JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF IRRIGATION AND DRAINAGE
MINISTRY OF AGRICULTURE
MALAYSIA

THE NATIONAL RIVER MOUTHS STUDY IN MALAYSIA

VOL. III

MAIN REPORT

FEASIBILITY STUDY

AUGUST 1994

CTI ENGINEERING CO., LTD.

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LIST OF REPORTS

THE COST ESTIMATE IS BASED ON NOVEMBER 1992

PRICE LEVEL AND EXPRESSED IN MALAYSIAN

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(AS OF NOVEMBER 27, 1992)

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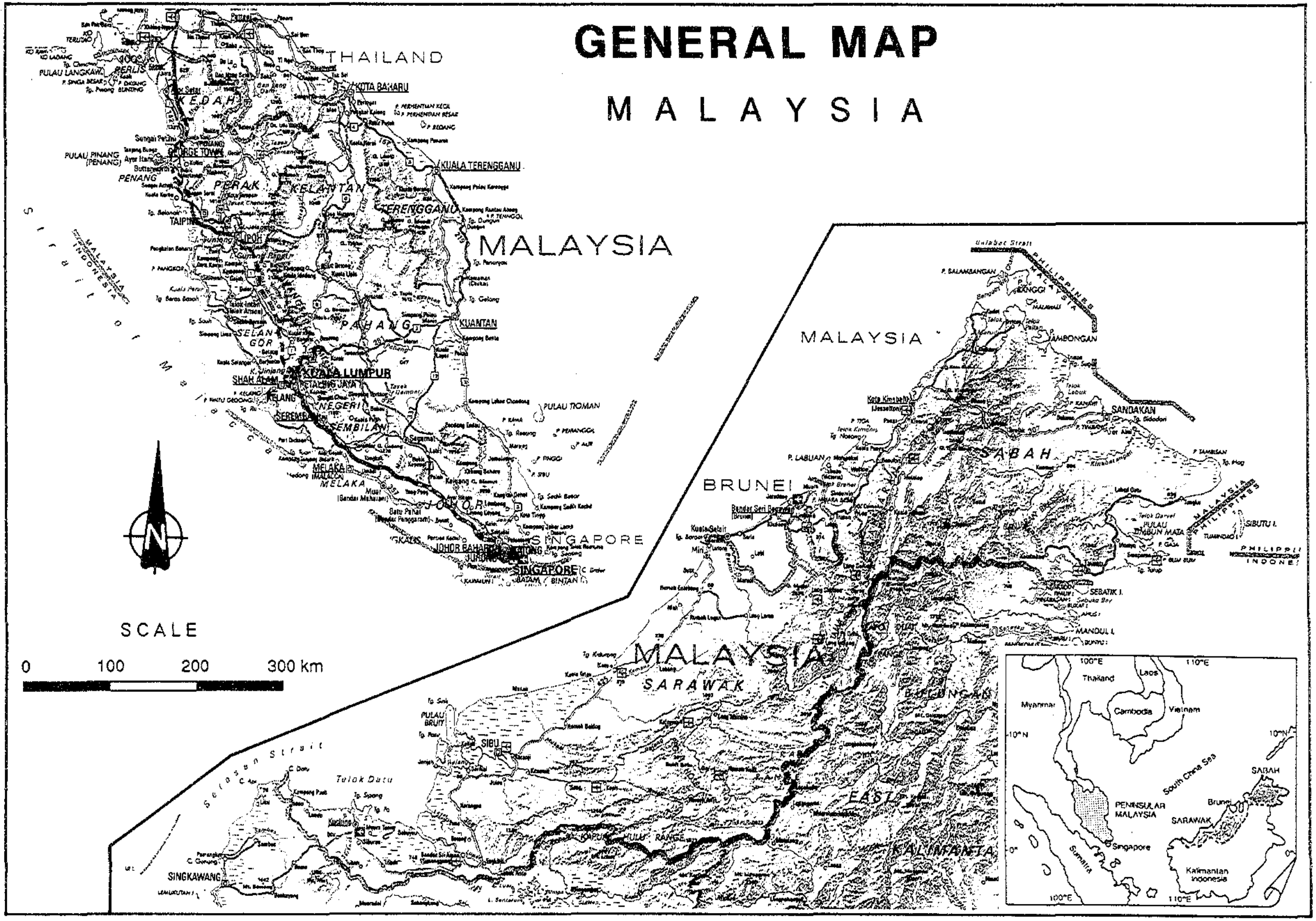

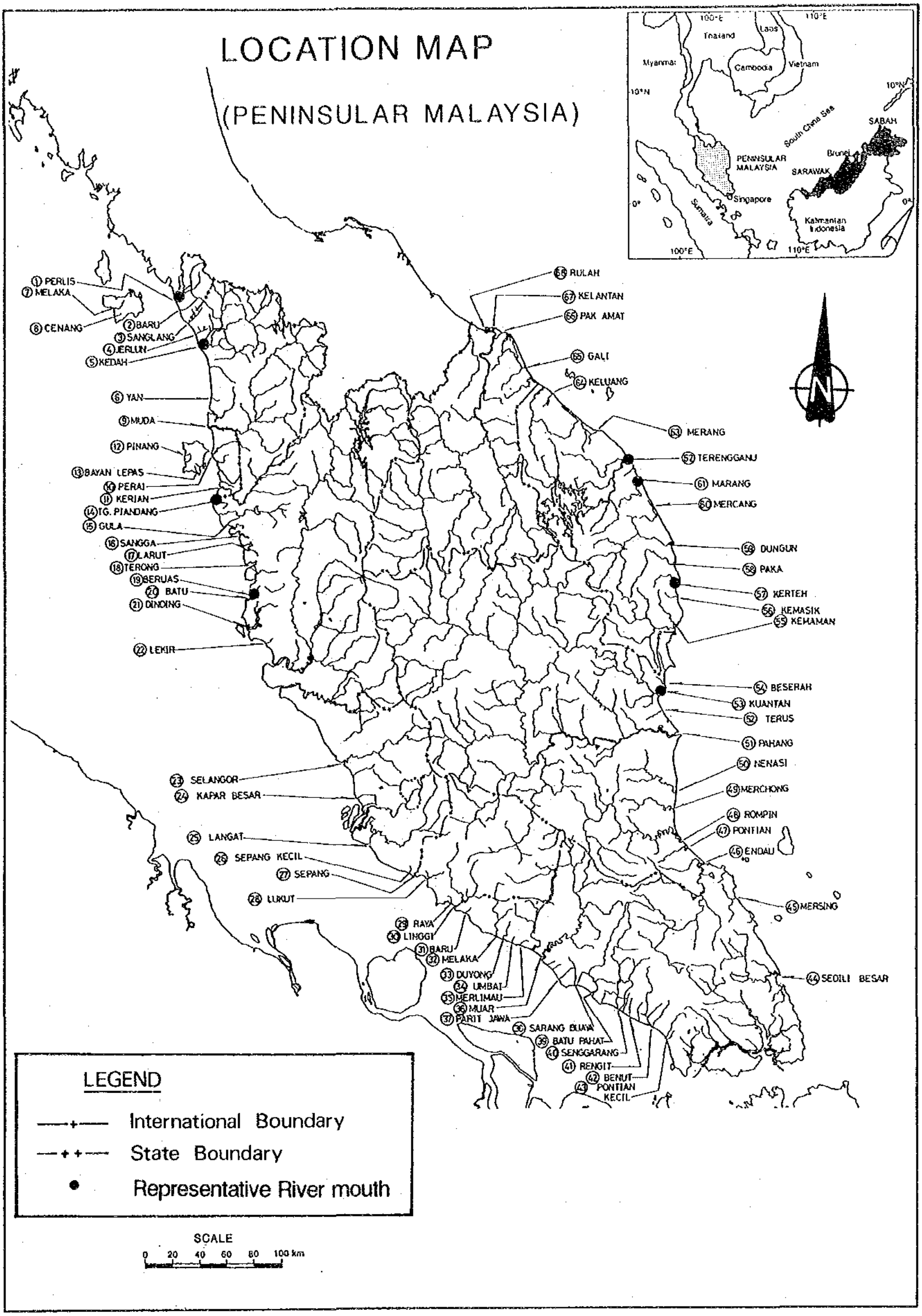
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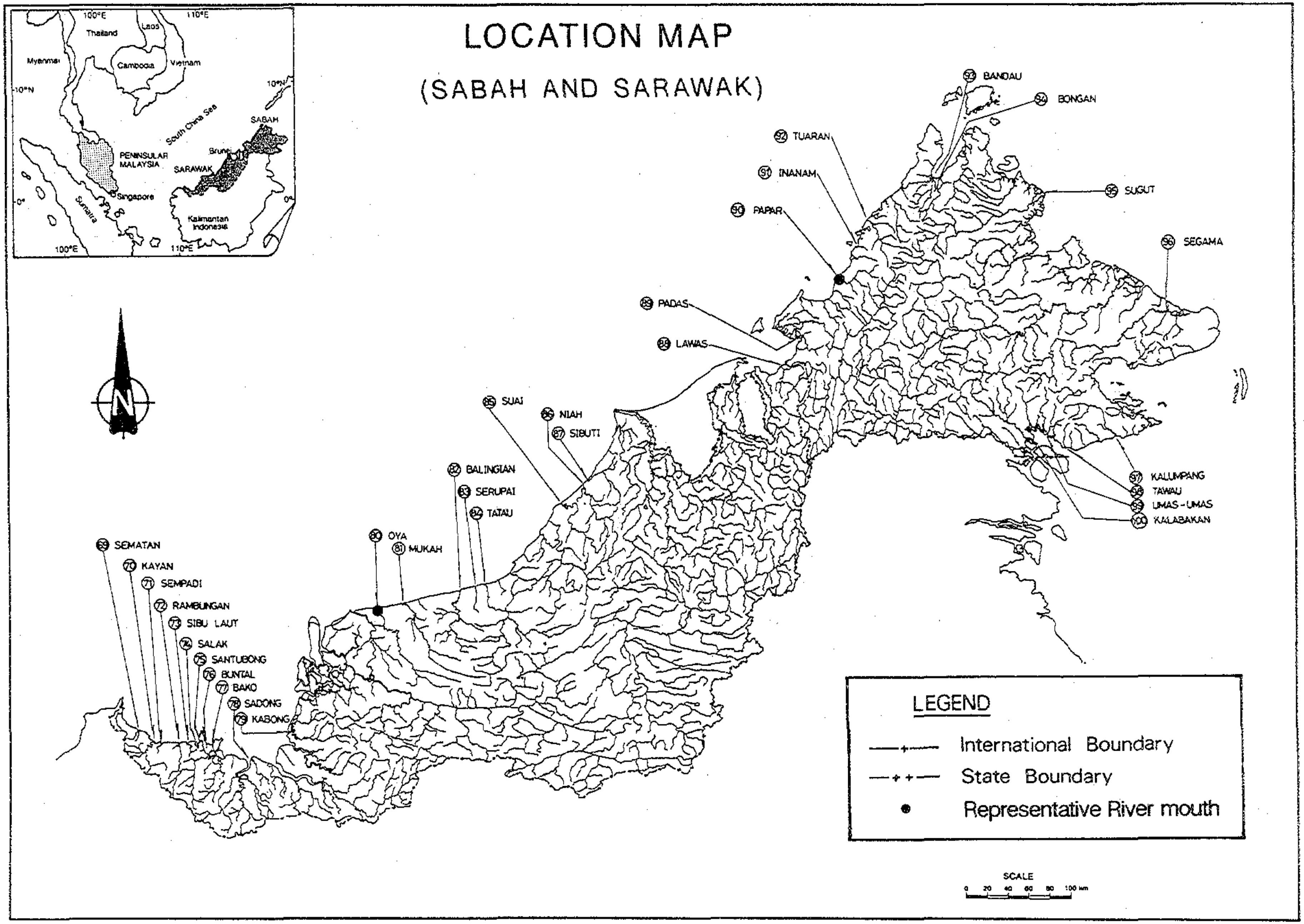
Representative River mouth
SCALE
0 20 40 60 80 100 km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SUMMARY

SUMMARY

1. SELECTION OF THE OBJECTIVE RIVER MOUTH

The objective river mouths for the Feasibility Study were selected from among those of the Master Plan Study under the following considerations:

(1) Two river mouths are selected from the group under Category 1 (Critical Condition).

(2) One of the objective river mouths selected is from a muddy coast and the other is from a sandy coast.

Among the river mouths under Category 1, the following are given high priority by each State:

Coast	State	River Mouth with High Priority
West Coast	Perlis	Perlis*
	Kedah	Kedah*
	P. Pinang	Muda
	Perak	Tg. Piandang*, Beruas*
	Selangor	Selangor*
	N.Sembilan	---
	Melaka	Melaka
East Coast	Kelantan	Kelantan
	Terengganu	Marang, Terengganu
	Pahang	Kuantan
	Johor	Mersing
	Sabah	---
	Sarawak	---

* River mouth located in a muddy coast.

The comparative study has led to the selection of the Tanjung Piandang and Marang river mouths, which are from a muddy coast and a sandy coast, respectively, for the following reasons:

(1) In the physical aspect, a river mouth with a small basin has less flow discharge to maintain the mouth open.

(2) In the economic aspect, the B/C ratio is high enough and worth conducting the feasibility study.

(3) In the social aspect, complaints of fishermen are very serious.

2. IMPROVEMENT OF TANJUNG PIANDANG RIVER MOUTH

2.1 Optimum Countermeasures

River Mouth Problem

In Tg. Piandang River Mouth the water depth which is only about 1.0 m below LSD (Land and Survey Datum) becomes some 10 cm at low tide both in the inner channel and the approach channel, while the draft of boat is about 1.5 m, so that fishing boats as well as fishing activities are forced to depend on the tide.

Selection of Countermeasures

As the optimum countermeasure, dredging in combination with capital and maintenance dredging which has an economical advantage and is also reliable in the technical aspect is selected in the Master Plan Study.

2.2 Further Basic Study and Analysis

The following study and analysis were conducted to determine the design features and benefit for the river mouth improvement plan formulation.

Siltation Rate in the Navigation Channel

In the Master Plan, the siltation rate is presumed from the previous dredging records and hydrographic survey results. In this Feasibility Study, the siltation rate is examined by numerical analysis using the monitoring data on siltation for test pits as the data for verification. The siltation rate of 0.9 m/year in the outer channel and 0.3 m/year in the inner channel are obtained.

Wave Intrusion into the River Mouth

In general, countermeasures are provided to keep the river mouth open, so that sea waves tend to intrude into the river mouth sometimes resulting in damage to facilities and ships moored around the river mouth. To confirm the magnitude of wave intrusion, wave refraction analysis was made and the results show that the wave height in the inner channel is less than 30 cm, which is within the limit in the guidelines used in Japan to plan fishing port facilities. Thus, the selected countermeasures are considered acceptable.

Influence of Countermeasures to Adjacent Coastline

Countermeasures for river mouth improvement sometimes bring about adverse influence to the adjacent coastline in a manner of coastal erosion resulting in damage to assets and facilities. The influence of countermeasures were examined by numerical analysis. The results show that dredging does not bring about severe erosion to the adjacent coastline, while the coastline of the northern side of the river mouth is currently retreating.

2.3 Design Features for Project Formulation

Design Boat Size

In the Master Plan Study, the design boat size of 40 GRT is given as the design criteria. In this Feasibility Study, the design boat size was examined considering the present and the expected future distribution of boat size. Although the future distribution of boat size is difficult to project because of unknown factors involved such as fishing resources, market and government policy, DOF presumes the following future distribution:

Period	Distribution of Boat Size (No.)		
	10 GRT>	10-40 GRT	40 GRT<
Present	481	5	0
1995	476	0	0
2000	456	0	0
2005	438	0	0

According to the table above, it is expected that only boats with the size of less than 10 GRT will engage in fishing at the Tg. Piandang River Mouth even in 2005. There is no plan to accommodate fishing boats from the other river mouths nearby. Therefore, the design boat size of 10 GRT is applied to the design features of dredging in this Feasibility Study.

Design Water Depth and Dredging Stretch

The design depth for the navigation channel is decided on the basis of the draft of design boat and allowance. In this connection, a clearance of 0.5 m is applied, while the design draft is 1.0 m. The design water depth is 2.5 m below LSD, considering that MLLW is -1.0 m LSD.

Dredging Stretch

(1) Outer Channel

The dredging stretch seaward, which is decided by the distance from the river mouth to the point where the sea bed height corresponds to the design water depth, is 1.9 km from the river mouth.

(2) Inner Channel

The dredging stretch of the inner channel is from the river mouth to the point of 0.9 km where the design dredging width corresponds to the river width, although fishing boats cannot access to their private jetties located in the further upper reaches of the design dredging stretch.

To assure the landing of catch for such boats even at low tide, it is proposed to provide common jetties in the dredging stretch.

Dredging Width

A two-lane navigation channel is provided to assure safe navigation in accordance with the guidelines commonly used in Malaysia.

2.4 Selection of Dredging Method

In accordance with the DID's guidelines, the dumping site of dredging material is proposed at a site located 3.0 km away from the river mouth.

Among several dredging methods applicable to the proposed navigation channel, the grab dredger, which has an economical advantage in consideration of dredging site and dumping site, is selected as the suitable dredging method.

2.5 Implementation Schedule

The project contains a few work items and the work quantities are rather small. Therefore, the project should be implemented altogether in the same year soon after the detail design work and fund preparation. All works, namely capital dredging, jetty and bank protection works, can be completed in the first year after commencement. In addition, maintenance dredging should be annually implemented.

2.6 Project Cost

The main work is channel dredging in combination with capital and maintenance dredging. As minor works, construction of common jetty and bank protection works are proposed. The project cost is summarized as below. (Price Level: As of November, 1992)

(a)	Main and Minor Works			
	- Capital Dredging	:	RM	1,059,000
	- Jetty Work	:	RM	88,000
	- Bank Protection Works	:	RM	68,000
(b)	Miscellaneous Works	:	RM	122,000
(c)	Mobilization and Demobilization of Dredger and Barges	:	RM	134,000
(d)	Compensation Cost	:	RM	0
(e)	Engineering and Administration Cost	:	RM	147,000
(f)	Physical Contingencies	:	RM	162,000
(g)	Price Escalation	:	RM	129,000
	Total	:	RM	1,909,000
(h)	Annual Maintenance Dredging	:	RM	660,000

2.7 Project Benefit and Economic Evaluation

Project Benefit

The presently estimated number of fishing boats and fishermen which will receive the benefit from the project is 480 and 720, respectively, and this may change in the future. The annual project benefit is calculated at RM 899,400 in 1996 when the benefit is expected to accrue, RM 869,000 in 2000 and RM 834,000 in and after 2005 in accordance with the change in number of boats in the future.

Economic Evaluation

The economic viability is evaluated by internal rate of return (EIRR) and cost-benefit ratio (B/C), and the EIRR of 17.0% and B/C of 1.173 are figured out.

2.8 Preliminary Environmental Impact Assessment

Major Environmental Impacts and the Consequences

The major environmental impacts arise from the project activities including capital dredging, spoil disposal and related activities, and the consequences are given as follows:

(1) Dredging will increase turbidity and possible release of trapped nutrients, organic matters and toxic substances from the sediment into the water phase. These impacts may not be significant because the river already carries a very high SS load.

(2) When the dredged spoil is disposed of at sea, the adverse impacts will be increased turbidity and possible release of trapped nutrients, organic matters and toxic substances into the water phase. The exceedance of the limit may not be of much significance in the case of Tg. Piandang because the metal level at depth is usually much lower than that at the surface, especially for polluted sediment.

Mitigation of Dredging Impacts

The capital dredging should be scheduled to avoid the southwest monsoon season which generates big waves aggravating the turbidity and water quality problems if dredging activities are undertaken. In a similar manner, the daily dredging activities should be scheduled so as to minimize disruption to movement of fishing boats.

When the disposal of spoil is at sea, it is important to ensure that the disposal site is not in the near vicinity of known fishing grounds and aquaculture areas. In addition, the DID's guidelines pertaining to the disposal of dredged material at sea should be complied with.

3. IMPROVEMENT OF MARANG RIVER MOUTH

3.1 Optimum Countermeasures

River Mouth Problem

In the Marang River Mouth the water depth which is only about 1.5 m below LSD (Land and Survey Datum) becomes a few 10 cm at low tide in the navigation channel, while the draft of boat is about 2.5 m, so that fishing boats as well as tourist boats are forced to depend on the tide. The river mouth and the river channel shift in location and course and thus, unstable. Wave intrusion into the river mouth is expected to be severe when the river mouth is kept open.

Selection of Countermeasures

As the optimum countermeasure, the combination of capital dredging, jetty, breakwater, river and coastal groins and reservoir is selected in the Master Plan Study.

3.2 Further Basic Study and Analysis

The following study and analysis were conducted to determine the design features and benefit for the river mouth improvement plan formulation.

Siltation Rate in the Navigation Channel

In the Master Plan, it is assumed that siltation can be prevented by the construction of a jetty to maintain the navigation channel without maintenance dredging. In this Feasibility Study, the siltation rate was examined through the hydraulic model experiment and it was confirmed that maintenance dredging in the navigation channel could be minimized.

Wave Intrusion into the River Mouth

As in the case of Tg. Piandang River Mouth, the magnitude of wave intrusion by the river mouth improvement of Marang was also examined through the hydraulic model experiment. The results show that the wave height in the inner channel is less than 30 cm, which is within the limit in the guidelines used in Japan to plan fishing port facilities. Thus, the countermeasures are considered acceptable.

Influence of Countermeasures to Adjacent Coastline

Countermeasures for river mouth improvement sometimes bring about adverse influence to the adjacent coastline in a manner of coastal erosion resulting in damage to assets and facilities. The influence of countermeasures was examined by numerical analysis. The results show that the countermeasures may bring about coastal erosion of 35 m in 30 years. However, the rate of retreat does not seem to be severe, although the shoreline is relatively stable around the Marang River Mouth in these years.

3.3 Design Features for Project Formulation

Design Boat Size

In the Master Plan Study, the design boat size of 40 GRT is given as the design criteria. The same design boat size is adopted in this Feasibility Study considering those at the present condition and future prospect, as follows.

Period	Distribution of Boat Size (No.)		
	10 GRT>	10 - 40 GRT	40 GRT<
Present	140	48	0
1995	130	40	0
2000	110	30	10
2005	90	20	20

Design Water Depth and Dredging Stretch

The design depth for the navigation channel is decided on the basis of the draft of design boat and allowance. In this connection, a clearance of 1.0 m is applied for the 40 GRT boat size, while the design draft is 1.7 m. The design water depth is 3.5 m below LSD, considering that MLLW is -0.8 m LSD.

(1) Dredging Stretch

(a) Outer Channel

The dredging stretch seaward, which is decided by the distance from the river mouth to the point where the sea bed height corresponds to the design water depth, is 460 m from the river mouth.

(b) Inner Channel

The dredging stretch of the inner channel is from the river mouth to the center of the port of 790 m where landing facilities are located.

(2) Dredging Width

A two-lane navigation channel is provided to assure safe navigation in accordance with the guidelines commonly used in Malaysia.

Structures

The design features of the structures examined through the hydraulic model experiment are as follows.

Jetty

- North Jetty : 490 m
- South Jetty : 450 m

Breakwater : 200 m

River Groin	:	40 m x 4
Coastal Groin	:	200 m x 2
Reservoir	:	11.6 ha

3.4 Selection of the Dredging Method

The dumping site of dredging material is proposed at the south coastline, where coastal erosion is expected, to fill the coastal erosion.

Among several dredging methods applicable to the proposed navigation channel, the cutter suction dredger which has an economical advantage is selected as the suitable dredging method.

3.5 Implementation Schedule

The project consists of the construction of north and south jetties, breakwater, river and coastal groins, reservoir and dredging of the navigation channel.

The proposed implementation period is two years, including mobilization and preparatory works. This was decided considering previous practices on similar projects.

3.6 Project Cost

The project cost is summarized as follows:

(a)	Preparatory Works	:	RM	1,066,000
(b)	Main Works			
	- Breakwater	:	RM	2,836,000
	- North Jetty	:	RM	2,774,000

	- South Jetty	:	RM	1,737,000
	- River Groin	:	RM	196,000
	- Navigation Channel Dredging	:	RM	1,295,000
	- Reservoir	:	RM	41,000
(c)	Miscellaneous Works	:	RM	507,000
(d)	Compensation Cost	:	RM	0
(e)	Engineering and Administration Cost	:	RM	1,172,000
(f)	Physical Contingencies	:	RM	1,289,000
(g)	Price Escalation	:	RM	1,183,000
	Total Estimated Construction Cost	:	RM	15,366,000
(h)	Annually Recurrent O&M Cost	:	RM	227,000

3.7 Project Benefit and Economic Evaluation

Project Benefit

The presently estimated number of fishing boats, fishermen and tourist boats which will receive the benefit from the project is about 170, 350 and 20, respectively, which may change in the future. The annual project benefit is calculated as below.

Year	Fishery	Sea Transport	Total (RM)
1997*	1,153,000	281,000	1,434,000
2000	1,254,000	298,000	1,552,000
2005	1,422,000	329,000	1,751,000

* The year when full benefit is expected to accrue, although partial benefit is expected in 1996.

Economic Evaluation

The economic viability is evaluated by internal rate of return (EIRR) and cost-benefit ratio (B/C), and the EIRR of 11.1% and B/C of 1.302 are figured out.

3.8 Preliminary Environmental Impact Assessment

Major Environmental Impacts

Major environmental impacts could arise from project activities including capital dredging and construction of structures. No significant impact is anticipated in the disposal of dredged material.

Mitigation of Dredging Impacts

The construction of structures scheduled after the known breeding period of a number of economically important species of fish should begin from March to avoid interference with the normal breeding period.

The capital dredging should be scheduled to avoid the northeast monsoon season which generates big waves aggravating the turbidity and water quality problems if dredging activities are undertaken. The daily dredging and construction activities should be scheduled so as to minimize the disruption to the movement of fishing and tourist boats.

4. RECOMMENDATIONS

(1) In this Feasibility Study, river mouth improvement plans for Tg. Piandang and Marang are formulated, and it is confirmed that the river mouth improvement projects for the two river mouths are both technically feasible and economically viable with the Economic Internal Rate of Return (EIRR) of 17.0% and 11.1%, respectively. Therefore, it is strongly recommended that the projects be promoted to the next stage of implementation at the earliest possible opportunity.

(2) In the case of Tg. Piandang River Mouth, dredging in combination with capital and maintenance dredging is selected as the optimum countermeasure. Under past experiences, only capital dredging is undertaken and maintenance dredging is never executed due to financial restrictions, so that the river mouth easily returns to its original condition before dredging. In this connection, it is recommended that maintenance dredging should be carried out regularly to ensure the accessibility of the river channel throughout the year and, for the purpose, the provision of funds for maintenance dredging should be considered from among the options for financial sources including the Federal and State governments and beneficiaries.

(3) In the case of Marang River Mouth, structures including the jetty, the breakwater, the river and coastal groins, and the reservoir, as well as capital dredging, are selected as the optimum countermeasures. Such coastal structures may bring about adverse influences to the adjacent coastal zone. Therefore, the construction should be carefully implemented by monitoring the influences.

PRINCIPAL FEATURES OF THE PROJECT

1. TANJUNG PIANDANG RIVER MOUTH

Design Boat Size	:	10 GRT
Countermeasures	:	Capital and Maintenance Dredging.
Dredging Stretch		
- Inner Channel	:	0.9 km
- Outer Channel	:	1.9 km
Design Cross Section		
- Bottom Width	:	28 m
- Depth	:	LSD -2.5 m
- Slope Gradient	:	1 : 5
Volume of Capital Dredging		
- Inner Channel	:	58,900 m^3
- Outer Channel	:	56,500 m^3
Volume of Maintenance Dredging		
- Inner Channel	:	7,500 m^3
- Outer Channel	:	47,900 m^3
Common Jetty for Landing	:	1 unit

2. MARANG RIVER MOUTH

Design Boat Size	:	40 GRT
Countermeasures	:	Combination of Jetty, Breakwater, River Groin, Coastal Groin, Reservoir, and Capital Dredging.

Jetty (North Side)

- Length	:	490 m
- Crown Width	:	6 m
- Design Height	:	LSD +3.0 to 5.0 m
- Slope Gradient	:	1 : 2; 1 : 1.5

Jetty (South Side)

- Length	:	450 m
- Crown Width	:	6 m
- Design Height	:	LSD +3.0 to 5.0 m
- Slope Gradient	:	1 : 2; 1 : 1.5

Breakwater

- Length	:	200 m
- Crown Width	:	6 m
- Design Height	:	LSD +5.0 m
- Slope Gradient	:	1 :2; 1 : 1.5

River Groin

- No. of Units	:	4 units
- Length	:	40 m
- Crown Width	:	2 m
- Design Height	:	LSD +1.1 m
- Slope Gradient	:	1 : 3

Coastal Groin

- No. of Units	:	2 units
- Length	:	200 m
- Crown Width	:	4 m
- Design Height	:	LSD +2.0 m
- Slope Gradient	:	1 : 1 . 5

Reservoir

- No. of Units	:	1 unit
- Reservoir Area	:	11.6 ha

Capital Dredging

- Length (Inner Channel)	:	790 m
- Length (Outer Channel)	:	460 m
- Bottom Width	:	45 m
- Dredging Depth	:	LSD -3.5 m
- Slope Gradient	:	1 : 2
- Volume of Dredging		
(Inner Channel)	:	79,700 m^3
(Outer Channel)	:	51,300 m^3

THE NATIONAL RIVER MOUTHS STUDY
IN MALAYSIA

VOLUME III

FEASIBILITY STUDY

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ABBREVIATIONS AND GLOSSARY

Abbreviations

DID	:	Department of Irrigation and Drainage
DOA	:	Department of Agriculture
DOE	:	Department of Environment
DOF	:	Department of Fisheries
DOS	:	Department of Statistics
DSM	:	Department of Survey and Mapping
EPU	:	Economic Planning Unit
ESCAP	:	Economic and Social Commission for Asia and the Pacific (UNDP, United Nations Development Programme)
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GRT	:	Gross Relative Tonnage
JICA	:	Japan International Cooperation Agency
JKR	:	Jabatan Kerja Raya (Public Works Department)
JPS	:	Jabatan Pengairan dan Saliran (= DID)
JPT	:	Jabatan Parit dan Taliair (= DID)
LEO	:	Littoral Environmental Observations
LKIM	:	Lembaga Kemajuan Ikan Malaysia (Malaysian Fisheries Development Authority)
MD	:	Marine Department
MMS	:	Malaysian Meteorological Service
MOA	:	Ministry of Agriculture
MOF	:	Ministry of Finance
NCES	:	National Coastal Erosion Study
NWRS	:	National Water Resources Study (by JICA)
NDP	:	National Development Policy
OPP2	:	Second Outline Perspective Plan
PA	:	Port Authority
PPC	:	Penang Port Commission
TNB	:	Tenaga Nasional Berhad (National Electricity Corporation)

Unit of Measurement

Area

ha	:	hectare
m^2	:	square meter
km^2	:	square kilometer

Weight

kg	:	kilogram
ton	:	1,000 kg

Volume

l	:	liter
ton	:	tonnage
m^3	:	cubic meter

Others

°C	:	degree centigrade
m^3/s	:	cubic meter per second

Currency

RM	:	Malaysian Ringgit
US$	:	U.S. Dollar
¥	:	Japanese Yen

Malayan Terms

Kg.	:	Kampong (village)
Kuala	:	river mouth
Pulau	:	island
Sg.	:	Sungai (river)
Telok	:	bay
Tg.	:	Tanjung (headland)

CHAPTER 1. INTRODUCTION

1.1 Selection of Objective River Mouth for Feasibility Study

The following considerations are taken into account in selecting the objective river mouths for the Feasibility Study:

(1) Two river mouths are selected from Category 1 (Critical) for the feasibility study.

(2) One of the objective river mouths for the feasibility study is selected from those located in a muddy coast and the other is from those in a sandy coast.

According to the interview survey, the following river mouths in each state are given high priority by the officials concerned, and the requirement for river mouth improvement has been confirmed through the Master Plan Study.

Coast	State	River Mouth with High Priority
West Coast	Perlis	Perlis*
	Kedah	Kedah*
	P. Pinang	Muda
	Perak	Tg. Piandang*, Beruas*
	Selangor	Selangor*
	N.Sembilan	-
	Melaka	Melaka
East Coast	Kelantan	Kelantan
	Terengganu	Marang, Terengganu
	Pahang	Kuantan
	Johor	Mersing
	Sabah	-
	Sarawak	-

* River mouth located in a muddy coast.

(1) River Mouth in Muddy Coast

River mouth features including catchment area, number of fishing boats, etc., are summarized in Table 1.1-1. Among the river mouths in a muddy coast, the Tg. Piandang River Mouth is selected as the objective river mouth for the feasibility study in view of the following reasons:

(a) Physical Aspect

In the physical aspect, the condition of seriousness is supposed to be the same among the river mouths mentioned above. However, the Tg. Piandang River Mouth with a small river basin has less discharge to maintain it open compared with the others. Therefore, the year to year condition of the Tg. Piandang River Mouth is presumed to be more serious.

(b) Economic Aspect

In the economic aspect, the B/C is high enough and worth conducting the Feasibility Study, although the value is not the highest among those in the muddy coast.

(c) Social Aspect

In the social aspect, complaints of fishermen from the Tg. Piandang River Mouth are more serious, although complaints are serious also at the Beruas and Selangor river mouths. The Tg. Piandang and Beruas river mouths have similar conditions in the three aspects, but no countermeasure has so far been undertaken for Tg. Piandang while dredging has been done for the Beruas River Mouth. Therefore, fishermen in Tg. Piandang are expecting the government more strongly to have some countermeasures undertaken.

(2) River Mouth in Sandy Coast

Two of the seven river mouths in a sandy coast are located in the west coast of the Peninsula. Since the river mouth in a muddy coast is located in the west coast, it seems advisable that the river mouth in a sandy coast is selected from among the five in the east coast. Comparison among the five river mouths in the east coast puts the selection to the Marang River Mouth for the following reasons:

(a) Physical Aspect

In the physical aspect, conditions in all the river mouths seem to be the same. However, the Marang River Mouth with the second smallest river basin has a more serious siltation problem considering the condition throughout the year compared with the other river mouths that have much bigger basins. As to the Terengganu River Mouth, it has a dam to control the flow regime and this possibly contributes to the maintenance of the river mouth, and it may be possible to alleviate the seriousness of the problem by operating the dam. In the case of the Marang River Mouth, seriousness in the physical aspect is amplified with the remarkable change of shipline due to the development of a sandbar; whereas, the other river mouths are relatively steady.

(b) Economic Aspect

In the economic aspect, the B/C for Marang River Mouth is high enough and worth conducting the Feasibility Study, although the value is only the second highest among the river mouths.

(c) Social Aspect

In the social aspect, the complaints of fishermen at the Marang River Mouth are quite strong compared with those at the other river mouths.

1.2 Outline of the Master Plan

In the Master Plan Study, the following results were obtained for the Tg. Piandang and Marang river mouths.

1.2.1 Tanjung Piandang River Mouth

The water depth, which is only about 1.0 m below LSD, becomes some 10 cm at low tide both in the inner channel and the approach channel, while the draft of boat is about 1.5 m. The channel filled with seawater also becomes very narrow, so that fishing boats as well as fishing activities are forced to depend on the tide.

Among several countermeasures, the combination of capital and maintenance dredging which has an economical advantage and is also reliable in the technical aspect is selected (refer to Fig. 1.21).

1.2.2 Marang River Mouth

The minimum water depth of the navigation channel at the Marang River Mouth is about 1.5 m below LSD, while the draft of fishing boats is about 2.5 m. Thus, entering and leaving the river mouth are generally not possible at low tide. The river mouth and river channel course are shifting and unstable, and wave intrusion is expected to be severe when the river mouth is kept open.

Among several countermeasures, the combination of capital dredging, jetty, breakwater, river and coastal groins, and reservoir is selected as the optimum countermeasure because of the economical advantage and reliability in the technical aspect (refer to Fig. 1.2-2).

CHAPTER 2. IMPROVEMENT OF TANJUNG PIANDANG RIVER MOUTH

2.1 General Conditions

2.1.1 River Mouth Geomorphology

The Tanjung Piandang River Mouth, which has a catchment area of 9 km^2 and a channel length of 10 km, is located on a relatively straight coastline with a shallow shore zone having a very gentle gradient of 1/1500. Over a long term period of 25 years or more, the south coast had undergone shoreline changes at the average rate of 10 m/year as identified in the Master Plan Study. Siltation is caused by tidal current in the Strait of Malacca and the predominant direction is from NNW to SSE. The survey data by the present JICA Study Team presents less profile changes during the two survey periods. By comparing the data of the two bathymetric surveys conducted, short term profile changes are observed, as described below. (Refer to Fig. 2.1-1 to 2.1-3.)

(1) Inside of the River Mouth

The waterline has not changed much, except at a few locations where deposits caused by tidal flow are found at the entrance of the stream and at the narrow part of the main channel.

(2) Around the River Mouth

Both sides of the shoreline had erosion, especially the southern beach which had receded by 1 to 2 m. Siltation is observed not only on the river mouth area but on quite a large area from a depth of 0 m to -3 m. Movement is from south to north, caused by alongshore current. The bottom slope of Tanjung Piandang River Mouth is gentle and some 20 to 50 cm of deposit at each survey line is observed.

2.1.2 Navigational Conditions

The number of boats passing through Marang River Mouth was surveyed in a time range of 30 minutes from 0:00 to 24:00 in the classification of outboard engine, inboard engine (below 10 GRT; 10 GRT and above) fishing boats and tourist boats. The number of outgoing and incoming boats are summarized on a daily basis in Table 2.1-1.

At Tg. Piandang, the survey was carried out together with the measurement of tidal levels for 8 days on June 30, July 2, 4, 14, 18, 21, 23, and 25, 1993, and the survey results show that fishing efforts and fishermen's livelihood are considerably subject to tidal conditions. On the day of favorable tidal conditions, outgoing and incoming boats abound from the hours of 6:00 to 8:00 and 13:00 to 15:00, respectively, as shown in Fig. 2.1-4. Fishing can be made offshore for about 7 to 8 hours a day, which is equivalent to the average one-day trip duration of small fishing boats, and hence catch amount possibly reaches the expected level.

In case that low tide comes at 4:00 to 5:00, fishing boats delay their out-going time for one or two hours to wait for a higher tide, and the outgoing boats abound around 8:00 with a very sharp peak as shown in Fig. 2.1-5. Boats densely return to the river mouth in three hours from 12:00 to 15:00 before the tidal level drops down. The fishermen are forced to reduce the fishing duration on this day, five or six fishing hours on an average, possibly resulting in insufficient catch.

On the day when the low tide comes around 8:00, the peak of outgoing boats appear three times a day; 5:00, 11:00 and 17:00, and accordingly the boat incoming time varies widely from 12:00 to 17:00 and midnight as shown in Fig. 2.1-6. The fishing duration of about eight hours seems to be attained on this day, although the low tide is the most unfavorable tidal condition from the viewpoint of fishermen's livelihood.

2.1.3 Environmental Conditions

Water Quality

The water quality of Tg. Piandang River Mouth is poor, being grossly polluted with organic wastes, most probably sewage, in view of the relatively high ammoniacal nitrogen and FC concentrations detected (refer to Table 2.1-2 and Fig. 2.1-7). The water quality gradually improves towards the river mouth due to the dilution effect of the sea. The river water carries extremely high SS content especially near the river mouth. Most of these solids probably originate from the muddy coast and are carried into the river by tidal action. Over the years, large quantities of silt have been deposited on the river mouth making the river very shallow. As a result of the shallow bottom along the navigable stretch of the river, the busy fishing boat traffic constantly churn up large amounts of silt, causing murkiness of the river water.

Tg. Piandang River is polluted with Pb, Cu and Zn in view of the high TNR metal concentrations comparable to those found in a polluted river (refer to Table 2.1-3 and Fig. 2.1-8). The most significant source of Zn pollution is the sewage discharged from the town of Tg. Piandang. Copper pollution is probably caused by the use of anti-fouling marine paints for boats and others. The source of Pb pollution probably comes from urban runoff since leaded petrol is still in use.

Biological Environment

(1) Mangrove Vegetation

The coastal vegetation in the Tg. Piandang area is made up of mangroves which had partially been reclaimed for agriculture. The present mangrove vegetation can be regarded remnant mangrove of a much more extensive mangrove forest which includes *Rhizpphora spp.* (or bakau), *Sonneretia spp.* (berembang, perepat and gedabu), *Cereiops* (tenger) and *Kandelia* (berus-berus).

A number of species usually found in the mangrove ecotone (i.e., the zone between mangrove forests and dry land forest) were found in Tg. Piandang.

(2) Mangrove Fauna

The macrofauna community of Tg. Piandang is typical of the Avicennia mangrove community of northern Malaysia. However, there are considerable differences between the macrofauna of the dead mangrove stands and live stands. The major differences can be attributed to the presence or absence of the Abicennia stands. Uca, Sesarmid and Scylla crabs dominate the mongroves here. The number of these are higher in the dead mangrove areas, while Scylla is absent within the live mangrove stands.

(3) Marine and Estuarine Communities

The invertebrates of the estuarine and marine communities involve those species of economic importance to the area. These were the Panaeid shrimps harvested at or near the Tanjung Piandang estuary.

The vertebrates of the estuarine and marine communities can be classified according to their habitat: the pelagic community and the benthic community. The pelagic community consists mainly of fishes described below. Of the benthic animal communities found at Tg. Piandang mangroves, the crustaceans and molluscs are the only dominant groups.

(4) Fishes

Most of the species collected during the study are common estuarine species such as the families *Ariidae* (ikan duri/catfish), *Cyanoglossidae* (ikan lidah/tounge sole), *Engraulidae* (ikan bilis/anchovies) and *Sciaenidae* (ikan gelama/jewfish). Families such as *Ariidae* are commonly found in estuarine areas due to their ability to tolerate fluctuating salinity and suspended sediment in the water. However, these hardy species are not preferred commercially and are seldom exploited by fishermen.

Engraulid species which are commonly available along Malaysian coastal areas and usually exploited by artisanal fishermen are also observed.

Sciaenid species are also observed. The fish, locally known as "gelama" is caught by fishermen for use as salted fish. These species congregate primarily inshore and are usually available in estuaries and areas with extensive mangrove.

Other important commercial species include bawal putih, belanak anding, kedara and siakap.

(5) Birds

The whole coastal mangrove/intertidal mudflats in Penang State are important feeding and wintering grounds for northern winter migrants, as well as major stopover feeding and resting grounds for migrants on transit to the southern region and on their way back north for the summer.

Although there are no extensive mudflats around the Tg. Piandang River Mouth, some narrow coastal mudflats are exposed along the mangrove coast at ebb tide. This exposed area and the very shallow areas during low tide conditions are the feeding grounds of shore birds, waders, egrets, herons and birds of prey. Terns, gulls and birds of prey also feed over the sea just off the coast, though the number of birds and the diversity of species feeding in this section of the coastline is relatively small.

Socio-Economic Environment

(1) Population and Income

Located at the Tg. Piandang estuary is the fishing village of Tg. Piandang which has a population of 13,485 being predominantly of Chinese "Teochew" origin. The primary income for the inhabitants of Tg. Piandang is related to the harvesting, sorting and distribution of fish and prawns from coastal waters and partly from fish cultured in floating cages in the sea off Bagan Tiang.

(2) Capture Fisheries

The capture fisheries are dependent on 180 "Apollo" mini-trawlers, 255 gill-netters of various types, 13 trap-netters and 5 purse seiners. At Tg. Piandang, there are a total of 486 registered fishing boats, but since "brother" boats are needed for operating the "Apollo" trawls and the purse seines, it is estimated that the boat numbers at Tg. Piandang estuary is about 640.

(3) Fish Marketing

There are 30 private fish dealers at Tg. Piandang and there is no LKIM fish landing complex. It is estimated that about 70% of the total prawn landings and 80% of the total finned-fish landings for the Krian district originate from Tg. Piandang.

(4) Mariculture

Eight residents of Tg. Piandang are owner-operators of floating fish farms in coastal waters, each having multiple units of floating cages. None of these farms are located within 3 km vicinity of the Tg. Piandang estuary. All of them are located in coastal waters off Bagan Tiang where apparently better water quality is available.

(5) Future Development

According to the Draft Structure Plan for Larut & Matang, Selama and Kerian 1990-2010, Tg. Piandang will be further developed as a service center for the fisheries industry.

2.2 Basic Study and Analysis

2.2.1 Siltation Rate

Numerical analysis was conducted to estimate the siltation rate at the Tg. Piandang navigation channel. When sea bed materials consist of clayey soil, movement of the materials is caused by tidal current and dispersion; hence, siltation rate analysis falls under tidal current analysis and advection-dispersion analysis.

Tidal Current Analysis

Tidal current analysis was carried out to analyze the action of tidal current in the objective area and thus, the siltation rate. The objective area starts from the Tg. Piandang tidal gate to the place where the sea bed level is deeper than -2.5 m to the on-offshore direction and extends for about 2 km to the longshore direction. The objective area is shown in Fig. 2.2-1 and referred to as the small scale area in this document.

Tidal current analysis was also carried out to determine the boundary condition of the small scale area using a large scale area. The large scale area covers the Tg. Piandang River Mouth and the site where tidal current was observed in the Study as shown in Fig. 2.2-1, and extends for 20 km and 15 km.

On the other hand, harmonic analysis was carried out using the observed data of the wave gauge installed during the Study. The harmonic analysis for the tidal current ellipse shows that the component along the longshore axis and its angle is 160 degrees clockwise from the north, as shown in Fig. 2.2-2. For verification of the tidal current analysis for the large scale area, the following values are adopted:

(a) Tide

Amplitude	:	84 cm
Phase	:	2.26 rad
Period	:	12.42 hr

(b) Current

Amplitude	:	20.7 cm
Phase	:	1.75 rad
Period	:	12.42 hr

(1) Basic Equation and Method of Numerical Analysis

As the basic equation for tidal current analysis, the following shallow water flow equation is adopted.

(a) Equation of Motion

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial \zeta}{\partial x} = 0$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial \zeta}{\partial y} = 0$$

(b) Equation of Continuity

$$\frac{\partial \zeta}{\partial t} + \frac{\partial Hu}{\partial x} + \frac{\partial Hv}{\partial y} = 0$$

where;

u	:	current velocity for x-direction
v	:	current velocity for y-direction
h	:	water depth
ζ	:	tidal amplitude
H	:	$h + \zeta$
g	:	gravity acceleration

As the method of numerical analysis in this Study, the finite element method is adopted.

(2) Tidal Current Analysis for Large Scale Area

To determine the boundary conditions for the small scale area, a time series of tide and current was calculated by adjusting the tidal level of the north and south boundaries to the wave gauge observation results. The current is reproduced correctly, as shown in Fig. 2.2-3 which gives the calculated tidal level and current velocity at the wave gauge.

Fig. 2.2-3 also shows the current velocity from the Tg. Piandang River Mouth towards offshore. Fig. 2.2-4 shows the maximum current pattern at the southward and northward directions.

(3) Tidal Current Analysis for Small Scale Area

The tidal current was calculated at the Tg. Piandang River and its mouth to compare the flow pattern with and without navigation channel.

Temporal changes of the tidal level and current velocity are shown in Fig. 2.2-5. The current velocity decreases corresponding to the increase of the water depth of the navigation channel.

Fig. 2.2-6 shows the current pattern at the mouth with and without navigation channel.

Advection-Dispersion Analysis

To estimate the siltation rate in this Study, the following advection-dispersion equation is adopted.

$$\frac{\partial \bar{c}}{\partial t} + u \frac{\partial \bar{c}}{\partial x} + v \frac{\partial \bar{c}}{\partial y} =$$

$$\frac{1}{h} \frac{\partial}{\partial x} \left(hD_x \frac{\partial \bar{c}}{\partial x} \right) + \frac{1}{h} \frac{\partial}{\partial y} \left(hD_y \frac{\partial \bar{c}}{\partial y} \right) + Q_L C_L \frac{1}{h} - S$$

where;

$\bar{c}$	:	depth averaged concentration (g/m^3)
u, v	:	depth averaged flow velocities (m/s)
D_x, D_y	:	dispersion coefficients (m^2/s)
h	:	water depth (m)
S	:	deposition/erosion term ($g/m^3/s$)
Q_L	:	source discharge per unit horizontal area ($m^3/s/m^2$)
C_L	:	concentration of the source discharge (g/m^3)

The rate of deposition is expressed by:

$$S = \frac{W_c}{h_a} \{ 1 - (\frac{V}{V_{cd}})^2 \} , \qquad V > V_{cd}$$

where;

W_c	:	mean settling velocity of suspended particles
h_a	:	average velocity through which the particles settle
V	:	depth averaged flow velocity
V_{cd}	:	critical deposition velocity

The rate of erosion is expressed by:

$$S = \frac{E}{h} \{ 1 - (\frac{V}{V_{ce}})^2 \} , \qquad V > V_{ce}$$

where;

E	:	erodibility of the bed ($g/m^2/s$)
V_{ce}	:	critical erosion velocity (m/s)

In the calculation, the coefficients are determined by referring to the previous studies, as follows:

Dispersion coefficients D_x and D_y are determined from the following equation:

$$\frac{D}{hu_*} = 340$$

where;

h	:	water depth
u_*	:	friction velocity $= \dfrac{n*g^{(1/2)}}{h^{(1/6)}} * V$
n	:	Manning's n
g	:	gravitational acceleration

Critical erosion velocity is set at 0.1 m/s and critical deposition velocity is calculated by the following Turuya's formula:

$$V_{cd} = A_1 * C \qquad (C < C_H)$$

$$V_{cd} = 0.0026\ m/s \qquad (C > C_H)$$

where, $A_1 = 0.6\ m^4/g/s$ and $C_H = 4{,}300\ g/m^3$

Erodivity of the bed is calibrated at 0.02 g/m^2/s to reproduce the refilling rate of 0.7 m/yr and the mud concentration from 300 g/m^3 to 2,000 g/m^3 at the test pit of the outer channel in Tg. Piandang River Mouth.

Comparison of Observed and Calculated Results

Results	Refilling Rate (m/yr)	Concentration (g/m^3)
Observed	0.7	300 to 2,000
Calculated	0.7	400 to 1,000

The refilling rate of the dredged channel is as given in the table from the calculation.

Refilling Rate of Dredged Channel

Place	Dredging Depth (m)	Refilling Rate (m/yr)
Outer Channel	2.5	0.9
Inner Channel	2.5	0.3

The refilling in the test pit of the inner channel is caused mostly by boat navigation rather than tidal current. Since the refilling by tidal current is considered only in the calculation, some adjustments are needed when the calculated results are applied to the actual situation.

2.2.2 Intrusion of Wave into River Mouth

In general, countermeasures are provided to keep the river mouth open, so that sea waves tend to intrude into the river mouth sometimes resulting in damage to facilities and ships moored around the river mouth. The intrusion of wave into the river mouth is examined as described in the following paragraphs.

In Tg. Piandang River Mouth, a combination of capital and maintenance dredging is selected as the optimum countermeasure for river mouth siltation. In addition, a shipping facility is proposed to be constructed 0.65 km inward from the river mouth to ensure the landing of fishermen's catch even during low tide. The location and cross section of the proposed dredging are presented in Fig. 2.3-1.

The intrusion of waves is examined by wave refraction analysis. The calculation conditions are as follows:

(1) Tide Level

The mean high water springs of 1.0 m above LSD is applied as the tide level.

(2) Intruding Wave

The initial waves with a height of 2.5 m and a period of 6, 8 and 10 seconds are given in parallel with the proposed dredged channel at -0.5 km. The wave height of 2.5 m is the breaking wave height at this section, namely; the probable maximum wave height.

Through 4-step wave chasing, the wave refraction diagram is obtained, as shown in Fig. 2.2-8, and the wave height at the proposed shipping facility is given as follows:

Intruding Waves			
Initial Height (m)	Period (sec)	Refraction Coefficient Kr	Wave Height at Landing Facility (0.65K) (m)
2.5	6	0.12	0.30
2.5	8	0.10	0.25
2.5	10	0.10	0.25

Intruding high waves are refracted and attenuated to smaller waves. The wave height at the proposed shipping facility is 0.3 m at the highest, which is within the limit for fishing port facilities, as shown below. Therefore, the inner channel of Tg. Piandang is calm enough for fishing port activities such as mooring of boats, and loading and unloading of fish catch and equipment.

Wave Height Limit for Fishing Port Facilities

Place	Water Depth at Place	
	3 m>	3 m<
Navigation Channel	0.9 m	1.2 m
Loading Place	0.3 m	0.4 m
Mooring Place	0.4 m	0.5 m

Source: Manual for Design of Fishing Port, Japan Port Association

Wave Height Limit for Loading Work

Place	Wave Height Limit
Mooring Place	0.3 m
Other Places	0.5 to 0.7 m

Source: Design Standard for Port Facilities, Japan Port Association

2.2.3 Influence to Adjacent Coastline

When sea bed materials consist of clayey soil, movement of the materials is caused by tidal current and dispersion. Suspended particles lifted up by high velocity exceeding the critical erosion velocity are transported by current and settle in a calm place.

Therefore, it is considered that very little movement occurs at the place where current velocity is the same as the natural condition after dredging of the navigation channel.

The difference of maximum velocity between the natural condition and the dredged condition along the shoreline as shown in Fig. 2.2-7 is 0.2 to 0.3 cm/s. These values are considered small enough as far as erosion and deposition are concerned, so that the influence to the adjacent coastline due to dredging can be considered negligible.

2.3 Project Formulation

2.3.1 Design Features

Basic Design Conditions

The countermeasure design conditions for Tg. Piandang River Mouth consider the following factors:

(1) Optimum Countermeasure

The optimum countermeasure selected for Tg. Piandang River Mouth is a combination of capital and maintenance dredging as mentioned in Section 1.2. Shipping jetty and bank protection works are additionally proposed in the Feasibility Study to assure the landing of fish catch because there are a number of small boats that cannot use their own jetty inside of the estuary beyond the dredging stretch in low tide. The bank protection works are placed in front of the proposed shipping jetty.

(2) Tide Level

The tide levels at Tg. Piandang River Mouth are as given below:

HAT	:	1.7 m (LSD)
MHWS	:	1.0 m
MHWN	:	0.3 m
MSL	:	0.1 m

MLHW	:	-0.1 m
MLWS	:	-1.0 m
LAT	:	-1.5 m

(3) Design Boat Size

In the Master Plan Study Stage, the design boat size of 40 GRT is given as the design criteria. In this Feasibility Study, the design boat size is examined considering the present and the expected future distribution of boat size. Although the future distribution of boat size is difficult to project because of unknown factors involved such as fishing resources, market and government policy, DOF presumes the following future distribution:

Period	Distribution of Boat Size (No.)		
	10 GRT>	10-40 GRT	40 GRT<
Present	481	5	0
1995	476	0	0
2000	456	0	0
2005	438	0	0

According to this table, it is expected that only boats with the size of less than 10 GRT will engage in fishing at the Tg. Piandang River Mouth even in 2005. There is no plan to accommodate fishing boats from the other river mouths nearby. Therefore, the design boat size of 10 GRT with the length of 14.02 m, beam of 2.80 m, depth of 1.00 m and draft of 1.00 m is applied to the design of dredging in this Feasibility Study.

(4) Siltation Rate

To design the maintenance dredging volume, it is necessary to figure out the annual siltation rate. Based on the siltation rate analysis, the annual rate is 0.9 m for the outer channel and 0.3 m for the inner channel.

Design Criteria

The countermeasures for Tg. Piandang River Mouth are capital dredging, maintenance dredging, shipping jetty and bank protection. The design criteria for each countermeasure are discussed as follows.

(1) Capital Dredging

To design dredging, the dredging width, side slope, depth and stretch must be clarified. The criteria to figure out the dimensions are as follows:

(a) Width

A two-lane navigation channel is provided to assure safety to navigation. As in the Master Plan, the following equation is applied to determine the width of the dredging channel, and the dredging width figured out is 28.0 m.

$$W = 10 * B$$

where,

W	:	dredging width (m)
B	:	ship beam (m)

(b) Side Slope

The design side slope of the dredging channel varies from 1:2 to 1:5 depending on the soil conditions. In this study, 1:5 is applied to the muddy coast.

(c) Depth

The design depth below chart datum (CD) is decided by the draft of ship plus allowance. The allowance is decided considering the squat of ship, draft, wave, siltation, etc., which can be hardly identified in the site. Here, the clearance of 1.0 m is used for 40 GRT and 0.5 m is applied for 10 GRT design boat size. Thus, the design depth of dredging is CD -1.5 m which corresponds to about 2.5 m below LSD.

(d) Stretch

As in the Master Plan Study, the dredging stretch seaward is decided by the distance from the river mouth to the point where the seabed height corresponds to the design water depth. That of the inner channel is decided to be the point where the design dredging width corresponds to the river width of Tg. Piandang River.

Outer Channel

The dredging stretch seaward is decided by the distance from the river mouth to the point where the sea bed height corresponds to the design water depth. As shown in Fig. 2.3-1, the stretch is 1.9 km from the river mouth in this Feasibility Study due to the reduction of the design dredging depth, while it was 2.3 km in the Master Plan Study.

Inner Channel

The dredging stretch of the inner channel is from the river mouth to the 0.9 km point where the design dredging width corresponds to the river width from the following reasons:

- The river width becomes narrower from some ten meters to a few meters at 0.9 km from the river mouth. A number of private jetties have been constructed on soft mud along the inner channel with only a few meters in width, where fishermen maneuver their boats for going out and coming in.

- Although it is desirable to dredge the whole stretch where the fishing boats navigate for landing their catch, dredging is not realistic for such a narrow channel because it causes collapse of private jetties and evacuation problem on houses and loading facilities.

(2) Maintenance Dredging

The design criteria for maintenance dredging are the same as those for capital dredging. The calculation of maintenance dredging volume is based on the rate of siltation mentioned in the design conditions.

(3) Shipping Jetty

Jetty works are located 0.6 km from the river mouth. They are to be constructed of wooden pile and board. The length of jetty is 40.0 m from the bank and the number of jetties are three. The height of the shipping jetty is MLWS+1.0 m for easier loading of fish. The facilities for fish loading consist of a simple house and an open space with pavement of reddish sand and gravel stone. An approach road is also provided from the existing road. (Refer to Fig. 2.3-2.)

(4) Bank Protection Works

Gabion mattress is used for bank protection in front of the jetty and the slope will follow the existing condition. The size of gabion mattress is 3.0 by 1.5 by 0.5 m. Stone masonry is placed on top of the gabion mattress 0.3 m high.

Work Items and Quantities

The work items and quantities of the countermeasures are given in Table 2.3-1 and summarized below.

(a) Capital Dredging

Inner Channel	:	58,900 m^3
Outer Channel	:	56,500 m^3
Total	:	115,400 m^3

(b) Annual Maintenance Dredging

Inner Channel	:	7,500 m^3
Outer Channel	:	47,900 m^3
Total	:	55,400 m^3

(c) Jetty Works

Land Adjustment	:	2,000 m^2
Wooden Jetty	:	700 m^2 (3 units)
Jetty House	:	1 unit
Gravel Pavement	:	2,800 m^2

(d) Bank Protection Works

Stone Masonry	:	42 m^3
Gabion Mattress	:	1,050 m^2

2.3.2 Selection of Dredging Method

Introduction

The Master Plan Study selected dredging as the most suitable measure for river mouth improvement in the west coast. In accordance with the design features of the navigation channel, more detailed study on dredging is carried out based on an in-depth supplemental survey to decide the suitable dredging method and to estimate the cost.

To draw up the dredging plan, the following conditions are considered:

(1) Water Depth of the Sea at the Entrance to River Mouth

The water depth of the nearshore zone and the river mouth area is too shallow for dredgers to normally operate. For this reason, dredging works should commence from the offshore portion. Dredging and other vessels with a small draft should be employed.

(2) Environmental Impact

The dumping site for dredged materials should be selected not only from the economical aspect, but also from the environmental aspects such as the preservation of mangrove, the protection of fishing zone and so on.

(3) Passage of Fishing Boats

During the operation of dredger and other working vessels, obstruction to the passage of fishing boats should be minimized as much as possible.

(4) DID Guidelines for Dredging Work

DID's guidelines pertaining to dredging work should be followed.

Disposal of Dredged Materials

Sea/river bed materials are identified as clay to silt having a particle diameter range of 0.05 to 0.001 mm. The surface layer to be dredged is very soft, and its N value (SPT) is estimated at less than 4. Therefore, dredging production rates are considered rather high.

As to the disposal of dredged materials, there are basically three options: (a) disposal in inland spoil bank; (b) disposal in spoil bank on coastal area; and (c) dumping at sea.

(1) Disposal in Inland Spoil Bank

Inland areas adjacent to the river mouth are utilized intensively as agricultural land. There seems to be no land available for the spoil bank.

(2) Disposal in Spoil Bank on Coastal Area

The coast in both north and south of the river mouth is composed of mangrove swamps having a zone width of 300 to 700 m. The inland area is protected by the bund from seawater intrusion. The plan to dispose dredged materials is to provide a spoil bank by enclosing a part of the mangrove area with bund. In view of the distance from the river mouth, this spoil bank would be both convenient and economical for the dredging. According to this plan, about 9 ha of the mangrove area would be replaced by the spoil bankyard.

(3) Dumping at Sea

The DID's guidelines pertaining to the dumping of dredged material at sea are as follows:

(a) Dumping site is to be located at least 3 km away from the river mouth;

(b) Water depth at the dumping site is to be more than 10 m; and

(c) The site is to be located downside of the littoral drift.

In addition to the above, approval by the Marine Department (MD) is necessary. From the viewpoint of protecting the fishing zone, special care should be taken [as to items (a) and (b), either of them must be fulfilled]. To fulfill the conditions given above, the only dumping site available is an area 3 km away from the river mouth. Considering the dredging method, the suitable dumping site is selected through further study between the two cases, dumping at sea and disposal on the coast, as shown on Fig. 2.3-3.

Dredging Method

There are four kinds of dredging methods considered applicable to the proposed navigation channel, as follows:

Method 1: Cutter Suction Pump Dredger; small size dredger is preferable, because the draft of the dredger is restricted by the shallow nearshore zone. Dredged material is discharged by pipeline into the spoil bank on the coastal area mentioned above.

Method 2: Dredging machine with cutter suction pump, which is applicable in the shallow river mouth area, discharging by pipe into the spoil bank on the coastal area. The pipe length must be kept below 1,000 m.

Method 3: Grub (Clamshell) Dredger, discharging to hopper barges, and barges being unloaded into the offshore dumping site. Dredger and barges will be restricted to the smaller scale ones which can operate even at low tide.

Method 4: Trailing Suction Hopper Dredger, dumping to the disposal ground offshore.

The methods are compared, as shown in Table 2.3-2, and assessed as follows:

(1) Method 1 would be applicable under the condition that the spoil bank could be provided on the coastal area, as shown in Fig. 2.3-3.

(2) Method 2 is applicable only to inner channel dredging but the operation in offshore area is considered impossible, because the machine cannot resist big waves.

(3) Method 3 is applicable and advantageous under the condition that the dumping site is at sea 3 km away from the river mouth.

(4) Method 4 is not applicable, because the water depth of the proposed channel is not enough for this type of dredger to pass during low tide.

Through the above considerations, Method 1 with disposal on the coast and Method 3 with dumping at sea are found to be technically feasible. To select the best alternative, a detailed comparison study is carried out as discussed below.

<u>Selection of Dredging Method and Dumping Site</u>

Method 1 (Cutter Suction Pump Dredger) and Method 3 (Grab Dredger) are compared in detail from various aspects, as shown in Table 2.3-3. The comparative study concludes as follows:

(1) Method 1 with Disposal on the Coast

This method needs about 1,500 m long pipeline to discharge dredged material into the spoil bank provided on the coastal area. As a result, about 9 ha of mangrove swamp will be converted into the spoil bank. This might be debatable from the viewpoint of mangrove preservation. Besides, the pipeline might be obstructive to the passage of fishing boats. Costwise, the unit price of dredging is lower than that of Method 3; however, higher cost for pipeline setting and spoil bank treatment is required. The total cost is estimated to be higher than Method 3.

(2) *Method 3 with Dumping at Sea*

This method has been widely employed for navigation channel dredging on the west coast. Compared to Method 1, the dredging efficiency is lower and a longer hauling time is required for dumping dredged materials. This might lead to higher unit cost and longer period of dredging work. However, the total dredging cost is estimated to be lower than Method 1. From the environmental aspect, Method 3 is preferable, since a suitable dumping site is available offshore 3 km away from the dredging site and no serious problem is expected to the navigation of fishing boats.

From the overall assessment, Method 3 (Grab Dredger) with dumping at sea is recommended for both inner and outer channel dredging.

2.3.3 Implementation Schedule

The project contains a few work items and the work quantities are rather small as mentioned before. The project, therefore, should be implemented altogether in the same year soon after the detail design and fund preparation. All works, namely capital dredging, jetty works and bank protection works, can be completed in the first year after commencement.

In addition, maintenance dredging is to be implemented annually. To perform an effective maintenance work, periodical monitoring of the navigation channel is required. Besides, investigation on the dumping site should be carried out to decide the appropriate site which is less affecting the nearby sea environment. Regarding the dredging period, the dredging should be scheduled to avoid the southwest monsoon season (April to July) as suggested by the preliminary environmental impact assessment.

The proposed implementation schedule of the project is as shown in Fig. 2.3-4.

2.3.4 Cost Estimate

Conditions for Cost Estimate

Project cost is estimated on the following assumptions:

(1) Construction works are to be executed by local bidding.

(2) All unit costs are expressed based on the price level of late 1992 with the annual price escalation rate of 2.4%.

(3) The unit cost of each construction work item is estimated on the unit price basis, except for some items which are estimated on lump sum or percentage basis. The estimated unit costs of necessary construction work items are as shown in Table 2.3-4.

(4) Total construction costs are estimated in consideration of the following components:

(a) Main Works

(b) Miscellaneous Works [10% of (a)]

(c) Mobilization and Demobilization Expenses for dredger and barges [10% of Dredging Works]

(d) Engineering and Administration Cost [10% of (a)+(b)+(c)]

(e) Physical Contingencies [10% of (a)+(b)+(c)+(d)]

Dredging Unit Cost by Grab (Clamshell) Dredger

An accurate unit cost of dredging by this type is, in general, quite difficult to estimate, because there is no proper standard cost estimate system in the country. Prior to estimating dredging cost for this study, actual costs quoted in similar projects undertaken by DID were examined. The following table shows the dredging unit costs by Grab (Clamshell) dredger.

Location	Year	Dredging Volume (m^3)	Unit Cost (RM)	Site
Beruas	1988-1990	132,000	4.5	7 km offshore
Perlis	1990	15,000	10.0	Inland
Johor Bharu	1991	400,000	6.0	3 km offshore
Kuantan	1990	400,000	5.0	3 km offshore

As can be seen on the table, unit costs range from RM 4.5 to RM 10 depending on the total volume of dredging. The table also shows that the bigger the dredging volume, the lower is the unit cost. To estimate the proper unit cost as of late 1992, a cost estimate calculation is tried based on the data collected in Malaysia and the cost estimate method in Japan. The conditions for the calculation and results are as follows:

(1) Calculation Conditions

Grab (Clamshell) Dredger	:	320 HP, Bucket Capacity 3.0 m^3
Sea/River Bed Material	:	Soft clay, N-Value < 4
Total Dredging Volume	:	100,000 m^3
Hourly Production	:	115 m^3
Operation Hours	:	10 hours
Dumping Site	:	3 km offshore
Necessary Vessels	:	Anchor boat (1) Tugboat (2) Hauling Barge 90 m^3 (3)

(2) Results

Unit Cost (Average)	:	RM 8.5/m^3
For Outer Channel	:	RM 7.6/m^3 (Average hauling distance: 2.0 km)
For Inner Channel	:	RM 9.5/m^3 (Average hauling distance: 3.5 km)
Required Dredging Period	:	3.5 months

The unit cost calculated is judged responsive in comparison with actual unit costs employed by other dredging projects in this country. Therefore, the unit costs obtained above are used for this project cost estimate.

Project Cost

(1) Capital Project Cost

The estimated project cost (financial cost) of the proposed river mouth improvement works is as shown in Table 2.3-5, and summarized below.

1. Construction Base Cost

(a) Main Works

Dredging	:	RM	1,059,000
Jetty Works for Fishing Boats	:	RM	88,000
Bank Protection	:	RM	68,000

(b) Miscellaneous Works : RM 122,000

(c)	Mobilization/Demobilization of Dredger and Other Vessels	:	RM 134,000
2.	Compensation Cost	:	RM 0
3.	Engineering and Administration Cost	:	RM 147,000
4.	Physical Contingencies	:	RM 162,000
5.	Price Escalation	:	RM 129,000
	Total Estimated Project Cost	:	RM 1,909,000

(2) Maintenance Cost

Maintenance dredging of the navigation channel is the only maintenance work in this river mouth. Dredging volume for the maintenance, which is annually recurrent, is estimated to be 55,400 m^3, and most of it is for the outer channel. The cost of maintenance dredging is estimated on condition that the dredging method is the same as that of capital dredging. Hence, the same unit price mentioned before is employed. As to the mobilization cost, 20% of the total dredging cost is used considering the annual volume of dredging. The maintenance cost is estimated, as follows:

1. Maintenance Dredging Cost

Outer Channel (47,900 m^3 x RM 7.6/m^3)	:	RM 364,000
Inner Channel (7,500 m^3 x RM 9.5/m^3)	:	RM 71,000
Total	:	RM 435,000

2. Mobilization/Demobilization Cost

(20% of item 1 = 20% of RM 435,000)	:	RM 87,000

3.	Provisional Sum and Others (15% of items 1+2 = 15% of RM 522,000)	:	RM 78,000
4.	Administration Cost (10% of items 1+2+3 = 10% of RM 600,000)	:	RM 60,000
	Total Annual Maintenance Cost	:	RM 660,000

2.4 Economic Evaluation

2.4.1 Project Benefit

Project benefit is defined as the difference between "without-the-project" and "with-the-project" situations. River mouth siltation at Tg. Piandang causes economic loss to the fishing activities of small boats (less than 10 GRT), the number of which is expected to be 476 in 1995, 456 in 2000 and 438 in 2005, as discussed in Subsection 2.3.1. Hence, project benefit may accrue in the areas of fishery, but it has been verified by the site investigation, interview survey and basic analysis that sea transport and flood mitigation benefits are not expected.

<u>Unnavigable Hours</u>

The shallowest bed of Tg. Piandang River Mouth has been surveyed at -1.5 m (LSD), and this hampers navigation at low tide. The 1990 tidal records at the Kedah Pier Station, the nearest station from Tg. Piandang, is studied to calculate the unnavigable hours for small boats which require a minimum water depth of 1.0 m to navigate as shown in Fig. 2.4-1. The water depth of less than 1.0 m takes place for 14.5% on an average. The actual average unnavigable hours is calculated at 0.87 hour per day/boat, i.e., 14.5% x 24 hours x 50% x 50%, considering that river mouths are used only in the daytime (50% of a day) and assuming that boats stay offshore for normal fishing activities for about 50% of the duration affecting navigation at river mouths.

Benefit Calculation

The major problem of small size fishing boats is the suspension of fishing activities with a catch lesser than the capacity so as to return to port within a period of high tide or to wait for the high tide when they go out to sea. In both cases, river mouth siltation causes reduction of fishing duration resulting in lesser fish catch. In this context, the benefit for small boats is defined as the increase of fish catch which is calculated proportionately with the extension of fishing effort duration, although incremental boat running cost and refrigeration cost should be subtracted from the incremental catch amount. The unit values necessary for the calculation are obtained from the annual fisheries statistics (1990), the DOF, the LKIM and the interview with local fishermen, and those on the small fishing boats are as follows:

No. of Trips per Year	:	265
Duration per Trip (hrs.)	:	8
Annual Catch (RM)	:	20,000
Boat Running Cost (RM/hr.)	:	0.97
Refrigeration Cost (RM/hr.)	:	0.20

The annual benefit can be calculated by the formula [(increase of catch) - (incremental running cost + cooling cost)]; i.e., the annual benefit per small fishing boat is as follows: RM 20,000 x [(8+0.87) hrs./8hrs. - 1] - [RM 0.97/hr. x 0.87 hrs./trip x 265 trips + RM 0.20/hr. x 0.87hrs./trip x 265 trips], and it makes RM 1,905 per boat. The annual benefits are thus calculated as follows:

	1995	2000	2005
No. of Boats	476	456	438
Annual Benefit ('000 RM)	907	869	834

2.4.2 Economic Viability

The Tg. Piandang river mouth improvement project is designed to assure navigation with adequate safety for small fishing boats. The economic evaluation for this project is made by figuring out the economic viability in terms of internal rate of return (IRR) and cost-benefit ratio (B/C), comparing the economic project cost and annual average benefit which may accrue in accordance with the expected cost-benefit flow in the project life. To calculate the IRR and B/C, the following basic conditions are set up:

(1) Target completion year is set at 2005, and project life is assumed to be 40 years including the construction period, which considers the durable life of structures to be installed.

(2) All the monetary calculations are expressed in Malaysian Ringgit (RM) at the price level of the later part of 1992.

(3) The annual benefit starts to accrue fully after the completion of construction works, and vary until 2005 in line with the changes in number of boats as discussed in the preceding section, and keep the same level after then.

(4) Economic construction cost is estimated from the financial cost by multiplying it with a social conversion factor of 0.88, which is derived from the National Parameters for Project Appraisal in Malaysia, and price contingencies are disregarded for the calculation of economic viability, as follows.

Item	Financial ('000 RM)	Economic ('000 RM)
Construction Cost	1,471	1,294
Compensation Cost	0	0
Engineering and Administration Cost	1,147	147
Physical Contingencies	162	144
Price Contingencies	129	0
Annual O&M	600	538

(5) A discount rate of 8% is applied for the calculation of B/C, considering base lending rates in recent years.

A cash flow of annual benefit and economic cost is prepared to figure out the values of IRR and B/C as presented in Table 2.4-1, and the results are as follows:

Internal Rate of Return (IRR)	:	17.0%
Cost-Benefit Ratio (B/C)	:	1.173

The Tg. Piandang project involves only dredging works without structural protection, and thus the annual maintenance cost required to assure the design navigation channel accounts for as much as 41% of the capital costs. As reflected in Fig. 2.4-2, the economic viability is sensitive to the change of construction cost and also maintenance cost. On the other hand, the fishery benefit is calculated to a possible maximum extent within its potential, and it cannot be denied that the calculation involves assumptions with unknown factors. Sensitivity analysis is, therefore, carried out on various cost and annual benefit, and the change of economic viability is examined as follows.

	Case	IRR	B/C
(1)	Construction Cost, 10% up	15.5%	1.154
(2)	Maintenance Cost, 10% up	13.4%	1.094
(3)	Annual Benefit, 10% down	11.0%	1.056
(4)	Combination of (1) + (3)	10.0%	1.039

2.4.3 Economic Evaluation

IRR is a reliable tool to evaluate a project in economic terms, and the borderline is generally around 10% in this kind of infrastructure project, although the IRR of the Tg. Piandang project is very sensitive to the increase of maintenance cost as mentioned in the preceding subsection. Even in the case of 10% up in the maintenance cost, the project is evaluated to maintain adequate economic viability.

Consideration is also given to intangible benefits to be brought about by the project, especially, the enhancement of safety to navigation and the stabilization of fishermen's livelihood. Fishery is the most important economic activity at Tg. Piandang River Mouth, and it contributes much to the regional economy to which the project will afford favorable socio-economic impacts.

In view of the high economic viability and favorable socio-economic impacts, as well as the necessity of assuring the safe navigation of fishing boats at Tg. Piandang River Mouth, river mouth improvement works should be implemented at the earliest opportunity.

2.5 Preliminary Environmental Impact Assessment

2.5.1 Potential Significant Impacts

Project activities which will give rise to major environmental impacts include capital dredging, spoil disposal and consequent activities.

Capital Dredging

(1) Physico-Chemical Impacts

The major adverse impacts associated with dredging are increased turbidity and possible release of trapped nutrients, organic matters and toxic substances from the sediments into the water phase. Increase in turbidity will result in reduced light penetration and reduced photosynthesis. Increase in organic matters will result in depletion of dissolved oxygen along the river stretch downstream of the dredging activities. These impacts may not be important in the case of Tg. Piandang because the river already carries very high SS load. The main concern is the possible release of some heavy metals from the sediments into the water phase during dredging. Studies by Wingom (1972) and May (1974) had shown that heavy metals do not appear to be increased in the vicinity of actual dredging.

(2) Biological Impacts

The impacts of the increased turbidity is temporary as sediment would eventually settle and part of it carried away by currents. The removal of mud by dredging means that the habitat on which various benthic organisms live would be lost. However, there are not many organisms of economic importance in the affected area as no cockle culture takes place in the proposed dredging zone.

Possible remobilization of heavy metals and other toxic substances would affect the growth and survival of some of the macrobenthic organisms. However, the levels of heavy metals may be low and, if dispersed over a larger area, may be diluted to below critical levels. A scientific study is required to evaluate such an impact.

(3) Socio-Economic Impacts

From an economic point of view, there is very little actual fishing activities in the proposed alignment of the dredging. Hence, there would be negligible economic impact.

Dredged Spoil Disposal

(1) Physico-Chemical Impacts

In case the spoil is disposed of at sea, the adverse impacts will be increased turbidity and possible release of trapped nutrients, organic matters and toxic substances into the water phase. The U.S. Environmental Protection Agency (EPA) has listed the limits of the various pollution parameters in sediments for determining the acceptability of disposal to fresh and saline waters, as tabulated below. The sediment is considered unacceptable for open water disposal if one or more of the limits is exceeded. However, the exceedance of the limit may not be of much significance in this case because the metal level at depth is usually much lower than that at surface especially for polluted sediment.

U.S. EPA Criteria

Parameter	Unit (ppm)
Mercury	10
Lead	50
Zinc	50

(2) Biological Impacts

There will be adverse impact on benthic communities at the spoil disposal site but there is no easy way to predict whether the impact will be long term or whether recolonization will be rapid. Impacts on organisms with relatively high mobility such as fishes will not be long term since water quality changes such as increased turbidity appear to be transient.

(3) Socio-Economic Impacts

There are very little negative socio-economic impacts for the spoil disposal at sea.

Consequent Activities

The main beneficiaries of the river mouth improvement works are the fishermen. It was observed that they have adapted to the shallow river channels by traversing the estuary only during high tides. If the channel were to be deepened, it is likely that the fishermen would be able to reap certain benefits, e.g., zero waiting time for bringing in their fisheries and they can do fishing without having to wait for high tide.

2.5.2 Mitigation and Abatement Measures

Various adverse environmental impacts could be significantly reduced by the application of mitigation measures consisting of design practices, planning control and legal requirements.

Mitigation of Dredging Impacts

The capital dredging should be scheduled to avoid the southwest monsoon season which lasts from April to July. The monsoon season always generates big waves which will aggravate the turbidity and water quality problems if there are dredging activities.

In a similar manner, the daily dredging activities should be scheduled so as to minimize the disruption to the movement of fishing boats.

Mitigation of Spoil Disposal Impacts

It is important to ensure that the disposal site is not in the near vicinity of known fishing grounds and aquaculture areas. In addition, the DID's guidelines pertaining to the disposal of dredged material at sea should be complied with.

2.5.3 Environmental Monitoring Programme

Under the monitoring programme, environmental quality data are collected to detect possible changes to the environment due to the project. Since this kind of exercise demands heavy commitment of financial and human resources, the parameters chosen should be limited to those of utmost importance.

As to the physico-chemical parameters, the level of selected heavy metals in the water near the disposal site should be monitored before and after dumping.

As to the biological parameters, the levels of primary productivity in the vicinity of the disposal site at sea should be monitored before and after dumping of spoil.

To gauge the impact on economic activity, the shrimp catch in the vicinity of dredging and spoil disposal site should be monitored, as this is economically the most important catch of the inshore artisan fishermen.

CHAPTER 3. IMPROVEMENT OF MARANG RIVER MOUTH

3.1 General Conditions

3.1.1 River Mouth Geomorphology

The Marang River has a catchment area of 460 km^2 and a total channel length of 50 km. Its mouth is located 15 km SSE from the Terengganu River Mouth in Terengganu State. The shoreline of the stretch of 70 km from the Terengganu River Mouth to the Dungun River Mouth consists of a continuous sandy beach with a straight coastline and is generally aligned in a N35W direction.

The dominant wave direction around this area is from ENE to NNE and the angle between orientation of shoreline and wave direction (assumed NE) is about 80°. In general, the equilibrium shoreline is perpendicular to the wave direction unless there are specific characteristics of the topography and/or sand supply and demand are in equal volume at a certain wide area.

The shoreline from Dungun in the north up to Merang passing through Terengganu may likely be in equilibrium, because the angle of the orientation of shoreline and wave direction is nearly 90° and the balance of sand movement from upstream to downstream with alongshore current is maintained at the same bottom profile.

Kapas Island is located offshore 5 km from the river mouth, and the topography of the area is partially affected by the island. The convex pattern of the shoreline just south of the river mouth is formed by the modified wave direction caused by the island.

As for the short-term profile changes, they are reflected from the two bathymetric survey data, as summarized below. (Refer to Fig. 3.1-1 and 3.1-2.)

(1) Inside of the River Mouth

The two bathymetric survey results show that some sediment have been transported from the upper stream. The cross section at each survey line shows that sediment is not deposited at the navigation channel but in other shallow areas, and the channel can be maintained because of the constant flow capacity. The deepest point of the cross section may shift to another place, but it will keep an almost the same profile.

(2) Around the River Mouth

The survey observation data cover only six months from the beginning of the northeast monsoon season; hence, it might be hard to know the annual beach profile changes. However, high waves concentrate on this season and, generally, it is a good period to observe changes in topography. Comparison of the survey data shows that the limit of sediment movement could be between -4 m and -5 m (LSD) and the beach profile further from the river mouth shows a lesser change. There are some sediment deposited near the river mouth transported from the upper stream of Marang River and by alongshore current, especially those transported from the river and pushed back by wave forces. Therefore, sand accretion in front of the river mouth is developing based on storm wave attack.

3.1.2 Navigational Conditions

The number of boats passing through Marang River Mouth was surveyed in a time range of 30 minutes from 0:00 to 24:00 on June 16, 18 and 20, 1993 in the classification of outboard engine, inboard engine (below 10 GRT; 10 GRT and above) fishing boats and tourist boats. The survey was attempted again on November 2 and 3, 1993, but no fishing and tourist boats were allowed to navigate on those dates because of high waves caused by the monsoon. The number of outgoing and incoming boats are summarized on a daily basis in Table 2.1-1.

According to the three-day survey results, outgoing and incoming fishing boats abound from the hours of 17:00 to 19:00 and from 6:00 to 8:00, respectively. On the survey dates, catching of squids was briskly carried out offshore at midnight.

The observed tidal levels on the same days at the Chedering Port located about 8 km north of Marang show that peaks of high tide appear from 8:00 to 10:00 and the tidal level rapidly drops down after 19:00. It seems that the outgoing fishing boats attempted to avoid the tidal drop-down, as shown in Fig. 3.1-3.

The tourist boats provide ferry service (60 to 70 trips/day) mainly between Marang and Kapas Island in the day time. The service hours were from 8:00 to 19:00 under the favorable tidal conditions on the days of the survey.

According to LKIM officials, both fishing and tourist boats are seriously affected by tidal conditions at the Marang River Mouth. They often change their outgoing and incoming time so as to pass the river mouth safely while adequate water depth is assured.

3.1.3 Environmental Conditions

Water Quality

Marang River is relatively clean because of the large amount of dilution provided by the seawater (refer to Table 3.1-1 and Fig. 3.1-4). The salinity data show very clearly that the bulk of the water at the river mouth and even as far upstream is seawater. The microbial data indicate significant bacterial pollution most probably due to sewage for the stretch of the river downstream of Kampung Batangan to the river mouth.

There is no discernible trend in the distribution patterns of both the total and TNR metal concentrations along the course of the river (refer to Table 3.1-2 and Fig. 3.1-5). Comparison of the TNR values with those rivers indicate clearly that Marang River is not polluted by Pb, Cu, Zn and Cd, because their TNR concentrations are lower than those of an unpolluted river.

Biological Environment

(1) Coastal Vegetation

The coastal soil is sandy and the beach regularly subjected to wave action. As a result, there is very little vegetation on the beach itself. Above the high tide mark, there are a number of different species which are common along the whole of the sandy coast of the east coast of Peninsular Malaysia. Since the land immediately above the high tide mark is inhabited, with a number of villagers, most of the natural vegetation had been cleared, and coconut trees planted instead.

(2) Coastal Fauna

(a) Mangrove and Estuarine Communities

Most of the mollusks found within the riparian zones of the Marang estuary were either on the sediment surface or attached to the vegetation along this zone. The dominant mollusc on the surface is *Telescopium telescopium*.

(b) Marine Communities

The coastal areas of Marang experience true marine waters with salinity reaching that of the open seas at 35 ppt. This is reflected by the presence of nearshore submerged coral reefs just off the Marang estuary. The distribution of molluscs on the beaches of Marang is patchy. The expanse of this zone at Marang especially near the estuary is large. *Donax sp.* is abundant. This small shellfish is collected by locals as food.

(3) Fishes

The waters around the Marang River Mouth and surrounding seas are very clear without any visible suspended matters. As such, more open-sea and species preferring clean, clear water are present. A school of silversides (Family *Atherinidae*) was observed among the pilings of the LKIM jetty. A large population of archer fish was also observed in the estuary.

Important commercial species include *Decapterus russlli, Gerres filamentosus, Leiograthus spp.* and so on. However, engraulids and sciaenids are rare in this area.

(4) Birds

The East Coast of Peninsular Malaysia is an important flyway for migrant waders, but the more vital feeding and wintering areas are in the extreme northern part of the East Coast and Southeastern Johore.

The Marang estuary and the adjacent estuaries being sandy, offer less nutrients than muddy estuaries and coastlines. As a result, only a small number of waders use the Marang Estuary as feeding/wintering grounds along the migration flyway.

There are a few sandbanks exposed during low tide on the seaward side of the coast. The sandbanks are often awashed by strong waves and the sub-strata is coarse and are deficient in nutrients. Only a single Little Tern was seen resting on the sandbank of the outer river mouth.

The coastal shoreline substrata is coarse sand. Very few bird species inhabit this area except for a few Common Myna, Eurasian Tree-sparrow, Spotted Dove, etc. The bird density at this shoreline is estimated to be 1 to 2 per 10 kilometer of coast (J.R. Howes et al, 1986).

The enlarged inner river mouth is fringed by a small mangrove patch on the right side of the shore. The sub-strata is sandy-mud. The dominant mangrove vegetation is *Rhizaphora dpiculata* in this thinly vegetated mangrove. The most abundant birds in this small mangrove area are the Collared Kingfisher, the Common Myna and the Brown-throated Sunbird.

Socio-Economic Environment

(1) Population and Income

Marang town and Kampung Seberang Marang, located only about 500 m from the sea, have a population of 4,738. Many of the inhabitants are of the low income group earning less than RM 350 per mensem, many of which are dependent on the marine fisheries. In the Marang district, there are a total of

1,057 fishermen, all of which are of Malay origin. At the Marang estuary, there are 966 Malay fishermen.

Other than the marine fisheries, another major economic activity in Marang is tourism. In 1992, an estimated 35,000 tourists visited Marang during March-October and this number is expected to increase as improved facilities in both Marang and the neighboring coral island of Pulau Kapas to attract tourists are being planned or constructed.

(2) Capture Fisheries

For most part of the year, small fishing boats exploit mainly the coastal pelagic fisheries. Most of the boats at Marang exploit the fishing grounds south of Pulau Kapas, the smaller boats fishing within 20 km of Pulau Kapas. Purse-seiners may fish as far as 50 km away from the coast depending on pelagic fish movements in the area. The waters in the vicinity of Pulau Kapas are a very important fishing ground for squid, which are caught using gill nets or by jigging using artificial lures.

(3) Mariculture

At present, there is no Master Plan for mariculture development in the Marang estuary, though the mariculture potential seems to be high.

(4) Tourism in Marang

Tourism is an important economic activity in Marang. Tourists come to Marang to enjoy the scenic beauty of Marang which has a variety of natural habitats with its interesting fauna and flora. As yet, the tourism resources in the district have to be fully exploited. It is envisaged that the number of tourists to the district will increase by 2 to 4% annually, provided the accommodation and support service facilities be further developed. Currently, foreign tourists constitute 76% of the total number of tourists staying for at least a night in the district.

3.2 Basic Study and Analysis

3.2.1 Siltation Rate

Hydraulic model experiment was conducted to analyze the effect and influence of proposed countermeasures for the improvement of Marang River Mouth. This experiment was carried out using the facilities of DID, as shown in Fig. 3.2-1 and 3.2-2.

The model is constructed with a movable bed coast and a reservoir for the water area upstream, as shown in Fig. 3.2-3. The scale model selected is 1/100 horizontal and 1/50 vertical considering mechanical and physical conditions.

The experiment was carried out in two stages. The first stage was the preliminary experiment to mainly examine the similarity of the model. The second stage was the experiment to examine the effect and influence of countermeasures.

For the second stage, seven cases of countermeasures were considered with the case of only dredging of navigation channel, as shown in Fig. 3.2-4. As the results of this preliminary experiment, the following wave conditions which reproduce the actual shore profiles were adopted.

Wave Height (H)	:	3.0 cm
Wave Period (T)	:	1.6 sec

In this experiment, the movable height of the sea bed provided was in the range of about -3.5 m to -4.0 m above LSD.

To examine the siltation rate, the height along the navigation channel was measured before and after the experiment for each case. The results of the experiment are shown in Fig. 3.2-5.

The Case with Only Dredging (Case 1)

The river mouth was finally clogged and the navigation channel silted up perfectly because of the longshore transport from both sides.

The Case with Breakwater (Case 2 and 3)

In these cases, only diffracted wave was intruded from the opening and the jetties prevented the longshore transport. So the navigation channel was clearly maintained.

The Case with Short Jetties (Case 4)

In this case, the tips of the jetties were adjusted to the required height of the navigation channel for small boats, so that the height of the sea bed at the tip was -2.7 m. The navigation channel was silted at about 1.0 m on average from the tip of the navigation channel to about 100 m inside. In addition to this, the sea bed between the jetties was also disturbed by intruded waves.

The Case of Medium Length Jetties (Case 5)

In this case, the tips of the jetties were almost adjusted to the movable height of the sea bed. The navigation channel was silted at about 0.3 m on average from the tip of the navigation channel to 100 m inside.

The Case with Long Jetties (Case 6 and 7)

In these cases, the jetties were lengthened beyond the active sediment transport zone. Therefore, not only the navigation channels but also the sea beds between the jetties were perfectly maintained.

To apply the results of the experiment to the actual situation, some modifications were needed because of the limitation of the hydraulic experiment. The following main points were not included in the experiment:

(a) Fluctuation of wave direction; and
(b) Discharged sediment from the upper reaches.

The experiment was made using the waves that approach the coastline in the right angle direction, although wave directions vary due to wind and it is expected that some waves approach the coast from the south. In this case, intrusion of a small part of littoral drift is estimated because of the short length of the south jetty compared with the critical depth for sediment movement of -3.5 to -4.0 m. Moreover, the discharged sediment is transported from the upper reaches during floods and this sediment will settle inside the jetty at the place where the flow velocity is slow. Therefore, it is necessary to make the opening width of the jetties narrow and to keep the cross sectional area of flow as same as that of the downstream of Marang Bridge to maintain the tractive force. Then the silted sediment can be flushed out to the sea and minimize maintenance dredging.

3.2.2 Intrusion of Wave into River Mouth

One of the purposes of countermeasures is to maintain the calmness inside the jetties. Therefore, wave heights inside the countermeasures were measured by ruler at the LKIM jetty just downstream of the Marang Bridge.

In general, the intruded wave height is small on account of the long distance from tip to jetty, the diffraction to the rightside estuary and the wave absorbing effect of countermeasures. However, the following differences were detected.

Case	Intruded Wave Height
1	less than 15 cm (after clogging)
2	10 to 15 cm
3	15 to 20 cm
4	20 to 25 cm
5	15 to 20 cm
6	less than 15 cm
7	less than 15 cm

Note that Case 3 only reduces the height of the breakwater of Case 2. In addition to this, intrusion wave height of actual conditions was estimated to be about less than 15 cm by the preliminary experiment.

3.2.3 Influence to Adjacent Coastline

The influence of river improvement works to the adjacent coastline takes two forms: one is the beach scouring along the jetties, and the other is the coastline change adjacent to the river mouth.

For the first problem, it was clear in the model study that no significant change occurred near the structures. For the other problem, the coastline change was estimated by the one-line model which can be applied to the coastal change caused by longshore transport. The coastline of 22 km from Chedering Port to the south was chosen for the calculation. The breaking wave angle was calibrated to simulate the coastline changes from 1973 to 1987, as shown in Fig. 3.2-6.

Fig. 3.2-7 shows the results of the coastline change due to the construction of structures. According to the results, the northern part of the river mouth expects accretion by about 35 m in 30 years, while the southern part retreats directly opposite the north side. Therefore, it is necessary to consider some measures for beach erosion prevention.

3.3 Project Formulation

3.3.1 Design Features

Basic Design Conditions

When a structure is constructed on a coast that is considered to be subject to various influences of littoral drift, taken into full consideration are the characteristics of littoral drift in the area concerned such as coastal topography, bottom material size, critical water depth for littoral movement, transport rate of littoral drift, and predominant direction of littoral drift and its influences.

(1) Optimum Countermeasures

As in the Master Plan Study, the countermeasures proposed for the improvement of Marang River Mouth are breakwater, jetty, river and coastal groin, reservoir and dredging.

(2) Wind

As determined in the Master Plan Study, the predominant wind direction is ENE to NNE.

(3) Tide Level

The tide levels at the Marang River Mouth are as given below.

HAT	:	2.0 m (LSD)
MHHW	:	1.3 m
MHW	:	0.6 m
MSL	:	0.3 m
MLW	:	- 0.1 m
MLLW	:	- 0.8 m
LAT	:	- 1.3 m

(4) Sea Bottom Conditions

Bed materials for the Feasibility Study were sampled at 50 locations from 1.1 km upstream of the river mouth to 500 m offshore. Gradation analysis and specific gravity tests were conducted for these samples. Median diameter d50 of the samples is 0.356 mm and the predominant material is sand.

(5) Critical Water Depth for Sediment Movement

The structure to be constructed on a coast to prevent alongshore sediment has to consider the critical water depth for sediment movement, because this is an important factor to determine the seaward length of the structure. Using several ways such as the calculation equation, thecomparison of bathymetric survey results and the model experimentation, the approximate value of the critical water depth was determined at around - 4.5 m.

(6) Design Boat Size

In the Master Plan Study, the design boat size of 40 GRT was given as the design criteria. In this Feasibility Study, the design boat size was examined considering the present and the expected future distribution of boat size. Although the future distribution of boat size is difficult to project because of unknown factors involved such as fishing resources, market and government policy, DOF presumes the following future distribution:

Period	Distribution of Boat Size (No.)		
	10 GRT>	10-40 GRT	40 GRT<
Present	140	48*	0
1995	130	40	0
2000	110	30	10
2005	90	20	20

* Out of 48 fishing boats, the size of 42 boats are smaller than 21 GRT, while 6 are larger than 21 GRT.

According to this table, all boats are smaller than 40 GRT and the majority is less than 21 GRT against only 6 boats larger than 21 GRT. Therefore, it may not be necessary to apply the design boat size of 40 GRT for only six boats at present, although 40 GRT is indispensable in the future. In this connection, the following two cases are examined to identify the economic efficiency of the project.

Case 1 : Only the design boat size of 40 GRT is applied.

Case 2 : Design boat size of 21 GRT is applied at present, 30 GRT at the year 2000 and 40 GRT at 2005.

The economic viability of the two cases is tentatively evaluated in internal rate of return (IRR) and cost-benefit ratio (B/C), and are figured out at almost the same value. In this project, therefore, employed is Case 1 which makes implementation of the works simpler and brings about project benefits earlier.

Design Criteria

The design criteria for countermeasures is as discussed below. The design features are as shown in Fig. 3.3-1 and 3.3-2.

(1) Breakwater

(a) Location

Breakwater is to be constructed in the offshore part of the north jetty to prevent waves coming into the navigation channel.

The connection between breakwater and jetty is a gentle shift without any rough step. The location is based on the experimental results, wave direction and alignment of the navigation channel.

(b) Alignment

High wave direction is concentrated between NNE and ENE, therefore, the alignment of breakwater should curve smoothly from the jetty until it becomes perpendicular to the NE direction, the center of both dominant wave directions.

(c) Length

The length of breakwater should prevent incident waves from coming into the navigation channel directly, and should consider smooth ship navigation. The design length is 200 m.

(d) Crest Height

The design crest height is decided on consideration that waves intruding into the river mouth will not damage navigating or mooring boats as well as port facilities. The design wave height to decide on the design crest height adopts the breaking wave height at the location where the breakwater is provided, because this height is assumed to be the maximum that could possible exist at that point.

The breaking wave height can be calculated in the following procedure:

Breaking Wave Condition

$h_b = 1.3\ m + 3.5\ m = 4.8\ m$; where 1.3 m is MHHW (+LSD) and 3.5 m is seabed height (-LSD).

$$L_o = 1.56\ T^2 = 1.56 \times 8^2 \approx 100\ m$$

$$h_b / L_o = 4.8 / 100 = 0.048$$

$$I = 1/50$$

where;

h_b	:	breaking wave depth
L_o	:	wave length
T	:	wave period
I	:	seabed gradient

Breaking Wave Height

$h_b / H_b \approx 0.73$ (obtained from Fig. 3.3-3)

$H_b = 0.73 \times 4.8 = 3.5\ m$

$H_b / H_o = 1.1$ (obtained from Fig. 3.3-3)

$H_o = 3.5 / 1.1 = 3.2\ m$

where;

H_b : breaking wave height

H_o : deepsea wave height

The design crest height is decided based on the relation between H_t/H_o and R/H_o shown in Fig. 3.3-4, allowing 10% of the wave height to be transmitted to the breakwater considering the guidelines for fishing port planning:

$B / L_o = 6/100 = 0.06$

$H_{t'} / H_{o'} = 0.01$

$R / H_{o'} = 1$

$R = 3.2\ m$ (above MHHW; about 5 m +LSD)

where;

B	:	crest length (= 6 m)
$H_{t'}$	:	wave height to be transmitted (m)
$H_{o'}$	:	deepsea wave height (= H_o m)
R	:	crest height (m)

(2) Jetty

(a) Location

To maintain the navigation channel and to prevent structural materials from falling into the channel, the jetty and the channel should keep a certain distance. The head of the north jetty is connected to the breakwater in a smooth curve. Under the above conditions, the location of the jetty is decided and the adequacy of the location is confirmed through the model experiment.

(b) Width between Breakwater and Jetty

Considering the rise of water level and the flow capacity at flood stage, the minimum width between structures is calculated at 90 m by the non-uniform flow calculation. In this project, in consideration of the model experimental results and to obtain the maximum flushing effect of sediment between the breakwater and the south jetty, the width is decided at 90 m.

(c) Alignment

The main purpose of the jetty is to prevent longshore transport from flowing into the navigation channel and let the stream flow smoothly into the sea. The jetty should be aligned nearly in parallel to the navigation channel alignment and the angle between jetty and the longshore current flow should be bigger than 90 degrees. The alignment is determined as shown in Fig. 3.3-1.

(d) Length

In the landside, the length of the jetty should consider the wave run-up to the shoreline and the wind-blown sand moving at the beach. Hence, the backshore length of the north jetty is 100 m and the seaside length is 390 m based on the model experiment. The south jetty has the same backshore length for protection against wave action at the back of the structure, and the seaside length is 350 m.

(e) Crest Height

Generally, the crest height of a jetty connected to a breakwater adopts that of the breakwater and then gradually lowers to the ground level with 1.0 m clearance (LSD +2.5 m) toward the beach site. However, considering the results of the model experiments, the crest height at beach site is decided at LSD +3.0 m because it was observed that longshore transport invades the navigation channel, overtopping the jetty. The beach site crest height of LSD +3.0 m is adopted to the position where the depth is LSD -1.5 m of seabed height in accordance with the analysis of the model experiment, and then gradually connects with the height of the breakwater at LSD +5.0 m.

As to the head portion of the south jetty, the height was determined on the condition that some wave overtopping is allowed under the maximum possible wave (critical wave) in front of the jetty. By the same method used in the design of breakwater, the critical wave height (H_b) and the design wave height at -3.1 m (LSD) are given by using Fig. 3.3-3 as follows:

$$H_b = 3.21\ m$$
$$H_o = 2.89\ m$$

Generally, the crest height (H_s) of a jetty under the MHHW tidal condition is derived by using the following formula:

$$H_s = 1/2 * H_b + MHHW$$
$$= 1.605 + 1.3$$
$$= 2.905\ m\ (LSD)$$

From the wave diminishing effect, the jetty in terms of height and width is designed as follows:

Given: Width of Jetty (B) = 6.0 m
Design Wave Length (L) = 99.84 m

By using Fig. 3.3-4 and assuming that $R/H_{o'} = 0.5$ and $B/L = 0.06$, the wave transmission coefficient $H_t/H_{o'}$ is found to be around 0.13. This means that the design wave height is reduced to about 0.38 m at the inner seaside of the jetty.

Thus, $R = H_{o'} x\ 0.5 = 1.445$; and $H_s = 1.445 + 1.3 = 2.745\ m\ (LSD)$.

By considering the above results, the crest height and the width of the south jetty are determined at +3.0 m (LSD) and 6.0 m, respectively.

(3) River Groin

The design features of river groin are emphasized with the height, slope, crown width and interval. The height of river groin (LSD +1.1 m) is decided to be the MHW (LSD +0.6 m) plus a clearance of +0.5 m to avoid unexpected influence to the bank in the neighboring area. The slope of groin is 1:3 and the length is 40 m with 2.0 m of crown width. Moreover, the interval of 120 m corresponding to 3 times the groin length is applied.

(4) Coastal Groin

The design features of the coastal groin is similar to the jetty in view of similarity of structure and purpose. The design height is 2.0 m LSD, which is the MHHW plus uprush. The slope is 1:1.5, and the length is 50 m at landside and 150 m at seaside. The crown width is 4.0 m to prevent wave overtopping and for easier implementation of construction. The interval between groins is two times the groin length from berm crest to the seaward end.

(5) Reservoir

The design of the reservoir is made considering the present condition of the lagoon. The civil works is mainly concerned with the stability of the slope to maintain the existing tidal volume effectively.

(6) Dredging

For the design of dredging, the width, depth and stretch must be clarified. The concept is the same as the design criteria of dredging for Tg. Piandang River Mouth.

(a) Width

A two-lane navigation channel is provided to assure safety to navigation. For the 40 GRT boat size, the width of dredging shall be 45.0 m as applied in the Master Plan Study.

(b) Side Slope

Since the dredging materials at Marang River consist of sand, 1:3 is applied as the side slope as in the Master Plan Study.

(c) Depth

An allowance is provided considering the squat of ships, wave, siltation, etc. The clearance of 1.0 m is used for 40 GRT boats with a draft of 1.70 m, and the design dredging depth is LSD -3.5 m.

(d) Stretch

The dredging stretch seaward is decided by the distance from the river mouth to the point where the seabed height corresponds to the design water depth. For the inner channel, the stretch is from the river mouth to the center of the port where landing facilities are provided. Since the nearest landing facility from the Marang River Mouth is the LKIM's jetty, the dredging length at seaside shall be 460 m, and at landside, 790 m.

Work Items and Quantities

The work items and quantities for Marang are given in Table 3.3-1 and summarized as follows:

(1) Breakwater

Armor Stone 1 (3-5 ton)	:	15,700 m^3
Secondary Stone (300-500 kg)	:	11,200 m^3
Core Stone 1 (100-300 kg)	:	11,300 m^3
Geo-textile Mat	:	2,200 m^2

(2) Jetty

Armor Stone 2 (1-3 ton)	:	32,200 m^3
Core Stone 2 (10-100 kg)	:	29,700 m^3
Geo-textile Mat	:	4,700 m^2

(3) River Groin

Armor Stone 2 (1-3 ton)	:	1,840 m^3
Core Stone 2 (10-100 kg)	:	720 m^3

(4) Coastal Groin

Armor Stone 2 (1-3 ton)	:	9,900 m^3
Core Stone 2 (10-100 kg)	:	7,800 m^3

(5) Reservoir : 11.6 ha in area

(6) Navigation Channel Dredging

Capital Dredging:

- Sand	:	109,000 m^3
- Soft Rock	:	22,000 m^3

3.3.2 Selection of Dredging Method

Disposal of Dredged Material

Dredged materials are expected to be basically the same in quality as that of the coast; therefore, disposal on the coast near the river mouth would be more convenient and economically advantageous for dredging works. In addition, after completion of the proposed jetty, the coastal area behind the jetty which is located in the downside of the littoral drift tends to be eroded in the long run. Considering this situation, it is recommended that the dredged materials be dumped on the coast near the foot of the south jetty for the beach filling which may be necessary in the future.

Dredging Method

The dredging methods which may be considered for the Marang River Mouth are as follows:

Method 1: Cutter Suction Dredger and Discharge Pipeline

Method 2: Grab (Clamshell) Dredger and Hauling Barges

Method 3: Dipper (Dustpan) Dredger and Hauling Barges

The river mouth water zone is very shallow, so that the operation/activity of dredgers and hauling barges will be limited especially in Method (2) and (3). Besides, approach to the proposed dumping site by hauling barges is considered impossible because of their deep draft. On the other hand, disposal by pipeline to the dumping site is more efficient and less costly, and the pipeline length is less than 800 m. Therefore, the cutter suction dredger is recommended for this river mouth.

Excavation of Riverbed Rock

Some parts of the riverbed at the river mouth contain soft rocks. The soft rocks to be removed are estimated to be 22,000 m^3. To excavate these rocks, the combination of a breaker and grab (clamshell) dredger is suitable. Compared to the dredging by cutter suction dredger, the work capacity of this method is lower and as a result, the unit cost becomes higher.

3.3.3 Implementation Schedule

Outline of the Project

The project consists of construction of the north and south jetties, the breakwater, the river and coastal groins, and dredging of the navigation channel. The structures are made up of seaworks such as riprapping, stone filling, rock armoring and placement of geo-textile mat. Capital dredging will be done to realize the design section of the proposed channel. Regular maintenance dredging will also be required to keep the design section from siltation. Since the sediment volume in the channel is expected to be small, maintenance dredging is incorporated into the O&M works. The work items and quantities are given in Table 3.3-1, and summarized below:

Project Implementation

(1) Particular Conditions

In drawing up the implementation schedule for the project, considered are the following:

(a) Construction and Work Capacity

More than half of the works is undertaken under or on water, and they are subject to wave action. It is therefore impossible to complete the whole works within a one-year period even if the monsoon season is included. According to the estimate, considering previous similar projects, a period of 16 months is required.

(b) Fish Breeding Period

Sea works during the fish breeding period should be avoided from the aspect of preservation of fish ecology. The survey shows that the fish breeding period in this river covers the late monsoon season to the following month.

(2) Order of Construction

The order of construction is determined as follows, considering the direction of littoral drift, the effect of flushing river mouth sediment, and the planning of effective countermeasures.

(a) Construction of North and South Jetty
(b) Construction of Breakwater
(c) Dredging of Navigation Channel
(d) Construction of River and Coastal Groins

The proposed implementation schedule based on the proposed order of construction is as presented schematically in Fig. 3.3-5. Judging from the nature of the works, the project should be conducted in two packages, namely; the construction of structures and thedredging of navigation channel. Each package is to be implemented under the "Bill of Quantities" contract system.

3.3.4 Cost Estimate

Conditions for Cost Estimate

Sea works such as riprap, stone filling and rock armoring for the jetty and the breakwater account for a major part of the project. Taking the nature of the works into account, the project cost is estimated under the following conditions:

(1) Construction works are to be executed by means of international open competitive bidding based on the "Bill of Quantities" contract system.

(2) The unit cost of each construction work item is estimated on the unit price basis, except for some items which are estimated on the lump sum or percentage basis.

(3) The total construction cost is estimated in consideration of the following components:

  (a) Main Works

  (b) Preparatory works including mobilization/demobilization of dredger [10% of Main and Miscellaneous Works]

  (c) Miscellaneous Works [5% of Main Works]

  (d) Engineering and Administration Cost [10% of (a)+(b)+(c)]

  (e) Physical Contingencies [10% of (a)+(b)+(c)+(d)]

(4) Rock materials, the major part of structures, are locally available (assuming hauling distance is less than 30 km).

(5) The unit costs are estimated based on the price level of late 1992.

(6) Price escalation rate is assumed to be 2.4% per year.

Construction Unit Cost

The unit cost for construction works is estimated using the basic prices (materials cost, equipment rental rate and labor cost), referring to the actual unit costs adopted in similar projects. Unit dredging cost is estimated on the condition that the cutter suction dredger with the following specifications is adopted. The unit construction costs calculated are given in Table 2.3-4.

Capacity of Dredger	:	1,000 HP class
Sea/River Bed Material	:	Loose sand, N-value < 5
Hourly Production	:	240 m^3
Working Hours	:	18 hours (2 shifts)
Operation Hours	:	14 hours (2 shifts)
Daily Production	:	4,320 m^3
Pipeline Length	:	600 m (average)
Dredging Volume	:	116,000 m^3
Required Dredging Time	:	3.5 months

Operation and Maintenance Cost

After completion of construction of the structures and the navigation channel dredging, operation and maintenance works (O&M) will be required for the following purposes:

(1) Regular inspection of jetty, breakwater and groin.

(2) Repairs when faults on the structures are found.

(3) Some maintenance dredging of the navigation channel with respect to unforeseen siltation in the channel.

(4) Beach filling or coastal protection works in preparation for erosion which may occur in the nearby beaches back to the proposed jetties.

These O&M works should be carried out annually and costs are estimated based on the percentage of total construction cost, as follows:

(1) Structures

- Rock/Stone Structures	:	0.6% of capital cost
- Concrete Structures	:	1.0% of capital cost

(2) Maintenance Dredging : 10% of capital dredging cost

(3) Beach Filling and Coastal Protection Works : 0.7% of cost of structures

(4) Administration Cost : 10% of [(1)+(2)+(3)]

Total Project Cost

Based on the conditions mentioned above, the total project cost for all structures and dredging works corresponding to 40 GRT boat size is estimated, as given is Table 3.3-2 and summarized as follows.

(a)	Preparatory Works	:	RM	1,066,000
(b)	Main Works			
	- Breakwater	:	RM	2,836,000
	- North Jetty	:	RM	2,774,000
	- South Jetty	:	RM	1,737,000
	- River Groin	:	RM	196,000
	- Coastal Groin	:	RM	1,270,000
	- Navigation Channel Dredging	:	RM	1,295,000
	- Reservoir	:	RM	41,000
(c)	Miscellaneous Works	:	RM	507,000
(d)	Compensation Cost	:	RM	0
(e)	Engineering and Administration Cost	:	RM	1,172,000

(f)	Physical Contingencies	:	RM	1,289,000
(g)	Price Escalation	:	RM	1,183,000
	Total Estimated Construction Cost	:	RM	15,366,000

In addition, annually recurrent operation and maintenance cost is estimated to be RM 227,000. The annual disbursement schedule based on the proposed construction schedule is given in Table 3.3-3. As can be seen in the table, the total project cost including price escalation amounts to RM 15,366,000.

3.4 Economic Evaluation

3.4.1 Project Benefit

Project benefit is defined as the difference between "without-the-project" and "with-the-project" situations. River mouth siltation at Marang causes economic losses to fishing boats, the number and size of which are projected as discussed in Subsection 3.3.1, and also to the tourist boats commuting to Kapas Island, 5 km away from the river mouth. Hence, project benefit may accrue in the areas of fishery and sea transport, but it has been verified by the basic analysis that flood mitigation benefits are not expected.

Unnavigable Hours

The shallowest bed of Marang River Mouth has been surveyed at -0.9 m (LSD), and this hampers navigation of sea boats at low tide. The 1990 tidal records at the Chedering Station, the nearest station from Marang, was studied to calculate the unnavigable hours as shown in Fig. 3.4-1. Unnavigable water depth takes place by 39.4% for small fishing and tourist boats (less than 10 GRT), 82.3% for medium fishing boats (10 to 39.9 GRT), and 97.0% for large fishing boats (40.0 to 69.9 GRT) on an average.

The actual average unnavigable hours are calculated by the formula [(unnavigable hours' percentage) x 24 hours x 50% x 50%], considering that river mouths are used only in the daytime (50% of a day) and assuming that boats stay offshore for normal fishing activities for about 50% of the unnavigable duration at river mouths. The unnavigable hours calculated are as follows:

Small Fishing and Tourist Boat	:	2.36 hours
Medium Size Fishing Boat	:	4.94 hours
Large Size Fishing Boat	:	5.82 hours

Benefit Calculation

(1) Small Fishing Boat (less than 10.0 GRT)

The annual benefit for small fishing boats is calculated in the same methodology and conditions as Tg. Piandang, as discussed in Subsection 2.4.1, but there is a difference in unnavigable duration; 2.36 hours. The annual benefit is thus calculated at RM 5,168 per boat.

(2) Medium Size Fishing Boat (10.0 to 39.9 GRT)

Medium size fishing boats are supposed to keep on fishing until they gain a full catch, and the problem is the wasted time waiting for the tide level to rise. The benefits may accrue in the areas of:

(a) Savings on fishermen's opportunity cost;
(b) Savings on fish refrigeration cost; and
(c) Preservation of fish quality.

Unit values necessary for the calculation were obtained from the annual fisheries statistics (1990), the DOF, the LKIM and the interview with local fishermen, and those on the medium size fishing boats are as follows.

No. of Trips per Year	:	266
No. of Fishermen per Boat	:	4
Annual Catch (RM)	:	101,000
Refrigeration Cost (RM/hr.)	:	1.20
Fisherman's Opportunity Cost (RM/hr.)	:	1.7
Value Decrease Ratio per Hour	:	0.01

Fisherman's opportunity cost is calculated from the average wage (RM 2.0/hour) multiplied by the conversion factor to shadow wage (0.85). When they miss the prime marketing time, they have to wait for the subsequent marketing time for a maximum of about 20 hours with value decrease of 10 to 20%. In this situation, the value decrease ratio of 1% per hour is applied for the quantification of preservation of fish quality.

Annual savings on fishermen's opportunity cost per boat can be calculated by the formula [(no. of trips) x (no. of fishermen) x (unnavigable hours) x (opportunity cost)]; i.e., 266 trips/boat x 4 persons/boat x 4.94 hours/trip x RM 1.7/hour/person, and it makes RM 8,935 per boat.

Annual savings on refrigeration cost is obtained from the formula [(no. of trips) x (unnavigable hours) x (unit cooling cost)]; i.e., 266 trips/boat x 4.94 hours/trip x RM 1.20/hour, and it makes RM 1,577 per boat.

Preservation of fish quality is quantified by the formula [(annual catch) x (unnavigable hours) x (value decrease ratio)]; i.e., RM 101,000/boat x 4.94 hours/boat x 0.01/hour, and it makes RM 4,989 per boat. The annual benefit per boat is the total of these values, namely; RM 8,935 + RM 1,577 + RM 4,989 = RM 15,501 per boat.

(3) Large Fishing Boat (40.0 to 69.9 GRT)

Large size fishing boats have the same problem as the medium size boats. The benefits are thus expected in the areas of:

(a) Savings on fishermen's opportunity cost;

(b) Savings on fish refrigeration cost; and

(c) Preservation of fish quality.

The annual benefit for large fishing boats is calculated in the same methodology and conditions as the medium size boats, as discussed above. The unit values necessary for the calculation are as follows:

No. of Trips per Year	:	92
No. of Fishermen per Boat	:	9
Annual Catch (RM)	:	399,000
Refrigeration Cost (RM/hr.)	:	5.26
Fisherman's Opportunity Cost (RM/hr.)	:	1.7
Value Decrease Ratio per Hour	:	0.01

The annual benefits of the above three categories are calculated at RM 8,192, RM 2,816 and RM 23,222, respectively, totaling RM 34,230 per boat.

(4) Tourist Boat (less than 10.0 GRT)

Tourist boats are available between Marang River Mouth and Kapas Island except the monsoon season. Small size fishing boats have been rebuilt into tourist boats with a maximum capacity of 12 passengers. Navigation survey was carried out for three days in June 1993, and it shows that about 60 round trips are available daily on an average.

Annual sales are estimated at RM 5,832,000, calculated by the formula [RM 30/passenger x 12 passengers/trip x 60 trips/day x 30 days/month x 9 months]. Assuming that 60% of direct costs are included, the net annual product is RM 2,332,800 (RM 5,832,000 x 40%).

The operation of tourist boats is affected by low tide, similar to fishing boats. Under the present conditions, these boats have unnavigable hours at the river mouth with a probability of about 10% on average, and the net annual product increases to RM 2,592,000 (RM 2,332,800 x 1/90%) under the with-the-project situation. Hence, the annual benefit is calculated at RM 259,200 (RM 2,592,000 - RM 2,332,800). The benefit is assumed to increase until 2005 at the annual growth rate of 2%, considering the estimated annual population growth rate from 1990 to 2000 in the Peninsula.

Project Benefit

The number of fishing boats is projected by boat size, as mentioned in Subsection 3.3.1. For the detailed benefit calculation, the medium size boats are further classified into 10.0 to 19.9 GRT (Medium 1) and 20.0 to 39.9 GRT (Medium 2). The estimated number by boat size is as follows:

	1995	2000	2005
Small	130	110	90
Medium 1	30	15	0
Medium 2	10	15	20
Large	0	10	20
Total	170	150	130

The annual benefit for Medium 2 is estimated from those of Small and Medium 2 to be RM 8,612 per boat. The project annual benefit consisting of fishery and sea transport benefits is thus calculated as follows:

	1995	2000	2005
Fishery	1,085	1,254	1,422
Sea transport	270	298	329
Total	1,355	1,552	1,751

3.4.2 Economic Viability

The Marang river mouth improvement project is designed to assure navigation with adequate safety for fishing and tourist boats. The economic evaluation for this project is made by figuring out the economic viability in terms of internal rate of return (IRR) and cost-benefit ratio (B/C), comparing the economic project cost and annual average benefit which may accrue in accordance with the expected cost-benefit flow in the project life. The calculation of IRR and B/C are made on the same basic conditions as Tg. Piandang, described in Subsection 2.4.3.

The economic project cost is calculated as given in Table 3.4-1. A cash flow of annual benefits and economic costs is prepared to figure out the values of IRR and B/C, as presented in Table 3.4-2, and the results are as follows:

Internal Rate of Return (IRR)	:	11.1%
Cost-Benefit Ratio (B/C)	:	1.302

The Marang project involves many structural works such as breakwaters and jetties, and requires a little maintenance cost compared with the construction cost. On this point, it is different from the Tg. Piandang project; namely, the economic viability is sensitive to the change of capital cost. On the other hand, the project benefits are calculated to the possible maximum extent within the project potential, and it cannot be denied that the calculation involves assumptions with unknown factors. Sensitivity analysis is, therefore, carried out under various construction cost and annual benefit, and the change of economic viability was examined, as follows:

	Case	IRR	B/C
(1)	Construction Cost, 5% up	10.6%	1.255
(2)	Construction Cost, 10% up	10.2%	1.211
(3)	Annual Benefit, 5% down	10.5%	1.237
(4)	Annual Benefit, 10% down	9.8%	1.172
(5)	Combination of (1) and (3)	10.0%	1.192

Since the design boat size is 40 GRT, it may be difficult for large boats to use the river mouth all the time. In this connection, sensitivity analysis was also made for the case where future boat distribution by size is altered with no change in the total number, as follows:

	1995	2000	2005
Small	130	110	90
Medium 1	30	15	0
Medium 2	10	25	40
Total	170	150	130

The economic viability in this case is 9.2% in IRR and 1.108 in B/C.

3.4.3 Economic Evaluation

IRR is a reliable tool to evaluate a project in economic terms, and the borderline is generally around 10% in this kind of infrastructure project. Even in the cases of increase of construction cost and decrease of annual benefit, the project is evaluated to maintain an adequate economic viability as mentioned in the preceding subsection.

Consideration is also be given to intangible benefits to be brought about by the project, especially, the enhancement of safety to navigation and the stabilization of living standards of people living on the fishery and tourism industries. Fishing boats at Marang River Mouth is on the way toward up-sizing to realize more offshore fishery in line with the national policy as witnessed in the change of boat size distribution, and the state government also puts emphasis on tourism development at the river mouth, which may be highly related to passenger ferry services between the river mouth and Kapas Island. Under these circumstances, intangible benefits, though unquantifiable, are expected to accrue to a considerable extent.

In view of the high economic viability and favorable socio-economic impacts, as well as the necessity of assuring the safe navigation of fishing boats at Marang River

Mouth, river mouth improvement works should be implemented at the earliest opportunity.

3.5 Preliminary Environmental Impact Assessment

3.5.1 Major Environmental Impacts

Project activities which would give rise to major environmental impacts include the following:

(1) Countermeasures for the improvement of the Marang River Mouth, namely; construction of breakwater, jetty, river and coastal groins, and capital dredging;

(2) Dredged spoil disposal; and

(3) Consequent activities.

Impact by Countermeasures

(1) Physico-Chemical Impacts

Since the dredged material is sand which would settle rapidly after dredging and is not polluted, the impact on the water quality would be very minimal.

(2) Biological Impacts

The impact of dredging on marine life would be low. However, the construction of breakwater, jetty and groins may affect the movement of fish to the estuary for feeding and breeding.

(3) Socio-Economic Impacts

There may be some disruption to the fishing boats traversing the estuary because of the construction of the breakwater. However, this disruption would only be for the duration of the construction.

Impact by Dredged Spoil Disposal

It is proposed that the dredged sand is deposited on the southern bank of the river mouth to replenish the sand that may be eroded away and not replenished because of the construction of breakwater and jetty. No significant impact is anticipated in the disposal of spoil.

Consequent Activities

The impact of the river mouth improvement works would benefit both the fishing and tourist industries. The latter is developing rapidly for Marang. The overall impact on the fishing industry is that it will mainly allow the fishermen to go and come into the estuary without waiting for the tide. The tourist industry will also benefit from a deepened channel as they can be certain about their travel plans. The tourism industry can be expected to grow in Marang.

3.5.2 Mitigation and Abatement Measures

Mitigation of Dredging and Construction Impacts

(1) Mitigation of Dredging and Construction Impacts

The capital dredging should be scheduled to avoid the northeast monsoon for the same reason as explained in Section 2.5.2. The construction of countermeasures should be scheduled after the known breeding period of a number of economically important species of fish. The known breeding period is immediately after the northeast monsoon. Construction should therefore begin from March to avoid interference with the normal breeding period.

The daily dredging and construction activities should be scheduled to minimize disruption to the movement of fishing and tourist boats.

(2) Mitigation of Spoil Disposal Impacts

Since significant environmental impact arising from the dredged spoil disposal is not anticipated, mitigation measures are not necessary.

3.5.3 Environmental Monitoring Programme

Physico-Chemical Parameters

The turbidity of the estuarine water during dredging and construction of the countermeasures should be monitored. In addition, it is important to monitor the changes in coastal geomorphology because of possible erosion in the southern bank of the estuary.

Biological Parameters

The level of primary productivity in the vicinity of construction areas should be monitored as primary productivity is the basis of the productivity of all fisheries. Two species of shrimps are locally important in the vicinity of the estuary and should be monitored.

CHAPTER 4. INSTITUTIONS AND REGULATIONS

4.1 Background

The maintenance of river mouths has always been the responsibility of the Federal Government. The main objectives of river mouth maintenance are the provision of navigation channel for commercial and fishing boats, the provision of drainage, and the alleviation of floods. Under the Federal Constitution, Navigation as a subject covering shipping, navigation and fisheries, including shipping and navigation in the high seas and in tidal and inland waters, ports and harbors, and foreshores, are the responsibility of the Federal Government. Similarly, Fisheries as a subject, covering shipping, navigation and fisheries including maritime and estuarine fishing and fisheries excluding turtles is the responsibility of the Federal Government.

Thus, the maintenance of river mouths for the purpose of navigation has always been the responsibility of the Federal Government. State Governments do not provide any funds for the maintenance program, although the requests for river mouth maintenance projects are normally channelled through the States.

Over the years, river mouth problems have aggravated due mainly to:

(1) the increased upstream and coastal zone development resulting in increased siltation; and

(2) the increase in commercial and fishing vessel sizes as a result of expansion in both marine transportation and fisheries.

Due to the above two reasons, many river mouths have become inaccessible, particularly during low tides. Thus, except for small boats with outboard motors, most boats have to wait at sea until high tide before being able to land. The only solution to this problem is to deepen the river mouths.

4.2 Current Practice on River Mouth Improvement

Existing Legislation

There are a number of existing State and Federal laws which control and regulate development and activities within the river mouth areas, as well as in areas outside which could have adverse impacts.

The Water Enactment of 1920 (Cap 146) and the subsequent Water Act of 1920 (Revised, 1989) are the basic legislation for the management of rivers and the utilization of river water. The Land Conservation Act of 1960 has provisions for the conservation of hill land and the protection of soil from erosion and control of silt. Both of the above laws are administered by the Land Office in the District.

The Environmental Quality Act of 1974 (Amended, 1985) is the Federal law which regulates all development activities to minimize or eliminate any adverse impact on the environment. Under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987, construction of ports or expansion of existing ports involving an increase of more than 50% in handling capacity requires Environmental Impact Assessment reports to be submitted to the Department of Environment for approval.

In addition, General Administrative Circular No. 5 of 1987 issued by the Prime Minister's Department requires all developments in the coastal zone to be referred to the Coastal Engineering Branch of the Department of Irrigation and Drainage for comment.

The Town and Country Planning Act of 1976 can be of relevance to the problem of river mouth siltation, if an integrated approach to the planning, siting and development of fishing ports is to be considered.

Laws which control and regulate activities within the river mouths and estuarine waters are the Fisheries Act of 1985 and the Merchant Shipping Ordinance of 1952. The Fisheries Act regulates fisheries activities in Malaysian waters, while the Merchant Shipping Ordinance relates mainly to marine transportation and merchant shipping.

Existing Institutions

The responsibility for the improvement of river mouths is shared between the Department of Irrigation and Drainage and the Marine Department. The responsibility of the Department of Irrigation and Drainage is on river mouths where the benefits from improvement works are for flood mitigation and for better fishing boats access to landing facilities in the rivers. The Marine Department is in charge of river mouths leading into gazetted commercial ports.

The Coastal Engineering Branch of the Department of Irrigation and Drainage is directly responsible for the dredging of river mouths. Its main activities are:

(1) to submit dredging program to the Ministry of Agriculture for assignment of priority and approval;

(2) to carry out surveys and investigation works on river mouths scheduled for dredging;

(3) to prepare design sections for dredging works;

(4) to prepare estimates and tender documents;

(5) to call for tenders, appoint contractors and monitor progress; and

(6) to monitor post dredging conditions of river mouths.

There are more than 50 commercial ports in Malaysia. Five of these ports; namely, Port Kelang, Penang, Johor, Kuantan and Bintulu are each administered by a Port Authority, except Penang which is by a Port Commission. The remaining ports are under the Marine Department, which is responsible for the safety of navigation for merchant ships and to provide shipping services to vessels entering Malaysian ports.

The Dredging and Hydrographic Activity Branch of the Marine Department is responsible for the maintenance of river mouths and channels leading to the ports. To ensure that commercial vessels can access the ports at all times, the Marine Department provides its own dredgers at a few important ports to carry out year round dredging.

The Fisheries Department is responsible for the planning of fisheries development through the preparation of the Fisheries Plans. Under the Fisheries Act, 1985, it is in charge of the issuance of annual fishing licenses, control of foreign fishing vessels in Malaysian fisheries waters, enforcement of the Fisheries Act, promote the development of inland fisheries, aquaculture and the establishment of marine parks.

The objectives of the Fisheries Development Authority of Malaysia are to improve the socio-economic status of fishermen, in particular, to increase their income, and to expand and develop the fishing industry in Malaysia. To achieve the above objectives, LKIM develops large integrated fish landing complexes at selected locations comprising modern storage and marketing facilities including boat repairs and construction workshops and other related fisheries industries. In accordance with the National Agriculture Policy, LKIM is promoting deep-sea fishing utilizing boats of 40 GRT and above.

The Ministry of Agriculture through its River Mouth Dredging Committee coordinates the river mouths dredging program by determining the priority order of the river mouths to be dredged. The Committee is composed of the representative of the Ministry of Agriculture who is the Chairman, and the representatives of the Department of Irrigation and Drainage, the Fisheries Department and Lembaga Kemajuan Ikan Malaysia (LKIM). The Committee meets to finalize the program for each Malaysian Plan and whenever necessary.

Financing

The dredging of river mouths by the Department of Irrigation and Drainage is submitted as a five-year programme under each of the Malaysia Development Plan. Thus, funds for the dredging of river mouths are from the Federal Development Fund. No funds are provided from the operating budget and hence all river mouth dredging are considered as capital works. Neither the Department of Irrigation and Drainage nor the Fisheries Development Authority of Malaysia submit annual operating budgets for the maintenance of the river mouths after capital dredging works have been completed.

The funds for the dredging of river mouths by the Marine Department are all from its annual operating budget. Since all the dredging works are carried out by its own dredgers, the annual budget provided is for the operation and maintenance of these dredgers. The initial capital for the purchase of dredgers is provided from the Development Fund under the Malaysia Development Plan.

State governments do not provide any funds for the dredging or maintenance of river mouths. State governments look upon dredging as an unsatisfactory solution for the problem of river mouth siltation, as the dredged sections are silted up again within a year or so, thereby requiring additional funds for maintenance dredging. States prefer structural measures as a means to overcome river mouth siltation problems as such measures will have little or no necessity for maintenance.

River Mouth Dredging

Desilting or deepening of river mouths is normally carried out by dredging, although structural works have been constructed in a few river mouths in Kelantan to prevent siltation through harnessing the river flows. However, the very high capital cost for structural measures and the possibilities for inducing coastal erosion have made dredging the preferred option.

While deepening of river mouths by dredging is relatively low-cost and simple to carry out, the main disadvantage is that the dredged sections are silted up again very quickly, often within a year. Maintenance dredging has to be carried out on an annual basis. Thus, compared to structural measures which have low maintenance cost, maintenance dredging cost is often as high as the capital dredging carried out initially.

Another problem faced by river mouth dredging is the lack of technical basis on which dredging works are carried out. There is very little collection of technical data or monitoring of river mouth siltation problems. Regular monitoring programs will provide information for a better understanding that the current status is as predicted in the design, as well as a means to verify the behaviour of the river mouths after completion of dredging works.

The need for technical information is therefore very important as they provide the basic input for increasing the knowledge on the phenomenon of river mouth siltation problems and the effectiveness of the countermeasures for solving the problems. There is at present no formal mechanism for the gathering, developing and disseminating technical information on river mouth siltation.

The issue of proper disposal of the dredged material so as not to cause any adverse impact has to be addressed. Increased intrusion of waves into the dredged river mouth as a result of increased water depth could cause damage to facilities and boats moored in the river. This problem too, has to be considered.

Planning of Fishing Ports

The main problem of river mouth maintenance is to provide sufficient water depth for fishing and commercial boats to land, at all times, at the ports located in the rivers.

For commercial ports, the Ministry of Transport has a master plan for the location and development of ports in the country.

LKIM's development plans for fishing ports up to year 2000 show that only 18 locations will be expanded to cater for deep-sea fishing for boats of 40 GRT and above. Of these 18 locations, 5 are in the West Coast, 8 are in the East Coast, 4 are in Sarawak and probably one in Sabah. The existing LKIM fishing ports which are not to be expanded, will remain as they are. As such, any expansion in size of existing fishing boats in other rivers will have to utilize landing facilities in one of the 18 large landing facilities to be developed by LKIM.

In the planning for the development of fishing ports, LKIM has selected the least cost option, which is to identify existing ports for upgrading and expansion without taking into consideration the dredging cost for maintenance of the river mouths. Many of these existing ports are located in river mouths which are subjected to serious silting problems. If the dredging cost is included in the project cost and in the operating cost in subsequent years, most of the selected ports will prove to be not viable for development. By leaving out the dredging cost, LKIM is actually passing both the cost and responsibility to the Department of Irrigation and Drainage to solve the siltation problem in river mouths.

Existing fishing ports located in some river mouths, therefore, may not be the best option, especially where much dredging works is required annually. In such cases, a *properly sited fishing port in the coast, complete with breakwaters for protection* against rough seas will be more viable. Although the capital development cost of the project will be high, the reduction in or the elimination of annual maintenance dredging can be very attractive.

For some fishing ports in river mouths, the construction of breakwaters and jetties together with capital dredging can provide a viable solution, which will require minimal maintenance dredging after completion of the project.

From the above, it is obvious that a comprehensive integrated approach to the planning and location of fishing ports has to be adopted. A national master plan for fishing and commercial ports should be formulated within an integrated coastal zone management plan. The master plan should take into consideration development plans of other sectors, the risk of coastal erosion, the potential damage to mangrove swamps and the needs of the fishing industry and commercial navigation.

4.3 Proposed Institutional Setup

The existing arrangement where the Marine Department is the agency responsible for the maintenance of river mouths for commercial ports and the Department of Irrigation and Drainage for fishing boats access is clear and should not be changed.

The Coastal Engineering Branch of the Department of Irrigation and Drainage, which is already responsible for executing river mouth maintenance works, should assume in full, the technical responsibilities for river mouth problems in Malaysia. Its responsibilities should be expanded to include the collection of basic data related to river mouths, some of which are already being gathered under its coastal data collection programme. A regular comprehensive monitoring programme of the siltation rates of river mouths, both prior to and after dredging works should be implemented.

As the technical center for river mouths, the Branch will be responsible for feasibility studies and detailed designs for river mouth dredging and structural works. The availability of the Hydraulics Laboratory in DID Ampang is an additional asset, as physical modelling and research programmes could be carried out there.