Seriousness	Number of Fishermen	Number of River Mouths
Very Serious	More than 200	35
Serious	200 - 50	39
Fair	Less than 50	26

(3) Social Aspect

The existence of complaints from fishermen is taken up, since they reflect the situation as serious even if the number of fishermen at the river mouth is small. River mouths are then classified into three groups based on the existence of complaints, as follows:

Seriousness	Condition
Very Serious	Existence of very strong complaint
Serious	Existence of fairly strong complaint
Fair	No complaint

2.2.3 Categorization

Using the above-said levels of seriousness which amount to 27 combinations, the river mouths are categorized into three; namely, Category 1 (Critical), Category 2 (Significant), and Category 3 (Acceptable) in accordance with the following criteria:

(1) Among three (3) aspects, physical and economic aspects are used as primary factors for the categorization; and

(2) The social aspect is used as a supportive factor to upgrade the river mouths from a significant to critical condition.

The combinations for the categorization are as follows:

(1) Category 1 (Critical)

River mouths that fulfill the following combinations are included in Category 1:

Combination 1: The river mouth condition in both the physical and economic aspect is very serious.

Combination 2: The river mouth condition in both the physical and social aspect is very serious, but in the economic aspect it is serious.

Combination 3: The river mouth condition in the physical aspect is serious, but in the economic aspect it is very serious and in the social aspect it is very serious or serious.

(2) Category 2 (Significant)

Except the river mouths in Category 1, those which fulfill the following combinations fall under Category 2:

Combination 1: The river mouth condition in both the physical and economic aspect is more than serious.

Combination 2: The river mouth condition in the physical aspect is very serious, but in the economic aspect it is fair and in the social aspect it is very serious or serious.

Combination 3: The river mouth condition in the physical aspect is fair, but in the economic condition it is very serious and in the social aspect it is very serious or serious.

(3) Category 3 (Acceptable)

The remaining river mouths that do not fulfill any of the combinations under Category 1 and Category 2 belong to Category 3.

The combinations of seriousness in each aspect of categorization above are shown in Table 5.2-8. The categorization results are shown in Table 5.2-9, and Table 5.2-10 shows the river mouths by category.

2.3 *Selection of Objective River Mouth for the Master Plan*

River mouths belonging to Category 1 and Category 2 in the categorization mentioned above are selected as the objective river mouths for the Master Plan Study. Since conditions in Category 3 are acceptable, river mouths under this category are not considered. As summarized in the following table, there are 75 objective river mouths for the Master Plan Study.

Category	Number of River Mouths	Remarks
Category 1 (Critical)	35	Objective river mouth for Master Plan.
Category 2 (Significant)	40	Objective river mouth for Master Plan.
Total	75	
Category 3 (Acceptable)	25	Conditions acceptable; not considered for Master Plan.
Grand Total	100	

2.4 Selection of Representative River Mouth

2.4.1 Grouping of River Mouth

Criteria for Grouping of River Mouth

In accordance with the principle for formulation of the Master Plan, the objective river mouths are grouped according to physical characteristics, as mentioned in Chapter 2. The main physical characteristics of the river mouth were identified through quantification (Quantification III, for detailed explanation see Annex 1). The quantification was further confirmed through empirical approach based on the results of the preliminary investigation.

For the grouping, the following factors were considered.

(1) Coastal Geomorphology and Shoreline Formation

Coastal geomorphology and shoreline formation are divided into several categories as shown in Table 5.2-11. These categories are grouped into the following three main categories:

(a) Straight

Coastal geomorphology is straight. This includes the coastal geomorphological conditions of Embayed Coast, Headland and Sheltered by Island.

(b) Estuary

Coastal geomorphology is estuary, or shoreline formation is concave.

(c) Protruding

Coastal geomorphology is protruding; delta formation and/or shoreline formation is convex.

(2) External Force

External forces, namely wave and tide, have been proven through quantification as the principal factors to determine the condition of the river mouth. Wave is categorized into the following three types:

(a) High Straight Wave

Wave is comparatively high and straight direction is predominant.

(b) High Oblique Wave

Wave is comparatively high and oblique direction is predominant.

(c) Low Wave

Wave is comparatively low.

Tidal prism is also a factor which characterizes river mouth condition. It is categorized into the following two types:

(a) Large Tidal Prism

Tidal prism is larger than 1,000 m^3.

(b) Small Tidal Prism

Tidal prism is less than 1,000 m^3.

River flow with a parameter of catchment area is considered to be included in the scale of the tidal prism; namely, a larger tidal prism generally reflects a wider river and a larger catchment area. Accordingly, the river flow factor is not considered for the grouping.

(3) River Course Pattern

This factor does not dominate the river mouth condition, as indicated in the quantification results and is, therefore, not selected as a factor for the grouping. Almost all of the river mouths belong to the meandering category.

(4) River Mouth Condition and Coastal Material

These factors are reflected in the results of coastal geomorphology and external force. Consequently, it is expected that a group based on the grouping by external factors will have a similar shoreline formation, river mouth condition and coastal materials. Thus, it is not necessary to take these factors into account for the grouping.

Results of Grouping

The objective river mouths are classified into groups, as shown in Table 5.2-11 and the following table. Although the possible number of combinations is 18, the actual number of groups is 10 because there are no subject river mouths in 8 of the combinations.

No.	Coastal Geomor-phology	External Force		No. of River Mouths
		Wave	Tidal Prism	
1	Straight	High & Straight	Large	6
2	"	"	Small	none
3	"	High & Oblique	Large	10
4	"	"	Small	4
5	"	Low	Large	4
6	"	"	Small	26
7	Estuary	High & Straight	Large	none
8	"	"	Small	none
9	"	High & Oblique	Large	3
10	"	"	Small	none
11	"	Low	Large	16
12	"	"	Small	none
13	Protruding	High & Straight	Large	4
14	"	"	Small	none
15	"	High & Oblique	Large	none
16	"	"	Small	3
17	"	Low	Large	3
18	"	"	Small	none

2.4.2 Selection of Representative River Mouth

A representative river mouth is selected for each of the 10 groups shown in the table above for the detailed study on optimum countermeasures and project benefit. Selection of the representative river mouths is made in consideration of the availability of data (Table 5.2-12), the seriousness of the problem (categorization results), etc., the priority of the river mouth in the state where it is located, as well as the physical representativeness of the river mouth in the group. A representative river mouth for each group is selected as indicated in Table 5.2-13 and 5.2-14, and shown in the following table.

Grp. No.	Coastal Geomor-phology	External Force		No. of River Mouths	Representative River Mouth	
		Wave	Tidal Prism		Serial	Name
1	Straight	High & Straight	Large	6	61	Marang (T'gganu)
2	"	High & Oblique	Large	10	53	Kuantan (Pahang)
3	"	"	Small	4	57	Kerteh (T'gganu)
4	"	Low	Large	4	1	Perlis (Perlis)
5	"	"	Small	26	14	Tg.Piandang (Perak)
6	Estuary	High & Oblique	Large	3	80	Oya (Sarawak)
7	"	Low	Large	16	19	Beruas (Perak)
8	Protruding	High & Straight	Large	4	62	Terengganu (T'gganu)
9	"	High & Oblique	Small	3	90	Papar (Sabah)
10	"	Low	Large	3	5	Kedah (Kedah)

2.5 Selection of Applicable Countermeasures

2.5.1 Possible Countermeasures

There are several countermeasures to cope with the problem of river mouth siltation and the following structural measures are considered (refer to Fig. 5.2-1).

(1) Breakwater

A breakwater is a structure for the protection of a shore area, harbor, anchorage, river mouth or basin from waves and, generally, protection against intrusion of drifting sand in the navigation channel is not included in the breakwater's function. Breakwaters for navigational purposes are constructed to create calm water in a river mouth and provide protection for safe mooring, operating and handling of ships, and to provide protection for harbor facilities. Breakwaters may be rubble-mound, composite, concrete caisson, sheet piling, etc.

Breakwaters built on the open coast are generally of rubble-mound construction. Occasionally, they are modified into a composite structure using a concrete cap for stability. Precast concrete shapes such as tetrapods or tribars are also used for armor stone when rock of sufficient size is not obtainable. In relatively sheltered areas, breakwaters are occasionally built of a single row of braced and tied timber piling or steel sheet piling.

(2) Jetty

A jetty is a structure extending into the water to direct and confine river or tidal flow into a channel, and to prevent or reduce intrusion of littoral drifting sand to the navigation channel. Jetties located at the entrance to a bay or river also serve to protect the entrance channel from cross currents. When located at inlets through barrier beaches, they also stabilize the inlet location. Normally, the height of jetty is decided considering the spring high tide and clearance, and thus the jetty normally appears above the sea level. In case the bed material like marine clay does not have enough bearing capacity for such a heavy structure, a submerged jetty is proposed because of its reduced load.

As in breakwaters, jetties are of several types. They have been built of rubble-mound, steel sheet pile cells, caissons, and cribs using timber, steel or concrete. The main difference between a breakwater and a jetty is emphasized in their functions; the former has the function to protect the area from wave action and the latter is to direct and confine river or tidal flow into a channel and to prevent the intrusion of drifting materials into the navigation channel.

(3) Training Wall

A training wall is provided to stabilize the river mouth and the waterway by controlling the development of a sandbar. The materials used for a training wall include concrete, concrete block, stone masonry, etc. An example can be seen at the Terengganu River Mouth.

As in breakwaters, a training wall is commonly employed at a river mouth in a sandy coast where the location of the river mouth habitually changes due to the development of a sandbar.

(4) Groin

There are two types of groins; river groins and coastal groins. River groins are also known as spurdikes and are training structures that extend from the river bank to the river at an angle, or perpendicular, to the flow. Their functions are training a river along a desired course, protecting the bank by keeping the flow away, and contracting a wide river channel for the improvement of depth for navigation.

Coastal groins are barrier-type structures that extend from the shore to the wave breaking zone. Their basic purposes are to interrupt longshore sand movement, to accumulate sand on the shore, or to retard sand losses, and they have been constructed in various configurations using timber, steel, concrete or rock.

(5) Dredging

Usually, dredging is of two types, as described below.

(a) *Dredging with Conventional Equipment*

There are basically three kinds of dredging methods applicable to navigation channel dredging, as follows:

Method 1: Cutter suction dredger with a booster station, discharging to the coastal area. Disposal of dredged soil at sea can be possible as well.

Method 2: Trailing suction hopper dredger, pumping ashore to the coastal area or continuing to the disposal ground offshore.

Method 3: Dredging by grab or backhoe, discharging to barges; barges being unloaded and pumped onto the coastal area or offshore disposal ground.

Method 1 is the most popular and reliable dredging method for navigation channels, applicable to almost all objective river mouths. The bigger the dredging volume, the lower is the cost. Besides, dredging capacity per day is bigger than other methods. This means less time-consuming and lower total cost.

Method 2 is feasible if the dredged materials are soft soil and lose fine sand. However, dredging efficiency is inferior to Method 1. Besides, this method requires a longer time for traveling to an offshore disposal ground at times of low water.

Method 3 is usually employed for a small scale dredging of inner channel. This method is far slower than the other two methods.

Taking all these factors into consideration, Method 1 is adopted for this master plan study.

(b) Agitation Dredging

Since dredging with conventional equipment is generally costly and requires high investment cost, intensive machinery and trained manpower for operation which are not sometimes available to small ports, low cost dredging methods have been developed. Agitation dredging is one of such low-cost dredging methods specially suited to maintenance dredging, and is generally considered to be effective for river mouths in muddy coasts. In this study, the applicability of agitation dredging is examined.

(6) Reservoir for Extension of Tidal Prism

In general, water depth at the river mouth is maintained by the eroding current caused by tidal prism and it is noted that a river mouth is maintained in proportion to the volume of tidal prism. To assure the water depth at the river mouth, provision of a reservoir to extend the tidal prism is sometimes considered. A reservoir however may not be effective to maintain the water depth of the outer channel unless a jetty is provided along the outer channel, because the current by tidal prism spreads out in the outer channel resulting in the reduction of sediment transport capacity.

2.5.2 Considerations for Setting Alternative Study Cases

As mentioned above, there are seven applicable countermeasures including agitation dredging for river mouth improvement. However, these countermeasures are adopted according to the objectives to cope with the river mouth problem as shown in Table 5.2-15. These objectives are (1) provision of navigation channel, (2) maintenance or assurance of navigation channel, (3) protection against wave intrusion into the river mouth, (4) stabilization of river mouth, and (5) stabilization of river channel.

In this connection, the following considerations are made for setting the alternative study cases.

(1) Since Objective (1), provision of navigation channel, is indispensable to assure navigation of the design boat at the first stage, dredging, which is the only applicable measure for this objective, is included in all the alternative cases.

(2) Since Objective (2), maintenance or assurance of navigation channel, is to maintain the navigation channel at a certain depth, alternative cases are set up to compare the advantages of the four countermeasures applicable for this objective, i.e., jetty, dredging with conventional equipment, agitation dredging and reservoir.

(3) For comparison among the countermeasures in Objective (2), it is assumed that a jetty is effective to completely provide protection against the intrusion of drifting materials into the navigation channel, so that maintenance dredging is not necessary for inclusion in the alternative cases. However, in case of a submerged jetty, siltation in the navigation channel is partially prevented according to the height of the submerged jetty and therefore, maintenance work is necessary. A reservoir may be effective for the maintenance of the navigation channel if a jetty is provided, so that a reservoir when possible using the natural reservoir such as lagoon and swampy area is employed only in combination with a jetty.

(4) Since there is only one countermeasure having Objective (3), protection against wave intrusion into the river mouth, this countermeasure will be applied to the alternative cases as necessary.

(5) As for Objective (4), stabilization of river mouth, there are two countermeasures, jetty and training wall. The former has the additional function of maintaining/assuring the navigation channel, while the latter is provided only for this objective. Consequently, a training wall is adopted to the alternative case which requires protection against shifting of the river mouth and does not include a jetty.

(6) Since there is only one countermeasure having Objective (5), stabilization of river channel, this countermeasure will be applied to the alternative cases as necessary.

The countermeasures are provided to solve the river mouth problems. However, the provision of countermeasures sometimes brings about adverse influences. In case of jetty which traps drift materials, it sometimes causes coastal erosion in neighboring areas. To prevent such adverse influence, countermeasures such as revetment, nourishment and coastal groin are considered, and selection of the optimum countermeasure requires further detailed study using detailed basic data. In this study, coastal groin which is commonly used for the prevention of coastal erosion is adopted when a jetty is considered as an alternative case.

2.6 Effect of Countermeasures

The effect of countermeasures can be evaluated in quantitative or qualitative terms. In this present study, the effect is examined in quantitative terms for only the countermeasures that can be evaluated in quantitative terms.

2.6.1 Dredging

General

Dredging is one of the countermeasures for construction and maintenance of navigation channels widely used in the world. In Malaysia, structural countermeasures e.g. breakwaters are recently applied as river mouth improvement countermeasures in sandy coasts mainly in the east coast. Dredging is, however, still one of the most effective and realistic countermeasures especially in the west coast.

Important consideration for dredging works planning is that after completion of the designed section by capital dredging, maintenance dredging is required continuously to remove deposit to assure the effectiveness of the function.

In this part of the report, a study is made to examine the siltation rate for dredged channel in order to know maintenance dredging cost. Mechanism of siltation to the dredged channel is also examined in order to know the most effective dredging plan with less maintenance and to know the most effective measures to prevent siltation by investigating where and how the siltation takes place.

Mechanism of Siltation

The mechanism of siltation is a very complicated phenomenon in relation to bed material, wave and tidal conditions, etc. To study the mechanism of siltation of dredged channel it is appropriate to broadly divide into two, namely, sandy and muddy bed material.

(1) *Sandy Coast*

In the case of sandy bed material, siltation in the dredged navigation channel occurs when the drifting sand falls in the channel. In most cases, longshore drifting sand has almost a straight angle to the channel and drifting sand on both directions, i.e, left to right and right to left of the channel, will be trapped. For siltation of the dredged navigation channel, offshore drifting sand will not be *dominant*.

The volume of littoral drift sand can be calculated, although there are various equations proposed, and the results to be obtained from these equations are in a wide range.

Accordingly, siltation in the sandy coast will be calculated by applying an appropriate equation of longshore transport rate. This equation will be checked and adjusted referring to the actually observed siltation rate. Observed data for the siltation in the sandy coast is available at Mersing.

In addition, the river is also one of the major sources of sediment. In particular, such a big river as Terengganu transports a large amount of sand to the river mouth. The volume of sand supplied by the river can be estimated by an empirical formula, as discussed in Hydrology Sector.

(2) Muddy Coast

The siltation in muddy coast is not well studied in the world and it contains much unknown factor compared to the sandy coast. The mechanism will be divided into two, namely, transportation and deposition of muddy material by current and mass movement of muddy material by wave.

Accordingly in the former, stirring of bed material by littoral current and tidal current, transportation and diffusion of the stirred material and settling and deposition take place, and in the latter, wave in the muddy material will occur. Simulation models for both mechanism are not established and very complicated, and it is more practical to determine siltation rate on the basis of actual observation.

Accordingly for the muddy coast, actual siltation rate at various river mouths are checked and plotted to determine the general siltation rate for the purpose of the master plan study.

Available Data

Bathymetric survey results collected from related agencies are the main sources of data.

(1) Bathymetric survey results from Marine Department

(2) Bathymetric survey results from DID

  (a) Conducted for dredging before.

  (b) Conducted for the purpose of this study during the second field survey.

(3) Bathymetric survey conducted by the JICA Study Team for the representative river mouths.

Table 5.2-16 shows a list of available data and information by river mouth.

Study on Siltation

In this report, a study is made on the Perlis, Kurung Tengar, Kedah, Beruas and Mersing river mouths. The Mersing River Mouth is located in a sandy coast and the others are in muddy coasts.

(1) Perlis River Mouth

The Marine Department is conducting dredging continuously in the Perlis River Mouth for the maintenance of the navigation channel to Langkawi Island. The dredging stretch is 3.5 km long with a width of 60 m. The average dredging depth is reported to be 3 m. The historical dredging volume is tabulated below:

Year	Dredging Volume (m^3)
1986	100,000
1987	45,000
1988	-
1989	-
1990	122,000
1991	607,000
1992	313,000

Fig. 5.2-2 show typical cross sections of the outer channel in different years based on bathymetric survey results of the Marine Department. The following discussions are made from this illustration.

(a) It is difficult to estimate the siltation rate where dredging is conducted in the same location as in Section -0.30 km. Accordingly, siltation rate is estimated in sections where the dredging section is shifting.

(b) As shown in Section -0.53 km, the maximum siltation is 1.7 m for a 1 year period after dredging from March 1991 to February 1992. The sectional siltation rate is likewise obtained as follows in other sections:

Section	Siltation Height	
	April '90 to March '91	March '91 to February '92
-0.53 km	-	1.7
-1.05 km	1.6	-
-1.52 km	1.5	-
-2.05 km	1.1	-

The average siltation height is accordingly obtained at 1.5 m/year.

(c) The outer channel profile developed on the basis of sounding survey conducted during the Second Field Work in 1992 is presented in Fig. 5.2-3. As shown in the illustration, the deepest point of each section from -0.2 km to -2.0 km is around LSD -3 m. In accordance with the information from the Marine Department, the Marine Department dredged to the elevation of LSD -4 m until May 1992 and after that no dredging was conducted. This means that siltation height is 1 m for the period of 8 months from May to December 1992.

(d) Fig. 5.2-4 shows the comparison of cross sections in the inner channel. Considering that no dredging has been conducted in the inner channel, the inner channel may be generally stable. The deepest point of each section is around LSD -3.5 to -4.0 m. It is presumed that if the outer channel is maintained deep, the inner channel will also be maintained deep.

(e) Perlis River Mouth is less affected by swells intruding from the Andaman Sea and wind waves generated in the Strait of Malacca sheltered by Langkawi and Tarutao islands. Accordingly, sediment stirring, diffusion and transportation mechanism in this river mouth is assumably controlled by tidal and river flows. This is a typical case in muddy coasts.

(2) Kurung Tengar River Mouth

The Kurung Tengar River Mouth is not included in the 100 objective river mouths under the present study. DID dredged this river mouth in December, 1989 and sounding survey was conducted upon the request of the JICA Study Team to confirm the siltation volume.

The Kurung Tengar River Mouth is one of the drainage channels under the Muda Project. There is a tidal gate about 300 m upstream from the mouth and the gate is usually closed to maintain the higher water level in the inland irrigation area. Accordingly the inner channel is dried up during the lowest tide.

Fig. 5.2-5 shows cross sections of the outer channel before and after the dredging and the dredged section. The following discussion are made for the illustration.

(a) Dredging volume was checked from the sections before dredging and the dredged section. The average sectional area for dredging of 22 m^2 is multiplied by the dredging stretch of 1.4 km and the volume is calculated at 31,000 m^3. This is almost the same value as the recorded volume.

(b) The bottom elevation for dredging was set at LSD -2 m. On the basis of the sounding survey results in December 1992, 3 years after dredging in December 1989, an average of 2.5 m siltation height is obtained. The siltation rate is accordingly 2.5 m/3-year.

(3) Muda River Mouth

DID dredged the outer channel of the Muda River Mouth in August 1986. The dredging is for a stretch of 1.2 km from the mouth with the design bottom elevation of LSD -4 m. Fig. 5.2-6 shows longitudinal profiles of before dredging, just after dredging in August 1986 and in December 1992. The following discussions are made on the illustration.

(a) The average siltation height in the outer channel for the period of 76 months after dredging is 1.36 m.

(b) The characteristics of siltation are examined; the bottom was dredged 1 m deeper for the sections from -0.6 km to -0.85 km and these sections present higher level compared to other sections. This means that partially deeper dredging assures no deeper bottom and it rather has a tendency of more siltation than the other sections.

(c) The inner channel is maintained relatively deep and it can be said that if the outer channel is maintained deep, the inner channel is also maintained deep by the flushing effect of river discharge.

(4) Beruas River Mouth

DID dredged Kuala Beruas from 1988-90 for a stretch of 1.7 km with an average width and a depth of 30 m and 3.7 m, respectively. Fig. 5.2-7 shows the longitudinal profile for a stretch from 0 to 1.3 km. The following discussions are made on the illustration.

(a) Profiles before and 20 months after dredging show generally convex shape for the stretch of 0 to 1.3 km. If the profile before dredging is considered to be in equilibrium condition, the shallowest part is approximately LSD -1.4 m. The stretch just after the river mouth is maintained deeper as in the case of the Perlis River Mouth.

(b) The average longitudinal siltation height for 20 months from June 30, 1990 to March 10, 1992 is 1.35 m. The average height for 29 months from June 1990 to December 1992 is 2.04 m.

(c) The Beruas River Mouth is located in a muddy coast. In accordance with wave roses, waves seem not to be a dominant factor for siltation in this area. The river mouth is sheltered by a headland located to the south and, accordingly, effect of tidal current in the Strait of Malacca to the river mouth is moderate. Siltation in this area is assumably controlled mainly by river discharge and tidal intrusion.

(d) As for the inner channel, Fig. 5.2-8 compares the bottom of each section and Fig. 5.2-9 shows the comparison of typical cross sections. The average siltation height is small at 40 cm for the stretch of 1.5 km from the mouth for the period of 30 months after dredging. This siltation seems to occur after the outer channel is silted and, accordingly, the outlet is clogged. If the outer channel is maintained deep, the inner channel is presumed to be maintained naturally.

(5) Mersing River Mouth

Dredging was conducted in the middle of July in 1981 in the Mersing River Mouth. Profiles before and after dredging and a dredged profile are illustrated in Fig. 5.2-10. A topographical map showing the river mouth and neighboring areas is presented in Fig. 5.2-11. The following is found from these materials.

(a) The channel bed presents a convex profile similar to other river mouths. The stretch near the mouth is maintained relatively deeper.

(b) In accordance with information, siltation in the channel started immediately after dredging, and after 8.5 months the channel bed has risen 1.5 m in most part.

(c) The bottom width of the design dredging section is 50 m and the slope is assumed to be 1 vertical to 4 horizontal. The siltation volume was accordingly estimated at about 130,000 m^3 from the average siltation height of 1.5 m for the stretch of 1.6 km as shown in the illustration.

(d) This siltation is for the period from the middle of July 1981 to April 5-7, 1982 and it contains one northeast monsoon season. The northeast monsoon dominates waves in the east coast and sedimentation is likely to occur with the highest rates during this season.

Assessment of Results

(1) Outer Channel

The siltation volume in outer channels of river mouths in muddy coasts is summarized in the following table:

River Mouth No.	Name	Siltation Height (m)	Period (month)
01	Perlis	1.5	12
01	Perlis	1.0	8
-	Krg. Tengar	2.5	36
09	Muda	1.4	76
19	Beruas	1.4	20
19	Beruas	2.0	29

These values are plotted in Fig. 5.2-12. The temporal rate of siltation is considered constant from the siltation mechanism as discussed before. The rate of 1 m/year is shown in the illustration.

In the case of the sandy coast, the siltation rate on the dredged channel at 130,000 m^3 from July 1981 to April 1982 for the Mersing River Mouth is considered in the drifting sand calculation in Hydrology Sector. The siltation rates of the representative river mouths are obtained by summing the longshore transport rates and the sediment supply rates from the rivers, as presented in Table 5.2-17.

(2) Inner Channel

Inner channels are maintained relatively deep compared to outer channels and there is less variation of sections. Siltation data after dredging are available only at the Beruas River Mouth and the siltation rate is comparatively smaller at 40 cm for 30 months than 1.4 m for 30 months and 2.0 m for 29 months.

In the Supporting Report on Hydrology and Oceanography, a numerical approach is tried to simulate mud siltation in the inner channel of Tg. Piandang. The results show that the inner channel will remain stable even after dredging.

As discussed before, siltation in the inner channel is due to clogging of the outlet caused by siltation of the outer channel. If outer channels are maintained deeper, inner channels might be maintained deeper as in the case of other river mouths.

2.6.2 Agitation Dredging

Principle of Agitation Dredging

The report entitled "Agitation Dredging" prepared by ESCAP in 1985 describes agitation dredging as follows.

River and estuary bed sediment may fall under three different states; namely, mobile suspension, stationary suspension and settled sediment.

(1) Mobile Suspension

Mobile suspensions are fluid supported sediment particles carried in suspension by currents in the river or estuary. The suspended particles are supported by viscous and turbulent momentum exchange.

(2) Stationary Suspension

Stationary suspensions are fluid supported or partly particle-framework supported sediment, often having an excess pore water pressure which remains within the same small vertical element of the estuary close to the bed. This includes fluid mud or sling mud.

(3) Settled Sediment

Settled sediment are stationary suspensions consolidated to form settled mud supported by the sediment particle framework.

The quantity of particles in each of the above three states of bed sediment is variable in time and in a state of dynamic equilibrium.

The continuous exchange between these states greatly depends upon the nature of soil and the unsettling forces introduced by waves and currents. For fine sands, for example, stationary suspensions are non-existent so that settling and consolidation are one process only. When the sediment is clay, consolidation takes a long time and the mud component is the most predominant.

Owing to the weight of particles, there is a tendency to settle down. This is counterbalanced by the turbulent exchange of momentum trying to keep the particles in suspension. The weight and dimensions of particles and the hydraulic conditions of the supporting fluid mechanism determine the settling characteristics. The effect of flocculation as a result of certain chemical actions can have a marked influence on settling conditions.

After settlement the soil-water mixture is in a fluid mud condition; it is like a viscous fluid without solid structure. The weight of the particles slowly expels the intergranular water until a complete particle framework which can support its own weight is realized. This is the consolidation phenomenon.

To redisperse the mud, it is necessary to add energy to the settled particles. Since the cohesion forces in a stationary suspension are very low, a small turbulent velocity can deliver enough force to reactivate the mud. Even weak currents or small waves may have this effect.

If the stationary suspensions have had time to consolidate and acquire a particle structure, the quantity of energy necessary to break the cohesion in the settled sediment is much higher. Very high velocities are needed to start the erosion process, but these velocities do not occur frequently in nature. The erosion and re-dispersion however can be stimulated artificially and that in fact forms the basis for agitation dredging.

This characteristic of stationery suspensions and consolidated layers is illustrated by the Hjullstrom diagram shown in Fig. 5.2-13. In the Hjullstrom diagram the particle size in millimeters is plotted against velocity in centimeters per second (logarithmic scale). Two curves divide the diagram into three zones. The zone to the right and below the lower curve is the sedimentation zone. Particle sizes in this zone if acted upon by the currents with corresponding velocities on the diagram continue to remain settled.

The second area lies between the two curves and represents the transport zone. Particles of different sizes if in suspension will be transported under the influence of currents at corresponding velocity.

The area on the diagram above the top curve is the erosion zone. Particles of different sizes when acted upon by currents with corresponding velocities will be eroded and transported. Settled particles of 0.1 mm in size will continue to remain static if acted upon by a current of increasing velocities up to 20 cm/sec, but if the particles were already in suspension they will be transported at velocities lower than 20 cm/sec. If the velocity goes beyond 20 cm/sec, the particles will be eroded under the influence of the current and they will go into suspension.

After the particles have been brought into suspension by natural or artificial means, their removal or transport away from the location is in accordance with the sediment transport mechanism described earlier.

Effect of Agitation Dredging

The effect of agitation dredging is determined by (1) the volume of bed materials stirred up by agitation and (2) the distance travelled by the materials.

(1) Volume of Bed Materials Stirred up by Agitation

The volume of bed materials stirred up by agitation depends on several factors such as the size of bed materials, current condition and equipment utilized. Fig. 5.2-13 also shows the relation between the particle size and volume of materials stirred up by different kinds of equipment like the mud wheeler, bed leveller and boom dredge.

(2) Distance Travelled by the Materials

The distance travelled by the materials can be calculated by the following equation:

$$L = 0.6 * D * T * V$$

where,

L	:	distance travelled (m)
D	:	depth of water (m)
V	:	current velocity (cm/s)
T	:	time required to fall after 1 m (min.) (Refer to Fig. 5.2-14)

In the above equation, the relation between the settling time for one meter falling of the stirred up materials and the diameter of the materials is based on the Stoke's Theory, while the depth of water and current velocity were obtained from the river survey results and discharge observation. (Refer to Fig. 5.2-11.)

The effect of agitation dredging is examined firstly by the volume of sediment stirred up by agitation, secondly by the volume transported and required time to the offshore, and, finally, evaluated in monetary term in comparison with conventional dredging. The effect of agitation dredging is further discussed in Subsection 3.3.1, and it is concluded that this is not applicable because of the low tide current velocity which is essential to carry sediment materials stirred up by the agitation equipment.

2.6.3 Increment of Tidal Prism

Parameters Used for the Analysis

Increase in tidal prism leads to the increase in river mouth cross-sectional area and thus, the depth of the river mouth is maintained. In order to know the effect of the increment of tidal prism, the characteristics of the 100 river mouths were analyzed using the following parameters:

(a) River mouth cross-sectional area
(b) River mouth width
(c) River mouth depth
(d) *Tidal prism*
(e) Wave and tidal condition

Calculation of Tidal Prism

Tidal prism is defined as the volume of water from the sea to the river between low tide slack to the next high tide slack. In accordance with the availability of data, the tidal prism for the 100 river mouths is estimated by the following equation (refer to Table 5.2-18).

$$P = 0.5 * B * L * H$$

where,

P	:	tidal prism (m^3)
L	:	stretch of tidal influence (m)
B	:	mean width of the river stretch (m)
H	:	astronomical maximum tidal range (m)

0.5	:	coefficient assuming that the tidal influence decreases linearly upstream

Relation between Cross Sectional Area and Tidal Prism

In the analysis, the river mouth is specified at the position where it expands between land and sea. The cross-sectional area is calculated from the depth taken at a certain interval. The relation between tidal prism and cross-sectional area for the 100 river mouths is as shown in Fig. 5.2-15 in logarithmic scale.

According to this figure, an increase in tidal prism enlarges the cross-section at the river mouth. The ratio of tidal prism to the cross-sectional area shows some differences according to the wave and tidal conditions, and it is related to the current velocity at the river mouth by the following equation:

$$V_p = \pi \cdot (P/A) / T$$

where,

V_p	:	velocity of tidal current at spring tide (m/s)
T	:	tidal period (s)
P	:	tidal prism (m^3)
A	:	cross-sectional area (m^2)

The results are shown in the following table together with current velocity. In this calculation, the tidal period is assumed to be 12 hours.

Wave and Tidal Condition	Log(P/A)	P/A (m)	Vp (m/s)
Sheltered	3.21	1,620	0.12
Moderate	3.30	2,000	0.15
Tidal	3.11	1,290	0.09
Normal Wave	3.50	3,160	0.23
Oblique Wave	3.75	5,620	0.41
Mean Value	3.40	2,510	0.18

In the above table, the wave and tidal condition is classified in the following definitions:

(1) Sheltered indicates that the mouth is sheltered by an island or a headland;

(2) Moderate indicates that the waves and tides are in a moderate condition like on the northwest coast of the Peninsula;

(3) Tidal indicates that longshore tidal current is significant like on the coast at Malacca Strait;

(4) Normal wave indicates that high waves come normal to the mouth; and

(5) Oblique wave indicates that high waves come oblique to the mouth.

In accordance with the figure, the following matters are pointed out:

(1) The river mouth is relatively large on the coast where tidal currents are predominant. This is because the bed material consisting of silt and mud is moved easily by tidal current.

(2) The river mouth is relatively small on the coast where high oblique wave comes, because the river mouth tends to close by the action of longshore drift.

The bed material on the coast is sandy and rather difficult to move by waves or tidal action.

Relation between Width and Maximum Depth

The cross section profile at the river mouth is regulated by wave and tidal conditions. The relation between the width and the maximum depth at mean sea level is shown in Fig. 5.2-16. Generally, the river becomes deeper as it becomes wider as shown in the figure and it has the following relation:

$$D = K1 \times W^{1/2}$$

where,

D	:	maximum depth at river mouth (m)
W	:	width of river mouth (m)
$K1$	:	coefficient ($m^{1/2}$)

The effect of waves and tides is clearly shown as the coefficient $K1$ given in the following table for the five conditions.

Wave and Tide Condition	$K1$
Sheltered	0.17
Moderate	0.17
Tidal	0.28
Normal Wave	0.22
Oblique Wave	0.24
Mean	0.21

The foregoing shows that the river mouth is relatively deep compared with the width on tidal coasts, while it is relatively shallow on sheltered and moderate coasts.

Effect of Increase of Tidal Prism

As indicated by the study results for the 100 river mouths, the following is pointed out as the effect of the increase of tidal prism:

(1) Increase of tidal prism brings about the increase of cross-sectional area of the river mouth, i.e., a 100% increase in tidal prism has an effect of about 100% increase in cross-sectional area.

(2) Increase in cross-sectional area brings about the increase in depth. However, the relation between cross-sectional area and depth is in a cube root, so that a 100% increase in the cross-sectional area brings about only approximately 30% increase in the depth.

The effect of the increase of tidal prism is clear at the river mouth. However, the increase in tidal prism may not be effective to maintain the outer navigation channel, because the current by tidal prism spreads out in the outer channel. To maintain the effectiveness of the increase of tidal prism, a combination of jetty should be considered.

3. IMPROVEMENT PLAN FOR REPRESENTATIVE RIVER MOUTH

3.1 Perlis River Mouth

3.1.1 Identification of Problem and Measures Taken

Present Problem

Natural waterways formed by the flow of the Perlis River serve as the navigation channel at the Kuala Perlis Port. A shallow area is seen in the approach channel about 2.0 km from the river mouth, which has the water depth of about 2.8 m below Land and Survey Datum (LSD) according to the bathymetric survey in 1992 (refer to Fig. 5.3-1). On the other hand, the minimum depth of the inner channel is about 4.0 m below LSD. Since the Perlis River Mouth is relatively stable, the shifting of river mouth is not serious problem and also the wave seldom causes the problem to the ships mooring in the river mouth because the river mouth are sheltered from the wind waves generated in the Strait by Langkawi and Terutao islands.

Ferries and fishing boats must wait for the high tide, because their draft is more than 2.0 m and the water depth is not enough for navigating through the river mouth in low tide as discussed in Section 6.8. Although this condition has been improved by dredging works by MD, the channel will easily go back to the original condition, if maintenance dredging is not conducted.

Since arrivals and departures of ferries concentrate at high tide, loading and unloading are not performed smoothly and efficiently. Furthermore, ferries berth side by side and passengers often have to climb over one or two boats when boarding or unboarding, creating serious safety problems.

Fishing boats and fishing activities largely depend upon the tide. Sometimes, the fishing boats have to wait for a long time at the shore for the next high tide. Besides, the boats tend to leave port or return to port all at the same time. The present limited capacity of the facilities, therefore, makes landing and loading operations inefficient during high tide, while the facilities remain free in low tide.

Inundation due to river mouth siltation seems not to be a main problem. Flood damage has been reported in Kangar, the capital of Perlis State, located at about 10km upstream, and river channel improvement as well as construction of floodway have been conducted starting at the point of 2.0 km upstream from the river mouth with the design discharge of 8,000 cusec (227 m^3/s). The stretch between the river mouth and 2.0 km upstream will be left untouched because it has a large capacity enough for the design discharge. The existing flow capacity near the river mouth is estimated at 280 m^3/s corresponding to the 50-year flood in Subsection 6.2.2.

Measures Taken

The Marine Department have been conducting dredging works since 1986, mainly to maintain the navigation channel for the ferries to Langkawi Island. The dredger, which is exclusively used at the Perlis River Mouth, is a trailing suction type with a hopper of 500 m^3 capacity. The gross and net relative tonnages of the dredger are 714 tons and 214 tons, respectively.

The stretch dredged is about 3.0 km offshore from the river mouth, 60 m wide and 3 m deep below chart datum (CD). The dredging volume is shown below:

Year	Dredging Volume (m^3)
1986	100,000
1987	45,000
1988	-
1989	-
1990	122,000
1991	607,000
1992	313,000

(Source: Marine Department)

Related Projects

The projects related to the Perlis River Mouth are given as follows:

(1) Perlis Port Development Plan

The study for the Perlis Port Development Plan was conducted by JICA in 1984 to minimize the expenditure for dredging, to promote the effective use of facilities through the appropriate allotment of functions between the existing port area and the new port area, to establish a new port administrative organization suited to the situation at the Kuala Perlis Port, and to promote the port and urban development taking advantage of the Langkawi Island development.

In this development plan, the construction of the following facilities are proposed in the master plan level having the target year 2000: (1) reclamation of 32 ha of tideland along the coastal area south of the Perlis River Mouth; (2) construction of fish landing facilities for large fishing boats, pontoons for passenger boats, berthing facilities for vehicular ferries, wharves for cargo vessels, ship repairing facilities and site for factories; (3) dredging the navigation channel and basins; and, (4) construction of breakwaters surrounding the basins.

At present, land reclamation along the coastal area south of the Perlis River Mouth is being carried out by the State Economic Development Corporation.

(2) Flood Control Plan for Kangar

In the Perlis river basin, a flood control project is being executed mainly to alleviate the flood damage at Kangar, the capital of the State, through river channel improvement and floodway construction together with dam construction. The project is composed of river channel improvement in a stretch of 9.0 km, construction of floodway in a stretch of 5.6 km and construction of the Timah-Tasoh Dam which has a regulation storage capacity of 16 mcm for flood control. It is now in its final stage of construction and the only remaining work is the river channel improvement for a stretch of 2.0 km.

(3) Timah-Tasoh Dam Project

Timah-Tasoh Dam was planned to provide a dependable and adequate water supply for domestic and industrial use and augment irrigation supply for the main season while providing additional supply for off-season paddy cultivation. Flood control is included in the main purposes.

The Timah-Tasoh Dam of the embankment type has the height of 10.67 m and the storage capacity of 56 mcm allocated to sediment capacity of 7 mcm, water supply capacity of 33 mcm and 16 mcm for flood control. By using the flood control capacity, the design flood discharge of 467 m^3/s is regulated to 408 m^3/s.

As of October 1992, the construction of the dam is almost completed except minor related works, and the impounding in the reservoir has started.

3.1.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Some countermeasures are conceptually excluded for the Perlis River Mouth, as discussed below.

(1) Since the Perlis River Mouth is not seriously affected by wave action, a breakwater is not necessary.

(2) Although a jetty is an effective countermeasure for protection against the intrusion of drifting materials, a heavy structure is not basically applicable, because the bed soil composed of marine clay will likely create problems of subsidence, sliding and so forth unless a measure against high compressibility and lack of stability of the marine clay is undertaken. The only applicable facility may be a submerged jetty using flexible sand-filled tubes which can reduce the weight with the light materials inside the tube.

(3) Training walls for the stabilization of river mouth are not necessary, because the Perlis River Mouth is relatively stable and thus, the main issue is not stabilization of the river mouth.

(4) River groins for the stabilization of river channel are not necessary, because the Perlis river channel is relatively stable.

(5) A large space is required to provide a reservoir for the increment of tidal prism using a lagoon or a swampy area. Since there is no suitable space for the reservoir around the river mouth, this countermeasure is not applicable.

Thus, the applicable countermeasures for the Perlis River Mouth include a submerged jetty and dredging with conventional equipment. Since a submerged jetty cannot completely prevent the intrusion of drifting sand into the navigation channel, it is necessary to provide additional countermeasures such as maintenance dredging to maintain the navigation channel.

In this connection, the following two alternative cases are studied (refer to Fig. 5.3-2):

Case 1: Capital and Maintenance Dredging of Navigation Channel

Case 2: Capital Dredging and Combination of Submerged Jetty and Maintenance Dredging

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of other representative river mouths.

Design Features of Countermeasures

The design features of countermeasures are given as follows:

(1) Capital Dredging

In the Perlis River Mouth, boats are proposed to have the design size of 150 GRT, draft of 2.93 m and beam of 7.5 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the said design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The volume of required maintenance dredging depends on the annual siltation rate as discussed in Chapter 6. For the Perlis River Mouth, the necessary maintenance dredging volume is calculated on the basis of the annual siltation height of 1.0 m for muddy coasts. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Submerged Jetty

Since the mean sea level of the Perlis River Mouth is 0.0 m above LSD (1.9 m above CD), the top elevation of the jetty is LSD 0.0 m at the river mouth. The design features and work volume for the submerged jetty are as shown in Table 5.3-4.

In the case of a submerged jetty which cannot completely prevent the intrusion of drifting materials, the volume for maintenance dredging is expected to decrease because siltation after capital dredging is reduced. The reduction of siltation is due to two factors, namely, (1) that the submerge jetty can partly prevent dispersion and transportation of bed materials stirred up by waves and tidal current from entering the navigation channel depending on the height of the jetty and water depth; and, (2) that the tidal prism is confined in the navigation channel bringing about an increase of sediment transport capacity depending on the depth of the navigation channel with the submerged jetty.

In this study, it is assumed that the reduction rate by the former factor is 50% and that by the latter factor is 10%, or a total of 55%. The annual maintenance dredging volume will then be 162,400 m^3.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost is estimated in a manner of net present value (NPV) which is obtained by the following formula:

$$NPV = \sum_{n=1}^{N} \frac{C_n}{(1+i)^n}$$

where,

N	:	project life
C_n	:	cost in *n-th* year
i	:	discount rate
n	:	*n-th* year

The results are summarized in the following table, assuming that the project life is 30 years and the discount rate is 8%. (Refer to Table 5.3-5.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	10,134	39,261	49,395
Case 2	19,919	38,423	58,342

Selection of Optimum Countermeasure

The optimum countermeasure is selected on least cost basis, because the benefit is assumed to be the same between the two alternative study cases. Thus, the combination of capital and maintenance dredging which has an economical advantage and is also more reliable in the technical aspect than the submerged jetty, is selected as the optimum countermeasure for the Perlis River Mouth. (Refer to Fig. 5.3-3.)

3.2 Kedah River Mouth

3.2.1 Identification of Problem and Measures Taken

Present Problem

Natural waterways formed by the flow of the Kedah River serve as the navigation channel at the port. The water depth at both the inner channel and the approach channel is around 3m below LSD, but the depth at the stretch between the river mouth and 2 km offshore was previously between 1.5 m to 2 m below LSD according to the bathymetric survey in 1990, and it is presumed that the water depth was only some 10 cm at spring low tide at that time (refer to Fig. 5.3-4). This condition has been improved by the dredging work recently conducted by MD. However, the navigation channel will go back to the previous condition unless maintenance dredging is undertaken. Under the previous condition, ferries and fishing boats must wait for the high tide to go in and out of the port.

Since the Kedah River Mouth is relatively stable, the shifting of river mouth is not serious problem and also the wave seldom causes the problem to the ships mooring in the river mouth because the river mouth are sheltered from the wind waves generated in the Strait by Langkawi and Terutao islands.

Boats largely depend upon the tide. Although Kedah State intends to increase the number of ferry trips to Langkawi, the river mouth condition does not allow such an intention. Likewise, the fishing boats have to wait for a long time for the next high tide at the shore, even after having the expected volume of fish catch.

Besides, the boats leave and return to port all at the same time, so that the present capacity of the facilities is not enough. Since these facilities remain free at other times, their operation efficiency is low.

Inundation due to river mouth siltation has not been reported so far, but inundation could be caused by the insufficient flow capacity of the river channel.

Measures Taken

In the Kedah River Mouth, countermeasures to cope with the siltation problem started only in 1992, when dredging work was planned by MD in the stretch of 4.0 km offshore from the river mouth with the width of 60 m and a depth of 3.0 m below chart datum. The work commenced in May 1992, but was interrupted due to a mechanical problem after completion of dredging works for the stretch between 600 m offshore and the river mouth (refer to Fig. 5.3-5).

The dredger engaged in this work is of the cutter suction type. A dumping yard is provided 400 m south of the dredging stretch.

Related Projects

There is one project related to the Kedah River Mouth, the MUDA Irrigation Project, which was implemented to provide irrigation, drainage and other facilities for the double cropping of rice in the coastal plain of Kedah and Perlis. The gross area covers approximately 126,000 ha, out of which the net paddy area is about 96,000 ha. The project is divided into three main parts; namely, reservoir, barrage and primary canals, and internal reticulation system.

The reservoir consists of two basins linked by a tunnel. The Pedu Basin, which has a small catchment area but provides most of the storage, is formed by the rockfill type Pedu Dam of about 60.97 m high. The Muda Basin, which has a catchment area very much larger than the Pedu Basin, provides most of the water which is diverted through the 6.84 km long Saiong Tunnel by the Muda Dam, a reinforced concrete buttress dam about 30.50 m high.

The primary barrage at Pelubang diverts the water coming from the river into the primary canals, i.e., the northern, central and southern canals with a total length of 96.30 km. The primary canal system is regulated by 15 large regulators to control the flow of water.

The internal reticulation system consists of branch primary, secondary canals and drains within the paddy area, together with river improvement and tidal barrage. These works also include numerous water control structures, bridges, booster pump house, etc. The average canal density is approximately 10 m per ha.

Construction works started in 1966 and substantially completed in 1970. The Malaysian Government established a regional authority named Muda Agricultural Development Authority (MADA) in 1970 to promote, stimulate and undertake the social and economic development in the Muda Region.

3.2.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Some countermeasures are conceptually excluded as discussed below:

(1) The Kedah River Mouth is not seriously affected by wave action, therefore, a breakwater is not necessary.

(2) Jetty is not basically applicable, because the bed soil composed of marine clay will possibly bring about the problem of subsidence, sliding and so forth. The only applicable facility is a submerged jetty using flexible sand-filled tubes.

(3) Training wall is not necessary, because the main issue is not stabilization of the river mouth.

(4) Groin is not necessary, because the river channel course is relatively stable.

(5) Since there is no suitable space for a reservoir like a lagoon or swampy area around the river mouth, the reservoir is not applicable.

In this connection, the following two alternative cases consisting of the remaining countermeasures of dredging and submerged jetty are studied (refer to Fig. 5.3-6):

Case 1: Capital and Maintenance Dredging

Case 2: Capital Dredging and Combination of Submerged Jetty and Maintenance Dredging

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

Design Features of Countermeasures

The design features of countermeasures are given as follows.

(1) Capital Dredging

In the Kedah River Mouth, boats are proposed to have the design size of 150 GRT with the draft of 2.93 m and beam of 7.5 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the said design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The volume of required maintenance dredging depends on the annual siltation rate as discussed in Chapter 6. For the Kedah River Mouth, the necessary maintenance dredging volume is calculated on the basis of the annual siltation height of 1.0 m for muddy coasts. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Submerged Jetty

Since the mean sea level of the Kedah River Mouth is 0.0 m above LSD (1.9 m above CD), the crown elevation of the jetty is LSD 0.0 m at the river mouth. The design features and work volume of the submerged jetty are as shown in Table 5.3-4.

In the case of a submerged jetty, as mentioned in the previous section, it is expected that the volume for maintenance dredging is reduced because siltation after capital dredging is reduced. The main factors that bring about the reduction of siltation are (1) the prevention of dispersion and transportation of stirred up materials and (2) the increase in sediment transport capacity.

It is assumed in this study that the reduction rate by these factors is 45% in total. The annual volume of maintenance dredging will then be 149,600 m^3.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and the discount rate is 8%. (Refer to Table 5.3-6.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	8,347	35,876	44,223
Case 2	18,267	37,012	55,279

Selection of Optimum Countermeasure

The optimum countermeasure is selected on least cost basis, because the benefit is assumed to be the same between the two alternative study cases. Thus, the combination of capital and maintenance dredging which has an economical advantage and is also more reliable in the technical aspect than the submerged jetty, is selected as the optimum countermeasure for the Kedah River Mouth. (Refer to Fig. 5.3-7.)

3.3 Tanjung Piandang River Mouth

3.3.1 Identification of Problem and Measures Taken

Present Problem

The existing tide control gate prevents the intrusion of saltwater and confines river water in the river channel. This results in the diminution of the tidal influence stretch, and the river mouth functions only like a small lagoon where silt in the seawater is brought in by tidal movement and silted up forming a shallow riverbed.

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 boats is about 1.5 m (refer to Fig. 5.3-8). 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. Since the Tg. Piandang River Mouth is relatively stable, the shifting of river mouth is not serious problem and also the wave seldom causes the problem to the ships mooring in the river mouth because the river mouth are sheltered from the wind waves generated in the Strait by Langkawi and Terutao islands.

As to inundation due to river mouth siltation, this may not be a serious concern. No inundation has been reported except in high tide and incidental heavy rains.

Measures Taken

In the drainage channel in the Kerian Laut area where the Tanjung Piandang River Mouth is located, efforts were made to increase channel depth by using a mud-wheeler and ship propeller, and promising results were obtained from the ship propeller trials. Dredging works in this river mouth are further scheduled in the Sixth Malaysia Plan.

Related Projects

In the Tanjung Piandang drainage channel, a tide control gate consisting of two sluice gates facing the upper stream of the river channel and two flap gates facing seaward were constructed in the 1970's under the Kerian Sg. Manik Integrated Agricultural Development Project which was completed in 1989. In this project, the Bukit Merah Reservoir was enlarged to 76.4 mcm of live storage in the early 1960's, and a tidal barrage on the Kerian River and a new pumping station with a design capacity of 4 x 5.1 m^3/s were constructed in 1976. The area covered by this project is about 24,000 ha.

3.3.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

The condition of Tanjung Piandang River Mouth is similar to the Perlis River Mouth, therefore, some countermeasures are conceptually excluded as discussed below:

(1) Since the Tanjung Piandang River Mouth is not seriously affected by wave action, a breakwater is not necessary.

(2) Jetty is not basically applicable, because the bed soil composed of marine clay will possibly bring about the problem of subsidence, sliding and so forth. The only applicable facility is a submerged jetty using flexible sand-filled tubes.

(3) Training wall is not necessary, because the main issue is not stabilization of the river mouth.

(4) Groin is not necessary, because the river channel course is relatively stable.

As regards dredging, the applicability of agitation dredging is worth studying, since the Tanjung Piandang River Mouth seems to have some favorable conditions for agitation dredging. However, it determined that agitation dredging is not applicable because of the following reasons:

(1) The size of bed materials with d50 of about 0.035 mm which requires only 15 minutes to fall 1.0 m in water (refer to Fig. 6.5-13) is not so small that the moving time by tidal current during the time they are stirred up is not large.

(2) The velocity of tidal current is only 0.03 m/s at maximum when the channel is dredged up to a depth of 3.8 m below LSD (refer to Fig. 6.2-10). Consequently, the moving distance of the materials for about 60 minutes (3.7 x 15) for one time dredging is calculated at about 110 m (0.03 m/s x 60 min x 60 sec).

(3) According to previous experimental results, a mudwheel type agitation dredger can stir up about 500 m^3/hr of materials (refer to Fig. 6.4-1). Assuming the

operation time of two hours, the equipment can stir up 1,000 m^3 of bed materials which will move 110 m at one time. Since the required distance to move the materials is about 2,000 m on average, 18 times of agitation dredging for 18 days are needed to move 1,000 m^3 from the inner channel to the river mouth. Consequently, it takes more than 1,000 days to move 225,000 m^3 of materials which the volume required for dredging the inner channel.

(4) The results of the above calculation depend on the size of materials. In case that the size of materials is the 0.011 mm sampled at 800 m from the river mouth, the required number of days to move about 100,000 m^3 of materials at point 800 m to the river mouth would be 300 days, but this figure is still quite large.

(5) Thus, agitation dredging seems to be ineffective for maintenance dredging of Tg. Piandang River Mouth.

A reservoir is not applicable because no suitable space can be found around the river mouth.

In this connection, the following two alternative cases are studied (refer to Fig. 5.3-9):

Case 1: Capital and Maintenance Dredging

Case 2: Case 1 plus Submerged Jetty

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of other representative river mouths.

Design Features of Countermeasures

(1) Capital Dredging

In the Tanjung Piandang River Mouth, boats are proposed to have the design size of 40 GRT with the draft of 1.70 m and beam of 4.2 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the said design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging by Conventional Equipment

The volume of required maintenance dredging depends on the annual siltation rate as discussed in Chapter 6. For the Tg. Piandang River Mouth, the necessary maintenance dredging volume is calculated on the basis of the annual siltation height of 1.0 m for muddy coasts. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Submerged Jetty

Since the mean sea level of the Tanjung Piandang River Mouth is 0.1 m above LSD (1.5 m above CD), the crown elevation of the jetty is LSD 0.1 m at the river mouth. The other design features and work volume of the submerged jetty are as shown in Table 5.3-4.

In the case of a submerged jetty, as mentioned in the previous section, it is expected that the volume for maintenance dredging is reduced because siltation after capital dredging is reduced. It is assumed that the reduction rate of the volume of maintenance dredging is 45%. Consequently, the annual maintenance dredging volume will be 32,600 m^3.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and discount rate is 8%. (Refer to Table 5.3-7.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	2,668	8,070	10,738
Case 2	11,167	8,824	19,991

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same among the three alternative study cases. Thus, the combination of capital and maintenance dredging which has an economical advantage and is also more reliable in the technical aspect than the submerged jetty, is selected as the optimum countermeasure for the Tanjung Piandang River Mouth. (Refer to Fig. 5.3-10.)

3.4 Beruas River Mouth

3.4.2 Identification of Problem and Measures Taken

Present Problem

Natural waterways formed by the flow of the Beruas River serve as the navigation channel for fishing boats. Although the minimum water depth in the inner channel is maintained relatively deep at about 2.5 m below LSD, the shallow shore with a depth of about 1.5 m below LSD blocks the entrance channel at a distance of about 400 meters from the river mouth (refer to Fig. 5.3-8. Since the Tg. Piandang River Mouth is relatively stable, the shifting of river mouth is not serious problem and also the wave seldom causes the problem to the ships mooring in the river mouth because the river mouth are sheltered from the wind waves generated in the Strait by Langkawi and Terutao islands.

In view of this and the congested condition within the inner channel, fishing boats which have drafts of about 1.5 m have to wait inordinately for a long time between two and three hours for returning to land the catches.

Inundation due to river mouth siltation has not been reported so far, and river mouth siltation may not bring about any inundation problem judging from the siltation condition as aforementioned.

Measures Taken

To cope with the river mouth siltation problem, DID conducted dredging works seaward as well as the inner channel from 1988 to 1990. The dredging works was conducted under the condition of a dredged width of 30 m, a stretch of about 1,700 m and a depth of 3.5 m in the approach channel, while the dredged bottom width is 18 m, stretch is about 1,700 m and the maximum dredged depth is about 0.7 m in the inner channel. The dredging volume was about 122,000 m^3.

The bathymetric survey result conducted in 1992, however, revealed that the dredged outer channel has been silted up again and mostly returned to its previous condition. (Refer to Section 6.5)

Related Projects

No specific project has been planned or conducted in the area around the Beruas River Mouth, except minor shore protection works at the left side and some small scale jetties for landing of fish catch.

3.4.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Some countermeasures are conceptually excluded as discussed below:

(1) Since the Beruas River Mouth is not seriously affected by wave action, a breakwater is not necessary.

(2) A jetty is not basically applicable, because the soil composed of marine clay will possibly bring about the problem of subsidence, sliding and so forth. The only applicable facility is a submerged jetty using flexible sand-filled tubes.

(3) A training wall is not necessary, because the main issue is not stabilization of the river mouth.

(4) Groins are not necessary, because the river channel course is relatively stable.

(5) Since there is no suitable space for a reservoir like a lagoon or swampy area around the river mouth, a reservoir is not applicable.

(6) Agitation dredging is not also considered as an applicable countermeasure, because of similar hydraulic condition as Tg. Piandang.

In this connection, the following two alternative cases are to be studied.

Case 1: Capital and Maintenance Dredging

Case 2: Case 1 plus Submerged Jetty

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

Design Features of Countermeasures

(1) Capital Dredging

In the Beruas River Mouth, boats are proposed to have the design size of 100 GRT with the draft of 2.37 m and beam of 6.09 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design feature for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design feature is shown in Table 5.3-3.

(2) Maintenance Dredging

The volume of required maintenance dredging depends on the annual siltation rate as discussed in Chapter 6. For the Tg. Piandang River Mouth, the necessary maintenance dredging volume is calculated on the basis of the annual *siltation height of 1.0 m for muddy coasts. The annual siltation volume is* estimated as shown in Table 5.3-3.

(3) Submerged Jetty

Since the mean sea level of the Beruas River Mouth is 0.2 m above LSD (1.5 m above CD), the crest elevation of the jetty is LSD 0.2 m at the river mouth. The other design features and work volume for the submerged jetty are as shown in Table 5.3-4.

In the case of a submerged jetty as mentioned in the previous section, it is expected that the volume for maintenance dredging is reduced because siltation after capital dredging is reduced. The main factors that bring about the reduction of siltation are (1) the prevention of dispersion and transportation of stirred up materials and (2) the increase of sedimentation transport capacity.

It is assumed that the reduction rate by these factors is 45%. Consequently, the annual maintenance dredging volume will be 57,700 m^3.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and discount rate is 8%. (Refer to Table 5.3-8.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	4,464	14,196	18,660
Case 2	11,559	10,643	22,202

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same among the two alternative study cases. Thus, the combination of capital and maintenance dredging which has an economical advantage and is also more reliable in the technical aspect than the submerged jetty, is selected as the optimum countermeasure for the Beruas River Mouth. (Refer to Fig. 5.3-9.)

3.5 Kuantan River Mouth

3.5.1 Identification of Problem and Measures Taken

Present Problem

Natural waterways formed by the flow of the Kuantan River serve as the navigation channel at the Kuantan River Mouth. Entering and leaving the port at the river mouth is generally not possible at low tide due to the presence of shallow areas 1 to 2 km offshore. The depth of the water in the approach channel which is about 2 m below LSD becomes only 1.0 m at spring low tide, while the draft of boats of more than 40 GRT is over 2.5 m (refer to Table 5.2-3 and Fig. 5.3-10).

On the other hand, the inner channel of the river mouth is relatively well maintained by river water as well as current in tidal prism. The depth of the inner channel is between 7 m and 11.5 m below LSD. The location of the river mouth is fixed because of existence of headland, while the outer channel is shifting year by year.

Inundation due to river mouth siltation has not been reported so far. Flood damage has been reported in the upper reaches when high tide and flood occur at the same time.

Measures Taken

Although measures to alleviate river mouth problems have not been taken so far, a study on the matter was conducted in March 1976 under the Kuantan Fishing Port Project. In this study, three alternative measures were proposed: (1) construction of two training dikes at shore side with a length of about 2.7 km from the river mouth, (2) construction of one training dike at shore side with a length of about 2.7 km and one breakwater with a length of 750 m to prevent intrusion of littoral current with drift sand, and (3) dredging of the navigation channel. (Refer to Fig. 5.3-11.)

To select the optimum countermeasure, a hydraulic model test was conducted in 1878. It was concluded that dredging of the approach channel without any training dike would be sufficient. In order to minimize maintenance dredging of the channel to once in every 2 years, it was recommended that the seaward section be dredged to one extra meter below the proposed depth of 4 m (below CD) of the approach channel. It is also possible to achieve a self-maintaining channel and the advantage of protection against wave attack during the North-East monsoon by one training dike and one breakwater.

Dredging is scheduled in 1993 at the shore side of the approach channel with a length of about 3 km, a width of 60 m and a depth of 3.7 m below CD. The total volume of about 400,000 m^3 is expected to be dredged with the budget of RM 2.0 million (US$800,000).

Related Projects

Some projects are related to the Kuantan River Mouth, as follows:

(1) Kuantan Port

To meet the growth in the number of vessels for export and import in the east coast, the Kuantan Port was constructed at Tanjung Gelang about 25 km north of Kuantan based on the feasibility study in 1973. The port provides the facilities for ships of up to 35,000 DWT and 34 ft loaded draft. The port capacity for non-container traffic is 2,692,000 tons per year, while that of the container terminal is 2,624,000 tons per year.

(2) Land Reclamation at Shore near River Mouth

For tourism development, land reclamation of 290 ha on the coast in the Tanjung Tembeling area near the left side of the Kuantan River Mouth is proposed, where hotel, golf course, lagoon resort, etc., are to be provided.

(3) Bridge Construction

A bridge crossing the Kuantan River at about 500m upstream from the river mouth is under construction to connect Kuantan City and the villages situated in the coastal zone south of the Kuantan River Mouth. The construction work is expected to be completed in the middle of 1993.

3.5.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

A study was once conducted under the Kuantan Fishing Port Study in 1975. In this study, the following three alternative cases were proposed:

Case 1: Construction of Two Jetties along the Approach Channel

Case 2: Construction of One Jetty along the Approach Channel and One Breakwater

Case 3: Dredging of Navigation Channel

The study included hydraulic model test for the three alternative cases and it was concluded that dredging of the approach channel without any jetty would be sufficient. There was no description on cost comparison and economic evaluation for the alternatives, which are necessary to identify the suitable countermeasure.

Dredging work in the Kuantan River Mouth was already selected as a suitable countermeasure and it is scheduled in the beginning of 1993. However, the following two alternative cases are to be studied to confirm the adequacy of the dredging countermeasure.

Case 1: Capital and Maintenance Dredging

Case 2: Capital Dredging, Jetty and Coastal Groin

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

Design Features of Countermeasures

(1) Capital Dredging

In the Kuantan River Mouth, boats are proposed to have the design size of 200 GRT with the draft of 3.21 m and beam of 7.3 m. The design alignment of the navigation channel follows that of present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The necessary maintenance dredging volume corresponds to the annual volume of drifting sand and sediment from the catchment and it is assumed that the siltation rate does not exceed the capital dredging volume. In the Kuantan River Mouth, the capital dredging volume is more than the annual volume of drifting sand and sediment from the catchment. The maintenance dredging volume is shown in Table 5.3-3.

(3) Jetty

Since the higher high water level of the Kuantan River Mouth is 1.6 m above LSD (3.3 m above CD), the crown elevation of the jetty is LSD 1.6 m at the river mouth. The design features are shown in Table 5.3-4. The work volume of the breakwater based on the design features is also shown in the table.

During or after construction of the jetty, beach erosion may occur downstream of current. Some sand will be provided by capital dredging, but it may not be enough to maintain the annual condition. Therefore, to prevent beach erosion, coastal groins are proposed for shore protection.

(4) Groin (Coastal Groin)

As mentioned above, beach erosion may occur downstream of the current. Three groins, 1,000 m, 500 m and 150 m long, respectively, will be set up at the southern beach of the river mouth (refer to Table 5.3-9).

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and the discount rate is 8%. (Refer to Table 5.3-10.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	3,706	19,796	23,502
Case 2	11,242	14,210	25,452

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis. As may be noticed from the cost comparison, there is not much difference in cost between the two alternative study cases. Thus, dredging is selected as the optimum countermeasure for the Kuantan River Mouth for the following reasons:

(1) In the previous study for the Kuantan Fishing Port, it was concluded through the hydraulic model test that dredging is the optimum countermeasure.

(2) In case of a jetty, it may cause adverse influence to the adjacent coast because a large amount of drift materials will be trapped by the jetty resulting in the erosion downstream of the littoral current. It is however necessary to conduct a more detailed study to confirm the adequacy of the coastal groin adopted in this study.

A general layout of the proposed countermeasures is illustrated in Fig. 5.3-12.

3.6 Kerteh River Mouth

3.6.1 Identification of Problem and Measures Taken

Present Problem

The natural waterways maintained by river flow and current due to tidal movement serve as the navigation channel at the Kerteh River Mouth. Since the river flow and tidal prism are so small to well maintain the river mouth, the water depth at the river mouth is shallow. Further, due to the presence of shallow areas in the shore, entering and leaving the river mouth are generally not possible at low tide. The minimum water depth of the navigation channel in the approach channel and inner channel are 1.0 m and 2.5 m below LSD, respectively, while the draft of fishing boats is about 1.5 m (refer to Fig. 5.3-13 and Table 5.2-3). Consequently, the river mouth problem can be focused on the stretch of about 1.0 km in and out of the river mouth. The river mouth area is in very unstable judging from the photographs, which is attributed to the longshore transport.

Since the houses are located at a higher elevation, inundation is not a serious problem around the river mouth, although right bank erosion has been reported. This was alleviated by the construction of a floodway nearby.

Measures Taken

To cope with the river mouth siltation problem, in 1992, a fisherman's association constructed a breakwater at the right bank and a training wall along the right bank which separated the lagoon from the river channel. The construction works which were financed by DID were executed on the basis of fishermen's experience without any detailed study and design work. The breakwater is 138 m long with a crown width of 10 m and a height of 3.0 to 4.0 m. The materials used for this breakwater include crashed rock in two sizes; one is 30 inches (75 cm) and the other is between 6.0 inches (15 cm) and 9.0 inches (22.5 cm).

Dredging works have also been conducted for the stretch of 0.5 km in the inner channel by using a suction type dredger. The dredging volume is 53,000 m^3.

For the works, RM 400,000 (US$160,000) including RM 100,000 for dredging works was spent and in the next fiscal year, RM 300,000 is allocated to prevent erosion on the left bank of the river mouth.

Related Projects

To prevent erosion of the right bank where a fishing village and a road exist, DID provided revetment in a stretch of 800 m in 1985, and a flood diversion channel was constructed in 1987. The diversion channel is 400 m long, 30 m wide and 3.0 m deep.

3.6.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Judging from the current problem of the Kerteh River Mouth, i.e., the shifting of river mouth and channel and the shallow navigation channel at both inner and approach, it seems to be necessary to examine the applicability of (1) jetty, (2) training wall, (3) dredging, and (4) reservoir. A breakwater may not be necessary because the wave from oblique direction breaks in the shallow shore zone, so that wave intrusion into the river mouth is not a serious problem. The following two alternative study cases were then set by applying these countermeasures in combination with each other in accordance with the considerations for alternative study cases mentioned in Subsection 6.4.2.

Case 1: Capital and Maintenance Dredging and Training Wall

Case 2: Capital Dredging, Jetty, Coastal Groin and Reservoir

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

Incidentally, a jetty has been provided at the Kerteh River Mouth and dredging work has also been conducted based on fishermen's experience without any study and design. Furthermore, a lagoon at the right bank, which may be effective to maintain the river mouth by increasing the tidal prism capacity, was separated by a training wall. The optimum countermeasure will thus be selected from the above alternative cases considering these conditions.

Design Features of Countermeasures

(1) Capital Dredging

In the Kerteh River Mouth, boats are proposed to have the design size of 40 GRT with the draft of 1.70 m and beam of 4.2 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The maintenance dredging volume corresponds to the annual volume of drifting sand and sediment from the catchment and it is assumed that the siltation rate does not exceed the capital dredging volume. In the Kerteh River Mouth, the capital dredging volume is less than the annual volume of drifting sand and sediment from the catchment. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Breakwater

Since the mean sea level of the Kerteh River Mouth is 0.3 m above LSD (1.7 m above CD) and the uprush is 0.87 m, the height of the breakwater is LSD 4.23 m at the river mouth. The design features are shown in Table 5.3-4. The work volume of the breakwater based on the design features is also shown in the table.

(4) Jetty

Applying the higher high water level, the height of the jetty is 1.6 m at the river mouth. The other design features are the same as those of the breakwater as shown in Table 5.3-4.

(5) Reservoir

At present, there exists a lagoon on the right side which is now shut off from the Kerteh River by a training dike. This can be used as reservoir to increase the tidal prism only by providing a culvert box. The size of the reservoir is roughly estimated at 462,000 m^3.

Since the tidal volume increases to 41,250 m^3 which corresponds to 9.8% of the present tidal prism (see Subsection 6.5.3), the navigation channel is expected to deepen to 0.2 m from the present navigation channel bed height; thus, the dredging volume will decrease.

(6) Groin

For the prevention of beach erosion downstream of the current, two groins, 200 m and 100 m long, will be constructed at the southern beach as shown in Fig. 5.3-14. The stretch is as shown in Table 5.3-7.

(7) Training Wall

For stabilization of the right bank at the river mouth, training wall is provided along the flow direction. The stretch for the training wall is as shown in Table 5.3-7.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and the discount rate is 8%. (Refer to Table 5.3-11)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	2,670	9,524	12,194
Case 2	6,614	2,360	8,974

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same among the two alternative study cases. In the case of the Kerteh River Mouth, the direction of long shore transport from south to north is predominant so that one-side jetty on the northern side seems to be enough to prevent the intrusion of sediment into the navigation channel, and this will minimize the cost for the construction of jetty (Case 2). On the other hand, the cost of maintenance dredging is quite large because of the large amount of longshore transport. Thus, the combination of capital dredging, jetty, coastal groin and reservoir is selected as the optimum countermeasure for the Kerteh River Mouth. (Refer to Fig. 5.3-14.)

3.7 Marang River Mouth

3.7.1 Identification of Problem and Measures Taken

Present Problem

The natural waterways maintained by river flow and current due to tidal movement serve as the navigation channel at the Marang River Mouth. Entering and leaving the river mouth are generally not possible at low tide due to the presence of shallow bars just offshore the river mouth and water depth at the river mouth is not sufficient for navigation. The minimum water depth of the navigation channel at the river mouth is about 1.5 m below LSD, while the draft of fishing boats is about 2.5 m (refer to Fig. 5.3-15 and 5.3-16, and Table 5.2-3). The river course and the river mouth, which have moved from right to left according to the aerial photographs, are not stable due to the intrusion of longshore transport.

Since the houses are located at a higher elevation, inundation is not a serious problem around the river mouth, although inundation was reported in the upper reaches due to the coincidence of high tide and storm rainfall.

Measures Taken

To cope with the river mouth siltation problem, DID conducted dredging works for a volume of about 231,000 m^3 from October to December in 1980. The design feature is not clear. Further dredging works are scheduled in the Sixth Malaysia Plan.

Related Projects

Some projects are related to the Marang River mouth, as follows.

(1) Bank Protection Works at River Mouth

To prevent bank erosion, cylindrical concrete piles have been provided by JKR along both river banks from the bridge to the river mouth in the stretch of 700 m, financed by the Marang Town Board in a context of resort development. The works were conducted in 1981 and 1986 for left bank protection and right bank protection, respectively.

(2) Development of a Recreation Park

This project is planned to improve the town of Marang as a tourist resort and as a jetty for tourist to travel to Kapas Island. The study area involves the Marang River Mouth from Kijin River's lagoon in which the high attraction force will provide the water recreation. This project is under the planning stage.

3.7.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Judging from the current problem of the Marang River Mouth, i.e., shifting of river mouth, shifting of river channel course, intrusion of straight wave, and shallow navigation channel of both inner and approach, it seems to be necessary to examine the applicability of all countermeasures, i.e., breakwater, jetty, training wall, groin, dredging and reservoir. The following two alternative study cases were set by applying these countermeasures in accordance with the considerations on alternative study cases mentioned in Subsection 6.4.2.

Case 1: Capital and Maintenance Dredging, Breakwater, Training Wall and River Groin

Case 2: Capital Dredging, Jetty, Breakwater, Coastal and River Groins, and Reservoir

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

The optimum countermeasure will be selected through the comparative study on the above alternative study cases.

Design Features of Countermeasures

(1) Capital Dredging

In the Marang River Mouth, boats are proposed to have the design size of 40 GRT with the draft of 1.70 m and beam of 4.2 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works were figured out as shown in

Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The maintenance dredging volume corresponds to the annual volume of drifting sand and sediment from the catchment and it is assumed that the annual siltation rate does not exceed the capital dredging volume. In the Marang River Mouth, the annual siltation rate is less than the annual volume of drifting sand and sediment from the catchment. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Breakwater

Since the mean higher high water level of the Marang River Mouth is 1.3 m above LSD (2.6 m above CD) and the uprash is 0.87 m, the height of the breakwater is 3.93 m at the river mouth. The design features based are shown in Table 5.3-4. The work volume for the breakwater based on the design features is also shown in the table.

(4) Jetty

Applying the mean higher high water level, the height of the jetty is 1.3 m at the river mouth. The other design features are the same as those of the breakwater as shown in Table 5.3-4.

(5) Training Wall

As mentioned in the breakwater, the design height adding the uprash to the mean high water springs is 2.17 m. The stretch to provide the training wall is as shown in Table 5.3-7.

(6) Reservoir

At present, there exists a lagoon on the left side which is connected with the Marang River by a shallow channel. This lagoon can be used as reservoir to increase the tidal prism only by widening the shallow channel to assure the connection between the lagoon and the Marang River Mouth. The size of the reservoir is roughly estimated at 174,000 m^3.

Since the tidal volume increases to 57,700 m^3 which corresponds to 5.2% of the present tidal prism (see Subsection 6.5.3), the navigation channel is expected to deepen to 0.1 m from the present navigation channel bed height; thus, the maintenance dredging volume for the inner channel will decrease.

(7) Groin

Since the course of the inner channel is always changing due to the drifting sand pushed back by the tide, it is necessary to provide the river groin to stabilize the course of the inner channel.

A group of river groins is provided at the middle of the inner channel. The length and number of groins at the interval of 120 m are as shown in Table 5.3-7. For the prevention of beach erosion, one 200 m long coastal groin is set at the southern beach.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized in the following table, assuming that the project life is 30 years and discount rate is 8%. (Refer to Table 5.3-12.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	12,108	7,344	19,452
Case 2	12,639	4,696	17,325

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same among the three alternative study cases. In the case of the Marang River Mouth, the sea bed gradient is relatively steep, so that the stretch of the jetty is short resulting in the reduction of construction cost. On the other hand, the longshore transport is so large that the cost for maintenance dredging is relatively large. Thus, the combination of capital dredging, jetty, breakwater, river and coastal groins, and reservoir is selected as the optimum countermeasure for the Marang River Mouth. (Refer to Fig. 5.3-17.)

3.8 Terengganu River Mouth

3.8.1 Identification of Problem and Measures Taken

Present Problem

Natural waterways formed by the flow of the Terengganu River serve as the navigation channel at the Terengganu River Mouth. Although the water depth at the river mouth is very deep at 9 m below LSD, the water depth becomes very shallow at 2.0 m below LSD at about 0.5 km offshore the mouth and 3.5 m (LSD) about 2.5 km upstream in the inner channel (refer to Fig. 5.3-18). The shallow shore zone seasonally change its location, so that commercial and large size fishing boats can hardly locate the navigation channel at low tide and cannot also have access to the jetties and landing facilities located 1 to 2 km upstream of the river mouth.

Formerly, the river mouth has shifted due to the development or erosion of sand spit. However, this problem seems to have been settled after the construction of training works at the right bank.

As to inundation, it is reported that inundation in the area around the river mouth occurs a few times a year, which is mainly due to the insufficient drainage facilities. It is not clear whether the inundation is attributed to river mouth siltation.

Measures Taken

Some measures were taken for the Terengganu River Mouth, as follows:

(1) Dredging Works

Dredging works were conducted in 1976 by the Marine Department to maintain the navigation channel for commercial boats only in the inner channel. Since then, dredging has been conducted repeatedly in 1987, 1988 and 1991. The stretch dredged is about 1.3 km between 1.7 km and 3.0 km from the river mouth, and the depth and width are 3 m and 6 m, respectively. The reported dredging volume is as shown below.

Year	Dredging Volume (m^3)
1976	no data
1987	210,000
1988	460,000
1991	145,000

As of 1992, maintenance dredging is ongoing in the inner channel of the Terengganu River Mouth. Dredging works in the approach channel are scheduled in 1993.

(2) Construction of Training Wall

A training dike was constructed at the right bank of the Terengganu River Mouth, to stabilize the river mouth and to prevent erosion of the river bank. The works were proposed in the Terengganu Coastal Region Study in 1980.

In accordance with the study results, the training wall was constructed at the stretch of 800 m on the right bank of the river mouth from 1990 to 1991 at the cost of RM 5.26 million (US$2.1 million).

Related Projects

The projects related to the Terengganu River Mouth are given as follows.

(1) Coastal Protection Works at Severang Takir

The project area which is located to the north of Sg. Terengganu, comprises approximately 6 km of sandy beaches and extends northward from Tg. Takir to Sultan Mahmud Airport. Within this area are several fishing villages presently being seriously threatened by beach erosion. A number of village houses have already been swept away by waves.

In the feasibility study and detailed design of the Coastal Protection Works at Seberang Takir (Terengganu), beach nourishment was proposed for coastal protection. The volume is expected to be 3,600,000 m^3 of sand, which is to be taken from the Terengganu River Mouth. This was implemented starting in 1992.

(2) Land Reclamation

In the context of a resettlement plan, the swampy area extending in the left bank near the river mouth is to be reclaimed by the State Government.

(3) Transfer of Oil Base

Tankers carrying crude oil navigate through the Terengganu River Mouth to an oil base of Petronas located at the river mouth. This oil base is scheduled to be transferred by 1994.

3.8.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Basically, most of the countermeasures may be applicable for the Terengganu River Mouth which have several kinds of problems such as shifting of river channel, shallow navigation channel of both inner and approach, and development of sand bar. However, the following considerations are taken to select the applicable countermeasures, judging from the present situation:

(1) The Malaysian Government had already constructed a training wall at the right bank that presently functions well to stabilize the river mouth. Therefore, it is not necessary to apply this countermeasure for the Terengganu River Mouth.

(2) A reservoir may not be efficient, because there is no suitable space around the river mouth to provide an effective reservoir with enough capacity compared with the size of tidal prism of the Terengganu River Mouth.

(3) Although dredging work has been conducted several times in the inner channel, it is necessary to confirm the effect of the dredging work and also to examine the possibility of dredging work at the outer channel.

(4) Groin, which has the effect to stabilize the inner channel, seems to be worth studying.

(5) Breakwater is necessary, because straight waves rush into the river mouth and cause damage to fishing boats.

(6) To prevent flood damage, the river mouth width has to be enlarged.

(7) Jetty seems to be one of the most effective measures to solve the siltation in the navigation channel, although it is necessary to carefully examine the adverse influence on erosion to the adjacent coastline, especially, the left coastline where coastline erosion is a serious problem.

For the Terengganu River Mouth, therefore, the following two alternative cases will be studied:

Case 1: Capital and Maintenance Dredging, Breakwater and Groin

Case 2: Capital Dredging, Jetty, Breakwater, and Coastal and River Groins

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

Design Features of Countermeasures

(1) Capital Dredging

In the Terengganu River Mouth, boats are proposed to have the design size of 150 GRT with the draft of 2.93 m and beam of 7.5 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The maintenance dredging volume corresponds to the annual volume of drifting sand and sediment from the catchment and it is assumed that the annual siltation rate does not exceed the capital dredging volume. In the Terengganu River Mouth, the capital dredging volume is less than the annual volume of drifting sand and sediment from the catchment. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Breakwater

Since the mean higher high water level of the Terengganu River Mouth is 1.3 m above LSD (2.6 m above CD) and the uprash is 0.87 m, the height of the breakwater is 3.93 m at the river mouth. The design features and work volume of the breakwater are as shown in Table 5.3-4.

(4) Jetty

Applying the mean higher high water level, the height of the jetty is 1.3 m at the river mouth. The other design features is the same as those of the breakwater as shown in Table 5.3-4.

(5) Groin

Since the inner channel is always changing its course due to the drifting sand pushed back by the tide and flood discharge, it is necessary to provide the river groin to stabilize the course of the inner channel.

A group of river groins is provided at the middle of the inner channel. The length and number of groins at 200 m interval are as shown in Table 5.3-7.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized in the following table, assuming that the project life is 30 years and the discount rate is 8%. (Refer to Table 5.3-13.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	17,577	29,090	46,667
Case 2	19,066	32,558	51,624

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same between the two alternative study cases. In case of a jetty which is proposed with a long stretch due to the relatively gentle gradient, it becomes costly and, moreover, it may cause coastal erosion problem in the adjacent coast which currently has a severe erosion problem. Thus, dredging is selected as the optimum countermeasure for the Terengganu River Mouth. (Refer to Fig. 5.3-19.)

3.9 Oya River Mouth

3.9.1 Identification of Problem and Measures Taken

Present Problem

The natural waterways maintained by the river flow as well as the current due to tidal movement serve as the navigation channel at the Oya River Mouth. Since the river flow and tidal prism are large to well maintain the river mouth, the water depth of 3.5 m below LSD in the inner channel is relatively deep (refer to Fig. 5.3-20). However, that of about 1.0 m below LSD in the approach channel is quite shallow, which may be due to the sedimentation of sand from the upper reaches and littoral drift sand, so that entering and leaving the river mouth are generally not possible at low tide. The shallow shore zone emerges in the near shore between 0.3 km and 1 km.

Consequently, the river mouth problem should be focused on this stretch. Recently, a cargo ship with a crane sunk near the right bank of the river mouth and is still there. This hampers the navigation of other boats.

Since the houses are located at a higher elevation, inundation is not a serious problem around the river mouth. Only the coincidence of high tide and storm rainfall once a year brings about inundation.

Measures Taken

No specific measures have been taken to cope with the river mouth siltation problem so far.

Related Projects

The Sarawak Economic Development Corporation (SEDC) has a number of proposals to boost the fishery activity and to develop the river mouth area such as aquaculture and the construction of a reinforced concrete wharf. Recently, prawn aquaculture facilities were provided. Besides, an ice storage facility is presently being provided by a private ice factory owner.

3.9.2 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Judging from the current problem of the Oya River Mouth, i.e., shifting of river mouth and shallow navigation channel of approach, it seems to be necessary to examine the applicability of (1) jetty, (2) training wall and (3) dredging. The reservoir may not be applicable, because there is no suitable space around the river mouth to provide an effective reservoir with enough capacity compared with the size of tidal prism of the Oya River Mouth.

Two alternative study cases were set by applying the above countermeasures, as shown below.

Case 1: Capital and Maintenance Dredging and Training Wall

Case 2: Capital Dredging, Jetty and Coastal Groin

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

The optimum countermeasure is selected through a comparative study on the above alternative study cases.

Design Features of Countermeasures

(1) Capital Dredging

In the Oya River Mouth, boats are proposed to have the design size of 40 GRT with the draft of 1.70 m and beam of 4.2 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The maintenance dredging volume corresponds to the annual volume of drifting sand and sediment from the catchment and it is assumed that the annual siltation rate does not exceed the capital dredging volume. In the Oya River Mouth, the capital dredging volume is less than the annual volume of drifting sand and sediment from the catchment. The maintenance dredging volume is estimated as shown in Table 5.3-3.

(3) Jetty

Since the mean higher high water level of the Oya River Mouth is 0.6 m above LSD (2.3 m above CD), the height of the jetty is 0.6 m at the river mouth. The other design features based on the design criteria and the work volume of the jetty based on the design features is as shown in Table 5.3-4.

(4) Training Wall

As mentioned in the jetty, the design height adding the uprash to the mean higher high water spring level is 1.97 m. The stretch to provide the training wall is as shown in Table 5.3-7.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated by applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and the discount rate is 8%. (Refer to Table 5.3-14.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	2,107	3,027	5,134
Case 2	6,320	2,358	8,678

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same between the two alternative study cases. In the case of the Oya River Mouth, the stretch of the jetty becomes long due to the relatively gentle sea bed slope resulting in the high construction cost, though the longshore transport is also large. Thus, dredging is selected as the optimum countermeasure for the Oya River Mouth. (Refer to Fig. 5.3-21.)

3.10 Papar River Mouth

3.10.1 Identification of Problem and Measures Taken

Present Problem

The natural waterways maintained by river flow and current due to tidal movement are used as the navigation channel at the Papar River Mouth. Since the river flow and tidal prism are not enough to well maintain the river mouth, the water depth at the river mouth and the outer channel are very shallow, so that entering and leaving the river mouth are generally not possible at low tide. The minimum water depth of the navigation channel at the shore side is 1 m below LSD, while the draft of fishing boats is about 1.2 m. (Refer to Fig. 5.3-22.)

On the other hand, the water depth of the inner channel which seems to be formed in the rainy season is about 3 m, deeper than the river mouth and the outer channel. Consequently, the river mouth problem should focus on the outer channel.

After construction of the diversion channel in the 1970's, flood damage has not been reported; thus, the river mouth seems to be free from flood damage due to river mouth siltation.

Measures Taken

No specific measure has been taken to cope with the river mouth siltation problem.

Related Projects

To cope with the severe bank erosion problem, State DID has been conducting bank protection works for a total stretch of about 3 km since 1987.

3.10.3 Selection of Countermeasures

Application of Countermeasures and Setting of Alternative Cases

Judging from the current problem of the Papar River Mouth, i.e., shifting of river mouth and shallow navigation channel of both inner and approach, it seems to be necessary to examine the applicability of (1) jetty, (2) training wall, (3) river groin, (4) dredging, and (5) reservoir. Two alternative study cases are set by applying these countermeasures, as follows.

Case 1: Capital and Maintenance Dredging, Training Wall and River Groin

Case 2: Capital Dredging, Jetty, Coastal and River Groins, and Reservoir

The combination of countermeasures for each study case is presented in Table 5.3-1 for comparison with those of the other representative river mouths.

The optimum countermeasure will be selected through the comparative study on the above alternative study cases.

Design Features of Countermeasures

(1) Capital Dredging

In the Papar River Mouth, boats are proposed to have the design size of 40 GRT with the draft of 1.70 m and beam of 4.2 m. The design alignment of the navigation channel follows that of the present navigation channel.

In accordance with the design criteria and the design size of boats and design alignment, the design features for dredging works were figured out as shown in Table 5.3-2. The required dredging volume based on the design features is shown in Table 5.3-3.

(2) Maintenance Dredging

The maintenance dredging volume corresponds to the annual volume of drifting sand and sediment from the catchment and it is assumed that the annual siltation rate does not exceed the capital dredging volume. In the Papar River Mouth, the capital dredging volume is less than the annual volume of drifting sand and sediment from the catchment. The maintenance dredging volume is estimates ad shown in Table 5.3-4.

(3) Jetty

Since the mean higher high water level of the Papar River Mouth is 1.1 m above LSD (2.1 m above CD), the height of the jetty is 1.1 m at the river mouth. The other design features based on the design criteria and the work volume of the jetty based on the design features is as shown in Table 5.3-4.

(4) Training Wall

As mentioned in the breakwater, the design height adding the uprash to the mean high water spring level is 1.97 m. The stretch for the training wall is as shown in Table 5.3-7.

(5) Reservoir

At present, there exists a swampy area along the river course which can be used as reservoir to increase the tidal prism by excavation. The expected capacity of the reservoir is roughly estimated at 90,000 m^3.

Since the tidal volume increases to 7,200 m^3, which corresponds to 5.8% of present tidal prism (see Subsection 6.5.3), the navigation channel is expected to deepen to 0.07 m from the present navigation channel bed height; thus, the maintenance dredging volume for the inner channel will decrease.

(6) Groin

For the purpose of preventing beach erosion, two coastal groins 200 m and 100 m long, respectively, will be provided at the western beach.

Cost Comparison of Alternative Cases

The cost of countermeasures including initial cost and maintenance cost is calculated applying the unit cost described in Chapter 6 to the work volume based on the design features. The total cost in a manner of net present value is summarized below, assuming that the project life is 30 years and discount rate is 8%. (Refer to Table 5.3-15.)

Case	Initial Cost	Maintenance Cost	Total Cost (1000 RM)
Case 1	2,100	4,017	6,117
Case 2	2,637	907	3,544

Selection of Optimum Countermeasure

The optimum countermeasure is selected on the least cost basis, because the benefit is assumed to be the same among the three alternative study cases. In the case of the Papar River Mouth, the stretch of the jetty is not long due to the relatively steep sea bed slope resulting in the low construction cost, though the longshore transport is not so large. Thus, the combination of capital dredging, jetty, coastal groin and reservoir is selected as the optimum countermeasure for the Papar River Mouth. (Refer to Fig. 5.3-23.)

4. FORMULATION OF THE MASTER PLAN

4.1 Master Plan for the Objective River Mouth

The Master Plan is formulated for the 75 objective river mouths selected out of the 100 river mouths originally proposed.

4.1.1 Cost of Countermeasures

Countermeasures for Each River Mouth

The countermeasures selected for the representative river mouth in a group are applied to the other river mouths in the group for the estimation of cost.

Work Volume

Based on the work volume for the representative river mouth, the work volume for each of the other river mouths is calculated in the following manner:

(1) Capital Dredging

The volume of capital dredging is related to the dredging stretch, the width and the depth of both the outer and inner channels. Since the only sources of information available for the calculation of these parameters are the chart with a scale of 1/200,000 and the river mouth depth observed at the field investigation, the dredging volume for the outer channel is estimated based on the presumed parameters using the chart and the observed river mouth depth and design width, while the volume for the inner channel is estimated using the ratio between the volumes for the outer channel and the inner channel of the representative river mouth. The formula for the estimation is given as follows:

$$V = Vo + Vi$$
$$Vo = D \times B \times L \times k1$$
$$Vi = Vo \times k2$$
$$k1 = Vro / (Dr \times Br \times Lr)$$
$$k2 = Vri / Vro$$

where,

V, Vo, Vi	:	dredging volume for outer channel, inner channel and total of each river mouth.
Vro, Vri	:	dredging volume for outer channel and inner channel of representative river mouth based on bathymetric survey result.
D , B , L	:	dredging depth, width and stretch of each river mouth.
Dr, Br, Lr	:	average dredging depth, width and stretch of representative river mouth.
k1	:	ratio between volume of outer channel by bathymetric survey result and *DrBrLr*.
k2	:	ratio between volume of outer and inner channels of representative river mouth.

(2) Maintenance Dredging

The volume of maintenance dredging in the muddy coast is estimated based on the siltation rate at the representative river mouth and the dredging width and stretch. That in the sandy coast adopts the volume for the representative river mouth unless the volume of maintenance dredging is over the volume of capital dredging. In case that the volume of maintenance dredging is over the volume of capital dredging, the volume of maintenance dredging is assumed as the volume of capital dredging.

(3) Jetty

The volume of the jetty is estimated based on the stretch, width and depth of each river mouth using the following formula:

$$Jv = L \times kj1$$

$$kj1 = Jvr / Lr$$

where,

Jv, Jvr : volume of jetty proposed at each river mouth and representative river mouth.

L : length of jetty proposed at each river mouth.

Lr : length of jetty proposed at representative river mouth.

$kj1$: ratio between volume of jetty and Lr.

(4) Breakwater

As mentioned in the possible combination of countermeasures for representative river mouths, the breakwater in combination with jetty and offshore breakwater is adopted.

The work volume for the breakwater is difficult to obtain from the currently available data, while the work volume for the jetty can be calculated in the manner mentioned above. Since the volume of breakwater is related to that of the jetty, the volume for the breakwater is calculated using the ratio between jetty and breakwater for the representative river mouth. As for the offshore breakwater, the ratio between the proposed and the representative river mouth widths is adopted.

(5) River Groin, Coastal Groin, Training Wall and Reservoir

The work volume for the river groin, coastal groin, training wall and reservoir is hardly pertinent to mention with the currently available data.

The construction costs of river groin, coastal groin, training wall and reservoir are small amounts compared with the total construction cost. For example, the Marang River Mouth is calculated at 5% of the total construction cost. Therefore, the construction costs for these structures will not affect the project cost very much.

The volume for each river is calculated using the ratio between the construction cost and the total construction cost for the representative river mouth.

Cost for Each River Mouth

The cost for each river mouth improvement works is estimated based on the project work volume calculated as shown in Table 5.4-1 and the unit price of each countermeasure through the application of the cost of the ten (10) representative river mouth improvement works. The project costs shown in the table are expressed in net present value (NPV).

4.1.2 Annual Benefit for Each River Mouth

Annual benefit for river mouths other than the representative river mouths is estimated, as presented in Table 5.4-2, based on the concepts and methods described as follows.

<u>Fishery Benefit</u>

Fishery benefit is basically subject to the existing minimum water depth and the number and size of fishing boat at each river mouth. The relationship between water depth and benefit per boat is obtained by the size of boat at the representative river mouth as shown in Fig. 5.4-1, and, in line with the grouping of the 75 objective river mouths, the annual benefit at the other river mouths is estimated by applying the existing minimum water depth to the above-said relationship of their representative river mouth, multiplying the number of boats by each boat size. The fishing industry is assumed to augment by 2% per annum in the future until 2005, as derived from the annual average growth rate in the total number of powered fishing boats from 1970 to 1990.

<u>Sea Transport Benefit</u>

Sea transport benefit is expected at four representative river mouths, but it is not practicable to apply those benefits to the other river mouths where commercial boats are not available. In this context, the benefit at Mersing is calculated separately. The benefit is also expected to increase until 2005 at the annual rate of 2%, considering the estimated annual population growth rate from 1990 to 2000 in the Peninsula.

<u>Flood Mitigation Benefit</u>

Flooding problems due to river mouth siltation are recognized only at Terengganu, one of the representative river mouths. Since flooding conditions are considerably related to the physical condition of river channels, flood mitigation benefit can be expected at the other river mouths in the same group. (Grouping of river mouths is based on the physical conditions.)

The magnitude of flood loss depends mainly on the value of properties in the flood-prone area and the inundation water depth, and so is the benefit, because the reduction of loss is counted as benefit. In applying the Terengganu's benefit to the other river mouths in the group, however, the areal ratio of urban areas along the river course near the river mouth is used as a parameter which is most related to the benefit amount, and considered to be the best method within the availability of data.

4.1.3 Cost-Benefit Ratio

Cost-benefit ratio (B/C) for each river mouth is calculated using the above-said cost and benefit assuming that project life is 30 years and the discount rate is 8%. The ratio at each river mouth is shown in Table 5.4-3, and the following matters are pointed out:

(1) Most of the representative river mouths well known for having a critical river mouth problem are higher in rank; especially, Kuantan, Perlis and Kedah which are expected to have a high economic return.

(2) Although a high economic return is not expected in most of the river mouths, the B/C ratio of 0.72 as a whole is not so low.

(3) For comparison of priority between river mouths in Category 1 (Critical) and those in Category 2 (Significant), the B/C ratio of the former category is 0.98, while that of the latter is only 0.23. Thus, the adequacy of categorization can be verified as a whole.

4.2 Project Evaluation

As identified in the cost-benefit ratio, the economic viability of the Master Plan is not so high. However, the economic viability for the critical group shows a high economic return with a B/C ratio of 0.98. Consequently, the Master Plan puts emphasis on the critical group, while project execution for the significant group considers the future development of the area surrounding the river mouth.

4.3 Formulation of the First Phase Project

In accordance with the principle of master plan formulation, countermeasures for each of the 75 objective river mouths have been selected and costs and benefits have also been calculated. Since the number of river mouths for the Master Plan is too large that it may be difficult to simultaneously execute a project covering all the objective river mouths, a First Phase Project in the critical group has been examined to facilitate project realization.

4.3.1 Conditions for the Formulation of First Phase Project

The First Phase Project has been formulated under the following conditions:

(1) The objective river mouths for the First Phase Project are the 35 river mouths under critical condition, where early project implementation is urgently necessary.

(2) The 35 river mouths are classified into groups of 3 and 4 for priority of project execution. The prioritization is made considering economic efficiency, regional income distribution, social need, etc.

(3) It is assumed that the First Phase Project is completed within the target year 2005 which corresponds to the last year of the 8th Malaysia Plan. As alternative cases, those with target year extending up to the end of the 9th and the 10th Malaysia Plans are examined for comparison.

4.3.2 Prioritization of River Mouth

Prioritization has been made considering several aspects such as economic efficiency, regional income distribution, social need and so on. For the purpose, the following factors have been taken:

(1) For the economic efficiency, cost and benefit ratio is applied.

(2) For the regional income distribution, the State where the river mouth is located is considered.

(3) For the social needs, the development strategy of the fishing industry is considered, especially the LKIM complex and the fishing base of the Department of Fisheries. The design boat size for the river mouth improvement is also considered.

Table 5.4-4 shows the factors for prioritization. In accordance with these factors, the prioritization has been made, as shown in Table 5.4-5, in the following principles:

(1) The number of river mouths to be implemented in each stage is basically the same, but cost adjustment is made considering the financial burden; i.e., initial and maintenance costs. In this cost adjustment, two cases are considered, namely; (a) the total cost consisting of initial and maintenance costs is equally distributed; and (b), only the initial cost is equally distributed. Consequently, six cases are to be considered in combination with three cases of different target years.

(2) Considering the regional income distribution, at least one river mouth in each State is to be implemented in the early stage.

(3) Prioritization among the river mouths in each State is to be made considering the economic efficiency, the design boat size, the LKIM complex and the DOF base. Among these, more emphasis is put on the LKIM complex which is regarded as the development strategy of the fishing industry. Furthermore, the Tg. Piandang and Marang river mouths which have been selected as the objective river mouths for the Feasibility Study are to be given high priority.

4.3.3 Implementation Schedule and Construction Cost

<u>Implementation Schedule</u>

As mentioned above, it is assumed that the First Phase Project is to be completed within the target year 2005 starting from 1996, after the feasibility study and detail design of the river mouth improvement are completed. This period corresponds to the 7th and 8th Malaysia Plan.

The implementation schedule including alternative cases which follows the principles of prioritization is shown in the following table:

Case	Priority	Malaysia Plan			
		7th	8th	9th	10th
Case 1-1 and 2-1	First, Second	---------	*	*	*
	Third, Fourth		---------	*	*
Case 1-2 and 2-2	First	---------	*	*	*
	Second		---------	*	*
	Third			---------	*
Case 1-3 and 2-3	First	---------	*	*	*
	Second		---------	*	*
	Third			---------	*
	Fourth				---------

* Maintenance work

Construction Cost

The construction cost required for the First Phase Project has been estimated considering the implementation schedule. In this connection, it was assumed that the annual disbursement of cost for each priority group is to be distributed equally for each year in each construction stage. (Refer to Table 5.4-6.)

4.3.4 Selection of Optimum Case

For the selection of the optimum case, the following are considered:

(1) To satisfy the people concerned in navigation, it is desirable to adopt a project with a short period of implementation because it may not be realistic to have a first project with a long implementation period of over 20 years.

(2) In case the project with a short period of implementation is adopted, the main issues are the capability for project execution and the financial restriction of agencies concerned.

(3) The main agencies responsible for river mouth improvement are MD and DID. MD is mainly concerned with 6 river mouths out of the 35, while the remaining river mouths are managed by DID. Judging from the current capability of these agencies, which are handling improvement works for more than 10 river mouths a year, it seems to be possible to gradually increase their capability within 10 years to handle the 35 river mouths.

(4) In general, maintenance cost is shouldered by the beneficiaries, while the initial cost is by the Government. In this connection, it may be possible to allocate the initial cost of about RM 200 million within 10 years judging from the current budget allocation and future economic development.

(5) On the other hand, it may be possible to require the beneficiaries to shoulder the maintenance cost of about RM 890 per year per capita, which corresponds to about 4% of the wholesale price of fish of RM 2.1 per kg. Since it may not be fair to require all beneficiaries to shoulder the maintenance costs equally, it is necessary to carefully examine the collection system of maintenance cost from the institutional point of view.

Based on the above considerations, it is recommended that Case 2-1 be selected as the Implementation Schedule of the First Phase Project. Table 5.4-7 shows the prioritization of river mouths for implementation, together with the agencies involved in the implementation.

4.3.5 Economic Viability of the First Phase Project

The economic viability of the First Phase Project is assessed by means of internal rate of return (IRR) based on the cash flow presented in Table 5.4-8. The IRR is figured out at 11.5%, which is higher than the generally understood borderline of 10% for this kind of infrastructure project. Further, expected are intangible benefits such as enhancement of safety to navigation and stabilization of living standards of people concerned.

It is evaluated that the First Phase Project has enough economic viability to promote it for implementation, and that the Project can provide favorable socio-economic impacts for thousands of people.

5. FEASIBILITY STUDY

5.1 Selection of Objective River Mouth for the Feasibility Study

The following considerations were taken into account in the selection of objective river mouths for the Feasibility Study.

(1) Two river mouths are to be 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 were given high priority by the officials concerned in each state, 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 5.5-1. Among those in the muddy coast, the Tg. Piandang River Mouth is selected as the representative river mouth 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, though 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. 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 in view of 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 contribute 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.

5.2 River Mouth Improvement Plan of Tanjung Piandang

5.2.1 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 5.5-2.

(5) 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 of 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 will be 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 5.5-3, 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

5.2.2 Economic Evaluation

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. 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.

(1) Unnavigable Hours

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, has been 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. 5.5-1. 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.

(2) 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 the 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 were 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 0.87hrs./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

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 was 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 were 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 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	1147	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 the base lending rates in the recent years.

A cash flow of annual benefit and economic cost has been prepared to figure out the values of IRR and B/C as presented in Table 5.5-4, 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. 5.5-2, 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 was, therefore, carried out on various cost and annual benefit, and the change of economic viability was examined as follows.

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

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 should be 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.

5.3 River Mouth Improvement Plan of Marang

5.3.1 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) and referring to the actual unit costs adopted in similar projects. As to the dredging unit cost, it 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 5.5-2.

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 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 5.5-5 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	:	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 5.5-6. As can be seen in the table, the total project cost including price escalation amounts to RM 15,366,000.

5.3.2 Economic Evaluation

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 loss to fishing and 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.

(1) Unnavigable Hours

The shallowest bed of Marang River Mouth has been surveyed at minus 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, has been studied to calculate the unnavigable hours as shown in Fig. 5.5-3. 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 thus 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

(2) Benefit Calculation

(a) 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, but there is a difference in unnavigable duration; 2.36 hours. The annual benefit is thus calculated at RM 5,168 per boat.

(b) 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:

- Savings on fishermen's opportunity cost;
- Savings on fish refrigeration cost; and
- 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.

(c) 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:

- Savings on fishermen's opportunity cost;
- Savings on fish refrigeration cost; and
- 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.

(d) 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.

(3) Project Benefit

The number of fishing boats is projected by boat size. 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

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.

The economic project cost is calculated as given in Table 5.5-7. 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 5.5-8, 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 has been examined as follows:

	Case	IRR	B/C
(a)	Construction Cost, 5% up	10.6%	1.255
(b)	Construction Cost, 10% up	10.2%	1.211
(c)	Annual Benefit, 5% down	10.5%	1.237
(d)	Annual Benefit, 10% down	9.8%	1.172
(e)	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.

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 should 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.