The above activities will be carried out for a short period in one place. In addition, heavy works such as pile driving works and blasting works will not be carried out for the Seawall Project so that there is no source of generation of large vibration. Therefore, the generated vibration is not expected to influence the resident's lives.

(11) Marine Biota

On the north, south and west side of Male', demolition of existing structures will generate turbid water during the construction stage. There are fish and coral around Male' island. It may be possible that marine life will be influenced by turbid water. Coral fish will flee from the turbid water body while high concentration levels continue. These fish, however, are expected to come back into the reef after turbid water is no longer generated.

The generated turbid water contains coral sand and pieces of concrete blocks from demolition of existing structures. Generally speaking, if the mouth of polyparies is covered with small size sediments negative impact will take place on its growth. Also, turbid water has a negative effect on the photosynthesis by Zooxanthella. Provided that the amount of small size sediment covering the mouth of polyparies will be less than the amount coral can remove by itself using tentacles, stream by cilia and so on, negative impacts are not considered to be serious.

Taking the construction method and structural materials into consideration, it seems reasonable to suppose that not so much turbid water will be generated by demolition of the existing structures. Also, these small substances will be diffused by currents and waves. Therefore, the coral on the north, south and west side of Male' will not be seriously influenced.

In the northern part of east side of Male' however, coral may disappear due to the reclamation work.

4.2.2 After Construction

(1) Coastal Use

a) East Coast

The east coast is often used for washing tableware and kitchen utensils by four or five residents living in this area at the present time. After reclamation, however, they will not be able to wash their tableware, because activities of

washing tableware may cause deterioration of water quality. If they need a washing place, some facilities must be provided in the inner island.

(2) Recreation

a) East Coast

The east coast is popular for recreational activities with Male' residents. The reclaimed area in the northern part of the east coast is also used for fishing and swimming. If the inner reef of the northern part of the east coast is reclaimed, residents will not be able to enjoy marine recreational activities in the inner reef. Residents, however, will be able to walk and fish on the seawall. The step type seawall in the southern part of east coast can be enjoyed by swimmers.

Maldives government has a "Sport and Recreational Development Plan" for the reclaimed area. If recreational facilities such as tennis courts and a swimming pool are to be built in the reclaimed area after the construction, residents will be able to enjoy sports.

The front of the southern part of the east coast is popular for surfing among young people. This area is the only place available for surfing around Male' island. After construction, this area can continue to be used for surfing as before.

(3) Aesthetics

a) West Coast

There are residential areas and the Social Education Center, and there will be a new Indira Gandhi Memorial Hospital (under construction). Furthermore, Marine Drive will pass through the northern beach side in the future, to be named Marine Drive Construction Project. Traffic volume may increase after the building of the road. Therefore, the construction of the proposed structures should focus on aesthetic aspects.

At present, the horizon can barely be seen from the view point that is of the height of Maldives at 150 cm (see photo 4.2.1). If the new structures are built up more than 20 cm above the existing structures, the horizon cannot be viewed any more. The height of the proposed structures on the west side will be 2.60 m above the tidal datum level so that residents will be able to see the horizon.

Furthermore, there are some broken parts of the existing seawall at present. The seawall structures will be improved in aesthetical aspect after construction and not be an eyesore.

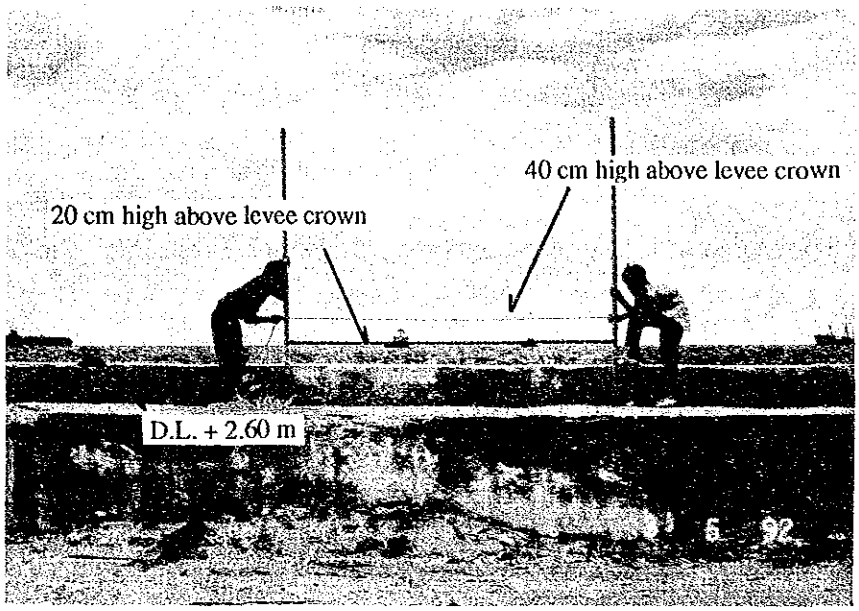


Photo 4.2.1 Aesthetical View of West Coast

b) East Coast

The east coast of Male' is very popular for walking and recreational activities. There is a reef flat which expands from the shoreline, and Marine Drive passes along the beach of the east coast of Male'.

The proposed plan on the east coast has three types of structures on the northern, center and the southern parts as follows:

the northern part of east coast:	reclaimed land
the center part of east coast:	step type seawall
the southern part of east coast:	seawall with wave dispersion concrete blocks

In the northern part of the east coast, the reclaimed area is expected to have 100 m of width from the shoreline after the reclamation. Since tennis courts and other facilities will be constructed in the reclaimed area, residents who come to

Marine Drive may not see the reef flat. After construction, the field of view from Marine Drive will include a park, sport facilities and garden plants. Furthermore, residents will be able to see the reef flat, if they come to the new shoreline. Therefore, the aesthetics for the residents is not expected to deteriorate.

In the southern part of east coast, residents will be able to see the horizon and surfing on the shoreline, because the height of the seawall is 1 m above ground level. However, wave dispersion concrete blocks may be barely seen from the seawall.

In the center part of east coast, residents will have easy access to the beach after the construction of the step type seawall is completed, and residents who sit on the sloping structure, will be able to see the horizon, waves and people enjoying swimming. Therefore, aesthetical conditions are expected to be much better than the existing conditions.

c) South Coast

The south coast of Male' is to have 2 types of seawalls: the eastern part of south coast is to have a retaining wall, and the central and western parts of south coast are to have a quaywall type. On the eastern part, the height of the existing crown is 0.8 m above ground level at present. The proposed structures have heights between 0.4 m and 0.6 m above ground level. Therefore, owing to the fact that the proposed structure is lower than the existing one, the field of view will not be hindered by the erection of the proposed structures without existing detached breakwater made of wave dispersion concrete blocks such as tetrapods.

On the central and western parts of south coast, the coastal structure has a quaywall, almost the same level as the ground height. Therefore, the field of view on the shoreline to the seaward side will not change.

(4) Coastal Hydrology

a) East Coast

At the present time, the reef flat expands more than 150 m away from the shoreline. The reef flat between the shoreline and the reef ridge has a length of less than 3 m, and the reef flat is shallower than that of the reef ridge. Main currents flow in from out of the reef ridge, and flow along the reef ridge. Therefore, an outline of current conditions will not change after reclamation of the inner reef.

(5) Marine Biota

a) West Coast

The proposed structures are planned to be built on the seaward side several meters along from the exiting shoreline. Therefore, the coral reef in the advanced area may die. Other marine life, however, may not receive such serious impacts.

b) East Coast

The coral in the proposed reclaimed area, which is approximately 48,000 m^2 may vanish altogether after the reclamation, and also the area of nursery ground for reef fish will decrease. Thus, marine biota will be influenced by the reclamation.

As for the proposed artificial beach, assuming that coral sand will be spread on the surface, coral under the sand fill may die. However, other marine life such as reef fish and coastal fauna will not receive serious impact and some of the beach marine life may increase.

4.3 Conclusion

Proposed structures are shown in Fig. 4.3.1.

During the construction period, impacts caused by the proposed project will not be serious for the environment, because, the working period is short, and the construction of structures will be carried out in sections.

Results of the environmental study after construction are described as follows.

- West Coast
  Proposed structures on the west coast will not receive serious impact.

- East Coast
  Marine life in the reclaimed area will be influenced after construction. However, impacts to the other environmental elements will not be serious. In terms of the human activities, new recreational facilities are being planned in the project, including the artificial beach and reclaimed area so that residents can enjoy sports and other activities as before.

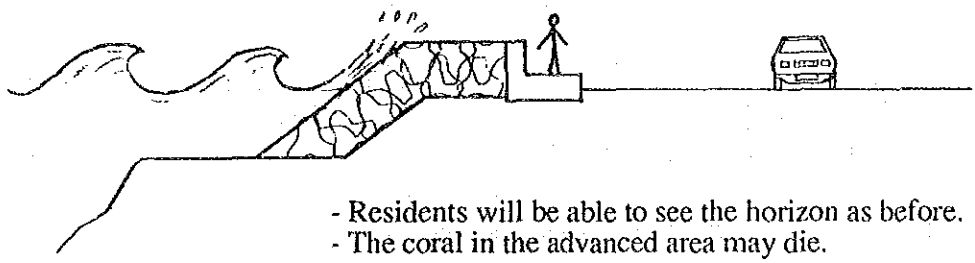
- South Coast
  Proposed structures on the south coast will not change from existing structures. Therefore, the south coast area will not be influenced after construction.

- North Coast
  Type of proposed structures are similar to existing structures. Therefore, the north coast area will not be influenced after construction.

The east coast can be enjoyed by residents at present. Provided that following facilities are built, recreational activities will increase.

- Plantation
- Terrace
- Public restroom
- Pictures on the seawall
- Fence
- Promenade
- Lighting equipment
- Ditch on the road sides

WEST COAST



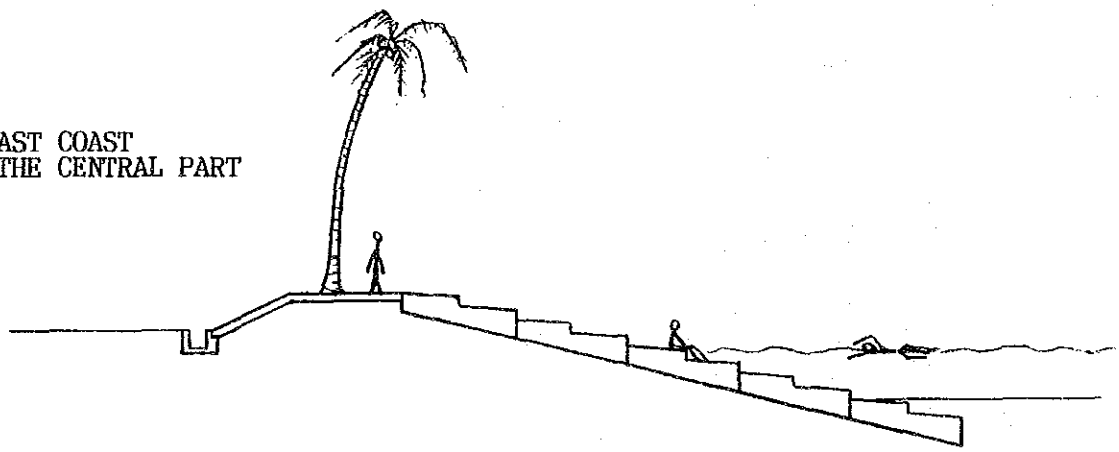
- Residents will be able to see the horizon as before.
- The coral in the advanced area may die.

EAST COAST
THE NOUTHERN PART

To be reclaimed by Government of Maldives

- Maldive's government has a "Sport and Recreation Development Plan" for the reclaimed area.
- Reclaimed area will vanish after the reclamation.

EAST COAST
THE CENTRAL PART



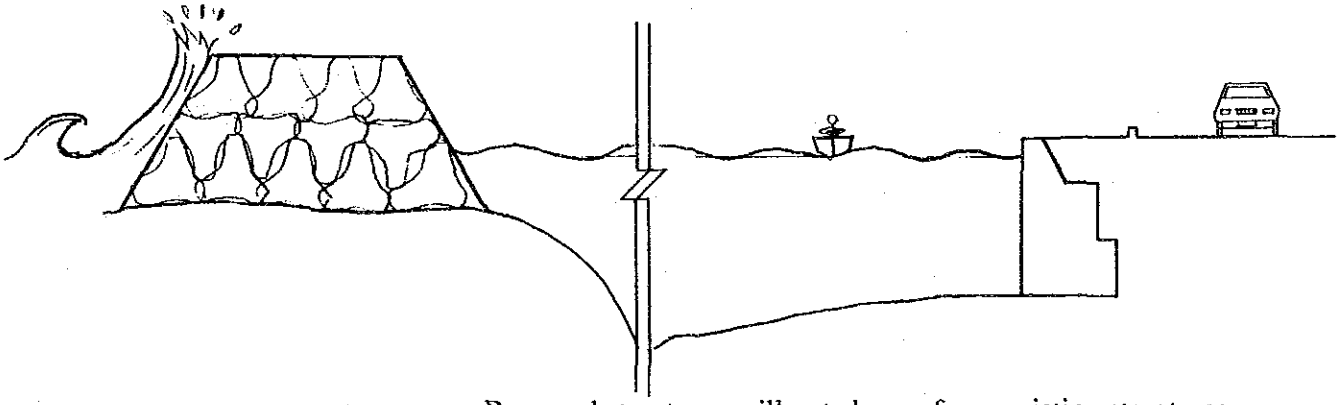
- Step type seawall in the southern part can be enjoyed by swimmers.

Figure 4.3.1 Proposed Structures in Male' Island (1)

EAST COAST
THE SOUTHERN PART

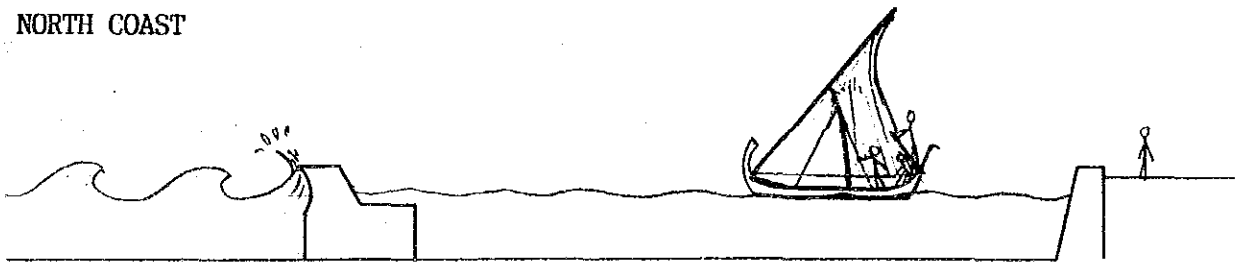
- This area can continue to be used for surfing as before.

SOUTH COAST



- Proposed structures will not change from existing structures.

NORTH COAST



- Proposed structures are similar to existing structures.

Figure 4.3.1 Proposed Structures in Male' Island (2)

Chapter 5. Organization and Management

5.1 Routine Business & Emergency Operation

The scope of this study covers both daily routine business and emergency operations of the Ministry of Public Works & Labour (MPWL).

Two aspects of operations, i.e., daily routine business and emergency operation at the time of disaster (see para 5.4.3) have to be covered by a set of organizations. The first may further be divided into three sections. They are maintenance and repair work of the seashore protecting structures (see para 5.3), recording of oceanographic data (see para 5.4.1), and public relations to the citizens (see para 5.4.2). In order to secure year-round effective operations, continuous training of the staff, and close coordination and communication among the concerned organizations are minimum requirements.

Organizational charts of the government, the MPWL and the MPE are given in Fig. 5.1.1 and 5.1.2, and a job description of the MPWL is given in Supporting Report 1; some statistical data of Male' Island in Supporting Data II.

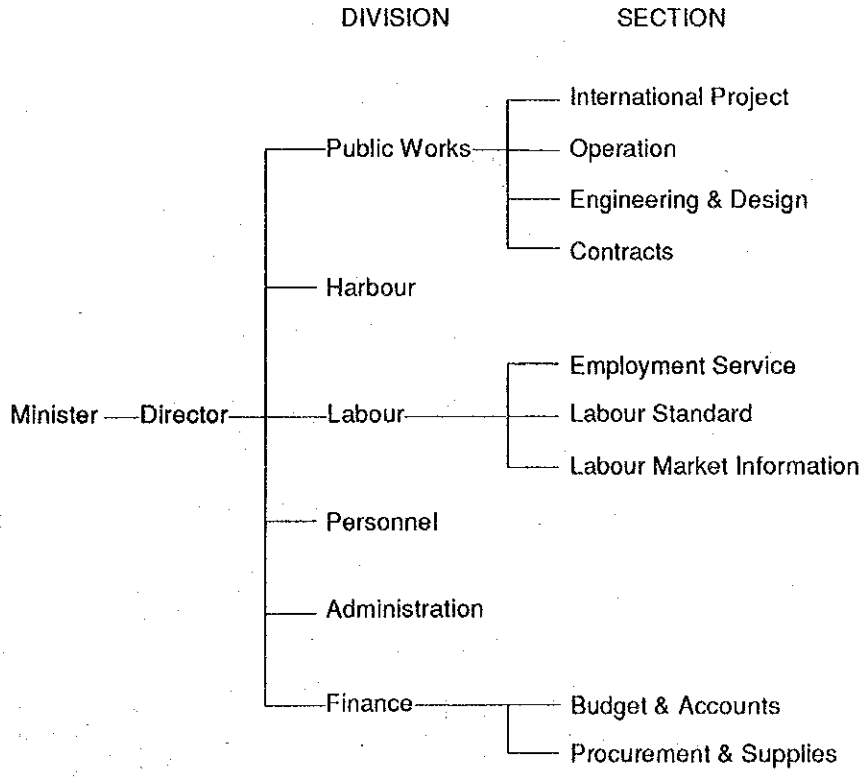


Figure 5.1.1 Ministry of Public Works and Labour: MPWL

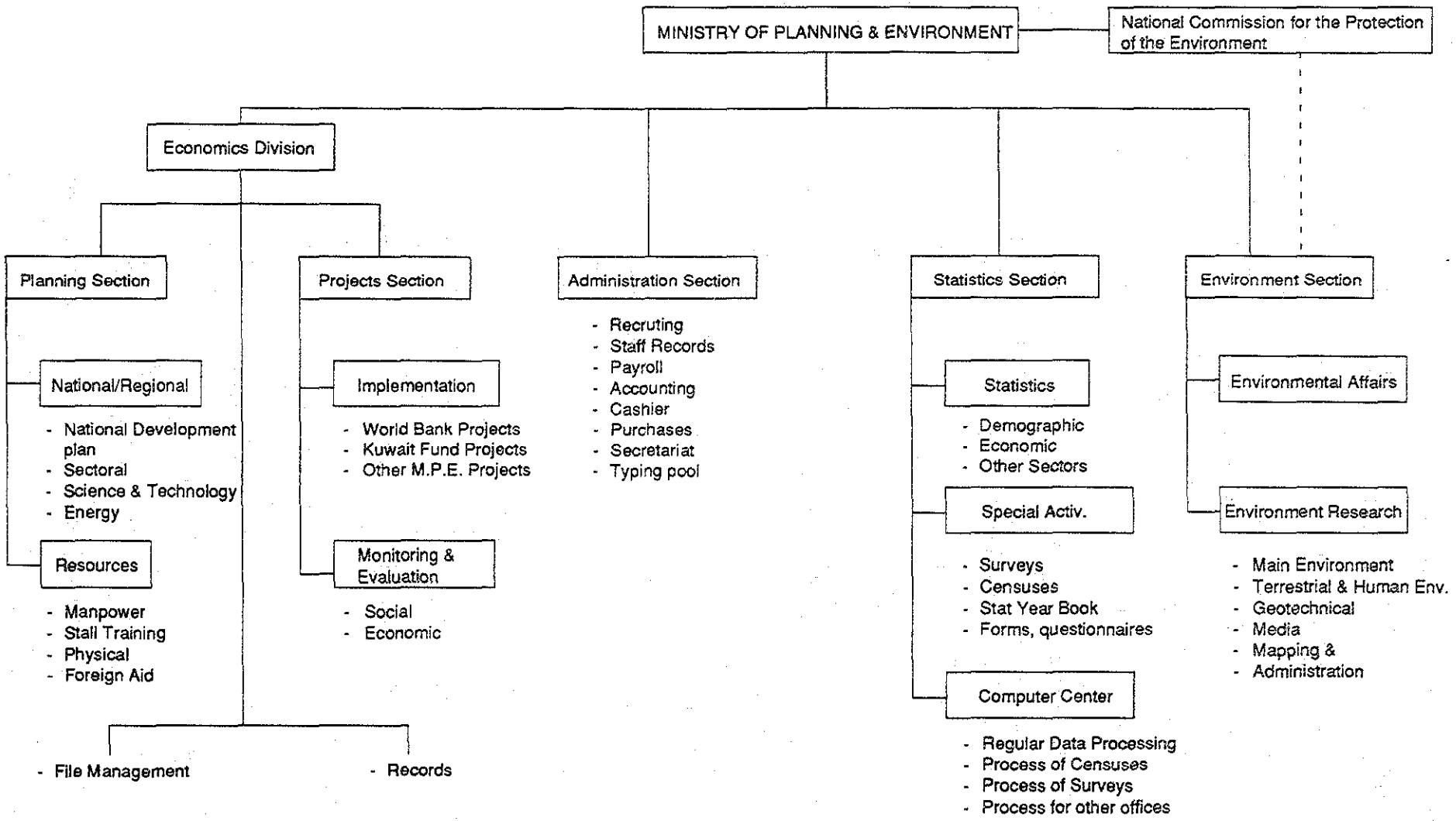


Figure 5.1.2 Ministry of Planning and Environment

A few of the general requisites for the organizations and their management are, therefore, as follows:

(1) The setup of the organizatons and its management system for the routine business are to be responsible to and capable of coping with situations drastically and quickly changing at the time of emergency.

(2) Within the unit of organization, a clear-cut specific job description is given to each member of staff, and a reporting system will be established.

The MPWL is holding the sole responsibility for carrying this project through to execution and conducting daily maintenance work of the structures after the completion of the project. Its routine business also includes collection of oceanographic data and public relations activities, the perspective of which requires broader framework than the MPWL itself. It is, therefore, assumed that the gist of the matter beyond this scope of work should be described for the better understanding of the position in which the MPWL will be placed in relation to the total organizational framework we propose.

5.2 Management Policy on the Seashore Protection

5.2.1 Principle behind the Policy

The phenomena which have been taking place along the shorelines are multifarious, and, therefore, complex. The Public Works Department (PWD) of the MPWL can cope with maintenance and repair of the seashore protecting structures; but to face the entirety of the issues which the shorelines are raising is beyond its scope. So, the cooperation of different organizations is called for as is mentioned in paragraph 5.1. It is easier said than done.

Let us look at the two other activities of the MPWL regarding our project. Collection of data of daily wave observations, for example, would be less valuable as the crucial data for future policy making, if they were not integrated into many other pieces of meteorological, oceanographic and ecological information.

Consequently, how much influence on the citizens can be expected when the budget of the PR activities is negligible in the ministry whose share of budget is only a few percent of the total, even if it tries to make them single-handedly.

On the other hand, as conventional wisdom tells us, cooperation among the units of different ministries cannot be expected without direction and monitoring from the top stratum of administration: In the case of the Maldives, it is the president who is at the same time the chief executive of the cabinet.

An inter-ministerial communication committee among the concerned ministries has been established for the expansion and integration of the meteoro-, oceano-, and eco-data base. But the PR of the maintenance activities of the MPWL in the framework of seashore-line management would be based on the far-sighted vision on the part of the government on the issue when the public does not realize its importance. The PR, in this case, is used as an important means to enlighten the people. Without paying any attention to the socio-psychological aspect of the residents, the system of emergency operation will end up as a castle in the air.

The people on Male' Island are no longer living on the islands inside lagoons as they were in their forefathers' time, when extensive and growing coral reefs were absorbing the energy of the waves. At present, the powerful waves from the Indian Ocean hit directly the island on the south and east faces. This being the case with its population of which more than 40 percent have registered their birth at other 'atholhuthah' (local administration area), the residents of Male' still behave as if there still lies a reef between them and the sea. The mentality of the citizen has to catch up with the reality, to begin with.

The nation's backbone lies in the sea. People identify with it; yet the nuance of the people's perception towards the sea has been varying, especially in the context of the national policy or political guidelines. People see the sea seldom in its entirety; instead, its partial aspects have been emphasized. In historical sequence, the emphasis changes according to the social awareness of the sea. The following diagram gives a broad idea.

Change in People's Perception of the Sea

(1) Economic → (2) Environmental → (3) Socio-Psychological

(1) Economic Aspect

Until quite recently, the sea had been regarded as the sphere in which two traditional activities, a primary industry and commerce, i.e., fishing and sea transport had been in operation. The Maldives celebrate The Fisherman's Day on the 10th of December, for example. According to President Gayoom's speech, "fishing and our country, and its people, are one and shall remain inseparable forever."

Here the people of the Maldives identify themselves with fishing, which is a manifestation of productivity on the part of the sea.

(2) Environmental Aspect

This aspect began to be emphasized with the surge of tourism, which has recently become the highest contributing industry to GDP. Attention has been paid to conserve the coral reefs and their surrounding sea with their marine fauna and flora within the atolls. But the major motive seems to be economically-oriented. Though the disaster of 1987 was caused by the neglect of attention to waste disposal, the ecologically friendly system is yet to be worked out. Solid waste goes to the pit dug at a piece of land being reclaimed from the sea without being sorted; the sewage is pumped raw into the sea. In this respect again, the residents have been relying on the sea; its ability to digest the sewage.

(3) Socio-Psychological Aspect

It is, therefore, about time to think about the relationship between the people and the sea as a whole. There have been needs to change social fabric of the island city of Male'.

It is the government's duty to guide the residents, of which the PR activity is one, and education is another. It is about time that the stage in which problems are dealt piecemeal without formulating principles which underlie the policies concerning seashore protection is to be moved forward to get basic things right.

5.2.2 National Commission for the Protection of the Environment

Two methods may normally be conceived to coordinate the different administrative organizations each of which partly participates in the seashore management; i.e., establishing an inter-ministerial council or a leading agency. The former functions through policy and procedural standardization. The latter directs all the activities of concerned organizations. What we need most in the multifarious activities of the different organizations is a body of coherent policy- and decision-making for the betterment of seashore management policies which always prepare for an unexpected disaster caused by the rising sea. For that reason, the latter type of agency would suit our aims better.

National Commission for the Protection of the Environment (NCPE) was established in the MPE on 19 June 1989 to oversee all the aspects of activities of the seashore management and to make pertinent decisions. It is an extension of the disaster committee which was formed soon after the 1987 disaster. The committee has 21 members who are the representatives of concerned organizations. They are the President's Office and almost all the ministries except those of Finance, Foreign Affairs, and Justice. The President's Office is, more specifically, represented by the Office of Physical Planning & Design (OPPD), Male' Municipality (MM), Department of Meteorology (DM), Department of Civil Aviation, Television Maldives (TM) and Voice of Maldives (VOM). The MPE sends four members including the Minister who functions as chairman, and the Ministry of Fisheries & Agriculture sends two.

Note: The organization charts of the Government, MPWL and MPE are given in Fig. 5.1.1 and 5.1.2.

One of the commission's major duties is to plan and monitor all the environmental issues of the nation. At the time when this study was carried out, the commission's administrative responsibility was to counsel the minister of MPE and to make recommendations on environmental issues. In the future, however, after proclamation of environmental registration, which will be discussed in the next diet session, the NCPE will be the mandatory organization for making decisions on environmental issues of the Maldives.

The Environment Division of the MPE has been functioning as the NCPE's secretariat.

Once the NCPE gets the above mentioned mandate, four major aspects of the seashore management activities, i.e., maintenance and repair, data collection and analysis, public relations, emergency operation will come under its jurisdiction.

We shall not discuss an aspect of environmental criminal code here, except on the kinds of sentences. They may not be confined to a fine and prison-term for town dwelling offenders, but a unique sentence of the Maldives of confinement in a remote island be included, where he/she shall live in a fishermen's community as a general helper to give them a chance to learn the dynamics of nature and reach a real state of penitence.

Table 5.2.1 gives an idea how the member organizations participate in the activities.

Participation of four Ward Development Committees (WDC) of Male' Island in the activities of public relations and emergency operation is very important.

Table 5.2.1 National Commission for the Protection of Environment

Activity	Planning Body	Executing Body
1. Maintenance & Repair (of seashore protecting structures) design criteria, renovation plan, maintenance & repair	OPPD; MPWL; MM	HD*, MPWL
2. Data Collection & Analysis overall policy making, data collection, processing, analysis	MPE;	ERU*, MPE; DM; PWD, MPWL
3. Public Relations (PR) national identity formation PR of the committee's activity education-at school & away from school	MPE; DIB*; ME* WDC	VOM; TM; DIB ME; WDC
4. System of Emergency Operation emergency operation training & practice	MDNS*; WDC	see Fig. 5.4.1

*

HD : Harbour Division
ERU : Environment Research Unit
DIB : Department of Information & Broadcasting
ME : Ministry of Education
MDNS : Ministry of Defence & National Security

5.3 Maintenance and Repair System

The HD of the MPWL is to be in charge of all aspects of maintenance and repair works of the system.

It is one thing that the seawall itself which we propose is structurally so durable and almost maintenance free, it is quite another to check the total network of the seashore protection structures surrounding the island including the harbour area.

The principle, "a stitch in time saves nine", is the golden rule which governs the operation of maintenance and repair works; it implies regular observation practice, to begin with. Information about damage to the structures is supplied by regular patrol by the duty staff or through reporting from some residents, if the PR activity of the MPWL progresses.

The shoreline map with structural information (material, age, etc.) as a database will be provided before fixing an observation plan.

The patrol plan and timetable will be formulated by the analysis of the following elements of the structures given in Table 5.3.1.

Table 5.3.1 Elements to be considered for Patrol Planning

Site	On shore		Off shore	
Sea Level	above	below	above	below
Means	on foot	by diving	on boat	by diving
Frequency (once a)	week	month*	month*	month*

* The patrol work will be carried out at the time when the automatic wave gauges are not attended. It won't be unwise to train a staff member in scuba diving.

The total seashore line may be divided into four sectors of east, west, south and north. The patrol duty may be performed at the ebb. And a log book is prepared and filled by the duty staff for further processing.

Maintenance and repair works will be carried out or overseen by the PWD. In future, the recurrent budget for maintenance and repair of the structures and the capital budget for the renovation of the existing structures will be separately prepared. Improvement of the existing structures will be planned by the coordination of the OPPD.

The HD will be provided with a maintenance manual in order to facilitate smooth operation of maintenance, repair and other related activities. They will revise the manual to suit better the local situation as their experiences accumulate in the future.

Note: Prior to the construction of the sea walls, the HD of MPWL will have to set up a joint working unit with Electricity Board and Water & Sewerage Department of MM in order to minimize suspension of supplies or the use of public utilities during the sea walls construction period. The resulting renewal of network maps will eventually be incorporated into the database kept in the NCPE.

5.4 Managerial Countermeasures against Coastal Disaster

5.4.1 Oceanographic Observations

The PWD has been processing some oceanographic data collected from the wave gauges installed last year. First, this asset of scientific information will be incorporated into other meteorological data collected by the meteorological stations for shorter range correlational analysis. Then, they will be compiled into an integrated data base with other environmental information collected by the ERU for longer range study on greenhouse effects or more specifically, of projecting sea-level rise.

This ultimate scope in mind, the ERU will take the initiative in formulating the network cooperating with the DM and the PWD.

As continuous and regular recording is one of the most important elements of observation, the PWD's responsibility is to take good care of the under-water gauges, for which at least one of its staff will obtain a license for scuba diving and the PWD will have a set of diving gear. A diver is also required for under-water patrol of the seashore protecting structures as is mentioned in para 5.3.1

5.4.2 Public Relations

The ultimate purpose of PR activity is to let the citizens understand the nature of the sea in its totality through promoting the idea of maintaining the shore protecting structures, which is the mainstay of safeguarding the citizens' life.

On the other hand, once the protecting structures against the high waves of the sea are constructed, people are apt to become too complacent to visualize the real danger of the sea. The PR activity is to warn the residents and to get them prepared for the future disaster.

The PR activity has two facets. First, it has to provide the residents with the information about all the aspects of relationship between the people and the sea; second, it keeps reminding people the necessity of preparing against the exceptional case of natural disaster by showing the regular modest maintenance and repair activities carried out by the PWD, or data collecting activities of the DM or the ERU, or the scene of training for emergency operation. The MPWL is to supply the related information to the committee.

The DIB will be in charge of the operation.

Educating adults as well as the coming generation is another necessary activity on the part of the government for the same purpose mentioned above.

A workshop on disaster may be incorporated in the curriculum of teachers training school to give the students chances to participate in discussion on the subject.

The subject must be taught at primary school level also. A story about a Dutch boy who saved the dike by sticking his finger into a tiny leak for many hours till another villager came to notice it may be used as one of the contents of the texts. A prize named "Finger in the Dike" has been awarded every year to some meritorious pupils in a local shoreline management contest in Netherlands.

Some basic outdoor training such as first aid may be taught with reference to the disaster to the members of boy/girl scouts.

The ME will take care of this aspect of activities.

It may be worth while to make a motion to declare April 10th a national holiday for commemoration and a reminder of the disaster that occurred on the day in 1987. If the "Sea Defence Day" is authorized as a holiday, the programme making is one of the PR activities.

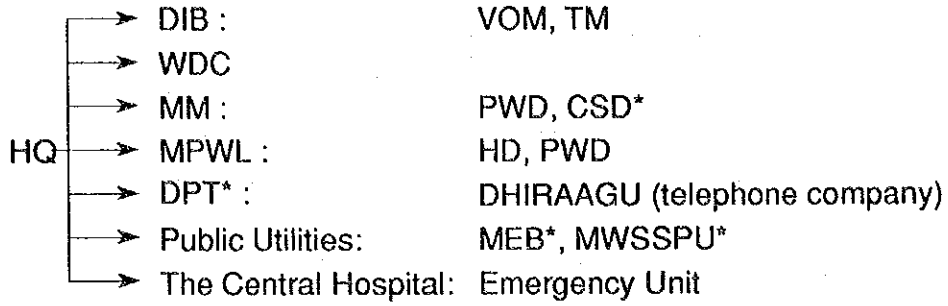
5.4.3 Emergency Operation System

The HQ headed by the minister of MDNS will be established instantly in the NCPE when disaster takes place, and the HQ staff will be notified to assemble through emergency communication network. At the same time, all the concerned organizations will be alerted. In the case of a storm, there will have been a period of vigilance before the final climax is reached, during which preparatory action can be taken. Otherwise, in the case of a tidal wave, when no such luxury is allowed, that will be the time when routine practice will be called for.

Upon receiving the alert, a duty officer in each body will contact the staff concerned according to its own emergency manual.

A sample diagram of the emergency communication channel between the HQ and each operating body is shown in Fig. 5.4.1.

Figure 5.4.1 An Emergency Communication Network



*
CSD: Community Service Department
DPT: Department of Posts & Telecom
MEB: Maldives Electricity Board
MWSSPU: Male' Water Supply & Sewage Project Unit

The HQ is manned by the emergency brigade of MDNS assisted by an engineering corps with necessary equipment, besides members of the CSD and duty officers dispatched from each operating ministry.

Preparation of disaster operation in normal times involves formation of residents' voluntary emergency brigade under each WDC. They will get regular training. Training manual will be prepared by the CSD and instructors will be provided by the emergency brigade, MDNS.

Chapter 6. Project Appraisal

6.1 Introduction

In this chapter, firstly, the quantitative and descriptive appraisals of the project are carried out from the benefits and costs point of view (see para 6.2); after which, the project is assessed more comprehensively by using the Disaster Prevention Appraisal Index (DPAI), which was proposed by Prof. Y. Kawata in 1990 (*) (see para 6.3).

*Kawata, Yoshiaki: Estimation of Countermeasures against Natural Disaster, Journal of Natural Disaster Science, 9-1, pp.1-16, 1990

6.2 Costs and Benefits Aspect of the Project

6.2.1 Economic Internal Rate of Return (EIRR)

1) Project Cost

i) Construction Cost (1992 price)

As estimated in Table 3.4.1, construction cost (1992 price) will be as follows;

West Coast	US$10,328,156
East Coast	US$13,632,487
South Coast	US$17,057,963
North Coast	US$10,403,567

ii) Maintenance Cost

These seawalls are almost maintenance free. On the other hand, maintenance costs for shore protection structures in 1990 reached US$203,000 (53 % of the cost in 1989), and half yearly costs in 1991 were US$198,000; almost a 100 % increase from the previous year.

2) Project Benefit

Project benefit will be calculated from a definite integral of Damage Probability Curve (D-P Curve) between the return period of the scale of disaster that the project is supposed to counter and that of one, which is equivalent to a yearly benefit.

The tidal wave of April 10, 1987 caused Male' island to be burdened with the estimated damage cost of MRf. 29,348,621 (1987 price), (see Table 6.2.1). This is a part of the direct damage costs (Direct 1:*1). We have enumerated two more types of

the direct costs, which are not included in the above list. They are the damages which were caused to the residences and small shops in the inundated area (Direct 2:*2), and the one to the household goods kept in the houses (Direct 3:*3).

Neither does the list include such an indirect loss as loss of profit opportunity, or cost of emergency medical services. Furthermore all, two lives were lost and more than a score of patients were hospitalized due to an outbreak of cholera as an aftermath of the disaster, though the number is surprisingly small.

Table 6.2.1 Total Estimated Cost for Direct Damages caused by the 1987 Tidal Waves

MRf: 1987 price

*1	*2	*3	Items	*4 Value
1	M	P	Gov. Premises & Buildings	1,413,420
3	M	P	PWs & Related Places	14,498,000
4	M	P	Electric Cables	80,000
5	M	P	Breakwater, Jetty, Harbour	2,708,308
6	M	P	Henveyru District	376,115
7	M	P	Galolhu District	200,575
8	M	P	Machchangolhi District	54,685
9	M	P	Maafannu District	3,863
10	M	P	Ships: Gov. & Priv.: SW Harbour	989,000
19	M	P	Water Supply, Sewerage	4,825,000
20	M	P	Trees	200,855
	Sub-total: M & P			25,349,821
11	M	S	Clearing of Garbage	1,480,000
12	M	S	Labour	191,000
13	M	S	Food	26,000
14	M	S	First Aid	9,200
15	M	S	Others	501,000
16	M	S	Transportation	84,100
22	M	S	Cars used for Relief Work	1,707,500
	Sub-total: M & S			3,998,800
	Sub-total: Male'			29,348,621
17	O	-	Other Islands	284,800
18	O	-	Resorts	671,000
21	O	-	Male' International Airport	18,620,000
	Sub-total: Other Islands			19,575,800
	Grand Total			48,924,421

*1 Given in the original sheet:
No. 2 is a duplicate of No. 1; so omitted.
*2 M = Male' Island; O = Other Islands
*3 P = Primary Damages; S = Secondary Damages
*4 Prices are rounded.

On top of that, as the island is the administrative center of the Maldives, the effects of disruption of various services felt all over the country is beyond enumeration. Loss of positive earning opportunity shall, therefore, be estimated as a type of indirect loss (*4).

Table 6.2.2 Cost of Damage and Yearly Benefit

US$: 1992 price

Type	Damage Cost	Yearly Benefit
Direct 1	4,121,573	2,040,179
Direct 2	7,921,488	3,921,167
Direct 3	2,066,882	1,023,107
Indirect	11,306,708	5,596,821
Total	25,416,651	12,581,242

*1 Direct 1: Applying the following data on consumer price indices (CPI) and an exchange rate of MRf-US$ in 1992, it is estimated at US$4,121,573 in current price (1992).

Table 6.2.3 Damage Estimated

	Damage Estimated		CPI: '80 = 100	AAIR #	MRF/US$
MRf: '87	29,348,621		157.32	7.13 %	
MRf: '92	41,421,806	= US$4,121,573	ca.222.04		10.05

* Average Annual Inflation Rate between 1987 and 1990 (CPI = 193.45). The same value of the AAIR is extrapolated in 1991 and 1992.

The significant wave height (Hs) of the tidal wave of Apr. 10, 1987 is 3.0 m with the period (T) of 16 sec., wheres Hs of 1/100 at S-E corner of the island is calculated at 2.70 m with T = 14.5 sec., (I/R(I) 3.1.10). Broadly speaking, with moderate estimation in mind, the magnitude of the tidal wave assaulted on Apr. 10, 1987 can be regarded as the one with the return period of 100 year. So a point (4,121,573, 0.01) is fixed on the D-P Curve. Then we presume damage costs of probability 1 is equivalent to zero (0,1).

Table 6.2.4 D-P Curve

		US$ (1992 price)
Probability (P)	1	1/100
Total Damage (D)	0	4,121,573

YB expected from the construction of sea walls which would prevent a tidal vase of 100 year return period from intruding is calculated at US$2,040,179.

YB = (1-1/100) x (4,121,573-0)/2

*2 Direct 2 : Inundated areas are measured

Table 6.2.5 Inundated Areas

ha (area)

Ward	Residence	Non-Residence	Total
Henveiru	12.8	3.6	46.8
Galolhu	8.9	9.5	34.8
Machchangolhi	8.8	14.3	38.8
Maafannu	10.9	12.2	59.6
Total	40.8	39.5	180.0

We have estimated an average unit value of the house at US$70.06 (1992 price) per m^2 and an average damage ratio at 0.308. And 90 percent of the surface of the residential area are covered by housing plots. The damage is estimated at US$7,921,488.

70.058 x 40.79 x 10,000 x 0.9 x 0.308 ≒ 7,921,488 (because of rounding)

*3 Direct 3 : Average unit value of household effects is estimated at US$2,454.6, the number of the household in the island is at 11,226, and damage ratio at 0.331. The damage is estimated at US$2,066,882.

2,454.6 x 11,226 x 40.79/180.0 x 0.331 ≒ 2,066,882

*4 Indirect : Losses are assessed by a supposition that a month and a half of paralyzation of daily life took place on the island after the disaster, which led to a reduction of positive production.

MRf.50.5/day/capital x 45 days x 50,000(Population of the island in 1987)/10.05 (MRf/US$) ≒ 11,306,708

in which;

MRf.1.132 bil(GDP:1992 estimate:1985 price) x 1.07^2/200,000(population of the Maldives)/365 x 50 % (the island's share of GDP #)/25 % (the island's share of population) x 1.073^5 ≒ MRf.50.5/day/capita.

5 % (secondary sector x 1/3) + 45 % [tertiary sector 57 % - (half of tourism and transport: 12 %)] = 50 %

Note 1:
We make reference to the recent disasters reported so far in terms of estimation of damage for the sake of contrast.

* Hurricane Andrew hit southern Florida and Louisiana on the 24th and the 25th of Aug.; it caused an estimated US$17 - 20 bil. of direct damage.

** An earthquake off the coast of Nicaragua triggered tsunami upto 15 meters high on the 1st of Sep.; it caused 150 deaths and destroyed 16,000 houses; it caused an estimated US$20 mil. of direct damage.

*** Cyclone Iniki assaulted Hawaii recently and caused an estimated US$500 mil. of insured damage.

Note 2:
Though indirectly, the disaster caused two deaths. Costing of lives has been carried out by various organizations in relation to assessment of countermeasures against disasters, natural and man-made. British Rail's (BR) price tag on the value of a death is £2 mil. (US$ 3.5 mil.), for example. The Road Department's (RD) is £0.65 mil. (US$1.14 mil.). So two deaths are equivalent to US$7 mil. by BR standard, and US$2.3 mil. by RD's.

4) EIRR

Useful life of the seawalls are set to 50 years. Prices are basically not regulated; the exchange rate to US dollar is pegged. Being physically isolated from the production centers of the world, most of commodities except fish and some agro-produce are imported. Unemployment is rare in the island, though incoming fishermen from the other atolls is restricted and the necessary number of guest workers are brought in. There is not much skewness in pricing of commodities, labour and foreign exchange to determine any coefficients to calculate economic price i.e., national parameters. So economic prices are set to be equivalent to financial ones.

EIRR of the project is calculated at 30 % (except construction cost of north coast) and 24 % (including four coasts). The chart is given in the Table 6.2.6. We omit sensibility analysis from the check items as the figures of costs and benefits we handled are lump sums.

6.2.2 Other Benefits

Some portions of the indirect losses caused by such incidents as stoppage of traffic, communication, electric generation and public utilities, or spread of epidemic, or loss of profit opportunities in the tourist industry are counted into the indirect damages cost as lump in our calculation of benefits, but not all of them. Besides, implementation of the project will surely result in efficient land use, which will further induce overall stability of local economy; and acquisition of know-how on the seashore protection technology. But what is important above all is the psychological effect on the citizens. The following discussion will throw light on the subject.

6.3 Disaster Prevention Potential

6.3.1 DPAI

In this section we shall assess the project in terms of its contribution to the increase of disaster prevention potential of the population living in Male' Island as a whole.

Disaster prevention potential of a society against flood could be measured by the following five aspects: *1

1) Disaster Prevention Facilities
2) Change in Landuse.
3) Change in Hydrological Phenomena.
4) Response of System, Administration and Organization for Disaster Prevention.
5) Change in Awareness on Prevention of Disaster.

*1 H. Takahashi's unpublished manuscript cited in Kawata, Y : ibid.

1) corresponds to the "hardware" aspect of the potential; 2), 4) and 5) to the "soft ware" aspects, and 3) signifies changes in natural forces.

Kawata (KY) has found that the probability of encountering a disaster in a region (P) can be explained by an average lifespan of its population, and that "soft ware" aspects of the potential can be represented by the average lifespan. Then, he has introduced two equations; P and combined potential of both "soft and hard ware" countermeasures (Pd).

Table 6.2.6 EIRR

						92.10.7	Unit: US $
		Without North Coast			With North Coast		
Year	A.D. Year	Benefit	Cost	B-C	Benefit	Cost	B-C
1	1993	0	10,328,156	-10,328,156	0	10,328,156	-10,328,156
2	1994	2,828,904	13,632,487	-10,803,582	2,057,322	13,632,487	-11,575,165
3	1995	7,066,596	17,057,963	-9,991,367	5,139,185	17,057,963	-11,918,778
4	1996	12,581,242	0	12,581,242	9,149,714	10,403,567	-1,253,853
5	1997	12,581,242	0	12,581,242	12,581,242	0	12,581,242
6	1998	12,581,242		12,581,242	12,581,242		12,581,242
7	1999	12,581,242		12,581,242	12,581,242		12,581,242
8	2000	12,581,242		12,581,242	12,581,242		12,581,242
9	2001	12,581,242		12,581,242	12,581,242		12,581,242
10	2002	12,581,242		12,581,242	12,581,242		12,581,242
11	2003	12,581,242		12,581,242	12,581,242		12,581,242
12	2004	12,581,242		12,581,242	12,581,242		12,581,242
13	2005	12,581,242		12,581,242	12,581,242		12,581,242
14	2006	12,581,242		12,581,242	12,581,242		12,581,242
15	2007	12,581,242		12,581,242	12,581,242		12,581,242
16	2008	12,581,242		12,581,242	12,581,242		12,581,242
17	2009	12,581,242		12,581,242	12,581,242		12,581,242
18	2010	12,581,242		12,581,242	12,581,242		12,581,242
19	2011	12,581,242		12,581,242	12,581,242		12,581,242
20	2012	12,581,242		12,581,242	12,581,242		12,581,242
21	2013	12,581,242		12,581,242	12,581,242		12,581,242
22	2014	12,581,242		12,581,242	12,581,242		12,581,242
23	2015	12,581,242		12,581,242	12,581,242		12,581,242
24	2016	12,581,242		12,581,242	12,581,242		12,581,242
25	2017	12,581,242		12,581,242	12,581,242		12,581,242
26	2018	12,581,242		12,581,242	12,581,242		12,581,242
27	2019	12,581,242		12,581,242	12,581,242		12,581,242
28	2020	12,581,242		12,581,242	12,581,242		12,581,242
29	2021	12,581,242		12,581,242	12,581,242		12,581,242
30	2022	12,581,242		12,581,242	12,581,242		12,581,242
31	2023	12,581,242		12,581,242	12,581,242		12,581,242
32	2024	12,581,242		12,581,242	12,581,242		12,581,242
33	2025	12,581,242		12,581,242	12,581,242		12,581,242
34	2026	12,581,242		12,581,242	12,581,242		12,581,242
35	2027	12,581,242		12,581,242	12,581,242		12,581,242
36	2028	12,581,242		12,581,242	12,581,242		12,581,242
37	2029	12,581,242		12,581,242	12,581,242		12,581,242
38	2030	12,581,242		12,581,242	12,581,242		12,581,242
39	2031	12,581,242		12,581,242	12,581,242		12,581,242
40	2032	12,581,242		12,581,242	12,581,242		12,581,242
41	2033	12,581,242		12,581,242	12,581,242		12,581,242
42	2034	12,581,242		12,581,242	12,581,242		12,581,242
43	2035	12,581,242		12,581,242	12,581,242		12,581,242
44	2036	12,581,242		12,581,242	12,581,242		12,581,242
45	2037	12,581,242		12,581,242	12,581,242		12,581,242
46	2038	12,581,242		12,581,242	12,581,242		12,581,242
47	2039	12,581,242		12,581,242	12,581,242		12,581,242
48	2040	12,581,242		12,581,242	12,581,242		12,581,242
49	2041	12,581,242		12,581,242	12,581,242		12,581,242
50	2042	12,581,242		12,581,242	12,581,242		12,581,242
			EIRR=	30%		EIRR=	24%

$P1 = 1 - P = (1 - 1/T)^{T1}$ ---------- (1)

T_1: average lifespan, T: return period (year)

$Pd = 1/[1 + \exp\{ - (\alpha + \beta P_1 + \gamma P_2)\}]$------- (2)

where: P_1 : probability of non-encountering of disaster; see (1)

P_2 : average lifespan (ALS)/the limit of lifespan (=120 set by KY)

α: see 3);

Trial for standardization without data to determine the coefficients means simplification of their relationship. So the KY puts $\alpha=0$, $\beta=\gamma=0.5$

a) When $P_1=P_2=0$, $P_d=0.5$; b) When $P_1=P_2=1$, $P_d=0.731$ $(=1/(1+e^{-1}))$

He standardizes the relationship by giving 100 to the situation a), and 0 to b); then he gets:

$DPAI = 433 \times (0.731 - Pd)$

The Fig. 6.1 gives four cases of countermeasures on the DPAI - Average Lifespan Diagram.

The ALS of the Maldives has been increasing rapidly in recent years. The following table shows it. This is a proof of the Maldivians own efforts, public and private, in improving its socio-economic infrastructures as a whole; this itself is a great achievement.

Table 6.3.1 ALS of the Maldives

Year	1970	1985	1990
ALS (Years)	46.5	61.0	65.8

The relationship among this trend in the ALS, installation of seawalls, which can stand off a disaster of 100 year return period, and the DPAI can be represented by the bent arrow in the Fig. 6.3.1. A gain by the installation at the time when the ALS will be 70, which will come sometime in late 90s, will be 25 points in terms of the DPAI, and will reach DPAI 43. Incidentally, KY classifies the countries in terms of the DPAI. The DPAIs of many developing countries are above ca.70, those of the NICS between 70 and 50, and most developed countries below 50.

6.3.2 Maximum Risk of Life (RL) at the Time of Disaster

KY has studied available data on catastrophic natural disasters, i.e., earthquakes, storm surges, river flooding, tsunami, famine, land slide and eruption in the world since the 13th century, and got an equation on maximum risk of life:*

$RL = 10^{-0.036T1-0.471}$ (T1 < ca.60)

T1: ALS of the country concerned at the time of disaster

When T1 > ca.60, RL reduces dramatically, and reaches in the order of 10^{-5} at a level of T1 = 70. The relationship between RL and T1 is shown in the Fig. 6.3.2. Then the number of deaths (Np) can be calculated by the equation:

$Np = \alpha 1 * RL * PO * R$ ($\alpha 1 * R = 1$ in ordinary cases)

Legend: PO = Population
R: Disaster Amplification Factor of cities with high population density (PD). R = PD of the city concerned/PD of the country concerned.

KY has discovered a phenomenon of phase transition in which Np increases suddenly, i.e., $\alpha 1 * R > 1$, when R = 15 ~ 20.

* Kawata Y: Of Disasters characteristic to Urban Areas and a Scenario for their Catastrophic Growth, Journal of Natural Disaster Science, Vol. 10, No. 1, pp. 33 - 44, 1991.

The RLs of Male' Island in different years and R are calculated in the Table 6.3.2.

Table 6.3.2 RL and R of Male'

Year	1977	1985	1990	Area	PD (/km^2)
T1	46.5	61.0	65.8		
RL (10^{-3})	6.86	2.04	1.36		< 25.07 x 10^3:'85
PO (10^3)		45.87	55.13	1.83 km^2	< 30.13 x 10^3:'90
(Male')					
Np (capita)		93	75*		< 604:'85
PO (10^3)		180.09	213.22	298 km^2	< 716:'90
(The Maldives)					
R		41.5	42.1		

Figure 6.3.1 DPAI Lifespan Diagram

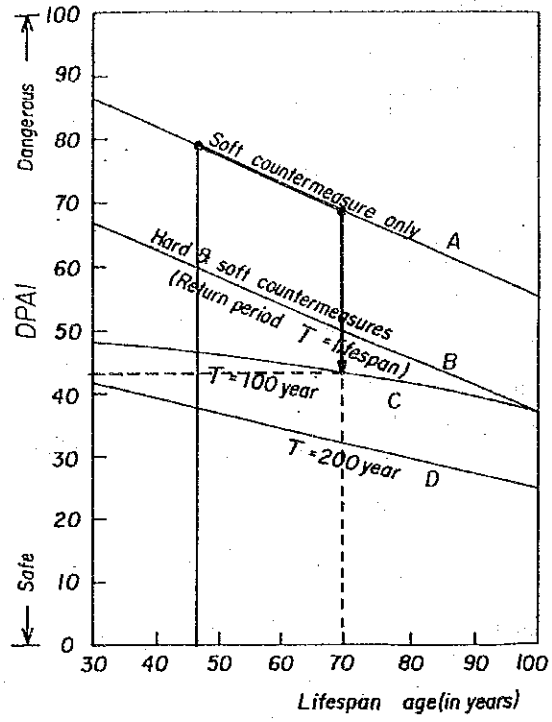
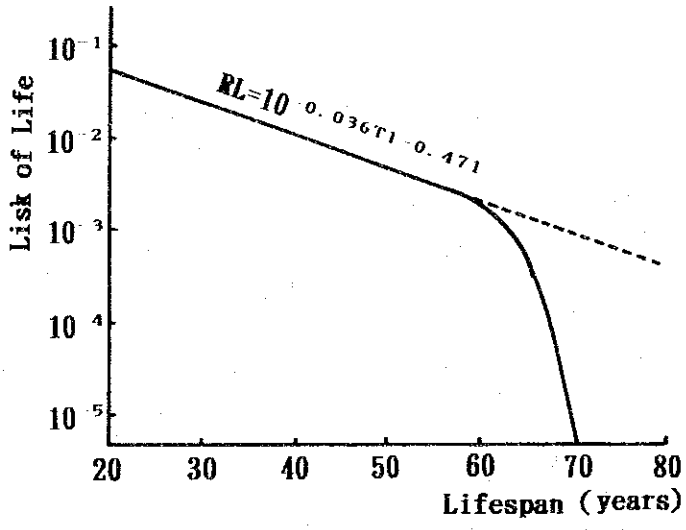


Figure 6.3.2 RL - Lifespan Diagram



Source: Kawata Y. : ibid, 1991; p. 40, Fig. 2.

In urban Tokyo R = 57.1 in 1985, and KY sets $\alpha 1 = 0.43$, which means $\alpha 1 * R = 24.6$. So we may safely set $\alpha 1 * R = 20$ for Male'. Then we shall get Np = 1860 in 1985, and 1500 in 1990.

In actual situation, at the time of 1987 disaster, in contrast with world records of disaster, only two persons died of cholera, i.e., $RL = 4 \times 10^{-5}$. This is even far less than Np without the Disaster Amplification Factor (R) taken into account, and RL is at the level of ALS = ca.70. This extreme low risk of life gives proof that the island has been lucky enough never to have been devastated by any severe cyclones or earthquakes. Yet there has been an indication or two that the area is prone to be hit by stronger storms than before due to local atmospheric turbulences. (An example: the one in May 1993 which uprooted approximately 190 thousand trees.) So it is only natural that the National Development Plan for 1991 - 1993 has envisaged the plans to strengthen coastal defence in areas of high vulnerability on both Male' and the atolls. This project is one of the major plans.

Islanders' other anxiety lies in global warming. If the CO_2 conference of this year's diagnosis is correct, the sea-level rise will be up to 65 cm by 2100. Though this is basically rather an argument of purely mathematical nature*, the seawalls which would be provided by the project would surely mitigate the effect of rise of the sea levels and lessen the citizens worry, mentally as well as physically, for some time to come.

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* 65 cm rise in 108 years (1992 to 2100) means 0.6 cm rise per year. So 50 years after the construction of seawalls, ie, at the end of their useful life, the sea may rise 30 cm from the present level. Meanwhile the structure would counter the high tide of Hs at 3.0 m at present, therefore, if might protect citizens from that of 2.7 m at the end of their useful life; the height still corresponds to the probability of 1/100 according to the Sri Lankan Oceanographic Instutute.

Chapter 7. Implementation Programme

7.1 Implementing Priority

As stated in Chapter 3, the first priority for construction of shore protection facilities will be given to the west, east, south and north coasts in this order.

Construction sequence will be set-up as shown in Fig. 7.1.1.

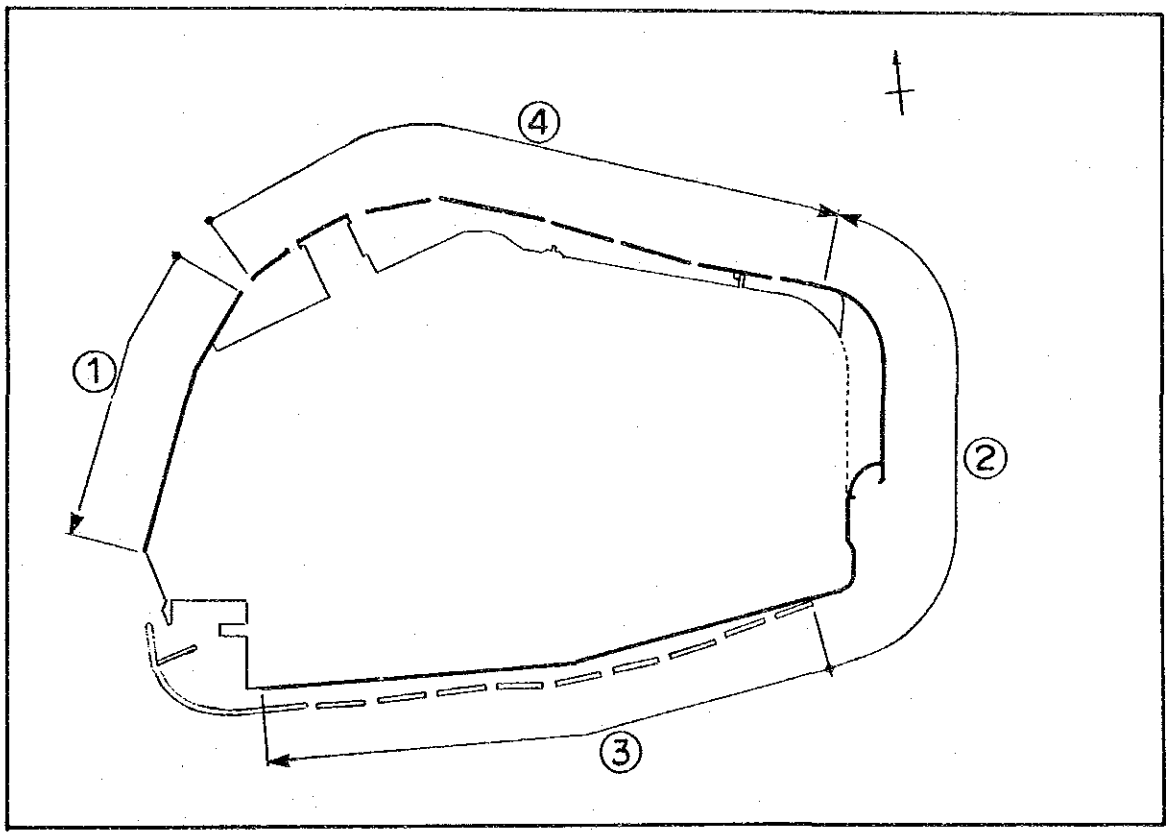


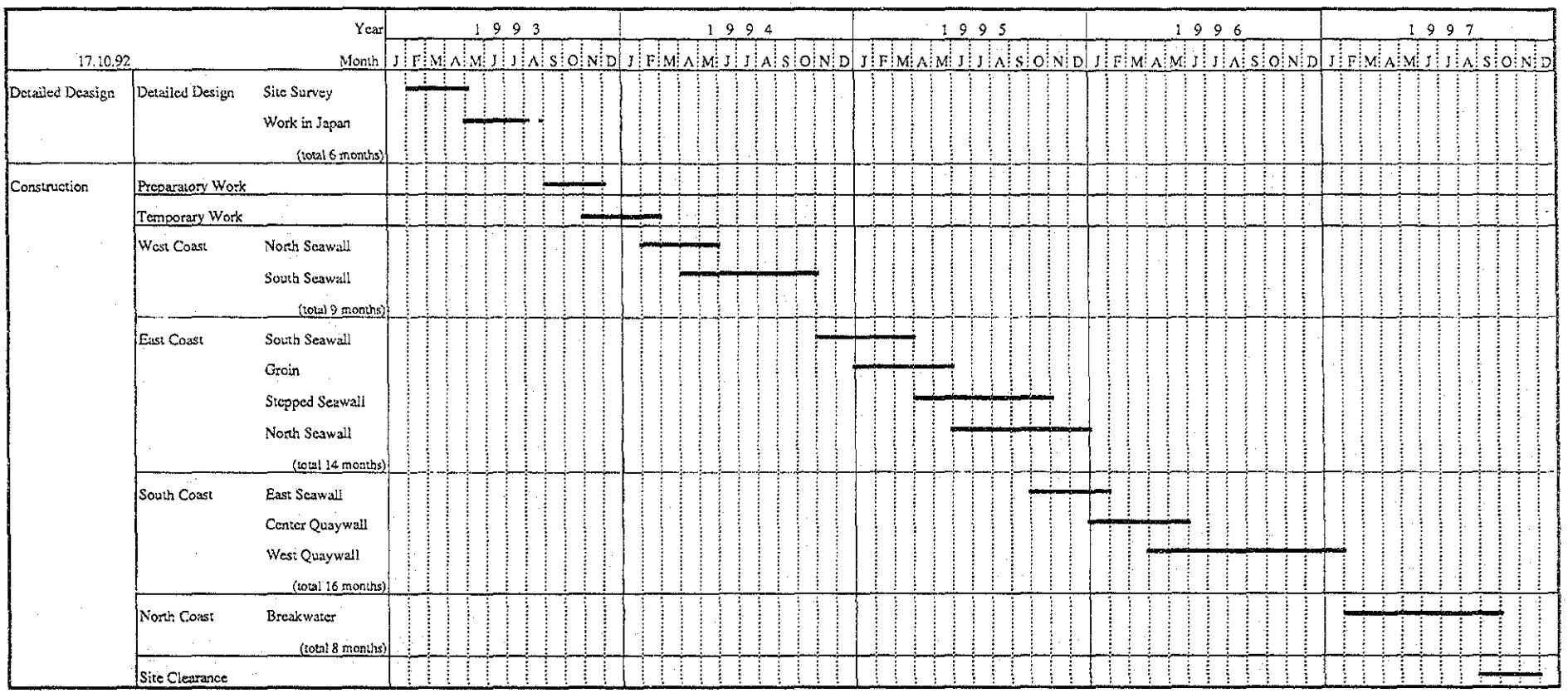
Figure 7.1.1 Construction Sequence by Priority

7.2 Construction Schedule

The construction schedule is prepared taking into consideration the four-year phase programme including the detailed design, preparation of tender documents and construction work.

The Table 7.1.1 shows the proposed construction schedule based on the construction sequence.

Table 7.1.1 Construction Schedule



Note: It is assumed that the Project will start at the beginning of February, 1993.

Chapter 8. Conclusion and Recommendations

8.1 Conclusion

(1) Necessity of Shore Protection

Maldives consists of 1,190 coral islands of which only 202 islands are inhabited. Each island is surrounded by a shallow lagoon which is enclosed by a coral reef providing protection from the hazards of the sea. Maldives, however, has experienced many inundation disasters by waves since the 1980s. For example, extremely high tides accompanied by high waves attacked Male' Island in April 1987 and caused serious damages on seawall and private houses resulting in flooding on the low lying coastal areas and in the outbreak of epidemic disease by standing waters.

With the increase of population in Male' Island, the shallow reef flat has been required to be reclaimed of the nearby reef edge in order to compensate for the shortage of space for houses, roads, public facilities and so on. The shorter the width of shallow reef flat becomes, the stronger the wave force appears in exerting damage to the land side including the rise of sea level due to wave run-up. The reclaimed land will consequently suffer disasters from storms and the reclaimed area of Male' Island has actually experienced inundations several times since 1987.

In Addition, the present seawall made of coral stones covered with thin concrete layer, is not adequate in both the strength of structure and the crown elevation of seawall to withstand wave forces.

Therefore, in order to ensure safe livelihood for the residents the construction plan of an appropriate seawall is urgently required on all coasts of Male' Island.

(2) Shore Protection Plan

Based on the results of field investigations as to environment, topography, geology, meteorology, oceanography and existing protection facilities, shore protection plans are proposed for each coast taking into account the requirements from the Government of Maldives, the technical suitability by hydraulic model tests, and the ease and economy of construction works. Moreover, the high priority for construction works is given to the west, east, south and north coasts in this order from their urgency against wave attacks.

The shore protection works for each coast are proposed as follows:

1) West Coast;
   - armor block mound type seawall,

2) East Coast;
   - armor block mound type seawall on the south and north part of this coast,
   - step type seawall on the middle part of this coast,

3) South Coast;
   - concrete block type vertical quaywall,

4) North Coast;
   - concrete block type breakwater.

Considering the process of construction works, it will take a total of five years to complete the above proposed seawalls on all coasts of Male' Island.

The construction of the proposed protection works is considered adequate to prevent extremely strong storm waves from overtopping into the hinterland area, and to promote the economic and social activities of the local residents.

(3) Environmental Impacts

Environmental impacts were examined with regard to socio-economic, physical and natural elements in each stage of during and after construction. In both stages impacts caused by the proposed plans are thought to not be serious to the environment.

8.2 Recommendations

In order to construct countermeasure works smoothly and effectively, and to acquire semi-permanent functions of shore protection facilities, the following recommendations are proposed:

(1) A next stage of detailed design for construction works succeeding the seawall project be initiated as early as possible;

(2) More civil engineers of MPWL who are responsible for carrying out this project be encouraged to study abroad coastal engineering and to establish a maintenance and repair system for the shore protection facilities as well as to obtain the knowledge of various coastal phenomena such as wave, current, tide, sea level rise and so on;

(3) Acquisition of enough space be kept for construction works such as a site base for heavy equipment, stock yard for material and armor blocks and other requirements;

(4) The seawall construction on the northern part of east coast be conducted in coordinating well with the reclamation plan which will be prepared and implemented by the Government of Maldives (the volume of reclamation material is estimated at approximately 92,000 m^3);

(5) A patrol inspection after construction be emphasized to observe wave height, wave run-up height and overtopping at high wave attacks in order to grasp actual effects on the seawall and to assist in dealing with shore protection problems in other islands of Maldives;

(6) A submerged permeable breakwater, which is beyond the scope of this seawall project, is preferable to be set between the existing detached breakwaters on the south coast at its necessary position in order to obtain harbor calmness for safe anchorage of small boats. Construction of this submerged permeable breakwater will not prevent the exchange of the seawater in the channel into the open sea.

(7) The proposed seawall position should not be changed seaward because the crown elevation of seawall and the weight of armor blocks are determined to meet wave forces around Male' Island.

Appendix : List of Personnel Concerned

(1) Maldivian Government

Hon. Abdulla KAMALUDEEN	(MPWL)	:	Minister
Mr. Mohamed SHIHAB	(MOFA)	:	Director of External Resources
Mr. Abdulla MASEEH	(MOFA)	:	Assistant Under-Secretary
Mr. Ibrahim MANIKU	(MPWL)	:	Director of Public Works
Mr. Wang ZHENG-DE	(MPWL)	:	Coastal & Harbor Engineering Advisor
Mr. Quirico F. ORENCIA	(MPWL)	:	Civil Engineer
Mr. Ragheb Ahmed KHALAF	(MPWL)	:	Civil Engineer
Mr. Mohamed SAEED	(MPE)	:	Director, Programme
Mr. Hussain SHIHAB	(MPE)	:	Director of Environment Affairs
Mr. Mohamed ALI	(MPE)	:	Deputy Director, Environmental Research
Mr. Mohamed HUNAIF	(MPE)	:	Assistant Director, Physical Planning
Mr. Hamdoon A. HAMEED	(MPE)	:	Director, Projects
Mr. Mahjoob SHUJAU	(MM)	:	Civil Engineer
Mr. Abdulla SALEEM	(MM)	:	Under-Secretary
Mr. Mohamed SHAFEEGU	(OPPD)	:	Director
Mr. Ali HAIDAR	(OPPD)	:	Senior Planner

(2) Counterparts

Mr. Ahmed ASHRAF	(MPWL)	:	Assistant Under-Secretary, Overall Management
Ms. Fathmath RASHEED	(MPWL)	:	Architect Trainee, Soil Investigation Facility Design Environmental Analysis
Mr. Ajwad SHAKEEL	(MPWL)	:	Civil Engineer Trainee, Wave Observation Topo/Hydrographic Survey Coastal Analysis

(3) JICA Advisory Committee

Dr. Takaaki UDA	(MOC)	:	Chairman
Mr. Hisaaki EMON	(MOC)	:	Member
Mr. Masanori SETA	(MOC)	:	Member

(4) JICA Study Team

Dr. Tamio ONO	(INA)	:	Team Leader till March 1992
Mr. Hiroshi SAKURAMOTO	(INA)	:	Team Leader from May 1992
Mr. Kazuo UNOKI	(INA)	:	Shore Protection Planning
Mr. Tsuyoshi NAGAYOSHI	(INA)	:	Oceanographic Observation
Mr. Yoji TERAZU	(INA)	:	Geological and Geophysical Survey
Mr. Masakazu IKEHARA	(PCI)	:	Hydrographic Survey
Mr. Naoshi HIGA	(INA)	:	Topographic Survey
Mr. Sadao ORISHIMO	(PCI)	:	Structural Design
Mr. Katsuhiko TAKAHASHI	(PCI)	:	Cost Estimate/Construction Planning
Mr. Akinori SATO	(PCI)	:	Environmental Analysis
Mr. Fumiaki ONODA	(PCI)	:	Institutional/Managerial Evaluation

INA : INA Corporation

PCI : Pacific Consultants International