide at Project Site: Laamu Atoll and Thaa Atoll

Tide data are collected at four locations, namely,

- Kulhudhuffushi, Haa Dhaalu Atoll (Latitude 07.37N, Longitude 073.04E)
- Hulhule, Male' (Latitude 04.11N, Longitude 076.32E)
- Maandhoo, Laamu Atoll (Latitude 02.10N, Longitude 073.30E)
- Gan, Addu Atoll (Latitude 00.37S, Longitude 073.05E)

Among these, tidal data at Hulhule and A. Gan are given by the Department of Meteorology. Design tide data of the projects at four locations are indicated as follows:

Table 1.5 Tide at Male, Maandhoo, Kulhudhuffushi and Hithadhoo

Unit: m

No.	Location	HHWL	HWL	MSL	LWL	LLWL	LAT*
1	Male	-	+1.34	+0.64	-	-	±0.00
2	Maandhoo	-	+1.20	+0.65	+0.10	-	±0.00
3	Kulhudhuffushi	+1.33	-	+0.72	-	±0.00	-
4	Hithadhoo	+1.41	-	+0.75	-	±0.00	-

Note: LAT is Lowest Astronomical Tide

Male' and Maandhoo are similar in tidal conditions. Maandhoo is located in Laamu Atoll and close to the project sites. However, tide of Male' is used for the project since it has higher water rises.

2) Applied Tide during Site Investigation in April and May 2005

Since no survey benchmarks exist at the project site, survey by the Team was based on the sea level, variation of which is known as the Tide Table, indicating daily high water and low water with time. The Team converted this into hourly data and used it for survey purposes. Tide Table of A. Gun was used; it indicates average value.

(3) Currents

1) General View on the Currents

It is believed that ocean current generally changes its direction by season. This current keeps its direction in the open sea then changes gradually approaching the atoll and island. The current regime in the Indian Ocean is strongly influenced by the monsoon climate. In the region of the Maldives, the currents flow westward during NE monsoon season, and they flow eastward during the SW monsoon season. The ocean currents flowing through channels between the atolls are driven by the monsoon winds. Generally, tidal currents are eastward in flood and westward in ebb. At the outer east coast of atoll, general pattern of flow is as follows:

- Offshore waves is 1.5 to 2.5 m
- Breaking at reef edge then wave height is 0.5 to 1.0 m
- Simultaneously the water level raises modifying kinetic energy to static one
- On propagating on the flat reef, the wave further losses its energy by bottom friction and the wave height became lower to 0.3 ~ 0.6 m, and this wave height is regulated with the water depth too.
- In case island is on the route, waves hit the beach and generate coastal current that further travels along the beach shallow water. And finally, it return its head to the reef edge, then ocean.
- In case flat reef and no island, waves are propagating through and changing its energy into

current, then to lagoon.

2) In and Out Water Level Difference at Fonadhoo Causeway

Water level changes from time to time. It is observed that there is water head difference between the east side water and west side water. Observed head difference ranges between 25 to 35 cm. It is observed that the water level on outer side is always higher than that of inner side. It is the major reason why water flows always to lagoon side.

3) Current Pattern by the Sea Bottom Configuration at Site

Current pattern on the sea bottom shows the general water flow. Flow goes to the back site and goes through the passage to another site. If no passage, water current will be forced to return to reef flat then the open ocean as discussed above. It is believed that the sea bottom level (if only smooth) changes before the construction of existing causeways. The Team found that there is an elevation gap of 0.5 m between the east side (outer reef) and southwest side (inner reef). It is concluded that the west side was affected by siltation and deposits by fine sand settlement due to the low speed current. Construction of causeway automatically cuts down the natural sea water passing. The western area was shaped as a catchments area of sand. This indicates the necessity of careful design of causeway taking the possible deeper water by 0.5 to 1.0 m at the west side of causeway after the openings (bridge and box culverts) are provided. This indicated necessity of deeper foundation of slope protection works.

(4) Waves

1) General Conditions

The wave condition in Maldives is rather moderate. No serious cyclone is recorded. The swells and wind waves experienced by the Maldives are conditioned by the prevailing biannual monsoon wind directions, and are typically strongest during April-July in the SW monsoon season. During this season, swells generated north of the equator with heights of 2-3 m with periods of 18-20 sec have been reported in the region. However, the Maldives also experiences swells originating from cyclones and storm events occurring well south of the equator.

It is reported that the swell waves from SE to SSE occur due to strong storms in the southern hemisphere in the area west of Australia with direction towards the Maldives. The swell waves that reached Male' and Hulhule in 1987 had significant wave heights on the order of 3 m (JICA, 1987). Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves.

2) Waves in front of Causeway Fishing Port Site at Laamu Atoll

The Study Team observed that all offshore waves are breaking at the edge to the outer reef. This is common in similar conditions. After this breaking, wave intensity is significantly decreased, then bottom friction at shallow flat reef will further consume the wave energy resulting in lower wave height.

3) Wave Data at Maandhoo

The Team collected the available wave data. Among these Maandhoo is the closest location to the project sites. Wave adopted in the Maandhoo fisheries port is as follows:

Table 1.6 Design Wave Conditions at Maandhoo; Significant Waves

	Study	Offshore Wave Height (m) In Lagoon	Period (sec.)	Fetch (km)	Wind (m/s)
1	Structural Stability Study	2.3	5.0	21	23
2	Calmness Study	0.8	3.3		

Note: Calmness study is carried out to achieve 94 % utilization of harbour

4) Wave Data at Male Main Island

Wave data at Male Main Island constructed by MPA was collected. Wave data are presented in the following table;

Table 1.7 Design Wave Conditions at Male Main Island

No.	Direction	Ho(m)*	T (sec)	Notes
1	NW	1.20	4.6	Applied to West coast shore Protection
2	SW	1.60	6.7	
3	SE	2.60	14.5	

Note: 1. Ho ; Significant Offshore Wave Height

2. Design Wave of North coast shore protection is H1/3=0.60 m, T=4.6 sec.

5) Application to the Project

The Team estimated the design wave height using SMB system for the island harbours in the Laamu Atoll. Estimation method is SMB system. Distance on which wind blow (fetch) is fixed as 21 km of Laamu.

Table 1.8 Wind Wave Estimation at Laamu Atoll

				Wind Speed	m/ sec	
		17	20	23	26	29
1	Wave Height in m	1.9	2.3	2.5	2.8	3.1
2	Periods in sec.	5.1	5.6	5.9	6.1	6.4

Data is similar to the wave forecast data at the Maandhoo Fishing Port.
Wave data at Maandhoo Fishing Port is applied for the project site in Laamu Atoll and Thaa Atoll.
Actual design wave will be reduced by seabed friction of flat reef.

4 Geotechnical Conditions

(1) General Conditions

In the Maldives, the structure of the reef flats generally consists of layers of either coral sand, soft or hard coral rock and is usually overlaid with a relatively thick layer of coral sand. On the lagoon side of the reef edge the reef is mostly covered with dead corals and a few colonies of live corals. The cavities between the coral heads are constantly being filled up with coral sand and pieces of broken and dead corals and will ultimately become a substantially hard cemented material.

The Study Team is undertaking geotechnical investigation at the Causeway No.2 at Kadhoo. It is expected to complete the soil boring to assure the foundation of bridge and causeway main dike structures by the end of August 2005.

(2) Geotechnical Data at Three Locations

Available geotechnical conditions are collected to assume the site conditions. The nearest soil data is four boring undertaken for design of the Maandhoo fisheries port located within 500m from the Causeways No.1 at Kadhoo. It shows that the general composition of layers are sandy layers and the bearing stratum is appearing at 12 m below the Datum, LAT. Table 6.5.9 shows subsoil conditions at Laamu Maandhoo.

Table 1.9 Subsoil Conditions at Laamu Maandhoo

No.	Nature of soil	Depth (DL. m)	N-value
1	Soft～Medium sand	＋2.0～－12.0	5～20
2	Hard sand	＞－12.0	＞40

Collected soil data other than those of the Maandhoo are as follows (Tables 1.10 ~1.11);

Table 1.10 Subsoil Conditions at Male Main Island

No.	Nature of soil	N-value	Unconfined Compression Strength (kg/cm^2)	Limit bearing capacity (tf/m^2)	
				Range	Design
1	Coral Sand & Gravel	3～33	-	16～22	16
2	Coral Rock	2～50	5～135	45～60	45

The subsoil condition at Seem Hithadhoo for reference is shown as follows;

Table 1.11 Subsoil Condition at Seem Atoll Hithadhoo

Boring No.	Depth (DL.m)	Nature of soil	N-value
1	－5.8～－6.4 m	White pieces of coral with coral sand	-
	－6.4～－9.0 m	Whitish coral rock	28＜N＜38
	－9.0～－10.0 m	White coral sand with pieces of coral	17
2	±0.0～－2.0 m	White coral rock boulders with coral sand	24＜N＜28
	－2.0～－4.0 m	White fine grained coral sand with pieces of coral and rock	9＜N＜14
	－4.0～－5.0 m	Whitish coral rock	34

In connection with dredging works for the regional development project the coral formation have been classified as shown in Table 6.5.12. This classification is used for the present Maldives Ports Development Project for simplicity.

Table 1.12　Classification of Soil

Soil Class	Description	Criteria (N-value from SPT)
1	Loose coralline sands without any cohesion, Cementation etc.	N＜10
2	White coral sands with inter-bedded thin Layers of cemented soils	10＜N＜30
3	White coral rock	40＜N＜70 (average N=60)
4	White coral rock	70＞N

Source ; Regional Development Project (RDP)

(3) Application to the Project

It is proposed that soil data at Maandhoo fishing port is tentatively applied to the project site. Since Maandhoo is the closest location to the project site where the data is available. Figures 6.5.1 and 6.5.2 6.4.2 show boring location and assumed soil stratum in Maandhoo fishing port. The soil properties in Maandhoo Fishing Port is assumed from surface soil to about -12 m stratum loose coralline sands and N-value average 10～20, more than -12 m stratum dense white coral sands and N-value more than 40. However this data will not be applied to the Causeway No.2 which located about 4,000m north of the port. The borehole position in Maandhoo Fishing Port is shown as follows Figure 1.1.

(4) Soil Boring for the Project

The Study Team is undertaking soil borings in three numbers at the bridge site and two box culvert sites of Causeway No.2.

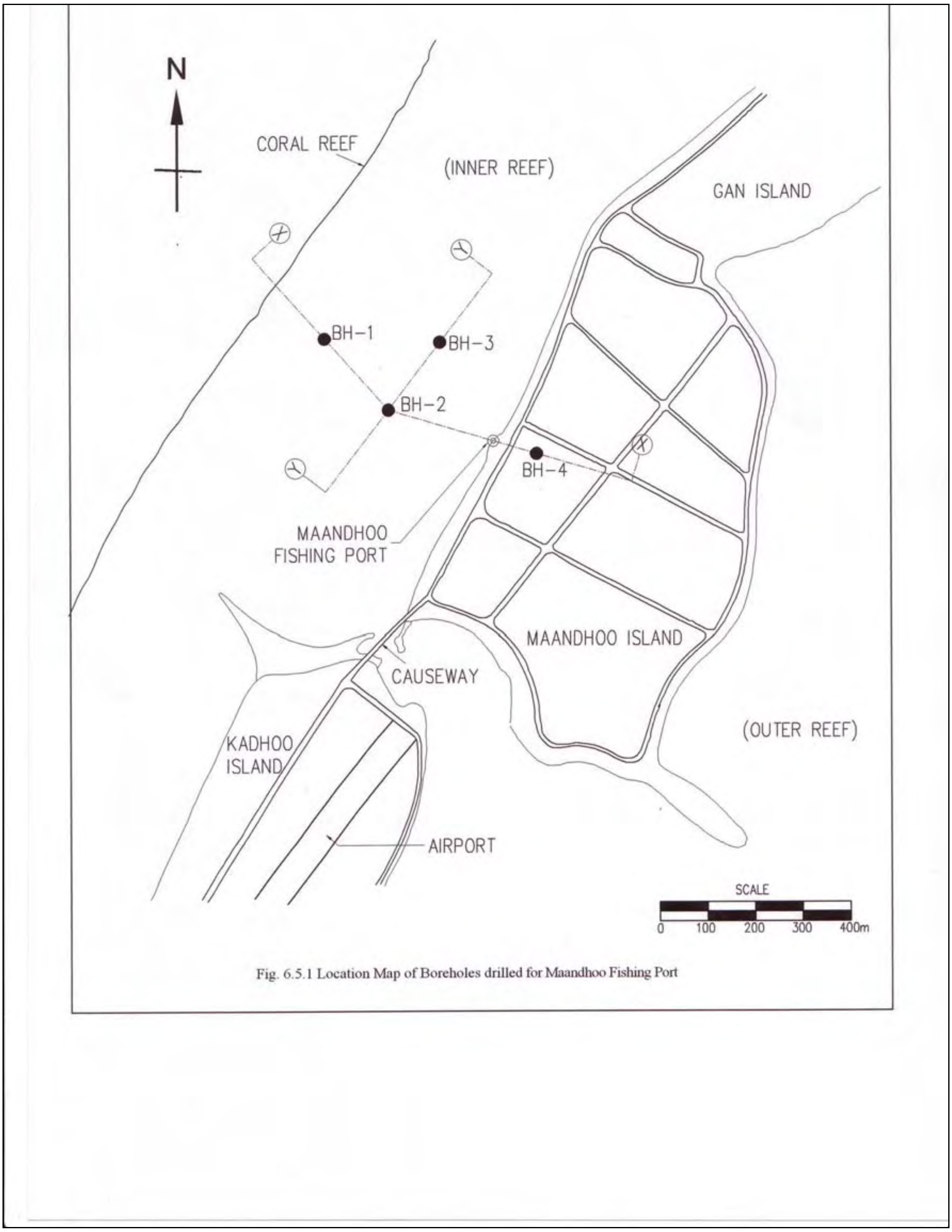


Figure 1.1 Location Map of Borehole Drilled for Maandhoo Fishing Port

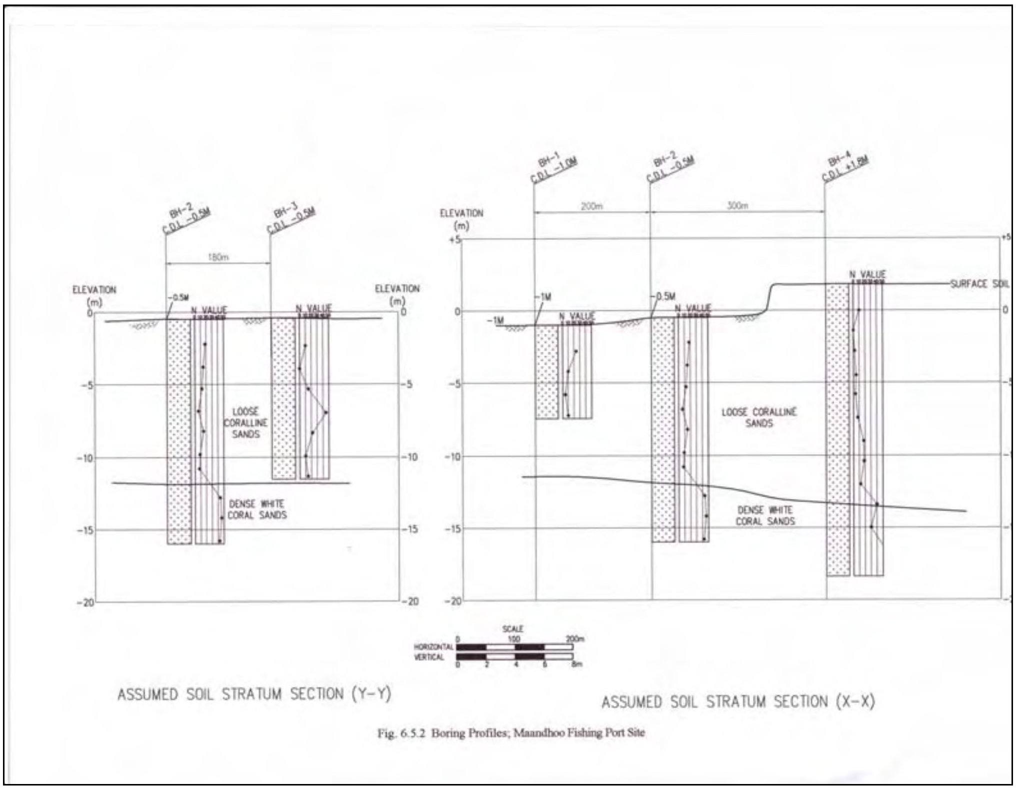


Figure 1.2 Boring Profiles: Maandhoo Fishing Port Site

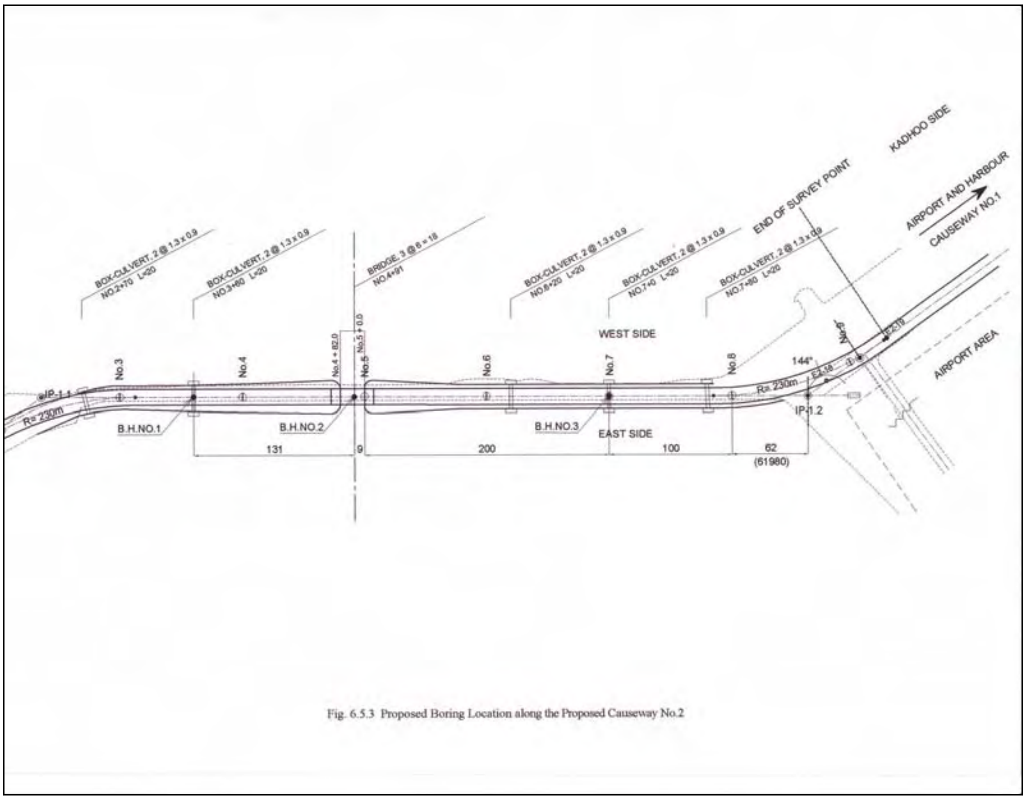


Figure 1.3 Proposed boring Location along the Proposed Causeway No.2

5 Underwater Investigation

(1) General Descriptions and Methods

Diving investigation was conducted to survey the underwater conditions of the damaged harbour structures. The extent of the damages were photographed and analyzed by the Study Team.

(2) Damaged Structures

Concrete lining works were not observed below water level. The underwater section of the quay wall were made from coral rocks. Some quay walls were entirely damaged and their crown concrete has fallen down into the seabed. In other quay walls, coral rock in mid layer has collapsed making a hollow indent in the wall. Fig. 1.4 shows an example of the damaged quay walls.

(3) Findings in Harbour Basin

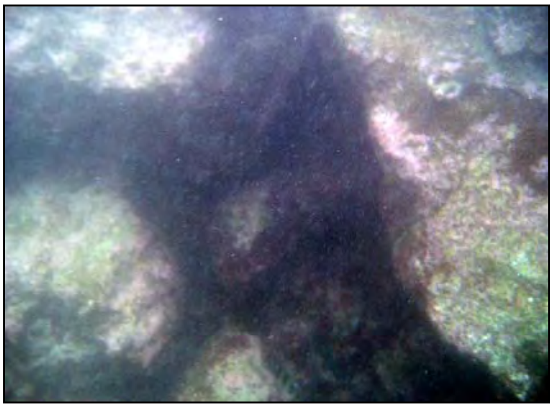
Harbour basin and channel bed were also investigated. Seabed at the harbour basin could not be investigated due to bad visibility and complicated mooring ropes. Seabed of the approach channel were usually composed of sand and coral rocks. Fig. 1.5 shows a typical seabed along the approaching channel. Live and dead corals were sometimes observed at the entrance of the channel, though at very low density.

6 Environmental Observation

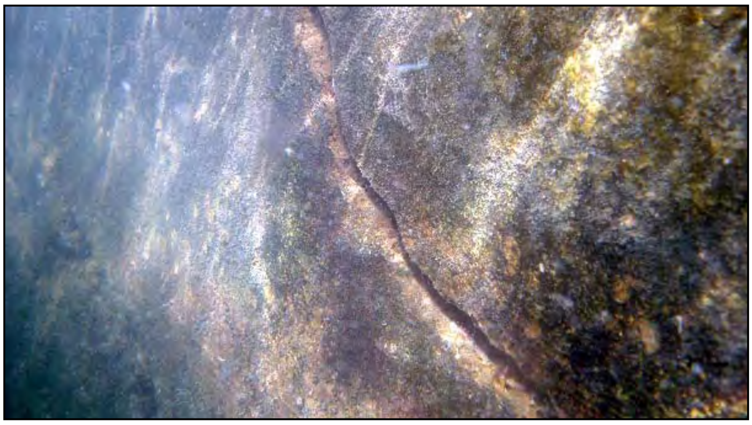
Refer to Chapter 10

Maabaidhoo

Damaged quay wall foundation at Maabaidhoo



Damaged quay wall foundation at Maavah



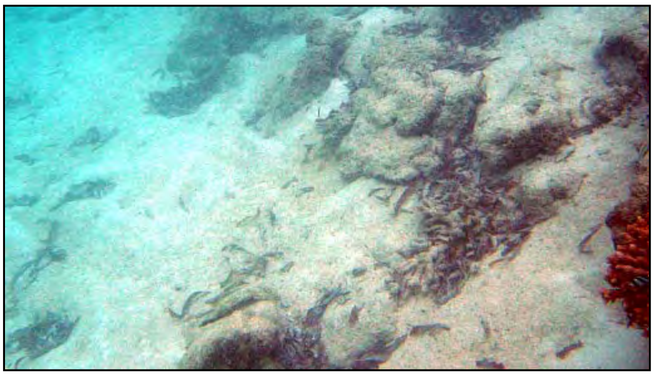
Damaged quay wall foundation at Kinbidhoo

Submerged pre-cast concrete blocks of suspended quay wall construction at Dhiyamigili

Figure 1.4 Diving Investigation of Damage Island Harbour Structures - 1

Channel toe with marine organism and fish at Maavah

Sandy channel bottom with sea grassesd and marine organism at Maavah



Coral rock breakwater and sandy channel bottom at Thimarafushi

Coral rock basement covered by silty soil at Thimarafushi

Fig. 1.5 Diving investigation for Damage Island Harbour Structures - 2

7 Topographic Conditions

(1) Datum

Male' sea defense report which is financed by JICA indicates the datum is the lowest possible sea level or LAT (Lowest Astronomical Tide). Theoretically the sea level does not become lower than this. It is assumed that the survey of on-land topography will be carried out by the datum of Mean Sea Level; however, the datum for the project is set as LAT as applied in the Male sea defense project since boat users of the island harbour measure the water depth at low tide ensuring safety navigation and maneuverability in the harbour basin and approaching channel. The survey to be carried out by the Study Team is based on LAT.

(2) Base Line

Topographic maps were used by the Team to identify the location and position of the project sites. Each island office has a map that is very useful to grasp the general view of town arrangement, community center and major access. It shows the island harbour, though not to scale. No causeway is covered in the maps. MTCA and MAC are conducting surveys of island harbour and causeways at Kadhoo for their preparation of reconstruction plan of damaged island harbours and causeways. It was also very timely for the works to be carried out by the Study Team. Since no topographic data was available as of the end of April 2005, the Study Team carried out outline topographic survey indicating the layout of harbours and major structural indications.

The survey carried out by the Study Team was by relative location method not by absolute location. Thus, it is recommended that complete topographic survey be carried out before starting the actual construction works.

8 Water Depth

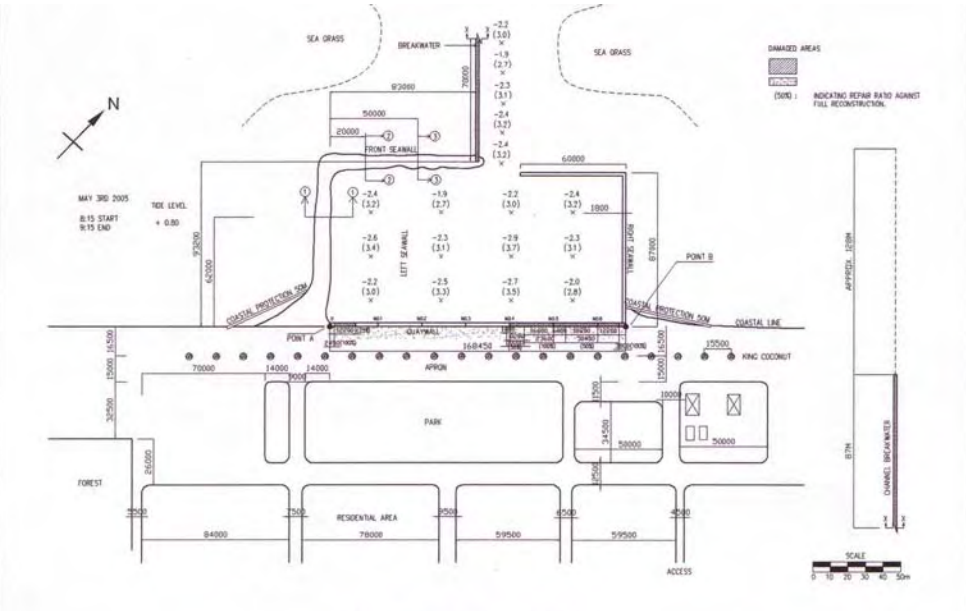
Atoll consists of several segments and zones. Two target atolls namely; Laamu and Thaa, also show typical structural constitution and configuration as follows:

- Outer reef edge
- Outer flat reef (200 to 700 m wide, -0.5 to +0.5 m deep below Datum)
- Islands (200 to 700 m wide, +1.5 to 2.5 m in altitude)
- Inner flat reef (50 to 700 m wide, -0.5 to +0.5 m deep below the datum)
- Inner reef edge
- Lagoon (about 30 km wide, 20 to 30 m deep below the datum)

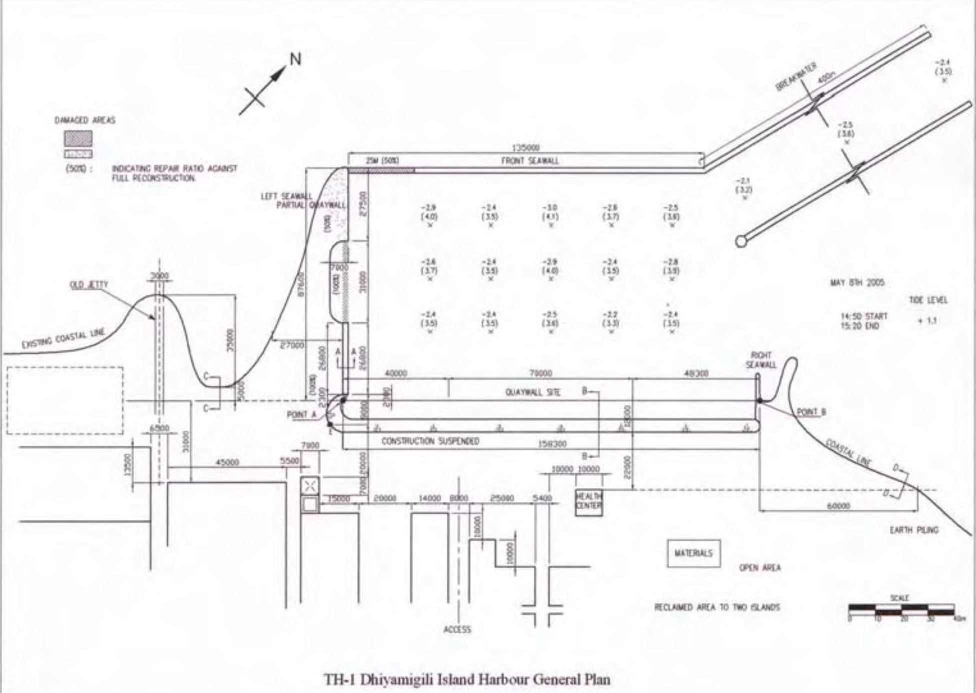
Note: Datum is LAT as used in Seawall Project at Male'.

All the island harbours and causeways are located in the inner flat reef zone. Boats calling the harbour should access the port through the artificially dredged channel, approximately -2.0 m below the datum. This makes a barrier against waves propagating to the coastal area. Offshore waves break at the outer reef edge, then reducing gradually in height. The floating equipment of contractor cannot approach the site without these artificial channels. Excavation of channel bed is frequently carried out by on-land equipment, not by dredges. Thus, dredging works or excavating works are required to provide the approach channel leading to the harbour basin.

The water depth survey carried out by the Study Team at the 17 sites is based on the Datum of LAT (Possible Lowest Astronomical Tide), calculating it theoretically. The tsunami damage information given by Island indicated affected of depth of 2 to 3 feet on the route where the Tsunami current passed. However, there is little evidence to support the stories. Seabed conditions at the channels show exposed coral, rocks and seaweeds indicating little sand deposit by tsunami. Refer to Fig. 1.6 for the preliminary sounding carried out by MTCA and the Study Team.



L-4 Fonadhoo Island Harbour General Plan



TH-1 Dhiyamigili Island Harbour General Plan

Figure 1.6 Fonadhoo and Dhiyamigili Island Harbours, General Plan

S2-1(2) : DESIGN CALCULATIONS

A. **Coastal Protection**

B. **Causeway**

C. **Island Harbour**

DESIGN CALCULATIONS

A. Coastal Protection

Technical study on the coastal protection was carried out for the following aspects;

- Crown Height (Wave run up)
- Weight (Size) of armor rock

1. Design Conditions

(1) Design Tidal Level

1) H.W.L D.L.+1.43 m

2) L.W.L D.L.±0.00 m

(2) Reef Level D.L.+0.5m～-0.5m

(3) Design Wave of Reef

1) Wave Height Hrf=0.78m～1.25m

2) Wave Period T=5.0 sec

(4) Permissible value of the Rate of Wave Overtopping

q<0.005 $m^3/s/m$

Permissible value of the Embankment

Condition of Protection	Rate ($m^3/s/m$)
All surfaces are concrete covered.	0.05
The crown is paved. There is no back pavement.	0.02
The crown is not paved.*	< 0.005

(5) Gradient of slope 1:2

2. Calculation of the Crown Height D.L.+1.92m～+2.25m

Reef Depth dr DL (m)	Reef Water Depth hrf(m)	Rise Height hsu (m)	Water Depth h'rf (m)	Reef Wave Height Hrf	Hrf/Lo	hrf'/Hrf	D.W.L DL (m)
-1.50	2.84	0.01	2.85	1.72	0.0441	1.6570	1.35
-1.25	2.59	0.04	2.63	1.61	0.0413	1.6335	1.38
-1.00	2.34	0.06	2.40	1.49	0.0382	1.6107	1.40
-0.75	2.09	0.08	2.17	1.37	0.0351	1.5839	1.42
-0.50	1.84	0.10	1.94	1.25	0.0321	1.5520	1.44
-0.25	1.59	0.13	1.72	1.13	0.0290	1.5221	1.47
+0.00	1.34	0.15	1.49	1.01	0.0259	1.4752	1.49
+0.25	1.09	0.17	1.26	0.90	0.0231	1.4000	1.51
+0.50	0.84	0.19	1.03	0.78	0.0200	1.3205	1.53

Reef Depth dr DL (m)	$q/(2g\cdot Hrf^3)^{0.5}$	hc/Ho'	hc (m)	Height of Crown (m)
-1.50	1.57E-03	0.75	1.29	+2.64
-1.25	1.73E-03	0.73	1.18	+2.56
-1.00	1.94E-03	0.71	1.06	+2.46
-0.75	2.20E-03	0.68	0.93	+2.35
-0.50	2.53E-03	0.65	0.81	+2.25
-0.25	2.94E-03	0.60	0.68	+2.15
0.00	3.48E-03	0.58	0.59	+2.08
0.25	4.14E-03	0.55	0.50	+2.01
0.50	5.13E-03	0.50	0.39	+1.92

Where Reef Water Depth ; hrf = H.W.L.-dr (m)

Rising Height of Reef Tide;; hsu = 0.27-0.09hrf (m)

Water Depth after Rising ; h'rf = hrf+hsu (m)

Design Water Level ; D.W.L = h'rf+dr (m)

hc/Ho'→depends on Fig.-1 Example of Diagram to Estimate the Rate of Wave Overtopping.

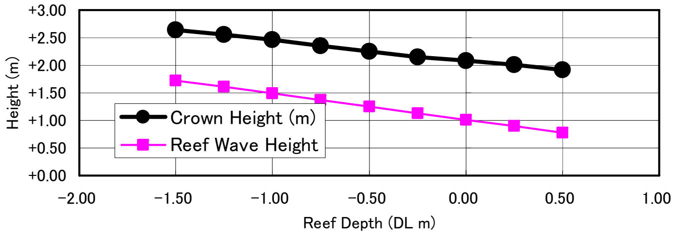


Fig. Relation between Reef Depth and Crown Height of Sea Protection

3. Calculation of the Weight of Armor Rock

The weight of rubbles or concrete blocks covering the slope surface of a structure receiving the action of wave force may be calculated by the following formula.

$W = \gamma r \cdot H^3 / \{K_D \cdot (Sr-1)^3 \cot \alpha\}$

Where W: Minimum weight of rubbles or concrete block (tf)

γr: Unit weight of rubbles or block in air (tf/m^3)

Sr: Specific gravity of rubble or block to sea water

α: Angle of the slope to horizontal plane (degrees)

H: Wave height (m)

K_D: Constant determined by the arming material and damage rate

K_D=3.2 (Damage rate 0～1%)

γr=2.65 tf/m^3

$Sr = \gamma r / \gamma w$=2.57

γw=1.03 tf/m^3

$\tan \alpha$=2.00

Reef Depth dr DL (m)	Reef Wave Height Hrf	W (tf)
-1.50	1.72	0.544
-1.25	1.61	0.447
-1.00	1.49	0.354
-0.75	1.37	0.275
-0.50	1.25	0.209
-0.25	1.13	0.154
0.00	1.01	0.110
0.25	0.90	0.078
0.50	0.78	0.051

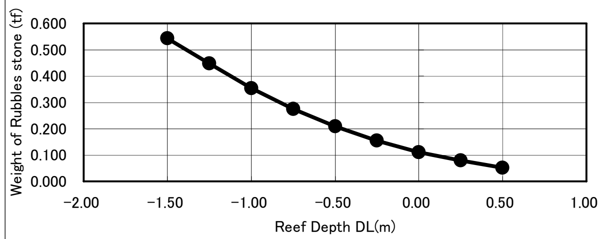


Fig. Relation Between Reef Depth and Rubbles Weight

B. Causeway

a. Current flow study

1. Box Culvert

(1) Basic Equation

$$H_1+\alpha_1 \cdot v_1^2/(2g)+(\Delta x/2)\cdot\{(n_1\cdot v_1/R_1^{2/3})^2+(n_2\cdot v_2/R_2^{2/3})^2\}=H_2+\alpha_2\cdot v_2^2/(2g)$$

$v_1=Q_1/A_1$, $v_2=Q_2/A_2$

Note; Lower figure 1 and 2 show the downstream side and the upstream side

where, H: Water Depth =(Tide Level)-(Culvert bottom Level +0.65) (m)

v: Flow velocity (m/s)

Q: Flowing quantity (m^3/s)

R: Hydraulic mean depth (m) R=A/(2H+B)

B: Width of Box B=1.30 m

A: Cross-sectional area of stream (m^2) A=H*B

n: Manning's coefficient of roughness n=0.012

Δx : Distance between sections Δx =23.00 m

g: Acceleration of gravity (9.8 m/s^2)

α : Correction coefficient of energy α =1.1

(2) Calculation of flow velocity

Tide Level (DL m)		Water Level H (m)		Sectional area A (m^2)		Mean depth R (m)	
East	West	East	West	East	West	East	West
1.34	1.09	0.69	0.44	0.897	0.572	0.335	0.262
1.29	1.04	0.64	0.39	0.832	0.507	0.322	0.244
1.24	0.99	0.59	0.34	0.767	0.442	0.309	0.223
1.19	0.94	0.54	0.29	0.702	0.377	0.295	0.201
1.14	0.89	0.49	0.24	0.637	0.312	0.279	0.175
1.09	0.84	0.44	0.19	0.572	0.247	0.262	0.147
1.04	0.79	0.39	0.14	0.507	0.182	0.244	0.115
0.99	0.74	0.34	0.09	0.442	0.117	0.223	0.079
0.94	0.69	0.29	0.04	0.377	0.052	0.201	0.038

Tide Level (DL m)		Flowing quantity Q(m^3/s)		Flow velocity v (m/s)		$\alpha\cdot v^2/(2g)$ (m)	
East	West	East	West	East	West	East	West
1.34	1.09	1.333	1.333	1.486	2.330	0.124	0.305
1.29	1.04	1.145	1.145	1.376	2.258	0.106	0.286
1.24	0.99	0.966	0.966	1.259	2.186	0.089	0.268
1.19	0.94	0.794	0.794	1.131	2.106	0.072	0.249
1.14	0.89	0.627	0.627	0.984	2.010	0.054	0.227
1.09	0.84	0.471	0.471	0.823	1.907	0.038	0.204
1.04	0.79	0.322	0.322	0.635	1.769	0.023	0.176
0.99	0.74	0.1833	0.1833	0.415	1.567	0.010	0.138
0.94	0.69	0.0602	0.0602	0.160	1.158	0.001	0.075

Tide Level (DL m)		h=(n・v/R^{2/3})^2		(Δ x/2)*(h1+h2)(m)	Total Head of Water (m)		Water level difference
East	West	East	West		East	West	
1.34	1.09	0.001	0.005	0.069	0.814	0.814	0.000
1.29	1.04	0.001	0.005	0.070	0.746	0.746	0.000
1.24	0.99	0.001	0.005	0.071	0.679	0.679	0.000
1.19	0.94	0.001	0.005	0.073	0.612	0.612	0.000
1.14	0.89	0.001	0.006	0.077	0.544	0.544	0.000
1.09	0.84	0.001	0.007	0.084	0.478	0.478	0.000
1.04	0.79	0.000	0.008	0.097	0.413	0.413	0.000
0.99	0.74	0.000	0.010	0.122	0.350	0.350	0.000
0.94	0.69	0.000	0.015	0.176	0.291	0.291	0.000

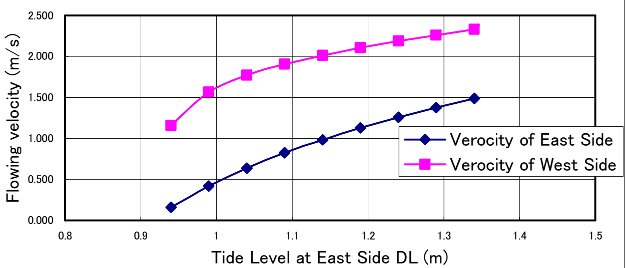


Fig. Calculation of flow velocity (Box Culvert)

2. Bridge

(1) Design Condition

Water Depth H=(Tide Level)-(Sea bottom Level -0.50) (m)

Width of Bridge B=15.00 m

Distance between sections Δ x =13.00 m

(2) Calculation of flow velocity

Tide Level (DL m)		Water Level H (m)		Sectional area A (m^2)		Mean depth R (m)	
East	West	East	West	East	West	East	West
1.34	1.09	1.84	1.59	27.6	23.85	1.478	1.312
1.24	0.99	1.74	1.49	26.1	22.35	1.412	1.243
1.14	0.89	1.64	1.39	24.6	20.85	1.346	1.173
1.04	0.79	1.54	1.29	23.1	19.35	1.278	1.101
0.94	0.69	1.44	1.19	21.6	17.85	1.208	1.027
0.84	0.59	1.34	1.09	20.1	16.35	1.137	0.952
0.74	0.49	1.24	0.99	18.6	14.85	1.064	0.875
0.64	0.39	1.14	0.89	17.1	13.35	0.990	0.796
0.54	0.29	1.04	0.79	15.6	11.85	0.913	0.715

Tide Level (DL m)		Flowing quantity Q(m^3/s)		Flow velocity v (m/s)		$\alpha \cdot v^2/(2g)$ (m)	
East	West	East	West	East	West	East	West
1.34	1.09	96.50	96.50	3.496	4.046	0.686	0.919
1.24	0.99	88.00	88.00	3.372	3.937	0.638	0.870
1.14	0.89	80.00	80.00	3.252	3.837	0.594	0.826
1.04	0.79	72.00	72.00	3.117	3.721	0.545	0.777
0.94	0.69	64.40	64.40	2.981	3.608	0.499	0.731
0.84	0.59	57.00	57.00	2.836	3.486	0.451	0.682
0.74	0.49	50.05	50.05	2.691	3.370	0.406	0.638
0.64	0.39	43.30	43.30	2.532	3.243	0.360	0.590
0.54	0.29	36.90	36.90	2.365	3.114	0.314	0.544

Tide Level (DL m)		$h=(n \cdot v/R^{2/3})^2$		$(\Delta x/2)*(h1+h2)$(m)	Total Head of Water (m)		Water level difference
East	West	East	West		East	West	
1.34	1.09	0.001	0.002	0.017	2.526	2.526	0.000
1.24	0.99	0.001	0.002	0.018	2.378	2.378	0.000
1.14	0.89	0.001	0.002	0.018	2.234	2.234	0.000
1.04	0.79	0.001	0.002	0.018	2.085	2.085	0.000
0.94	0.69	0.001	0.002	0.018	1.939	1.939	0.000
0.84	0.59	0.001	0.002	0.018	1.791	1.791	0.000
0.74	0.49	0.001	0.002	0.019	1.646	1.646	0.000
0.64	0.39	0.001	0.002	0.019	1.500	1.500	0.000
0.54	0.29	0.001	0.002	0.020	1.354	1.354	0.000

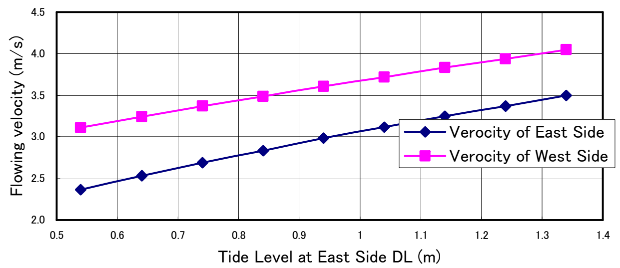


Fig. Calculation of flow velocity (Bridge)

b. Size of Armour Rock

Ⅰ. Slope Protection of Causeway Mound

1. Design Condition

(1) Design Seabed Level D.L. -0.50 m

(2) Design Tide Level

H.W.L +hsu(Rise Height by Reef) D.L. +1.44 m

(3) Design Wave Height

Reef Wave Height Htf=1.25 m

(4) Unit weight of rubbles γr=2.65 tf/m^3

(5) Density of seawater γw=1.03 tf/m^3

2. Basic Equation

The weight of rubbles or concrete blocks covering the slope surface of a structure receiving the action of wave force may be calculated by the following formula.

$W=\gamma r \cdot H^3/\{K_D \cdot (Sr-1)^3 \cot\alpha\}$

where, W: Minimum weight of rubbles or concrete block (tf)

γr: Unit weight of rubbles or block in air (tf/m3)

Sr: Specific gravity of rubble or block to sea water

α : Angle of the slope to horizontal plane (degrees)

H: Wave height (m) H=Htf=1.25m

K_D: Constant determined by the arming material and damage rate

K_D=3.2 (Damage rate 0～1%)

γr=2.65 tf/m^3 ,Sr= $\gamma r/\gamma w$=2.57, γw=1.03 tf/m^3 , tan α =1.50

W=0.279 tf

Ⅱ. Seabed Protection of Box Culvert and Bridge

1. Basic Equation

$D_m=V_0^2/\{E_1^2 \cdot 2g(\rho s/\rho -1)\}$

where, V_0; Design flow velocity (m/s)

D_m; Average particle size of stone (m)

ρs; Density of stone $\rho s=2.65$

ρw; Density of seawater $\rho w=1.03$

E_1; Coefficient of turbulent flow

Usually $E_1=1.2$

Turbulent flow $E_1=0.86$

g: Acceleration of gravity (9.8 m/s^2)

2. Design of Foundation Stone Size

(1) Front of Box Culvert

Tide Level (DL m)		Water Depth H (m)		Flow velocity Vo (m/s)		Particle Size D(m)	
East	West	East	West	East	West	East	West
1.34	1.09	0.69	0.44	1.486	2.330	0.050	0.122
1.29	1.04	0.64	0.39	1.376	2.258	0.043	0.115
1.24	0.99	0.59	0.34	1.259	2.186	0.036	0.108
1.19	0.94	0.54	0.29	1.131	2.106	0.029	0.100
1.14	0.89	0.49	0.24	0.984	2.010	0.022	0.091
1.09	0.84	0.44	0.19	0.823	1.907	0.015	0.082
1.04	0.79	0.39	0.14	0.635	1.769	0.009	0.071
0.99	0.74	0.34	0.09	0.415	1.567	0.004	0.055
0.94	0.69	0.29	0.04	0.160	1.158	0.001	0.030

(2) Sea Bed of Bridge

Tide Level (DL m)		Water Depth H (m)		Flow velocity V (m/s)		Particle Size D (m)	
East	West	East	West	East	West	East	West
1.34	1.09	1.84	1.59	3.496	4.046	0.536	0.718
1.24	0.99	1.74	1.49	3.372	3.937	0.499	0.680
1.14	0.89	1.64	1.39	3.252	3.837	0.464	0.646
1.04	0.79	1.54	1.29	3.117	3.721	0.426	0.607
0.94	0.69	1.44	1.19	2.981	3.608	0.390	0.571
0.84	0.59	1.34	1.09	2.836	3.486	0.353	0.533
0.74	0.49	1.24	0.99	2.691	3.370	0.318	0.498
0.64	0.39	1.14	0.89	2.532	3.243	0.281	0.461
0.54	0.29	1.04	0.79	2.365	3.114	0.245	0.425
0.25	0	0.75	0.5	1.796	2.693	0.141	0.318

3. Required weight of armor rock for stabilization

Japanese design standards indicates to estimate it by hydraulic model tests or applying the following formula.

$M = \pi P_r U^6/(48g^3y^6(S_r-1)^3 (\cos\theta - \sin\theta)^3$

Where; M: Weight of stabilized armor rock in ton

Pr: Density of rock (t/m^3)

U: Current velocity along the rock (m/s)

g: Acceleration of gravity m/s^2

y: Constants

$y = 1.20$ in embedded rock

$y = 0.86$ in exposed rock

Sr: Specific gravity

θ : angle of slope on the current direction (degree)

Applied figures of the project:

$Pr = 2.65\ t/m^3$

U = 2.3 m/s (Box culvert),U= 4.0 m/s (Bridge)

$\theta = 0°$,$g = 9.8\ m/s^2$,$y = 1.20$, $Sr = 1.8$

M = 0.018 tf=18 kgf (Box culvert)

= 0.494 tf=494 kgf (Bridge)

c. Bridge Concrete Structures Study

1. Design Conditions

(1) Load Conditions

1) Unit Weight

Plain Concrete 2.30 tf/m³

Reinforced Concrete 2.45 tf/m³

2) Wheel load

Front wheel load $P1=1.4$ tf

Rear wheel load $P2=5.6$ tf

Impact coefficient $i=0.2$

Distribution load $w=0.245$ tf/m²

Line load $W=3.5$ tf/m

(2) Size of material

Thickness of Surface pavement 0.03m

Thickness of Slab $d=0.25$ m

Girder Interval 1.70 m

Width 0.50 m

Thickness 0.90 m (The thickness of the slab is contained)

Length 6.00 m

Girder Receiving Beam

Interval 2.55 m

Width 1.40 m

Thickness 0.70 m

Length 6.30 m

2. Calculation of Floor Slab

(1) Design method

1) Slab of Edge; It calculates as a simple beam of fixation and pins.

The calculation of the bending moment is as follows.

Concentrated load

$M_C=R_A \cdot a$、$M_B=P \cdot a \cdot b \cdot (a+l)/(2 \cdot l^2)$、$R_A=P \cdot b^2(a+2 \cdot l)/(2 \cdot l^3)$

Distribution load

$M_{max}=9 \cdot w \cdot l^2/128$、$M_B=wl^2/8$

2) Center Slab; It calculates as a simple beam where both ends were fixed.

The calculation of the bending moment is as follows.

Concentrated load

$M_C=M_B=Pl/8$

Distribution load

$M_B=wl^2/12$、$M_C= wl^2/24$

(2) Calculation of load

1) Dead Load

Item	Thickness d (m)	Unit Weight (tf/m³)	Load p (tf/m²)
Surface pavement	0.03	2.30	0.069
Slab	0.25	2.45	0.613
Total			0.682

2) Wheel load

Concentrated load $P2=6.72$ tf

Distribution load $w=0.245$ tf/m²

Line load $W=3.5$ tf/m

(3) Calculation of section force

1) Slab of Edge

Kind of load	Value of Load	Width of Slab l (m)	Position of load a (m)	Position of load b (m)	M_{max} tf･m	M_B tf･m
Dead Load (tf/m²)	0.682	1.20	—	—	0.069	0.12[illegible]
Concentrated Load (tf)*1	6.720	1.20	0.690	0.510	1.078	1.55[illegible]
Concentrated Load (tf)*2	6.720	1.20	0.450	0.750	1.403	1.29[illegible]
Distribution load(tf/m²)	0.245	1.20	—	—	0.025	0.04[illegible]
Line Load (tf/m)	3.500	1.20	—	—	0.354	0.63[illegible]

Concentrated load $R_A=1.563$ tf *1、Concentrated load $R_A=3.117$ tf *2

Combination of Loads

a) Dead Load+Concentrated Load

Kind of load	Effective Width B(m)	Effective load (tf･m/m) M_{max}	Effective load (tf･m/m) M_B
Dead Load (tf/m²)	1.000	0.069	0.123
Concentrated Load (tf)	0.700	2.004	2.217
Total		2.073	2.340

b) Dead Load+Distribution Load+Line Load

Kind of load	Effective Width B(m)	Effective load (tf·m/m)	
		M_{max}	M_B
Dead Load (tf/m^2)	1.000	0.069	0.123
Distribution load(tf/m^2)	1.000	0.025	0.044
Line Load (tf/m)	0.400	0.886	1.575
Total		0.980	1.742

2) Center Slab

Kind of load	Value of Load	Width of Slab l (m)	M_C tf·m	M_B tf·m
Dead Load (tf/m^2)	0.682	1.20	0.041	0.082
Concentrated load (tf)*1	6.72	1.20	1.008	1.008
Distribution load(tf/m^2)	0.245	1.20	0.015	0.029
Line load (tf/m)	3.500	1.20	0.210	0.420

a) Dead Load+Concentrated Load

Kind of load	Effective Width B(m)	Effective load (tf·m/m)	
		M_C	M_B
Dead Load (tf/m^2)	1.000	0.041	0.082
Concentrated Load (tf)*1	0.700	1.440	1.440
Total		1.481	1.522

b) Dead Load+Distribution Load+Line Load

Kind of load	Effective Width B(m)	Effective load (tf·m/m)	
		M_C	M_B
Dead Load (tf/m^2)	1.000	0.041	0.082
Distribution load(tf/m^2)	1.000	0.015	0.029
Line Load (tf/m)	0.400	0.525	1.050
Total		0.581	1.161

Standard Design Strength σck=240(kgf/cm^2)
Allowable Bending Compressive Stress σca=80(kgf/cm^2)
Allowable Shearing Stress τa=9(kgf/cm^2)
Allowable Tensile Stress of Reinforcement σsa=1,800 (kgf/cm^2)

(4) Calculation of Reinforced Concrete

Item of examination	Slab of Edge		Center Slab	
	Lower bar	Upper bar	Lower bar	Upper bar
Bending moment (tf·m)	2.073	2.340	1.481	1.522
Shearing force (tf)	6.72	—	—	—
Bar Arrangement	D13 @125	D13 @125	D13 @125	D13 @125
Area of bar (cm^2)	10.14	10.14	10.14	10.14
Width (cm)	100	100	100	100
Height (cm)	25	25	25	25
Effective Height (cm)	17	17	17	17
Covering Thickness (cm)	8	8	8	8
Stress σ (kgf/cm^2)				
Compression Stress σc	47	53	34	35
Tension Stress σs	1,359	1,533	970	997
Shearing force τc	4.5	—	—	—

Standard Design Strength σck=240(kgf/cm^2)
Allowable Bending Compressive Stress σca=80(kgf/cm^2)
Allowable Shearing Stress τa=9(kgf/cm^2)
Allowable Tensile Stress of Reinforcement σsa=1,800 (kgf/cm^2)

3. Calculation of Girder

(1) Design method

It calculates as a simple beam where both ends were pins.

The calculation of the bending moment is as follows.

Concentrated load

$M_{max}=P\cdot l/4$、$R_A=P/2$

Distribution load

$M_{max}=w\cdot l^2/8$、$R_A=w\cdot l/2$

(2) Calculation of load

1) Dead Load

Item	Width B (m)	Thickness d (m)	Unit Weight (tf/m³)	Load p (tf/m)
Surface pavement	1.70	0.03	2.30	0.117
Slab	1.70	0.25	2.45	1.041
Girder	0.50	0.65	2.45	0.796
Total				1.955

2) Wheel load

Concentrated load　Front wheel load　P1= 2.52 tf (Wheel load x 1.5)

　　　　　　　　　Rear wheel load　P2= 10.08 tf (Wheel load x 1.5)

Item	w or W	Width	Σ w or W
Distribution load	0.245	1.70	0.417
Line load	3.5	1.70	5.95

(3) Calculation of section force

Kind of load	Value of Load	Length of Girder l (m)	M_{max} tf·m	R_x tf·m
Dead Load (tf/m)	1.955	6.00	8.797	5.864
Front Wheel Load (tf)	2.520	6.00	3.780	1.260
Rear Wheel Load (tf)	10.080	6.00	15.120	5.040
Distribution load(tf/m)	0.417	6.00	1.877	1.251
Line Load (tf/m)	5.950	6.00	8.925	2.975

1) Dead Load+Concentrated Load

Kind of load	Value of Load	M_{max} tf·m	R_x tf·m
Dead Load	1.955	8.797	5.864
Concentrated Load	10.080	15.120	5.040
Total		23.917	10.904

2) Dead Load+Distribution Load+Line Load

Kind of load	Value of Load	M_{max} tf·m	R_x tf·m
Dead Load (tf/m²)	1.955	8.797	5.864
Distribution load(tf/m²)	0.417	1.877	1.251
Line Load (tf/m)	5.950	8.925	2.975
Total		19.598	10.090

(4) Calculation of Reinforced Concrete

Item of examination	Lower bar	Lower bar
Bending moment (tf·m)	23.917	19.598
Shearing force (tf)	10.904	10.090
Bar Arrangement	D25x4	D22x4
Area of bar (cm²)	20.27	15.48
Width (cm)	50	50
Height (cm)	90	90
Effective Height (cm)	80	80
Covering Thickness (cm)	10	10
Stress σ (kgf/cm²)		
Compression Stress σc	52	47
Tension Stress σs	1,651	1,750
Shearing force τc	3.1	3.1

Standard Design Strength　$\sigma ck=240(kgf/cm^2)$

Allowable Bending Compressive Stress　$\sigma ca=80(kgf/cm^2)$

Allowable Shearing Stress　$\tau a=9(kgf/cm^2)$

Allowable Tensile Stress of Reinforcement　$\sigma sa=1{,}800\ (kgf/cm^2)$

4. Calculation of Girder Receiving Beam

(1) Design method

It calculates as a simple beam of fixation and pins.

The calculation of the bending moment is as follows.

Concentrated load

$M_C=R_A\cdot a$、$M_B=P\cdot a\cdot b\cdot(a+l)/(2\cdot l^2)$、$R_A=P\cdot b^2(a+2\cdot l)/(2\cdot l^3)$

Distribution load

$M_{max}=9\cdot w\cdot l^2/128$、$M_B=wl^2/8$

(2) Calculation of load

1) Dead Load

Item	Width B (m)	Thickness d (m)	Length L (m)	Unit Weight (tf/m^3)	Load p (tf)
Surface pavement	1.70	0.03	6.00	2.30	0.704
Slab	1.70	0.25	6.00	2.45	6.248
Girder	0.50	0.65	6.00	2.45	4.778
Total					6.951
Receiving Beam	1.40	0.70	-	2.45	2.401

2) Wheel load

Concentrated load　Front wheel load　P1= 4.41 tf (Wheel load x 2.625)

Rear wheel load　P2= 10.08 tf (Wheel load x 1.5)

Total　14.49 tf

Item	B (m)	L (m)	w or W	p (tf)
Distribution load	1.70	6.00	0.245	2.499
Line load	1.70	-	3.5	5.95
Total				8.449

(3) Calculation of section force

Kind of load	Value of Load	Beam Span l (m)	Position of load a (m)	Position of load b (m)	M_C tf·m	M_B tf·m
Dead Load (tf)	6.951	2.55	1.70	0.85	1.751	3.283
Receiving Beam (tf/m)	2.401	2.55	-	-	1.098	1.952
Wheel Load (tf)	14.490	2.55	1.70	0.85	3.649	6.843
Distribution load(tf)	8.449	2.55	1.70	0.85	2.128	3.990

Kind of load	R_A (tf)	R_B (tf)
Dead Load (tf)	1.030	5.921
Receiving Beam (tf/m)	2.296	3.827
Wheel Load (tf)	2.147	12.343
Distribution load(tf)	1.252	7.197

Combination of Loads

1) Dead Load+Concentrated Load

Kind of load	Effective load (tf·m/m)		Reaction of Support	
	M_C	M_B	R_A (tf)	R_B (tf)
Dead Load	1.751	3.283	1.030	5.921
Receiving Beam	1.098	1.952	2.296	3.827
Wheel Load	3.649	6.843	2.147	12.343
Total	6.498	12.077	5.472	22.091

2) Dead Load+Distribution Load+Line Load

Kind of load	Effective load (tf·m/m)		Reaction of Support	
	M_C	M_B	R_A (tf)	R_B (tf)
Dead Load	1.751	3.283	1.030	5.921
Receiving Beam	1.098	1.952	2.296	3.827
Distribution load	2.128	3.990	1.252	7.197
Total	4.976	9.224	4.577	16.945

(4) Calculation of Reinforced Concrete

Item of examination	Wheel Load		Distribution Load	
	Lower	Upper	Lower	Upper
Bending moment (tf·m)	6.498	12.077	4.976	9.224
Shearing force (tf)	5.472	22.091	4.577	16.945
Bar Arrangement	D16x7	D16x7	D16x7	D16x7
Area of bar (cm^2)	13.9	13.9	13.9	13.9
Width (cm)	140	140	140	140
Height (cm)	70	70	70	70
Effective Height (cm)	60	60	60	60
Covering Thickness (cm)	10	10	10	10
Stress σ (kgf/cm^2)				
Compression Stress σc	14	25	10	19
Tension Stress σs	835	1,551	639	1,185
Shearing force τc	0.7	3.1	1.0	2.0

Standard Design Strength σck= 240 (kgf/cm²)

Allowable Bending Compressive Stress σca= 80 (kgf/cm²)

Allowable Shearing Stress τa= 9 (kgf/cm²)

Allowable Tensile Stress of Reinforcement σsa= 1,800 (kgf/cm²)

d. Pile bearing capacity analysis

1. Design Conditions

(1) Material of Piles

1) Coupled Steel Sheet Piles

Type-Ⅲ、SY295

Allowable Stress σsa= 1,800 kgf/cm²

Sectional Area

Area of Steel a= 137.6 cm²

Area of Inside A_p= 0.100 m²

Circumferential surface area A_s= 1.390 cm²

Width B= 0.40 m

2) Steel Pipe pile

SS400 φ= 500 mm t= 9.0 mm

Allowable Stress σsa= 1,400 kgf/cm²

Sectional Area

Area of Steel a= 138.8 cm²

Area of Inside A_p= 0.196 m²

Circumferential surface area A_s= 1.570 m²

Width B= 0.50 m

3) Corrosion tc= 1.8 mm (Life time 30 years)

4) Safety Factor of Pile Bearing Capacity F= 2.5

(2) Subsoil Condition

Level DL (m)	Depth(m)	N value
-0.5～-12.0	11.5	5
-12.0～	―	40

(3) Load Condition

1) Load of superstructure

W= 2xR_B= 44.18 tf

2) Load of Pile

Coupled Steel Sheet Piles w= 0.120 tf/m

Steel Pipe pile w= 0.109 tf/m

2. Bearing Capacity of Pile

(1) Estimation of Axial Ultimate Bearing Capacity

The ultimate bearing capacity of a pile driven in sandy soil shall be calculated in accordance with following formula.

$R_u=30NA_p+N_mA_s/5$

where, R_u; Ultimate bearing capacity of the pile (tf)

A_p; Tip area of the pile (m²)

A_s; Total circumferential surface area of the pile (m²)

N; N value of the subsoil at the tip of the pile

N_m; Mean N value for the total embedded length of the pile

In this case, N shall be calculated in a accordance with following formula.

$N=(N_1+N_{m2})/2$

where, N_1; The value whichever smaller of the N value at the tip of the pile or mean N value in the range from the tip of the pile to below.

N_{m2}; Mean N value in the range from the tip of the pile to 10B above.

B; Diameter or width of the pile.

(2) Allowable Bearing Capacity

$Ra=R_u/F$

(3) Calculation of the Pile Length

1) Coupled Steel Sheet Piles

Level of Pile Tip DL(m)	Embedded Length (m)	Pile Length L (m)	Load W(tf)	N_1	N_{m2}	N	N_m
-12.0	11.5	14.0	45.86	40.00	5.00	22.50	5.00
-12.5	12.0	14.5	45.92	40.00	9.38	24.69	6.46
-13.0	12.5	15.0	45.98	40.00	13.75	26.88	7.80
-13.5	13.0	15.5	46.04	40.00	18.13	29.06	9.04
-14.0	13.5	16.0	46.10	40.00	22.50	31.25	10.19
-14.5	14.0	16.5	46.16	40.00	26.88	33.44	11.25
-15.0	14.5	17.0	46.22	40.00	31.25	35.63	12.24
-15.5	15.0	17.5	46.28	40.00	35.63	37.81	13.17
-16.0	15.5	18.0	46.34	40.00	40.00	40.00	14.03

2. Bearing Capacity of Pile

(1) Estimation of Axial Ultimate Bearing Capacity

The ultimate bearing capacity of a pile driven in sandy soil shall be calculated in accordance with following formula.

$$R_u=30NA_p+N_mA_s/5$$

where, R_u; Ultimate bearing capacity of the pile (tf)

A_p; Tip area of the pile (m^2)

A_s; Total circumferential surface area of the pile (m^2)

N; N value of the subsoil at the tip of the pile

N_m; Mean N value for the total embedded length of the pile

In this case, N shall be calculated in a accordance with following formula.

$$N=(N_1+N_{m2})/2$$

where, N_1; The value whichever smaller of the N value at the tip of the pile or mean N value in the range from the tip of the pile to below.

N_{m2}; Mean N value in the range from the tip of the pile to 10B above.

B; Diameter or width of the pile.

(2) Allowable Bearing Capacity

$$Ra=R_u/F$$

(3) Calculation of the Pile Length

1) Coupled Steel Sheet Piles

Level of Pile Tip DL(m)	Embedded Length (m)	Pile Length L (m)	Load W(tf)	N_1	N_{m2}	N	N_m
-12.0	11.5	14.0	45.86	40.00	5.00	22.50	5.00
-12.5	12.0	14.5	45.92	40.00	9.38	24.69	6.46
-13.0	12.5	15.0	45.98	40.00	13.75	26.88	7.80
-13.5	13.0	15.5	46.04	40.00	18.13	29.06	9.04
-14.0	13.5	16.0	46.10	40.00	22.50	31.25	10.19
-14.5	14.0	16.5	46.16	40.00	26.88	33.44	11.25
-15.0	14.5	17.0	46.22	40.00	31.25	35.63	12.24
-15.5	15.0	17.5	46.28	40.00	35.63	37.81	13.17
-16.0	15.5	18.0	46.34	40.00	40.00	40.00	14.03

Level of Pile Tip DL(m)	$30NA_p$ (tf)	$N_mA_s/5$ (tf)	R_u (tf)	$Ra=R_u/F$ (tf)	
-12.0	67.50	15.99	83.49	33.39	
-12.5	74.06	21.55	95.61	38.24	<Load out
-13.0	80.63	27.11	107.73	43.09	
-13.5	87.19	32.67	119.85	47.94	
-14.0	93.75	38.23	131.98	52.79	
-14.5	100.31	43.79	144.10	57.64	
-15.0	106.88	49.35	156.22	62.49	
-15.5	113.44	54.91	168.34	67.34	
-16.0	120.00	60.47	180.47	72.19	

2) Steel Pipe pile

Level of Pile Tip DL(m)	Embedded Length (m)	Pile Length L (m)	Load W(tf)	N_1	N_{m2}	N	N_m
-12.0	11.5	14.0	45.71	40.00	5.00	22.50	5.0
-12.5	12.0	14.5	45.76	40.00	9.50	24.75	6.4
-13.0	12.5	15.0	45.82	40.00	14.00	27.00	7.8
-13.5	13.0	15.5	45.87	40.00	18.50	29.25	9.0
-14.0	13.5	16.0	45.92	40.00	23.00	31.50	10.1
-14.5	14.0	16.5	45.98	40.00	27.50	33.75	11.2
-15.0	14.5	17.0	46.03	40.00	32.00	36.00	12.2
-15.5	15.0	17.5	46.09	40.00	36.50	38.25	13.1
-16.0	15.5	18.0	46.14	40.00	41.00	40.50	14.0

Level of Pile Tip DL(m)	$30NA_p$ (tf)	$N_mA_s/5$ (tf)	R_u (tf)	$Ra=R_u/F$ (tf)	
-12.0	132.30	18.06	150.36	60.14	
-12.5	145.53	24.34	169.87	67.95	>Load ok
-13.0	158.76	30.62	189.38	75.75	
-13.5	171.99	36.90	208.89	83.55	
-14.0	185.22	43.18	228.40	91.36	
-14.5	198.45	49.46	247.91	99.16	
-15.0	211.68	55.74	267.42	106.97	
-15.5	224.91	62.02	286.93	114.77	
-16.0	238.14	68.30	306.44	122.57	

Tie Rod ; SS400

Allowable stress σ sa＝960 kgf/cm^2

Wale ; SS41

Allowable stress σ sa＝1,400 kgf/cm^2

Backfilling

Materials	Unit Weight γ (tf/m3)		φ	
	In air	In water	(°)	(rad)
Backfill of Coral Stone	1.80	1.00	30	0.5236
Backfill of sand	1.80	1.00	30	0.5236

Unit weight of water γ w＝1.03 tf/m^3

(5) Safety Factor of Embedded F＝1.5

(6) Angle of wall friction δ＝15.0 °

(7) Condition of Subsoil

Depth DL-0.5m～-12.0m

γ '＝1.0 tf/m^3 (under the water), N= 5, φ＝28.0 °

Depth DL-12.0m～

γ '＝1.0 tf/m^3 (under the water), N= 40, φ＝40.0 °

2. Calculation of Load

(1) Active Earth Pressure and Residual Water pressure

Level	Hight	Σ γ h+q	Kah	Pressure Pa (tf/m2)		
DL (m)	h (m)	tf/m^2		Earth;pa	Water;pw	Total
+3.30		1.50	0.2911	0.437	0.000	0.437
+1.00	2.30	5.64	0.2911	1.642	0.000	1.642
+0.89	0.11	5.84	0.2911	1.700	0.000	1.700
+0.00	0.89	6.73	0.2911	1.959	0.917	2.876
-0.50	0.50	7.23	0.2911	2.105	0.917	3.022
-0.50	0.00	7.23	0.3140	2.270	0.917	3.187
-3.00	2.50	9.73	0.3140	3.055	0.917	3.972

Note; Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m^2	Σ Pa tf/m	Center y (m)	Pa･y tf･m/m
+3.30		0.437	0.503	-1.533	-0.771
+1.00	2.30	1.642	1.888	-0.767	-1.448
+1.00		1.642	0.090	0.037	0.003
+0.89	0.11	1.700	0.094	0.073	0.007
+0.89		1.700	0.757	0.407	0.308
0.00	0.89	2.876	1.280	0.703	0.900
0.00		2.876	0.719	1.167	0.839
-0.50	0.50	3.022	0.756	1.333	1.008
-0.50		3.187	3.984	2.333	9.295
-3.00	2.50	3.972	4.965	3.167	15.724
Total	6.30		15.04		25.865

(2) Passive Earth Pressure

Level DL (m)	Height h (m)	Σ γ h tf/m^2	Kph	Pp tf/m^2
-0.50	2.50	0.00	0.000	0.000
-3.00	2.50	2.50	4.3312	10.828

Note; Kph is horizontal Coefficient of passive earth pressure

Level DL (m)	Height h (m)	Pp tf/m^2	Σ Pp tf/m	Center y (m)	Pa･y tf･m/m
-0.50		0.000	0.000	2.333	0.000
-3.00	2.50	10.828	13.535	3.167	42.865
Total			13.535		42.865

3. Design of Sheet Piles

(1) Embedded Length of Sheet Piles

The embedded length of sheet piles shall be calculated to satisfy the following formula

F= Pp･y/Pa･y

where, Pp･y : Moment for the tie rod setting point by passive earth pressure

Pa･y: Moment for the tie rod setting point by active earth pressure and residual water pressure

F: Safety factor

F= 1.657 > 1.5 ok

(2) Section of Sheet Piles

1) Active Earth Pressure and Residual Water pressure above the design depth

Level DL (m)	Σ Pa tf/m	Pa･y tf･m/m
+3.30	0.503	-0.771
+1.00	1.888	-1.448
+1.00	0.090	0.003
+0.89	0.094	0.007
+0.89	0.757	0.308
+0.00	1.280	0.900
+0.00	0.719	0.839
-0.50	0.756	1.008
Total	6.087	0.846

2) Reaction force of design depth

Ro= Pa･y:/lt= 0.564 tf/m

where, lt: Distance from Tie rod to Design depth lt= 1.50 m

3) Reaction at the tie rod setting point

Ap= Σ pa-Ro= 5.523 tf/m

4) Zero Point of Shearing force

$Q= A-B\cdot y-C\cdot y^2$

A= 0.911 , B= 2.876 , C= 0.1456

(DL -)y= 0.3120 m → Q= 0.000

5) Maximum bending moment of sheet piles Mmax

Level DL (m)	Height h (m)	Pa tf/m^2	Σ Pa tf/m	Center y (m)	Pa･y tf･m/m
-0.312	0.188	2.967	0.279	0.063	0.018
-0.500	0.188	3.022	0.284	0.125	0.036
Total			0.563		0.054

6) Section Characteristic of Sheet Pile

Sectional modulus (Steel Sheet Pile Type-III)

Z= 1,340 cm^3 /m(Before Corrosion)

Z'= 945 cm^3 /m(After Corrosion ; Life time 30 years)

7) Stress of Sheet Piles

σ =Mmax／Z'= 6 kgf/cm^2 ＜1,800 kgf/cm^2 ok

(3) Design of Tie Rods

1) Tension of the tie rod

Tension acting on a tie rod shell be calculated in accordance with following formula.

T= Ap*L

where, l: Tie rod setting interval = 1.6 m

∴T= 8.837 tf

2) Stress of Tie Rod

Diameter of Tie Rod φ= 38 mm

Corrosion tc= 1.8 mm (Life time 30 years)

Sectional area A= 1029.2 mm^2

Stress of Tie Rod σ = T/A= 859 kgf/cm^2 ＜960 kgf/cm^2

(4) Design of Wale

1) Maximum bending moment

M= T・ L/10= 1.414 tf・m/m

2) Stress of Wale

Using material Ditch type Steel 2x［ 125x65x6.0x8.0

Sectional modulus Z= 2x67=134 cm^3 (Before Corrosion)

Z'= 2x57=114 cm^3 (After Corrosion ; Life time 30 years)

Stress of Wale σs= M/Z= 1240 kgf/cm^2 ＜1,400 kgf/cm^2

(5) Design of Anchorage Steel Sheet Piles

1) Section Characteristic of Sheet Pile

Sectional modulus (Steel Sheet Pile Type-III)

Z= 1,340 cm^3 /m(Before Corrosion)

Z'= 1,160 cm^3 /m(After Corrosion ; Life time 30 years)

Pile flexural rigidity EI ($kgf\cdot cm^2$)

EI= 3.360E+10 $kgf\cdot cm^2$ /m (Before Corrosion)

EI= 2.879E+10 $kgf\cdot cm^2$ /m(After Corrosion ; Life time 30 years)

2) Coefficient of lateral subgrade reaction kh

kh= 0.15N= 0.75 kgf/cm^3

where, N= 5 (N-value of the ground)

3) $\beta = \{kh\cdot B/(4EI)\}^{1/4} = 0.00486\ cm^{-1} = 0.486\ m^{-1}$

$\beta' = \{kh\cdot B/(4EI')\}^{1/4} = 0.00505\ cm^{-1} = 0.505\ m^{-1}$

where, Width of Pile B= 100 cm

4) Maximum bending moment

Mmax＝0.3224・T/β

where, Tension of a tie rod T= 5.523 tf/m

∴Mmax＝3.664 tf・m/m

5) Stress of Sheet Piles

σ＝Mmax／Z'= 316 kgf/cm² ＜1,800 kgf/cm² ok

6) Embedded Length of Sheet Piles

L= 3.0/β= 6.17 m →6.50 m

Length of Sheet Piles Ls= 7.00 m

7) Displacement of a Sheet Pile at Tie Rod

σ＝T/(2EIβ³)= 0.744 cm <5.0cm ok

8) Distance between Sheet Piles L(m)

Height between Tie Rod and Sea Bed h1= 1.50 m

Effective height of Anchorage Sheet Piles Lm1/3=π/(3β)= 2.155 m

Angle of the failer plane of active earth pressure cotζa= 0.653

Angle of the failer plane of passive earth pressure cotζp= 2.653

L= h1・cotζa+h2・cotζp= 6.697 m →7.00 m

Calculation result table

Structures	Calculation Item	Unit	Calculation value	Allowab value
Sheet Piles	Materials	Steel Sheet Piles L=4.50 m		
	Standard	JIS A 5528,Type U-Ⅲ,SY295		
	Section	A=76.42cm²,Z=1,340cm³/m,I=16,800cm⁴/m		
	Stress	kgf/cm²	6	1,800
	Embedded Level	DL(m)	-3.00	―
	Safety Ratio of Embedded	―	1.657	1.5
Tie Rods	Materials	Tie Rod , SS400 , ϕ=38.00 mm		
	Stress	kgf/cm²	859	960
	Length of Tie Rod	m	7.00	6.70
Wales	Materials	Ditch Type Steel,ss400 ,2[125x65x6.0x8.0		
	Stress	kgf/cm²	1,240	1,400
Anchorage	Materials	Steel Sheet Piles L=6.50 m		
	Standard	JIS A 5528,Type U-Ⅲ,SY295		
	Section	A=76.42cm²,Z=1,340cm³/m,I=16,800cm⁴/m		
	Stress	kgf/cm²	316	1,800
	Embedded Level	DL(m)	-5.50	-5.17
	Displacement of Head	cm	0.74	5.00

(6) Calculation of the Sheet Pile Length

Level of Pile Tip DL(m)	Embedded Length(m)	Pile Length L (m)	Load W(tf/m)	N_1	N_{m2}	N	N_m
-12.0	11.5	14.0	17.08	40.00	5.00	22.50	5.00
-12.5	12.0	14.5	17.16	40.00	12.00	26.00	6.46
-13.0	12.5	15.0	17.23	40.00	19.00	29.50	7.80
-13.5	13.0	15.5	17.31	40.00	26.00	33.00	9.04
-14.0	13.5	16.0	17.38	40.00	33.00	36.50	10.19
-14.5	14.0	16.5	17.46	40.00	40.00	40.00	11.25

Level of Pile Tip DL(m)	$30NA_p$ (tf)	$N_mA_s/5$ (tf)	R_u (tf)	$Ra=R_u/F$ (tf)	
-12.0	168.75	23.00	191.75	76.70	>Load
-12.5	195.00	31.00	226.00	90.40	
-13.0	221.25	39.00	260.25	104.10	
-13.5	247.50	47.00	294.50	117.80	
-14.0	273.75	55.00	328.75	131.50	
-14.5	300.00	63.00	363.00	145.20	

C. Island Harbours

Ⅰ. Concrete Block Type (Front wall inclination $\theta=0°$、Planed depth DL-2.5 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L D.L.+1.34 m

L.W.L D.L.±0.00 m

R.W.L D.L.+0.45m {=L.W.L+(H.W.L−L.W.L)/3}

(2) Design Level

Crown Height of Quay wall D.L.+2.00 m

Planed Depth of Quay wall D.L-2.50 m

Design Depth of Quay wall D.L.-2.50 m

Depth of Concrete Block D.L.-2.70 m

(3) Surcharge $q=1.5\ t/m^2$

(4) Materials

Plain concrete $\gamma c=2.30\ tf/m^3$

Backfilling

Materials	Unit Weight γ (tf/m^3)		ϕ (°)
	In air	In water	
Backfill of Coral Stone	1.80	1.00	30
Backfill of sand	1.80	1.00	30
Rubble Stone	1.80	1.00	40

Unit weight of water $\gamma w=1.03\ tf/m^3$

(5) Coefficient of static friction

Concrete against Concrete	0.5
Concrete against Rubble Stone	0.6

(6) Angle of wall friction $\delta=15.0°$

(7) Bearing capacity of Subsoil $qa=16.0\ tf/m^2$

2. Calculation of Load

(1) Weight of Concrete Block

Level of Block DL (m)	Height h (m)	Width b (m)	γc (tf/m^3)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.50				
+0.80	1.20	0.90	2.30	1.932	0.360	0.696
+0.80		1.80				
+0.45	0.35	1.80	2.30	1.449	0.900	1.304
+0.45		1.80				
-1.00	1.45	1.80	1.27	3.315	0.900	2.984
-1.00		2.30				
-2.70	1.70	2.30	1.27	4.966	1.150	5.711
Total	4.70			11.662		10.695

(2) Weight of Soil on the Block

Level DL (m)	Height h (m)	Width b (m)	γ (tf/m^3)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.40				
+0.80	1.20	0.00	1.80	0.432	0.767	0.331
+0.80	1.20	0.90	1.80	1.944	1.350	2.624
+0.45	0.35	0.50	1.80	1.395	2.050	2.860
+0.45		0.50				
-1.00	1.45	0.50	1.00	0.725	2.050	1.486
Total	3.00			4.496		7.301

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m²)	Σ γ h+q tf/m²	Kah	Pressure pa(tf/m²)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	0.906
-1.00	1.45		5.74	0.2911	1.671	1.211
-1.00			5.74	0.2911	1.671	1.420
-2.70	1.70		7.44	0.2911	2.166	1.841
Total	4.70					6.685

Note;Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa·y tf·m/m	y' m	Pv tf/m
+2.00	1.20	0.262	4.300	1.127		0.07
+0.80	1.20	0.640	3.900	2.494	0.516	0.17
+0.80	0.35	0.187	3.383	0.631		0.05
+0.45	0.35	0.219	3.267	0.714		0.05
+0.45	1.45	0.906	2.667	2.415		0.24
-1.00	1.45	1.211	2.183	2.645	1.228	0.32
-1.00	1.70	1.420	1.133	1.610		0.38
-2.70	1.70	1.841	0.567	1.043		0.49
Total		6.685		12.680	1.897	1.79

(4) Residual Water Pressure

Level DL (m)	Height h (m)	Pressure pw(tf/m²)	Pw tf/m	Center y (m)	Pw·y tf·m/m	y' m
+0.45		0	0.000	0.000	0.000	
+0.00	0.45	0.464	0.104	2.850	0.297	
-1.00	1.00	0.464	0.464	2.200	1.020	1.14
-2.70	1.70	0.464	0.788	0.850	0.670	
Total			1.356		1.987	1.46

3. Stability Calculation

(1) Examination Concerning Sliding of Wall

Safety Rate of Sliding F=f·W/P

Level	Weight and vertical force W (tf/m)			
DL (m)	Block	Soil	Pv	Total
+0.80	1.932	0.432	0.242	2.606
-1.00	6.696	3.771	1.745	12.212
-2.70	11.662	4.496	1.791	17.949

Level	Horizontal force P (tf/m)			Coefficient	Safety rate	Permissil
DL (m)	Pa	Pw	Total	of friction f	of sliding F	value
+0.80	0.902	0.000	0.902	0.5	1.445	1.20
-1.00	3.424	0.568	3.992	0.5	1.530	
-2.70	6.685	1.356	8.041	0.6	1.339	

(2) Examination Concerning Overturning of Wall

Safety Rate of Overturning F=W·x/P·y

Level	Weight and vertical force W·x (tf/m)			
DL (m)	Block	Soil	Pv·x	Total
+0.80	0.696	0.331	0.217	1.244
-1.00	4.984	2.955	3.141	11.080
-2.70	10.695	7.301	4.119	22.115

Level	Horizontal force P·y (tf/m)			Safety rate	Permissible
DL (m)	Pa·y'	Pw·y'	Total	F	value
+0.80	0.466	0.000	0.466	2.673	1.20
-1.00	4.206	0.648	4.854	2.282	
-2.70	12.680	1.987	14.667	1.508	

(3) Bottom Reactions of Concrete Block

Position of Gravity x=(W・x-P・y)/W=0.415 m

Eccentricity of Gravity e=b/2-x =0.735 m > B/6=0.383 m

Reaction at the front toe p1 = 2W/(3x) =28.83 tf/m² < 30.0 tf/m²

Width of Reactions b'=3x=1.245 m

(4) Bottom Reactions of Rubble Stone

Width of distribution of Reaction b1'

b1'=b'+D{tan(30 ° + θ)+tan(30 ° - θ)}

where, Depth of Rubble Foundation D=0.80 m

$\tan\theta = P/W = 0.448$

∴ $\theta = 24.1°$

b1'=2.434 m

Max. Reaction $p1' = b' \cdot p1/b1' + \gamma_2 \cdot D = 15.55$ tf/m² < 16.0 tf/m²

where、Unit Weight of Rubble Foundation $\gamma_2 = 1.0$ tf/m³

Calculation result table

Calculation Item	Calculation value			Allowable value
	+0.80	-1.00	-2.70	
Sliding Safety rate of Wall	1.445	1.530	1.339	1.20
Overturning safety rate of Wall	2.673	2.282	1.508	1.20
Bottom Reactions of Concrete Block	—	—	28.83	30.0
Bottom Reactions of Rubble Stone	—	—	15.55	16.0

II. Concrete Block Type (Front wall inclination $\theta = 18.43°$、Planed depth DL-2.5 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L D.L.+1.34 m

L.W.L D.L.±0.00 m

R.W.L D.L.+0.45m {=L.W.L+(H.W.L—L.W.L)/3}

(2) Design Level

Crown Height of Quay wall D.L.+2.00 m

Planed Depth of Quay wall D.L-2.50 m

Design Depth of Quay wall D.L.-2.50 m

Depth of Concrete Block D.L.-2.70 m

(3) Surcharge q=1.5 t/m²

(4) Materials

Plain concrete $\gamma c = 2.30$ tf/m³

Backfilling

Materials	Unit Weight γ (tf/m³)		ϕ (°)
	In air	In water	
Backfill of Coral Stone	1.80	1.00	30
Backfill of sand	1.80	1.00	30
Rubble Stone	1.80	1.00	40

Unit weight of water $\gamma w = 1.03$ tf/m³

(5) Coefficient of static friction

Concrete against Concrete	0.5
Concrete against Rubble Stone	0.6

(6) Angle of wall friction $\delta = 15.0°$

(7) Bearing capacity of Subsoil qa=16.0 tf/m²

2. Calculation of Load

(1) Weight of Concrete Block

Level of Block DL (m)	Height h (m)	Width b (m)	γc (tf/m³)	Weight W (tf/m)	Center x (m)	W･x tf･m/m
+2.00		0.50			1.707	3.298
+0.80	1.20	0.90	2.30	1.932	0.540	1.043
+0.80		1.70			1.990	2.820
+0.45	0.35	1.82	2.30	1.417	0.940	1.332
+0.45		1.82			1.832	6.949
-1.00	1.45	2.30	1.27	3.793	1.265	4.798
-1.00		2.30				
-2.70	1.70	2.87	1.27	5.581	1.572	8.773
Total	4.70			12.723		21.840

(2) Weight of Soil on the Block

Level DL (m)	Height h (m)	Width b (m)	γ (tf/m³)	Weight W (tf/m)	Center x ,x'(m)	,W･x' tf･m/m
+2.00		0.80			2.467	4.263
+0.80	1.20	0.80	1.80	1.728	1.300	2.246
+0.80		0.00			2.870	0
+0.45	0.35	0.00	1.80	0.000	1.820	0.000
+0.45		0.00			2.867	0
-1.00	1.45	0.00	1.00	0.000	2.300	0.000
Total	1.80			1.728		4.263

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m²)	Σγh+q tf/m²	Kah	Pressure pa(tf/m²)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	0.906
-1.00	1.45		5.74	0.2911	1.671	1.211
-1.00			5.74	0.2911	1.671	1.420
-2.70	1.70		7.44	0.2911	2.166	1.841
Total	4.70					6.686

Note；Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa･y tf･m/m	y' m	Pv tf/m
+2.00	1.20	0.262	4.300	1.127		0.070
+0.80	1.20	0.640	3.900	2.496	0.516	0.171
+0.80	0.35	0.187	3.383	0.633		0.050
+0.45	0.35	0.219	3.267	0.715		0.059
+0.45	1.45	0.906	2.667	2.416		0.243
-1.00	1.45	1.211	2.183	2.644	1.229	0.324
-1.00	1.70	1.420	1.133	1.609		0.380
-2.70	1.70	1.841	0.567	1.043		0.493
Total		6.686		12.683	1.897	1.791

(4) Residual Water Pressure

Level DL (m)	Hight h (m)	Pressure pw(tf/m²)	Pw tf/m	Center y (m)	Pw･y tf･m/m	y' m
+0.45		0	0.000	0.000	0.000	
+0.00	0.45	0.464	0.104	2.850	0.296	
-1.00	1.00	0.464	0.464	2.200	1.021	1.139
-2.70	1.70	0.464	0.788	0.850	0.670	
Total			1.356		1.987	1.465

3. Stability Calculation

(1) Examination Concerning Sliding of Wall

Safety Rate of Sliding　F=f･W/P

Level	Weight and vertical force W (tf/m)			
DL (m)	Block	Soil	Pv	Total
+0.80	1.932	0.000	0.242	2.174
-1.00	7.142	1.728	0.918	9.788
-2.70	12.723	1.728	1.791	16.242

Level DL (m)	Horizontal force P (tf/m)			Coefficient of friction f	Safety rate of sliding F	Permissible value
	Pa	Pw	Total			
+0.80	0.902	0.000	0.902	0.5	1.205	1.20
-1.00	3.425	0.568	3.993	0.5	1.226	
-2.70	6.686	1.356	8.042	0.6	1.212	

(2) Examination Concerning Overturning of Wall

Safety Rate of Overturning　F=W･x/P･y

Level	Weight and vertical force W·x (tf/m)			
DL (m)	Block	Soil	Pv·x	Total
+0.80	1.043	0.000	0.218	1.261
-1.00	9.017	3.283	2.111	14.412
-2.70	21.840	4.263	5.140	31.243

Level	Horizontal force P·y (tf/m)			safety rate	Permissible
DL (m)	Pa·y'	Pw·y'	Total	F	value
+0.80	0.465	0.000	0.465	2.709	1.20
-1.00	4.209	0.647	4.856	2.968	
-2.70	12.683	1.987	14.670	2.130	

(3) Bottom Reactions of Concrete Block

Bottom Reactions of Concrete Block

Position of Gravity　x=(W・x-P･y)/W= 1.020 m

Eccentricity of Gravity　e= b/2-x = 0.415 m < B/6= 0.478 m

Reaction at the front toe　p1 = (1+6e/B)*W/B = 10.57 tf/m² < 30.0 tf/m²

Width of Reactions　b'= 2.87 m

(4) Bottom Reactions of Rubble Stone

Width of distribution of Reaction　b1'

b1'= b'+D{tan(30°+θ)+tan(30°-θ)}

where、Depth of Rubble Foundation　D= 0.50 m

tanθ＝P/W　= 0.495　∴θ＝26.3°、b1'= 3.653 m

Max. Reaction　p1'= b'･p1/b1'+ γ_2･D　= 8.80 tf/m² < 16.0 tf/m²

where、Unit Weight of Rubble Foundation　γ_2= 1.0 tf/m³

Calculation result table

Calculation Item	Calculation value			Allowable value
	+0.80	-1.00	-2.70	
Sliding Safety rate of　Wall	1.205	1.226	1.212	1.20
Overturning safety rate of Wall	2.709	2.968	2.130	1.20
Bottom Reactions of Concrete Block	―	―	10.57	30.0
Bottom Reactions of Rubble Stone	―	―	8.80	16.0

III. Concrete Block Type (Front wall inclination θ＝18.43°、Planed depth DL-3.0 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L D.L.+1.34 m

L.W.L D.L.±0.00 m

R.W.L D.L.+0.45m {=L.W.L+(H.W.L—L.W.L)/3}

(2) Design Level

Crown Height of Quay wall D.L.+2.00 m

Planed Depth of Quay wall D.L-3.00 m

Design Depth of Quay wall D.L.-3.00 m

Depth of Concrete Block D.L.-3.20 m

(3) Surcharge q=1.5 t/m²

(4) Materials

Plain concrete γc＝2.30 tf/m³

Backfilling

Materials	Unit Weight γ (tf/m³)		φ (°)
	In air	In water	
Backfill of Coral Stone	1.80	1.00	30
Backfill of sand	1.80	1.00	30
Rubble Stone	1.80	1.00	40

Unit weight of water γw＝1.03 tf/m³

(5) Coefficient of static friction

Concrete against Concrete	0.5
Concrete against Rubble Stone	0.6

(6) Angle of wall friction δ＝15.0 °

(7) Bearing capacity of Subsoil qa＝16.0 tf/m²

2. Calculation of Load

(1) Weight of Concrete Block

Level of Block DL (m)	Height h (m)	Width b (m)	γc (tf/m³)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.50			1.873	3.619
+0.80	1.20	0.90	2.30	1.932	0.540	1.043
+0.80		1.80			2.207	3.304
+0.45	0.35	1.92	2.30	1.497	0.990	1.482
+0.45		1.92			2.022	9.932
-1.30	1.75	2.50	1.27	4.912	1.389	6.823
-1.30		2.50				
-3.20	1.90	3.13	1.27	6.793	1.717	11.664
Total	5.20			15.134		28.519

(2) Weight of Soil on the Block

Level DL (m)	Height h (m)	Width b (m)	γ (tf/m³)	Weight W (tf/m)	Center x ,x'(m)	W・x,W・x' tf・m/m
+2.00		0.90			2.683	5.216
+0.80	1.20	0.90	1.80	1.944	1.350	2.624
+0.80		0.00			3.137	0
+0.45	0.35	0.00	1.80	0.000	1.920	0.000
+0.45		0.00			3.133	0
-1.30	1.75	0.00	1.00	0.000	2.500	0.000
Total	2.10			1.944		5.216

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m^2)	$\Sigma \gamma h+q$ tf/m^2	Kah	Pressure pa(tf/m^2)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	1.093
-1.30	1.75		6.04	0.2911	1.759	1.539
-1.30			6.04	0.2911	1.759	1.671
-3.20	1.90		7.94	0.2911	2.312	2.196
Total	5.20					7.807

Note:Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa·y tf·m/m	y' m	Pv tf/m
+2.00	1.20	0.262	4.800	1.258		0.070
+0.80	1.20	0.640	4.400	2.816	0.516	0.171
+0.80	0.35	0.187	3.883	0.726		0.050
+0.45	0.35	0.219	3.767	0.825		0.059
+0.45	1.75	1.093	3.067	3.352		0.293
-1.30	1.75	1.539	2.483	3.822	1.348	0.412
-1.30	1.90	1.671	1.267	2.117		0.448
-3.20	1.90	2.196	0.633	1.391		0.588
Total		7.807		16.306	2.089	2.091

(4) Residual Water Pressure

Level DL (m)	Height h (m)	Pressure pw(tf/m^2)	Pw tf/m	Center y (m)	Pw·y tf·m/m	y' m
+0.45		0	0.000	0.000	0.000	
+0.00	0.45	0.464	0.104	3.350	0.348	
-1.30	1.30	0.464	0.603	2.550	1.538	1.228
-3.20	1.90	0.464	0.881	0.950	0.837	
Total			1.588		2.723	1.715

3. Stability Calculation

(1) Examination Concerning Sliding of Wall

Safety Rate of Sliding F=f・W/P

Level	Weight and vertical force W (tf/m)			
DL (m)	Block	Soil	Pv	Total
+0.80	1.932	0.000	0.242	2.174
-1.30	8.341	1.944	1.056	11.341
-3.20	15.134	1.944	2.091	19.169

Level	Horizontal force P (tf/m)			Coefficient	Safety rate	Permissible
DL (m)	Pa	Pw	Total	of friction f	of sliding F	value
+0.80	0.902	0.000	0.902	0.5	1.205	
-1.30	3.940	0.707	4.647	0.5	1.220	1.20
-3.20	7.807	1.588	9.395	0.6	1.224	

(2) Examination Concerning Overturning of Wall

Safety Rate of Overturning F=W・x/P・y

Level	Weight and vertical force W・x (tf/m)			
DL (m)	Block	Soil	Pv·x	Total
+0.80	1.043	0.000	0.218	1.261
-1.30	11.574	3.985	2.640	18.199
-3.20	28.519	5.216	6.545	40.279

Level	Horizontal force P·y (tf/m)			safety rate	Permissible
DL (m)	Pa·y'	Pw·y'	Total	F	value
+0.80	0.465	0.000	0.465	2.709	
-1.30	5.311	0.868	6.179	2.945	1.20
-3.20	16.306	2.723	19.029	2.117	

(3) Bottom Reactions of Concrete Block

Position of Gravity x=(W・x-P・y)/W=1.109 m

Eccentricity of Gravity e=b/2-x =0.456 m < B/6=0.522 m

Reaction at the front toe p1 = (1+6e/B)*W/B=11.48 tf/m^2 < 30.0 tf/m^2

Width of Reactions b'=3.13 m

(4) Bottom Reactions of Rubble Stone

Width of distribution of Reaction　b1'

$b1' = b' + D\{\tan(30° + \theta) + \tan(30° - \theta)\}$

where,　Depth of Rubble Foundation　　D=0.50 m

$\tan\theta = P/W$ =0.490　　∴ θ = 26.1 ° ,b1'=3.908 m

Max. Reaction　$p1' = b' \cdot p1/b1' + \gamma_2 \cdot D$ =9.70 tf/m² < 16.0 tf/m²

where、Unit Weight of Rubble Foundation　γ_2=1.0 tf/m³

Calculation result table

Calculation Item	Calculation value			Allowable
	+0.80	-1.30	-3.20	value
Sliding Safety rate of　Wall	1.205	1.220	1.224	1.20
Overturning safety rate of Wall	2.709	2.945	2.117	1.20
Bottom Reactions of Concrete Block	―	―	11.48	30.0
Bottom Reactions of Rubble Stone	―	―	9.70	16.0

IV. Concrete Block Type (Front wall inclination　θ = 18.43 ° 、Planed depth DL-2.0 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L　　D.L.+1.34 m

L.W.L　　D.L.±0.00 m

R.W.L　　D.L.+0.45m {=L.W.L+(H.W.L−L.W.L)/3}

(2) Design Level

Crown Height of Quay wall　　D.L.+2.00 m

Planed Depth of Quay wall　　D.L-2.00 m

Design Depth of Quay wall　　D.L.-2.00 m

Depth of Concrete Block　　　D.L.-2.20 m

(3) Surcharge　　q=1.5 t/m²

(4) Materials

Plain concrete　　γc = 2.30 tf/m³

Backfilling

Materials	Unit Weight γ (tf/m³)		ϕ (°)
	In air	In water	
Backfill of Coral Stone	1.80	1.00	30
Backfill of sand	1.80	1.00	30
Rubble Stone	1.80	1.00	40

Unit weight of water　　γw = 1.03 tf/m³

(5) Coefficient of static friction

Concrete against Concrete	0.5
Concrete against Rubble Stone	0.6

(6) Angle of wall friction　　δ = 15.0 °

(7) Bearing capacity of Subsoil　qa=16.0 tf/m²

2. Calculation of Load

(1) Weight of Concrete Block

Level of Block DL (m)	Height h (m)	Width b (m)	γc (tf/m³)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.50			1.540	2.975
+0.80	1.20	0.90	2.30	1.932	0.540	1.043
+0.80		1.60			1.773	2.369
+0.45	0.35	1.72	2.30	1.336	0.890	1.189
+0.45		1.72			1.642	4.581
−0.70	1.15	2.10	1.27	2.790	1.142	3.186
−0.70		2.10				
−2.20	1.50	2.60	1.27	4.477	1.421	6.362
Total	4.20			10.535		16.287

(2) Weight of Soil on the Block

Level DL (m)	Height h (m)	Width b (m)	γ (tf/m³)	Weight W (tf/m)	Center x ,x'(m)	W・x,W・x' tf・m/m
+2.00		0.70			2.250	3.402
+0.80	1.20	0.70	1.80	1.512	1.250	1.890
+0.80		0.00			2.603	0
+0.45	0.35	0.00	1.80	0.000	1.720	0.000
+0.45		0.00			2.600	0
-0.70	1.15	0.00	1.00	0.000	2.100	0.000
Total	1.50			1.512		3.402

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m²)	Σγh+q tf/m²	Kah	Pressure pa(tf/m²)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	0.718
-0.70	1.15		5.44	0.2911	1.584	0.911
-0.70			5.44	0.2911	1.584	1.188
-2.20	1.50		6.94	0.2911	2.021	1.516
Total	4.20					5.641

Note; Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa・y tf・m/m	y' m	Pv tf/m
+2.00	1.20	0.262	3.800	0.996		0.070
+0.80	1.20	0.640	3.400	2.176	0.516	0.171
+0.80	0.35	0.187	2.883	0.539		0.050
+0.45	0.35	0.219	2.767	0.606		0.059
+0.45	1.15	0.718	2.267	1.627		0.192
-0.70	1.15	0.911	1.883	1.716	1.108	0.244
-0.70	1.50	1.188	1.000	1.188		0.318
-2.20	1.50	1.516	0.500	0.758		0.406
Total		5.641		9.606	1.703	1.511

(4) Residual Water Pressure

Level DL (m)	Height h (m)	Pressure pw(tf/m²)	Pw tf/m	Center y (m)	Pw・y tf・m/m	y' m
+0.45		0	0.000	0.000	0.000	
+0.00	0.45	0.464	0.104	2.350	0.244	
-0.70	0.70	0.464	0.324	1.850	0.599	1.104
-2.20	1.50	0.464	0.695	0.750	0.521	
Total			1.123		1.365	1.216

3. Stability Calculation

(1) Examination Concerning Sliding of Wall

Safety Rate of Sliding　F=f･W/P

Level DL (m)	Weight and vertical force W (tf/m)			
	Block	Soil	Pv	Total
+0.80	1.932	0.000	0.242	2.174
-0.70	6.058	1.512	0.787	8.357
-2.20	10.535	1.512	1.511	13.558

Level DL (m)	Horizontal force P (tf/m)			Coefficient of friction f	Safety rate of sliding F	Permissible value
	Pa	Pw	Total			
+0.80	0.902	0.000	0.902	0.5	1.205	1.20
-0.70	2.937	0.428	3.365	0.5	1.242	
-2.20	5.641	1.123	6.764	0.6	1.203	

(2) Examination Concerning Overturning of Wall

Safety Rate of Overturning　F=W･x/P･y

Level DL (m)	Weight and vertical force W･x (tf/m)			
	Block	Soil	Pv･x	Total
+0.80	1.043	0.000	0.218	1.261
-0.70	6.896	2.646	1.653	11.195
-2.20	16.287	3.402	3.929	23.618

Level DL (m)	Horizontal force P･y (tf/m)			safety rate F	Permissible value
	Pa･y'	Pw･y'	Total		
+0.80	0.465	0.000	0.465	2.709	1.20
-0.70	3.254	0.473	3.727	3.004	
-2.20	9.606	1.365	10.971	2.153	

(3) Bottom Reactions of Concrete Block

Position of Gravity　$x=(W \cdot x - P \cdot y)/W = 0.933$ m

Eccentricity of Gravity　$e = b/2 - x = 0.367$ m $< B/6 = 0.433$ m

Reaction at the front toe　$p1 = (1+6e/B)*W/B = 9.63$ tf/m^2 < 30.0 tf/m^2

Width of Reactions　b'=2.60 m

(4) Bottom Reactions of Rubble Stone

Width of distribution of Reaction　b1'

$b1' = b' + D\{\tan(30° + \theta) + \tan(30° - \theta)\}$

where、Depth of Rubble Foundation　D=0.50 m

$\tan\theta = P/W = 0.499$　$\therefore \theta = 26.5°$, $b1' = 3.386$ m

Max. Reaction　$p1' = b' \cdot p1/b1' + \gamma_2 \cdot D = 7.90$ tf/m^2 < 16.0 tf/m^2

where、Unit Weight of Rubble Foundation　$\gamma_2 = 1.0$ tf/m^3

Calculation result table

Calculation Item	Calculation value			Allowable value
	+0.80	-0.70	-2.20	
Sliding Safety rate of Wall	1.205	1.242	1.203	1.20
Overturning sefty rate of Wall	2.709	3.004	2.153	1.20
Bottom Reactions of Concrete Block	—	—	9.63	30.0
Bottom Reactions of Rubble Stone	—	—	7.90	16.0

V. L-Shaped Block Type (Front wall inclination θ＝0°、Planed depth DL-2.5 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L D.L.+1.34 m

L.W.L D.L.±0.00 m

R.W.L D.L.+0.45m {=L.W.L+(H.W.L−L.W.L)/3}

(2) Design Level

Crown Height of Quay wall D.L.+2.00 m

Planed Depth of Quay wall D.L-2.50 m

R.W.L D.L.+0.45m {=L.W.L+(H.W.L−L.W.L)/3}

(2) Design Level

Crown Height of Quay wall D.L.+2.00 m

Design Depth of Quay wall D.L.-2.50 m

Depth of Concrete Block D.L.-2.70 m

(3) Surcharge q=1.5 t/m²

(4) Materials

Plain concrete γc＝2.30 tf/m³

Backfilling

Materials	Unit Weight γ (tf/m³)		φ (°)
	In air	In water	
Backfill of Coral Stone	1.80	1.00	30
Backfill of sand	1.80	1.00	30
Rubble Stone	1.80	1.00	40

Unit weight of water γw＝1.03 tf/m³

(5) Coefficient of static friction

Concrete against Concrete	0.5
Concrete against Rubble Stone	0.6

(6) Angle of wall friction δ＝15.0 °

(7) Bearing capacity of Subsoil qa＝16.0 tf/m²

2. Calculation of Load

(1) Weight of Concrete Block

Level of Block DL (m)	Height h (m)	Width b (m)	γc (tf/m³)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.50				
+0.80	1.20	0.90	2.30	1.932	0.360	0.696
+0.80		2.50				
+0.45	0.35	2.50	1.90	1.663	1.250	2.079
+0.45		2.50				
-2.70	3.15	2.50	1.05	8.269	1.250	10.336
Total	4.70			11.864		13.111

(2) Weight of Soil on the Block

Level DL (m)	Height h (m)	Width b (m)	γ (tf/m³)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.40				
+0.80	1.20	0.00	1.80	0.432	0.767	0.331
+0.80	1.20	1.60	1.80	3.456	1.700	5.875
Total	1.20			3.888		6.206

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m²)	Σγh+q tf/m²	Kah	Pressure pa(tf/m²)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	1.967
-2.70	3.15		7.44	0.2911	2.166	3.411
Total	4.70					6.686

Note; Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa·y tf·m/m	y' m	Pv tf/m
+2.00	1.20	0.262	4.300	1.127		0.070
+0.80	1.20	0.640	3.900	2.496	0.516	0.171
+0.80	0.35	0.187	3.383	0.633		0.050
+0.45	0.35	0.219	3.267	0.715		0.059
+0.45	3.15	1.967	2.100	4.131		0.527
-2.70	3.15	3.411	1.050	3.582		0.914
Total		6.686		12.683	1.897	1.791

(4) Residual Water Pressure

Level DL (m)	Height h (m)	Pressure pw(tf/m²)	Pw tf/m	Center y (m)	Pw·y tf·m/m
+0.45		0	0.000	0.000	0.000
+0.00	0.45	0.464	0.104	2.850	0.297
-2.70	2.70	0.464	1.251	1.350	1.689
Total			1.356		1.987

3. Stability Calculation

(1) Examination Concerning Sliding of Wall

Safety Rate of Sliding F=f·W/P

Level DL (m)	Weight and vertical force W (tf/m)			
	Block	Soil	Pv	Total
+0.80	1.932	0.432	0.242	2.606
-2.70	11.864	3.888	1.791	17.543

Level DL (m)	Horizontal force P (tf/m)			Coefficient of friction f	Safety rate of sliding F	Permissible value
	Pa	Pw	Total			
+0.80	0.902	0.000	0.902	0.5	1.444	1.20
-2.70	6.686	1.356	8.042	0.6	1.309	

(2) Examination Concerning Overturning of Wall

Safety Rate of Overturning F=W·x/P·y

Level DL (m)	Weight and vertical force W·x (tf/m)			
	Block	Soil	Pv·x	Total
+0.80	0.696	0.331	0.217	1.244
-2.70	13.111	6.206	4.478	23.795

Level DL (m)	Horizontal force P·y (tf/m)			safety rate F	Permissible value
	Pa·y'	Pw·y'	Total		
+0.80	0.466	0.000	0.466	2.673	1.20
-2.70	12.683	1.987	14.670	1.622	

(3) Bottom Reactions of Concrete Block

Position of Gravity x=(W・x-P·y)/W=0.520 m

Eccentricity of Gravity e=b/2-x =0.730 m > B/6=0.417 m

Reaction at the front toe p1 = 2W/(3x) =22.48 tf/m² < 30.0 tf/m2

Width of Reactions b'=3x=1.560 m

(4) Bottom Reactions of Rubble Stone

Width of distribution of Reaction b1'

b1'=b'+D{tan(30 ° + θ)+tan(30 ° - θ)}

where, Depth of Rubble Foundation D=0.50 m

$\tan\theta = P/W = 0.458 \therefore \theta = 24.6°$ b1'=2.312 m

Max. Reaction $p1' = b' \cdot p1/b1' + \gamma_2 \cdot D = 15.68$ tf/m² < 16.0 tf/m²

Where , Unit Weight of Rubble Foundation $\gamma 2 = 1.0$ tf/m³

Calculation result table

Calculation Item	Calculation value		Allowable value
	+0.80	-2.70	
Sliding Safety rate of Wall	1.444	1.309	1.20
Overturning safety rate of Wall	2.673	1.622	1.20
Bottom Reactions of Concrete Block	—	22.48	30.00
Bottom Reactions of Rubble Stone	—	15.68	16.00

VI. Cellular Block Type (Front wall inclination θ＝0 ° 、Planed depth DL-2.5 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L D.L.+1.34 m

L.W.L D.L.±0.00 m

R.W.L D.L.+0.45m {=L.W.L+(H.W.L—L.W.L)/3}

(2) Design Level

Crown Height of Quay wall D.L.+2.00 m

Planed Depth of Quay wall D.L-2.50 m

Design Depth of Quay wall D.L.-2.50 m

Depth of Concrete Block D.L.-2.70 m

(3) Surcharge q=1.5 t/m²

(4) Materials

Plain concrete $\gamma c = 2.30$ tf/m³

Backfilling

Materials	Unit Weight γ (tf/m³)		ϕ (°)
	In air	In water	
Backfill of Coral Stone	1.80	1.00	30
Backfill of sand	1.80	1.00	30
Rubble Stone	1.80	1.00	40

Unit weight of water $\gamma w = 1.03$ tf/m³

(5) Coefficient of static friction

Concrete against Concrete	0.5
Concrete against Rubble Stone	0.6

(6) Angle of wall friction $\delta = 15.0°$

(7) Bearing capacity of Subsoil qa＝16.0 tf/m²

2. Calculation of Load

(1) Weight of Concrete Block

Level of Block DL (m)	Height h (m)	Width b (m)	γc (tf/m³)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.50				
+0.80	1.20	0.90	2.30	1.932	0.360	0.696
+0.80		1.80				
+0.45	0.35	1.80	2.10	1.323	0.900	1.191
+0.45		1.80				
-1.00	1.45	1.80	1.20	3.132	0.900	2.819
-1.00		2.30				
-2.70	1.70	2.30	1.20	4.692	1.150	5.396
Total	4.70			11.079		10.102

(2) Weight of Soil on the Block

Level DL (m)	Height h (m)	Width b (m)	γ (tf/m³)	Weight W (tf/m)	Center x (m)	W・x tf・m/m
+2.00		0.40				
+0.80	1.20	0.00	1.80	0.432	0.767	0.331
+0.80	1.20	0.90	1.80	1.944	1.350	2.624
+0.45	0.35	0.50	1.80	1.395	2.050	2.860
+0.45		0.50				
-1.00	1.45	0.50	1.00	0.725	2.050	1.486
Total	3.00			4.496		7.301

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m²)	Σγh+q tf/m²	Kah	Pressure pa(tf/m²)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	0.906
-1.00	1.45		5.74	0.2911	1.671	1.211
-1.00			5.74	0.2911	1.671	1.420
-2.70	1.70		7.44	0.2911	2.166	1.841
Total	4.70					6.685

Note:Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa・y tf・m/m	y' m	Pv tf/m
+2.00	1.20	0.262	4.300	1.127		0.070
+0.80	1.20	0.640	3.900	2.494	0.516	0.171
+0.80	0.35	0.187	3.383	0.631		0.050
+0.45	0.35	0.219	3.267	0.714		0.059
+0.45	1.45	0.906	2.667	2.415		0.243
-1.00	1.45	1.211	2.183	2.645	1.228	0.325
-1.00	1.70	1.420	1.133	1.610		0.381
-2.70	1.70	1.841	0.567	1.043		0.493
Total		6.685		12.680	1.897	1.791

(4) Residual Water Pressure

Level DL (m)	Height h (m)	Pressure pw(tf/m²)	Pw tf/m	Center y (m)	Pw・y tf・m/m	y' m
+0.45		0	0.000	0.000	0.000	
+0.00	0.45	0.464	0.104	2.850	0.297	
-1.00	1.00	0.464	0.464	2.200	1.020	1.141
-2.70	1.70	0.464	0.788	0.850	0.670	
Total			1.356		1.987	1.465

(3) Earth Pressure

Level DL (m)	Height h (m)	Surcharge q (tf/m²)	Σ γ h+q tf/m²	Kah	Pressure pa(tf/m²)	Pa tf/m
+2.00		1.50	1.50	0.2911	0.437	0.262
+0.80	1.20		3.66	0.2911	1.066	0.640
+0.80			3.66	0.2911	1.066	0.187
+0.45	0.35		4.29	0.2911	1.249	0.219
+0.45			4.29	0.2911	1.249	0.906
-1.00	1.45		5.74	0.2911	1.671	1.211
-1.00			5.74	0.2911	1.671	1.420
-2.70	1.70		7.44	0.2911	2.166	1.841
Total	4.70					6.685

Note;Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m	Center y (m)	Pa·y tf·m/m	y' m	Pv tf/m
+2.00	1.20	0.262	4.300	1.127		0.070
+0.80	1.20	0.640	3.900	2.494	0.516	0.171
+0.80	0.35	0.187	3.383	0.631		0.050
+0.45	0.35	0.219	3.267	0.714		0.059
+0.45	1.45	0.906	2.667	2.415		0.243
-1.00	1.45	1.211	2.183	2.645	1.228	0.325
-1.00	1.70	1.420	1.133	1.610		0.381
-2.70	1.70	1.841	0.567	1.043		0.493
Total		6.685		12.680	1.897	1.791

(4) Residual Water Pressure

Level DL (m)	Height h (m)	Pressure pw(tf/m²)	Pw tf/m	Center y (m)	Pw·y tf·m/m	y' m
+0.45		0	0.000	0.000	0.000	
+0.00	0.45	0.464	0.104	2.850	0.297	
-1.00	1.00	0.464	0.464	2.200	1.020	1.141
-2.70	1.70	0.464	0.788	0.850	0.670	
Total			1.356		1.987	1.465

3. Stability Calculation

(1) Examination Concerning Sliding of Wall

Safety Rate of Sliding F=f·W/P

Level DL (m)	Weight and vertical force W (tf/m)			
	Block	Soil	Pv	Total
+0.80	1.932	0.432	0.242	2.606
-1.00	6.387	3.771	1.745	11.903
-2.70	11.079	4.496	1.791	17.366

Level DL (m)	Horizontal force P (tf/m)			Coefficient of friction f	Safety rate of sliding F	Permissible value
	Pa	Pw	Total			
+0.80	0.902	0.000	0.902	0.5	1.445	1.20
-1.00	3.424	0.568	3.992	0.7	2.087	
-2.70	6.685	1.356	8.041	0.7	1.512	

(2) Examination Concerning Overturning of Wall

Safety Rate of Overturning F=W·x/P·y

Level DL (m)	Weight and vertical force W·x (tf/m)			
	Block	Soil	Pv·x	Total
+0.80	0.696	0.331	0.217	1.244
-1.00	4.706	2.955	3.141	10.802
-2.70	10.102	7.301	4.119	21.522

Level DL (m)	Horizontal force P·y (tf/m)			safety rate F	Permissible value
	Pa·y'	Pw·y'	Total		
+0.80	0.466	0.000	0.466	2.673	1.20
-1.00	4.206	0.648	4.854	2.225	
-2.70	12.680	1.987	14.667	1.467	

(3) Bottom Reactions of Concrete Block

Position of Gravity x=(W・x-P·y)/W=0.395 m

Eccentricity of Gravity e=b/2-x =0.755 m > B/6=0.383 m

Reaction at the front toe p1 = 2W/(3x) =29.33 tf/m² < 30.0 tf/m²

Width of Reactions b'=3x=1.184 m

(4) Bottom Reactions of Rubble Stone

Width of distribution of Reaction　b1'

$b1' = b' + D\{\tan(30° + \theta) + \tan(30° - \theta)\}$

where、Depth of Rubble Foundation　D=0.80 m

$\tan\theta = P/W = 0.463$ ∴ $\theta = 24.8°$　b1'=2.393 m

Max. Reaction　$p1' = b' \cdot p1/b1' + \gamma_2 \cdot D = 15.32\ tf/m^2 < 16.0\ tf/m^2$

where、Unit Weight of Rubble Foundation　$\gamma_2 = 1.0\ tf/m^3$

Calculation result table

Calculation Item	Calculation value			Allowable value
	+0.80	-1.00	-2.70	
Sliding Safety rate of Wall	1.445	2.087	1.512	1.20
Overturning safety rate of Wall	2.673	2.225	1.467	1.20
Bottom Reactions of Concrete Block	—	—	29.33	30.0
Bottom Reactions of Rubble Stone	—	—	15.32	16.0

Ⅶ. Steel Sheet Pile Type (Front wall inclination　θ＝0°、Planed depth DL-2.5 m)

1. Design Conditions

(1) Design Tidal Level

H.W.L　D.L.+1.34 m

L.W.L　D.L.±0.00 m

R.W.L　D.L+0.89m (=L.W.L+(H.W.L-L.W.L)*2/3)

(2) Design Level

Crown Height of Quay wall　D.L+2.00 m

Planed Depth of Quay wall　D.L-2.50 m

Design Depth of Quay wall　D.L-2.50 m

Level of Tie Rod　D.L+1.00 m

Embedded Level of Sheet Pile　D.L -5.50 m

(3) Surcharge　$q = 1.5\ t/m^2$

(4) Materials

Steel Sheet Pile ; SY295

Allowable stress　$\sigma sa = 1{,}800\ kgf/cm^2$

Type-ⅢA Sectional modulus　$Z = 1{,}520\ kgf/cm^2/m$

Type-ⅡA Sectional modulus　$Z = 880\ kgf/cm^2/m$

Tie Rod ; SS400

Allowable stress　$\sigma sa = 960\ kgf/cm^2$

Wale ; SS400

Allowable stress　$\sigma sa = 1{,}400\ kgf/cm^2$

Backfilling

Materials	Unit Weight γ (tf/m³)		φ	
	In air	In water	(°)	(rad)
Backfill of Coral Stone	1.80	1.00	30	0.5236
Backfill of sand	1.80	1.00	30	0.5236

Unit weight of water　$\gamma w = 1.03 tf/m^3$

(5) Safety Factor of Embedded　F＝1.5

(6) Angle of wall friction　$\delta = 15.0°$

(7) Condition of Subsoil　$\gamma' = 1.0\ tf/m^3$　(under the water)

$\phi = 28.0°$

2． Calculation of Load

(1) Active Earth Pressure and Residual Water pressure

Level DL (m)	Height h (m)	Σγh+q tf/m²	Kah	Pressure Pa (tf/m2)		
				Earth:pa	Water:pw	Total
+2.00		1.50	0.2911	0.437	0.000	0.437
+1.00	1.00	3.30	0.2911	0.961	0.000	0.961
+0.89	0.11	3.50	0.2911	1.019	0.000	1.019
+0.00	0.89	4.39	0.2911	1.278	0.917	2.195
-2.50	2.50	6.89	0.2911	2.006	0.917	2.923
-2.50	0.00	6.89	0.3140	2.163	0.917	3.080
-5.50	3.00	9.89	0.3140	3.105	0.917	4.022

Note; Kah is horizontal Coefficient of active earth pressure

Level DL (m)	Height h (m)	Pa tf/m²	ΣPa tf/m	Center y (m)	Pa･y tf･m/m
+2.00		0.437	0.219	-0.667	-0.146
+1.00	1.00	0.961	0.481	-0.333	-0.160
+1.00		0.961	0.053	0.037	0.002
+0.89	0.11	1.019	0.056	0.073	0.004
+0.89		1.019	0.453	0.407	0.184
0.00	0.89	2.195	0.977	0.703	0.687
0.00		2.195	2.744	1.833	5.030
-2.50	2.50	2.923	3.654	2.667	9.745
-2.50		3.080	4.620	4.500	20.790
-5.50	3.00	4.022	6.033	5.500	33.182
Total	7.50		19.29		69.318

(2) Passive Earth Pressure

Level DL (m)	Height h (m)	Σγh tf/m²	Kph	Pp tf/m²
-2.50	3.00	0.00	0.000	0.000
-5.50	3.00	3.00	4.3312	12.994

Note; Kph is horizontal Coefficient of passive earth pressure

Level DL (m)	Height h (m)	Pp tf/m²	ΣPp tf/m	Center y (m)	Pa･y tf･m/m
-2.50		0.000	0.000	4.500	0.000
-5.50	3.00	12.994	19.491	5.500	107.201
Total			19.491		107.201

3. Design of Sheet Piles

(1) Embedded Length of Sheet Piles

The embedded length of sheet piles shall be calculated to satisfy the following formula

F=Pp･y/Pa･y

where, Pp･y: Moment for the tie rod setting point by passive earth pressure

Pa･y: Moment for the tie rod setting point by active earth pressure and residual water pressure

F: Safety factor

F=1.547 > 1.5 ok

(2) Section of Sheet Piles

a) Active Earth Pressure and Residual Water pressure above the design depth

Level DL (m)	ΣPa tf/m	Pa･y tf･m/m
+2.00	0.219	-0.146
+1.00	0.481	-0.160
+1.00	0.053	0.002
+0.89	0.056	0.004
+0.89	0.453	0.184
+0.00	0.977	0.687
+0.00	2.744	5.030
-2.50	3.654	9.745
Total	8.637	15.346

b) Reaction force of design depth

Ro=Pa･y:/lt=4.385tf/m

Where, lt : Distance from Tie rod to Design depth, lt=3.50 m

c) Reaction at the tie rod setting point

Ap=Σpa-Ro=4.252 tf/m

d) Zero Point of Shearing force

$Q=A-B \cdot y-C \cdot y^2$

A=2.013 ,B=2.195 , C=0.1456

(DL -)y=0.8672 m → Q=0.000

e) Maximum bending moment of sheet piles Mmax

Level DL (m)	Height h (m)	Pa tf/m^2	Σ Pa tf/m	Center y (m)	Pa·y tf·m/m
-0.867	1.633	2.448	1.999	0.544	1.087
-2.500	1.633	2.923	2.387	1.089	2.599
Total			4.386		3.686

f) Section Characteristic of Sheet Pile

Sectional modulus (Steel Sheet Pile Type-IIIA)

Z=1,520 cm^3 /m(Before Corrosion)

Z'=1,076 cm^3 /m(After Corrosion ; Life time 30 years)

g) Stress of Sheet Piles

σ =Mmax／Z'=343 kgf/cm^2 <1,800 kgf/cm^2 ok

(3) Design of Tie Rods

a) Tension of the tie rod

Tension acting on a tie rod shell be calculated in accordance with following formula.

T=Ap*L

Where , l: Tie rod setting interval l =1.6m

∴T=6.803tf

b) Stress of Tie Rod

Diameter of Tie Rod φ=32mm

Corrosion tc=1.8mm (Life time 30 years)

Sectional area A=716.3mm^2

Stress of Tie Rod σ =T/A=950kgf/cm^2 <960 kgf/cm^2

(4) Design of Wale

a) Maximum bending moment

M=T・ L/10=1.088tf・m/m

b) Using material

Ditch type Steel 2［ 125x65x6.0x8.0

Sectional modulus

Z=2x67=134cm^3 (Before Corrosion)

Z'=2x57=114cm^3 (After Corrosion ; Life time 30 years)

Stress of Wale σ s=M/Z=954kgf/cm^2 <1,400 kgf/cm^2

(5) Design of Anchorage Steel Sheet Piles

a) Section Characteristic of Sheet Pile

Sectional modulus (Steel Sheet Pile Type-ⅡA)

Z= 880 cm^3 /m(Before Corrosion)

Z'= 762 cm^3 /m(After Corrosion ; Life time 30 years)

Pile flexural rigidity EI ($kgf \cdot cm^2$)

EI= 2.226E+10 $kgf \cdot cm^2$ /m (Before Corrosion)

EI= 1.911E+10 $kgf \cdot cm^2$ /m(After Corrosion ; Life time 30 years)

b) Coefficient of lateral subgrade reaction kh

kh= 0.15N= 0.75 kgf/cm^3 where N= 5 (N-value of the ground)

c) $\beta = \{kh \cdot B/(4EI)\}^{1/4}$ =0.00538727 cm^{-1} = 0.539 m^{-1}

$\beta ' = \{kh \cdot B/(4EI')\}^{1/4}$ =0.00559674 cm^{-1} = 0.560 m^{-1}

where, Width of Pile B= 100 cm

d) Maximum bending moment

Mmax＝0.3224・T/β

Where, Tension of a tie rod T= 4.252 tf/m

∴Mmax＝2.543 tf・m/m

e) Stress of Sheet Piles

σ =Mmax／Z'= 334 kgf/cm^2 <1,800 kgf/cm^2 ok

f) Embedded Length of Sheet Piles

L= 3.0/β = 5.57 m→6.00 m

Length of Sheet Piles Ls= 6.50 m

g) Displacement of a Sheet Pile at Tie Rod

$\sigma = T/(2EI \beta^3)$= 0.635 cm <5.0cm ok

h) Distance between Sheet Piles L(m)

Height between Tie Rod and Sea Bed h1= 3.50 m

Effective height of Anchorage Sheet Piles Lm1/3=π/(3β)= 1.943 m

Angle of the failure plane of active earth pressure cot ζ a= 0.653

Angle of the failure plane of passive earth pressure cot ζ p= 2.653

L= h1・cot ζ a+h2・cot ζ p= 7.440 m →8.000 m

Calculation result table

Structures	Calculation Item	Unit	Calculation value	Allowable value
Sheet Piles	Materials	Steel Sheet Piles L=7.00 m		
	Standard	JIS A 5528,Type U-ⅢA,SY295		
	Section	A=74.4cm²,Z=1,520cm³/m,I=22.800cm⁴/m		
	Stress	kgf/cm²	343	1,800
	Embedded Level	DL(m)	-5.50	—
	Safety Ratio of Embedded	—	1.547	1.5
Tie Rods	Materials	Tie Rod , SS400 , ϕ=32.00 mm		
	Stress	kgf/cm²	950	960
	Length of Tie Rod	m	8.00	7.44
Wales	Materials	Ditch Type Steel,ss400 ,2[125x65x6.0x8.0		
	Stress	kgf/cm²	954	1,400
Anchorage	Materials	Steel Sheet Piles L=6.00 m		
	Standard	JIS A 5528,Type U-ⅡA,SY295		
	Section	A=43.2cm²,Z=880cm³/m,I=10,600cm⁴/m		
	Stress	kgf/cm²	334	1,800
	Embedded Level	DL(m)	-5.00	-4.57
	Displacement of Head	cm	0.64	5.00

S2-2 : REFERENCE DATA ON TELECOMMUNICATION SECTOR

1. **Provisional International Sunspot Numbers**
2. **Monthly Average Sunspot Number**
3. **HF Radio Propagation Model (Male'-Fonadhoo)**
4. **HF Radio Propagation Model (Male'-Hithadhoo)**

1. **Provisional International Sunspot Numbers**

From the SIDC (World Data Center for the Sunspot Index): Provisional International Sunspot Numbers

Provisional International monthly mean Sunspot Number for
April 2005 : 24.4 (twenty-four point four)

Maximum : 37 on 30 // Minimum : 9 on 24

Provisional daily International Sunspot Numbers for April 2005 :

1.. 16	6.. 29	11.. 13	16.. 28	21.. 16	26.. 11
2.. 20	7.. 28	12.. 21	17.. 26	22.. 16	27.. 17
3.. 28	8.. 27	13.. 29	18.. 26	23.. 14	28.. 30
4.. 33	9.. 27	14.. 35	19.. 26	24.. 9	29.. 35
5.. 35	10.. 27	15.. 36	20.. 25	25.. 13	30.. 37

42 cooperating stations on May 1, 09 UT

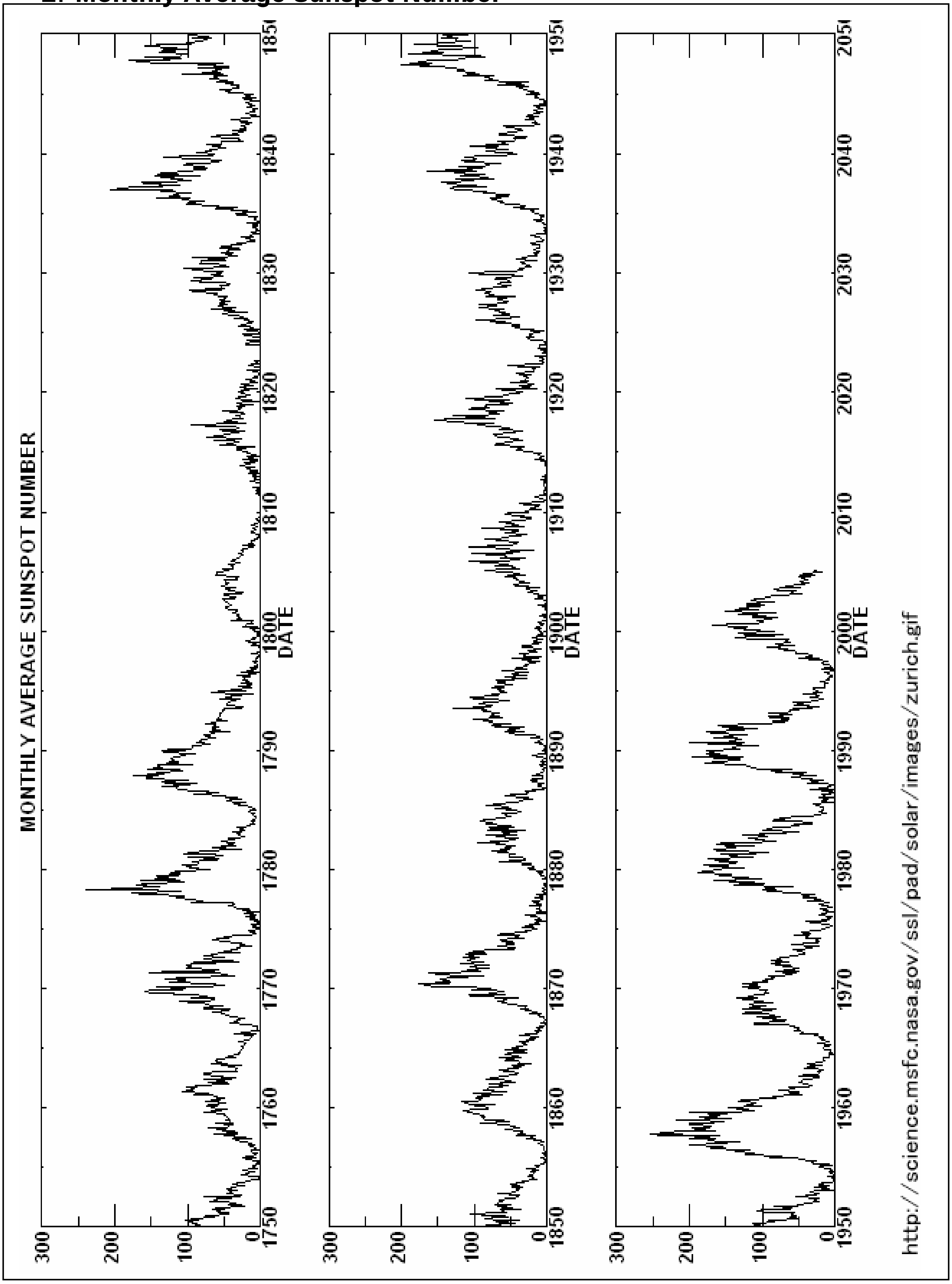
Predictions of the monthly smoothed Sunspot Number using the last
provisional value, calculated for October 2004 : 35.9 (+-5%)

	SM	CM		SM	CM		SM	CM
2004 Nov	35	35	2005 May	25	30	2005 Nov	17	23
Dec	32	34	Jun	23	29	Dec	17	21
2005 Jan	30	34	Jul	22	28	2006 Jan	16	20
Feb	29	33	Aug	20	27	Feb	15	18
Mar	27	32	Sep	19	26	Mar	14	16
Apr	26	31	Oct	18	25	Apr	13	15

SM : SIDC classical method : based on an interpolation of Waldmeier's standard curves; the estimated error ranges from 7% (first month) to 35% (last month)
CM : Combined method : the combined method is a regression technique coupling a dynamo-based estimator with Waldmeier's idea of standard curves, due to K. Denkmayr.
ref. : K. Denkmayr, P. Cugnon, 1997 : "About Sunspot Number Medium-Term Predictions", in "Solar-Terrestrial Prediction Workshop V", eds. G. Heckman et al., Hiraiso Solar Terrestrial Research Center, Japan, 103

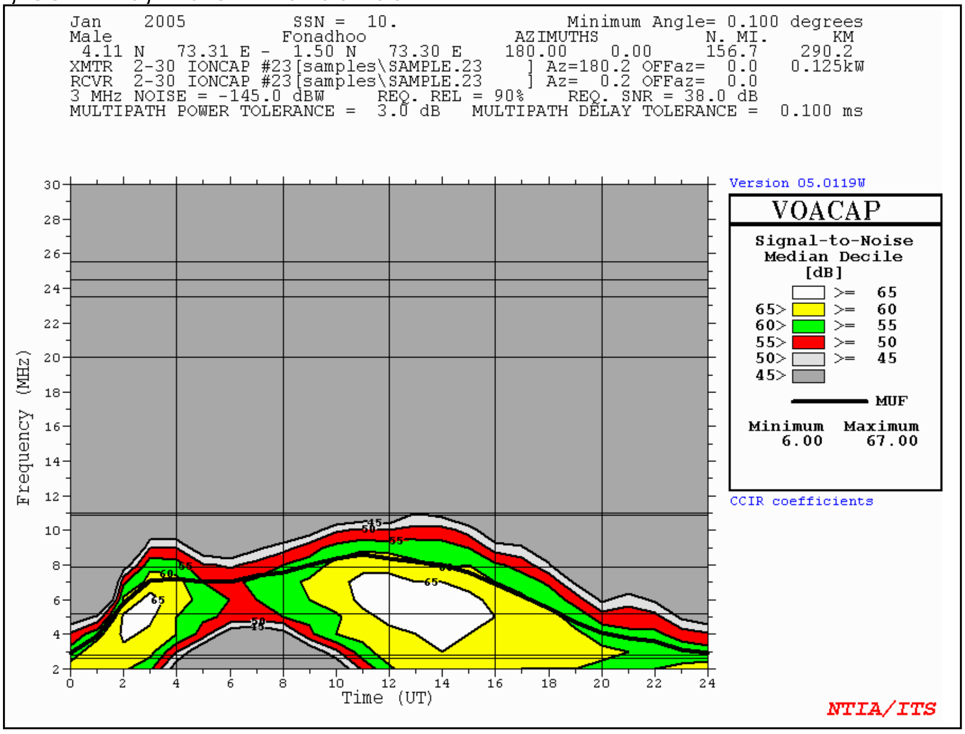
http://sidc.oma.be/current/ri.html 2005/05/23

2. Monthly Average Sunspot Number

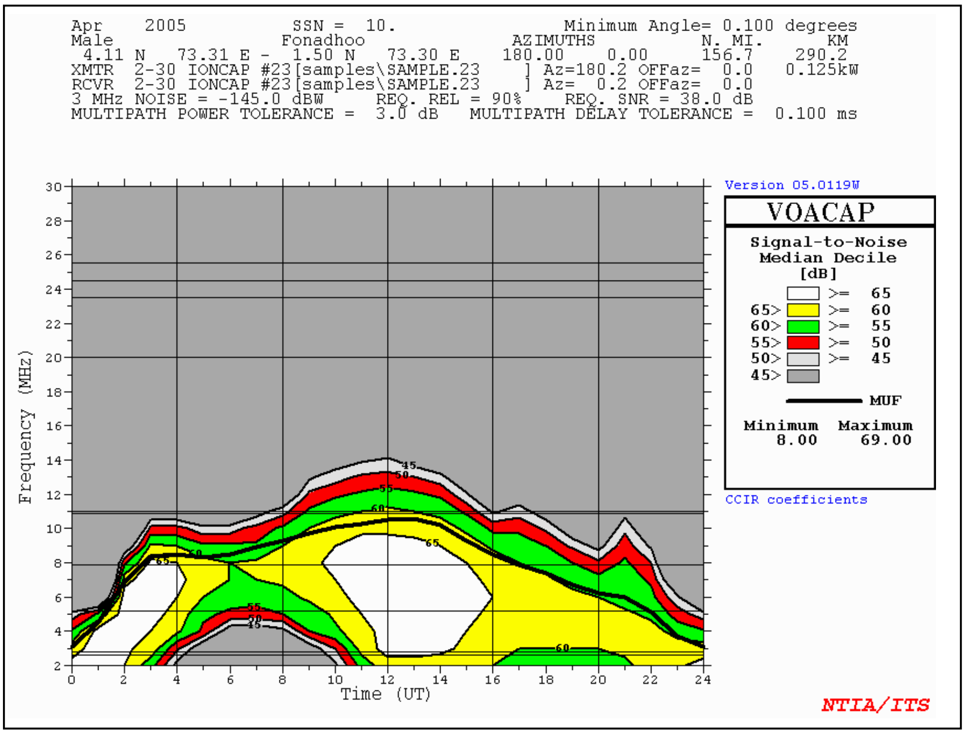


3. HF Radio Propagation Model (Male'-Fonadhoo)

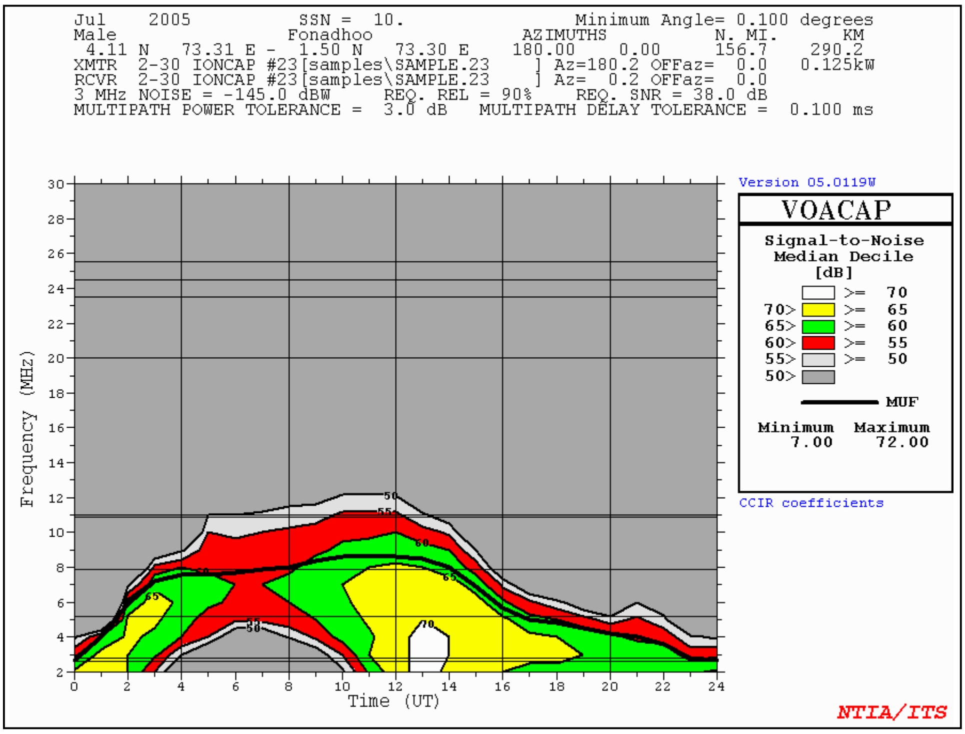
(1) Jan, SSN=10, Male' - Fonadhoo



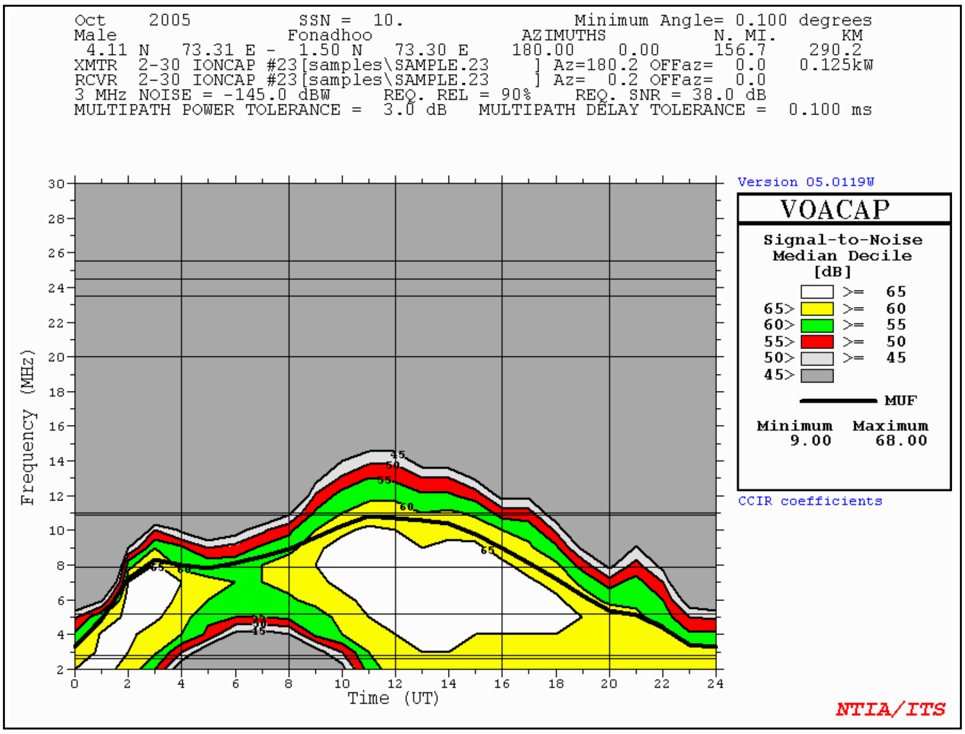
(2) Apr, SSN=10, Male' - Fonadhoo



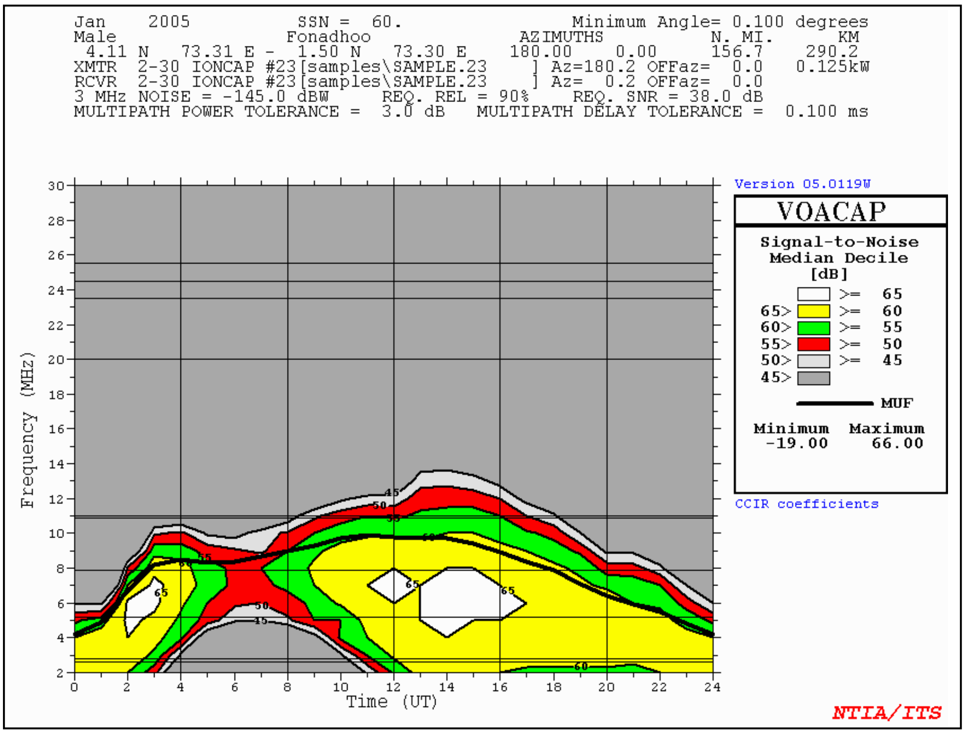
(3) Jul, SSN=10, Male' - Fonadhoo



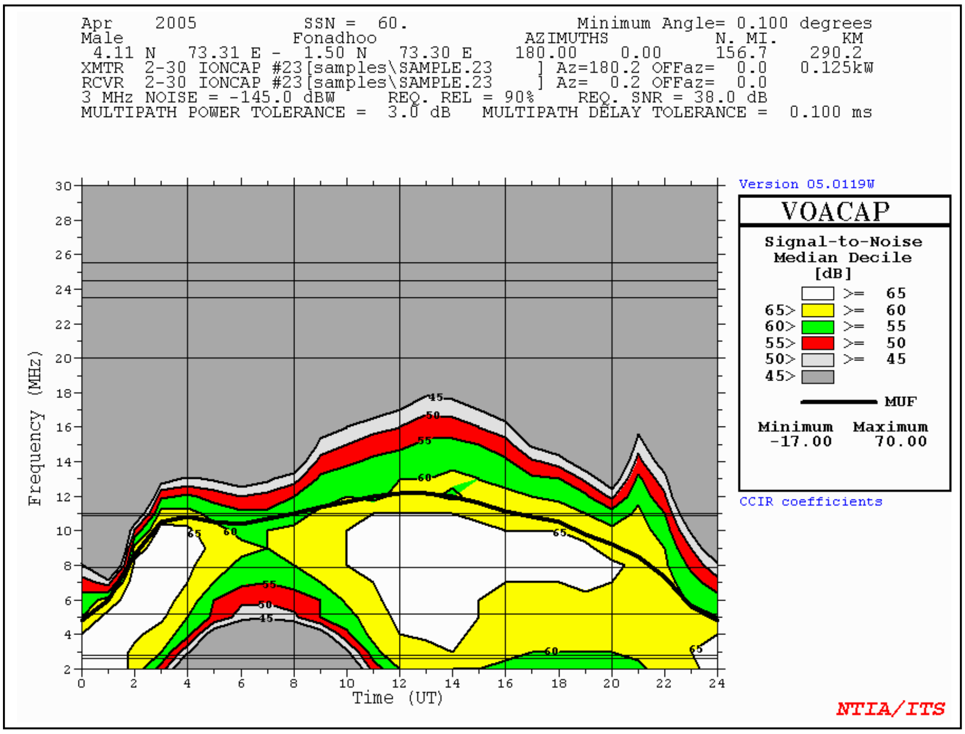
(4) Oct, SSN=10, Male' - Fonadhoo



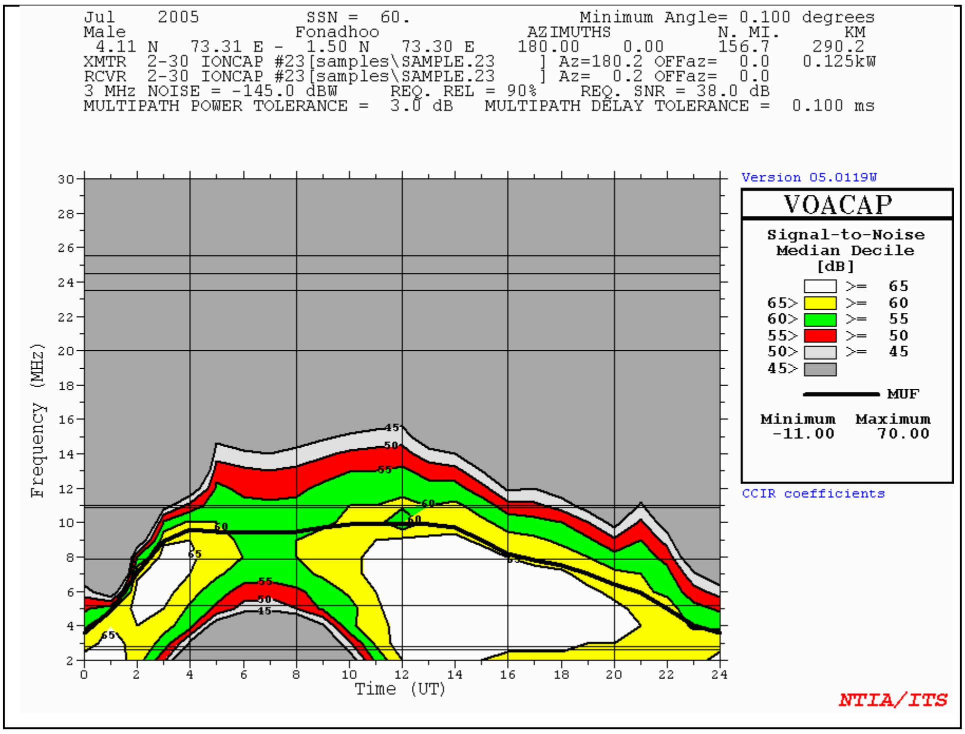
(5) Jan, SSN=60, Male' - Fonadhoo



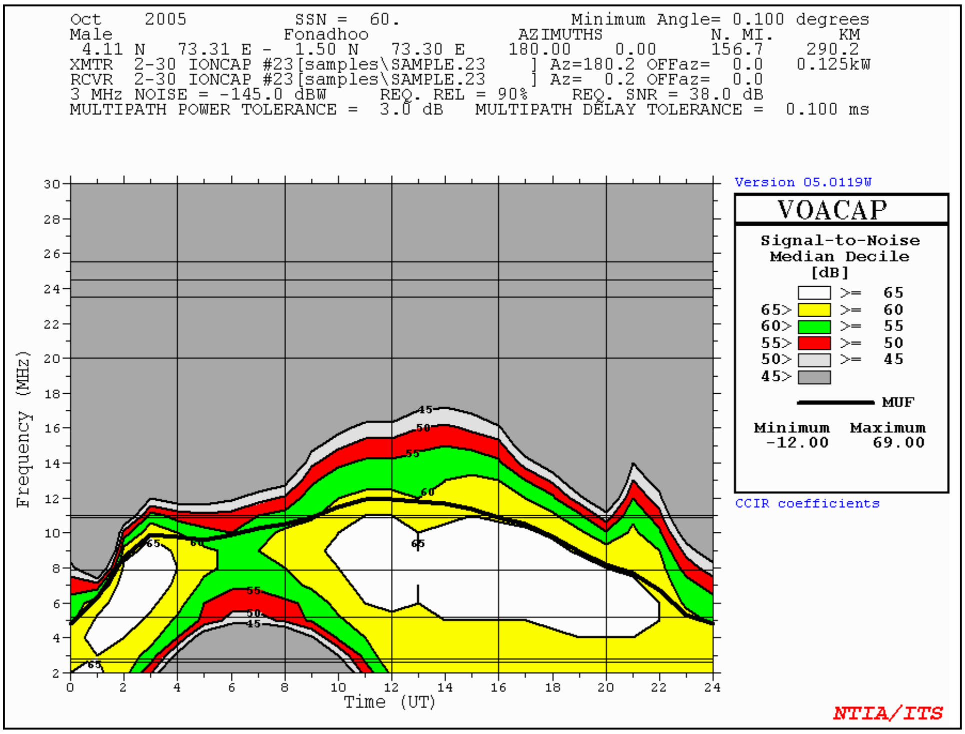
(6) Apr, SSN=60, Male' - Fonadhoo



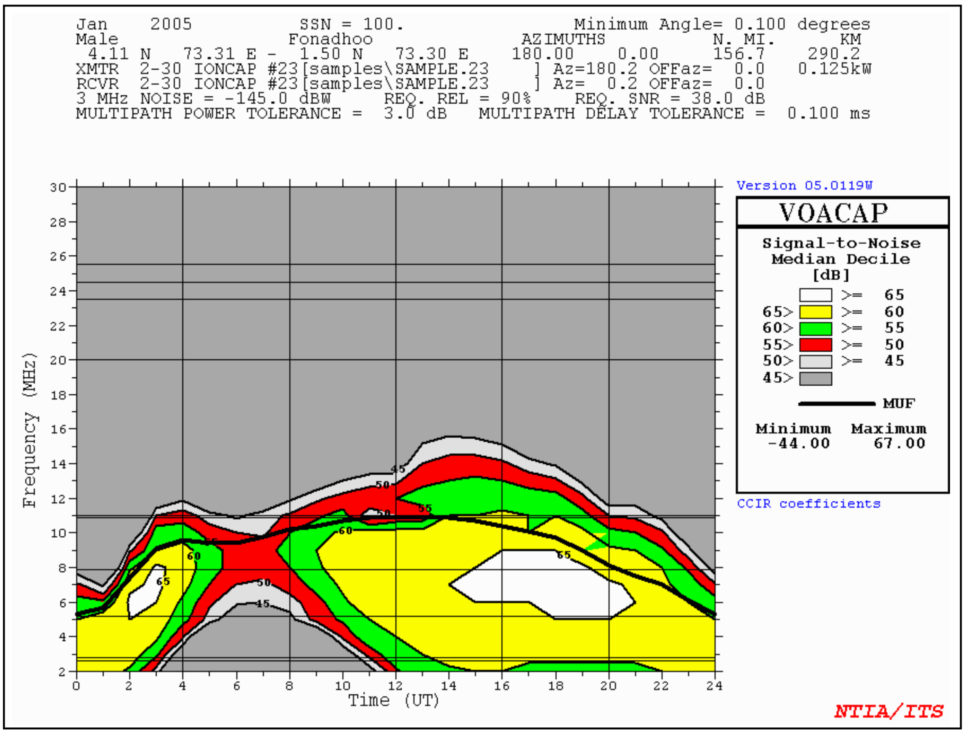
(7) Jul, SSN=60, Male' - Fonadhoo



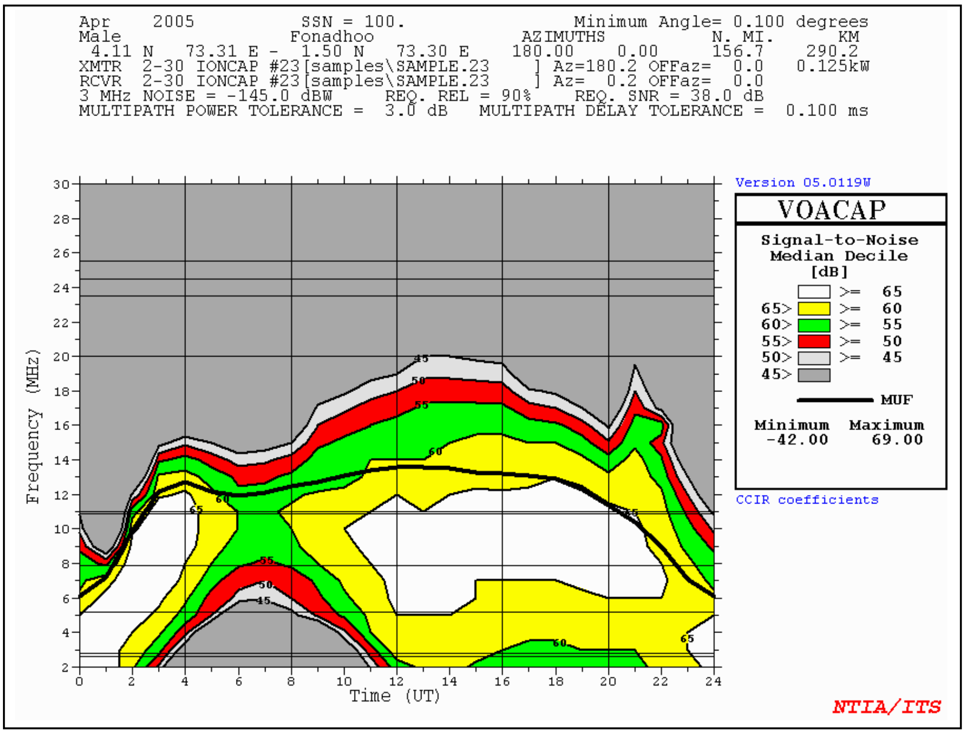
(8) Oct, SSN=60, Male' - Fonadhoo



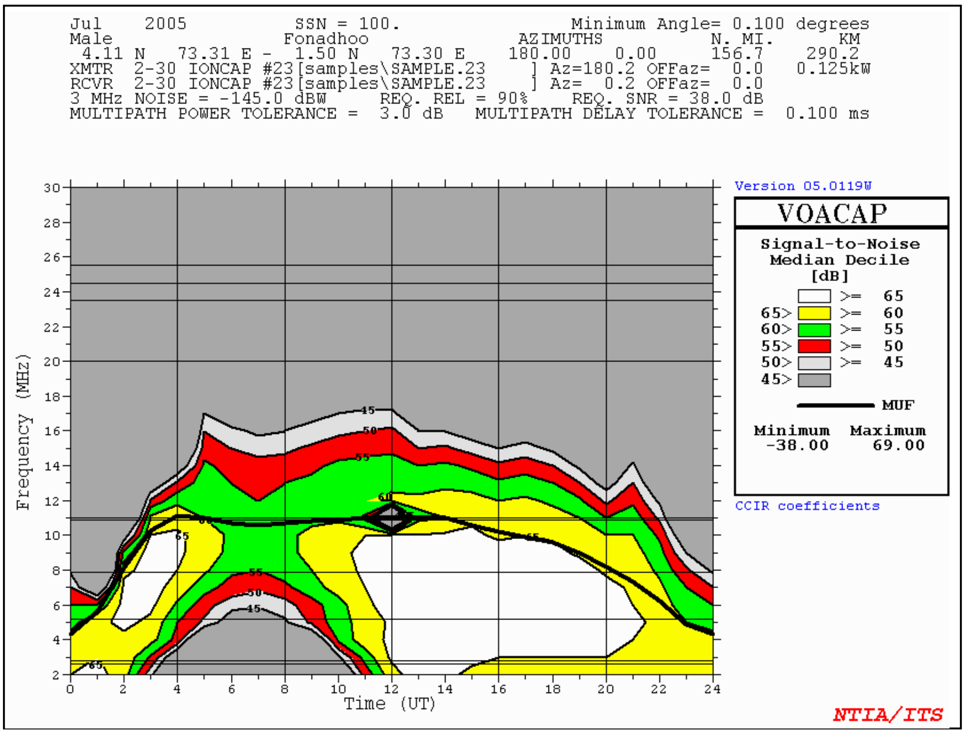
(9) Jan, SSN=100, Male' - Fonadhoo



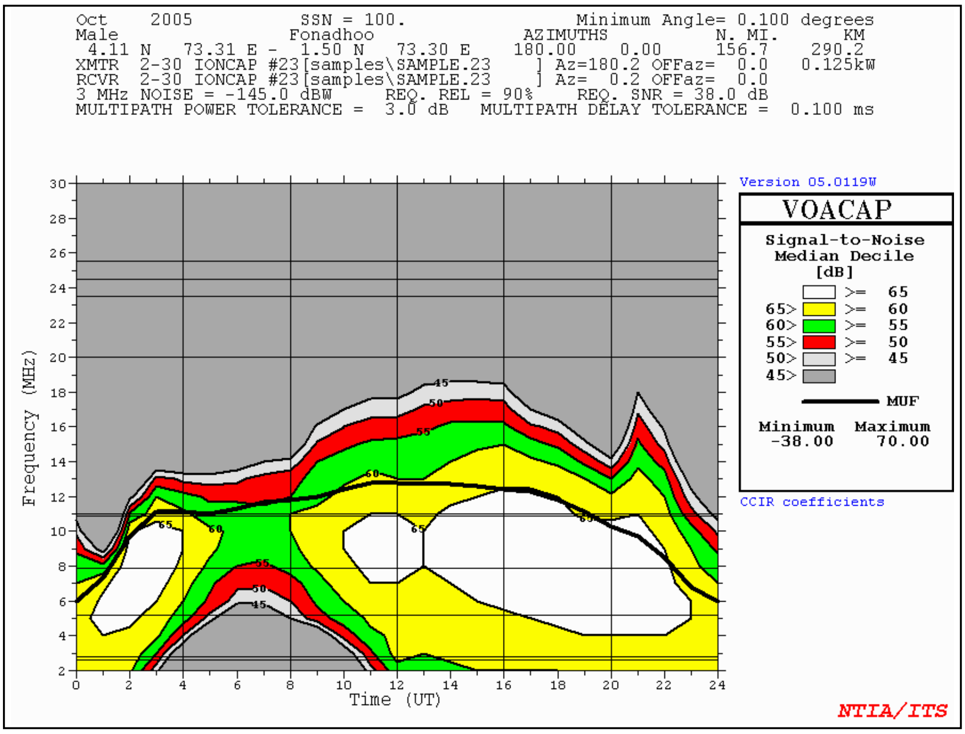
(10) Apr, SSN=100, Male' - Fonadhoo



(11) Jul, SSN=100, Male' - Fonadhoo

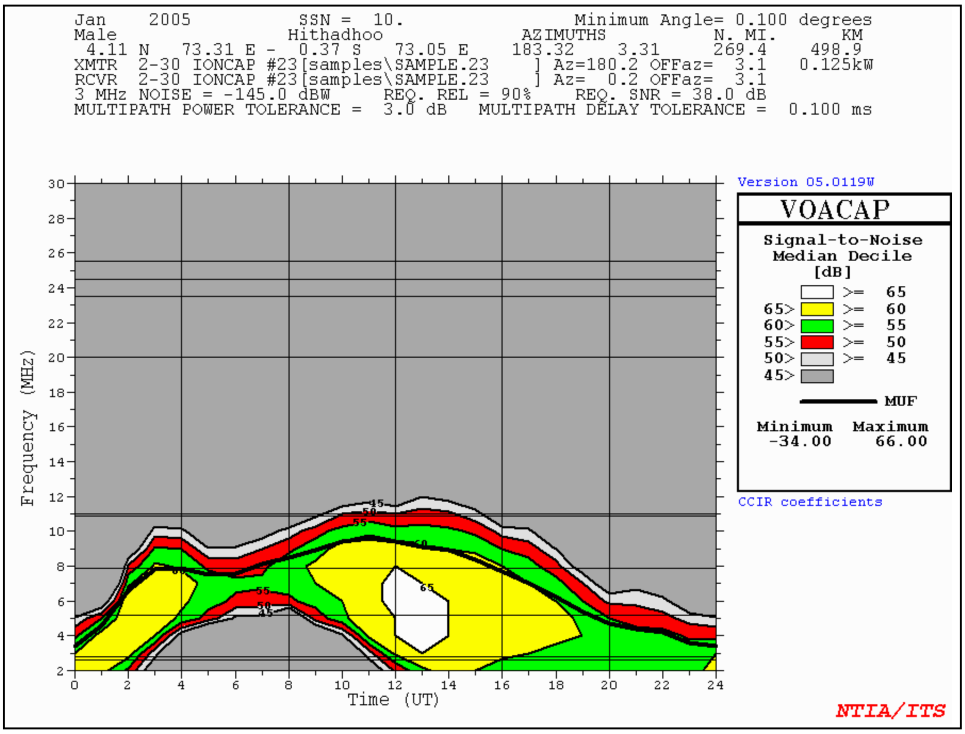


(12) Oct, SSN=100, Male' - Fonadhoo

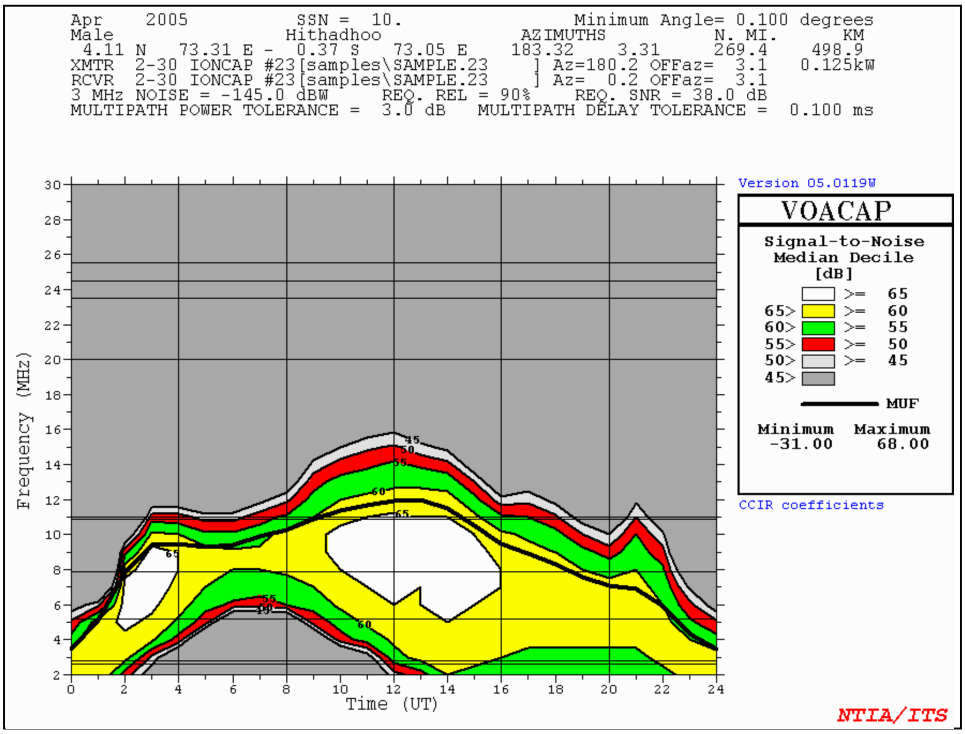


4. HF Radio Propagation Model (Male'-Hithadhoo)

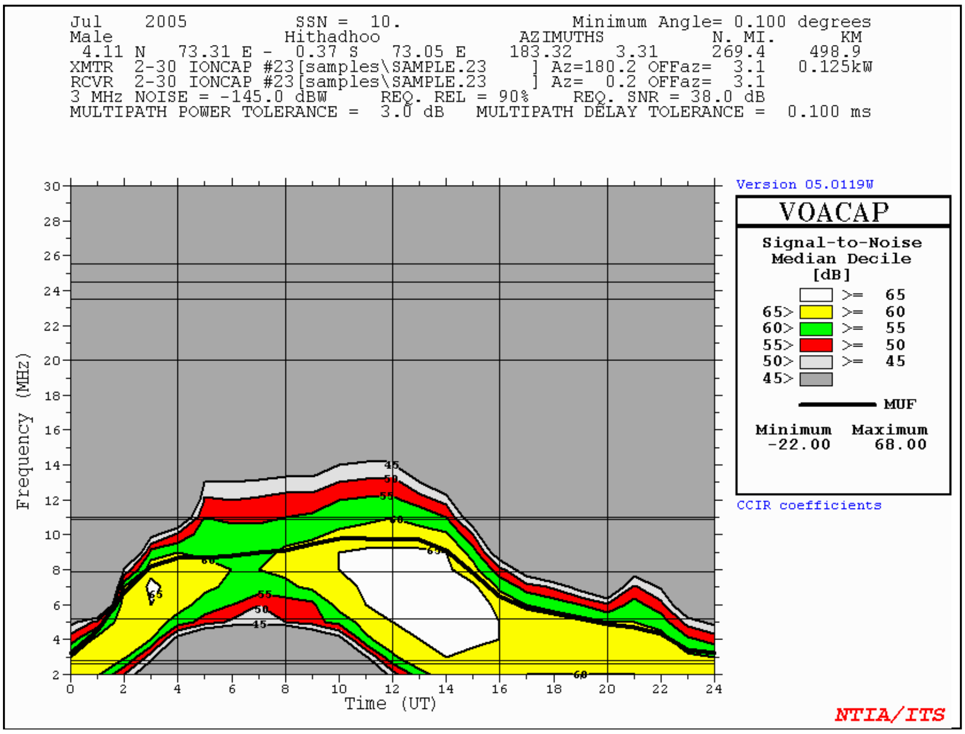
(1) Jan, SSN=10, Male' - Hithadhoo



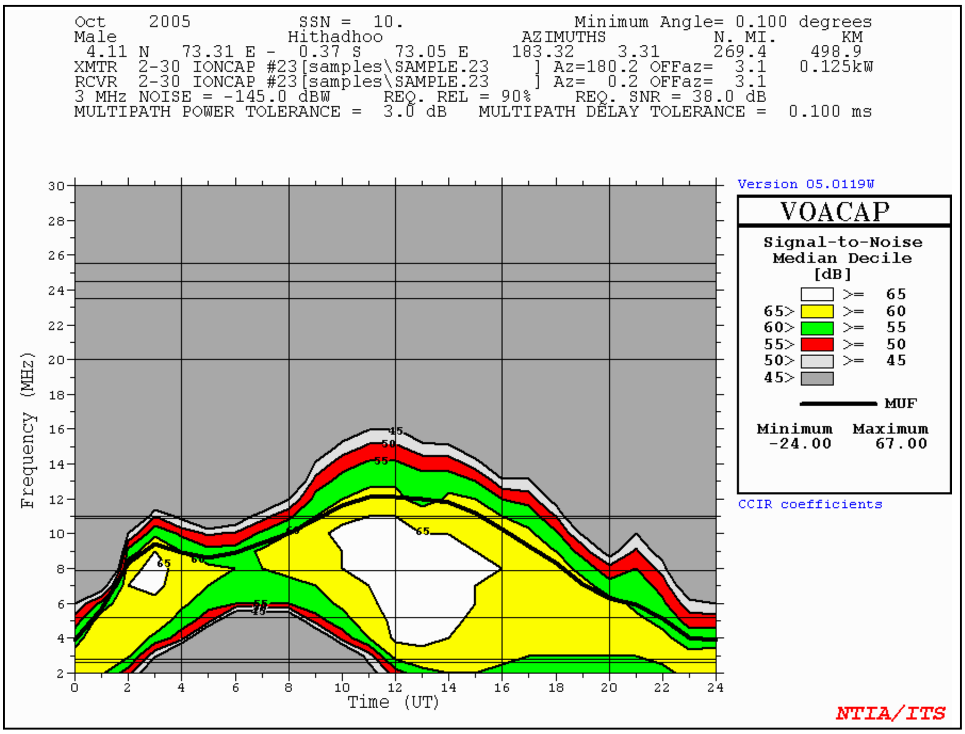
(2) Apr, SSN=10, Male' - Hithadhoo



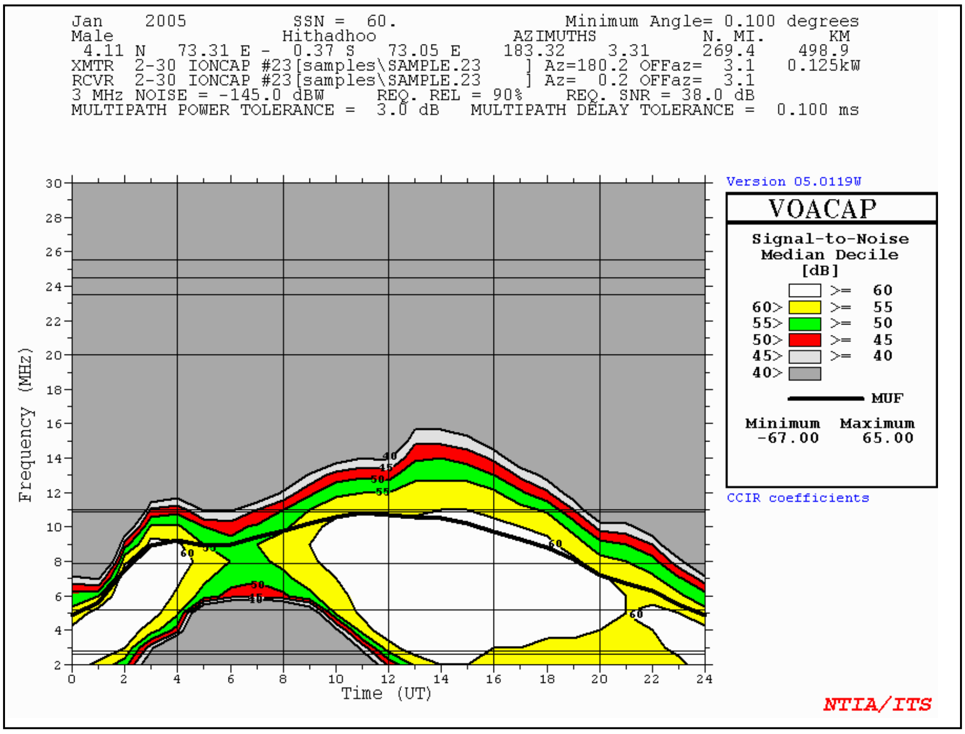
(3) Jul, SSN=10, Male' - Hithadhoo



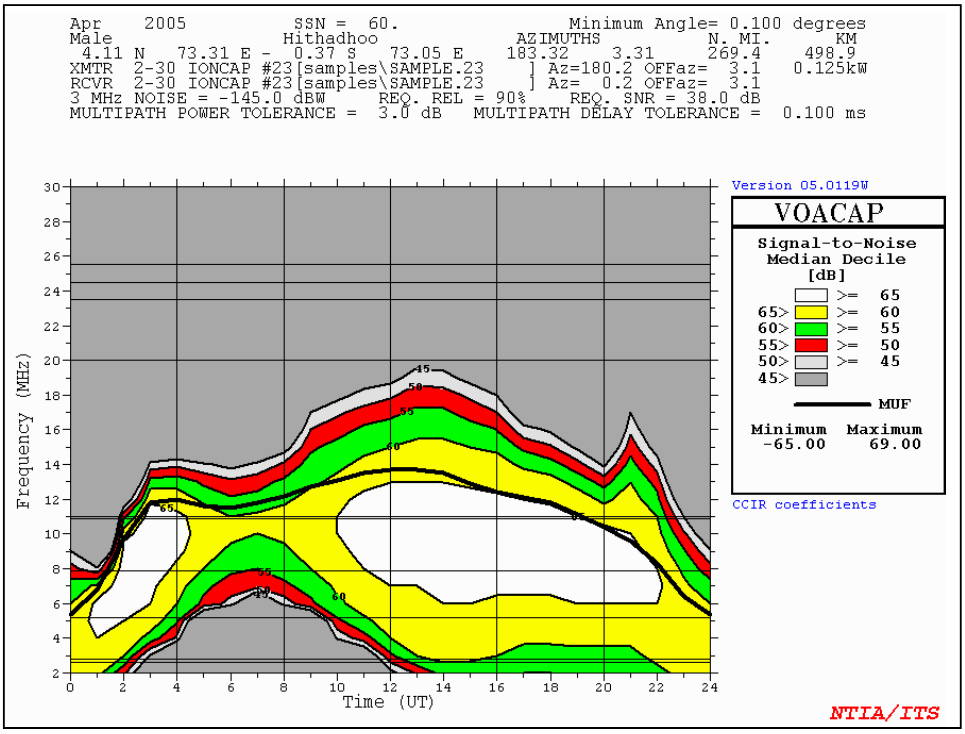
(4) Oct, SSN=10, Male' - Hithadhoo



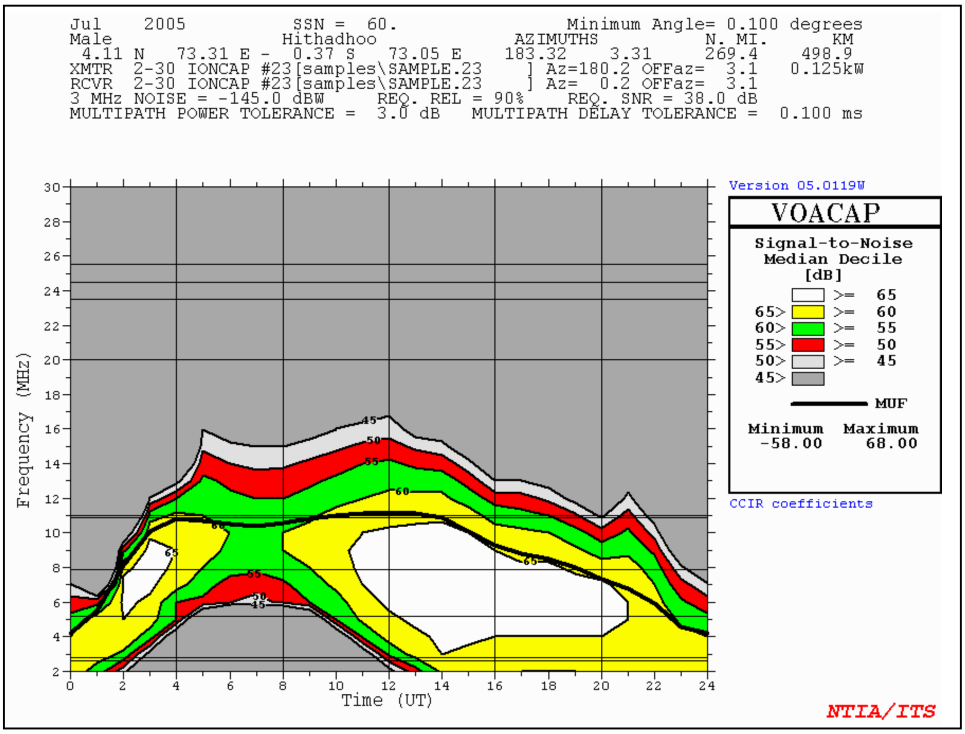
(5) Jan SSN=60 Male' – Hithadhoo



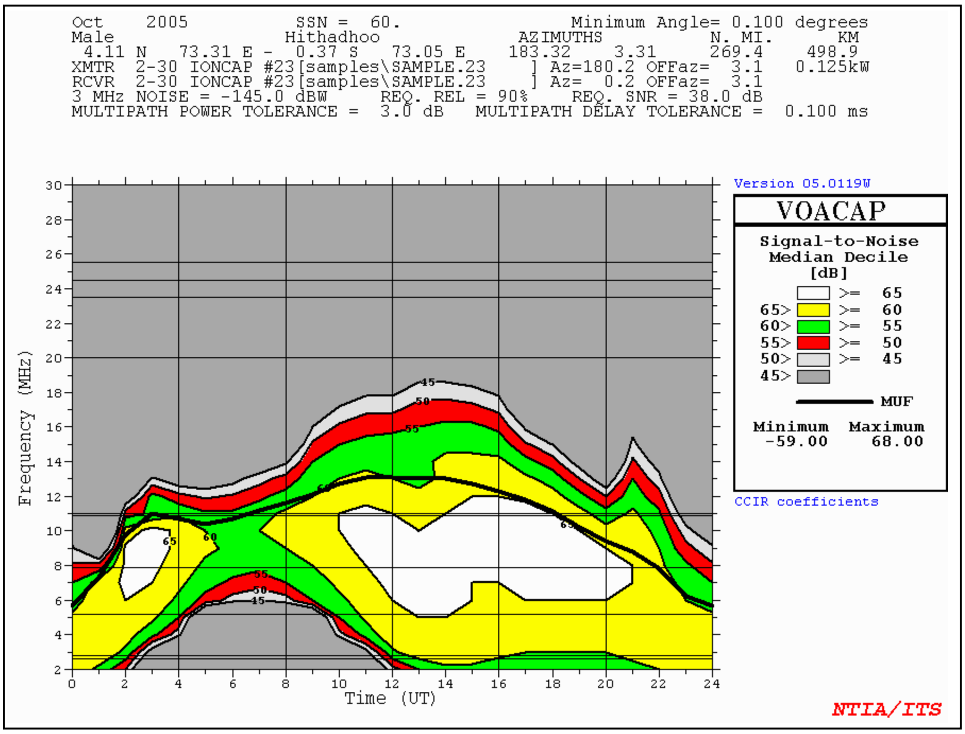
(6) Apr, SSN=60, Male' - Hithadhoo



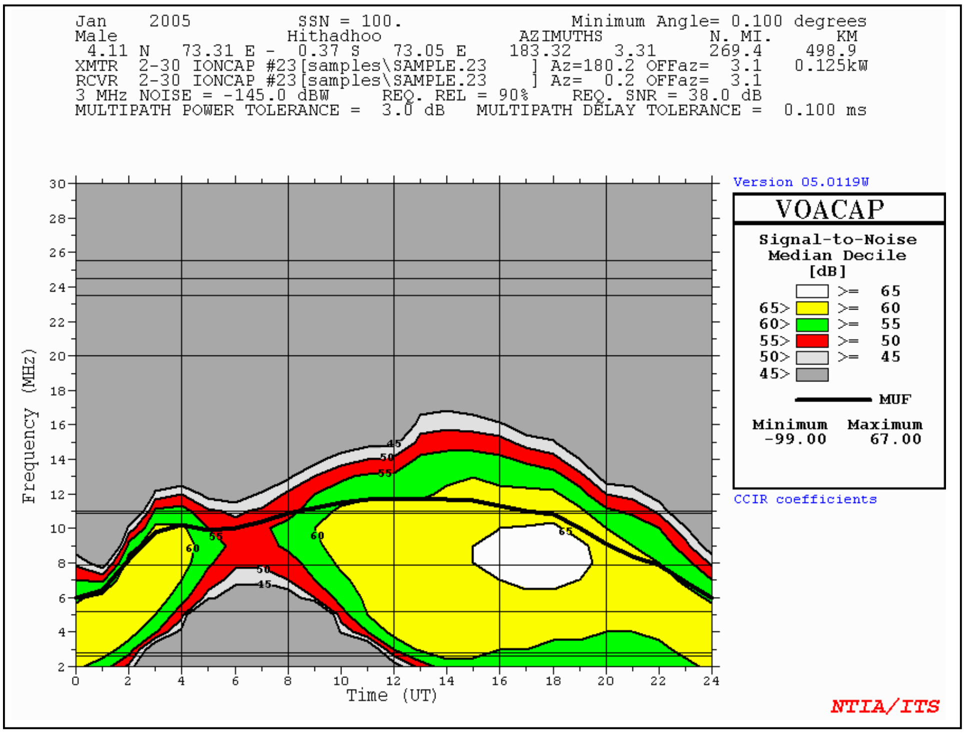
(7) Jul, SSN=60, Male' – Hithadhoo



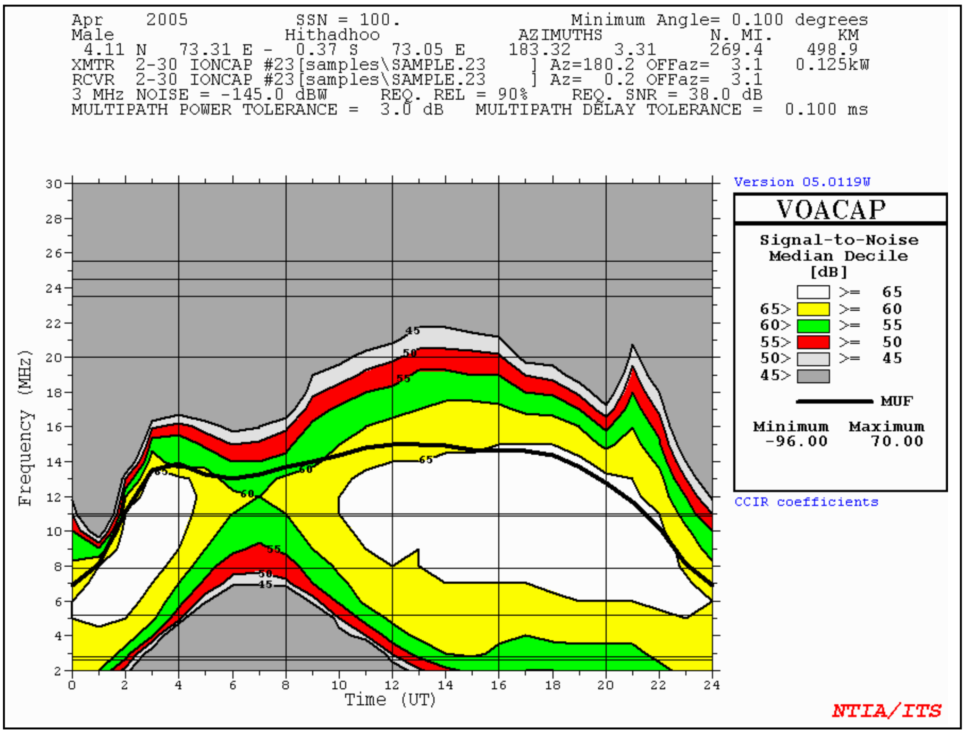
(8) Oct, SSN=60, Male' - Hithadhoo



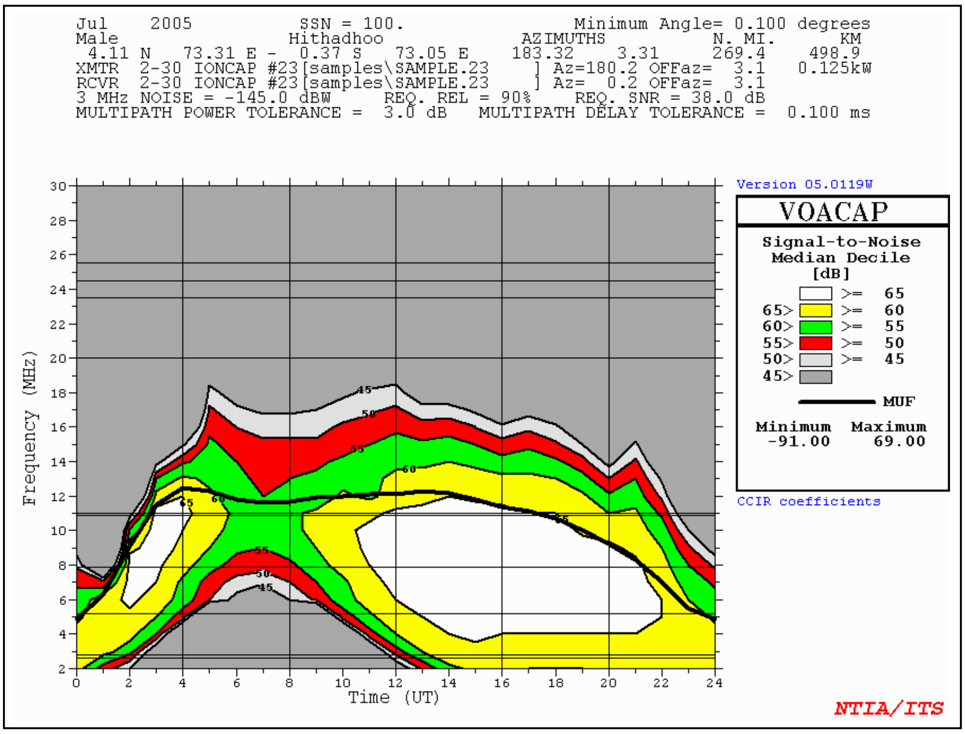
(9) Jan, SSN=100, Male' – Hithadhoo



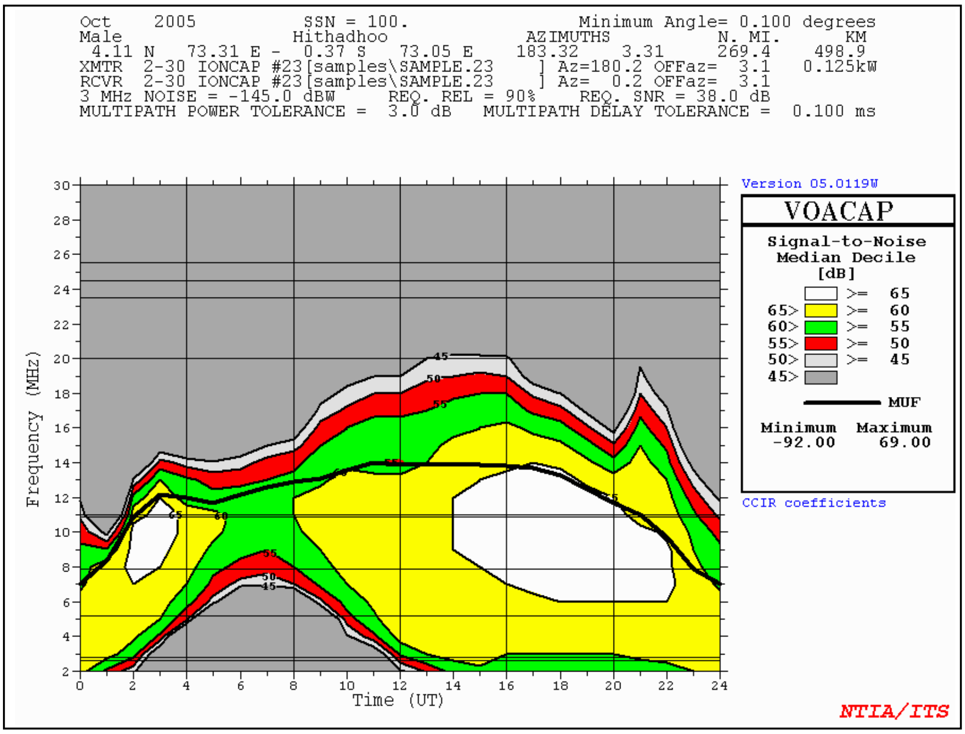
(10) Apr, SSN=100, Male' - Hithadhoo



(11) Jul, SSN=100, Male' - Hithadhoo



(12) Oct, SSN=100, Male' - Hithadhoo



S2-3 : SCOPE OF WORKS

SCOPE OF WORK

FOR THE STUDY

ON

TSUNAMI RECOVERY, REHABILITATION AND DEVELOPMENT OF ISLANDS IN MALDIVES

AGREED UPON BETWEEN

THE DEPARTMENT OF EXTERNAL RESOURCES,
MINISTRY OF FOREIGN AFFAIRS
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

MALE, 12th April, 2005

Ms. Aminath Didi
Assistant Director General,
Department of External Resources,
Ministry of Foreign Affairs
Republic of Maldives

Mr. Masami Fuwa
Leader of Project Monitoring Team,
Senior Advisor,
Social Development Department,
Japan International Cooperation Agency

(Witnessed by)

Ms. Lucia Moosa
Director, Programmes,
Ministry of Planning and National Development
Republic of Maldives

Ⅰ. INTRODUCTION

In response to the official request of the Government of the Republic of Maldives (hereinafter referred to as "GOM"), the Government of Japan (hereinafter referred to as "GOJ") has decided to undertake a study for "Tsunami Recovery, Rehabilitation and Development of Islands in Maldives" (hereinafter referred to as "the Study"), in accordance with the relevant laws and regulations in force in Japan.

Accordingly, Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the GOJ, will undertake the Study, in close cooperation with the authorities concerned of GOM.

The Department of External Resources (hereinafter referred to as "DER") , and Ministry of Planning and National Development shall act as the counterpart agency to the JICA Study Team and also act as the coordinating body with other relevant organizations for the smooth implementation of the Study, on behalf of the GOM.

The present document sets forth the Scope of Work for the Study.

Ⅱ. OBJECTIVES OF THE STUDY

The objectives of the Study are:

1. to formulate detailed project plans for the project area described in "III. STUDY AREA" based on the National Recovery and Reconstruction Plan (NRRP),
2. to assist the implementation of recovery and rehabilitation projects to be funded under the Japanese Non-Project Grant Aid and ODA Loan,
3. to share Japanese experiences in disaster management through the implementation of the Study and to monitor process and outcome.

Ⅲ. STUDY AREA

Study area shall be composed of following islands (see Annex-1);

Laamu Atoll (Gan, Fonadhoo, Maabaidhoo, Ishdhoo / Isdhoo-Kalaidhoo, Maavah)
Thaa Atoll (Guraidhoo, Kinbidhoo, Veymandoo, Dhiyamigili, Thimarafushi, Hirilandhoo)
Alif Alif Atoll (Mathiveri)
Vaavu Atoll (Felidhoo)

Map of Study Area is given in Annex-2.

Ⅳ. SCOPE OF THE STUDY

In order to achieve the objectives mentioned above, the Study will cover the following components, in collaboration with GOM:

1. Technical Assistance for Short-term Recovery Project for implementing reconstruction of social and economic infrastructure development:

   Project formulation based on the National Recovery and Reconstruction Plan (NRRP) for the following sectors shall be conducted under the Study.

   (1) Multi purpose buildings including island administrative complex in Laamu Gan
   (2) Island Offices in Laamu Fonadhoo, Alif Alif Mathiveri, and Vaavu Felidhoo
   (3) Power generation and distribution facilities in Laamu Gan
   (4) Sewerage System Rehabilitation for Laamu Isdhoo/Isdhoo-Kalaidhoo and Laamu Fonadhoo
   (5) Rehabilitation of Island Harbours for Thaa Atoll (Guraidhoo, Kinbidhoo, Veymandoo, Dhiyamigili, Thimarafushi, Hirilandhoo) and Laamu Atoll (Isdhoo/Isdhoo-Kalaidhoo, Fonadhoo, Maabaidhoo and Maavah) (only preliminary study will be required)

2. Support for implementing Medium-term reconstruction of social and economic infrastructure development project:

   2-1 Socio-economic Framework of the Study Area for the formulation of item 2-2.

   2-2 Project formulation based on the NRRP for the following sectors at the Project site according to Annex-1;

   (1) Island Harbours and Jetties
   (2) Coastal protection
   (3) Causeways in Laamu between Gan and Fonadhoo
   (4) Sewage System / Network
   (5) Water supply system
   (6) Emergency Communication System

3. Implementation of small community based demonstration project for Debris Recycling and Monitoring on process of community empowerment and disaster prevention education in Laamu Fonadhoo, assisted by JICA Study Team.

Ⅴ. SCHEDULE OF THE STUDY

The Study shall be carried out from March 2005 to January 2006. (see Annex-3)

VI. REPORTS

JICA shall prepare and submit the following reports in English to the GOM.

1. First Report: Twenty (20) copies, to be submitted in April, 2005. This First Report shall include following information;

   (1) Project concept paper which shows description of the project, sector,

estimated cost, proposed implementation schedule, etc. for projects in IV. 1.

(2) Candidate project list for projects in IV. 2.

2. Second Report: Twenty (20) copies, to be submitted in August, 2005.[1] This Second Report shall include following information;

(1) Technical Tender Specifications for the selected projects in IV.1 to be submitted on or before August, 2005.

(2) Conceptual plan for prioritized projects on the candidate project list for projects in IV. 2.

3. Third Report: Twenty (20) copies, to be submitted in January, 2006, result of the Study.

VII. <u>RESPONSIBILITIES OF GOM</u>

1. To facilitate smooth conduct of the Study, the GOM shall undertake the following necessary measures:
   (1) To permit the members of the JICA Team to enter, leave and sojourn in Maldives for the duration of their assignment therein, and meet the charges for temporary resident permit fees;
   (2) To meet the charges from import duties, and any other levies on equipment, machinery and other materials brought into Maldives for the conduct of the Study by the JICA Team;
   (3) To exempt the members of the JICA Team from income tax and charges of any kind imposed on or in connection with any emoluments or allowances paid to the members of the JICA Study Team for their services in connection with the implementation of the Study;
   (4) To provide necessary facilities to the JICA Team for remittance as well as utilization of the funds introduced into Maldives from Japan in connection with the implementation of the Study.

2. GOM shall bear claims, if any arises, against the members of the JICA Team resulting from, occurring in the course of, or otherwise connected with, the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or willful misconduct on the part of the members of the JICA Team.

3. Coordination with other donor in the Study area will be facilitate by the GOM

[1] By the end of May JICA Study Team will submit technical specification on equipment supply portion, and by the end of July JICA Study Team will submit technical specification on facility construction.

4. GOM shall, at its own expense, provide the Team with the following, in cooperation with other organizations concerned:
   (1) Security related information as well as measures to ensure the safety of the JICA team;
   (2) Available data and information related to the Study;
   (3) Counterpart personnel;
   (4) Credentials or identification cards; and
   (5) Information on obtaining medical services.

VIII. OTHER CONSIDERATIONS

JICA and the GOM shall consult with each other in respect of any matter that may arise from or in connection with the Study.

Annex-1 Project Site (JICA Study Areas and Sectors)

ATOLL	No.	ISLAND	SHORT-TERM RECOVERY PROJECT					DEMO PROJECT	MID-TERM INFRASTRUCTURE PROJECTS			
			Multi-purpose building	Island office	Power supply facility *1)	Sewerage system	Coastal facilities *2)		Coastal facilities *2)	Sewerage system	Water supply system	Emergency Communication
Alif Alif	AA-1	Mathiveri		●								
Vaavu	V-1	Felidhoo		●								
Thaa	Th-1	Dhiyamigili					○		●			
	Th-2	Guraidhoo					○		●			
	Th-3	Thimarafushi					○		●			
	Th-4	Veymandoo					○		●			
	Th-5	Kinbidhoo					○		●			
	TH-6	Hirilandhoo					○		●			
Laamu	L-1	Isdhoo/ Isdhoo-Kalaidhoo				●	○		●	●	●	●
	L-2	Maabaidhoo					○		●			●
	L-3	Gan	●		●				●*3)		●	●
	L-4	Fonadhoo		●		●	○*3)	●	●*3)	●	●	●
	L-5	Maavah					○		●			●

Notes:

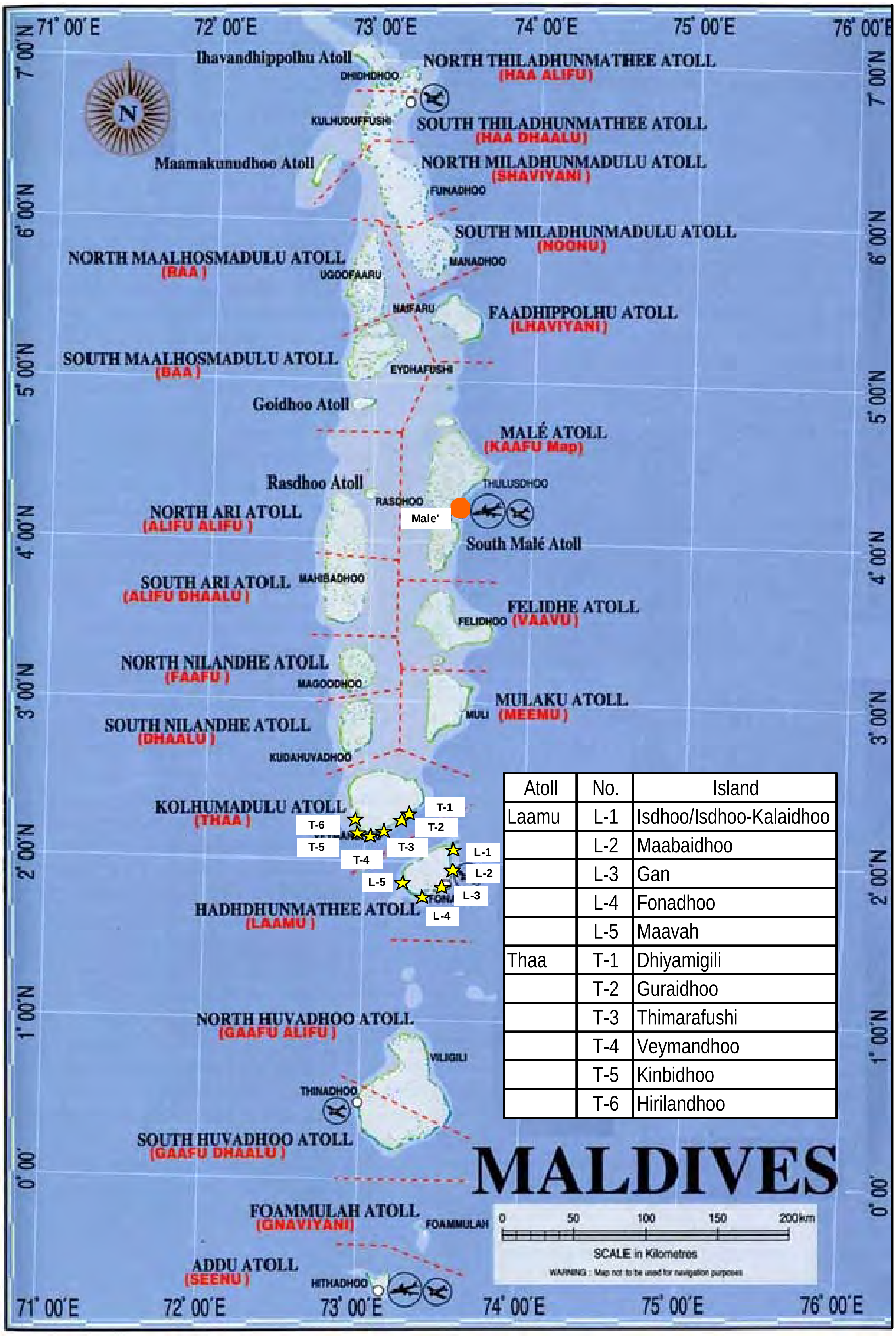
*1) consisting generation and distribution facilities

*2) consisting Island harbour/jetty, and coastal protection

*3) consisting Island harbour/jetty, coastal protection, causeway (between Gan to Fonadhoo)

● Main Study Component, ○ Preliminary Study

Annex-2 JICA Study Area



Atoll	No.	Island
Laamu	L-1	Isdhoo/Isdhoo-Kalaidhoo
	L-2	Maabaidhoo
	L-3	Gan
	L-4	Fonadhoo
	L-5	Maavah
Thaa	T-1	Dhiyamigili
	T-2	Guraidhoo
	T-3	Thimarafushi
	T-4	Veymandhoo
	T-5	Kinbidhoo
	T-6	Hirilandhoo

☆ : JICA Study Area

Annex-3 Schedule of the Study

Year	05/3	4	5	6	7	8	9	10	11	12	1	2
Duration (months)	1	2	3	4	5	6	7	8	9	10	11	12
Work in Maldives	━	━	━	━	━	━	━	━	━	━	━	
Work in Japan	-											
Reports		▲ 1st			▲ 2nd						▲ 3rd	

S2-4 : MINUTES OF MEETING

MINUTES OF MEETING

CONTENTS:

In response to the request of the Government of the Republic of Maldives (hereinafter referred to as “the GOM”), the Government of Japan dispatched the preparatory study team (hereinafter referred to as "the Team") headed by Mr. Masami FUWA to discuss a technical assistance on the Tsunami Recovery, Rehabilitation and Development of islands in the Republic of Maldives” (herein referred to as “the Study”).

The Team had a series of meetings with the Department of External Resources, Ministry of Foreign Affairs (herein referred to as “DER”), Ministry of Planning and National Development (“MPND”) and other organizations related to the Study in Maldives. The participants of the meetings are listed in Attachment I.

Based on the discussions, Maldives side and the Team agreed upon the Scope of Work for the Study. The main issues discussed by both sides in relation to the Scope of Work for the Study are summarized below.

The JICA as the executing agency of technical cooperation program of the government of Japan would like to assist Maldives people, society and governments to play each of their roles in reconstruction process, and to try to transfer lessons learned from Japanese reconstruction experience in devastating natural disasters i.e., earthquake and tsunami in the past.

Part I: Japanese Contribution and the Role of JICA

In order for Maldives to accomplish seamless transition through recovery, rehabilitation, and development after tsunami disaster, Japanese government would like to assist whole process by employing disaster relief teams, technical assistance of JICA, non-project grant aid, and JBIC loan programs. Thus, as a member of all Japanese agencies, JICA would like to conduct a study on recovery and rehabilitation plans in the short run, and development plans in the mid-term perspectives, and accordingly, to contribute to following financial assistance by the GOJ.

Major role of JICA as the technical cooperation agency of Japan, in the course of reconstruction phases, is to propose useful plans based on Japanese own experience in reconstruction from huge scale natural disasters in Japan. The aspects involved are to be environmental preservation, disaster prevention, social issues, and economic viability.

Study components listed in the Scope of Work (S/W) are, by and large, infrastructure rehabilitation and development that will contribute to rebuilding people’s living welfare, transportation, communication, and industries like tourism, fishery, cement manufacturing and others. In terms of living welfare of people, that infrastructure should be basis of superstructure including housing, factories, etc, and thus, that rehabilitation should come earlier than rebuilding superstructure.

Japanese experience in reconstruction from natural disasters is useful to apply to similar circumstances in Maldives, e.g., tsunami, earthquake, typhoon and volcanic disasters in isolated islands. Annex 1-show lessons learned from Japanese experience in reconstruction after natural disasters. Deriving from real experience, JICA will assume process of reconstruction through which infrastructure reconstruction by the government can be harmonized with reconstruction of people’s living welfare, seeking goals of much safer township plans from natural disasters, environmentally sustainable development, and avoiding unnecessary stress on people affected by tsunami.

Part II: Key aspects of reconstruction and development

1. Disaster Prevention Policy - Preparedness for recurring disasters -

The reconstruction plan of the tsunami affected areas needs to be consistent with disaster prevention policy in the country and the regions.

The National Recovery and Reconstruction Plan (NRRP) includes a program area on environment and disaster risk management, in which intended outcomes are assumed that “Develop suitable disaster risk management systems including early warning systems” and “Improve disaster resilience of key infrastructure facilities”.

In this context, Japanese experience and knowledge are to be utilized. Disaster prevention policy includes hardware solutions and software solutions. Based on analyses of damage caused by natural disaster e.g. hazard map, the government can prepare disaster prevention plan leading to an appropriate land use plan. Disaster prevention facility e.g. coastal protection surrounding islands, tsunami dike, breakwater system mitigating affects of tsunami, etc is an example of hardware solution. In the most dangerous area to tsunami, Japanese government set up Tsunami Evacuation Shelter to save lives because it may take time for people to evacuate to highland when tsunami attacks. On the other hand software solutions play key role for risk management: early warning system and disaster prevention education to the people. Together with international early warning system, national and local governments should have sound communication systems to get and transfer the disaster information. Finally, the most crucial point is people’s action of evacuation. Thus, disaster prevention education is essential to save lives.

The Team would like to recommend GOJ to provide more technical cooperation on disaster prevention policy to Maldives, though JICA has already accepted participants from tsunami affected countries including Maldives for seminar and site inspection on early warning system and disaster prevention systems working in Japan.

Mid-term reconstruction plans prepared by JICA should utilize Japanese knowledge and experience in disaster prevention. In addition, in the demonstration project by JICA some facility for disaster prevention, e.g., tsunami evacuation shelter, would be considered to apply to an island of Maldives.

2. Environmentally sustainable development

The reconstruction plan of the tsunami affected areas needs to be consistent with environmentally sustainable development policy.

The NRRP includes a program area on environment and disaster risk management, in which intended outcomes are assumed that “Develop environment contingency plans and waste management programs” and “Develop coral reef impact assessments and bio-diversity surveys”.

Considering the importance and significance of Tourism industry of Maldives, environmentally sustainable development is one of the most essential matters even in the case of reconstruction phases from natural disaster.

In this context, JICA will prepare appropriate plans and designs for social infrastructure to prevent pollution and damage to the environment that may arise from people’s activity and industry on the planned new townships and areas.

3. Economic development

On mid-term development plans JICA will consider to conduct preliminary feasibility studies of infrastructure development. Thus, It is necessary to conduct verification study on economic and financial viability.

4. Monitoring and supporting mechanism for appropriate implementation

Social and environmental impact should be carefully assessed and monitored (by the Study) throughout the recovery process. Although the assessment should not delay the implementation of reconstruction projects, the findings shall be constantly fed back to ongoing projects and the long-term development plan.

Part III : Clarification of the Scope of Work

1. Clarification of the Short-term Study component of item 1 in Article IV, S/W - Quickness –

Item 1 of the Scope of the Study is short-term reconstruction of some infrastructure to be implemented by finance programs, i.e.[1]

(1) Multi purpose buildings including island administrative complex [2]in Laamu Gan
(2) Island Offices in Laamu Fonadhoo, Alif Alif Mathiveri, and Vaavu Felidhoo
(3) Power supply and distribution facilities in Laamu Gan
(4) Sewerage System Rehabilitation for Laamu Isdhoo/Isdhoo-Kalaidhoo, and Laamu Fonadhoo
(5) Rehabilitation of Island Harbours for Thaa Atoll (Guraidhoo, Kinbidhoo, Veymandoo, Dhiyamingili, Thimarafushi, Hirilandhoo) (only preliminary study will be required), and Laamu Atoll (Fonadhoo, Isdhoo/Isdhoo-Kalaidhoo, Maabaidhoo, and Maavah)

The most important matter on item 1 is quickness of the work. JICA study team will conduct project design, cost estimation and technical specification by the end of May for the first portion (procurement of equipment), and by the end of July for the second portion (construction of facilities), so that construction work can be started properly.

In addition to rapidity, those infrastructure designs should contribute to environmentally sustainable and disaster-resistant reconstruction of new townships.

2. Clarification of the Mid-term Study component of item 2 in Article IV, S/W
- Mid-term reconstruction in harmonization with long-term development-

Item 2 of the Scope of the Study is Mid-term development of some infrastructure to be implemented by finance programs, i.e.

(1) Island Harbors and Jetties
(2) Coastal protection
(3) Causeways between Laamu Gan and Laamu Fonadhoo
(4) Sewage System / Network
(5) Water supply system
(6) Emergency Communication System

As mentioned in the S/W, the project sites are according to Annex 1 of the S/W.

Mid-term development shall be based on the long-term vision of the development of Maldives such as environmental sustainability, reducing the gap between Male and outer islands and preparedness for the sea level rising. For example, inter-atoll and intra-atoll transport could be improved even from the pre-Tsunami situation by the well-designed reconstruction projects, which shall encourage the recovery of local economy and livelihood.

At the same time, the mid-term recovery approach should be carefully clarified in balance with both the expanding tourism and maintaining the local lives.

3. Clarification of the demonstration Project component of item 3 in Article IV, S/W

Item 3 is Implementation of small community based demonstration projects for Debris Recycling in Laamu Fonadhoo and Social Impact Monitoring in Laamu Fonadhoo, assisted by JICA Study Team.

As mentioned in Part 2, some demonstration project will be implemented in the course of the Study. The objectives of the demonstration project are as following.

1) to generate income for affected people by involving and employing them in reconstruction

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[1] Note: Components proposed by GOM but deleted for short-term reconstruction are as followings:
Island offices (Repair) at Laamu Isdhoo-Kalaidhoo : because size of each repairing is small
New sewage system at Laamu Gan: because it could not be considered for short-term recovery project.
Waste management system at Laamu Gan, Laamu Isdhoo-Kalaidhoo, Laamu Fonadhoo, and Laamu Maabaidhoo: because it may take time for JICA to conduct environmental assessment
Amour rocks for sea walls at several islands: because it is simply a provision of raw materials, instead those components are to be included in "Repair of Harbours".

[2] Island administrative complex includes town hall, space for gathering community members, meeting/conference rooms, etc.

works of debris recycling

2) to make a memorial facility of Tsunami that may contribute to disaster prevention education for the people
3) to consider to build tsunami evacuation shelter building for risk management

4. Coordination with other Donors

Both sides agreed that the JICA Study Team shall conduct the rehabilitation Study mutually collaborating with the Donors Group for Rehabilitation in Maldives.

5. Counterpart Personnel

Both sides agreed that the Study should be conducted in a manner of a joint work of the Maldivian and Japanese sides. In this context, the Team requested the GOM to allocate necessary number of counterpart personnel. The GOM agreed to allocate a counterpart personnel (full-time and part-time basis) according to the composition of the Study Team.

6. Vehicles

The GOM requested JICA to provide transportation necessary for the Study. JICA agreed to prepare vehicles by the Japanese side.

7. Office Space and Equipment

The GOM requested JICA to prepare necessary office space and equipment for the Study in Male. JICA agreed and provided the necessary office facility for the Study Team.

List of Appendices

Annex 1: Attendants List

Annex 2: Lessons learned from Japanese experience in reconstruction after natural disasters

ANNEX 1

Attendants List

Maldivian side

<Ministry of Planning & National Development>

Mr. Hamdun Hameed	Minister
Mr. Mohamed Imad	Director, Spatial Planning
Ms. Lucia Moosa	Director, Programmes
Mr. Huda Ali Shareef	Assistant Director, Resource Management
Ms. Shafeea Rasheed	Assistant Secretary

<Department of External Resources, Ministry of Foreign Affairs>

Ms. Aminath Didi	Assistant Director General
Mr. Mohamed Shahudy	Assistant Director
Ms. Aishath Azeema	Senior Desk Officer

<National Disaster Management Center>

Mr. Mauroof Jameel	Director General
Mr. Thoriq Ibrahim	Deputy Director

<Ministry of Atolls Development>

Mr. Abdul Hameed Mohamed	Atoll Chief

<Ministry of Environment & Construction>

Mr. Ali Amir	Deputy Director
Mr. Mohamed Ali	Assistant Director

<Ministry of Finance & Treasury>

Mr. Riluwan Shareef	Executive Director
Ms. Aminath Ali Manik	Deputy Director
Ms. Aminath Inasha Shafeeq	Assistant Desk Officer

<Maldives Housing & Urban Development Board>

Mr. Ibrahim Rafeeq	Director General

Japanese side

<Japan International Cooperation Agency>

Mr. Masami Fuwa	Leader/ Senior Advisor, Social Development Department
Ms. Ai Yamazaki	Study Monitoring/ Global Environment Department

<Consultant Team>

Mr. Masatsugu Komiya	Leader/Disaster Reconstruction
Mr. Hiroshi Matsuo	Sub-Leader/City Planning
Mr. Tatsuru Ogawa	Housing Planning/Land Use Plan
Mr. Hisayuki Yamamoto	Construction Plan/Cost Estimation-1
Mr. Yoshiaki Kobayashi	Community/Social Condition-2

ANNEX 2:

Lessons learned from Japanese experience in reconstruction after natural disasters

1. Reconstruction process with initiative of the affected people

In Japanese experience of reconstruction from 1995 Hanshin-Awaji devastating earthquake, Japanese people learned that it is necessary to establish cooperation system between affected people, community, and governments.

In reconstruction process, there are two spheres of restoration: reconstruction of city and township (hardware), and restoration of people's living welfare. In the case of 1995 earthquake, Japanese people experienced that reconstruction of city and township itself could not secure the recovery of people's living welfare. A lot of people could not live in area they wanted to be, and suffered from trauma and injury due to the earthquake.

Major lessons learned from reconstruction process in 1995 Hanshin earthquake are:

1) It is the most important and indispensable that affected person himself/herself should start reconstruction activities. (self-reliance)
2) The community plays major role in tackling issues that can not be resolved by the affected people (community empowerment)
3) The government should assist people and community activities. (administration support)

The reconstruction can be defined to be "activities of the affected people to adjust themselves to the change in living condition in the society that are forced to drastically change due to devastation of earthquake."

2. Process of Reconstruction

It is very important to assume an appropriate process of reconstruction. The affected people need a certain period of time and temporary space to live, when and where the people heal mental and physical shocks, start reconstruction actions, consult each other and with government, building consensus of final plan of reconstruction of township, industries, houses, and living welfare.

This section explains Japanese experience in building community based organization, temporary and transitional township, role of the CBO and the government, and land adjustment program based on the unanimous consensus building.

2-1. Community empowerment

After the emergency relief period, it is necessary to start reconstruction activities. We should understand that it takes a long time to reconstruct cities and township and to rebuild living welfare.

The first step of reconstruction is to empower the community that should be the body of mutual helps among people, then a community reconstruction committee is set up. That is a "Community Based Organization (CBO)" intended to plan, implement, and monitor the process of reconstruction. The committee should represent the affected people who voluntarily join the committee. It is appropriate that decision making at the committee is unanimous.

The community reconstruction committee should try to make solution of issues the community faces, for example making reconstruction plans reflecting the needs of the community, making rule and regulation on building design and environmental preservation, and making agreement between the community and the government.

The government should assist activities of the community reconstruction committee in cooperation with a variety of experts and private enterprises. Because the issues of reconstruction consists of township, public health and social welfare, environment, and industry rebuilding, right expert team should be formed to assist and advise on the community's own activities and the government's support.

2-2. Temporary and Transitional Township

The affected people needs a certain period of time and temporary space when and where the people heal mental and physical shocks, start reconstruction actions, consult each other and with government, building consensus of final plan of reconstruction of township, industries, houses, and living welfare. Temporary and transitional township can provide the affected people with the space and the time to accomplish those processes of reconstruction.

The notion of “Temporary and Transitional Township” was invented after 1995 Hanshin earthquake in Japan. At the reconstruction period of 1995 earthquake, the local government tried to set up temporary camps very far away from affected areas. Those temporary camps could not include facilities and functions for commercial and industrial activities by law. People who were forced to move to the camps far away from their original places had to face difficulty harming mutual cooperation due to separation of original communities. Those people could dwell in temporary houses provided by the government, but could not restart their commercial and industrial activities and business there. People had to live in very inconvenient places without shops and public facilities.

It takes a long time to realize final goal of reconstruction, and also it should be assumed that the community faces some difficult issues for people to resolve by themselves.

“Temporary and Transitional Township” should accommodate the people’s transitional lives as comfortable as possible, and thus, it should consist of temporary houses, temporary shops, offices and factories, and public facilities. In Japan transitional period could be three years before final stage of reconstruction.

Temporary and transitional township scheme was implemented in the cases of 1995 Kobe Hanshin earthquake, 1999 Turkey Anatoria earthquake, and 1999 Taiwan Earthquake.

2-3. Functions of the Temporary and Transitional Township

The function and objectives of temporary and transitional township are assumed to be as follows.

1) Accommodate of Whole households

Publicly planned temporary houses should be prepared to accommodate whole households of the specific original community affected, so that the community is not separated when moving to the temporary town.

2) Temporary and transitional township near the affected area

Temporary and transitional township should be planned to be constructed as near as possible from the affected area, and not very far away from the original town. That can enable the affected people to remove the debris and rubble of the damaged houses, to exchange and transmit information among the community, and to communicate each other.

3) The initiative of the affected people

It should be avoided to exclude the affected people from construction process of the temporary and transitional township. Although the affected people tend to be “victims” who should be given and provided the services, they should be involved in the reconstruction process by utilizing their capabilities and intention of restoration for reconstruction energy of the community. That can lead to realization of community driven reconstruction in which the affected people themselves undertake and implement the reconstruction.

4) Integrated living condition/welfare in the temporary and transitional township

In temporary and transitional township, not only temporary shelters but also other facilities necessary for the life should be constructed. The temporary and transitional township is deemed to be the place of living and the base of rebuilding the life. Thus, there should be commercial, medical, and educational facilities, offices and factories, waste treatment plant, waste recycling unit, caring facility for aged people and disabled, job creating facilities for the unemployed people, space for children, community center, amusement facilities, etc.

2-4. Role of the community and Role of the government

When constructing temporary and transitional township, the land is to be provided and temporary facilities should be needed. The Community Based Organization (CBO) should play key roles in gathering information, acquisition of land, and constructing temporary facilities.

On the other hand, the government should make legal arrangement for the CBO to lend the land owned by private sector for a certain period to temporary and transitional township. The government also arranges functional system for the CBO to construct temporary facilities.

3. Land Adjustment Program for Reconstruction

The Land Adjustment Program of Japan is a legal scheme utilized in case of urban redevelopment.

As the final goal of reconstruction of township, it is recommended to plan and design a resistant town to natural disaster, and in some cases to add public spaces for common welfare.

Redevelopment of a congested area in a city and a town, the most serious constraint is the land. The land adjustment program can legally create the space based on unanimous consensus among people of landowners and people living and working there. The government intervenes the process of redevelopment of the area by making a plan and promoting community based organization consisting of the people.

With financial assistance of government, original alignment of the land is reorganized and designed to be well-organized town roads, public space, disaster prevention facilities, and necessary infrastructures, that can lead to enhancement of the value of the land. The CBO plays an important role to make consensus among the community, and to consult with the government.

In the case of reconstruction from devastating natural disaster, land adjustment program can be introduced to reconstruct a congested area. When temporary and transitional township program is implemented, it is easier to make unanimous consensus building on the land adjustment program.

4. Disaster Prevention Policy

The reconstruction plan of the tsunami affected areas needs to be consistent with disaster prevention policy in the country and the regions. The JICA will try to incorporate disaster prevention policy for the affected areas in cooperation with the Japanese government.

S2-5 : REQUESTS OF THE MALDIVES AND CHANGING SITUTAION OF THE STUDY CONTENTS

10th June, 2005

STUDY PROJECT TO ASSIST URGENT TSUNAMI RECOVERY, REHABILITATION AND DEVELOPMENT FOR ISLANDS IN THE MALDIVES

REQUESTS OF THE MALDIVES SIDE AND CHANGING SITUATION OF THE STUDY CONTENTS

<table>
<tr><th rowspan="2">At the Onset of the Study
(End of March, 2005)</th><th colspan="2">Modifications of the Study Following S/W Signed on 12th April</th><th colspan="2">Modifications of the Study Following Steering Committee Meeting on 5th May</th><th colspan="2">Modifications of the Study Following Steering Committee Meeting on 5th June</th></tr>
<tr><th>Modified Study Contents</th><th>Reasons for Modification</th><th>Modified Study Contents</th><th>Reasons for Modification</th><th>Modified Study Contents</th><th>Reasons for Modification</th></tr>
<tr>
<td>1. Basic Study Policies
1.1 Objectives of the Study

1) Formulation of Rehabilitation Plans and Policies (Development Master Plan)
To formulate medium to long-term rehabilitation plans and policies for the target islands of the Study and other islands while fully considering their compatibility with the Safe Islands Programme (the local island rehabilitation and development programme with due consideration of disaster prevention measures) which is a national project in the Maldives
2) Assistance for Implementation of Urgent Recovery and Rehabilitation Projects (Assistance for Formulation of Individual Projects)
To identify the concrete needs for the Rehabilitation and Development Project in the Study Area (target islands) and to conduct project monitoring at the design/estimation and implementation assistance/construction stages)</td>
<td>1. Basic Study Policies
1.1 Objectives of the Study
The Study has the following objectives.

Deletion of the objectives described left.

The objective of the Study is to assist the following plans in the Study Area.
1) Short-term recovery plan: technical cooperation to assist the swift recovery of socioeconomic infrastructure (planning and design, etc.)
2) Mid-term rehabilitation and development project: study contributing to the early commencement of the reconstruction of socioeconomic infrastructure
3) Demonstration project: small-scale participatory demonstration project by the JICA Team on Fonadhoo Island of Laamu Atoll (recycling of waste materials, community empowerment and disaster prevention education) and monitoring of the progress of these activities</td>
<td>Based on the S/W (signed on 12th April, 2005)

It was decided not to formulate a development master plan under the Study through discussions on the S/W.

Based on the S/W (signed on 12th April, 2005)</td>
<td>1. Basic Study Policies
1.1 Objectives of the Study

As left</td>
<td>—</td>
<td>1. Basic Study Policies
1.1 Objectives of the Study

As left</td>
<td>—</td>
</tr>
<tr>
<td>1.2 Study Area
The Study Area consists of the following seven islands (see Location Map 1).
① Target islands of the JICS non-project grant aid for housing construction

Table 1 Candidate Islands for Housing Construction for Non-Project Grant Aid
<table>
<tr><th>No. Under Safe Island Programme</th><th>Priority Ranking in Housing Construction Project</th><th>Atoll/Island</th><th>No. of Homeless</th><th>No. of Houses Requiring Reconstruction</th><th>No. of Houses Requiring Repair</th></tr>
<tr><td>S5</td><td>H1</td><td>Meemu/Konifushi</td><td>1,030</td><td>170</td><td>0</td></tr>
<tr><td>S7</td><td>H2</td><td>Thaa/Madefushi</td><td>733</td><td>125</td><td>52</td></tr>
<tr><td>—</td><td>H3</td><td>Laamu/Marbaidhoo</td><td>545</td><td>56</td><td>54</td></tr>
<tr><td>—</td><td>H4</td><td>Laamu/Fonadhoo</td><td>274</td><td>49</td><td>186</td></tr>
<tr><td>—</td><td>H5</td><td>Laamu/Isdhoo-Kalaidhoo</td><td>412</td><td>42</td><td>66</td></tr>
<tr><td>—</td><td>H6</td><td>Noonu/Maafaru</td><td>297</td><td>32</td><td>96</td></tr>
<tr><td></td><td></td><td>合計</td><td>2,582</td><td>474</td><td>454</td></tr>
</table>
Note: It is assumed that the Study only features the reconstruction of houses and excludes repair work from its scope.

② One island with severe tsunami damage but with high rehabilitation and development potential.
Laamu Atoll/Gan Island (S4)</td>
<td>1.2 Study Area
The Study Area consists of the following 13 islands (see Location Map 2).
① Alif-Alif Atoll: Mathiveri (AA-1)
② Vaavu Atoll: Felidhoo (V-1)
③ Thaa Atoll: Dhiyamigili (Th-1), Graidhoo (Th-2), Thimarafushi (Th-3), Veymandoo (Th-4), Kinbidhoo (Th-5), Hirilandhoo (Th-6)
④ Laam Atoll: Isdhoo/Isdhoo-Kalaidhoo (L-1), Maabaidhoo (L-2), Gan (L-3), Fonadhoo (L-4), Maavah (L-5)</td>
<td>Based on the S/W (signed on 12th April, 2005)

Based on the request of the Maldives side, modifications were made to avoid duplication with other donors and to establish geographical consistency.</td>
<td>1.2 Study Area
The Study Area consists of the following island (see Location Map 3).
① Thaa Atoll: Dhiyamigili (Th-1), Graidhoo (Th-2), Thimarafushi (Th-3), Veymandoo (Th-4), Kinbidhoo (Th-5), Hirilandhoo (Th-6)
② Laam Atoll: Isdhoo/Isdhoo-Kalaidhoo (L-1), Maabaidhoo (L-2), Gan (L-3), Fonadhoo (L-4), Maavah (L-5)</td>
<td>Based on the intentions of the Maldives side which were confirmed at the Steering Committee meeting on 5th May, 2005</td>
<td>1.2 Study Area

As left</td>
<td>—</td>
</tr>
</table>

At the Onset of the Study (End of March, 2005)	Modifications of the Study Following S/W Signed on 12th April		Modifications of the Study Following Steering Committee Meeting on 5th May		Modifications of the Study Following Steering Committee Meeting on 5th June	
	Modified Study Contents	Reasons for Modification	Modified Study Contents	Reasons for Modification	Modified Study Contents	Reasons for Modification
1.3 Basic Policies (1) Status of Present Urgent Development Assistance The Study is part of the recovery and rehabilitation project for the entire disaster-hit areas in the Maldives.	1.3 Basic Policies (1) Status of Present Urgent Development Assistance As left	Based on the S/W (signed on 12th April, 2005) As above	1.3 Basic Policies (1) Status of Present Urgent Development Assistance As left	—	1.3 Basic Policies (1) Status of present Urgent Development Assistance As left	—
(2) Compatibility with Rehabilitation Assistance Policies of the Maldives As the Department of External Resources (DER) of the Ministry of Foreign Affairs which acts as the front desk to deal with foreign aid on behalf of the GOM requests that the Study be compatible with the latest national development plan, this request will be fully taken into consideration. The Maldives side has set up the National Disaster Rehabilitation Unit consisting of representatives of various related organizations to coordinate the nationwide tsunami disaster rehabilitation efforts. The Unit arranged aid projects for the country by sector, identified the project contents, cost, funding sources (donors) and formulated the National Recovery and Reconstruction Plan (Programmes and Projects) in March, 2005. Given the fact that projects in the NRRP are moving quickly, the Study aims at formulating highly feasible projects which do not overlap with the projects of other donors and which are compatible with the NRRP through close liaisoning with the prospective implementation bodies in the Maldives.	(2) Compatibility with Rehabilitation Assistance Policies of the Maldives The Maldives side intends to implement all recovery and rehabilitation projects based on the NRRP. Accordingly, the compatibility of projects to be conceived under the Study with the NRRP will be attempted by checking the state of the tsunami disaster, present conditions and possible duplication of these projects with those of other donors, etc. through a field survey and other means. The compatibility with the latest 6th National Development Plan 2001 – 2005 (Ministry of Planning) will be confirmed. In 1998 prior to the tsunami disaster, the GOM formulated the Focus Island Initiative under which people would be resettled to major islands for efficient development. This Initiative examined the target islands from the following viewpoints. • Development potential • Potential for easy investment • Large island • Potential to increase the island size by reclamation In the aftermath of the tsunami disaster, while inheriting the concept of the Focus Island Initiative, the GOM formulated the Safe Island Programme with a disaster prevention function (construction of a 2 m high ring road to act as an embankment with the introduction of high ground at the centre of the island to provide emergency shelter, etc.) This Programme targets 19 islands nationwide. However, the early implementation of the Programme was believed to be difficult because of the question of the resettlement of the islanders and the GOM formulated the Host Island Programme based on the Safe Island Programme. Five islands have been selected for the Host Island Programme and development efforts are conducted in a priority manner to facilitate resettlement to these islands. Gan Island of Laamu Atoll, one of the target islands of the Study, is such a host island. At present, the GOM considers the implementation of the NRRP to be the highest priority while considering development under the Host Island Programme to be an exercise for the future. The Study will examine the ongoing status of the Safe Island Programme.	As above	(2) Compatibility with Rehabilitation Assistance Policies of the Maldives As left	—	(2) Compatibility with Rehabilitation Assistance Policies of the Maldives As left	—

At the Onset of the Study (End of March, 2005)	Modifications of the Study Following S/W Signed on 12th April		Modifications of the Study Following Steering Committee Meeting on 5th May		Modifications of the Study Following Steering Committee Meeting on 5th June	
	Modified Study Contents	**Reasons for Modification**	**Modified Study Contents**	**Reasons for Modification**	**Modified Study Contents**	**Reasons for Modification**
(3) Confirmation of Urgency of Reconstruction, Viewpoint for Rehabilitation and Trends of Non-Project Grant Aid At the tsunami disaster sites, reconstruction activities are in progress with the cooperation of donors, including Japan, NGOs and local residents, and the situation at these sites is changing on a daily basis. Under these circumstances, the Study aims at urgently finding sites which require urgent recovery and rehabilitation, confirming the present conditions at each site and identifying the needs. It is essential that the Study take the stance of urgently clarifying Japan's commitment to assistance to assist the achievement of the recovery and rehabilitation of the Maldives as a whole from the medium to long-term perspective through collaboration and coordination with all donors. It is also necessary to confirm the details of the JOG's assistance (non-project grant aid) to examine sectors for possible assistance in the course of the Study. The planned non-project grant aid of Japan at present is listed below. ・ Fishing gears (fishing nets, poles, GPS and fish finders): ¥500 million ・ Housing construction: ¥1,000 million (three bedroom houses: MOR estimate of 300,000 Rf (approx. US$ 23,500) per house ・ Reserve: ¥500 million	(3) Confirmation of Urgency of Reconstruction, Viewpoint for Rehabilitation and Trends of Non-Project Grant Aid The original S/W for intended signing by the GOM and the Study Team dispatched in March to discuss the S/W did not obtain the consent of the Ministry of Planning, presumably because of the ongoing negotiations between the GOM and the German Red Cross and Singapore Government, etc. regarding assistance for the construction of private housing as well as public facilities. The S/W was finally signed based on discussions held by the Study Team dispatched in March and discussions held by the subsequent Consultant Study Team and the JICA Sri Lanka Office with the GOM together with signing of the M/M explaining the intentions, concepts and proceedings of the JICA's cooperation (12th April). The present Study formulates rehabilitation assistance projects based on the purport of the S/W and the M/M (both signed on 12th April). The planned assistance by Japanese non-project grant aid was replaced by the procurement of house rehabilitation materials because of the fact that the housing reconstruction plan was withdrawn due to a problem of ownership. Accordingly, the prospective contents of the non-project grant aid have been changed to the following. ・ Fishing gears (fishing nets, poles, GPS and fish finders) approx. ¥500 million ・ Housing rehabilitation: approx. ¥500 – 700 million (inclusive of the transportation cost) ・ Construction of public facilities: approx. ¥800 – 1,000 million Given the above situation、<u>the Study will assist the public facility construction plan under the non-project grant aid scheme even though this will have no direct relation to the housing rehabilitation plan.</u>	Based on the S/W (signed on 12th April)	(3) Confirmation of Urgency of Reconstruction, Viewpoint for Rehabilitation and Trends of Non-Project Grant Aid In regard to Japan's assistance with non-project grant aid, the housing reconstruction plan was entirely withdrawn, including the procurement of rehabilitation materials, because of a problem of ownership. Accordingly, the prospective contents of the non-project grant aid are as follows. ・ Fishing gears (fishing nets, poles, GPS and fish finders): approx. ¥500 million ・ Agricultural tools: approx. ¥250 million ・ JICS agent fee: approx. ¥50 million ・ Construction of public facilities: approx. ¥1,200 million Given the above situation, the Study will assist the public facility construction plan under the non-project grant aid scheme.	Based on the intention to assist non-project grant aid as confirmed through discussions at the Steering Committee meeting held on 5th May, 2005	(3) Confirmation of Urgency of Reconstruction, Viewpoint for Rehabilitation and Trends of Non-Project Grant Aid As left	—
1.4 Contents of the Study (1) Development Master Plan (a) Formulation of a short to mid-term draft rehabilitation plan for infrastructure facilities (JBIC yen loan) ・ Study on tsunami damage to infrastructure facilities ・ Formulation of the rehabilitation project contents (draft) for each facility ・ Formulation of a rehabilitation project implementation plan (draft) (prioritising and cost estimation)	1.4 Contents of the Study (1) Short-Term Recovery Plan (Non-Project Grant Aid) Assistance will be provided for the implementation of the short-term recovery plan (social and economic infrastructure) to assist the urgent rehabilitation efforts. In consideration of speed, sustainability of the environment and disaster control, the planning and design of projects featuring the following facilities will be conducted based	The short-term recovery plan assumes implementation with non-project grant aid and was selected from the list of non-project grant aid targets shown by the GOM. The list was	1.4 Contents of the Study (1) Short-Term Recovery Plan The planning and design of projects featuring the following facilities will be conducted.	Based on the intentions of the GOM confirmed at the Steering Committee meeting on 5th May, 2005 and discussions with the project implementation bodies on the Maldives side on 22nd May	1.4 Contents of the Study (1) Short-Term Recovery Plan The planning and design of projects featuring the following facilities will be conducted. Development of social infrastructure on Laamu Atoll (preparation of draft tender documents and assistance for the evaluation of bids) ① Administrative complex	Modified to reflect the intentions of the GOM which were confirmed at the Steering Committee meeting held on 5th June, 2005 Following discussions between the GOM and the ADB, it was decided that the ADB would rehabilitate the sewerage system on

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	Modified Study Contents	**Reasons for Modification**	**Modified Study Contents**	**Reasons for Modification**	**Modified Study Contents**	**Reasons for Modification**
・ Advice on the compatibility with the Safe Island Programme and the National Development Plan ・ Assistance to obtain final approval for the Land Use Plan (assistance and advice at community meetings) Note1 Although telecommunications equipment is not included in the project, the situation of tsunami damage to telephone, TV, radio, cable TV and disaster warning systems will be studied from the viewpoint of ensuring the means of information conveyance at the time of an emergency. Proposals will be made for the necessary rehabilitation work. Note 2 In regard to fishing ports (harbours), the distribution routes from the fish market on each atoll will be studied to determine the necessity to introduce certain equipment (ice-making machine and others) for the target islands. (b) Assistance for the following projects associated with the construction of housing (JICS non-project grant aid) <u>Planning Stage</u> ・ Checking of the housing layout plan (confirmation of the compatibility with the Land Use Plan) ・ Assistance for the preparation of the technical specifications for the tender <u>Pre-Construction Stage</u> ・ Assistance for housing land development work: facilitation of surveying and ground preparation work ・ Waste recycling project (demonstration project candidate): participatory production of blocks (for housing walls and other uses) recycled from waste materials from collapsed houses <u>Construction Stage</u> ・ Assistance for the tender for housing construction and also for project monitoring in the construction period (to be decided by a decision between the JICS and the GOM in the coming months) ・ Tsunami memorial construction project (demonstration project candidate): participatory construction of the Tsunami Memorial Park (use of the recycled blocks mentioned above) (c) Assistance for community development (by the Study Team members responsible for social care and community development) ・ Survey on damage to economic activities ・ Assistance for the socioeconomic rehabilitation of the target communities	on the NRRP. ① Administrative complex building (Laamu Gan) ② Island office building (Laamu Fonadhoo, Alif-Alif Mathiveri and Vaavu Felidhoo) ③ Power generation and distribution facilities (Laamu Gan) ④ Sewerage system (Laamu Isdhoo/Isdhoo-Kalaidhoo and Laamu Fonadhoo) ⑤ Harbour facilities and seawalls (Thaa Atoll: Dhiyamigil, Guraidhoo, Thimarafushi, Veymandoo, Kinbidhoo and Hirilandhoo; Laamu Atoll: Isdhoo/Isdhoo-Kalaidhoo, Maabaidhoo, Gan, Fonadhoo and Maavah)	revised and shown four times from the first version submitted at the Steering Committee Meeting on 5th April to the fourth version on 12th April when the S/W was signed. As a result of donor adjustment by the GOM, the original request to Japan to assist the implementation of housing reconstruction was replaced by a request for assistance for the rehabilitation of social and economic infrastructure while the formulation of a development master plan was considered to be unnecessary. From the viewpoints of urgency and prospect of swift completion, coastal protection for Meemu Korufshi and Laamu Madifushi and the sewerage system and harbour facilities on Laamu Gan, which the Japanese side had proposed, were dropped from the scope of the Project and the waste treatment system on three Laamu Atoll islands as proposed by the Maldives side was also dropped because of the lengthy period required for environmental and social consideration. In the case of harbour facilities which would require time to reach the construction stage, it was decided to conduct the basic design as part of the short-term assistance and the detailed design as part of the mid-term assistance. As a result, it was decided to provide assistance for the urgent rehabilitation of infrastructure on 13 islands of Laamu Atoll (especially Fonadhoo) and Thaa Atoll.			building (Gan) ② Island office building (Fonadhoo) ③ Causeways (between Gan and Fonadhoo) ④ Power distribution system (Laamu Atoll: Isdhoo/Isdhoo-Kalaidhoo, Maabaidhoo, Gan-___ and Maavah) ⑤ Photovoltaic power generation system (for ① and ② above) ⑥ Sewerage system (Isdhoo/Isdhoo-Kalaidhoo)	Fonadhoo and the GOM (DER) sent a letter requesting a change of the target island for sewerage system rehabilitation to the Embassy of Japan in Sri Lanka. In response to this request, the target island was changed from Fonadhoo to Isdhoo/Isdhoo-Kalaidhoo. Following this decision, the Study Team conducted an urgent survey on Isdhoo/Isdhoo-Kalaidhoo together with representatives of the relevant ministries (Ministry of Health, Ministry of Planning and Ministry of Construction and Environment) on 25th May and confirmed that the planned design for the Isdhoo area would go ahead. In the case of the Isdhoo-Kalaidhoo area, however, it was said that 55 families (households) in the eastern part of this area have expressed a wish to be relocated to the western part because of their suffering from tsunami and high tides during discussions with the island chief and that a letter signed by all was submitted to the Ministry of Atoll Development. Because the JICA Study Team has to deal with the sewerage system as well as the power distribution system in the area, relocation of the residents will necessitate changes of the design and project implementation schedule, etc. The Maldives side (Ministry of Planning and Ministry of Atoll Development, etc.) is scheduled to make a decision on this requested relocation by 31st May. The Study Team will then conduct a survey based on this decision. It has been agreed by all related parties that the survey on the sewerage system will proceed by assuming the relocation sites until the GOM's policy regarding this relocation is finalised.
(2) Assistance for Formulation of Individual Projects (a) Formulation of a short to mid-term draft rehabilitation plan for infrastructure facilities (JBIC yen loan) Target Infrastructure <u>Laamu Fonadhoo (H4)</u> ・ Repair of the harbour facilities and causeway (request by atoll chief) ・ Water supply and sewerage systems (confirmation of their necessity by the Study Team through interviews) <u>Other housing sites (H2, H3, H5 and H5) and Laamu Gan (S4)</u>	(2) Mid-Term Rehabilitation and Development Plan As assistance for mid-term rehabilitation, a survey will be conducted to contribute to the early implementation of the mid-term rehabilitation and development plan (social and economic infrastructure). This survey will incorporate the viewpoint of the long-term development of the Maldives and will consider the sustainability of the environment, rectification of the socioeconomic gap between the major islands and remote islands and the impacts		(2) Mid-Term Rehabilitation and Development Plan The planning and design of projects featuring the following facilities will be conducted. ① Island harbour facilities and coastal protection facilities (Thaa Atoll: Dhiyamigili, Guraidhoo, Thimarafushi, Veymandoo, Kinbidhoo and Hirilandhoo; Laamu Atoll: Isdhoo/Isdhoo-Kalaidhoo, Maabaidhoo, Gan, Fonadhoo and Maavah)	As above	Same as left	

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	Modified Study Contents	**Reasons for Modification**	**Modified Study Contents**	**Reasons for Modification**	**Modified Study Contents**	**Reasons for Modification**
・ Roads, harbours, coastal protection, water supply, sewerage, waste collection and disposal, electricity (b) Assistance for the following projects associated with housing construction (collaboration with JICS non-project grant aid) <u>Planning Stage</u> ・ Checking of the housing layout plan (confirmation of the construction locations on the existing map as the houses in some areas are due for reconstruction) ・ Assistance for the preparation of the technical specifications for the tender <u>Construction Stage</u> ・ Assistance for the tender for housing construction and also for project monitoring in the construction period	of global warming. As in the case of the short-term recovery plan, projects featuring the following facilities will be designed and planned based on the NRRP. (1) Island harbours and jetties (2) Coastal protection (3) Causeways in Laamu between Gan and Fonadhoo (4) Sewerage system/network (5) Water supply system (6) Emergency communication system	These projects are extracted from the list for non-project grant aid prepared by the GOM in view of their scale, required time for construction and urgency, etc. to match the concept of mid-term rehabilitation. The Japanese proposals are mainly accepted but, in the case of Gan for which there is a redevelopment plan and where the potential for development assistance is high, improvement of the sewerage system was dropped from the viewpoint of swift implementation. Consequently, assistance for infrastructure rehabilitation will be provided for 11 islands of Laama Atoll (especially Fonadhoo) and Thaa Atoll.	② Emergency administrative radio communication system			As above

S2-6 LIST OF PARTIES CONCERNED

(Maldives side)

Office	Name	Designation
The President's Office	Mr. Mohamed H. Shareef	Chief Government Spokesman
Department of External Resources (DER), Ministry of Foreign Affairs	Ms. Aminath Didi	Deputy Minister
	Mr. Hussain Niyaaz, Ph.D.	Executive Director
	Mr. Ali Naseer Mohamed	Assistant Director General
	Mr. Mohamed Shahudy	Assistant Director
	Mr. Aishath Azeema	Senior Desk Officer
Ministry of Planning & National Development (MPND)	Mr. Hamdun A. Hameed	Minister
	Dr. Mohamed Shareef	Asst. Director General
	Ms. Lucia Moosa	Director, Programmes
	Mr. Mohamed Imad	Director, Spatial Planning
	Ms. Huda Ali Shareef	Director
	Mr. Thoriq Ibrahim	Deputy Director, Regional Development
	Mr. Ahmed Rasheed	
	Mr. Ahmar Mohamed	Planning Officer Trainee
	Mr. Mohamed Rasheed	Director, Administration & Finance
	Ms. Shafiyya Rasheed	Assistant Secretary
	Mr. Abdulla Shibau	City Planning / Spatial Planning
	Mr. Mohamed Luan Latheef	Spatial Planning
	Ms. Loona Abdul Hakeem	
	Ms. Mariyam Mirufath	
	Ms. Musliha Hasson	Planning Officer Trainee
	Mr. Fathimath Rashedha	
	Ms. Mnohhg Hassan	
	Mr. Miusam Saleem	Planning Officer Trainee
Ministry of Finance & Treasury (MFT)	Mr. Riluwan Shareef	Deputy Minister
	Mr. Mohamed Ahmed	Executive Director
	Ms. Aminath Ali Manik	Assistant Director General
	Mr. Abdul Wahid	
	Ms. Aminath Inasha Shafeeq	Senior Desk Officer

Office	Name	Designation
Ministry of Atolls Development (MOAD)	Mr. Abdhul Azeez Yoosuf	Deputy Minister
	Mr. Adam Moosa	Director
	Mr. Ahmed Rasheed	Assistant Executive Director
	Mr. Hamid Yoosuf	Director General
	Mr. Mohamed Farook	Deputy Director General
	Mr. Abdul Hameed Mohamed	Atoll Chief
	Mr. Abdulla Shibau	
National Disaster Management Center (NDMC)	Mr. Thoriq Ibrahim	Deputy Director
Ministry of Environment, Energy and Water (MEEW)	Mr. Abdul Razzak Idris	Deputy Minister
	Mr. Mohamed Ali	Assistant Director
	Mr. Thoriq Ibrahim	Deputy Director
	Mr. Ahmed Jameel	Deputy Director, Environment Assessment
	Mr. Ali Amir	Public Works Section
	Mr. Mohamed Zuhair	Deputy Director, Product Area Management
	Ms. Labuna Moosa	
	Mr. Gil Marshal	
	Mr. Abdulla Firag	Project Manager, Renewable Development Project
	Mr. Ajwad Musthafa	Assistant Director
	Mr. Ajwad Shakeel	Civil Engineer
Ministry of Transport and Communications (MTC)	Mr. Mohamed Saeed	MInister
Telecommunications Authority of Maldives (TAM)	Mr. Mohamed Amir	Chief Executive
National Security Service (NSS)	Mr. Ibrahim M. Didi	Communication, electronics and IT services
Maldives Electricity Bureau (MEB)	Mr. Mohamed Majdee	Dicrector, Energy Resources
	Mr. Abdulla Wahid	Deputy Director General
State Electric Company Limited (STELCO)	Mr. Mohamed Rasheed	Assistant Managing Director
	Mr. Mohamed Latheef	Director
	Mr. Ahmed Niyaz	Senior Engineer

Office	Name	Designation
	Mr. Ibrahim Athif	Mechanical Engineer
	Mr. Ahmed Shafeeu	Electrical Engineer
Maldives Ports Authority (MPA)	Mr. Mahadi Imad	Deputy Managing Director
	Mr. Ali Ahmed	Director Cargo Handling
	Mr. Mohamed Haneef	Deputy Director Cargo Handling
Maldives Airport Company Limited (MAC)	Mr. Ali Hashim	Assistant Managing Director
Regional Air port in MTCA	Mr. Mohamed Maahid Shareef	Deputy Director
Ministry of Health (MOH)	Ms. Sheena Moosa	Deputy Director of Health Services
	Mr. Shehenaz Fahmy	Deputy Director
	Mr. Ahmed Zahid	
	Mr. Ahmed Waheed	
	Mr. Aslam Rasheed	
	Dr. Roisin Rooney	
Maldives Water and Sanitation Authority (MWSA)	Ms. Shaheeda Adam Ibrahim	Director
	Mr. Mohamed Musthafa	Engineer
	Mr. Abdul Aleem	
	Mr. Ali Munaz Mubaarik	Engineer
Male' Water and Sewerage Company (MWSC)	Mr. Mohamed Rasheed Bari	Technical Manager
Ministry of Economic Development and Trade (MEDT)	Mr. Mohamed Jaleel	Minister
Ministry of Fisheries, Agriculture and Marine Resources (MFAMR)	Mr. Hussain Rasheed	Director of Statistic Department
Maldives Housing and Urban Development Board	Mr. Ibrahim Rafeeq	Minister
	Ms. Fathimath Rasheed	Assistant Director, Planning
Ministry of Construction and Public Infrastructure	Mr. Mauroof Jameel	Minister

Office	Name	Designation
L. Atoll Office (L. Funadhoo)	Mr. Moosa Ali Kaleyfaan	Atoll Chief
	Mr. Saud Ibrahim	Acting Atoll Chief
	Mr. Mohamed Haleem	Assistant Atoll Chief
Island Office (L. Ishdhoo-Kalaidhoo)	Mr. Abdull Raheem	L. Ishdhoo-Kalaidhoo Island Chief
Island Office (L. Maabaidhoo)	Mr. Mohamed Jameel	Island Chief
Island Office (L. Gan Thundhi)	Mr. Abdul Wahaby	Thundhi Island Chief
Island Office (L. Fonadhoo)	Mr. Ahmed Youshuf	Island Chief
	Mr. Ibrahim Mohamed	Island Chief
	Mr. Mohamed Jameel	Senior Secretary
	Mr. Mohamed Naif	Assistant Island Chief
	Mr. Ahmed Ali	Assistant Island Chief
	Mr. Aishath Salwa	Island Assistant
Island Office (L. Maafaru)	Mr. Abdul Sattar	Island Chief
	Mr. Ibrahim Mohamed	Senior Island Chief
Thaa Atoll Office	Mr. Abdul Setter Adam	Thaa Atoll Chief
Island Office (Th.) Thimarafushi	Mr. Ahmed Ali	Island Chief

Office	Name	Designation
MIFCO	Mr. Adil Saleem	Deputy Director
Fonadhoo Tuna Product	Mr. Husam Mohamed	Finance Manager
Horizon Fisheries	Mr. Adnan Ali	Managing Director

Office	Name	Designation
United Nations (UN)	Mr. Babar Sobhan	RC Coordination Specilist
World Bank	Mr. Richard Scurfield	Special Representative for Maldives
Food and Agriculture Organization (FAO)	Mr. Winston R. Rudder	FAO Maldives Officer
UNDP	Mr. Murrey Wilson	Infrastructure Advisor
	Mr. Man B. Thapa	Disaster Management Specialist

Office	Name	Designation
	Ms. Rita Missal	Recover Officer Disaster Management
	Mr. Knut Ostby	Recovery Management
UNICEF	Mr. Peter Wurzel (Zimbabwe)	Sewage and Water Supply
	Mr. Dan Martin (England)	Sewage and Water Supply
	Mr. Mohamed Saeed	Program Officer
	Mr. Anthony Raby	Regional Emergency Project Officer
	Mr. Ken Maskall	Representative
	Mr. Johan Fagersiold	Programme Coordinator
	Ms. Aishath Mohamed Didi	Program Officer
	Ms. Kyoko Takamizawa	
International Federation Red Cross	Mr. Jerry Talbot	Head of Delegation
	Ms. Selina Chan	Watson Delegate
British Red Cross	Mr. Per Andersson	Construction Manager
	Mr. Ventella Fortune	Programme Development Advisor
	Mr. Simon Little	Team Leader
French Red Cross	Mr. Ernesto HERPERA	Head of Mission
	Mr. Philippo Clay	Civil Engineer

(Japanese side)

Office	Name	Designation
Embassy of Japan	Mr. Hiroshi KARUBE	Minister, Deputy Chief of Mission
	Mr. Hideyuki ONISHI	Counselor
JICA Head Office	Mr. Masami FUWA	Senior Assistant to the Director General, Social Development Department
	Mr. Masafumi NAGAISHI	Team Director, Water Resources and Disaster Management Team II, Group III
	Mr. Hideaki MATSUMOTO	Water Resources and Disaster Management Team II, Group III

Office	Name	Designation
	Ms. Ai YAMAZAKI	Water Resources and Disaster Management Team II, Group III
	Mr. Naomichi MUROOKA	Transportation Team II, Group III
JICA Sri Lanka Office	Mr. Takumi UESHIMA	Resident Representative
	Mr. Ko GOTO	Assistant Resident Representative

S2-7 Study Team Member List

Name	Field in charge	Occupation
Masatsugu KOMIYA (Mr.)	Leader/Disaster Reconstruction	Yachiyo Engineering Co., Ltd.
Hiroshi MATSUO (Mr.)	Sub-Leader/City Planning	Pacet Co.,Ltd.
Tatsuru OGAWA (Mr.)	Housing Planning／Land Use Plan	Aoyama Urban Design Institute
Kazunori SEKI (Mr.)	Architect-1／Society Service	Pacet Co.,Ltd.
Atsushi MORIOKA	Architect-2	NIPPON KOEI CO., LTD.
Hisayuki Yamamoto (Mr.)	Construction Plan／Cost Estimation- 1	Yachiyo Engineering Co., Ltd..
Shigeki Yamaoka (Mr.)	Cost Estimation-2/Demonstration Project-1	NIPPON KOEI CO., LTD.
Hidenori OSUMI (Mr.)	Construction Monitoring/Demonstration Project-2	NIPPON KOEI CO., LTD.
Tadayuki OGAWA (Mr.)	Public Facility-1	Yachiyo Engineering Co., Ltd.
Yasuo HORIGOME (Mr.)	Public Facility -2	HORIGOME Architect Firm
Mamoru AMEMIYA (Mr.)	Coastal Facility	
Shinsuke KUBO (Mr.)	Cost Estimation for Coastal Facility	Omega Engineering Co., Ltd.
Katsumi FUJII (Mr.)	Communication Facility	NIPPON KOEI CO., LTD.
Akitoshi IIO (Mr.)	Community/Social Condition-1	Yachiyo Engineering Co., Ltd.
Fumiaki SHIOMI (Mr.)	Seashore Preservation	Yachiyo Engineering Co., Ltd.
Toshihiro HOTTA (Mr.)	Causeway Planning	Yachiyo Engineering Co., Ltd.
Fumiaki YOSHIKAWA (Mr.)	Tender Evaluation for Coastal Faiclities	Yachiyo Engineering Co., Ltd.
Osamu SASE (Mr.)	Natural Condition	OPC
Takashi SATOU (Mr.)	Environmental Assessment	METOCEAN ENVIRONMENT INC.
Ichiro KANO (Mr.)	Economic and Financial Analysis	Engineering and Consulting Firms Association, Japan (ECFA)
Tatsuya KOBAYASHI (Mr.)	Preparation of Tender Documents/Power Distribution Design	Yachiyo Engineering Co., Ltd.
Yoshiaki KOBAYASHI (Mr.)	Community/Social Condition-2/Coordinator-1	Yachiyo Engineering Co., Ltd.
Yoshinobu MATSUO (Mr.)	Coordinator/Public Facility-3	Yachiyo Engineering Co., Ltd.
Nobuaki TACHIBANA (Mr.)	Coordinator-3	Yachiyo Engineering Co., Ltd.
Yoriko KAWAZOE (Ms.)	Coordinator-4	Yachiyo Engineering Co., Ltd.