ANALYSIS OF COASTAL PROTECTION WORK ALONG THE SOUTHWESTERN COAST OF JOHORE , MALAYSIA

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Analysis of coastal protection work along the southwestern coast of Johore, Malaysia

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ABSTRACT

In 1974, the Malaysian government obtained a World Bank loan to develop agricultural land in the Southwest Johore Agricultural Development Project area (Johor Barat). The project entailed the construction of 198 km of river improvements, 1,041 km of drains, 1,486 km of farm and secondary roads, 942 structures, 66 km of coastal earth work (bunds), a dam and the necessary extension facilities.

The coastal bund, which excludes seawater from the agricultural area, was previously built inland with a belt of mangroves protecting it against direct wave action. However, mangroves along the coast have vanished, thus exposing the bund to direct wave action. Protecting the threatened coastal bund has now become a necessity. To date, a total of 4.8 km of bund revetment has been built at a cost of M$2.5 million. This measure protects thousands of hectares of coconut and cocoa plantations from seawater inundation.

This paper discusses the causes of erosion in the area, the economic analysis of coastal protection work and the recommended solutions for the protection of a highly developed coastal plain.

INTRODUCTION

The Western Johore Agricultural Development Project area is essentially agricultural, covering some 148,517 ha of Johore's western coast. Flooding, water logging and saline intrusion into the coastal area and the valley plains commonly occurred before the project's implementation. To alleviate these problems and to increase the area's economic potential, the government implemented an integrated agricultural development project in 1974. The project primarily involved the construction of coastal embankments, canalization and diversion of rivers, improvement of drainage networks, construction of control structures such as dams, barrages and tidal control gates, road communication, bridges and crossings, and the provision of important agricultural extension services. This paper does not deal with the project in its entirety; it focuses only on one aspect of its engineering work (i.e., coastal bunding).

Tidal flooding, an intrusion into the project area, is alleviated by an embankment (a coastal bund or dike) built along the coast and estuaries. Drainage of the hinterland is regulated through a series of tidal control gates. The coastal bund, constructed from earth, is 3.3 m (10 ft) wide at the top with a side slope of 3 (horizontal) to 1 (vertical). Its crest elevation is about +3.0 m LSD (Land Survey Datum). The spoil for the bund construction was obtained from the excavation of a borrow pit landward of the bund. This bund is constructed at least 400 m (20 chains) from the seaward edge of the mangrove area so that it is adequately protected against waves by the mangrove buffer. Quite often, however, the protection afforded by the mangrove vanishes due to erosion. Consequently, the waves will break directly on the bund slope and the wave run-up generated goes over the bund. The resulting bund breach and seawater intrusion will then damage the crops. Therefore, in this project, bund protection work has to be carried out along the major part of the 66-km project coastline. This paper evaluates the technical aspects of the coastal protection work in the project area (Fig. 1) and suggests the necessary improvements and economic viability of such a work and its impact on the environment.

CAUSES OF EROSION

The consequences of erosion worldwide have been most severe in recreational and urban areas, often situated on sandy beaches. While there is more information available on coastal engineering in sandy shores, the theory regarding the erosion and suspension of cleave material under waves and current action is not well developed. Various researchers have given different explanations on the erosion process on mud coasts.

Ueda (1980, 1982) distinguishes between erosion and scouring, which he says are the mechanisms by which shore retreat occurs on Johore's western coast. This distinction is based on the results of many case studies carried out in Malaysia over a long period of time. He believes that when a cohesive material is immersed under tidal water, its properties are changed and it becomes erodible. The scouring is caused by wave impact and proceeds shoreward by keeping a constant critical land elevation. The situation is accentuated by the abrasive action of driftwood, which further contributes to the disappearance of coastal lands.

Chan (1984), who did a study along the Kedah coast (northwestern coast of Peninsular Malaysia), cites the abrasive action of littoral shell fragments and the conditions that cause stress and unsuitable growth by the barraging and diversion of upstream freshwater supply. Such factors are responsible for the coastal erosion there. The loss of mangroves deprives the mud of their stabilizing effect and the seaward barrier afforded by the mangrove belt.

Freshwater supply is important to sustain the mangrove ecosystem. An alternative hypothesis explains the episodes of coastal erosion thus: When the freshwater supply, usually silt-laden, is not diverted, it brings with it a substantial amount of detrital materials. These materials get trapped in the mangroves' root system, accumulate and consolidate to form a relatively dense stratum. These materials replenish those that are brought into suspension by wave agitation and subsequently transported away by coastal currents. When the freshwater streams are diverted and discharged into the sea at discrete points through the tidal control gates, the affected stretch of mangroves suffers because it has difficult access to the detritus supply.

Another hypothesis, based on field observations, concerns the underwater migration of huge mud waves. Moni (1970) and Allersma (1980) reported the longshore propagation of a mud belt off the coasts of southwest India and Surinam, respectively. The transitory mounds and troughs of the mud belt correspond to the sites of accretion and recession along the coast, which alternate in a temporal cycle. This cyclic trend is also observed in Malaysia.

Since there was no long-term monitoring of data, no conclusion can be drawn on the causes of erosion in southwestern Johore. Nevertheless, any or all of the hypotheses described above need to be considered. Aerial photographs have revealed that in the Benut Forest Reserve area--the northern boundary of the South Johore Coastal Resources Management Project--a vast generation of new mangroves has grown over the last 20 years. The total area of new mangroves is 524 ha, of which 389 ha are in the Benut area. Concurrently, a total of 164 ha of mangrove forests was lost in the Buntu, Kukup, Piai and Chokoh areas.

No mangrove loss was observed by Chan (1984) in the Rambah Rimba Terjun area since the mangrove forest there has completely vanished with most of the coastal bunds provided with rock revetment on their seaward slope. The contiguous accretion and erosion of a mangrove-fringed shoreline in this area seems to be consistent with the above-mentioned causes of erosion.

With the exception of Kukup Island and Piai, erosion was reported in the areas where the upland has been bunded either for agriculture or aquaculture. In areas where the river systems retain their unaltered passage to the sea, a new generation of mangroves flourishes. Fig. 2 shows that even if the hinterland area of the Benut Forest Reserve is bunded and the local drainage is regulated by tidal gates to flow into the river, the Benut River still functions as a main drainage outlet for the large upland catchment. Thus, the river still brings sufficient sediment and freshwater to nourish the adjacent coast continuously. In other areas, small rivers and creeks have been closed and tidal gates constructed in their places to regulate the flow. This eventually deprives the coastal area of sediment and freshwater supply, thereby contributing to mangrove loss.

Regardless of the underlying mechanism of mud coast erosion, man's action in the coastal zone serves to either initiate or accelerate further erosion. Bund revetment only protects the properties behind it against erosion. Along the protected area at both ends, erosion continues and, most likely, becomes more severe because of the effects of wave diffraction. This phenomenon can be seen in the Buntu and Rimba Terjun areas, where the erosion down-coast of the completed revetment became more severe after the completion of the revetment in 1985-86.

TECHNICAL EVALUATION: THE PRESENT PROTECTION WORK

Traditionally, a coastal bund is built from earth (Fig. 3). The practice of the Drainage and Irrigation Department is to construct this earth bund about 400 m landward from the outer edge of the mangrove. A total length of 66 km of earth bund has been completed to protect the project area from tidal flooding and seawater intrusion at a cost of M$50/m run. However, along some parts of the coast, the removal of mangroves due to coastal erosion has exposed the earth bund to direct wave action. In these places, bund protection work has been carried out.

Fig. 4 shows a typical cross-section of the bund protected with rock revetment. Typically, the system comprises two layers of armor rocks, with the weight of each ranging from 200 kg to 300 kg so that they remain stable under the breaking wave and secondary layers made of smaller rocks and geotextile materials. The side slope of the revetment is 3 (horizontal) to 1 (vertical). The armor rock was designed to withstand waves of up to 1.05 m high and the crest to withstand waves of up to 1.05 m high. The crest level is sufficiently high to prevent overtopping by the associated wave run-up. The toe of the structure is located at R.L. -1.42 m LSD, which is about 1 m below the present seabed elevation. With the MHWS (mean high water spring) level of +1.32 m LSD and an average seabed level of 0.4 m LSD, the maximum water depth in front of the structure is 1.7 m.

Analysis of the structure's cross-section design reveals that it can withstand the significant wave heights normally encountered in the Strait of Malacca under present seabed conditions. Wave reflection results in scouring in front of the structure. When the water depth fronting the structure becomes deeper, bigger waves can reach the shore and break directly on the structure's slope. Unfortunately, no monitoring data are available to check the occurrence of the scouring phenomenon that may have occurred. However, monitoring data collected from 1979 to 1986 in Sg. Lurus, which is about 50 km north of this area, indicate that scouring occurs at an average rate of 0.23 m/year (C.H. Lim, pers. comm.).

The long-term scouring at the toe of a structure is not directly related to the extent of the future scouring that is likely to occur. As a rule, the maximum local scouring depth in front of the structure is about 1.5 times the wave height. The projected water depth in front of the structure is then the sum of the existing depth, the local scour depth, known erosion rate and the foreshore slope. This analysis leads to a maximum 2.8-m water depth in front of the structure during the 25 years of the project's life. The maximum unbroken waves that can be sustained in this water depth is 2.2 m or 0.78 times the water depth. However, the probability of the occurrence of a wave of such magnitude is very small. Therefore, the cost-benefit of this extreme wave height or the significant wave height using either design should be evaluated.

PROPOSED UPGRADING OF THE PROTECTION WORK

Assuming that this area is highly sensitive and can not afford any damage from erosion, then the design for protection work has to be based on the 2.2 m wave height. This will result in the use of 1.2 t of rocks if the side slope is kept at 3:1. This is still considered low when the effect of the impact by drifting logs and debris is taken into account (Ueda 1980). However, using heavier armor rocks may lead to foundation problems because quite often, the bund is built on very soft ground. Fig. 5 shows the typical surface spill profile along the western coast of Peninsular Malaysia (DID 1985). Typically, layers of soft to very soft coastal clay can be found from 20 to 30 m deep.

The sheer strength of this marine clay obtained from the drained striaxial compression stress ranges from 3 to 45 m^2 to 230 m^2. The bearing pressure of a revetment using 1.2 t of rock according to a profile of the soils of the type shown in Fig. 5 is 90 KN/m^2. Thus, when the structure is located on softer soil, the soil is unable to sustain the imposed pressure of the structure. Excessive settlement and slip failure may then ensue.

The various ways to overcome this geotechnical problem are:

a. the use of a flatter slope, hence a wider base;
b. soil improvement or replacement; and
c. the use of articulated concrete units that are lighter.

By flattening the slope, the revetment base becomes wider, which results in lower bearing pressure. However, the flatter section usually requires more materials. Soil improvement or replacement is also expensive and may not be justified unless the value of the properties protected is exceptionally high since articulated concrete units derive their stability from their interlocking system. Also, normally, under the same wave conditions, the weight required is only about a quarter of the weight of a rock. However, this system is a civil engineering innovation, and field experience and knowledge about its behavior is rather limited when compared to a rock environment. Moreover, its cost is normally less competitive than the rock's. Therefore, the use of such a system should be closely monitored.

Fig. 6 shows the general sequence of erosion in a mangrove-fringed coast. Erosion normally starts with the lowering of the mudflats in front of the foreshore scarp. This is followed by the erosion of the scarp, thereby stripping off the mangroves. This leads to the concept of scarp protection. By protecting the scarp instead of the bund, the rock size can be reduced and, at the same time, two defense lines are created. Bigger waves break offshore as they pass through the scarp revetment and the smaller regenerated waves are filtered by the mangroves. Replanting of mangroves can be done between the scarp and the bund, if site conditions permit. The possibility of using this method of protection depends on the foreshore bathymetry of the area and the availability of sufficient mangroves.

The foreshore bathymetry of the southwestern coast of Johore does not indicate the existence of a foreshore scarp, which could imply that this has already been eroded. This precludes the possibility of implementing the scarp protection scheme. Therefore, the most feasible method of improving the revetment is by adopting a flatter slope for the structure. This can be easily incorporated in the course of the maintenance work.

ECONOMIC EVALUATION: PROJECT BENEFITS

It is very difficult to separate the benefits of coastal protection work from the total benefits we can get from the project itself. The benefits derived from the implementation of the project (Nesadurai et al. 1970) are:

a. increased productivity of existing agricultural crops through drainage improvement;
b. increased availability of land suitable for cultivation; and
c. justification of the change of the existing cropping pattern to maximize returns from lands due to improved soil and drainage conditions of existing arable land.

All these benefits are the results of the overall drainage and flood mitigation improvement in the project area and are not exclusively due to coastal bunding alone, although bunding forms are major components of drainage improvement. Therefore, in the economic evaluation of coastal bunding and the required protection work, the above will be considered indirect benefits only. The direct benefit of coastal bunding is then the value of agricultural production from the crops planted on new cultivable lands, which were previously abandoned because of tidal flooding but are now made available through seawater exclusion measures.

To arrive at the benefit and cost analysis, the following assumptions are made:

a. an average continuous erosion rate of 4 m per year, without the project; and
b. land values of M$20,000/ha for first-grade agricultural land and M$12,500/ha for marginal land (MOF 1985).

Fig. 7 shows the area subject to tidal flooding before the implementation of the agricultural development project. The total affected area is about 7,260 ha. These marginal lands were either undeveloped or of a very low yield because of their susceptibility to tidal flooding. Construction of the 77-km earth bund has transformed these lands into first-grade agricultural lands. The area is now planted with coconut and cocoa. Therefore, the direct benefits derived from the bund construction are as follows:

a. Land value has increased from M$12,500/ha to M$20,000/ha. With a total improved area of 7,260 ha, the gain in land value is M$54.45 million; and
b. Increase in income of the farmers working on 2.2 ha of coconut land intercropped with cocoa is from M$819.5/year to M$2,463.18/year (MOA 1981); the net increase is M$5,424/year.

The National Coastal Erosion Study noted a total length of 13.7 km of eroding coastline in this area where protective measures are required to prevent the further loss of properties. If nothing is done in the next 25 years, erosion will lead to the loss of agricultural and village (*kampong*) lands and damage to commercial buildings, private and public houses and other amenities such as fish farms. The direct benefit of coastal protection work is then the stability of these properties (DID 1985), which are valued at about M$39 million. For example, in the event of bund breach due to erosion, about 1,050 ha of farmland will be inundated by seawater during high tide. Yields from these periodically submerged lands for the current crop will definitely plummet, with lower yields to be expected for the subsequent crops. This gradual loss of yield over the years has not been included in the benefit qualification.

Project cost

The total length of the coastline that requires protection is 13.7 km, out of which a total length of 4.8 km has been completed at a cost of about M$2.5 million. However, as mentioned earlier, upgrading these rock bunds along this stretch may be required as part of the maintenance program.

The proposed revetment with a typical cross-section (Fig. 8) costs about M$1,600/m. Hence, the total cost required for the balance of 8.9 km of eroding coast is M$14.24 million and the construction period may spread over a period of five years. Based on the scouring rate at a nearby site, the existing revetment may need to be upgraded in ten years' time, the cost of which is assumed to be M$1,000/m. The total revetment cost thus covers the cost in constructing the existing and new revetments and in upgrading the existing revetment.

Benefit-cost analysis

The benefit accrued from protecting 13.7 km of coastline is M$17.84 million in five years (DID 1985). This gives a present value of M$17.75 million at a discount rate of 8%. The capital cost to protect 8.9 km of coastline is about M$14.24 million spread over the first five years, plus the upgrading cost for the existing revetment will require a total of M$4.8 million after 10 years. In addition, M$2.5 million has been spent for 4.8 km of coastline, making the total cost of M$14.42 million at the same discount rate of 8%. Therefore, the benefit-cost ratio of the project is 1.23 at the discount rate of 8%.

ENVIRONMENTAL IMPACT OF COASTAL PROTECTION WORK

The effects of the development of coastal farmland for agriculture, in relation to the coastal ecosystem and the planning procedure for their preservation, is discussed by Ueda (1988). However, the Western Johore Project was planned and implemented since the early 1970s when environmental quality was not yet an issue. Therefore, it is very unlikely that this aspect of the project was considered adequately during the planning stage. Also, there is still no study on the impact of the project on the physical and biological environments, except for a casual remark that bunding has caused erosion in the mangrove area.

The present physical, biological and socioeconomic environments of South Johore, which includes the southwestern coast of Johore, have been discussed in detail (Kadri 1987). However, this study was prepared after the completion of the Western Johore Project and it did not include a comparison of the preproject condition. Therefore, the impact of the project on the environment is still unknown.

As for coastal protection work using rock armoring, the effect of the construction on the environment stems from the fact that rock layers replace the mud strata in the inner-tidal zone. Therefore, changes in the marine species composition in this zone can be expected. Invertebrates and shellfish, which attach themselves to rock surfaces, will most likely replace the mud-dwelling invertebrates in this zone. However, no change is expected in the subtidal and the terrestrial habitats since the physical environment in these zones remains the same. The revetment will prevent further losses to the land behind the bund, and the erosion of the mudflats and remaining mangroves seaward of the bund will continue until a stable offshore profile is reached. Changes, however, can be expected in the area both up- and down-coast of the protected area. In these areas, erosion will accelerate and more damage can be expected as a result of the end-scouring effects. This can be alleviated if the ends of the revetment are tied to natural formations such as hills, rocks or rivers.

CONCLUSION

Although there have been numerous speculations on the likely cause and effect relationship between coastal bunding and coastal erosion along a mangrove-fringed coast, no concrete conclusions can be derived since there has been no thorough study on this subject. However, on-site observation has indicated some correlation between the alteration of the natural drainage pattern and the demise of mangroves.

The existing revetment should be upgraded in some way to protect the area from projected long-term wave-induced erosion. This can be done by flattening the seaward slope of the rock revetment in the course of carrying out maintenance work. Protecting the entire 13.7 km of currently eroding coastline is economically viable, even without considering the various intangible benefits and their general contribution to the overall success of agricultural projects. Further study should determine the revetment's impact on the physical, biological and socioeconomic environments.

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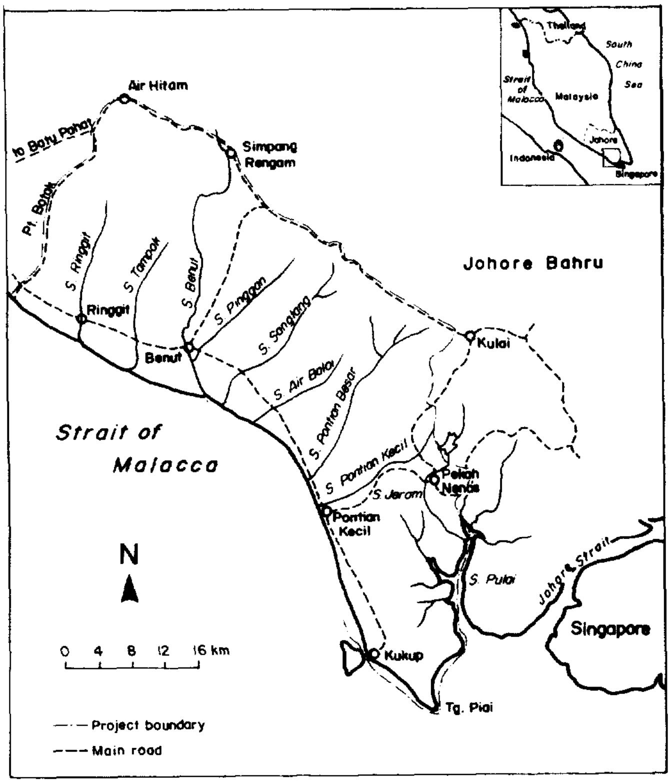

Fig. 1. Project location.

REFERENCES

Allersma, E. 1980. Mud in estuaries and along coasts. *In* Proceedings of the International Symposium on River Sedimentation, March 1980. Beijing.

Chan, H.T. 1984. Coastal and riverbank erosion of mangroves in Peninsular Malaysia. *In* Proceedings of the NARU Conference and Workshop on Coasts and Tidal Wetlands of the Australian Monsoon Region, November 1984. Darwin.

Chan, H.T. 1988. Report on Task 210-M. Presented at the ASEAN-US CRMP In-Country Workshop on the Development of a Coastal Resources Management Project, July 1988. Desaru, Johor.

DID (Drainage and Irrigation Department). 1985. Report on the site investigation for coastal bund protection at Sg. Lurus, Johor. Res. Memo. No. 172. Drainage and Irrigation Department, Malaysia.

Kadri, A. et al. 1987. Environmental profile of South Johor. Report on Task 110. ASEAN-USAID CRM Project, September 1987.

MOA (Ministry of Agriculture). 1981. West Johore Agricultural Development Project: Phase I. Annual report. Ministry of Agriculture, Malaysia.

MOF (Ministry of Finance). 1985. Property market report. Ministry of Finance, Malaysia.

Moni, N.S. 1970. Study of mud banks along the southwest coast of India, p. 739-750. *In* Proceedings of the 12th International Coastal Engineering Conference, ASCE, December 1970.

Nesadurai, S., A.H.K. Rahman, K. Kanapathy, K.O. Chye and P. Haridass. 1970. West Johore Agricultural Development Project: a feasibility study report. Ministry of Agriculture and Land, Malaysia.

Ueda, M. 1980. A manual for protection of agricultural coastal lands in Malaysia. JARQ 14(3). TARC, Ministry of Agriculture, Forestry and Fisheries, Japan.

Ueda, M. 1982. A study on erosion of coastal farmland in Malaysia. JARQ 42. TARC, Ministry of Agriculture, Forestry and Fisheries, Japan.

Ueda, M. 1988. Development of coastal farmland and coastal preservation in Southeast Asia. Hydraulic Engineering Department, Agricultural Engineering Research Station, Ministry of Agriculture, Forestry and Fisheries, Japan.

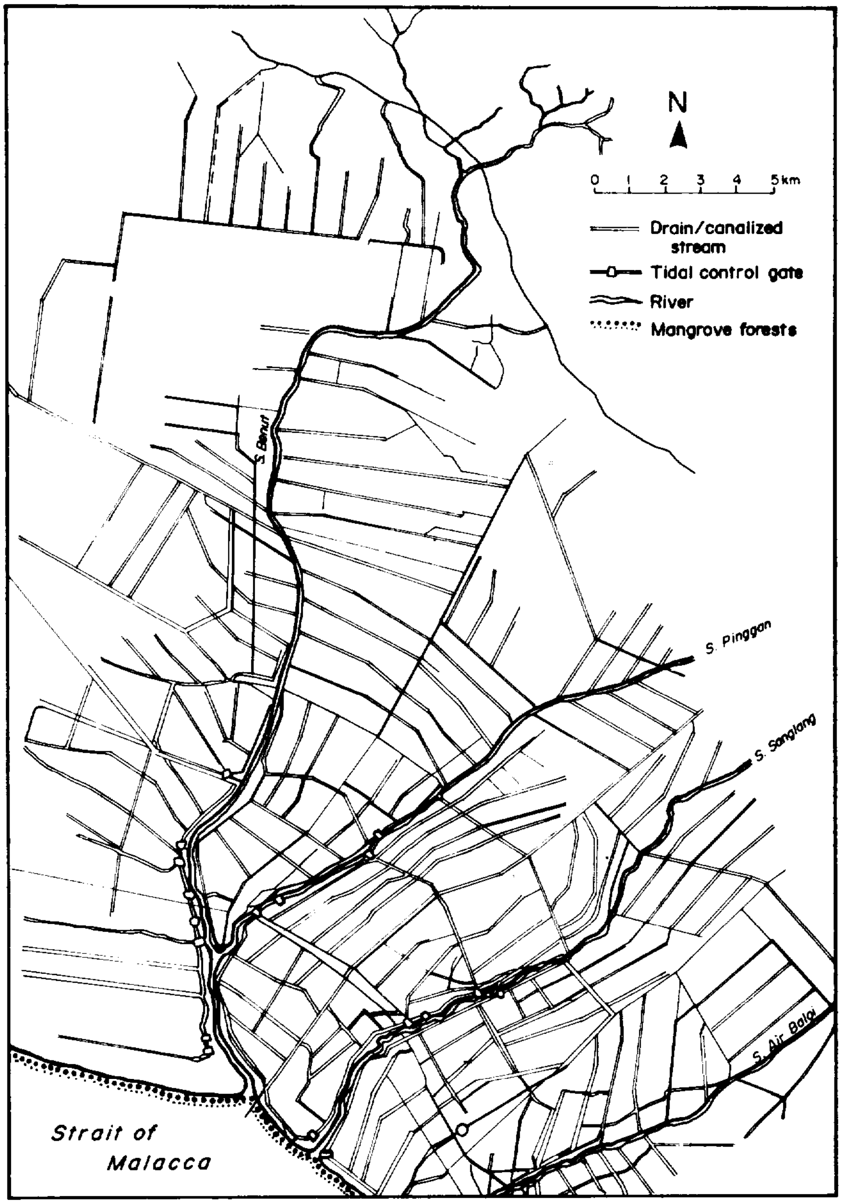

Fig. 2. Drainage controls in Sg. Benut catchment.

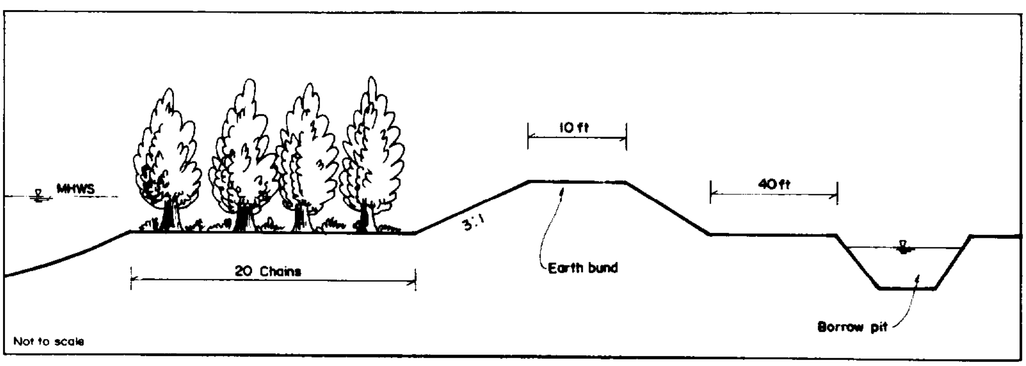

Fig. 3. A typical cross-section of a traditional earth bund.

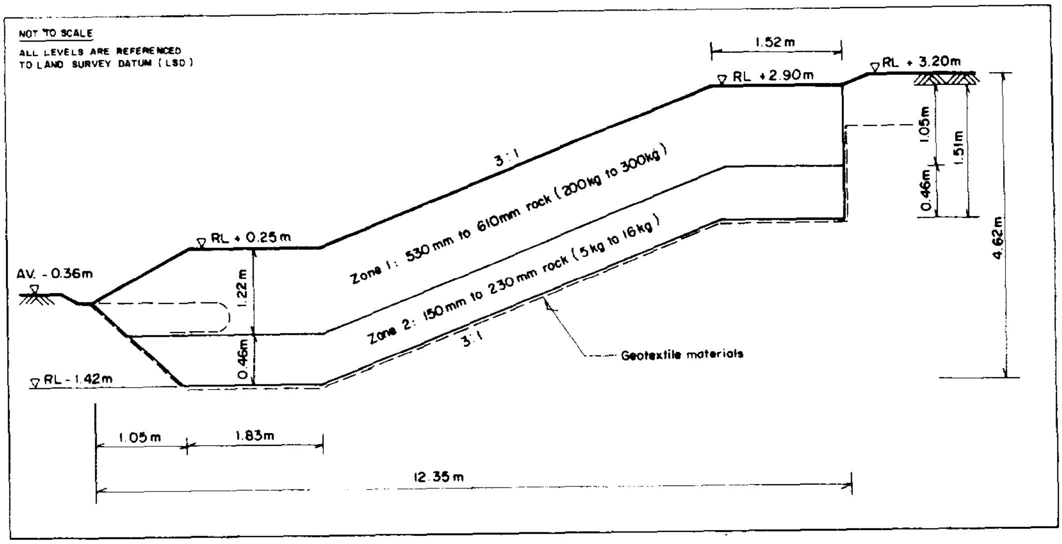

Fig. 4. A typical cross-section of the bund protected with rock revetment.

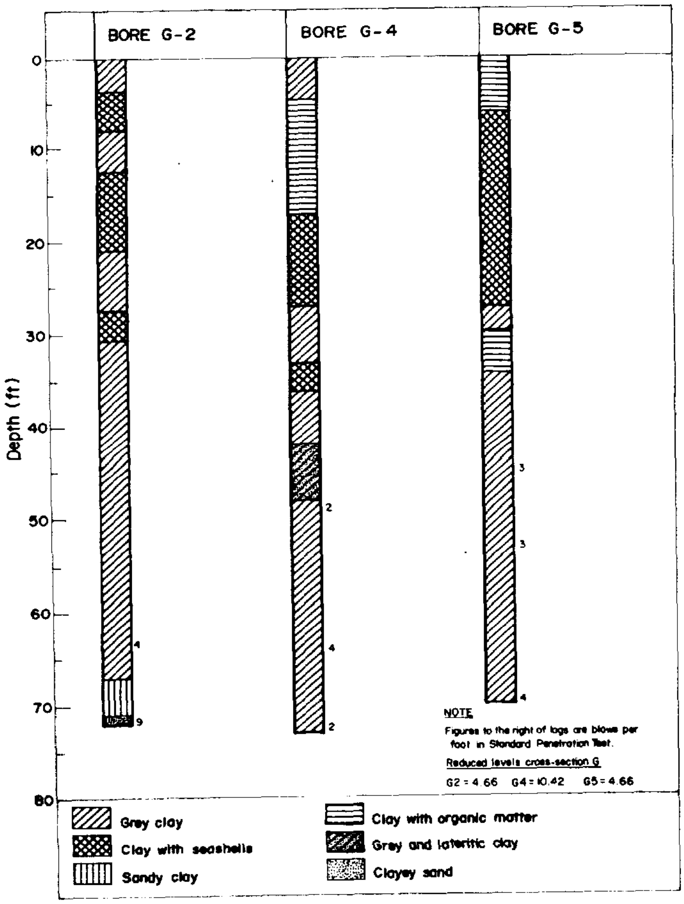

Fig. 5. Typical surface spill profile along the western coast of Peninsular Malaysia.

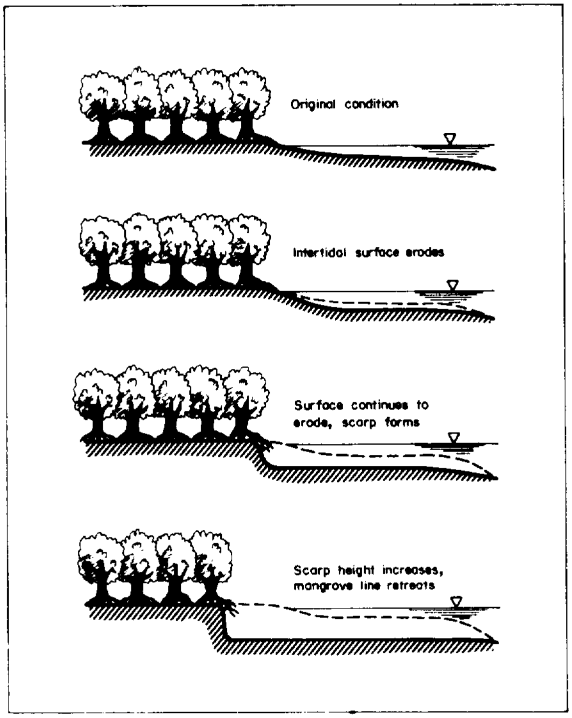

Fig. 6. Sequence of erosion in a mangrove-fringed coast. Source: Stanley Consultants, Inc. 1985.

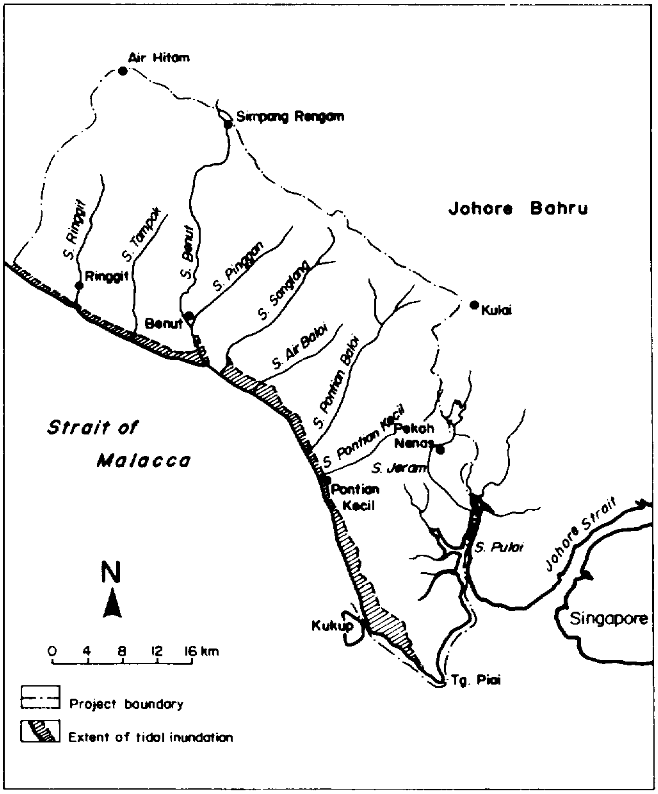

Fig. 7. Tidal inundation.

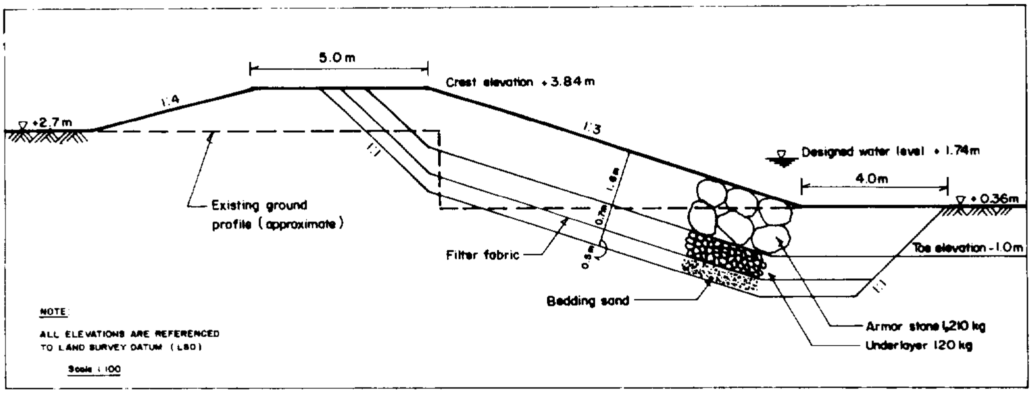

Fig. 8. A typical cross-section of the proposed rock revetment.