BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR CONSTRUCTING BREAKWATERS
ON
SOUTHERN COAST OF MALE'
IN
THE REPUBLIC OF MALDIVES

NOVEMBER, 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Maldives, the Government of Japan has decided to conduct a basic design study on the Project for Constructing Breakwaters on Southern Coast of Male' and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Maldives a study team headed by Dr. Takaaki Uda, Head, Coastal Engineering Division, Public Works Research Institute, Ministry of Construction from July 30 to August 21, 1987.

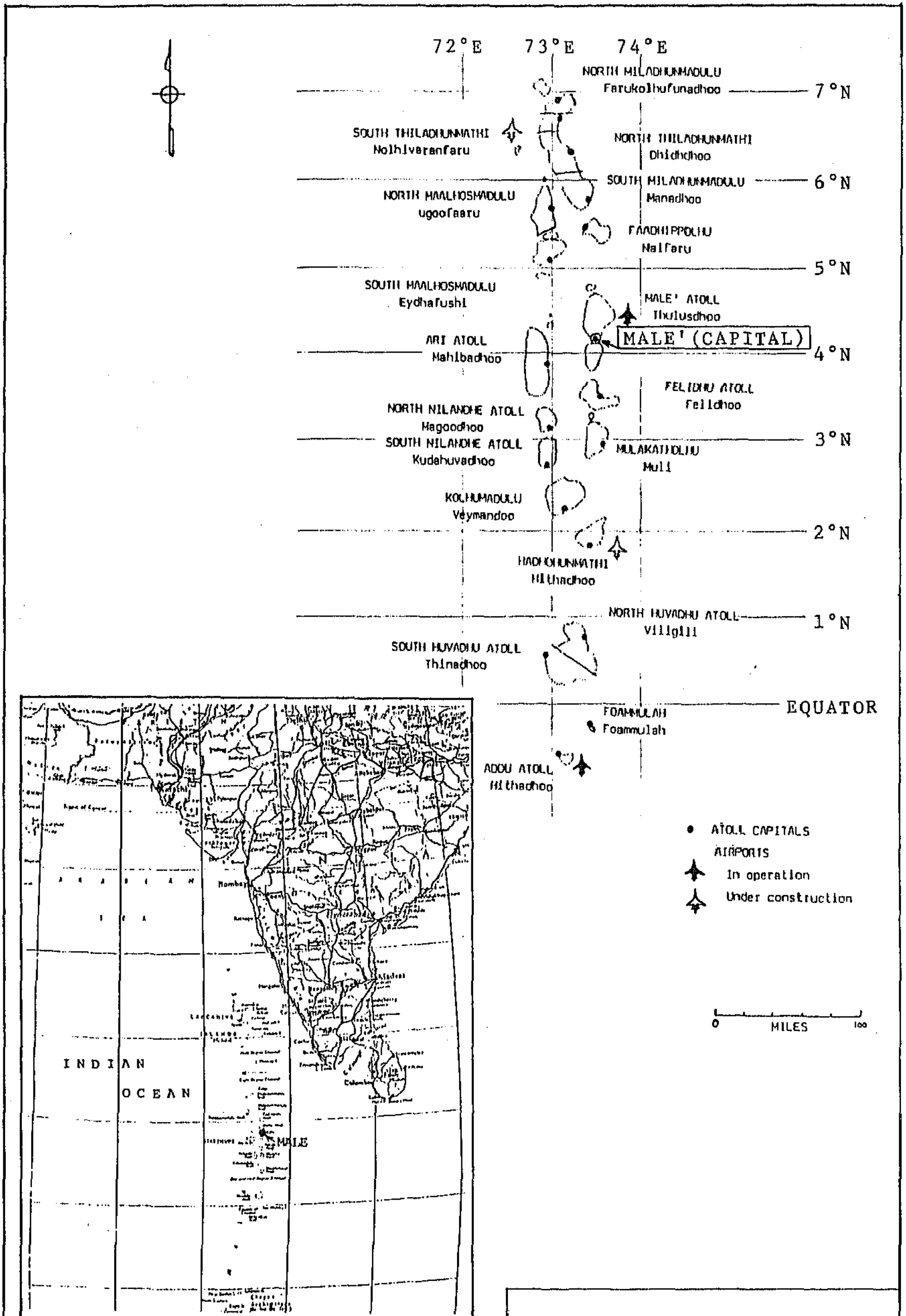
The team had discussions on the Project with the officials concerned of the Government of Maldives and conducted a field survey in the Project area. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Maldives for their close cooperation extended to the team.

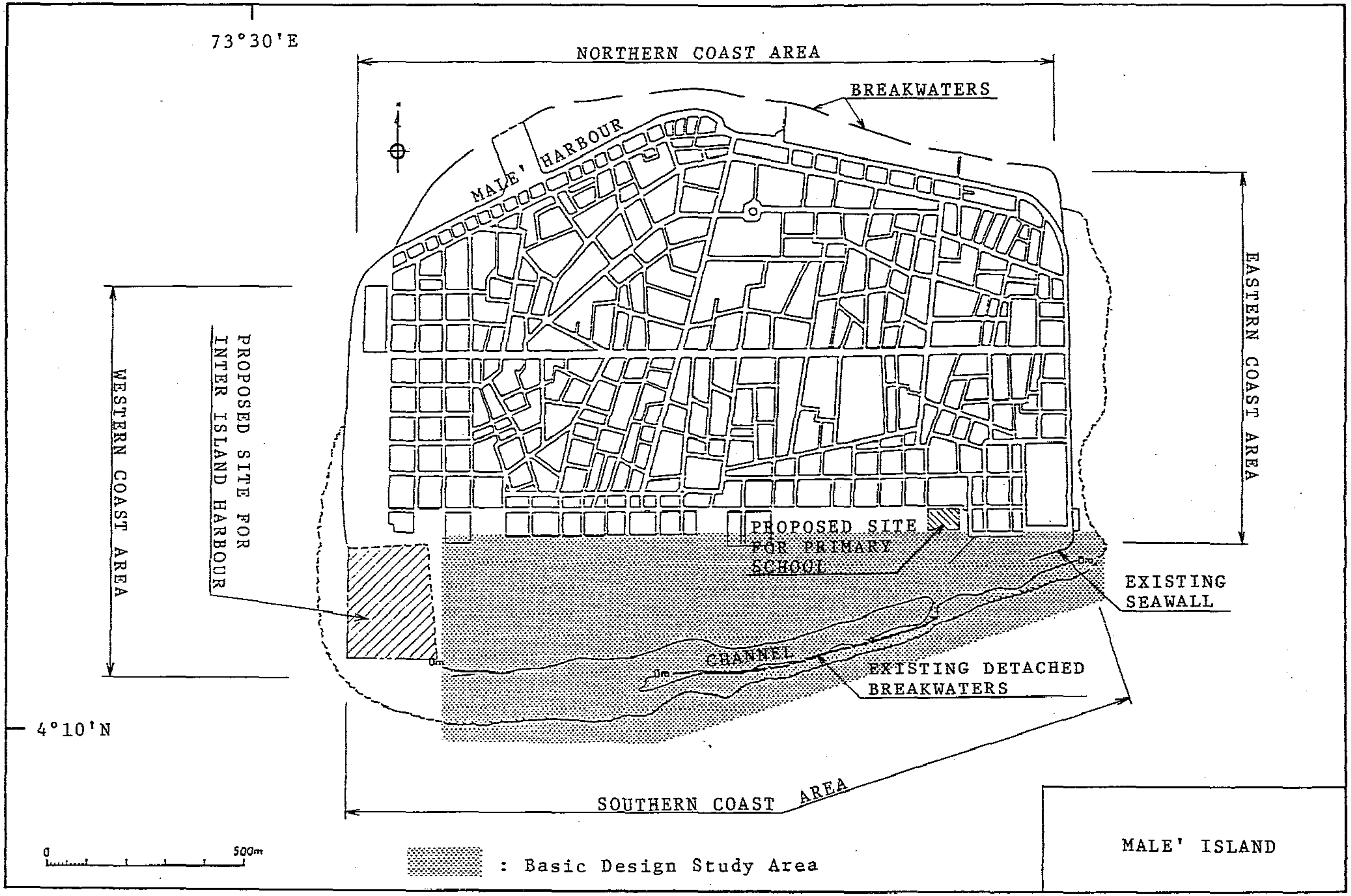
Novemeber, 1987

Keisuke ARITA
President
Japan International Cooperation Agency



THE WEST COAST OF INDIA DISTRICT

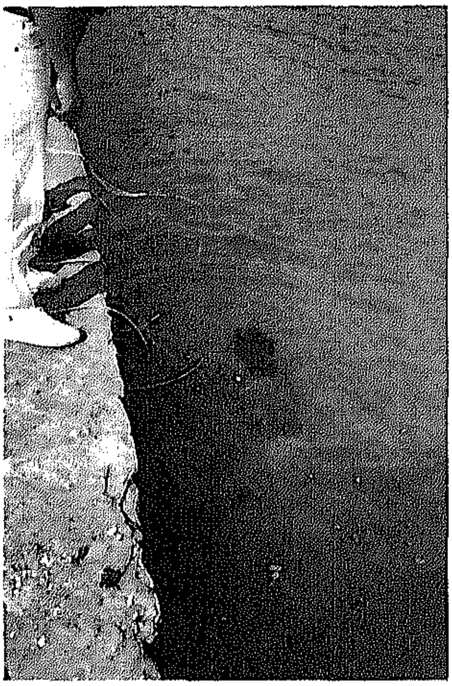
THE MALDIVES


73°30'E
NORTHERN COAST AREA
BREAKWATERS
MALE' HARBOUR
EASTERN COAST AREA
WESTERN COAST AREA
PROPOSED SITE FOR
INTER ISLAND HARBOUR
PROPOSED SITE
FOR PRIMARY
SCHOOL
EXISTING
SEAWALL
CHANNEL
EXISTING DETACHED
BREAKWATERS
4°10'N
SOUTHERN COAST AREA
0
500m
: Basic Design Study Area
MALE' ISLAND

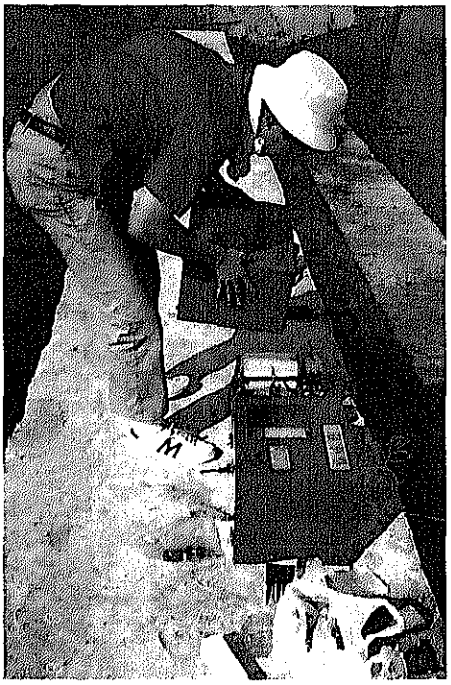
Panoramic View of Male' Island

Eroded Zone of Reclaimed Land on the Southern Coast
(Zone requiring the Construction of Detached Breakwaters with top priority)

Existing Detached Breakwaters made of Coral Rocks on the Southern Coast

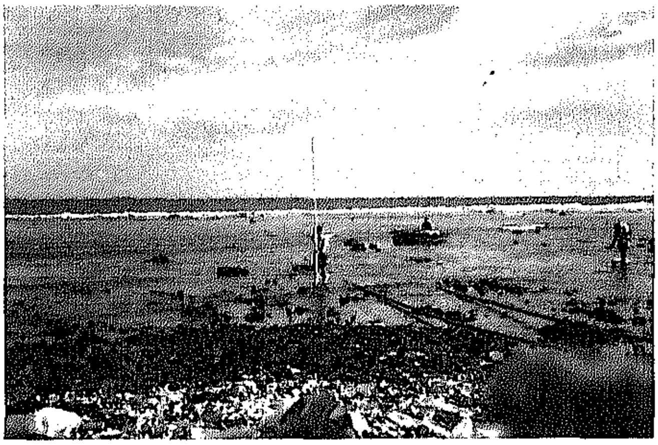


Installation of Pressure Sensor

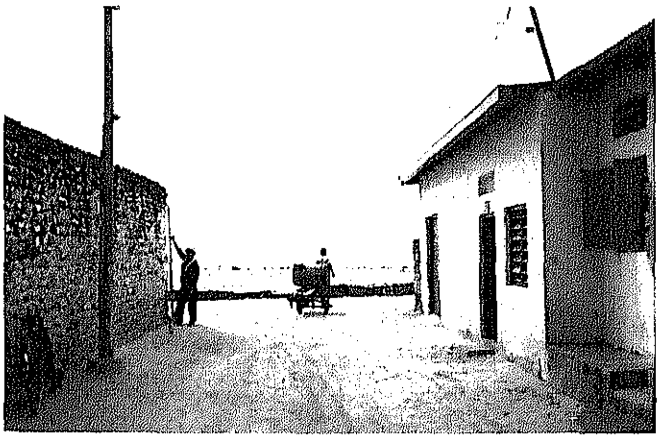


Installation of Tide Gauge

Trade Survey



Shoreline Survey and Sounding



Breaker Height Survey (1/2)

Breaker Height Survey (2/2)

SUMMARY

SUMMARY

Along with the rapid increase in population and the development of industries on Male' Island, the capital of the Republic of Maldives, the demand for land therein has increased year after year and it has become essential for the government to secure it.

The Male' Land Reclamation Project was thus started on the southern coast of Male' in 1979, and a total of about one million sq. meters of land have been reclaimed. However, the present shore protection facilities only consist of a few deteriorated seawalls and simple detached breakwaters piled up with coral rocks which do not constitute safe and durable shore protection. Consequently, a large portion of the eastern area on the southern coast was deeply eroded as a result of the high tidal waves that occurred in April 1987. Presently, the reclaimed area is only about 25 to 30m wide from the shoreline, and residential areas are exposed to very dangerous conditions. In those areas, several important projects such as construction of the primary school, power station and houses are being promoted rapidly, and immediate countermeasures are required for the shore protection.

Immediately after the disastrous high tidal waves mentioned above, the Government of Japan dispatched a team of Japanese experts on coastal engineering to the Maldives and conducted disaster investigation and relief activities in response to Maldives' request. The team of experts submitted their recommendations to the Government of Maldives on the necessity of the urgent construction of shore protection facilities on the southern coast of Male'.

Under these circumstances the Government of Maldives requested the Government of Japan to provide Grant Aid for the Project of constructing breakwaters on the southern coast of Male'.

In response to this request, the Government of Japan decided to send a basic design study team to the Maldives through the Japan International Cooperation Agency (JICA) from 30th July 1987 to 21st August 1987.

The team had a series of discussions with the Maldivian authorities concerned, and conducted various investigations including field survey. After returning to Japan, the study team compiled the optimum basic design for the Project based upon the results of the study and investigations.

The basic schemes for the Project of constructing breakwaters are as follows:

(1) The construction area of the Project shall cover 1.52 km on the southern coast of Male' from the eastern edge to the proposed inter-island harbour project site on the western edge.

(2) The Project will be planned so as to comply with the Development Proposals for Male' Reclamation prepared by the Government of Maldives.

(3) The shore protection facilities will be set up on the reef.

(4) The location of the shore protection facilities will be determined by topography, distance from the reef edge, water depth, wave breaking points, the development proposals for Male' reclamation, erosion conditions of reclaimed land, utilization of existing detached breakwaters, navigation route plans along the inland side of the existing breakwaters as well as the effect of the constructed shore protection facilities, safety and ease of construction, the cost of the Project, etc.

(5) The shore protection facilities shall be detached breakwaters with openings.

(6) The detached breakwaters shall be permeable ones comprised of concrete armour units and coral rocks.

(7) The first priority construction zone of the detached breakwaters shall be the front area of the proposed primary school construction site and the reclaimed area where is eroded landward widely and deeply by the high tidal waves of April 1987.

The outline of the construction of the shore protection facilities is summarized as follows:

Relevant project area	Front area of reclaimed land on the southern coast of Male'
Design length of shore protection facilities	1,520m
Type of protection facilities	Permeable detached breakwaters with openings
Composition and dimensions	Detached breakwaters comprised of concrete armour units and coral rocks Crest length 100m x Crest width 4.7m x Height 4m x 2 sets Crest length 120m x Crest width 4.7m x Height 4m x 8 sets

The costs for the Project to be borne by the Maldives side will be the following items, roughly estimated at 35,000 Maldives Rufiyaa (540,000 Japanese yen).

- To provide accessible roads to the Project site both from the main road and from the construction liaison office

- To provide facilities for the distribution of electricity, telephone and other incidental facilities to the temporary office

The agency responsible for the execution of the Project in the Maldives is the Department of Public Works and Labour (DPWL).

The DPWL will ensure the smooth progress of all works for the Project through close communication and coordination with the Japanese consultant and construction contractor.

The construction work will be divided into three phases. The outline of the construction work in each phase shall be as described below.

(1) Phase I

Construction of detached breakwaters made of concrete armour units (crest length 100m x 2 sets)

(2) Phase II

Construction of detached breakwaters made of concrete armour units and coral rocks (crest length 120m x 2 sets) and of detached breakwaters made of concrete armour units (crest length 120m x 1 set and crest length 70m out of 120m 1 set)

(3) Phase III

Construction of detached breakwaters comprised of concrete armour units and coral rocks (crest length 120m x 2 sets) and of detached breakwaters made of concrete armour units (crest length 120m x 1 set and crest length 50m out of 120m 1 set)

The construction period, including the detailed design and tendering periods after the Exchange of Notes, will be the following:

Phase I :	10.0 months
Phase II :	11.5 months
Phase III :	13.0 months
Total	34.5 months

The DPWL shall be responsible for acquiring land and securing accessible roads for construction, including land for the temporary material storage yard. Installation of power distribution facilities, telephone lines and other incidental facilities to the temporary office are also to be undertaken by the DPWL and shall be finished by the specified deadline.

The implementation of the Project will make it possible to enhance the security of reclaimed land and urban facilities in the southern coast area of Male'. It will also contribute to the promotion of a stable national development and it will protect the life and property of the citizen in Male'. Furthermore, its implementation will increase employment opportunities other than secure safeness of Male' island.

It is obvious that this Project will benefit the people of the Maldives and it is quite appropriate to implement it under the grant aid scheme of the Japanese Government.

PREFACE

LOCATION MAP

PHOTOGRAPHS

SUMMARY

CONTENTS

APPENDIX

LIST OF BASIC DESIGN DRAWINGS

LIST OF FIGURES AND TABLES

ABBREVIATIONS

ADB	Asian Development Bank
BM	Bench Mark
DL	Datum Level
DPWL	Department of Public Works and Labour
EEC	European Economic Community
E/N	Exchange of Notes
FAO	Food and Agriculture Draganization
FEP	Flexible Electric Pipe
GDP	Gross Domestic Product
GNP	Gross National Product
HHWL	Highest High Water Level
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standard
JOCV	Japan Overseas Cooperation Volunteers
KFW	Kreditanscalr Für Wlederardau
MEB	Maldives Electricity Board
MPD	Ministry of Planning and Development
MSL	Mean Sea Level
OPPD	Office for Physical Planning and Design
PERT	Program Evaluation and Review Technique
PVC	Poly-vinyl Chloride
ROM	Republic of Maldives
SFD	Saudi Fund for Development
UNCDF	United Nations Capital Development Fund

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

It is a primary feature of the archipelagic countries that they form their nations by integrating many of the isolated islands. Because of the scattered nature of the islands, its political and economic functions are inevitably concentrated in the main island. This situation often accelerates overpopulation in the main island and depopulation in others.

The Republic of Maldives shares such characteristics. In spite of the government's efforts to reduce migration from isolated islands or atolls to Male', the capital of the Maldives, it has become overpopulated due to the inflow of people searching for employment and high grade education and due to the natural growth of the population.

The country has consequently directed its efforts, since 1979, towards the acquisition of land for housing, schools, the power station, port facilities etc. by reclaiming reefs on the southern coast of Male'.

One of the existing shore protection facilities in the southern coast area of Male' is a heavily deteriorated old seawall about 100m long and 1.5m to 2.0m high, made of coral stones with cement mortar in the eastern edge area. The other is a detached breakwater 2m to 3m high, about 600m long toward the west from the point of 500m to 600m west from the east edge. This detached breakwater is made of coral rock of 0.[illegible] t to 3.0t per piece obtained by blasting coral reef rock foundations in shallow area of the reef and is piled up seaward.

Both of these shore protection facilities were damaged by the high tidal waves and piled coral rocks have been scattered. Other than these facilities, there are no shore protection facilities on the southern coast.

The reclaimed land is almost at sea level and, nearly flat, so that it is quite vulnerable to high tidal waves.

In April 1987, a high tidal wave swept the country. Because of the present situation of shore protection mentioned above, a wide range of the reclaimed land on the southern coast of Male' was eroded and the seawalls, housing and various other public facilities were seriously damaged. The construction sites of important facilities, such as the primary school and the power station, were inundated for several days.

Considering the protection of the life and property of Male' citizen, the preservation of the capital city functions, the promotion of stable urban development programmes and other requirements, the existing shore protection facilities in the southern coast area seem to be extremely insufficient in terms of both scale and quality. Under these circumstances, implementation of the Project is of urgent necessity. Ever since the disaster caused by unusual high tidal waves of April 1987, the construction of shore protection facilities in this area has been raised by the Government as the most urgent project. Furthermore, the international emergency aid teams which were dispatched from Japan and the Netherlands, respectively, had recommended to the Maldivian authorities that full-scale shore protection facilities should be constructed as early as possible.

Having such a background, the Government of Maldives submitted a request to the Government of Japan for the provision of grant aid for the construction of the shore protection facilities of Male'.

The Government of Japan reviewed the request and decided to execute a basic design study of the proposed Project. Based on this decision, the Japan International Cooperation Agency dispatched a basic design study team (Refer to APPENDIX II) headed by Dr. Takaaki Uda, Head, Coastal Engineering Division, Public Works Research Institute, Ministry of Construction, to the Maldives from 30th July 1987 to 21st August 1987.

The objectives of this study were to clarify the present situation of the shore protection facilities and study the propriety and effect of the aid for the construction of shore protection facilities on the southern coast of Male'.

The actual studies executed at Male' were tide level observation, surveying, sounding and levelling in the Project area, trace survey, breaker height survey and so forth.

The study team executed such field investigations while holding a series of discussions with the Maldivian authorities concerned on the background, objectives and other matters of the request. The Minutes of Discussion have been attached as the results of discussions (APPENDIX I).

After returning to Japan, the study team prepared the Basic Design Study Report on the Project of Constructing Breakwaters on Southern Coast of Male' based on the present conditions of reclaimed land and existing shore protection facilities, maintenance and management of the facilities and relation to other development projects as well as the propriety, contents and extent of this Project.

CHAPTER 2

BACKGROUND OF THE PROJECT

CHAPTER 2 BACKGROUND OF THE PROJECT

2-1 Present Shore Protection Conditions and its Administration

2-1-1 Conditions and Problems of Present Shore Protection Facilities

The existing shore protection throughout Male' island have been heavily deteriorated with the exception of a part of the quay wall of Male' Harbour on the northern side, which was constructed in recent years. The current situation and problems are as described below:

(1) Southern coast area

- There exists an old seawall of about 100m consisting of coral stones with cement mortar in the eastern edge area but there are no other protection facilities in the other area.

- Both ends of the above seawall were damaged due to high tidal waves, and the damage seems to be expanding year after year.

- Moreover, the height of seawall from the foundation bed is only about 1.5m to 2.0m and waves would overtop the seawall easily in times of rough weather.

- Although there are existing breakwaters of a height of about 2m to 3m from the foundation bed made of coral rocks of about 0.5t to 3.0t in weight per piece over an extension of about 600m towards the west side from the position of about 500m to 600m from the eastern edge section, there is no such breakwater in the other areas.

Meanwhile, the above detached breakwater is located some 30m to 50m offshore.

- Although the existing detached breakwaters have a substantial wavebreaking effect, they have been impaired as rocks are scattering. The breakwaters in the east side have been damaged extensively. Thus, it would be difficult to maintain the durability of the breakwaters over a long period.

(2) Eastern coast area

- There is an old seawall with a crest width of 1.5m and a height from foundation bed of about 1.5m made of coral stones with cement mortar and covered with concrete about 5cm to 10cm thick.

- As the concrete cover and base section of the seawall have been considerably damaged, there are serious problems in its durability and safety.

(3) Western coast area

- The shore protection structure, excluding that in the harbour area, is roughly in the same situation as those on the eastern coast, and surface concrete covering have been partially damaged.

- The base section of the seawall has been particularly damaged which brings about a problem concerning durability and safety.

(4) Northern coast area

- The majority of the shore protection structure along the Marine Drive in front of the President's Office, Ministry of Foreign Affairs and other governmental and private offices are comprised of quay wall which is made up of coral stones covered with concrete. Front water depth is of about 0.5m to 1.5m. This quay wall also has been damaged at its base section over a considerably long span.

- Adjacent to the reef edge in front of the existing quay wall, there are breakwaters with a crest width of about 1.5m and a height from the bed of about 3m to 4m. These were constructed by piling up coral stones and covering the surface with concrete. However, these breakwaters have deteriorated and been substantially damaged. Breakwaters which have been so damaged that their original form is hardly retained extend over several ten meters, especially near the west coast. It has a serious problem in its durability and safety.

2-1-2 Shore Protection Project and Foreign Aid

(1) Shore protection project

The maintenance and management of the shore protection facilities are undertaken by the DPWL. The position of the DPWL in the overall organization of the Government of Maldives is shown in Fig. 2-1.

Presently, however, any systematic maintenance and management of shore protection facilities have not been done except for easy repair of the seawall crest.

In addition, any future shore protection plan has not been concretely worked out.

ORGANISATION STRUCTURE – GOVERNMENT OF THE REPUBLIC OF MALDIVES

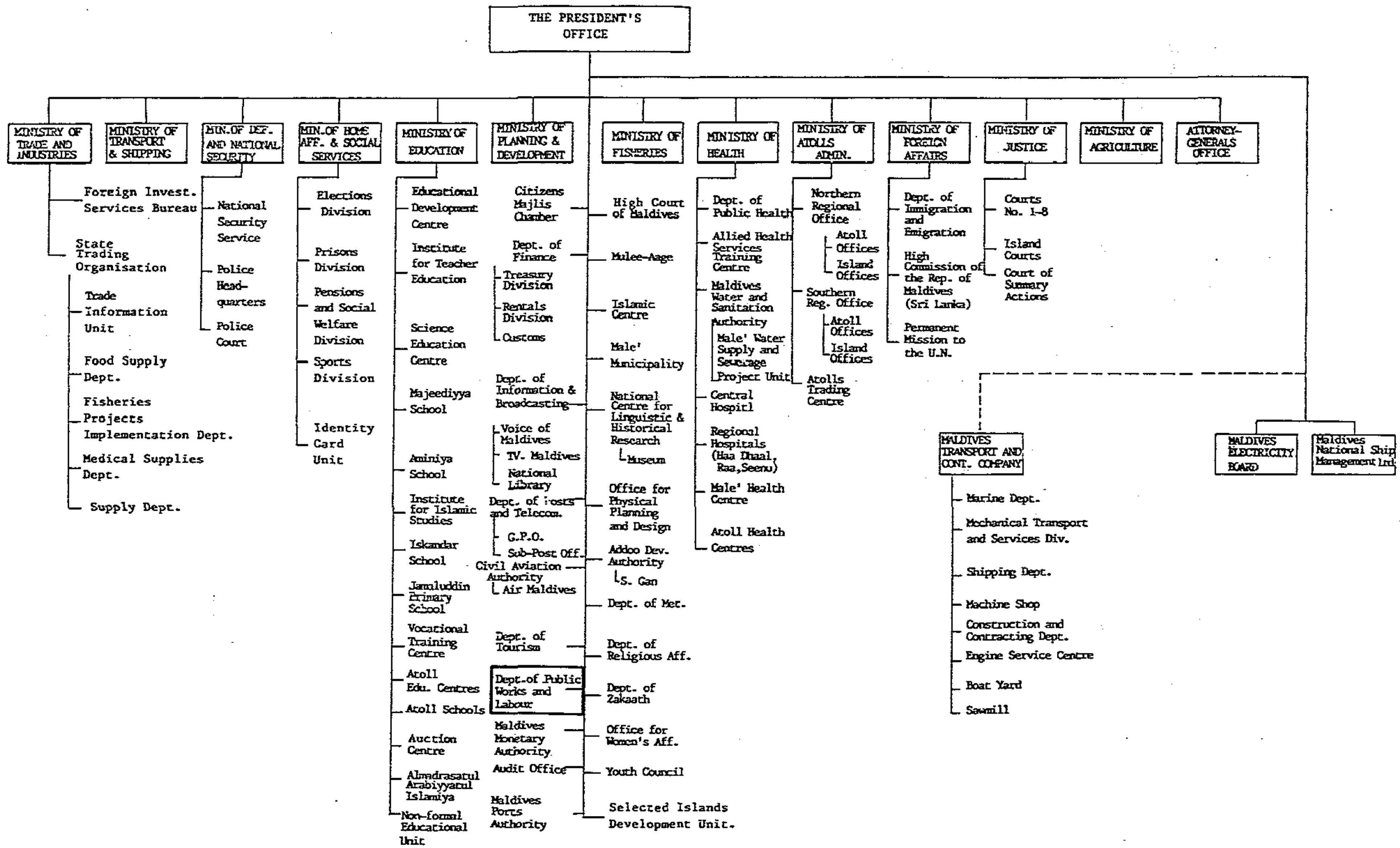


Fig. 2-1 Organization structure of the Government of Maldives and the Position of DPWL.

(2) Foreign aid

No foreign aid for shore protection has materialized until now.
With regard to the disaster caused by the high tidal waves of April 1987, however, assistance has been offered by several foreign countries as listed below.

a) Dispatch of a Japanese team of experts on tidal wave disaster assessment at Male' and Airport Island (Have already submitted a report)

b) Dispatch of a Dutch team of experts on the disaster at Male' and Airport Island (Have already submitted a report)

c) Dispatch of experts under FAO Fund

d) Dispatch of Indian experts to assess the damages on Airport Island

e) Dispatch of British experts to assess the damages on Airport Island

2-2 Outline of Related Development Plans

2-2-1 National Development Plan

In order to formulate a coherent strategy for the purpose of promoting economic and social development throughout the Maldives, the Gayoom administration established the National Planning Agency in 1978.

In 1982, the agency was renamed the Ministry of Planning and Development and prepared the Three-Year National Development Plan for 1985 - 1987, the first integrated development plan for the Maldives.

The plan is in two volumes. Volume 1 of the plan consists of two parts. Part I deals with the macro-aspects of economic and social development and Part II covers the outlook for sectorial development in detail. Volume 2 provides the details of development projects for implementation over three years from 1985 through 1987. The following long term objectives and policies of priority are described in this development plan.

Long Term Objectives

1. To improve the living standards of the people
2. To balance population density and economic and social progress between Male' and the atolls
3. To attain greater self-reliance for future growth

Priorities

1. To increase the national product and particularly foreign exchange earnings
2. To improve health and sanitary conditions
3. To achieve uniformity and upgrade education and training levels
4. To accelerate the integrated development of atolls
5. To relieve Male' of its congestion in terms of population and economic activity
6. To prevent damage to the national environment

2-2-2 Outline of Related Projects and Relationship with the Project

(1) Development Proposals for Male' Reclamation

For the purpose of securing land for the construction of the school, hospital, power station, harbour and other public facilities, the reclamation project in the southern coast area of Male' was started in 1979, and completed a reclaimed area of about one million square meter obtained by mainly using soil, sand, etc. which came from the Male' inner harbour extension work in the northern coast area.

Under instruction from the President's Office, the OPPD prepared the Development Proposals for Male' Reclamation (refer to Fig. 2-2). On the basis of these development proposals, relevant government agencies of the Maldives are promoting the various projects.

(2) Construction project for Inter-Island and Fisheries Vessel Basin

The construction of a harbour with the following objectives on the southwestern coast of Male' is projected, using financial assistance from the UNCDF since 1986:

- To provide an alternative inter-island fisheries vessel basin in order to accommodate the future expansion of the commercial harbour.
- To facilitate inter-island trade.
- To provide better landing facilities for the fishermen in Male'.

At present, the plan for this project is being worked out subsequent to the completion of sounding.

Since the site of this project is located close to the Project site and both projects aim to construct coastal facilities, it is necessary to be coordinated mutually. During the field survey period, the study team was certified by the Maldivian authorities concerned that the site of the harbour construction project would overlap with that of the Project. Since the Project is scheduled to be executed before the harbour construction project, coordination between both projects shall be ensured by reflecting the contents of this Basic Design Study Report onto the harbour construction design by the Government of Maldives.

(3) Male' garbage disposal scheme

This project is intended for the construction of garbage disposal and treatment facilities for the following objectives on the coral reef at the eastern edge of the southern coast of Male':

- To collect and dispose garbage in Male'.

- To maintain Male' - the capital in terms of cleanliness.

- To reprocess garbage and waste collected on a large scale for the production of compost, fish-meal, poultry feed, etc.

Since the outlook for securing overseas financial assistance is not clear, this project has not yet materialized.

The site of the garbage disposal and treatment facilities is planned close to the reef edge within the Project site and it is not feasible to construct such facilities, judging from the coastal engineering point of view. Therefore, it will be proposed to the relevant authorities that the construction site should be changed based upon the basic design study results for the Project.

(4) Male' new power station construction project

In order to meet the rapidly growing demand for electric power on Male' until 1991/1992, this project is intended for the construction of a 4MW diesel power station (2 x 2MW) based on a loan from the ADB on reclaimed land at the eastern edge of the southern coast of Male'. Under this project, a power transmission and a distribution network is also scheduled to be improved.

Currently, negotiations are under way for a loan agreement with the ADB. This project's design is due to be started at the end of 1987 and its construction at the end of 1988. Since the construction site of this power station is located in an area susceptible to the high tidal waves, it will be proposed to the relevant authorities to change its location slightly based on the basic design study results for the Project.

(5) Male' water supply and sewerage project

On the basis of the economic assistance from the KFW, the EEC and the SFD, this project is intended for the construction of potable water supply and sanitary sewage networks and facilities in order to secure an adequate supply of potable water, thereby preventing contagious diseases and reducing infant mortality.

At present, sewer drainage facilities are under construction and scheduled for completion in May 1988, with roughly 60% of the work already completed.

The construction work of the drainage system on the reclaimed land in the eastern part of the southern coast within the

Project area is executed based on the development proposals for Male' reclamation in item (1) above. In the case of the drainage system in the area where erosion of land was caused by the high tidal waves, however, the detailed design of the drainage network shall be carried out by the Government of Maldives based on the reclamation limit presented in this Basic Design Study Report. This is to ensure coordination of such facilities with the Project.

(6) Sea water desalination project

On the basis of grant aid assistance from Denmark, this project is intended for the construction of a 1,000t/day and a 200t/day sea water desalination plants. The 1,000t/day plant is designed to desalinate sea water through the effective utilization of waste heat from the proposed new power station in Item (4) above. In consideration of the fact that the intake pipes to this plant could interfere with the proposed detached breakwaters and the Project is scheduled to be started prior to the commencement of the desalination project, coordination of this project with the Project shall be ensured by reflecting the contents of this Basic Design Study Report into the plant design.

2-3 Course of the Progress and Contents of the Request

From the 10th through to the 15th of April 1987, an unusual high tidal waves swept the islands throughout the Maldives and caused damages to houses, airport facilities, various other facilities and the loss of seawall. Particularly seriously damaged was the southern coast of Male', the capital city, where the population and urban facilities are concentrated. The washing away of about 360,000 m^3 of soil from the large scale reclamation works by the DPWL severely hampered the promotion of the development project of the Maldives.

Still more, Hulule Island, the airport island, also suffered substantial damage and the total amount of damages throughout the country is reported to have exceeded US$6 million.

In response to the request of the Government of Maldives, the Government of Japan dispatched a Japanese expert team for tidal wave disaster assessment to the country from 24th April through to 2nd May 1987 and the team executed a field survey of the disaster conditions, provided medical relief and so forth. On this occasion, the team of experts recommended to the Government of Maldives that full-scale shore protection should be urgently promoted on the southern coast of Male'.

Under such a background, the Government of Maldives requested the Government of Japan to provide grant aid for the construction of shore protection facilities on the southern coast of Male'.

In response to the request, the Government of Japan decided to examine the said request, and the Japan International Cooperation Agency (JICA) sent a Basic Design Study Team headed by Dr. Takaaki Uda, Head, Coastal Engineering Division, Public Works Research Institute, Ministry of Construction to the Maldives, Sri Lanka and Singapore from 30th July through 21st August, 1987.

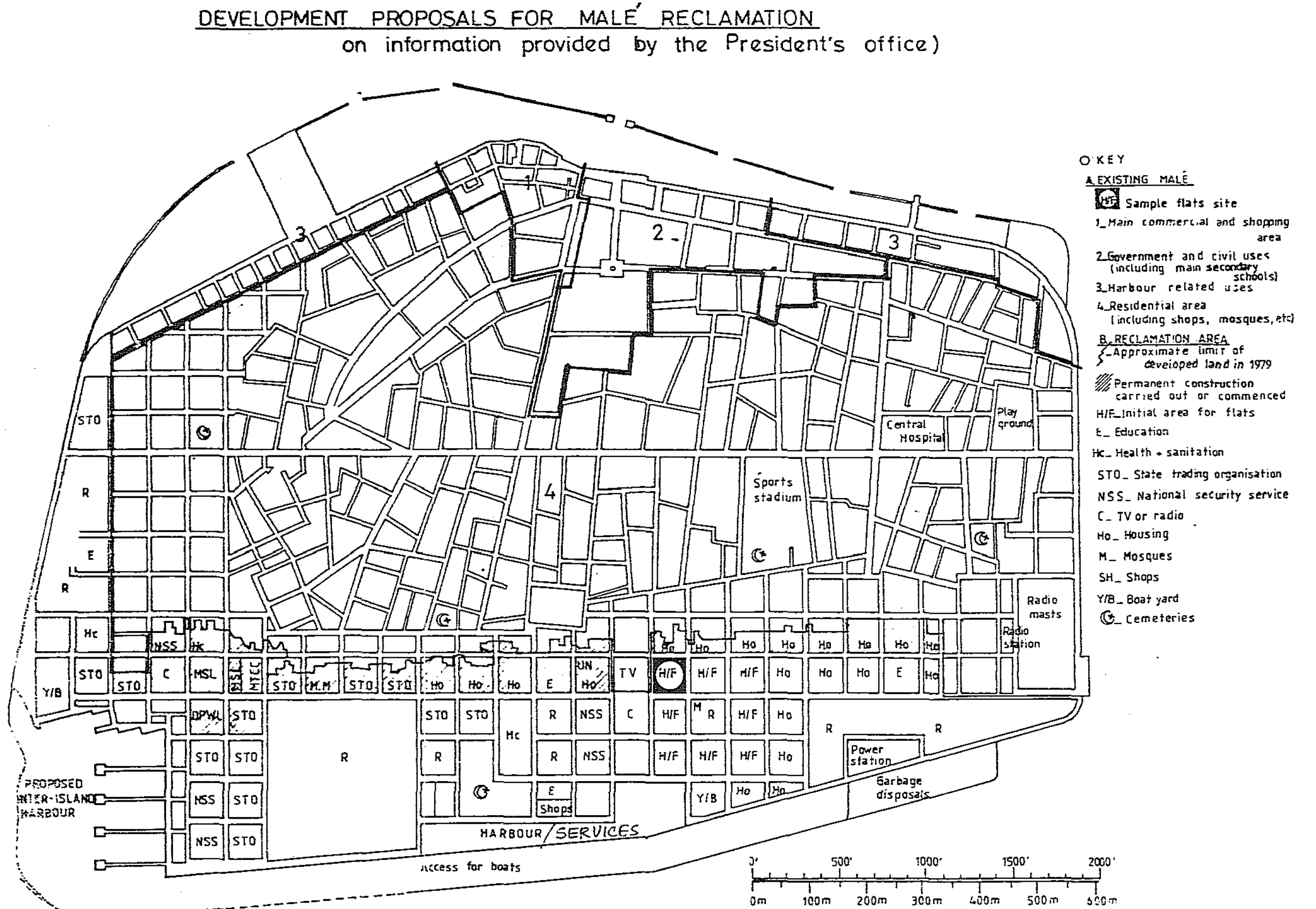


Fig. 2-2 Development proposals for Male' reclamation.

CHAPTER 3

OUTLINE OF THE PROJECT SITE

CHAPTER 3 OUTLINE OF THE PROJECT SITE

3-1 General Conditions

The Republic of Maldives is an archipelagic country comprised of about 1,200 coral islands forming 19 atolls spreading over a sea area of about 90,000 km^2 stretching over 120km in an east - west direction and 750km in a north - south direction in the central part of the Northern Indian Ocean.

According to the announcement of the Maldives, the total land area of the country is 298 km^2 and the number of inhabited and uninhabited islands are 202 and 987, respectively. The country's islands are generally flat and there are few islands where land rises over 2.5m above the sea level. The coral reefs surrounding each island form a natural protection against the action of waves.

Male' Island, where the capital bearing the same name is located, has the largest population in the country. It is located on the southern edge of the North Male' atoll with its size being about 1.6km long and about 1.2km large.

The total population in 1986 was estimated at 191,993 and 50,462 persons, corresponding to about 25% of the entire population, are concentrated on Male', which is the political and economic center of the country. From 1977 to 1985, the annual average growth rate of population on Male' Island reached 6.25% in total, At present, those visiting the capital for temporary stay from other atolls are registered at the Male' Municipality, and, according to the forecast of MPD, the annual average rate of increase of the population is estimated to decrease gradually from 4.2% to 2.1%.

The Maldive Islands became independent in July 1965 after the end of the British protectorate and immediately became the 114th member nation of the United Nations in September 1965. Subsequently, in 1968, a plebiscite was executed, and the country became the Republic of Maldives with the abolishing of the sultanate system after obtaining a concensus of over 80%.

With regard to the economic situation, GDP was 683 million Rufiyaa (US$96.2 million), corresponding to US$530 per capita in 1985.

The industrial structure is comprised of three major industries, namely, fishery, tourism and shipping, as well as other agricultural, traditional and modern industries. In 1985, the fishery industry shared 24% of GDP, 36% of total employment and as much as 68% of total exports. In 1985, the tourism industry occupied 16% of GDP and recorded 22% of total tax revenues. The annual number of tourists was 114,600 and the number of Japanese tourists has been increasing in recent years. The shipping industry is exerting a significant effect upon the Maldivian economy, judging from the fact that the industry is exporting an amount equivalent to 24% of GDP. On the other hand, the agricultural industry shares only 10% of GDP because of the lack of arable land and high alkalinity of the soil. Traditional industries are mainly comprised of boatbuilding and handicraft, while modern industries include those producing food and beverage, tuna canneries, mica fabrication, weaving and sawing, PVC plants and so forth. As can be recognized from the above, the Maldivian economy and its industrial structure is highly susceptible to the fluctuation of the international market because of its nature of the three largest industries.

Financially speaking according to the records of 1985, the annual revenue is equivalent to 20% of GNP, out of which 44% originates from government enterprises and income from property and 56% is the tax revenue. Annual expenditure is equivalent to 29% of GNP. The amount exceeding the internal revenue among the annual revenue is replenished by external financial resources.

3-2 Natural Conditions

3-2-1 Geological Features

(1) General

Geologically, the Maldive Islands are classified as coral reef islands.

According to existing data, the inland section of Male' Island consists of filling, conglomerate-containing sand, fine sand, organic silt, weathered reef coral and coral rock. The groundwater level is located 0.6m to 1.0m below the average surface level, and stays in a lens form inherent to coral reef islands while keeping the balance between the amount of rain water permeating into the ground, the amount of sea water advancing from the surrounding coast and that of pumped up water.

The contractor executing the sewerage construction work is using this underground water as water for construction. However, this underground water tends to become slightly insufficient because of recent small rainfall.

The amount of water required for construction, namely, for the mixing of concrete and the curing of concrete armour units and for other purposes under the Project, is roughly estimated to reach 6,500m^3 to 7,000m^3 during a period of about twenty-two months. Should such underground water be used for construction work under the Project, the balance of demand and supply will be biased on the demand side, thereby causing a major effect upon the life of the residents due to the progress of ground water salination and serious environmental disruption. Consequently, a simple sea water desalination plant shall be installed to ensure the supply of construction water for the Project.

Meanwhile, the elevation of the ground in the southern coast reclamation area is some 0.7m to 1.0m above the average sea level according to the results of levelling and tide level observation.

(2) Evaluation of the coral limestone as the bearing foundation bed in the proposed detached breakwater construction area

The proposed detached breakwater construction site is located on the reef some 30m to 50m landward from the reef edge and coral rock is exposed adjacent thereto.

The existing detached breakwaters were constructed by piling up crushed coral rock obtained by blasting coral limestone reefs. As a result of tests on the limestone samples brought back to Japan, the unconfined compressive strength and the unit weight were found to be 318 to 482 kg/cm^2 and 2.28 to 2.41 g/cm^3, respectively.
The excavated depth was about 4m to 6m, and it is thought that there is such coral rock down to the excavation bottom according to the results of visual observation.

Therefore, the coral limestone forming the foundation bed for the detached breakwaters is deemed to be considerably thick. When the overburden pressure of detached breakwaters is deemed to be as small as roughly 5t per square meter, this limestone is evaluated to have sufficient strength as foundation bed and to fully withstand the erosion or scouring by the waves.

3-2-2 Meteorological Features

The Maldive islands are located in a tropical climate zone and the temperature and humidity are high. The year is divided into two monsoon seasons. May through October is the southwest monsoon season and rainfall is heavy, while the season from December through March is the northeast monsoon season and rainfall is slight. The annual precipitation is about 2,000mm.

The lowest and highest temperatures are average 25°C and 32°C and the yearly temperature difference is small. The annual mean humidity is as high as 79 to 86%.

Presented hereunder are atmospheric temperatures, wind velocity and rainfall in Male' for the past two decades from 1967 to 1986.

	Temperature (°) Highest	Lowest	Wind velocity (knots)	Rainfall (mm)
Jan.	29.7	25.5	10.4	65.9
Feb.	30.1	25.7	8.7	57.6
Mar.	30.9	26.0	7.0	88.8
Apr.	31.4	26.4	7.7	125.5
May	30.9	26.3	10.3	228.1
June	30.5	25.9	10.0	157.2
July	30.4	25.7	9.6	170.1
Aug.	30.1	25.6	9.0	191.6
Sep.	30.0	25.3	10.5	230.3
Oct.	30.0	25.3	9.8	227.8
Nov.	30.0	25.3	8.8	199.3
Dec.	29.7	25.2	9.4	221.8
Average	29.5	25.7	9.3	163.7

Source: Meteorological data, 1966 - 1988
National Meteorological Centre
Department of Meteorology, Male',
Republic of Maldives

3-2-3 Oceanic Features

(1) Ocean currents and tidal currents

According to existing data, the flow of sea water around Male' Island seems to be much more affected by wind than the tidal current.

Within the channel on the eastern side of Male' Island, the ocean current flows in from the Wadu channel onto the southern side. During the northeast monsoon season, the distributary of this ocean current flows toward the northwest after passing through this channel. This ocean current then flows westward between Male' Island and Funadu Island.

According to the results of an observation carried out by a British Survey ship in Feb. 1972, this ocean flow starts one and half hours before the flood tide and continues to flow until one and half hours before the ebb tide. On the northern side of the Male' Island breakwaters, the current reaches its highest velocity of 2.5 to 3 knots during the flood tide. The current then flows along the northern side. During the northeast monsoon season, a strong current was reported near Male' Harbour. During the southwest monsoon season, the distributary of this current flows into the northern Male' lagoon through the channel on the southern side of the islands west of Male' Island. After passing through the channel on the western side of Male' Island and the channel between Male' Island and Funadu Island, the current flows to the south and runs out into the Wadu channel.

(2) Sea level

Based upon an analysis of the tide level records observed by the Basic Design Study Team inside Male' Harbour, the datum level was established to be 0.51m below mean sea level. The highest and lowest sea levels during the tide level observation period were as listed below:

Highest sea level: DL +0.94m
Lowest sea level : DL -0.18m

For further details, refer to APPENDIX VIII.

(3) Waves

The results of field investigation are as summarized below:

1) During the field investigation period, breaking wave height was roughly 1.5m and the period was about 10 to 11 sec.

2) From the results of field investigation by direct questioning, the following items were confirmed:

   a) During the northeast monsoon season, since waves advance mainly from the northeast, the southern coast of Male' Island is comparatively calm.

   b) During the southwest monsoon season, waves become high on the southern coast of Male' Island.

3-3 Infrastructure Condition

3-3-1 Harbour

All exports and imports of goods to and from the Maldives are effected by shipping and are handled in Male' Harbour.

Since there is no quaywall of sufficient draught for the mooring of large-scale ocean vessels in Male' Harbour, only fishing boats, inter-island transport ships, sightseeing boats, coral-taking boats and other small-scale ships can enter the harbour. Under the present situation, only a part of the quaywall, of a length of approximately 1,350m, is available for the repair of small-scale ships, fuel supply and other purposes. Thus, the cargo handling capacity of Male' Harbour is inadequate.

Consequently, ocean vessels are anchored in deeper lagoon outside the coral reef surrounding Male' Harbour and cargoes are carried by tugboats and barges to the island. A comparatively long time and a lot of work is therefore required and it is necessary to improve the handling capacity of Male' Harbour as soon as possible.

A 240ps tugboat, a 165ps tugboat and thirteen 50t to 150t barges are available in the harbour. The maximum lifting capacity of the cargo handling cranes (truck cranes) is 25t.

In anticipation of the future expansion of Male' Harbour and the promotion of inter-island trade, the Government of Maldives established a project for the construction of a harbour on the southwest corner of Male' Island and is developing a plan based upon economic assistance from the UNCDF since 1986.

3-3-2 Roads

Most of the roads within Male' Island are simply covered with coral stones and coral sands, and only parts of the main roads are covered with concrete. Although road width ranges from 3.6m to 10m, the majority of roads are narrow and limited to one-way traffic. They frequently intersect in a complicated manner and traffic of large scale vehicles is substantially limited.

Side ditches and other drainage systems have not been provided along the roads. Uneven road surfaces, as well as the lack of permeability due to the high ground water level and road materials, lead to the formation of puddles here and there on every road after rainfall and road conditions are not favourable.

For transporting the equipment and materials unloaded in Male' Harbour to the Project site, only the road along the harbour and that on the east side of the island are considered to be available. Judging from the conditions of these roads, however, it is considered difficult to transport such equipment and materials through these roads.

The equipment and materials for this construction work will therefore be transported directly to the work site on the southern coast by barges, etc., and a temporary jetty will be constructed for temporary customs clearance and unloading.

The adoption of this method has already been agreed upon with the Government of Maldives.

3-3-3 Electric Power

Responsibility for the supply of electric power to Male' and the international airport located in Hulule island rests with the Maldives Electricity Board (MEB). Namely, electric power is supplied from the 3.2MW diesel power plant on Male' Island and the 1MW diesel power plant for the international airport. On other islands including resort islands, electric power is supplied by private power plants.

Electric power from the thirteen substations on Male' Island is distributed after stepping downtown from 3.3kV to single phase 230V in the case of substations No. 1 to No. 8, while 11kV is distributed after stepped down to three-phase four-lines system 400/230V in the case of substations No. 9 to No. 13. The frequency is 50Hz.

Electric power consumption in Male' grew at an annual average growth rate of 7.7% from 1975 to 1980, and demand for industrial and commercial sectors has been also increasing. Since the capacity of the existing power plants is not sufficient to meet the increase in demand, the use of air conditioning units and other power-consuming equipment is prohibited from 6:30 P.M. to 10:00 P.M. Under such circumstances, the MEB decided to construct a 4MW power plant and to improve power transmission and distribution networks based on economic assistance from the ADB. Meanwhile, the MEB is reportedly preserving a one and half months portion of fuel, 25,000 gallons, required for power generation.

3-3-4 Water Supply and Sewerage Systems

The eradication of epidemics caused by water is an important task for the Maldives and it is of urgent necessity for the country to replenish its water supply and sewerage facilities and ensure a supply of safe potable water. There is no public water supply system in Male' so that rain water is used as potable water and every household is required to install a rainwater catchment facility. For other miscellaneous purposes, underground water is used.

At present, a sewerage and drainage piping network construction project is promoted by a West German contractor on Male' with the finance and local assistances of the KFW, the EEC and the SFD. This project is scheduled to be completed in 1988.

CHAPTER 4

CONTENTS OF THE PROJECT

CHAPTER 4 CONTENTS OF THE PROJECT

4-1 Objectives and Contents

The results of disaster caused by the high tidal waves in April 1987 gives a vivid account of its geographical weakness and susceptibility against those wave attacks.

As described in Clause 2-1, there are serious problems regarding the existing shore protection facilities, and should such facilities be left as they are, it would become difficult to ensure a stable life for the people. This Project is intended to reduce the extent of damages caused by the high tide or waves on Male' and to prevent the spread of epidemics and other secondary disasters. It is also intended to secure not only the life of the people but also the urban functions as the capital of the Maldives, and to support the stable urban development by constructing shore protection facilities on the southern coast of Male', where the functions of the capital city are concentrated.

For a country like the Maldives, where the ground level is geographically low, high tide and waves constitute a serious threat to the important functions of the capital city and to the life and property of the citizens. The Project will greatly contribute to securing the urban functions of Male' and ensuring the protection of the lives and properties of residents as well as enhancing the development of the island and the stabilization of the citizens' life.

4-2 Evaluation of the Request

Although the request from the Government of Maldives covered the construction of shore protection facilities on Male' to reduce the damages caused by such high tidal waves that occurred in April 1987, further details were not mentioned.

As a result of studies based on investigations of the conditions of the existing shore protection facilities, confirmation of the contents of the request from the Government of Maldives and a study of data and information collected during the field investigation, it has been concluded that the construction of the following facilities on the southern coast of Male' is appropriate. The outline of these facilities is as presented in Items (1) to (5) below. A draft plan for shore protection facilities indicated in ANNEX 2-1 and 2-2 in the Minutes of Discussion was presented to the authorities concerned of the Maldives and discussions were held with regard to technology, maintenance, management and other items during the period of field investigation. In the course of its preparation of the draft construction plan, the Basic Design Study Team considered not only the urgent necessity, effectiveness and safety, ease of execution and economics of the construction work, but also took into account the coordination of the Project with other related projects such as the primary school construction project, the power plant construction project, harbour construction and other projects as well as the current state of existing shore protection facilities.

(1) The Project area shall be 1.52km along the southern coast of Male' from the eastern edge to the proposed harbour project area in the western corner.

(2) The shore protection facilities shall be planned on the coral reef and be comprised of detached breakwaters of dimensions of 100m or 120m in crest length and 40m in opening width.

(3) The detached breakwaters shall be permeable and consist of concrete armour units and coral rocks.

(4) The proposed detached breakwaters shall be located at virtually the same position as that of the existing detached breakwaters, taking into account the topography, distance from the reef edge, water depth, and wave breaking point. In designing the facility, the Development Proposals for Male' Reclamation, the reclamation limit, the eroded conditions of the reclaimed land, the utilization of existing detached breakwaters, the navigation route plan provided on the inland side of the breakwaters along the existing detached breakwaters, the envisaged benefits, the safety, ease of execution and the cost of the construction work were considered. However, the detached breakwaters adjacent to the eastern edge area shall be arranged somewhat closer to the shore.

(5) The first priority construction zone shall be a zone of about 240m in the eastern edge of the southern coast because of reasons described below:

1) A wide range of reclaimed land was eroded deeply into the island up to a place about 25m to 30m from houses, and there is only a simple temporary protection facility provided by embanking 1m in height of earth along the shoreline. This area is therefore exposed to very dangerous situations.

2) There is even no coral rock detached breakwaters on the reef in this zone.

3) The power station and primary school, the most important facilities on Male' are scheduled to be constructed behind this area.

4) Housing construction is rapidly promoted close to the shoreline.

4-3 Outline of the Project

4-3-1 Execution System

The responsibility for shore protection services is undertaken by the DPWL. So far, the DPWL has executed only such maintenance work as simple repair work of crests of substantially damaged seawalls and, therefore, has not performed any full-scale improvement, maintenance, repairs or other works.

4-3-2 Basic Schemes for Planning the Project

The basic schemes for planning the Project are established as follows:

(1) The applicable project area shall be 1.52km on the southern coast of Male' from the eastern edge to the proposed inter-island harbour project site on the western edge.

(2) The shore protection facilities shall be permeable detached breakwaters with openings to be constructed on the reef.

(3) The zone of about 240m at the eastern edge of the southern coast shall be the first priority construction zone.

4-3-3 Summary of the Project

The Project of constructing breakwaters on the southern coast of Male' is summarized as follows:

(1) The Project area is divided into the following three zones:

a) Zone I: Area where the reclaimed land at the eastern edge of southern coast is most extensively eroded, with a total length of 240m. This zone is an area requiring urgent countermeasures to be taken.

b) Zone II: Area where existing detached breakwaters made of coral rocks are constructed and their surrounding area, with total length of 640m.

c) Zone III: Area on the west side from the terminal section of existing detached breakwaters, with a total length of 640m.

(2) In the respective zones, the permeable detached breakwaters with openings shall be constructed by randomly piling up nominal 3t concrete armour units.

(3) The crest elevation of the detached breakwaters shall be DL+3.8m, and the crest width shall be determined by taking into account the width in case three units are arranged in a row. The gradient of its slope shall be 1:4/3 or smaller on both the seaward and landward sides.

(4) The total sections of the detached breakwaters of Zones I and III shall be comprised of concrete armour units, while the breakwaters of Zone II shall be constructed by using the coral rocks of the existing detached breakwaters as core material and covering the surface with concrete armour units.

(5) In Zone I, two detached breakwaters, each with a crest length of 100m and an opening width of 40m, shall be constructed. In Zones II and III respectively, four detached breakwaters, namely, eight breakwaters in total with a crest length of 120m and an opening width of 40m shall be constructed.

CHAPTER 5

BASIC DESIGN

CHAPTER 5 BASIC DESIGN

5-1 Basic Design Policy

The basic design for the Project has been established in conformity with the following:

(1) In accordance with the development proposals for Male' reclamation prepared by the OPPD under the instructions of the President's office and the contents of the request made by the Government of Maldives to the Government of Japan, the basic design for the Project has been worked out for the purpose of constructing appropriate shore protection facilities in the area exposed to the dangers of high tidal waves and thereby reducing the potential danger caused by such waves.

(2) The project area will be a section of 1.52km on the southern coast of Male'.

(3) In a part of the Project area, it can be found the existing detached breakwater constructed by piling up coral rocks over about 600m in a line almost parallel to the reef edge. This breakwater is demonstrating a considerable wave-dissipating effect. Therefore, this existing detached breakwater made up of coral rocks will be utilized effectively for the Project.

(4) Under the Project, the existing seawalls and the Inter-Island Harbour project in the western edge area of the southern coast will be taken into consideration in order to ensure good coordination with other projects.

(5) In consideration of the urgent necessity and importance of the Project in reducing the disasters caused by high tidal waves and prevent the occurrence of epidemics and other secondary

disasters, the basic design will be intended so as to further shorten the construction period while taking into account the cost, ease of execution and safety of construction work. Moreover, the basic design will be drawn so that the construction works will be performed successively according to the priority order set by both the urgency and importance of each respective work.

(6) The design standards applicable to the Project will be the technical standards of Japan. Moreover, sufficient consideration will be given so that the facilities under the Project will not cause any problem in terms of compatibility with the existing facilities.

(7) The basic design for the Project will be drawn so as to permit ease of maintenance and management while minimizing the costs incurred in the future by taking into account the Maldives' financial situation.

(8) The basic design for the Project will be drawn so as to increase employment opportunities and the transfer of technical knowhow to Maldivian engineers and make possible the effective use of construction materials and equipment available in the Maldives.

(9) Sufficient consideration will be given to obtain the understanding and cooperation of the Maldivian people with regard to the implementation of the Project.

(10) The detached breakwaters will be permeable breakwaters with openings. Detached breakwaters have been selected for the prevention of high tidal waves for the following reasons:

1) In accordance with the development proposals for Male' Reclamation, the acquisition of a navigation route on the inland side of the breakwaters is required.

2) With the detached breakwaters, it is possible to break waves and reduce the amount of overtopping and wave runup height for the seawall which shall be constructed in the future. It is further possible to obtain a calm sea area behind the detached breakwaters.

   The safety of the navigation route can be enhanced through the effect of the breakwaters. In addition, it is possible to further reduce the scale of the shore protection facilities to be constructed around the reclaimed land.

3) Erosion of reclaimed land can be prevented.

4) By slightly modifying the shape of the existing detached breakwaters it will be possible to make utmost use of existing coral rocks as the stone core for the new detached breakwaters.

5) As the detached breakwaters will make it easier to execute the construction work within a short period, the intended objective could be attained earlier than by using other types.

6) The construction cost is comparatively low.

7) The detached breakwaters will ensure comparatively easy maintenance, management and repair work, and will not impose a major technical and economic burden to the Maldivian side after completion.

(11) The Project is divided into the following three phases and the construction work period of the respective phases after the Exchange of Notes shall be as follows:

Phase I :	10.0	months
Phase II :	11.5	months
Phase III:	13.0	months
Total	34.5	months

5-2 Study of Design Conditions

5-2-1 Summary of Design Conditions

The design and other conditions described in detail in 5-2-2 and subsequent clauses are summarized as follows:

(1) Design conditions

1) Datum level : 0.51m below MSL

2) Design highest high water level : DL +1.8m

3) Detached breakwater installation water depth: DL -0.7m to +0.3m

4) Design wave
   - Wave height : 2.0m
   - Period : 14 sec.
   - Wave direction : Perpendicular to the reef edge

(2) Arrangement of detached breakwaters

The arrangement of the detached breakwaters is based on the study in Clause 5-3 and as shown in Fig. 5-12.

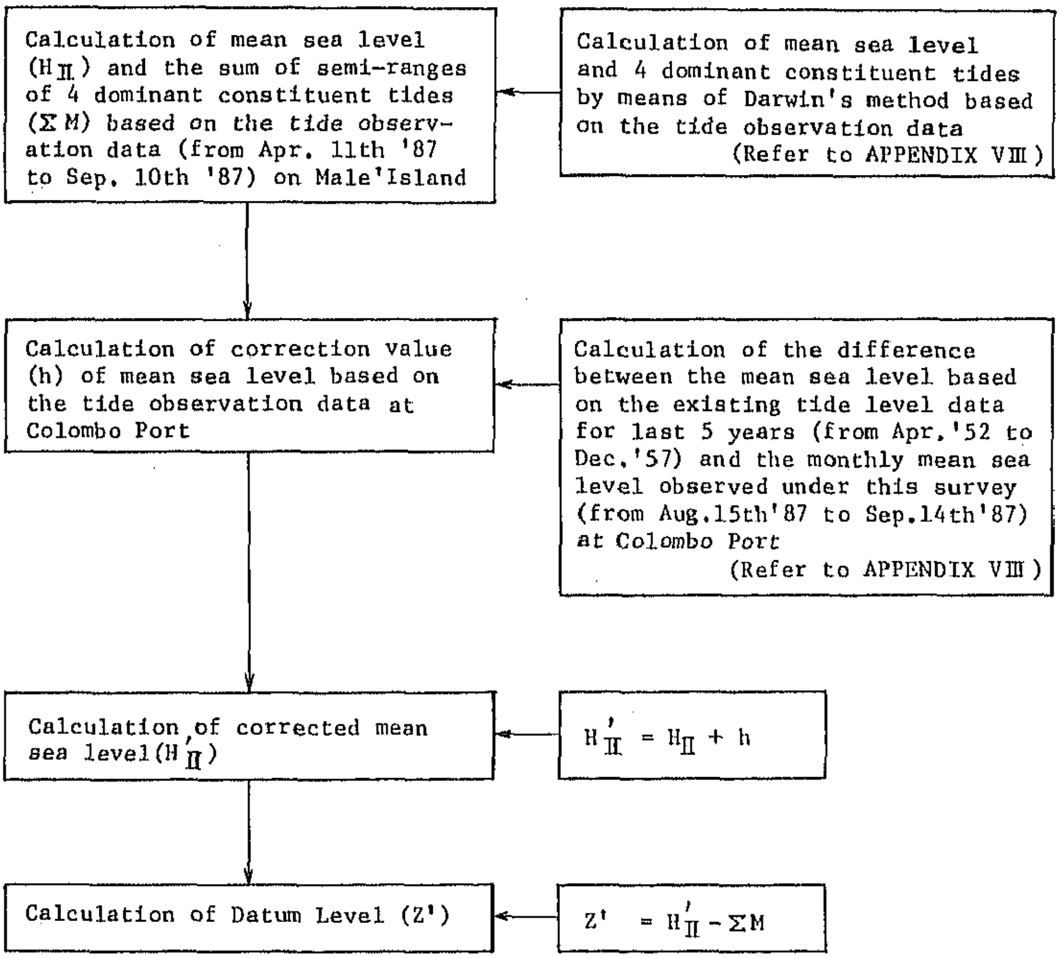
(3) Section of detached breakwaters

The typical sections of the detached breakwaters are based on the study in Clause 5-3 and presented in Figs. 5-16, 17 and 18.

5-2-2 Design Conditions

(1) Datum level

A clear datum level has not been established for Male' Island. As a reference for the Project and various projects of future facilities, the datum level has been established as presented hereunder. Based on the following flow chart, the datum level has been set to Zo = 0.51m below the mean sea level.



The symbols indicated in the above flow chart are specified in Fig. 5-1.

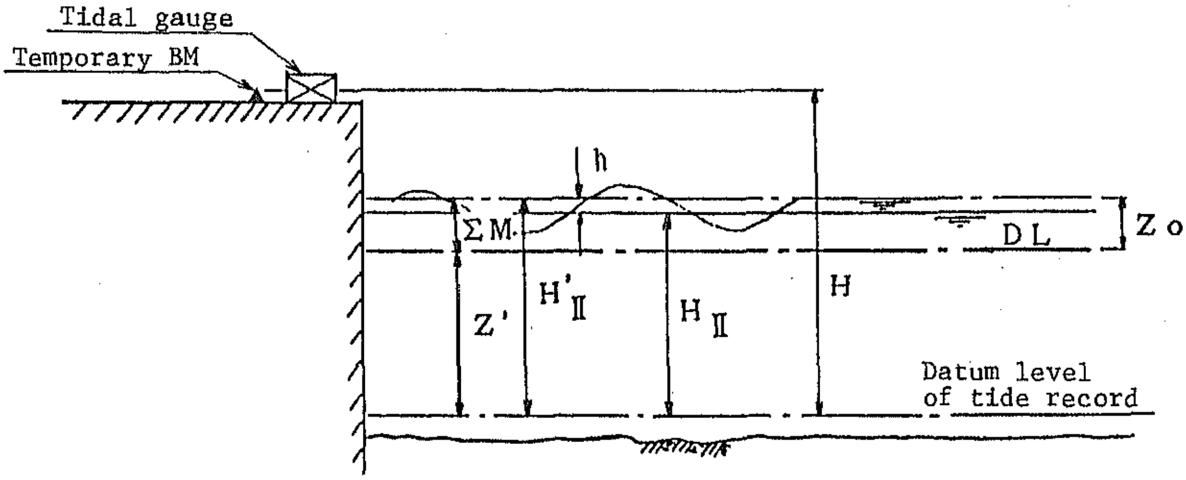


Fig. 5-1 Relationship among levels.

Calculations on tide observation data for Male' Island are listed below:

$H = 3.44m$

$H_{II} = 2.93m$

$h = 0.08m$

$\Sigma M = 0.51m$

From these values, the datum level is given as follows:

$H'_{II} = H_{II} + h = 3.01m$

$Z' = H_{II} - \Sigma M = 2.50m$ (0.51m below MSL)

(2) Design highest high water level

According to Japanese standards, the design highest high water level for coastal facilities for high tide conditions is determined based on either of the following two methods:

a) Recorded highest high water level

b) Summation of Mean Springs High Water Level and recorded maximum sea level departure from normal

Since there is not any observation data available pertaining to the sea level departure in Male', it is impossible to determine it for the island. The design's highest high water level is therefore estimated according to the method in Item a) above. The value in a) above is estimated according to the methods in Items ① and ② below:

The atmospheric pressure at the time of the anomalous high tide of April 1987 was 1,011mb to 1,012mb, according to the weather data at the airport island (Hulule). The sea level is therefore not considered to have been raised due to low pressure. According to the same data, moreover, wind velocity and direction were respectively 4m/s to 6m/s and northwest - west (NW - W). The sea level is therefore not considered to have been raised by wind, and it is difficult to identify the cause for this high tidal waves at the present moment.

① Water level obtained by adding the semi-range of four dominant constituent tides to MSL

The approximate HHWL is given by the following formula:

$$HHWL = MSL + (O1 + K1 + S2 + M2)$$

The MSL and the semi-range of four dominant constituent tides at Male' have been set as follows, based on tide observation records on Male'. For further details, refer to APPENDIX VIII.

$$MSL = DL+0.51m$$

Semi-range of four dominant constituent tides:

O1 (Principal lunar semi-diurnal)	:	0.04m
K1 (Lunar-solar semi-diurnal)	:	0.11m
S2 (Principal solar semi-diurnal)	:	0.13m
M2 (Large lunar elliptic semi-diurnal)	:	0.23m
Total		0.51m

The HHWL can be derived from the above:

HHWL = DL+0.51 + 0.51 = DL+1.02m

2 Maximum sea level estimated from the trace survey of the anomalous high tide in April 1987

The tidal wave trace level obtained by field investigation by the Basic Design Study Team is as shown in the table below:

Table 5-1 List of the trace survey results.

Survey Point	Trace Level (m)
A	DL + 1.73
B	DL + 1.60
C	DL + 1.63

Survey points are indicated in Fig. A11-1 in APPENDIX XI.

Based on the results of the study presented above, the HHWL has been determined by taking into account the accuracy of the data and the shortness of tide observation period.

HHWL = DL+1.8m

Using the offshore wave data based on the design waves in Item (5) hereafter, moreover, the rise of the water level at the reef edge is estimated as follows for reference:

Equivalent offshore wave height (H_0')	:	4.1m
Offshore wave period (T)	:	14 sec.
Offshore wavelength (Lo)	:	$1.56\ T^2 = 306$m
Steepness of offshore wave (H_0'/L_0)	:	0.013
Water depth at reef edge (R)	:	1m

$R/H_0' = 0.24$

From Fig. 5-2, $\eta_t/H_0' = 0.24$

Therefore, the wave setup (η_t) at the reef edge becomes approximately 1m as calculated below:

$$\eta_t = 0.24 \times H_0' = 0.24 \times 4.1 = 0.98\text{m}$$

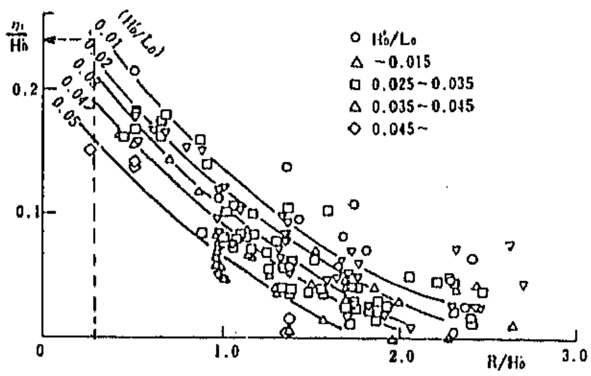


Fig. 5-2 Wave setup at reef edge.

Source: T. Uda and A. Omata, "A design method of artificial reef", KAIGAN, Vol. No.27, 1987

The MSL at the time of the high tide disaster estimated on the basis of the ten constituent tides at Male' obtained from the results of tide observation is DL + 0.82m. When the above-mentioned wave setup at the reef edge is added to this value:

DL+0.82m + 0.98m = DL+1.80m

As this value agrees with the design highest high water level set previously, it is highly probable that an above assumed degree of offshore waves swept the island.

(3) Detached breakwaters installation water depth

Based on the results of sounding, the installation water depth of detached breakwaters has been determined as follows:

DL-0.7m to +0.3m

(4) Unit weight of various materials

The unit weight of various materials adopted for design shall be as specified below.

General unit weight values can be adopted for plain concrete and sea water, and the unit weight of coral rocks has been determined based on the results of tests on samples brought back to Japan from the Maldives.

For further details regarding the results of coral rock tests, refer to APPENDIX IX.

a)	Plain concrete	:	$2.3t/m^3$
b)	Coral rock	:	$2.3t/m^3$
c)	Sea water	:	$1.03t/m^3$

(5) Design waves

1) Wave height and period

The design wave height has been estimated according to the methods elaborated in the following Items a) and b).

The design wave period has been set at 14 sec. taking into consideration the mean wave period (about 10 to 11 sec.) observed during the field investigation by the Study Team and the period (about 13 to 14 sec.) calculated based on the observation of the video tape taken at the time of the high tide disaster.

a) Estimation of wave height in the breaker zone

Generally, wave height in a breaker zone is estimated according to the following formula:

Wave height at breaking H_D = 0.78h (m)

where h: Water depth at toe of detached breakwaters (m)

From the results of sounding, the installation water depth of the detached breakwaters is approximately DL-0.7m to +0.3m, and, where the design highest high water level is assumed at DL+1.8m, the wave height at breaking becomes about 1.2m to 2.0m as calculated below:

$$h = 1.8 - (-0.7 \text{ to } +0.3) = 1.5\text{m to } 2.5\text{m}$$

The wave height at breaking point is therefore estimated to be:

$$H_D = 0.78 \times (1.5 \text{ to } 2.5) = 1.17\text{m to } 1.95\text{m}$$

b) Estimation from the Research Paper of Public Works Research Institute, Ministry of Construction, Japan

In order to estimate the design wave height acting on a detached breakwater, it is first required to estimate the offshore wave height. However, observation data of offshore waves in the Maldives is not available and wave height has been estimated based on data from Ocean Wave Statistics (refer to the next page).

i) Estimation of offshore wave height

As shown in the area code in Fig. 5-3, the Republic of Maldives belongs to Area 30.

The significant wave height ($H_{1/3}$) has been estimated by using the maximum value of the Wave Height Code in Area 30 indicated in Table 5-2.

Table 5-2 Wave height.

AREA 30

ALL SEASONS

DIRECTION CLASS - ALL DIRECTIONS

WAVE PERIOD CODE

WAVE HEIGHT CODE	X	2	3	4	5	6	7	8	9	0	1	TOTALS
00	1392	1718	28	11	13		2	1	2	33	16	3216
01	96	3607	326	84	17	7	4	1	1	5	134	4282
02	70	5099	2102	488	131	56	10	3	2	12	53	8026
03	70	2060	3143	974	245	95	19	11	2	1	1	6621
04	43	444	1660	1014	200	73	15	4			1	3454
05	11	146	608	558	192	66	19	2		1	2	1605
06	9	44	156	246	101	39	9	2				606
07	7	13	64	94	45	17	7					247
08	1	11	16	27	30	14	2	1				102
09	1	3	5	7	13	12						41
10		1	1		1	4						7
11		1		4		1						6
12				2						1		3
13				1								1
TOTALS	1700	13147	8109	3510	988	384	87	25	7	53	207	28217

WAVE HEIGHT CODE	WAVE HEIGHT FEET	WAVE HEIGHT METRES
00	1	0·25
01	1·5	0·5
02	3	1
03	5	1·5
04	6·5	2
05	8	2·5
06	9·5	3
07	11	3·5
08	13	4
09	14	4·5
10	16	5
11	17·5	5·5
12	19	6
13	21	6·5
14	22·5	7
15	24	7·5
16	25·5	8
17	27	8·5
18	29	9
19	30·5	9·5
90	33	10
91	36	11
92	39	12
93	43	13
94	46	14
95	49	15
96	52	16
97	56	17
98	59	18
99	62	19

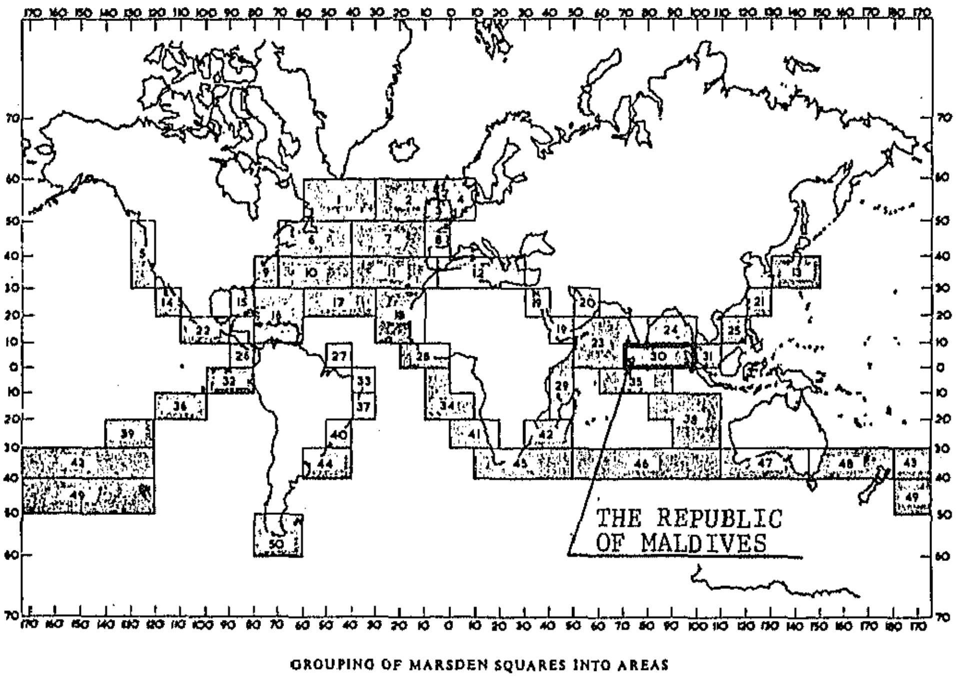


Fig. 5-3 Area code.

Source: Ocean Wave Statistics, Ministry of Technology National Physical Laboratory, N. Hogben & F. E. Lumb, London, 1967

The wave height of 6.5m obtained from Table 5-2 is based on visual observation on a ship, and the significant wave height has been derived as 4.1m using the formula indicated in Ocean Wave Statistics:

$$H_{1/3} = 1.23 + 0.44 \times \text{Visual observation wave height}$$
$$= 1.23 + 0.44 \times 6.5 = 4.1\text{m}$$

ii) Estimation of wave height at detached breakwaters

The wave height at detached breakwaters is estimated from the diagram below:

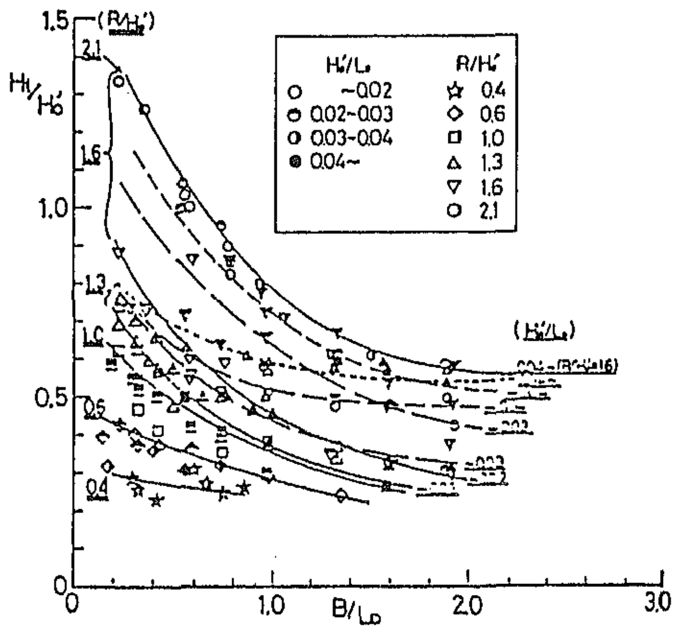


Fig. 5-4 Wave transmission coefficient due to artificial reef.

where,
- Hó: equivalent offshore wave height (m)
- Lo: offshore wavelength (m)
- R : water depth at toe of structure (m)
- B : width of the coral reef (m)
- Ht: transmitted wave height (m)

Source: T. Uda and A. Omata, "A design method of artificial reef", KAIGAN, Vol. No.27, 1987

$H_o' = 4.1m$

$Lo = 1.56 \times 14^2 = 306m$

$R = 2.5m$

$B = 30m$

Therefore,

$H_o'/Lo = 4.1/306 = 0.013$

$R/H_o' = 2.5/4.1 = 0.61$

$B/Lo = 30/306 = 0.10$

From the above values, the transmitted wave height is estimated at 1.93m as calculated below:

$Ht/H_o' = 0.47$

$Ht = 0.47 \times 4.1 = 1.93$

2) Determination of design wave height

The results of the above calculations are summarized as follows:

a) From the wave height at breaker zone,

$H_D = 1.17$ to $1.95m$

b) From the paper announced by the Public Works Research Institute, Ministry of Construction, Japan,

$H_D = 1.93m$

From these values, the design wave height shall be determined as 2.0m.

3) Wave direction

According to the reports prepared by the teams of experts for Tidal Wave Disaster Assessment dispatched by Japan and the Netherlands, the direction of offshore waves at anomalous high tide is to be southeast (SE).

During the field investigation period of the Study Team, however, although the direction was roughly southeast (SE), the direction of incident waves at the proposed detached breakwaters area was roughly perpendicular to the reef edge.

Furthermore, the direction of incident waves appeared in the aerophotographs of Male' and Hulule islands printed in the book entitled "MALDIVES A NATION OF ISLANDS" is also roughly perpendicular to the reef edge.

Therefore, the all design incident wave direction shall be perpendicular to the reef edge.

5-3 Basic Plan

5-3-1 Proposed Reclamation Limit

The proposed reclamation limit behind the detached breakwaters shall be established at an appropriate distance from the detached breakwaters in order to reduce the wave overtopping.
The overtopping rate shall be set to no higher than the allowable rate and by taking into account the scale of seawalls, etc. required for protecting the primary school and other facilities at the same time. In this report, a reclamation limit indicated in Fig. 5-5 has been proposed by taking into account the topography, ground elevation, the development proposals for Male' reclamation, navigation route plans along the inland side of the existing detached breakwaters and wave height along the navigation route. Effectiveness, ease of execution, and the cost of the construction work have also been considered.

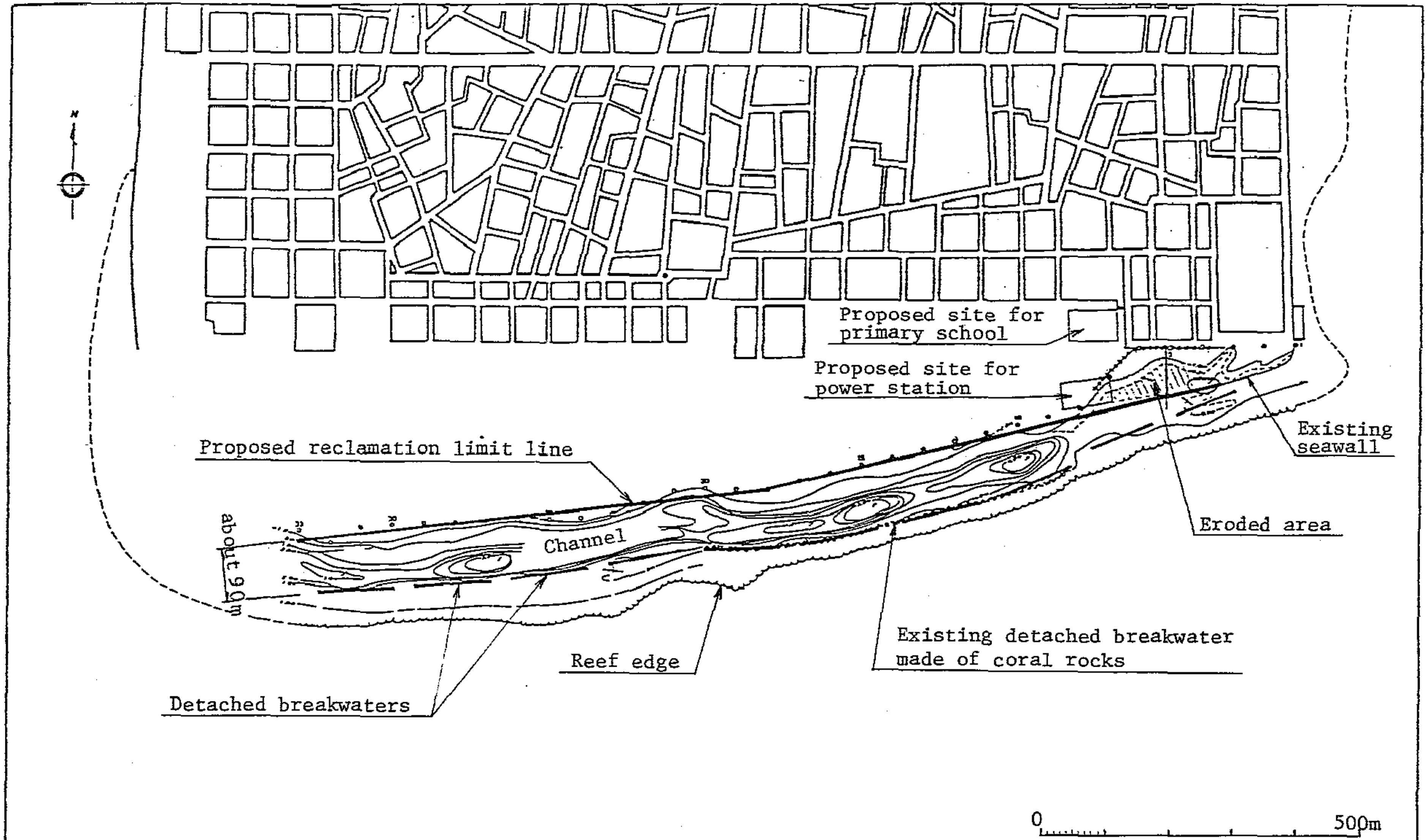


Fig. 5-5 Relation between proposed reclamation limit and detached breakwater.

5-3-2 Detached Breakwaters Construction Plan

(1) Arrangement plan

1) Design conditions

a) Design wave height: $H_D = 2.0m$

b) Design wave period: $T_D = 14$ sec.

c) Water depth at toe of structure : $h = 2.5m$ (at high tide)

d) Design wavelength : $L = \sqrt{g \cdot h} \cdot T_D = 69.3m$

The arrangement of the detached breakwaters has been determined mainly with regard to the wave dissipating rate.

2) Determination of the length of detached breakwaters

According to Japanese standards, wave height behind the opening of detached breakwaters becomes almost constant where breakwater length is no smaller than about 1.5 times the wavelength.

Therefore, the length of breakwaters can be determined at not less than 100m, as calculated below, and based on the ratio of wavelength to the breakwater length at which the wave height becomes constant.

Breakwater length $\ell = 1.5L = 1.5 \times 69.3 = 104m$

3) Determination of opening width

According to Japanese standards, the wave dissipating effect of detached breakwaters can be expected even at the opening section, provided that the opening width is not less than about 0.6 times the wavelength.

The opening width is therefore determined at 40m as calculated below:

Opening width $\ell' = 0.6L = 0.6 \times 69.3 = 41.6$m

4) Determination of crest elevation

In consideration of the following conditions, the crest elevation of detached breakwaters is established at a level equivalent to the summation of the design wave height and the design highest high water level.

a) Height of wave transmitted behind detached breakwater

b) Overtopping rate of waves at seawall behind detached breakwaters

c) Accuracy of design highest high water level, and design wave height and period

d) Durability of detached breakwater against wave overtopping

5) Determination of crest width

The crest width of detached breakwaters is determined to be equivalent to one row of three concrete armour units taking into consideration the increase in durability of breakwater structure against waves, the reduction of the rate of wave overtopping and transmitted wave height, past construction records, the effect on the onshore seawall, etc.

6) Determination of wave transmission coefficient

The wave transmission coefficient becomes approximately 0.4, calculated on the basis of Fig. 5-6 and specified according to Japanese standards.

Where $\bar{B}h$: average width of breakwater body above water level at water depth h, 7.37 (m),

D : height of one concrete armour unit, 1.65 (m),

Hi: incident wave height, 2.0 (m),

and Li: incident wavelength, 62.0 (m).

$\bar{B}h/D = 4.5$

$Hi/Li = 0.032$

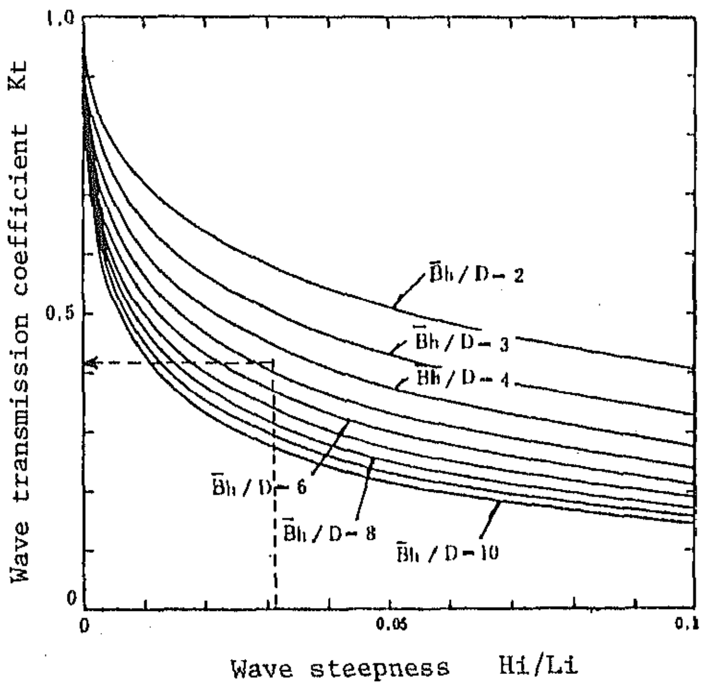


Fig. 5-6 Calculation diagram of wave transmission coefficient.

7) Determination of arrangement of detached breakwaters

The arrangement of detached breakwaters is studied with consideration to Zones I, II and III as indicated in Fig. 5-12.

a) Zone I

Zone I is an area where detached breakwaters will be constructed in order to protect the area eroded at the time of the anomalous high tide. By conducting a comparative study with consideration to the three cases shown in Fig. 5-7, the optimum arrangement has been selected.

Meanwhile, the respective cases have been adopted based on the following concept:

Case 1: Where the distance from the reef edge to detached breakwater is approximately 30m, as in the case of the existing detached breakwaters, the detached breakwaters are arranged parallel to the reef edge. The sea area behind the detached breakwaters is made as wide as possible, and continuity with Zone II is taken into account.

Case 2: The breakwaters overlap by some 20m with the existing seawall so that wave height will become approximately 0.7m to 0.8m at the western edge of the existing seawall. This takes into account the rate of wave overtopping and the safety of the existing seawall. The effect of waves diffracted from the edge of detached breakwaters is thereby reduced. The distance from the reef edge to the breakwater is made longer than in Case 1 in order to lower the height of waves acting to the breakwater. Continuity with Zone II is taken into account.

Case 3: The eastern edge of the detached breakwaters is arranged adjacent to the existing seawall in order to reduce the effect of waves from a south-eastern direction upon the existing seawall. At the same time, the distance from the reef edge to the breakwater is made longer than in Case 2 in order to lower the height of waves acting on the breakwater. Continuity with Zone II is also taken into consideration.

The arrangement in Case 2 has been selected as that in Zone I for the following reasons:

i) The western edge of the existing seawall has collapsed so that it causes problems of durability. Case 2 is excellent to protect the western edge of the existing seawall.

ii) Maximum wave height acting on the existing seawall will be relatively low and the seawall to be constructed in the future will roughly be of the same size as that in Case 1.

iii) The overtopping rate of waves over the seawall to be constructed in the future is smallest, namely, 1.6×10^{-2} (m^3/m·sec.). Case 2 is therefore most advantageous in view of the effective utilization of reclamation area, and affords the least effect from overtopping rate, splash, etc.

Comparisons of detached breakwater arrangements in each respective case are listed in Table 5-3.

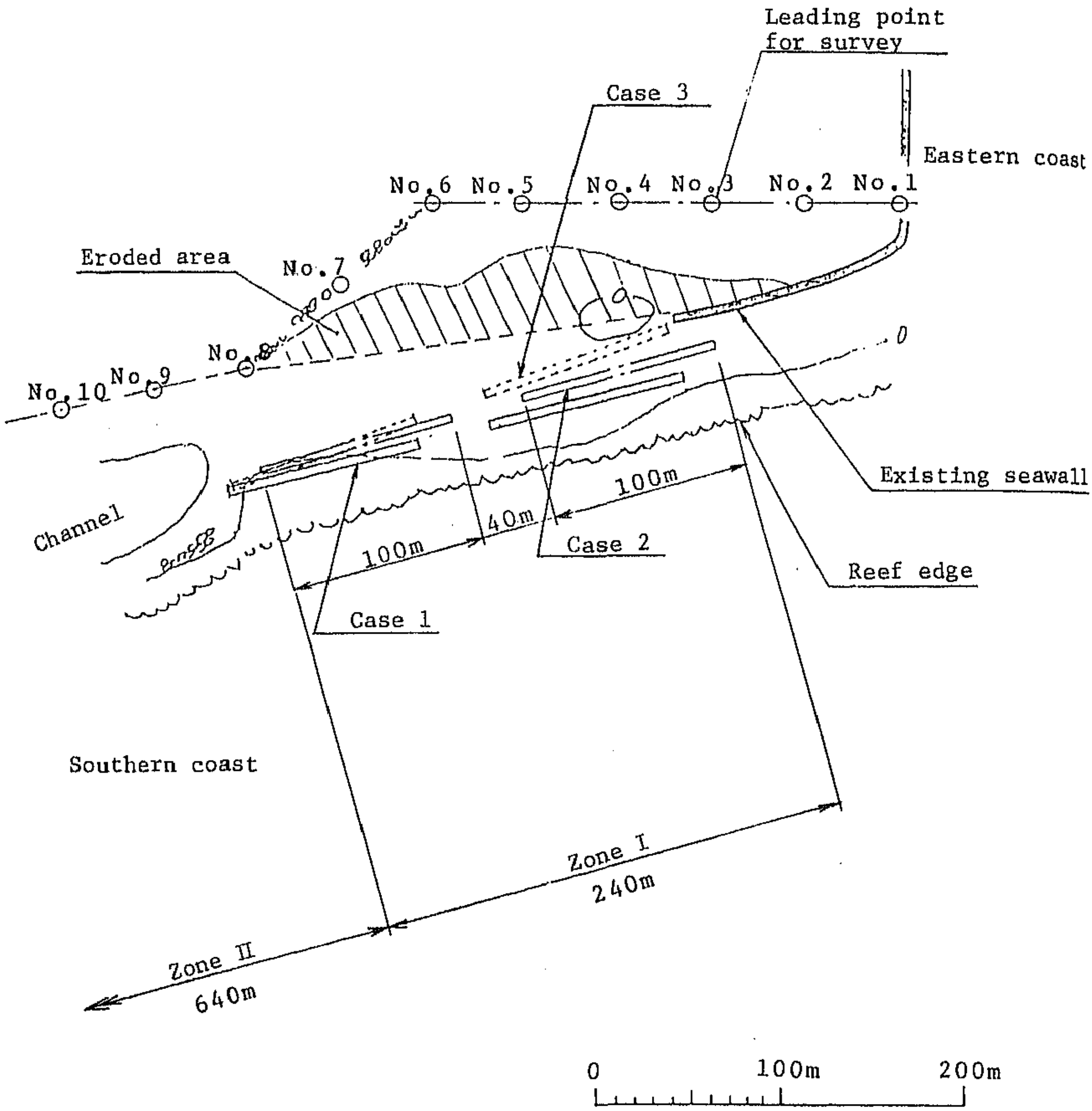
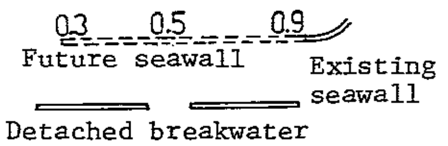
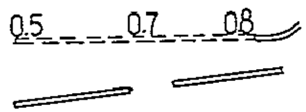
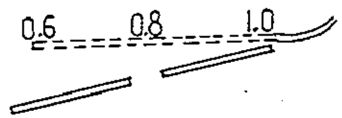


Fig. 5-7 Plan of breakwaters arrangement in each case.

[All of the 3 cases, breakwater length : 100m
opening width : 40m]

Table 5-3 Comparison table of each case.

Item \ Case	1	2	3
Relative construction cost	1.0 A	1.0 A	1.0 A
Relative construction period	1.0 B	1.0 B	1.0 B
Wave height along detached breakwater (m) *1	1.6 ~ 1.9	1.5 ~ 1.9	1.4 ~ 1.9
Protection of existing seawall	same as the condition without detached breakwater	possible	sufficient effect can not be expected
Wave height at the future seawall (m) *2	 0.3 0.5 0.9 Future seawall, Existing seawall, Detached breakwater	 0.5 0.7 0.8	 0.6 0.8 1.0
Maximum overtopping rate into reclaimed land (m^3/m·sec) *3	3×10^{-2}	1.6×10^{-2}	5×10^{-2}
Allowable overtopping rate (m^3/m·sec) *4	←	2.0×10^{-2}	→
Order of suitability	3	1	2

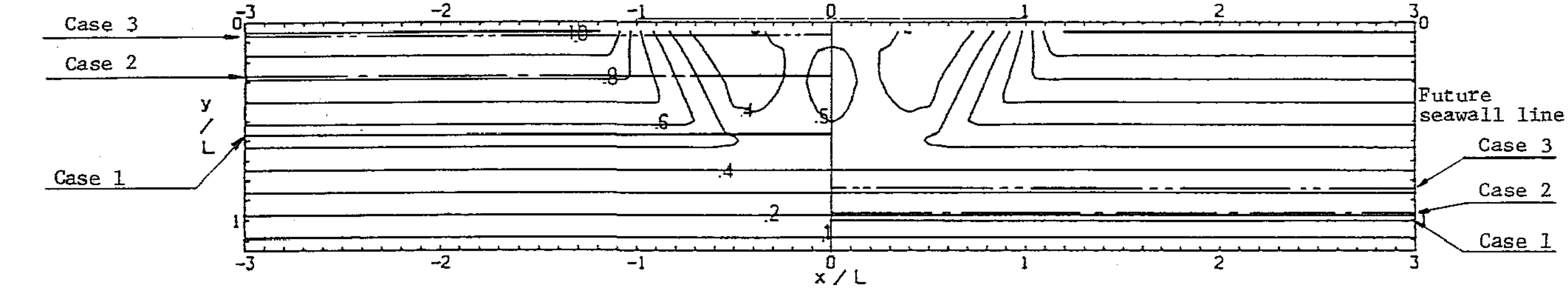
Notes *1 : The same process as 2), b), ii) of (5) design wave was applied to the calculation of the wave height along detached breakwater.

*2 : The wave height distribution at the position of future seawall was calculated according to Japanese Standards (Refer to Fig.5-8 to 5-10).

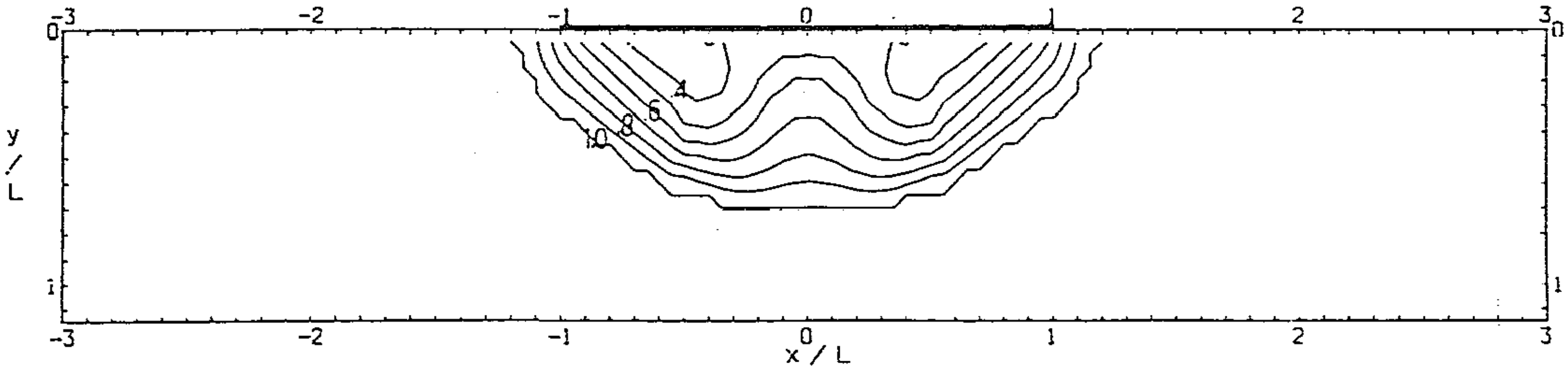
*3 : The same standard as above Note *2 was applied to the calculation of overtopping rate, assuming the top of future seawall to be DL+2.3m (Refer to Fig.5-11).

*4 Allowable overtopping rate was decided based on the proposed value by Prof. Nagai of Osaka City University,Japan.

(a) H/Hi [Contours for equal diffraction coefficient for incident wave height at the detached breakwater]



(b) H/Hn [Distribution of diffracted waves due to detached breawater]

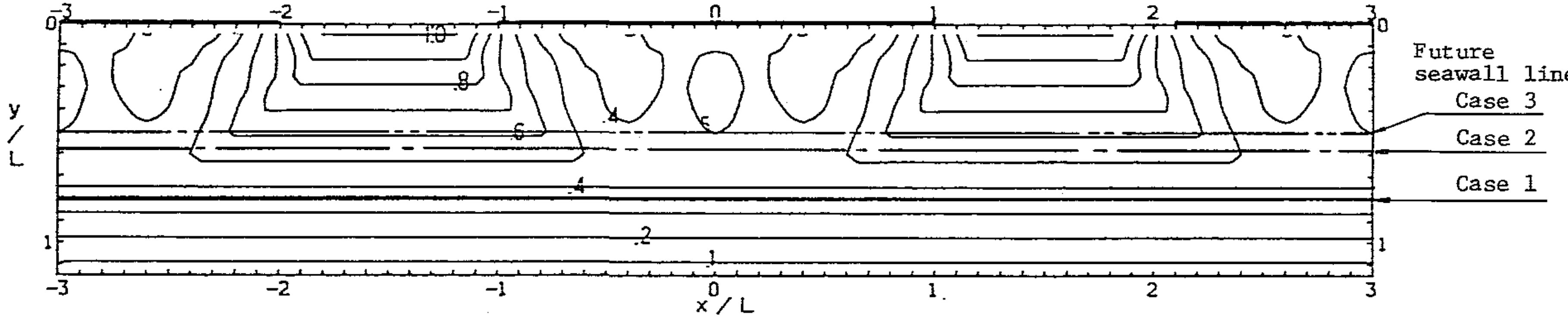


Calculation conditions [Detached breakwater length : $\ell = 2.0$ L
Wave transmission coefficient : Kt = 0.4
Relative wave height : Yb/Y > 1 , in the case that waves break at the seaward of breakwater]

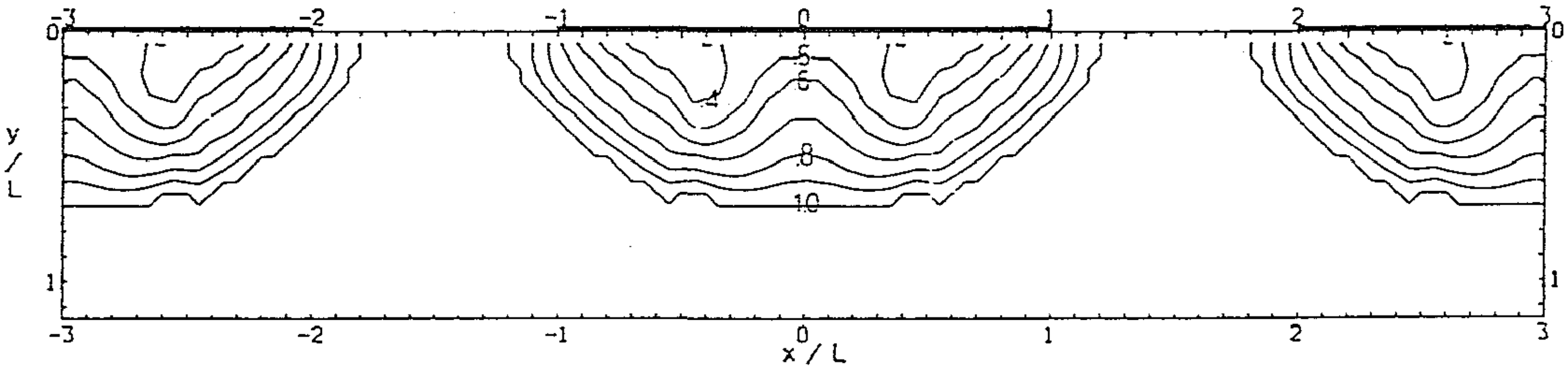
Fig. 5-8 Wave height distribution behind detached breakwater (single breakwater CASE-A-13).

[Remarks : Applicable to wave height hindcasting of eastern and western end of breakwater]

(a) H/Hi [Contours for equal diffraction coefficient for incident wave height at the detached breakwater]



(b) H/Hn [Distribution of diffracted waves due to detached breawater]

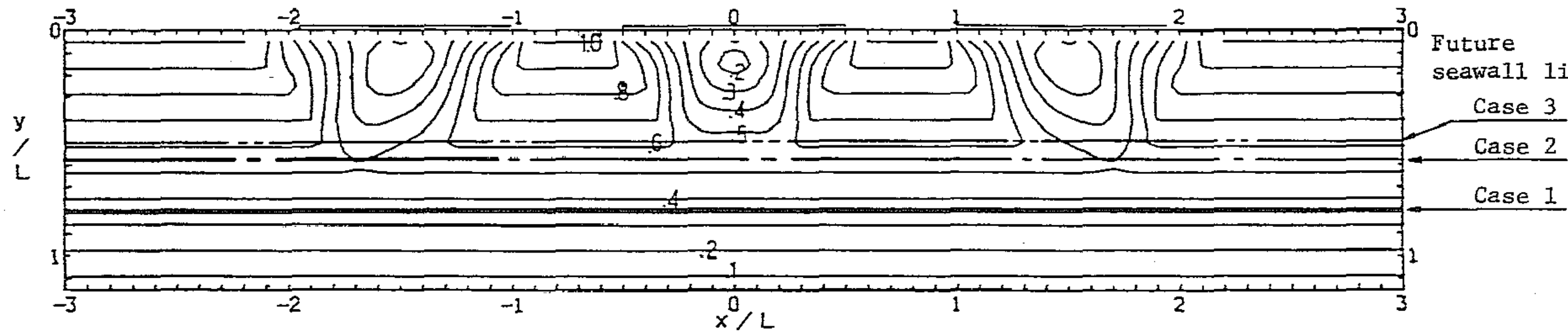


Calculation conditions:
- Detached breakwater length : $\ell = 2.0$ L
- Opening width : $\ell' = 0.5\ell$
- Wave transmission coefficient : Kt = 0.4
- Relative wave height : $Yb/Y > 1$, in the case that waves break at the seaward of breakwater

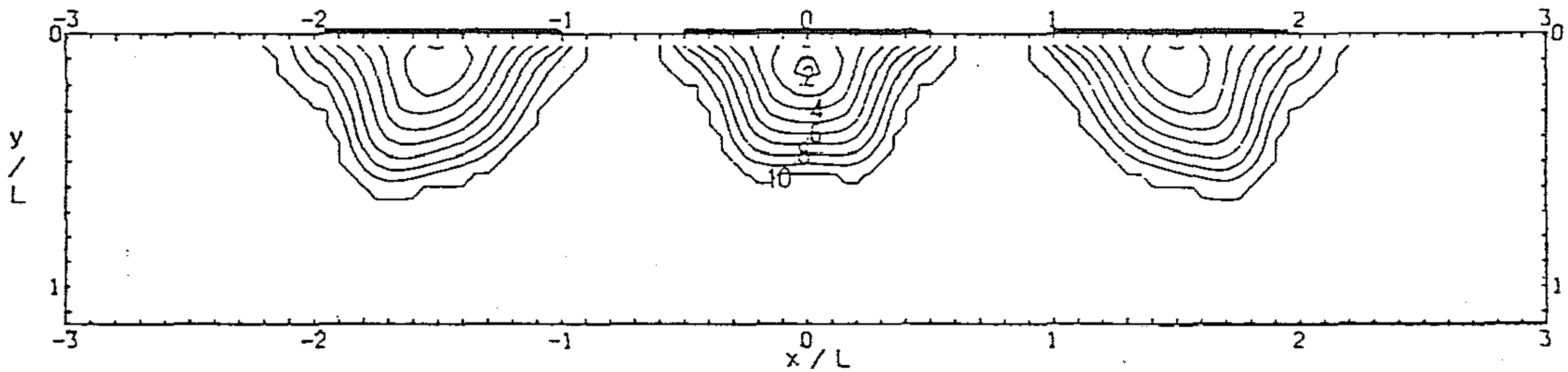
Fig. 5-9 Wave height distribution behind detached breakwater (group breakwaters CASE-B03).

Remarks : 1) Applicable to wave height hindcasting behind opening of breakwater
2) Average between case of $\ell = 2.0$ L and case of $\ell = 1.0$ L can be applied to case of $\ell = 1.5$ L .

(a) H/Hi [Contours for equal diffraction coefficient for incident wave height at the detached breakwater]



(b) H/Hn [Distribution of diffracted waves due to detached breawater]



Calculation conditions

- Detached breakwater length : $\ell = 1.0$ L
- Opening width : $\ell' = 0.5\ell$
- Wave transmission coefficient : Kt = 0.4
- Relative wave height : Yb/Y>1 , in the case that waves break at the seaward of breakwater

Fig. 5-10 Wave height distribution behind detached breakwater (group breakwaters CASE-B43).

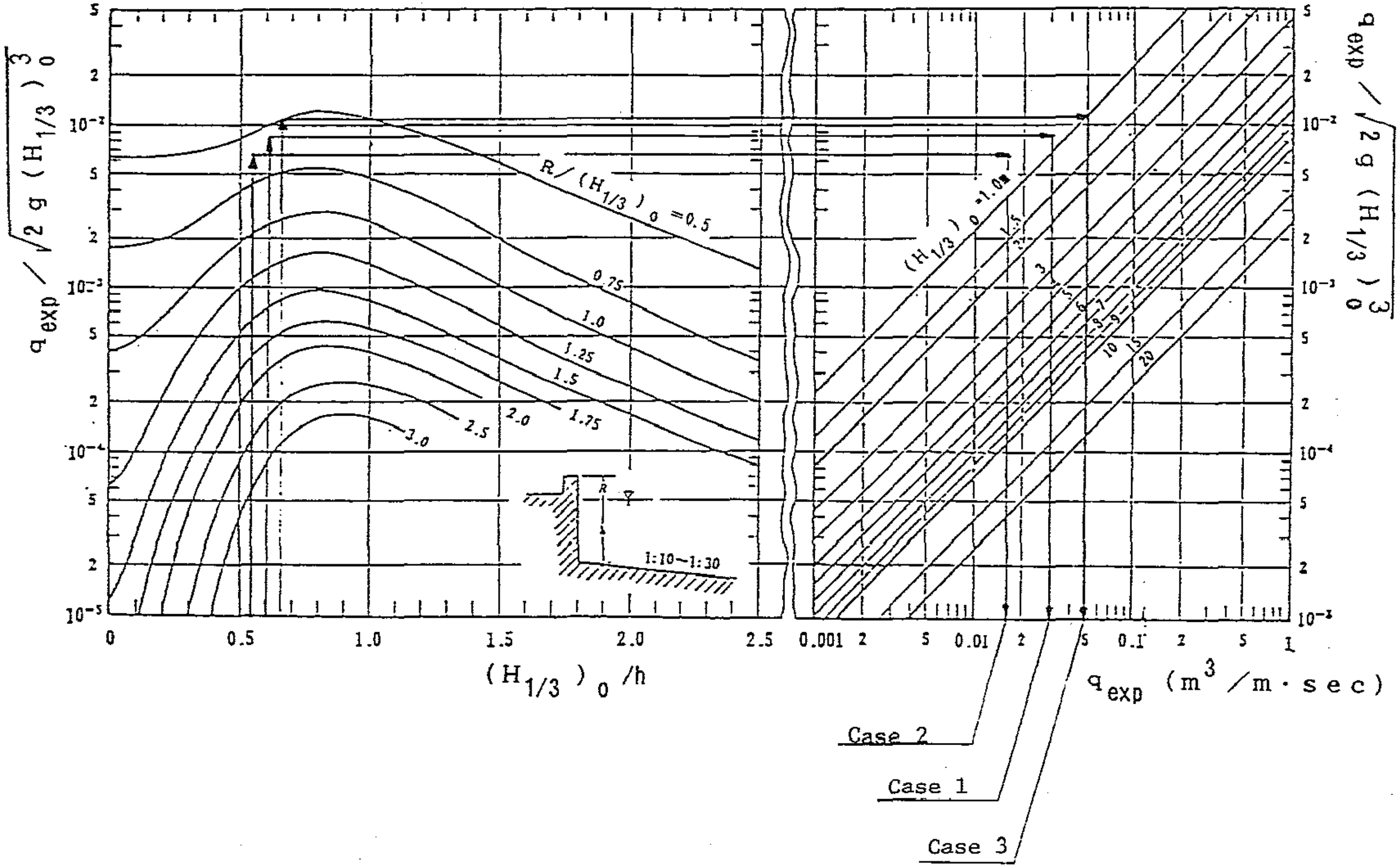


Fig. 5-11 Diagram to estimate the rate of wave overtopping.

b) Zones II and III

In consideration of the topography, distance from the reef edge, water depth, development proposals for Male' reclamation, effective utilization of the existing detached breakwaters, navigation route plans along the inland side of the existing detached breakwaters and calmness in the navigation route area as well as ease and cost of construction, the detached breakwaters in these zones are arranged in virtually the same positions as those of the existing detached breakwaters.

Based on the deliberations on Zone I above, the length of the detached breakwater was designed to be 100m or longer, and the opening width was designed to be 40m.

The detached breakwaters shall be so arranged as to cover the respective zones effectively and to minimize the total crest length of breakwater. The dimensions will be 120m in crest length and 40m in breakwater opening width.

The overall arrangement of the detached breakwaters to be constructed on the southern coast is shown in Fig. 5-12.

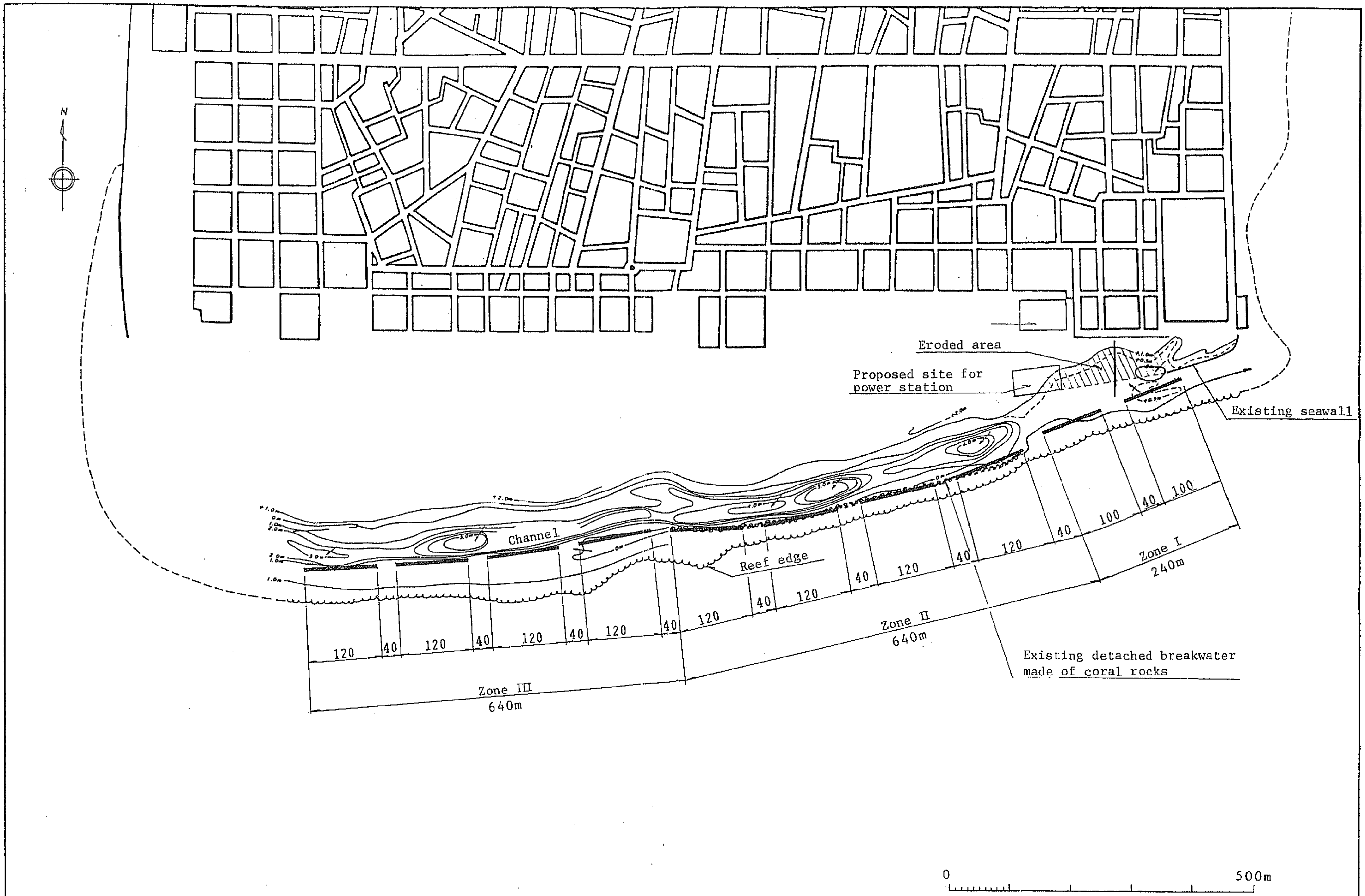


Fig. 5-12 Detached breakwaters construction area and the arrangement plan.

c) Estimation of wave height in the water area behind the detached breakwaters in Zones II and III

i) At the time of the anomalous tide level

In the water area behind the detached breakwaters in Zones II and III, there exists a channel with a depth of about 3m to 5m.

Assuming water depth in the area behind the detached breakwaters to be approximately 4m on an average and a period of incident wave T = 14 sec., wavelength (L) is given as follows:

$$L = 86.5m$$

Since the opening width of the detached breakwater (B) is equal to 40m, B/L becomes 0.46.

From the above values, the diffracted wave height in the water area behind the detached breakwaters is estimated (Fig. 5-14) by using the diagram shown in Fig. 5-13 (B/L = 0.5).

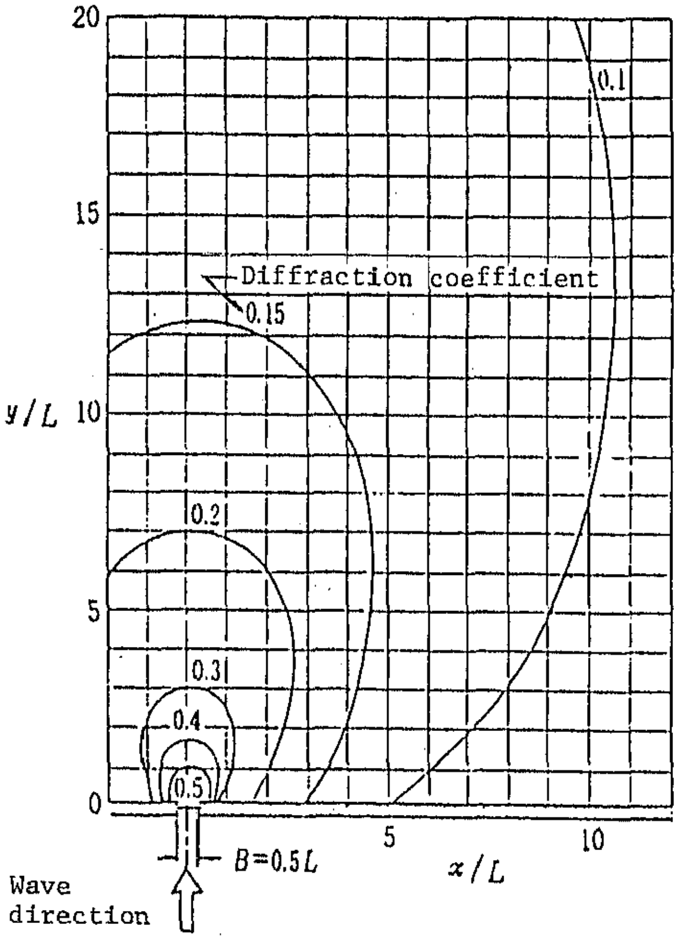


Fig. 5-13 Diffraction coefficient of regular wave by breakwaters with an opening.

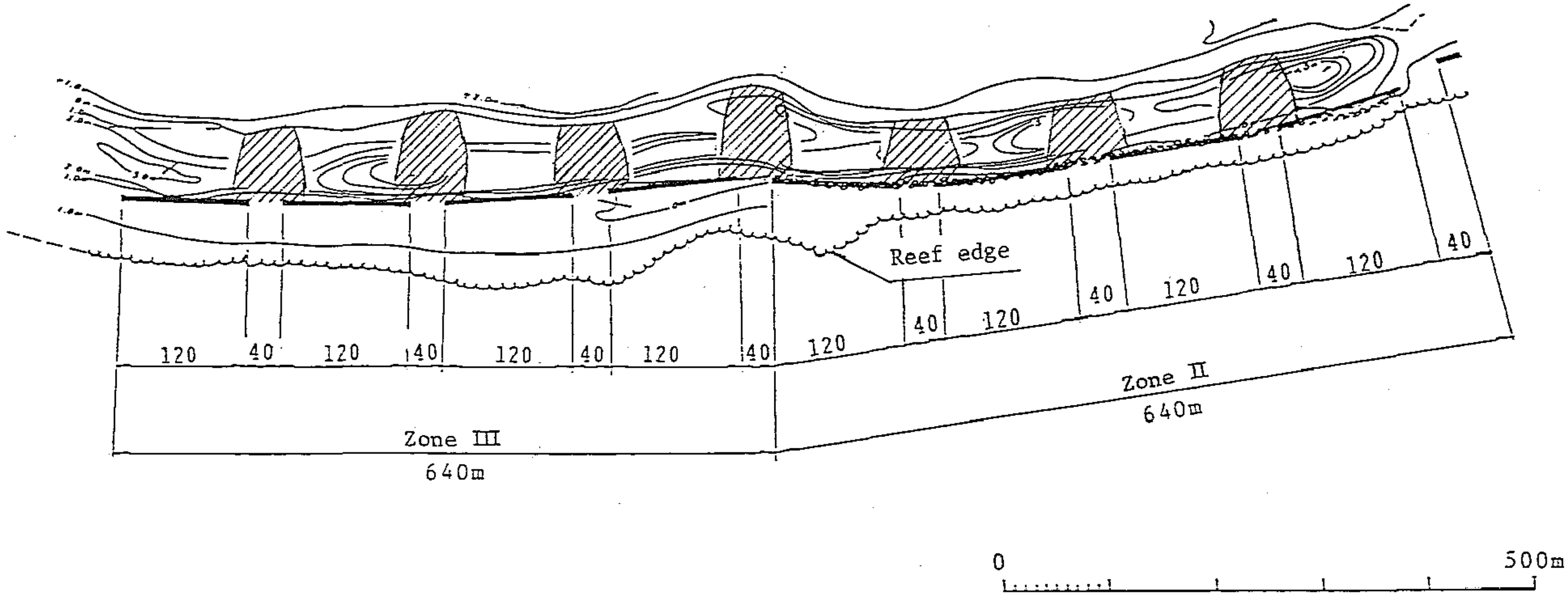


Fig. 5-14 Height of diffracted waves through the openings in Zone II and III under anomalous tide level (Under the condition of incident wave height 2.0m).

Note ; Hatched parts (▨) show the areas where the height of diffracted wave is greater than 1.0m.

Since the wave transmission coefficient through breakwaters is approximately 40%, transmitted wave height from the detached breakwater becomes:

$$2\text{m} \times 0.4 = 0.8\text{m}$$

Diffracted wave height from the breakwater opening evaluated at the central part of detached breakwaters becomes as follows from Fig. 5-13:

$$2\text{m} \times 0.3 = 0.6\text{m}$$

Wave height in the central part of the detached breakwaters becomes as follows by superimposing the transmitted and diffracted waves:

$$\sqrt{0.8^2 + 0.6^2} = 1\text{m}$$

Wave height of about 1m is therefore expected at the time of an anomalous high tide along the navigation route in the water area behind the detached breakwaters.

ii) Wave height under normal conditions

Assuming the wave height and period are 1m and 10 sec., respectively, under normal conditions, wave height distribution in the area behind the detached breakwaters is estimated to be as shown in Fig. 5-15.

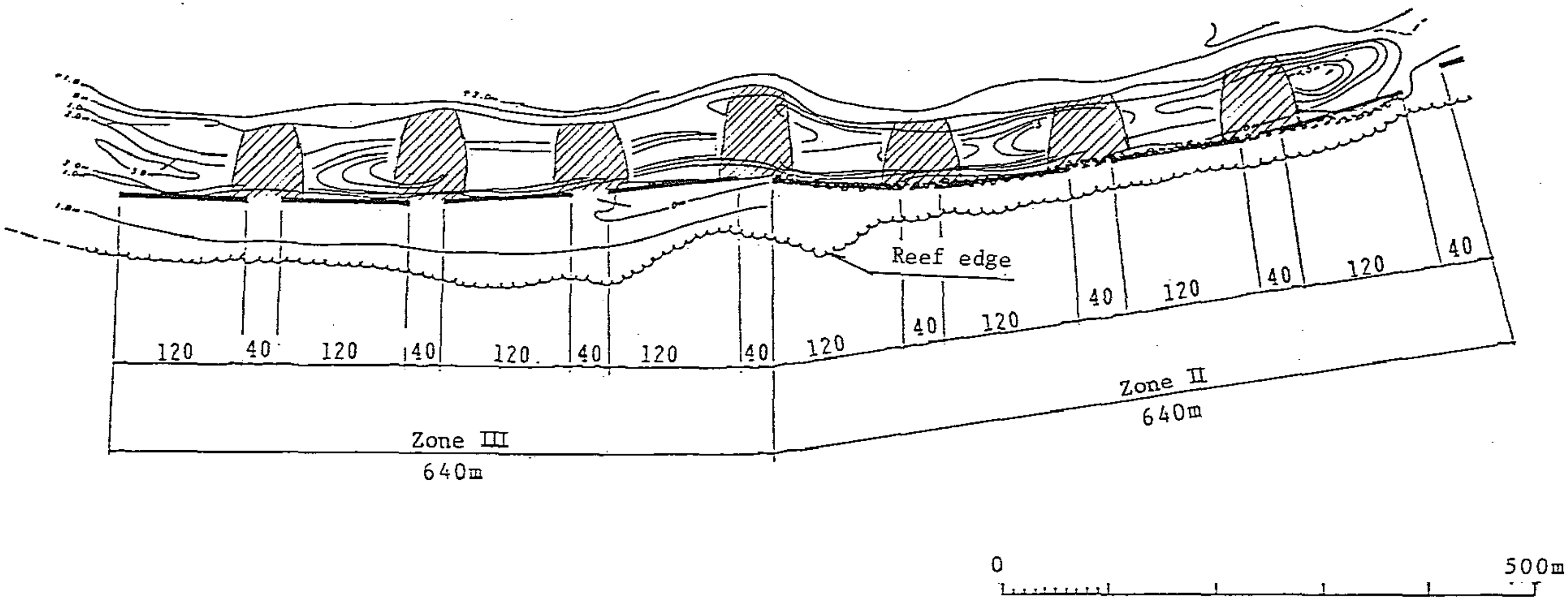


Fig. 5-15 Height of diffracted waves through the openings in Zone II and III under ordinary tide level (Under the condition of incident wave height 1.0m).

Notes ; 1) Hatched parts (▨) show the areas where the height of diffracted wave greater than 0.5m.

2) Transmitted wave height behind detached breakwater is about 0.4m.

(2) Design of Section

1) Determination of the required weight of one armour unit

The required weight of an armour unit is calculated based on Hudson's formula:

$$W = \frac{\gamma \cdot H^3}{K_D(\gamma/w-1)^3 \cdot \cot\alpha} \times Fs$$

where W : Weight of an armour unit (ton),

γ : Unit weight of concrete (2.3 ton/m^3),

w : Unit weight of sea water (1.03 ton/m^3),

H : Design wave height (2.0m),

K_D: Stability coefficient depending on the characteristics of an armour unit (8.3),

α : Angle between the slope and horizontal plane (36°52'),

and Fs: Safety factor (1.5).

Substituting the above values into Hudson's formula, we obtain:

$$W = \frac{2.3 \times 2.0^3}{8.3 \times (2.3/1.03-1)^3 \cdot \cot(36°52')} \times 1.5$$

$= 1.34t \rightarrow 2t$ type

Although the nominal required weight of an armour unit is calculated as 2t, a nominal weight of armour unit of 3t has been adopted taking into consideration uncertainty involved in the determinations of the design conditions (wave height and tide level) as well as the importance of the facilities, safety, durability and cost of construction works.

2) Determination of the detached breakwater section

The standard sections of the detached breakwaters in the respective zones are shown in Figs. 5-16 to 5-18.

All sections in Zone I shall be composed solely of a concrete armour unit.

The detached breakwaters in Zone II shall be constructed by utilizing the existing coral rocks as core material and covering it with concrete armour units. Should it be required, because of the relation between the detached breakwaters and existed channel positions, the armour units in the said portion shall be installed as indicated in Fig. 5-18.

All sections in Zone III shall be composed of concrete armour units as in the case of Zone I.

In order to protect the tip of the slope of detached breakwaters from deformation, collapse, etc. caused by waves and tidal currents and further to enhance the safety and durability of the breakwater, the tip of the slope shall be positioned after excavating the reef to a depth equivalent to the size of one armour unit, as indicated in the standard section in Figs. 5-16 to 5-18.

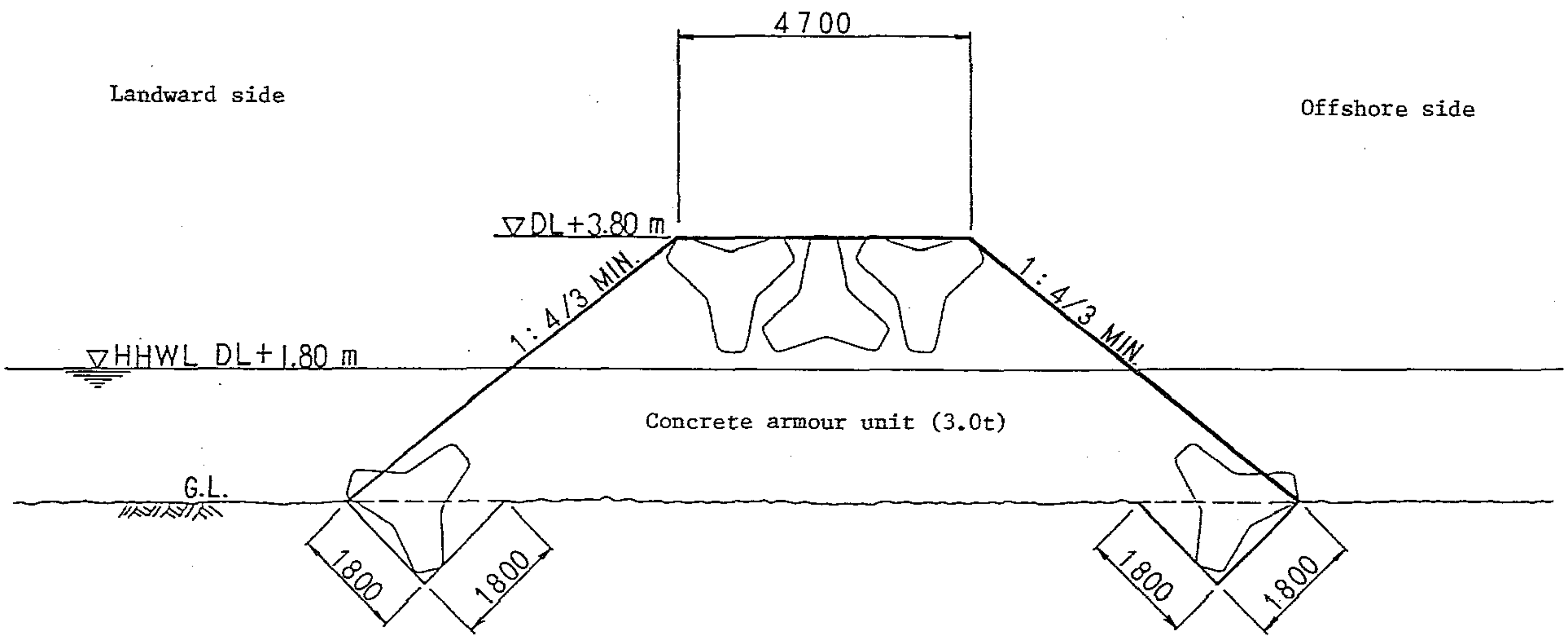


Fig. 5-16 Typical section of detached breakwater (Zone I and II).

[Unit : mm]

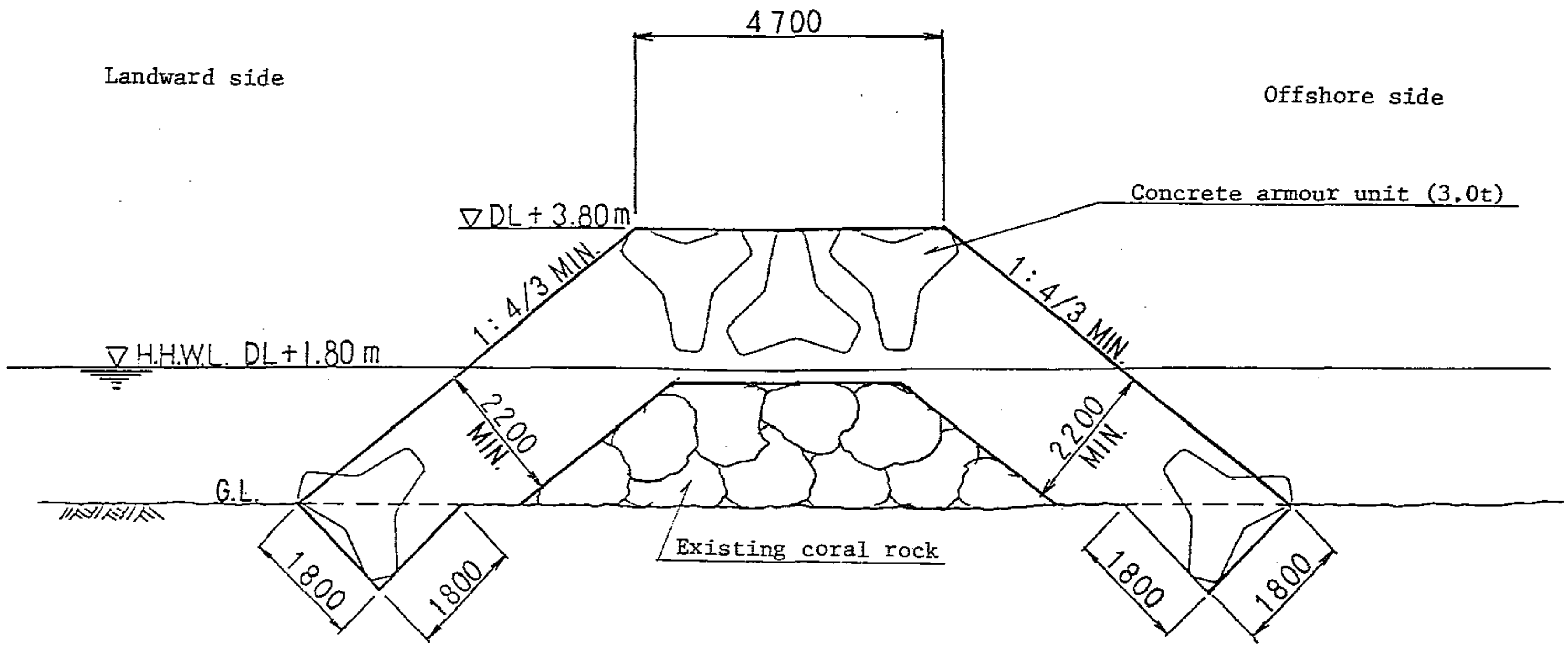


Fig. 5-17 Typical section of detached breakwater (Zone II).

[Unit : mm]

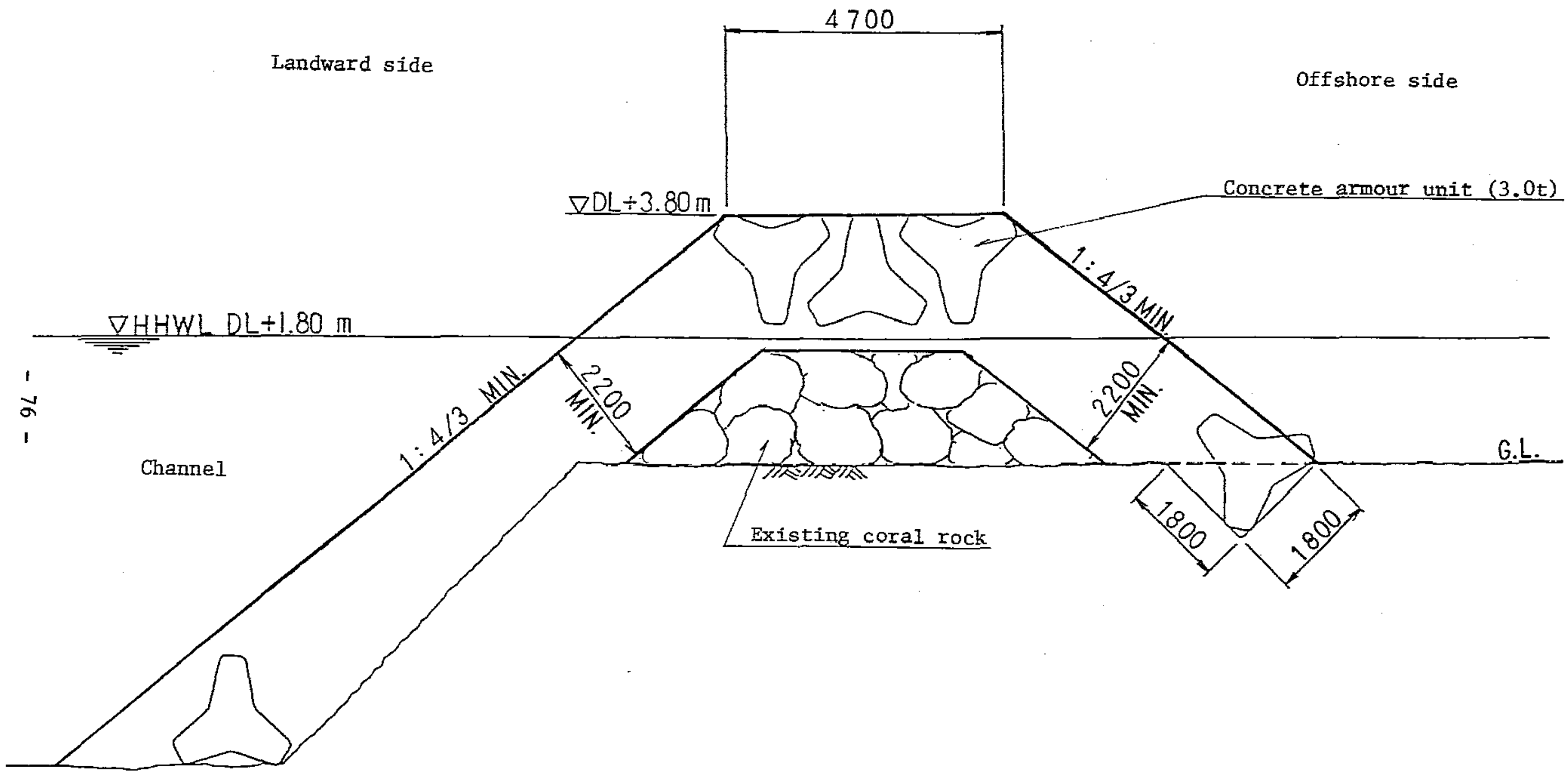


Fig. 5-18 Typical section of detached breakwater in the vicinity of the survey lines No.12 and No.16.

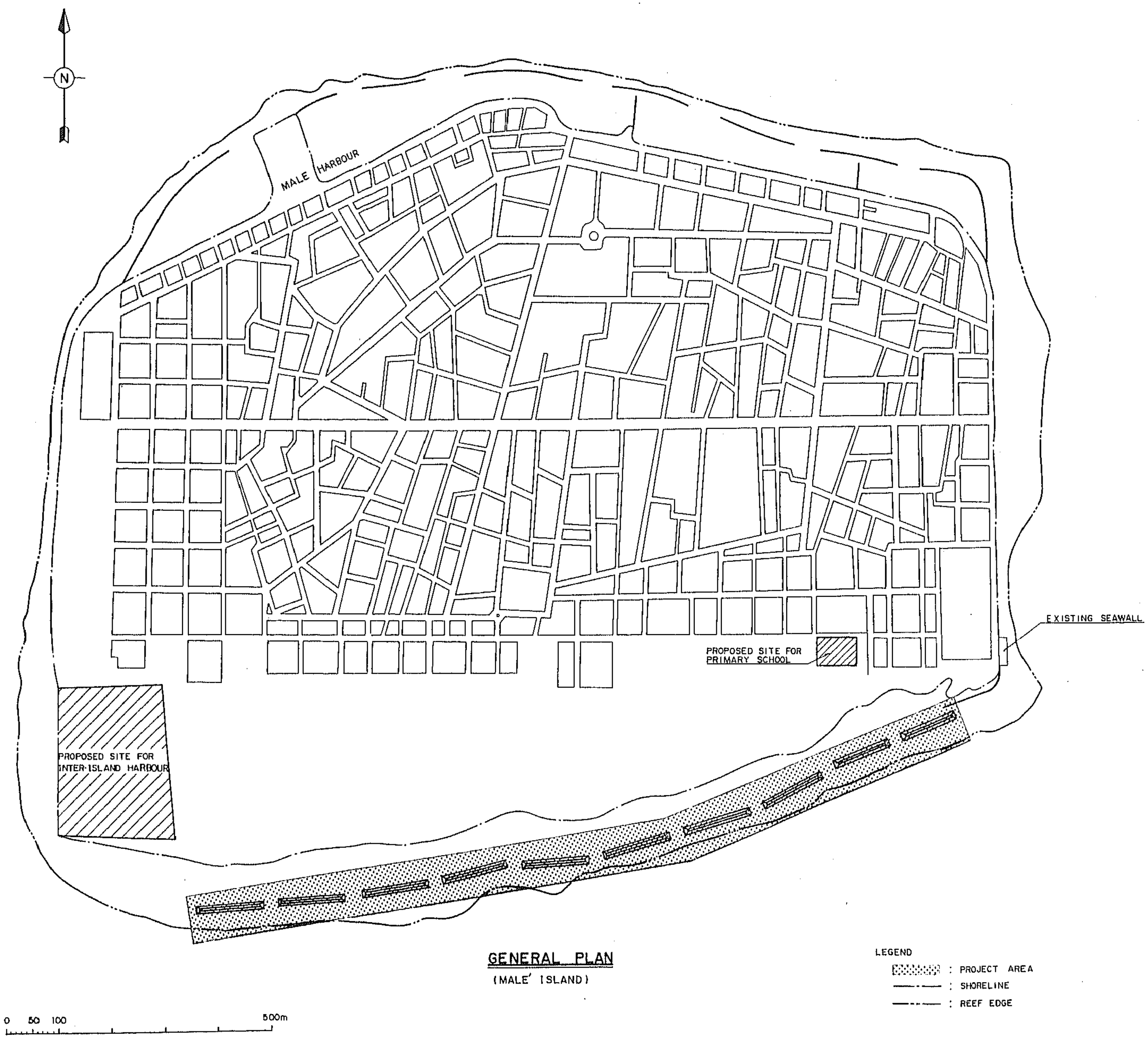
[Unit : mm]

5-3-3 Basic Design Drawings

The basic design drawings for the Project are presented in Drawings No. YMB-01 to 09 in the following pages.

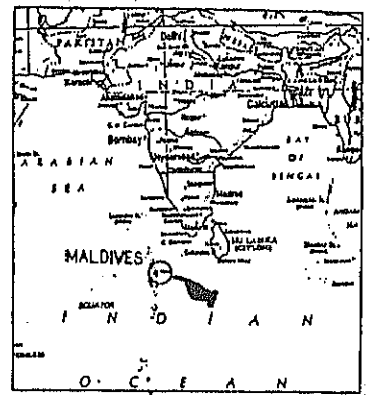
LIST OF BASIC DESIGN DRAWINGS

1. GENERAL LAYOUT OF DETACHED BREAKWATER
2. GENERAL PLAN OF DETACHED BREAKWATER
3. ZONE I PLAN
4. ZONE I SECTION
5. ZONE II PLAN
6. ZONE II SECTION (1/2)
7. ZONE II SECTION (2/2)
8. ZONE III PLAN
9. ZONE III SECTION

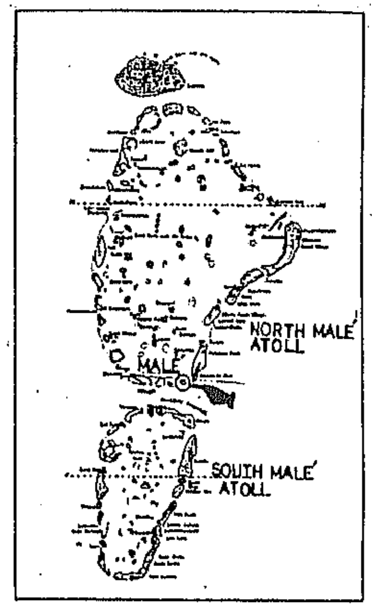


GENERAL PLAN
(MALE' ISLAND)

LEGEND
: PROJECT AREA
: SHORELINE
: REEF EDGE

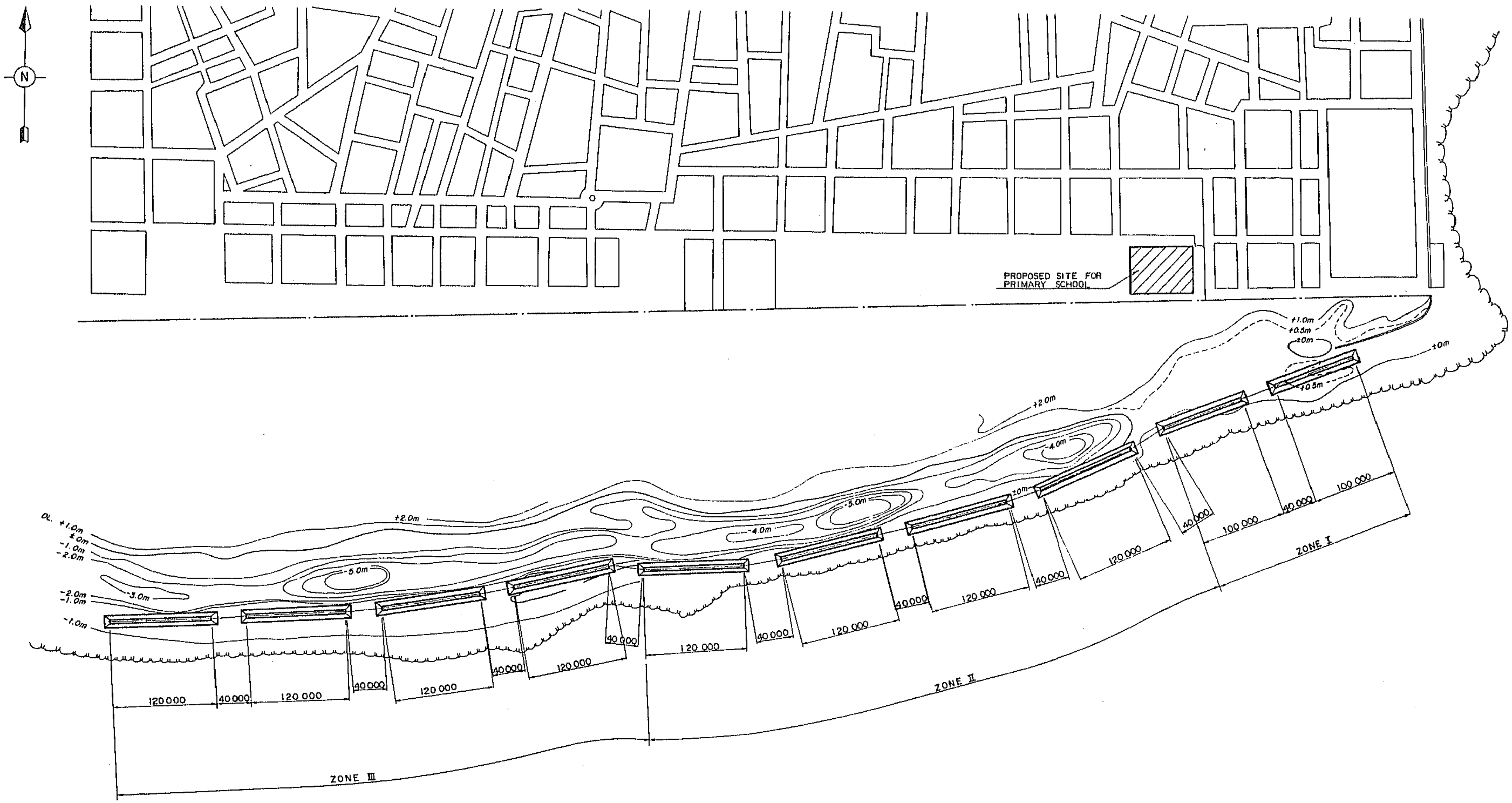


THE WEST COAST OF INDIA



MALE' ATOLL

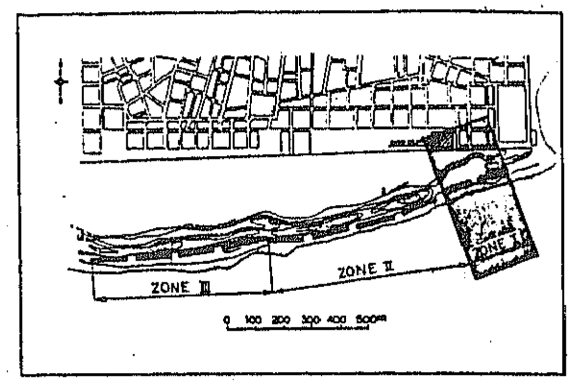
THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'			
GENERAL LAYOUT OF DETACHED BREAKWATER			
Date	NOV. 05, 1987	Drawing No.	YMB-01
JAPAN INTERNATIONAL COOPERATION AGENCY			



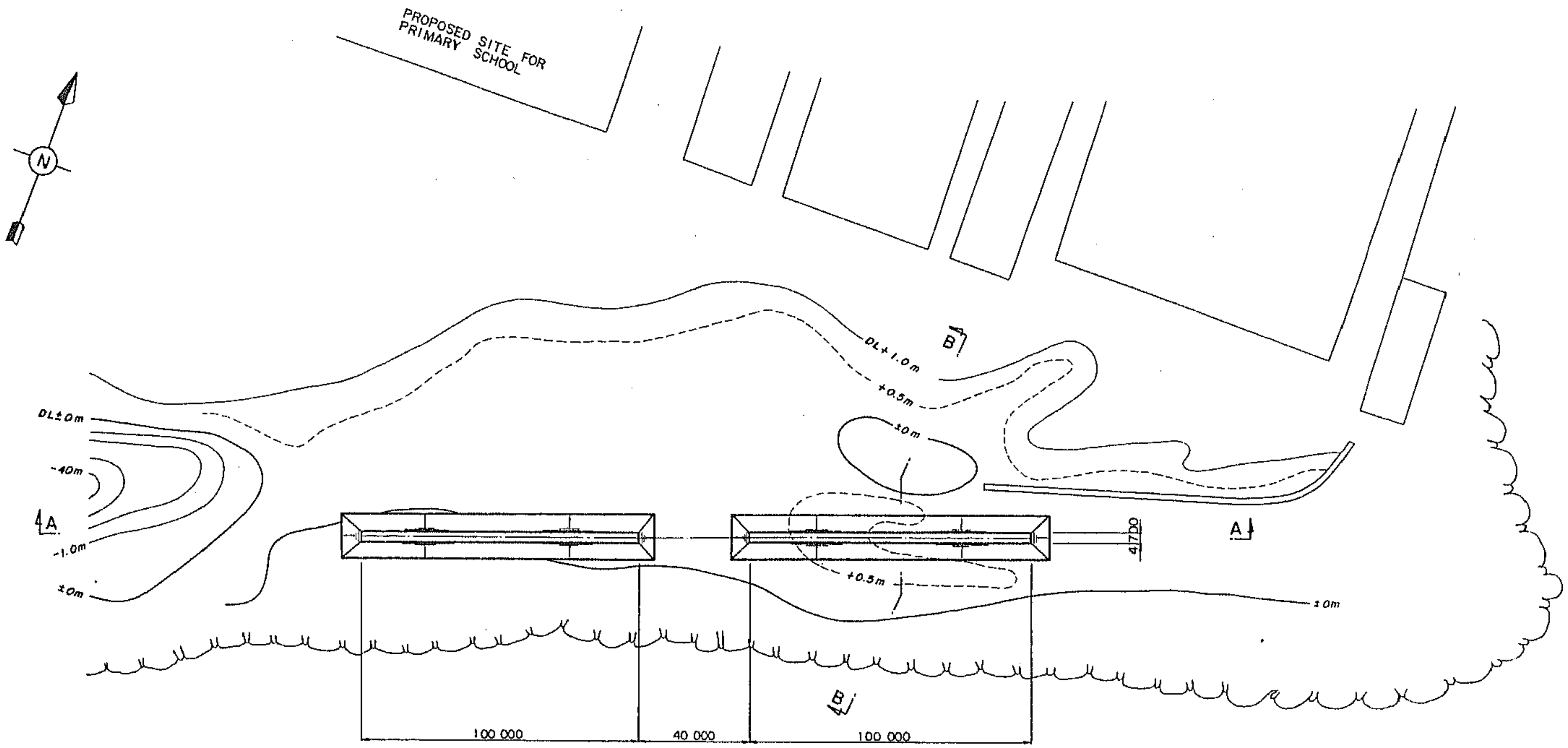
ARRANGEMENT OF DETACHED BREAKWATER

SCALE = 1/2,500

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'			
GENERAL PLAN OF DETACHED BREAKWATER			
Date	NOV. 05, 1987	Drawing No.	YMB-02
JAPAN INTERNATIONAL COOPERATION AGENCY			

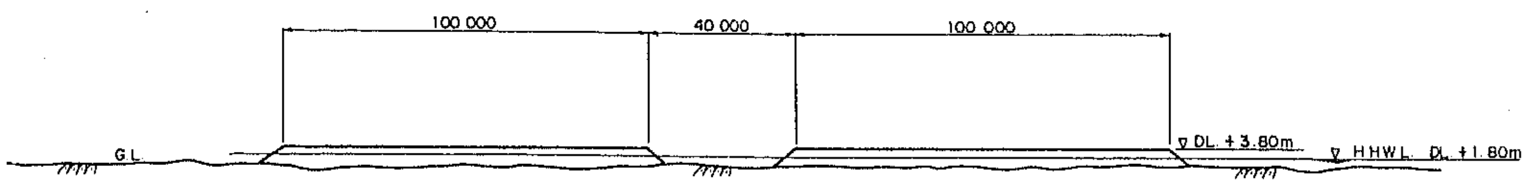


LOCATION MAP



PLAN OF ZONE I

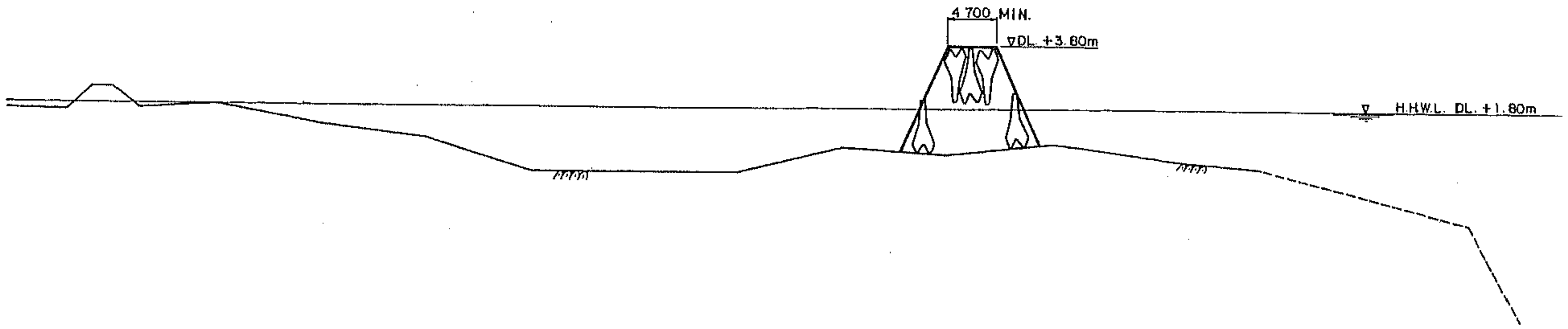
SCALE = 1/1000



SECTION A - A

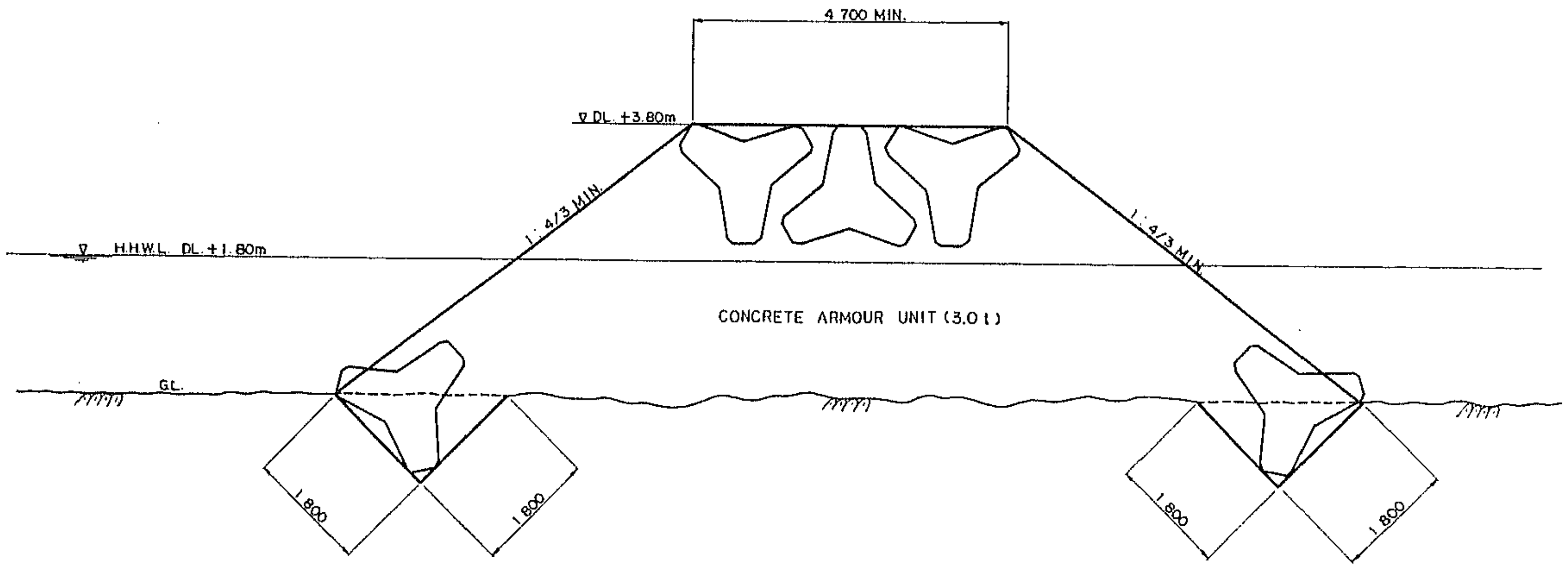
SCALE=1/1000

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'			
ZONE I PLAN			
Date	NOV. 05 ,1987	Drawing No.	YMB - 03
JAPAN INTERNATIONAL COOPERATION AGENCY			



SECTION B - B

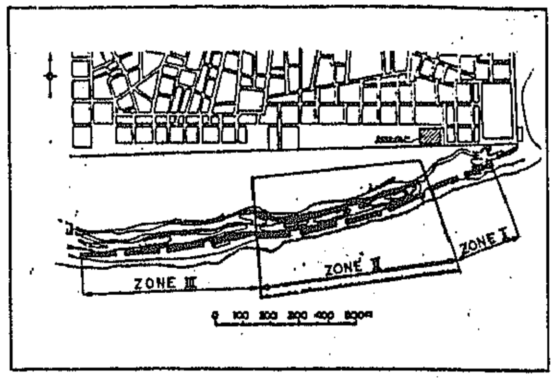
SCALE (V = 1/100, H = 1/300)



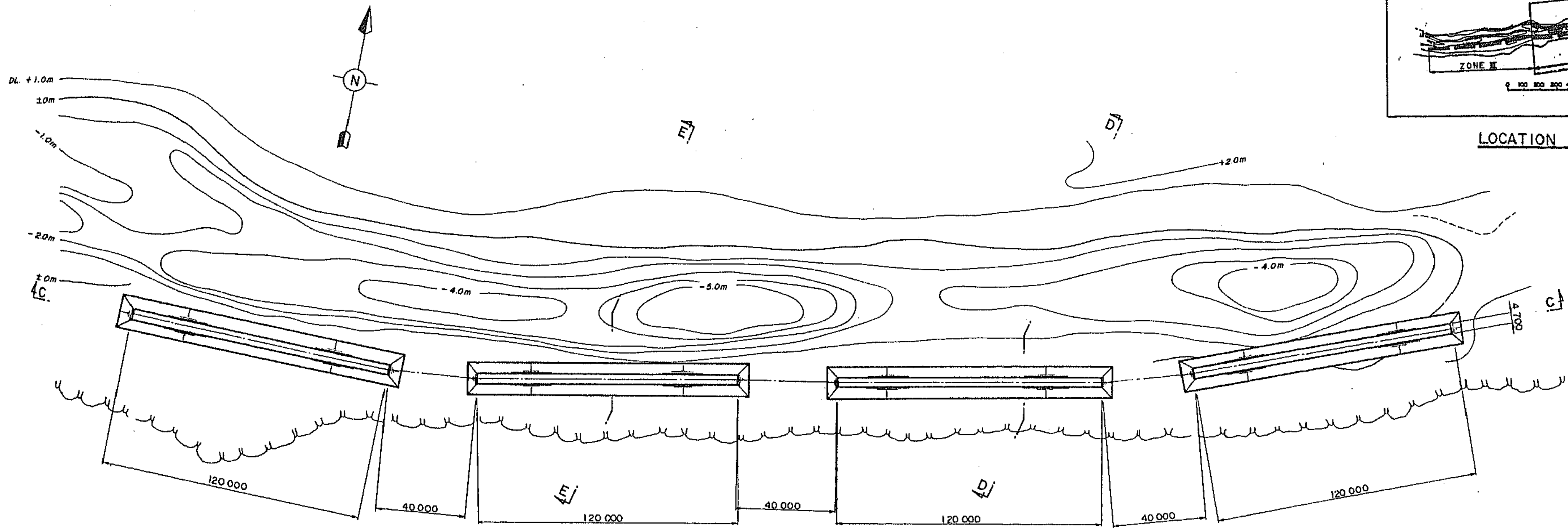
TYPICAL SECTION OF DETACHED BREAKWATER

SCALE = 1 / 50

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'			
ZONE I SECTION			
Date	NOV. 05, 1987	Drawing No.	YMB-04
JAPAN INTERNATIONAL COOPERATION AGENCY			

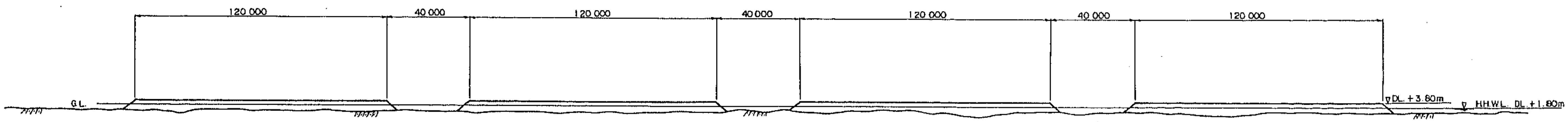


LOCATION MAP



PLAN OF ZONE II

SCALE = 1/1000



SECTION C - C

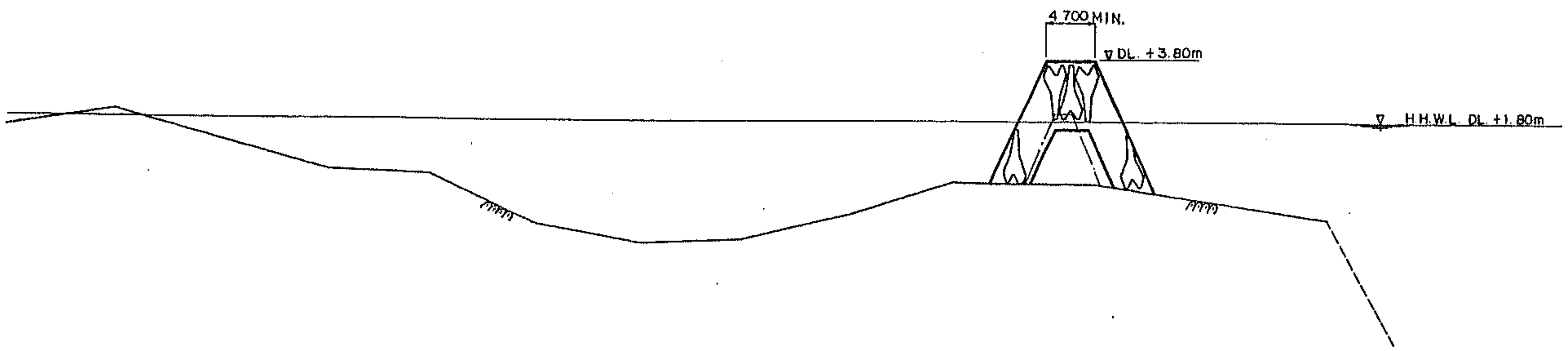
SCALE = 1/1000

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'

ZONE II PLAN

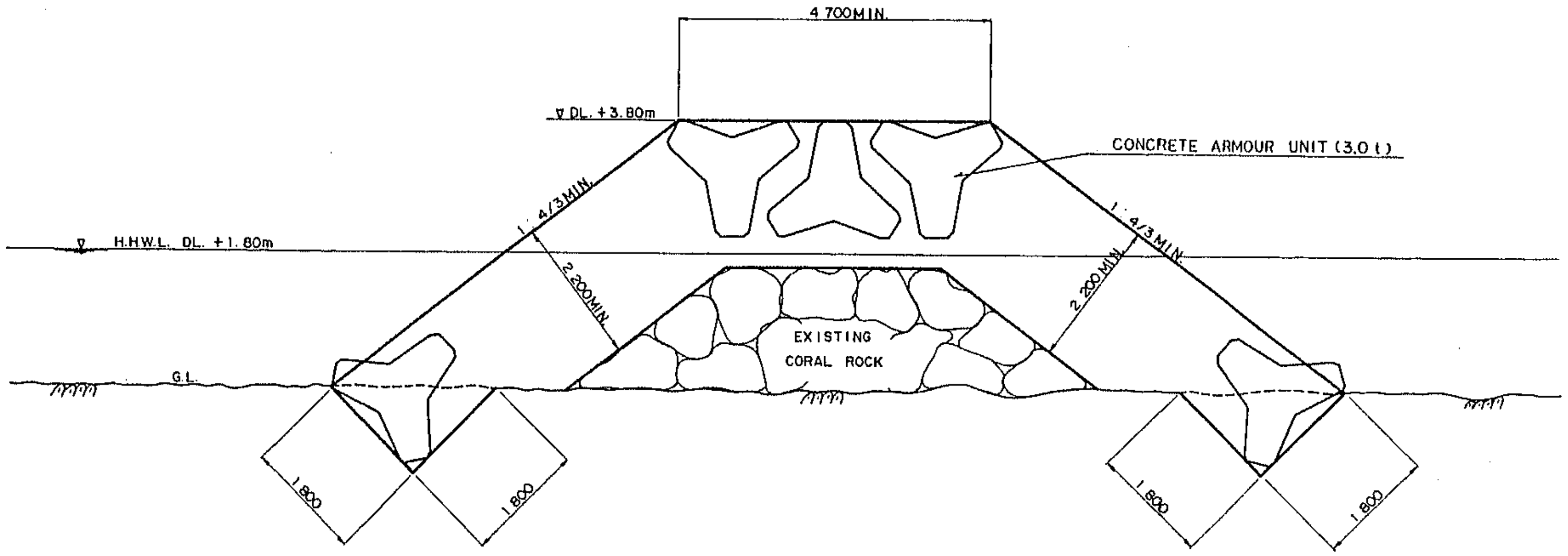
Date	NOV. 05, 1987	Drawing No.	YMB-05

JAPAN INTERNATIONAL COOPERATION AGENCY



SECTION D - D

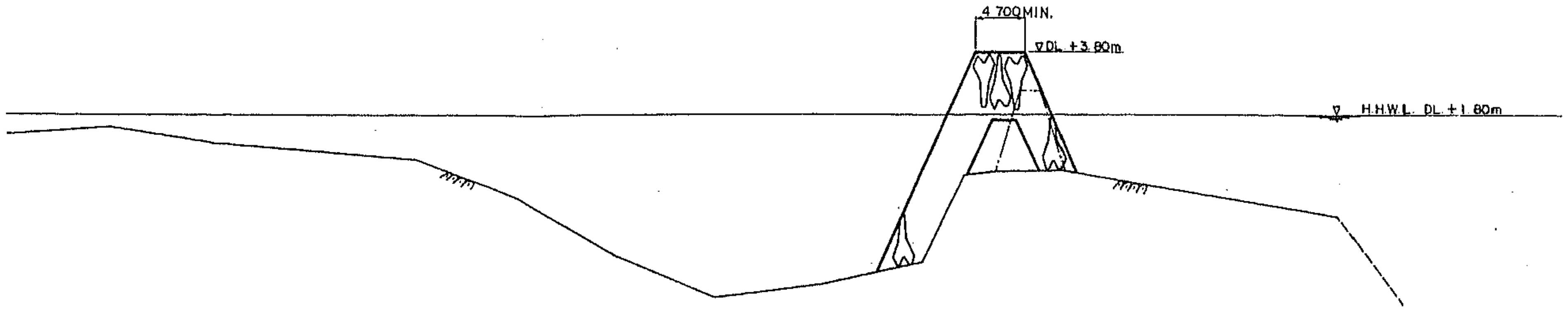
SCALE (V = 1/100, H = 1/300)



TYPICAL SECTION OF DETACHED BREAKWATER

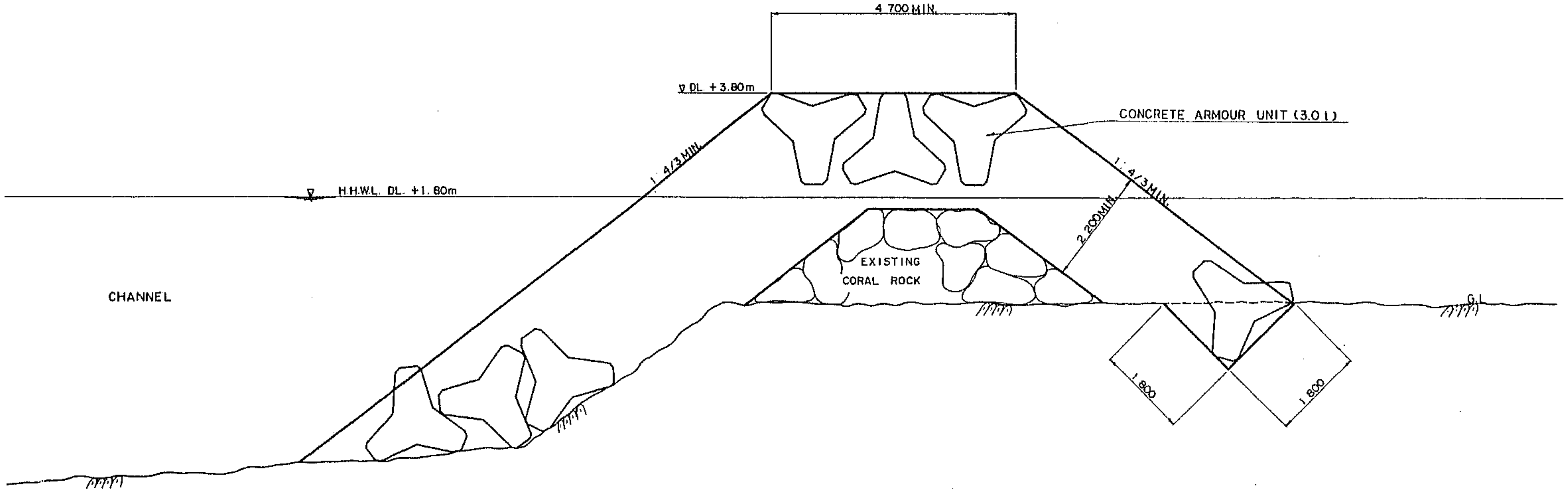
SCALE = 1/50

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'			
ZONE II SECTION (1/2)			
Date	NOV. 05, 1987	Drawing No.	YM8-06
JAPAN INTERNATIONAL COOPERATION AGENCY			



SECTION E - E

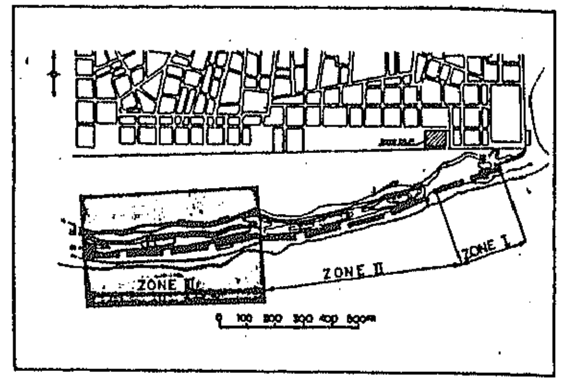
SCALE (V = 1 / 100, H = 1 / 300)



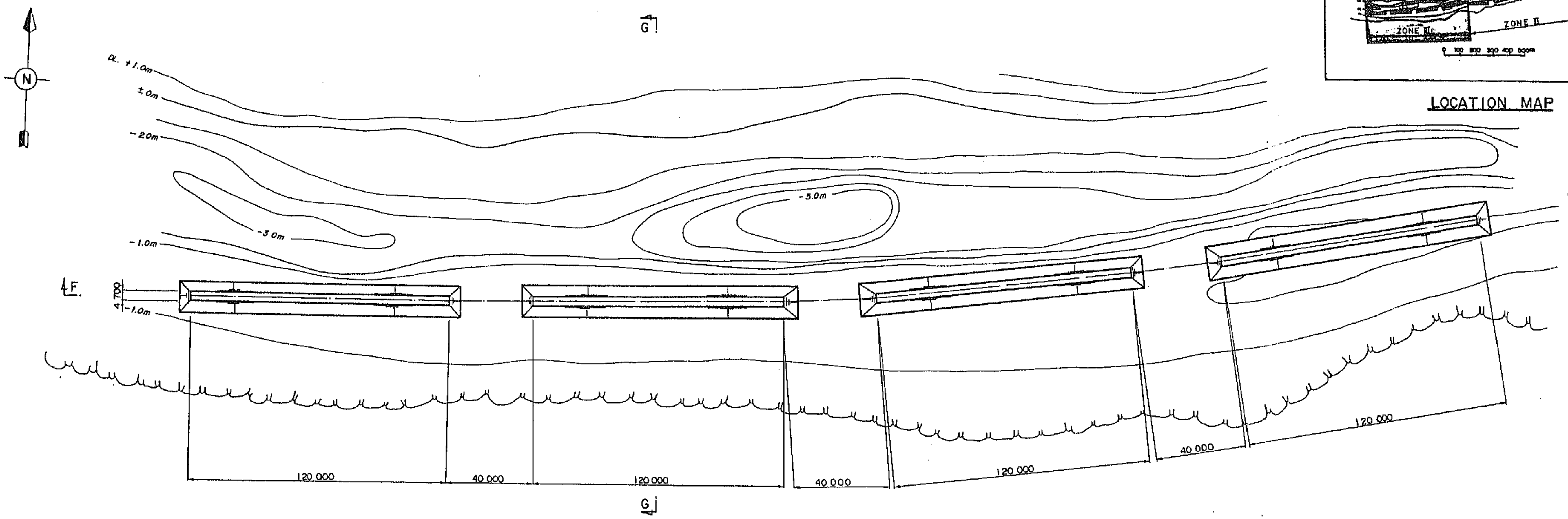
TYPICAL SECTION OF DETACHED BREAKWATER

SCALE = 1 / 50

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE			
ZONE II SECTION (2/2)			
Date	NOV. 05, 1987	Drawing No.	YMB – 07
JAPAN INTERNATIONAL COOPERATION AGENCY			

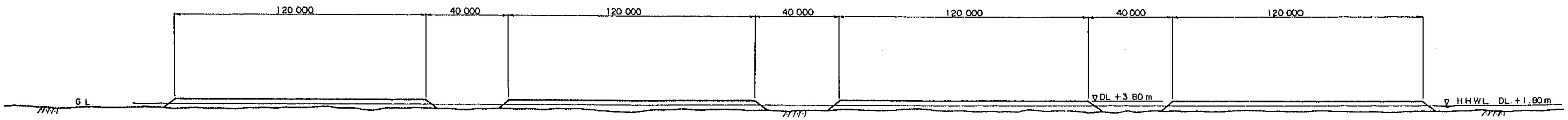


LOCATION MAP



PLAN OF ZONE III

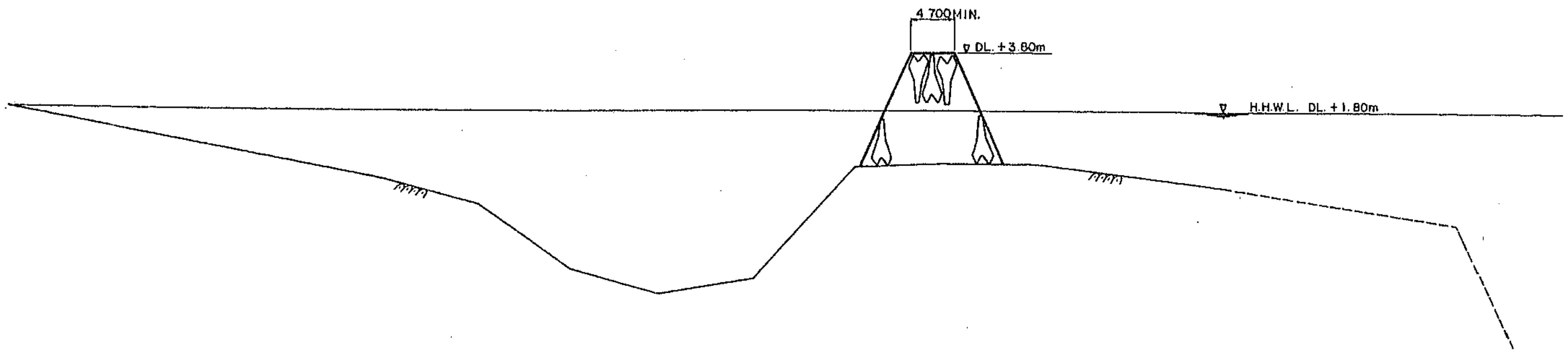
SCALE = 1/1000



SECTION F - F

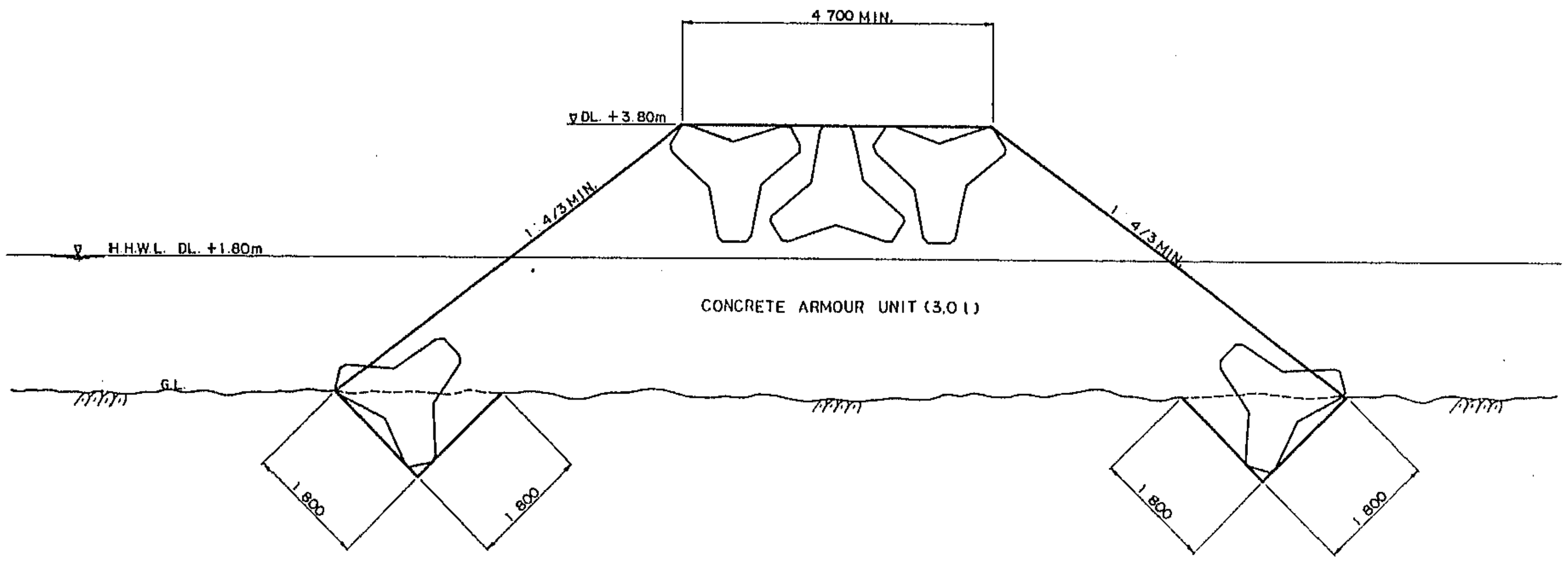
SCALE = 1/1000

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE			
ZONE III PLAN			
Date	NOV. 05, 1987	Drawing No.	YMB - 08
JAPAN INTERNATIONAL COOPERATION AGENCY			



SECTION G - G

SCALE (V = 1 / 100, H = 1 / 300)



TYPICAL SECTION OF DETACHED BREAKWATER

SCALE = 1 / 50

THE PROJECT OF CONSTRUCTING BREAKWATERS ON SOUTHERN COAST OF MALE'			
ZONE Ⅲ SECTION			
Date	NOV. 05, 1987	Drawing No.	YMB-09
JAPAN INTERNATIONAL COOPERATION AGENCY			

5-4 Execution Plan

5-4-1 Precautions for the Construction of Detached Breakwaters

The breakwaters should be constructed while paying particular attention to the following:

(1) The nature of this work should be understood sufficiently by the residents living near the Project site so as to obtain their cooperation and assistance and prevent any accident to a third party.

(2) Inspection of cranes and other heavy-duty construction equipments, wires, etc. shall be performed regularly to prevent the occurrence of accidents.

(3) Whenever construction equipments and other vehicles pass on the roads within the island, any person involved in such a work will strictly abide by the local traffic rules and pay full attention in order to avoid accidents and damages to the roads.

(4) Should a high tide occur, sufficient care will be taken to prevent the flooding of construction materials, private power plants and office facilities.

(5) Since some of the works will be carried out in the breaker zone, the particular attention shall be paid to high tides and waves in order to prevent occurrence of accidents.

(6) Any rock excavation will be executed so as to avoid causing damages to local residents through vibration, noise and so forth.