PROPOSED COASTAL EROSION MANAGEMENT FOR THE NORTHERN COAST OF JAVA INDONESIA

by

Dede M. Sulaiman

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I. INTRODUCTION

Indonesia is an archipelagic country in Southeast Asia lying at the equatorial zone between the continents of Asia and Australia and between the Pacific and Indian Ocean. Its coastline is approximately 80,000 km long (Table-1) and encloses 14,000 small and large islands (Soegiarto, 1976). The population of Indonesia is now over 170 million (Anon.,1985), making Indonesia the world's fifth most populous nation. About 60% of the population is concentrated in the island of Java whose total area is just 132,187 square km. Other large islands such as Sumatra, Kalimantan, Irian Jaya and Sulawesi are only lightly populated. The government of Indonesia has for a long time endeavored to resettle people from overpopulated areas into underdeveloped regions through transmigration projects. This has met with only limited success due to cultural barriers.

Most coastal areas of Indonesia have significant economic advantages over other areas of the country. As a consequence, 75% of the medium size cities, with population more than 100,000, are situated on the coast (Soegiarto, 1976). In Java, for example, the population center is located along the northern coast facing the Java Sea. This high concentration of population exerts heavy pressure on the coastal resources and makes Java the most complicated coastal area to manage in the whole of Indonesia. Conflict frequently occurs among resource users, developers and conservationists. Although natural hazards and calamities do occur, the role of human activities is more significant in causing coastal problems such as erosion, accretion and coastal pollution.

Many activities carried out by people in this region are directly or indirectly related to the use of coastal resources. However, until recently little attention had been paid to the reality that the coastal environment has a role of its own that needs special attention and proper management in order to ensure that future generations may share in the benefits derived from its utilization. In addition, the increase in competing pressures on the use of the coastal ecosystem is not being compensated by legislation and adequate planning. This makes the region seem unorganized and complicated.

As a tropical country, Indonesia is blessed with rich and diverse renewable and non-renewable coastal resources. Among the renewable coastal resources are coral reefs and mangroves. Coral reefs occur along the shallow coastline where the marine waters are oxygenated, clear and warm, and free of suspended sediment, excessive freshwater runoff and pollutants. Mangroves are well developed along the inner facing coastline of most of large islands. Approximately 70% of the total mangroves (4.25 million ha.) of Indonesia are located in Irian Jaya, while in Java the mangroves have been over-utilized to a critical extent (Soegiarto, 1985).

These coastal habitats are valuable both as natural ecosystems and for coastal communities. In their natural state, they serve as a buffer against coastal erosion and protection from tidal flooding as well as a catalyst for coastal accretion. To coastal people, coral reefs and mangroves serve as sources of food (i.e., the resource role as nursery, spawning and breeding ground for some commercial fish and shellfish). In addition, the resources provide economic benefits to coastal people through mining, harvesting and trading their products (e.g., limestone and wood products).

In densely populated area like Java, pressures for utilization of these resources are complicated. They emerge from human, economic, and planning forces, including the desire for short-term economic gain. This results in overexploitation, loss or damage to these resources, and loss of long-term economic benefit. One primary example of this loss is the beach erosion that frequently occurs following coral reef degradation and mangrove deforestation.

From observations of several areas along the northern coast of Java, it is becoming increasingly obvious that coastal erosion and its impact on community properties are caused by the harvesting and destruction of coastal resources. Appropriate management techniques should be applied to this problem, should be based on both resource impacts and, more importantly, on the socio-economics of the community. Management priorities are suggested in two main areas: 1) structural controls which attempt to inhibit or prevent the physical process of erosion of the fastland, and 2) institutional controls, such as zoning and buffer zone which attempt to limit or decrease the vulnerability of property improvements to erosion.

This paper will discuss some of the pressing issues and critical problems pertaining to the resources of the northern coast of Java and some alternative management strategies that may be applicable for the region. Some conclusions and recommendations are presented at the end of this paper.

II. THE ENVIRONMENT OF THE NORTHERN COAST OF JAVA

Unlike the southern coast, the northern coast of Java is characterized by the presence of broad deltaic plains built out into the relatively low-wave energy micro-tidal environment of the Java Sea by silt-laden rivers. These deltas are formed by mud, sand and other sediments resulting from siltation in the mouth of the rivers.

Climatic characteristics in Java and other parts of Indonesia are largely determined by the position of the Intertropical Convergence Zone (ITCZ), a zone where unstable air and heavy rainfall migrates north and south over Indonesia, crossing the equator in May and November and reaching latitudes of about 15 degrees south in January. This change in position of the ITCZ results in two kinds of seasons known as the rainy and dry seasons. The rainy season occurs when the ITCZ is to south, causing the prevailing westerly winds from about December to February that result in east-flowing surface currents (Figure 1a & 1b). The dry season occurs after it shifts to the north and winds move around to the southeast, usually from June to August causing a shift in currents to the west (Figure 1d & 1e). The rest of the year represents the transition periods from the northwest to the southeast from March to May (Figure 1c) and from the southeast to the northwest occurs from September to November (Figure 1f).

During the wet season, the winds blow eastward causing heavy rainfall throughout most of the western part of the Indonesian archipelago. The pattern of rainfall for this region is largely influenced by orographic factors, notably where moist air is forced upwards as it moves eastward.

By contrast, during the dry season, the winds blow northwestward coming from the Australian region, causing the air to be much drier. This southeast monsoon causes the southern part of the archipelago, especially the most eastern part, to have a smaller mean annual rainfall than the rest of the country. In the western part of the country even in the dry season, there are a lot of showers, especially in the afternoons, caused by local intensive heating and air mass convergence. Consequently, the wettest coastal areas are found to the west of the ranges, and the relatively dry areas are in the "rain shadow" to the east (Sukanto,1969).

Because of its geographic location close to the equator, the northern coast of Java and other part of the archipelago are intensely influenced by humid tropical conditions. Annual rainfall in this region is about 3,000 mm in the coastal region, while in the interior upland is about 3,200 mm (Figure 2). River systems thus carry a large amount of runoff from the high hinterland.

The northern coast is exposed only to low-wave energy. Wave action in this area is largely generated by local winds, gentle at the equator but stronger on the southern coast subject to the southeast trade winds. The tropical cyclones which generate short term high energy conditions on the coast of northern Australia and around the South

China Sea do not reach the Java Sea (Figure 3). However, waves generated by these disturbances are transmitted to Indonesian coastal waters south of Java and the Lesser Sunda islands, including Timor, and into the sea between western Kalimantan and the islands southeast from Singapore.

Tidal movement in the northern Java waters and adjacent Java Sea results from resonances of many pulses that come from the Indian and Pacific Oceans. Once a wave system originates and migrates from the northwest through the straits of Malaya, it generates a strong current and its range is amplified when the configuration becomes narrow. Another system comes from the South China Sea, diverging through the narrow waters west of Kalimantan producing an interacting system with Malayan tides south of Singapore. Tides from the Pacific Ocean advance through the south Philippine Sea to the north coast of Irian Jaya. Around Java there are minor but complex tides. The tidal characteristic in this region is mostly diurnal, with a tidal range of about 0.40 - 0.80 meter (Figures 4 & 5) except in the straits of Madura where Surabaya has an average tidal range of 1.70 meter (Bird and Ongkosongo, 1980).

Sediment content along the northern coast mostly consists of silt and clay. This fine-grained sediment is produced by chemical and biological weathering of rock and soil deterioritation in the steep hinterland. Coarser sediment is also found, derived from the lava and ash produced by volcanic eruptions. The combination of steep hinterlands, active volcanoes and frequent heavy rainfall produces large rivers systems that carry substantial quantities of sediment down to the coast. Deposition of this sediment has built extensive deltas and broad coastal plains which characterize the northern coast of Java. The sediment volume from many catchment areas in Java is dominated by sedimentary rock formations, which are much greater than those from volcanic catchments (Meijerink, 1977). Sediment yields for each catchment are shown in Table 2.

Beaches of sand and gravel are spread out along the northern coast of Java, especially near the mouth of rivers carrying this kind of material, close to sandstone or conglomerate cliffs and along coastlines to the rear of fringing coral reefs. Beach sediment of volcanic origin is typically black and grey, while those of coralline origin are white and yellow. Quartzese sands are also quite extensive in relation of quartz-arenite outcrops along the coast and within hinterland river catchments.

III. PROCESSES OF COASTAL EROSION AND ACCRETION

The shoreline represents one of the most variable and complex regions of our globe. It forms the unique interface between the land, the ocean and the atmosphere. It is an area of dynamic interaction and although we think of land is being solid and permanent, the shorelines are in a constant state of flux and change. Some are eroding and accreting only imperceptibly, but at other location we can observe dramatic changes. All are a result of physical processes, such as tides and winds, shifting small particles of sand and silts in the nearshore zone. Wave action has a forceful impact on the configuration of the coastlines. Longshore currents, rip currents and littoral transport of sediment materials are constantly moving the sediment and sand down the coasts. We also see at the mouth of rivers the formation of deltas. Rivers are the source of much of the sediment that continually replaces that being transported along coasts by littoral drift. Beach erosion is for the most part episodic, with the major retreats in the shoreline during unusually intense storms. Thus, the natural system itself is constantly altering and changing the shorelines.

Due to its impact on property and global patterns of human inhabitation, coastal erosion has received more attention than any other impact of coastal processes. Only in recent years have we begun to understand the diversity of processes involved in coastal erosion. Adequate knowledge to predict variability in the coastal ecosystem will contribute to protecting and preserving the shoreline.

In many ways, all beaches are similar both in their response to nature's forces and to the processes that operate on them. They differ in scale and intensity variables which are determined by the energy in the waves and in the physical dimensions of the surf zone (Inman and Brush, 1973). However, in response to dynamical processes, the severity of shoreline change depends largely on coastal factors such as: 1) the degree of exposure to current and wave attacks, 2) the supply of sediments and runoff to the coasts, 3) the topography of the continental shelf and the adjacent coast, 4) the tidal range and intensity of the current, and 5) the coastal climate.

Climatic factors are important in terms of the weathering of coastal rock outcrops, which results from physical, chemical and biological processes related to partly subaerial climatic conditions and partly to the presence of the sea. Rocks are decomposed by such processes as repeated wetting and drying, dissolution by rain water, thermal expansion and contraction. These all relate to temperature, precipitation and evaporation regimes in the coastal environment. Climate also influences modes of subaerial erosion, coastal slopes washed by runoff showing various kinds of mass wastage ranging from soil creep to landslides and mudflows. Marine erosion plays an important role in undercutting coastal slopes, initiating instability, and removing superficial material to expose fresh rock outcrops for further subaerial weathering (Bird, 1969). In the humid tropic areas like Indonesia, rapid chemical weathering at high temperatures results in deep decomposition of the rock formations. Riverine systems in these areas generally deliver an abundance of fine sediments, mostly consisting of silt and clay, to the coasts.

In general, there are two factors responsible for modifying the configuration of coastlines: natural processes and human activities. Natural processes that shape shorelines and operate in nearshore waters consist of storm surges, rip currents and longshore currents. Sea level changes initiated either by local or global occurrences can also be included in the list of natural processes.

A. Storm Surges

Even though the northern coast region is not on the track of most hurricanes, storm surges and rough water conditions frequently occur, more often in the months of the wet season. These events are a major factor in the occurrence and severity of coastal erosion of the northern coast. Westerly winds in the region are responsible for generating storm surges, resulting in high water levels in the coastal areas which in turn causes flooding of low-lying coastal areas and landward shifts the surf zone, so that the waves directly attack coastal properties.

The impact of westerly winds on beach erosion can be greatly enhanced if they occur simultaneously at a time when high spring tides occur. The spring tides occur twice each month, at the new and full moon. These are produced by the combined gravitational attraction of the moon and sun acting upon large bodies of water. In a situation where a storm occurs during high spring tides, the water levels of the high tide permit the storm waves to attack closer to or directly on the coastal property, therefore affecting the degree of the resulting erosion (Komar, 1986).

Wood (1977), demonstrated in a comprehensive fashion that unusually high spring tides have been a significant factor in historic occurrences of coastal flooding and erosion. He also described the occurrence of a perigian spring tides as "a window for potential flooding". In themselves, the unusual water levels may not produce appreciable coastal flooding and erosion but do increase the potential for those condition (Komar, 1983). For the northern coast this tidal flooding is dramatically amplified by a high rate of precipitation. The problem becomes more accentuated in the mouth of rivers, where shoaling as a result of sedimentation during dry season, becomes a natural hindrance to the small and large river discharges. The effect of these combinations not only cause damage to coastal properties and severe coastal erosion, but also result in adverse damage to agriculture and irrigation networks.

B. Rip and Longshore Currents

The processes in nearshore zones are driven by basic, interrelated forces that are systematic and essentially regular in form (Inman and Brush, 1973). These systematic driving forces lead, in turn, to the development of coherent processes such as the nearshore circulation cells and the longshore transport of sand (Figure 6). The energy which drives processes in these nearshore zones comes from the ocean and atmosphere. Waves and currents from the open ocean that are translated by the stress from winds which blow over the ocean, propagate toward coasts where they are concentrated and eventually dissipated. At the shoreline the breakers, storm waves, tides and secular changes in sea level reach their greatest height.

The pattern of nearshore currents as resulting from waves reaching a beach is largely depend on the angle of wave breaking. When the wave crests are parallel or nearly parallel to the shoreline, the nearshore currents are dominated by cell circulation with a seaward-flow called rip currents (Komar, 1986). The height of waves approaching the coast also determines the characteristics of rip currents. A light or moderate swell produces numerous rip current systems, while a heavy swell produces a few concentrated rips, fed by strong lateral currents in the surf zone (Bird, 1969).

Rip currents can be found commonly on long, straight beaches where their depth contour does not support wave refractions and longshore variations in breaker height. In relation to coastal erosion, rip currents have a tremendous impact in eroding the material of beaches. The currents can achieve high velocities and can combine with the wave action to rearrange the beach sediments. Most commonly, the rip currents transport sand offshore to beyond the breaker zone, hollowing out embayments in the process (Komar, 1983).

The process of coastal erosion due to rip currents is not prevalent on the north coast of Java. This condition partly is a result of the environmental characteristics of the region where the coasts are exposed only to low wave energy (Bird and Ongkosongo, 1980). Hollerwoger (1964), found no surf and small currents on the north coast. In fact, the sediments that are delivered by river discharges accreted at the mouth of the rivers and along the coasts. The waves and currents are not strong enough to rework and remove the sediments offshore. As a result, delta formations are more common, usually during the dry season when the river system flows slowly, delivering large quantities of silty sediments from upland.

As waves approach and break along the coast at an angle, they generate a longshore current. Sediment moves alongshore in the direction of wave travel. The back and forth motion of waves in nearshore waters produces stresses on the bottom that make sediment in motion. The energy needed for this sediment motion is supplied by the breaking waves. The interaction of the wave stresses with the bottom also generates a net longshore current, flowing in the direction of wave travel.

Beach modification, in terms of erosion and accretion, will continually occur as long as there are waves and an adequate supply of sediment. Erosion occurs, if more longshore drift leaves an area than enters. If more sediment enters a coastal area than leaves through longshore transport, the beach accretes.

C. Sea Level Rise

Sea level changes, both local and worldwide, play an important role in beach development. The changes can be in short and long term. In the short term, such changes may be influenced by tides and storm surges. In the long term, the sea level changes refers to worldwide changes result from glacial activity. As glaciers melt, global sea level tends to rise, while as glaciers enlarge, global sea level tends to fall.

As sea level rises, beaches retreat landward, enabling destructive waves to erode the beach at a higher level. Accompanying this shoreward migration is a narrowing of the beaches, and as a consequence of a reduction in their capacity to act as buffers against storms and waves.

D. Accretion

Sedimentation in the mouth of rivers and estuaries is the most common coastal process along the northern coast of Java. This causes shoaling and the gradual closing of river mouths which results in the inundation of outlying coastal areas from flash floods as well as navigation hindrances. This natural process is seasonal, related to the climate of the region (i.e., dry and rainy season) and is aptly demonstrated by hydrological and riverine characteristics of the numerous small and large river systems along the coast.

Accumulation of sediment at the mouth of estuaries generally results from poor farming practices and lack of land-use management in the upstream areas. As a result, erosion and soil material transportation is facilitated, resulting in rivers with heavy siltloads, sand and other soil particles which are deposited at the mouth of rivers as sand bars and deltas. This process more importantly occurs during the dry season when there is reduced water flow. As the rainy season begins, these sand bars serve as natural obstructions to the large river discharges and as a consequence, seasonal flooding of the low-lying coastal areas occurs, resulting in adverse damage to agriculture and irrigation networks.

IV. PROBLEMS AND CONSEQUENCES OF RESOURCE UTILIZATION

As the population increases in the coastal zone, human activities become a significant factor in causing many coastal problems. Generally speaking, there are four basic coastal problems faced by the local government in Java: 1) coastal erosion, 2) mining activities 3) concentration of population, and 4) over-exploitation of resources.

A. Erosion

Beach erosion is a significant problem along much of the coast of Java, threatening coastal structures, properties and facilities. The activities primarily affected by erosion are agriculture, housing, fisheries, transportation and recreation. Even though the occurrence of beach erosion is generally uniform along the coast, the most seriously threatened and impacted areas are those lying along the coasts of Jakarta and the northern coast of West Java where most of the houses and other man-made structures, such as "tambak" or brackish-water fishponds, are vulnerably situated. Since coastal erosion is widespread along the coastal zone of Java and its impact affects a wide range of social and economic activities, jurisdiction over the problem has been taken over by the central rather than the local government.

The most severe impact of coastal erosion in Java is caused by natural phenomena (e.g., storm surge) resulting from the interaction between climate, nearshore circulation, geographic orientation and soil type. The cyclical shifting of the wind pattern from the east to the west and back results from the seasonal movement of the thermal equator or ITCZ and causes wind drift currents that flow parallel to the major islands. Coupled with Indonesia's sandy to silty soil and gentle wave action, a complex erosional-depositional environment is created.

The impact of man on coastal erosion may be a result of direct and indirect activities along the coastal zone or in the hinterland. Direct effects include the building of sea walls, groins and breakwaters, the advancement of the shorelines artificially by land reclamation, and the removal of beach material from the coastal zone. Indirect effects include changes in water and sediment yield from river system after the clearance of vegetation (e.g.mangrove deforestation) or modifications of land use within the catchment areas, or the construction of dams to impound reservoirs that intercept some of the sediment flow.

The direct impacts of human activities from removal of beach material are distributed along the populated coastal areas. Along Cilincing Beach, on the southern coast at Jakarta, shoreline erosion has accelerated due to the increase in demand for building materials for construction. Between 1873 and 1938 the shoreline retreated about 50 meters, but between 1951 and 1975, with sand extraction active, it retreated 600 meters (Pardjaman, 1977).

Indirect effects of man's activities on coastal erosion more often occur in areas where there is deforestation of the mangrove fringe. In many sectors, erosion began following the clearance of the mangrove forest, exposing the brackish-water fishponds to wave attack. Along most the northern coast of Java, the brackish-water fishponds are commonly excavated in the mangrove fringe on low lying coastal areas, usually on delta margins (Bird and Ongkosongo, 1980). On some prograding sectors of deltas (e.g., on Cimanuk), fishpond construction began on accreting mudflats even before mangroves were established. Consequently, when erosion begins, as a result of diversion or decaying of a river outlet or a diminution of sediment yield from a river mouth, brackish-water fishponds that are constructed too close to the sea are soon eroded and cut away.

The impact of the loss of coastal terrain as a result of erosion is of particular importance when the coastal area is densely populated and intensively utilized. Fishing villages that spread out along the coast are often located on or immediately behind the beach. As a result, villages may be forced to retreat when the silty and sandy shoreline are driven back by washover.

B. Mining Activities

Another problem that is common not only along the coast of Java, but also in other regions of Indonesia as well are those that are related to unplanned and unmanaged mining activities. Due to its rich placer deposits, the northern coastal region attracts many investors, businessmen and job seekers. There are a number of mining activities taking place. Common deposits being exploited in the onshore and offshore areas for building materials are coral reefs, gravel, sand and shells. Mining of these materials is generally carried out using a destructive method, i.e., the use of explosive material, causing damage to other habitats which often result in adverse impacts to the living resources in the region. For many coastal communities, mining of coastal materials is one of the viable alternatives for its citizens to earn extra money while for some, it is actually their main livelihood and source of income. This causes it to be a very difficult management issue.

Coral products (e.g., cement) are obviously needed for many kinds of construction activities. Development agencies directly or indirectly encourage the people to pursue this economic activity. The government is then caught in a dilemma. On one side they must allow the continued harvesting of corals and other beach deposits to provide income to people as well as to satisfy the growing demand for building materials needed to improve its citizen's quality of life (e.g., provision for housing schools and hospitals). This is a tradeoff for the resulting destruction of the stability of that coast and the associated ecological problems. To curb activities in order to save the environment would mean fewer jobs and lower income for the people and the government itself.

C. Concentration of Population

The last issue and perhaps the most complicated problem faced by the government of Indonesia is population growth, growing at a rate of about 2 percent per year with most of the population concentrated in Java. This high concentration of population is regarded as the underlying cause of most of the present problems, including those related to coastal resources. Efforts to change this issue were initiated in 1960 through the transmigration project which became one of the principal national programs in Indonesia's Five Year Development Plan (Anon, 1984). Another effort to solve the population problem is through the initiation of the Family Planning Program whose main purpose is to reduce birth rate and improve the welfare of the family.

The transmigration program is a very important component of the long-term population policy. The program intended to improve the distribution of population, to provide land for the landless on Java, Bali and Lombok islands and at the same time to provide man-power for the labor-scarce areas outside of the three areas. In doing so, it was hoped that other areas may be developed as a new centers of production and economic activities, particularly in agriculture. The program is also expected to serve as a catalyst in promoting national stability and integration.

Population pressure produces very important impacts on coastal regions. In large cities this impact is even more pronounced due not only to the greater number of people but also to more advanced technology.

D. Overexploitation of Resources

Man's uses of coastal resources has tended to accelerate, and in some instances, adversely affect the natural structure of the shorelines and associated natural systems. Many of the changes in the shorelines that result from overuse of coastal resources are far more severe than that caused by seasonal natural hazards (i.e., storm surges). Mangroves and reefs normally act as a protective buffers for the land behind them. Without these coastal habitats, beaches are eroded more quickly.

In the case of mangrove utilization, there are two conflicting views. The first is from those who consider mangroves as "waste land," ready and suitable to convert into more profitable economic development projects, such as the establishment of industry, agriculture, fishponds and settlements. This group favors the more obvious and immediate economic gains generated from the conversion of the mangroves. But they tend to ignore or be less sensitive to the impacts of the conversion.

The second view is of mangroves as a unique coastal habitat for many wildlife species and, by virtue of location, as providing an effective natural and self maintaining buffer against coastal erosion and tidal flooding. Because of their high productivity, the mangroves afford a vital role in sustaining the productivity of coastal and estuarine fisheries. Therefore, this group wants the resources protected and left undisturbed (Soepadmo, 1985). If the former group favors more immediate economic gains without ecological consideration, the latter tends to select the long-term ecological and socio-economic benefits derived from the conservation and rational utilization of the mangroves. However, the former group often dominates the latter. As a result, many coastal problems become more complicated because of the lack of awareness of the environment.

Based on these two perspectives of mangrove values, the use of this resource can be categorized into non-destructive and destructive. Non-destructive uses include research, education, conservation of wildlife, recreation, flood buffering and shoreline protection against erosion. Traditional harvesting of mangrove products for firewood, construction materials, fish and food could be included in this category, as long as it is carried out on small scale by a small population. However, when the population grows denser and the utilization of the mangrove resource is expanded and uncontrolled, problems appear and this use becomes destructive.

Destructive uses of mangroves can be in the form of elimination and conversion of forest lands into other forms of land use. Mangrove conversion has occurred in recent years in most the Southeast Asian countries. In Indonesia, by the first half of 1980's more than 2.2 million ha. or about 42.5 % of the original mangrove areas had been converted into another uses (Soegiarto, 1984). Converted mangrove land in Indonesia is usually used for fishponds, agricultural lands, saltbeds, industrialization and human settlement.

The destructive uses of mangrove areas are more intense in Java where the population pressure produces very significant impacts on coastal resources. Mangrove deforestation occurs in many regions, e.g., Jakarta, Cimanuk Delta and Sagara Anakan (Ongkosongo, 1979). Deforestation triggers coastal degradation and the beaches are usually washed out following the conversion. The process is more apparent and tragic in the fishing communities where the fishponds are built on the converted lands. The disaster commonly occurs not long after the construction of fishponds is completed. As a result, there is a loss of property and long-term economic value.

Like mangroves, coral reefs are among the most productive coastal ecosystems due to their ability to use phosphorus, cycle energy efficiently, and fix nitrogen (Marten and Polvina, 1981). Naturally and without human interference, coral reefs serve as a source of food, construction material, decorative shells, coastline protection, and ecosystem stability. However, when human activity interferes with the ecosystem, the function becomes less effective and the effects not only damage the reefs but also cause problems to the coastal community.

Human impacts on coral reefs can be broadly defined as : 1) physical damage, 2) change in the deposition/erosion environment, 3) overexploitation, and 4) chemical pollution (White, 1986). The most destructive human activity to this resource is mining without any limitation. Destruction often occurs in densely populated areas especially where unowned resources are the only alternative for a livelihood. The resources are overexploited either by individuals or by groups in the community with no control or limits.

Overharvesting reefs can be considered as another "tragedy of the commons" (Hardin, 1968). The reefs are overexploited by individuals or groups who focus only on short-term economic gains. They attempt to increase short-term income by unlimited harvesting of the resource. Since the existence of valuable unowned resources provides an incentive for them, they try to exploit the resource before other potential users. This is likely to lead to premature use of the resource and increase the possibility of its total destruction (Bish, 1977).

Coastal erosion as an indirect effect of coral mining is apparent after mining activity takes place. This phenomenon has been recorded at several places outside Java and is more severe especially in Java. One example of how mining affects coastal degradation is at Cilincing Beach in Jakarta.

V. MANAGEMENT SOLUTIONS

A. Structural Controls

Erosion is a common natural phenomenon on most shorelines of the world. In fact, almost no coastal area of Indonesia that has been developed by man is free of problems caused by shoreline erosion. This process creates a great concern at all levels of government, but local governments are, perhaps most immediately concerned, since the consequences of erosion affect the lives of their citizens and property. However, to cope with the problem, local governments generally do nothing due to limited authority and resources. Most decision-making processes are carried out by the central government or at the federal level. In addition, the local governments are generally inadequate for either complete technical analysis of the problem or implementation of engineering works.

In response to the impacts of erosion, man commonly uses traditional approach by installing shore-front erosion control structures such as groins and bulkheads. This structural control is a management strategy in resolving the impact of erosion. The aim is to minimize the property loss through modifying the effect of the hazard by changing the characteristic of the natural shoreline (Chapman, 1985).

There are some disadvantages to employing structural control to manage the impacts of erosion. It can be expensive and the approach can be less than effective in stabilizing the shoreline, especially for the long-term. In the short-term, if designed properly, structures can provide security to individual property owners, but they do little to preserve the beach (Kana, 1983). This attempt to protect development against beach recession can impede the natural process in the nearshore zone that maintain a state of equilibrium, and in turn can interrupt the supply of sediment to the longshore current. The result is often increased erosion, either at the project site or downdrift.

The implementation of shoreline erosion management is probably less applicable than engineering approaches, particularly where the ownership in the coastal areas is not clearly regulated in legislation. The Indonesian Constitution however, does provide the basis for the management:

> "land and water, and the natural resources contained therein, shall be controlled by the state and utilized for the greatest feasible property of the people" (Hehanussa, 1979).

However, detailed strategies for erosion management are lacking, and legislation for determining ownership of coastal areas is not clearly defined. This vagueness in property rights leads to disorganization in constructing structural erosion controls.

Lack of real property law, which defines physical property boundaries and the rights of ownership is another stumbling block in management of shoreline erosion. Ownership of any coastal areas, whether it is private or publicly owned, can help determine the effectiveness of shoreline management. Full or partial public ownership of land offers the most direct means of managing erosion-prone shoreline (Hobb et al, 1981). Complete ownership of erodable property, although it is a limited approach, would basically insure full control of development.

Since physical boundaries are not recognized and the regulation of shoreline structures not practiced, property owners (i.e., motel and villa owners) often protect their properties against erosion by building shoreline erosion control structures. The structures are generally poorly designed and constructed without considerations of the rights of the public who are impacted by these structures. As a consequence, the structures that aim to reduce erosion can have adverse impacts by promoting erosion of other beaches. Moreover, the appearance of the structures reduces the aesthetic quality of the beach and sometimes, structures completely inhibit public use of the beach.

B. Institutional Controls

Institutional controls for erosion aim to minimize the erosion through avoiding the hazard. Institutional controls proposed for Indonesia consist of zoning for coastal habitats, the buffer zone concept, and educational/advisory services.

Zoning mechanisms in coastal zone management are derived from the management of land-based natural resources. The basic function is to direct, control and plan resource uses, as well as to provide a framework to prevent socially undesirable impacts of human activity on nature (Walther, 1986). A zoning system can insure preservation of both economic and social value of the resources. From an economic viewpoint, the value of a resource can be protected by minimizing land-use conflicts and degradation. While from social view, it can maintain a balance between conflicting perspectives of groups such as resource users and environmentalists.

Management of coastal resource is based on development control strategies traditionally applied to the management of natural resource lands. In coastal erosion management, the basic aim of the land-use approach is to minimize, and in some instances avoid, the erosion hazard through regulation of the amount of investment at risk (Chapman, 1985). Control over the type and intensity of development along erosion-prone shoreline can be achieved through land-use zoning, setback ordinances, and other types of regulations.

The concept of zoning is used to classify parcels of land into zones in which given land uses and conditions apply. With zoning, local government has a basic tool to regulate land uses. Enabling legislation for the coastal zone allows the local governments to establish shoreland zones and to establish special conditions for the development and use of environmentally sensitive lands (Hobb et al 1981).

Related to coastal problems along the northern coast of Java, the concept of zoning may be applied for a solution to coastal erosion problems. Since there are two basic factors causing erosion, two kinds of zoning can be applied to the management of the problem. The first is zoning for coastal habitats (i.e., coral reefs and mangroves), where the cause of shoreline erosion results from overexploitation of a coastal resource. This usually occurs in the rural coastal areas. The second form of zoning or land-use control is to create buffer zones. This kind of zoning is more appropriately applied to shoreline erosion caused by natural hazards in urban coastal areas or coastal recreation areas.

1. Zoning Mechanism for Coastal Habitats

For coastal areas which have conflicting activities and population pressures, it is difficult to decide which management techniques might be applicable and acceptable to all resource users. However, there is a management alternative suggested for these areas. This alternative is a marine protected area system. The approach is to apply a zoning system both for coral reef and mangrove areas.

Applying a zoning system of marine protected areas is one alternative to managing coastal resources and related activities. For areas such as Java which have many conflicting activities and increased population pressures, the concept of zoning may be the best solution to resolving the dual goals of preservation and multiple uses (Kelleher, 1988). The concept could maintain a balance between conflicting perspectives of groups such as environmentalists and resource developers. Because the latter tends to be growth-oriented due to economic needs, growth control and long-range planning become increasingly specific tasks for environmental management (Walther, 1986).

Establishing the zoning system can serve as a means of management for a specified area. Zoning may limit or exclude specified activities in heavily-use areas to protect the resources or to separate incompatible users (Saenger, 1985). The level of protection within the zone should be set based on resource classification. It can vary from almost no restriction in some regions (i.e., the resource may be utilized or harvested) to regions or zones within which almost no human activities are permitted. From the zoning of the Great Barrier Reef, Australia, for instance, Kelleher (1988) classified the system into three category zones. Category I is preservation and scientific zones, where human activity is permitted only for strictly scientific research. Category II is national park zones where the major uses permitted are scientific, educational and recreational. The last category is general use zone, where uses are held at level that do not disturb the ecosystem.

Coral mining and other related activities such as coral reef fisheries are the main livelihood for much of the community. To manage these activities, attention should not only focused on the resource, but also the socio-economy of the users. Banning and other types of law enforcement are often disregarded by local people. Therefore, the use of a zoning system might be a good alternative because it gives some flexibility, by allowing the community to harvest the resource in restricted regions.

A zoning system for mangrove areas is as important as for coral reefs. Mangrove and coral reefs are two important coastal habitats and their uses are related. In areas where coral mining is active, mangrove destruction is also a serious issue because mangrove wood is used as a fuel for the lime kilns. In Java, there is now a proposal to zone the mangrove areas into four regions (Sujastani, 1988): mangrove green belt used for protecting specific areas, conserving areas, utility (traditional use) areas, and conversion areas. This zoning plan, if implemented and accepted by the local community, will allow sustainable use of mangroves but not totally curtail traditional use or even conversion to aquaculture ponds. Mangroves will remain intact to protect beaches and coastal areas.

2. The Buffer Zone Concept

A buffer zone is a managed region between beach and development site, designated to accommodating maximum erosional or accretional processes within which restricted or no development allowed. The concept of a buffer zone for coastal erosion management is based on the philosophy that erosion is a natural part of coastal processes, and a beach is a natural self-regulating system. In the absence of human interference, it will self-adjust to, and recover from probabilistic erosional events provided that sufficient space for coastal processes is facilitated. The processes play an important role in the formation and maintenance of beaches, therefore it should be accommodated rather than prevented (Chapman, 1985). If coastal fluctuations are prevented, beaches will be degraded or disappear. Erosion is a part of natural fluctuations which will continually occur wherever beaches exist.

The problem of shoreline erosion is a combination of natural processes and human actions. The problem is conflict between the need to protect coastal property and the protection of beaches. The solution to this conflict is to accommodate coastal processes within a buffer zone, so that beaches are retained while property is kept unthreatened by erosion. The problems related to erosion will be reduced or disappear if property is insulated from erosion risk by a suitable buffer zone.

Implementation of the buffer zone concept requires reservation of an appropriately managed zone, between beach and the development site. In a buffer zone, dynamic coastal fluctuation is accommodated and land-use control can be applied where no development such as buildings or roads are permitted. Since this area must be free of development activity, some regulation should be employed so that the function of a buffer zone for management of the impact of erosion can be maximized.

In addition to legal action, adequate knowledge to predict the trend of erosion determines the effectiveness of the buffer zone. Scientific and technical data, therefore, should be prime considerations in the designation of buffer zones.

3. Educational/Advisory Services

Another action needed for managing coastal resources in Java is a community participation and education program. Participation is the key to implementing marine management schemes wherever coastal resources are intensively used (White, 1987). This is increasingly the situation in most developing countries, especially on tropical coasts where resources are often part of "common" property, readily accessible to many people. Unlike land areas, marine and coastal regions can not be fenced off for effective protection. For coastal resources such as coral reefs and mangroves, there is no private ownership or control of these resources.

Practically speaking, the success of natural resource management depends to a large degree on local public support, which means the existence of community participation. Such public support can be regarded as a sign of understanding conservation objectives and leads to adherence to the protected area rules by the local population (Salm, 1984). Participation is important in solving resource overuse problems. Involvement appears consciously from a desire to support the common values to gain some benefit for the individual and community. Without it, marine resources will never be conserved and sustained even though there is some kind of law enforcement.

Management of marine and coastal resources in populous areas would not be possible without participation of the local people. From the Philippines experience, White (1987) gave several reason why this participation is a necessary and workable approach. He mentioned that national law and other law enforcement are often scorned by local people (i.e., resource users). Focusing attention on the resource users may not be the best strategy. The basic cause of resource overuse is the need for employment. In the case of coral mining, it is obviously resulting from the demand for lime by the construction industry. The problem becomes apparent where those who finance and organize mining activities will continue to do so even if the current miners are relocated or given alternative employment.

There are no practical means for enforcing laws or regulation, especially in remote areas. Controlling the small and dispersed areas is unlikely to be effective. The best mechanism for monitoring such areas is by giving the local community the responsibility of controlling their region. Local people can see the effect of their destructive action, and if given proper incentives, will change their actions to enhance the available resources.

Involving the local people in the resource management program, will encourage total participation. Local communities, if given control over their marine resource areas will tend to protect it rather than destroy it. Basically and traditionally, these people understand the limits to the natural marine ecosystem and productivity, however, because of social changes in modern society and overpopulation, the tradition is being lost or degrading.

To make the people aware of their ecosystem and get them involved in protecting their environment, a bridge to support the awareness is required and an education program may be one of the answers. Public education should be placed as a top priority in the resource management program. Any resource management in populous areas may not be successful or enhanced unless those who exploit the resource are involved and committed to this goal (White, 1986).

There are some educational tools helpful in fostering community involvement in conservation and management of coastal resources. Personal contact, mass media, and working with local school may be useful in achieving the goal of resource management.

Personal contact, in the form of person-to-person approach is very effective in conveying conservation values to the community (Kaza, 1988). Personal contact may become more effective, specially for rural communities, through approaching community leaders or local leaders. The members of Indonesian communities are generally leader-oriented, they tend to respect what the leader says. Anyone who disobeys the community leader will usually be isolated. Influencing the local leaders maybe the most effective approach in successful of resource management, provided that delivered massages are understandable and do not violate traditional values and their beliefs.

Mass media, such as television and radio, have the advantage of reaching large numbers of people. Single-channel government controlled television media in Indonesia is a possibility for broadcasting information and other government programs. Siaran Pedesaan (rural area programs), a periodical program that attracts a large number of viewers may be used as a means of disseminating marine and coastal management program information. Radio, on the other hand, can also reach large audiences, particularly for the communities in remote areas.

Working with schools reaches right to the heart of the community, and serves as a road for contact with parents and other adults (Kaza, 1988). Educating people about an environmental ethic from an early stage is essential. It will give long-term success in caring for protected marine habitats. Future generations will have more awareness of their environment if they are given understanding from the school ages. Marine education can be presented either included in the curricula or in special presentations that might attract student enthusiasm.

In dealing with shoreline erosion problems,educational-advisory services can be used as a tool in management of the impact of erosion. The services must constitute a key component of any erosion abatement program. Educational activities for an erosion program would need to be targeted separately to the general public and to officials (Hobbs et al, 1981). For the general public, educational tools can be presented by means of mass media, meetings, and brochures. To the local officials and program staff, it would be essential if they provided some form of formal training program.

Advisory services are an important element of overall management of erosion programs. They are especially useful if local government does not have a comprehensive program to reduce the impact of erosion for private property owners. The services can provide the property owners with a guide to controlling shoreline erosion. Using this guide, the property owners are able to install shorefront structures without being afraid to exacerbate the erosion problem of adjacent property owners. In addition, the advisory services can be expanded to include development of design and construction guidelines for marine and coastal contractors.

4. Improve Role of Local Government

Much of the success of coastal resource management depends largely on the results achieved in the lower levels of government. Local governments also are the most immediately concerned with coastal problems due to the direct affect on their citizens. However, they are usually reluctant to take action because of limited authority and capability. To overcome this trend, a change in the delegation of decision-making authority is required. Decentralization could give the local government more authority and responsibility.

To make local government assume more authority, however, it is essential that the administrative capabilities of local government be improved and dependence on the central government reduced. For that to happen, training programs and the transfer of management and financial resources from higher levels of government need to be addressed.

VI. RECOMMENDATIONS AND CONCLUSIONS

A. Recommendations

Despite the fact that the ocean encloses 80% of the national territory, Indonesia remains a largely land-oriented nation. The majority of Indonesians are oriented to the land for a livelihood. Only a small part of society has long been dependent on the sea for their livelihood.

The pressures on the land-based resources is becoming more intense, especially due to the growth rate of the population and labor force. In recent years, therefore, Indonesia has begun to look to the resources of its marine and coastal areas in hopes of enhanced economic development and employment opportunities. In doing so, however, there are many cases where economic exploitation of marine and coastal resources has come too quickly. Resource users do not understand the sensitivity of the ecosystem. There is the likelihood that this lack of awareness of the environment could threaten sustainable resources in the future. Therefore, urgent steps need to be taken to provide sustainable development and to improve the coordination of marine and coastal resource development.

In accordance with Indonesia's Five Year Development Plan, it is suggested that four basic issues should be placed as prime considerations. The issues are community development, education and awareness programs, local government roles, and coordination in protection and management programs.

1. Coastal Community Development

Compared to the national standard, coastal communities are the poorest among all land regions. Due to their economic condition, therefore, they have a great possibility of exploiting and destroying the resources. Development of coastal communities is perhaps the most urgent overall marine and coastal resource management issue. The people in the coastal communities play an important role in the future development of the resources as active participants in sustainable economic development, and as social and economic beneficiaries.

Priority development should be addressed to these regions to increase their role in national development. To accomplish this, the capability of coastal community to participate in development must be enhanced, all constraints on their development must be addressed, and programs to benefit them must be planned.

2. Education and Awareness Programs

Since economic development is beginning to focus on marine and coastal resources, understanding of these resources should be promoted. Understanding is primarily important to develop effective management programs and make resource users aware of their impact. The awareness program can be realized gradually through training, education and other information dissemination.

For long-term success in promoting public awareness of coastal resources, understanding of and interest in coastal development needs to begin early. Marine and coastal management issues should be included in the school curricula, starting from elementary school, and continue through formal and informal educations.

3. Interagency Coordination

Interagency coordination for protection and management of marine and coastal resources needs to be reorganized to minimize incompatible uses of funding and to increase efficiency. Synchronizing the planning and implementation of programs affecting marine and coastal resources also need to be fostered at all government levels. In doing so, adequate scientific and technical knowledge of marine and coastal resources needs to be improved among officials involved in the programs.

Establishing an integrated program to control destructive activities such as overfishing, illegal coral mining, and cutting of mangroves, is essential. In avoiding lack of funding and fostering long-term success, coastal communities may be included in the programs. Their involvement can be regarded as a direct support to the program, providing job opportunities for the local community.

B. Conclusions

Coastal problems along the northern coast of Java are the result of human interference and dynamic natural processes. In many aspects, human actions cause greater impacts and problems. This is a result of the high population concentration in coastal areas and high dependence on coastal resources. The problems are increasingly apparent since resource users have little awareness that the resources are limited and vulnerable. Mining and deforestation are examples of resource exploitation that bring about severe impacts on the natural structure of the shoreline.

Overpopulation can also be regarded as the underlying cause of most of the present problems. In populated areas, man clearly emerges as a disruptive force. As the population is concentrated along the coast, the use of coastal resources increases. As uses increase, the conflicts become apparent, especially between uses and users.

Coastal problems caused by natural processes are largely influenced by geomorphological status in the region which in turn is affected by a number of environmental factors. Climatic factors are the most important in terms of the weathering of coastal rock outcrops. In this humid tropical region with high temperatures and precipitation rates, rapid chemical weathering is accommodated causing deep decomposition of many of the rock formations deposited along the coast.

Severe coastal erosion, as a result of natural processes is characteristically seasonal. It occurs during the rainy season in which westerly winds are responsible for generating storm surges that attack coastal properties. Wave attacks can be greatly enhanced as high spring tides occur simultaneously. As a consequence, the water level of the high tide permits the storm wave to attack directly on the coast.

The problems arising from coastal erosion are far more severe than those due to coastal deposition. Therefore, coastal erosion receives more attention since its impact always brings about loss of property.

Although there are some management alternatives for dealing with coastal problems, it is difficult to decide which alternative is more applicable and acceptable both for users and for those most concerned about the environment. The solutions discussed in this paper are only possibilities. Their applicability is strongly dependent on support from both sides and from decision-makers.

Solutions to resource utilization problems and other human interference with coastal resources in populous areas are best resolved if a flexible approach is provided. It means that the two different interest groups can be represented. A zoning system can provide a moderate alternative. It can serve as a management effort to protect and conserve coastal resources and at the same time enhance the communities ability to utilize the resources with some limitations. By using a zoning system, two conflicting interests could be served simultaneously.

Structural controls for managing the impacts of coastal erosion can be effective only if designed properly. Scientists and researchers still dispute the effectiveness of structural controls for long-term protection. Structures provide temporary respite and therefore, some experts concluded that structural control can not be judged as real "solution" to the problem. Furthermore, there is some debate whether structures induce more harm than protection. The presence of structures may accelerate the recession rate and consequently force placement of more structures. However, for a short-term solution, it may be helpful and provide effective protection against immediate coastal degradation. In addition, the structures can provide employment to the local community and economic benefit for the local government.

Unlike structural controls, the buffer zone concept can provide effective long-term protection for coastal property. The zoning concept must be strongly based on scientific and technical considerations. It sets a managed reservation zone within which dynamic coastal processes are accommodated. In many aspects, the buffer zone is similar to setback lines where legislation controlling development sets an arbitrary control line, seaward of which restricted or no development is allowed. The Buffer zone concept could be more effective if both legal action and adequate knowledge to predict trends in erosion are equally implemented and completed.

To avoid mismanagement of coastal erosion by private coastal property owner due to poor construction and improper design, educational and advisory services need to be established. They are useful, especially when local government doesn't have a comprehensive program to reduce the impacts of erosion for private property owners.

Management of coastal resources in populous areas would not be workable without participation of the local people. In tropical coasts where resources are often part of common property, community involvement is a key to success in managing coastal resources. Community participation requires public education programs. Through education, understanding occurs, with understanding come awareness and involvement. Therefore, public education is the most important factor in managing coastal resources, particularly for the populous rural coastal areas.

Successful marine and coastal resource management are largely affected by the results achieved in the lower levels of government. Decentralization and responsibility delegation to the local government where coastal resource development initiatives are implemented, provide effective government administration.

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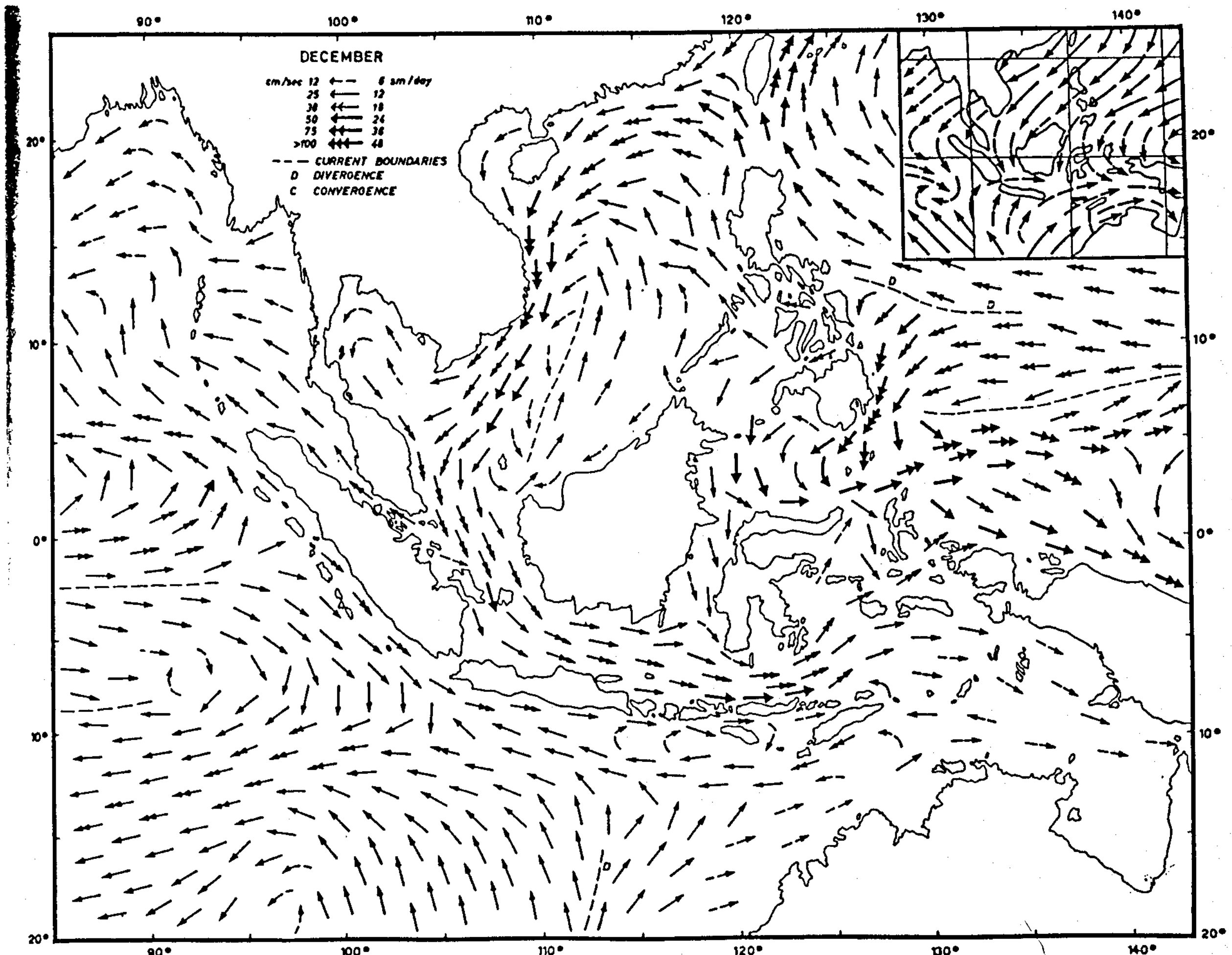

Figure 1.a. : Surface currents in December (From Wyrtki, 1961)

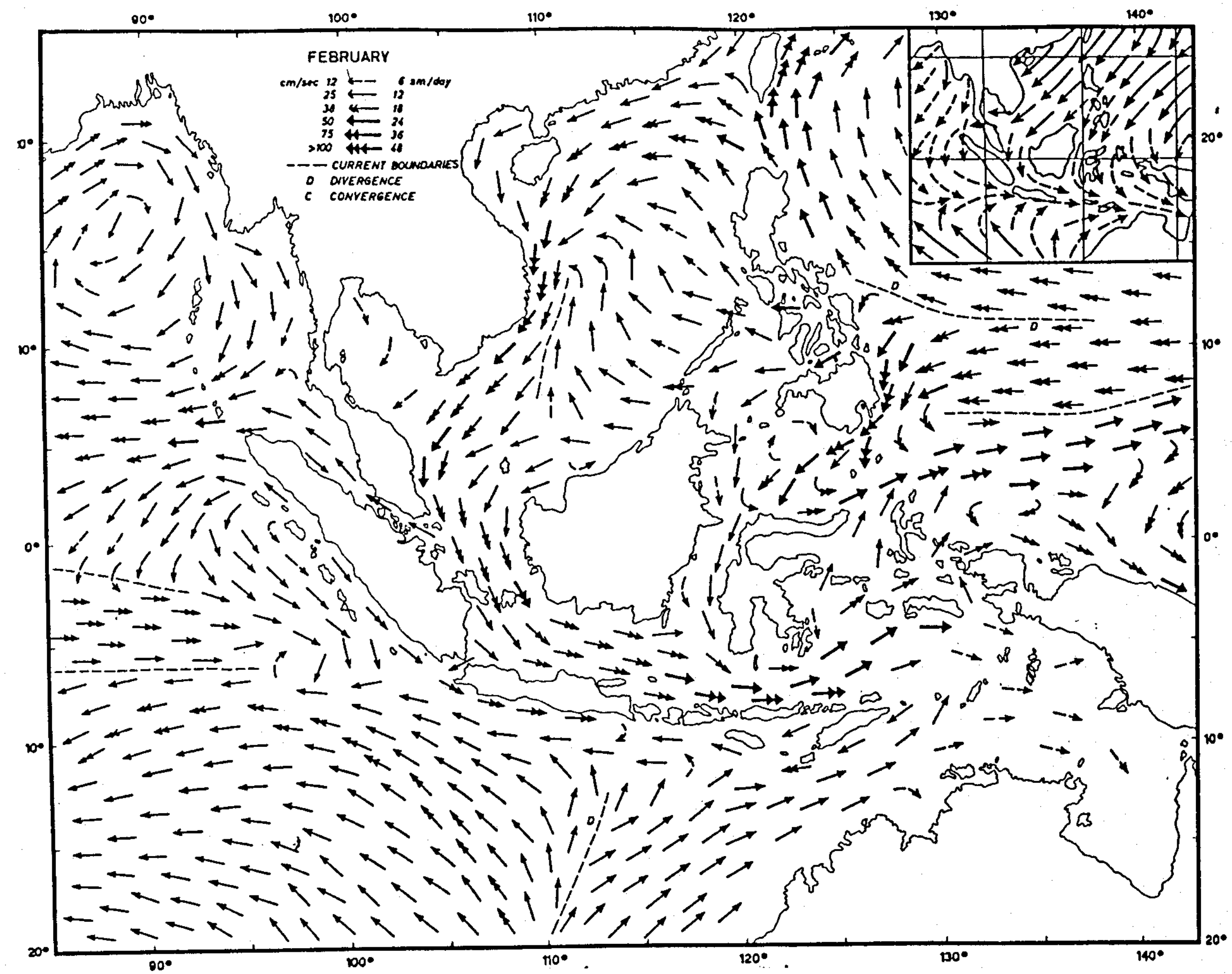

Figure 1.b. : Surface currents in February(From Wyrtki, 1961)

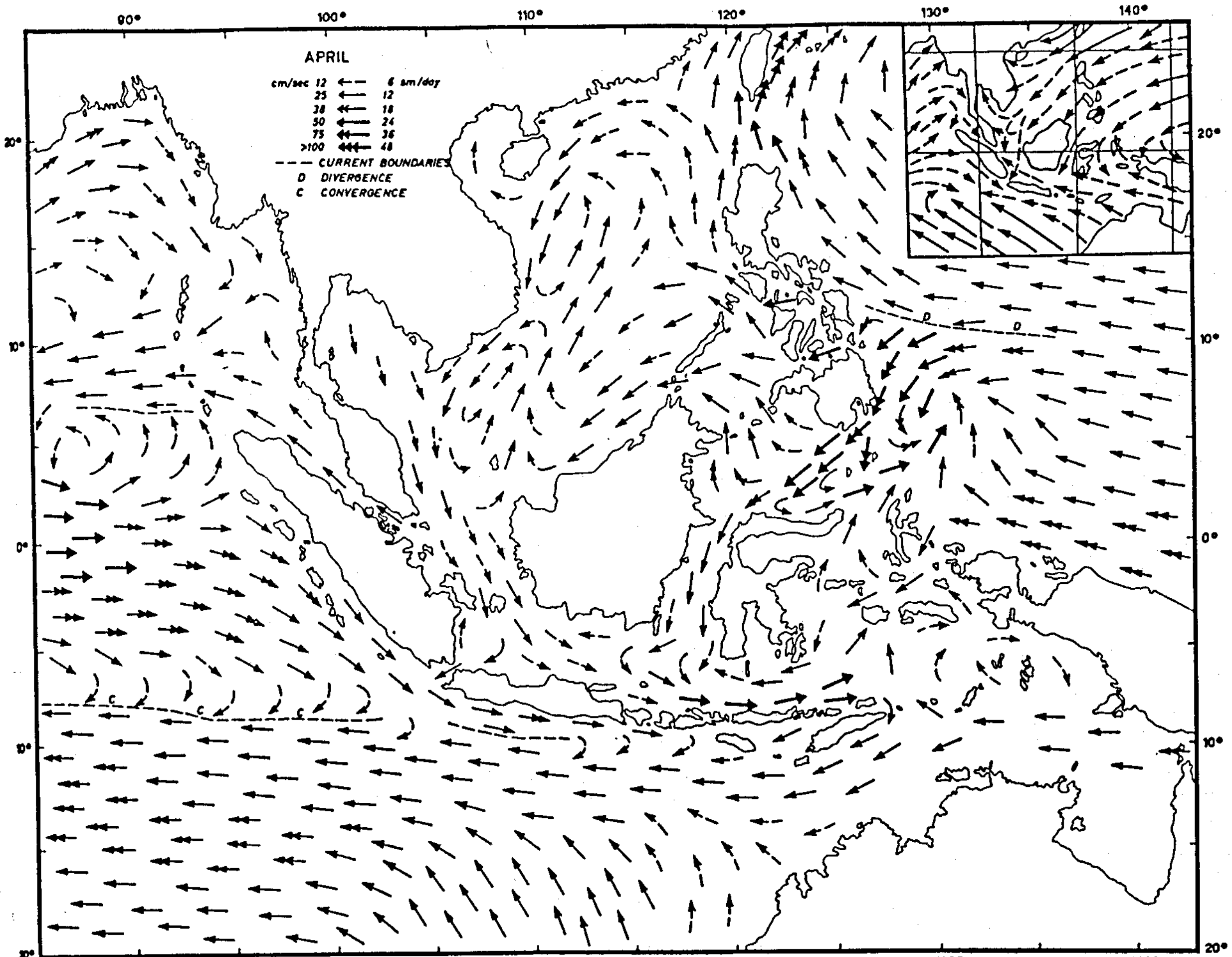

Figure 1.c. : Surface Currents in April (From Wyrtki, 1961)

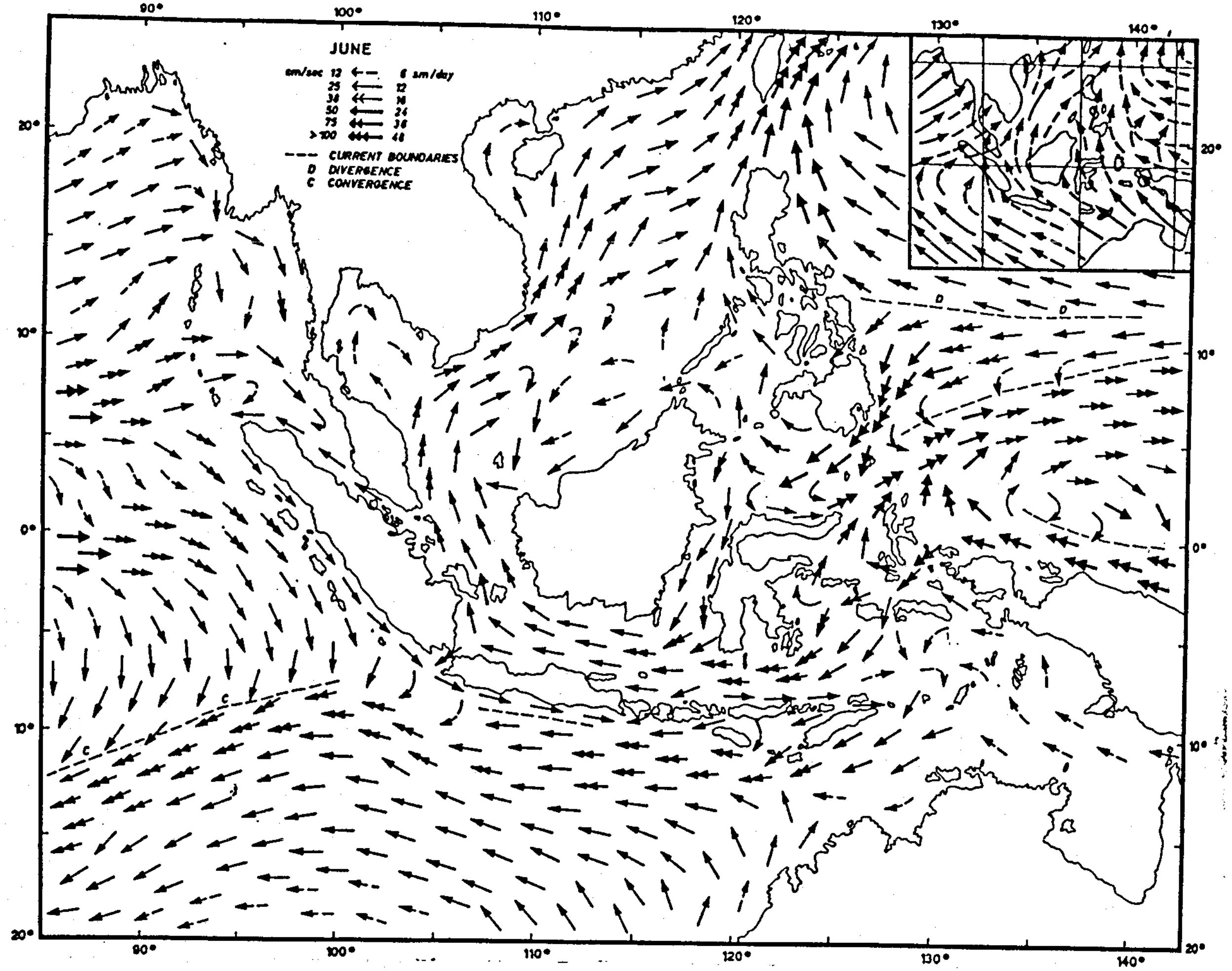

Figure 1.d. : Surface Currents in June(From Wyrtki, 1961)

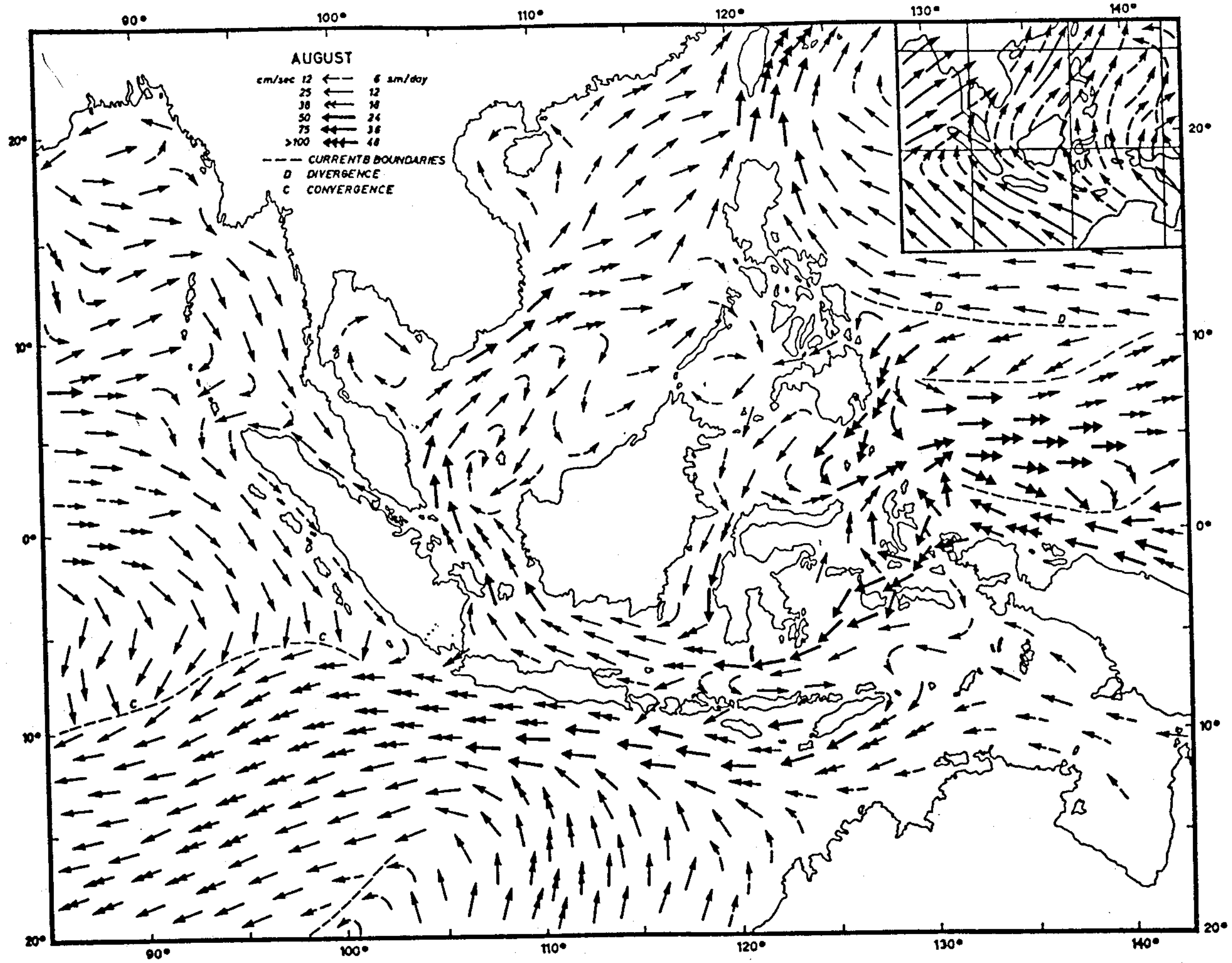

Figure 1.e. : Surface Currents in August (From Wyrtki, 1961)

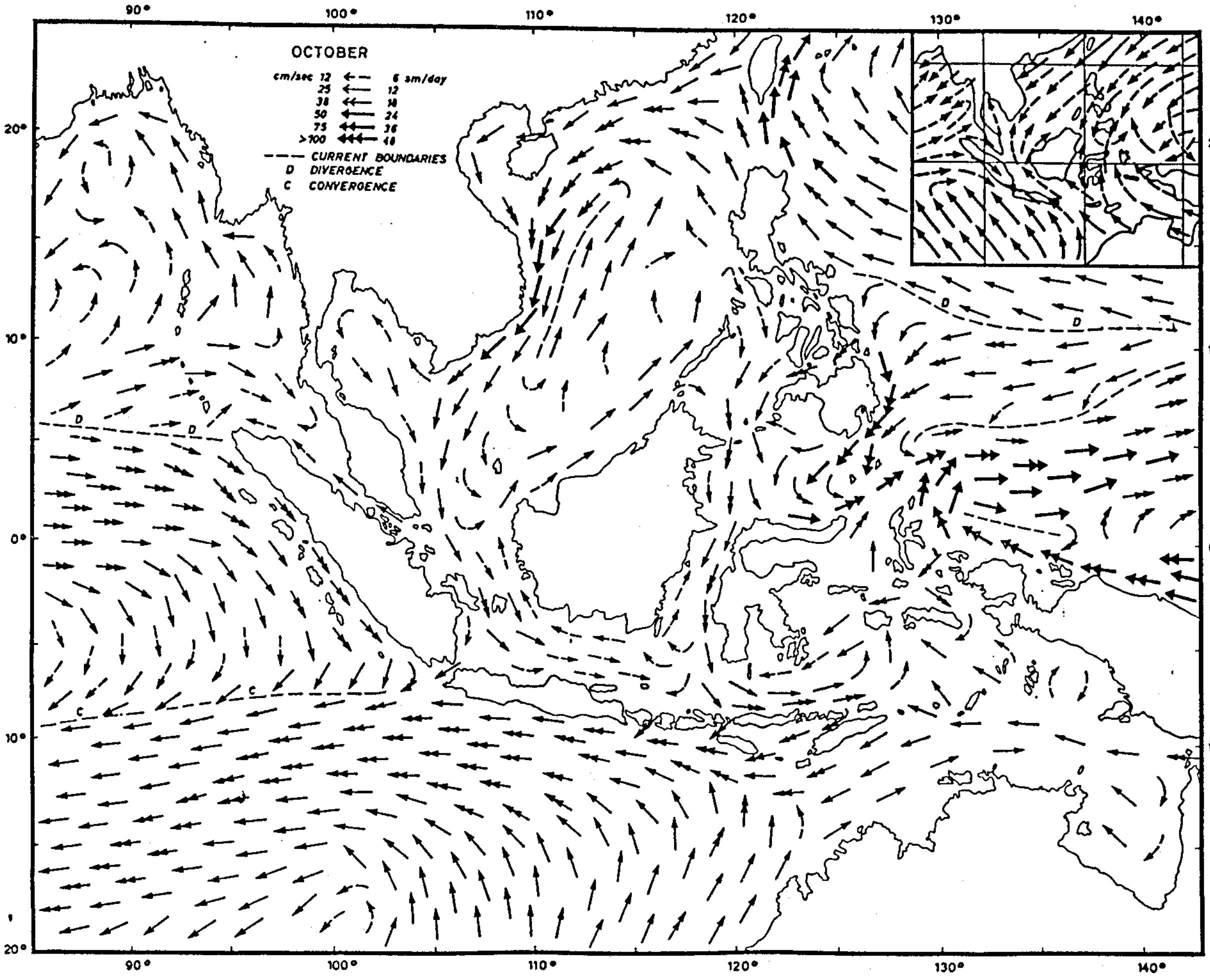

Figure 1.f. : Surface Currents in October (From Wyrtki, 1961)

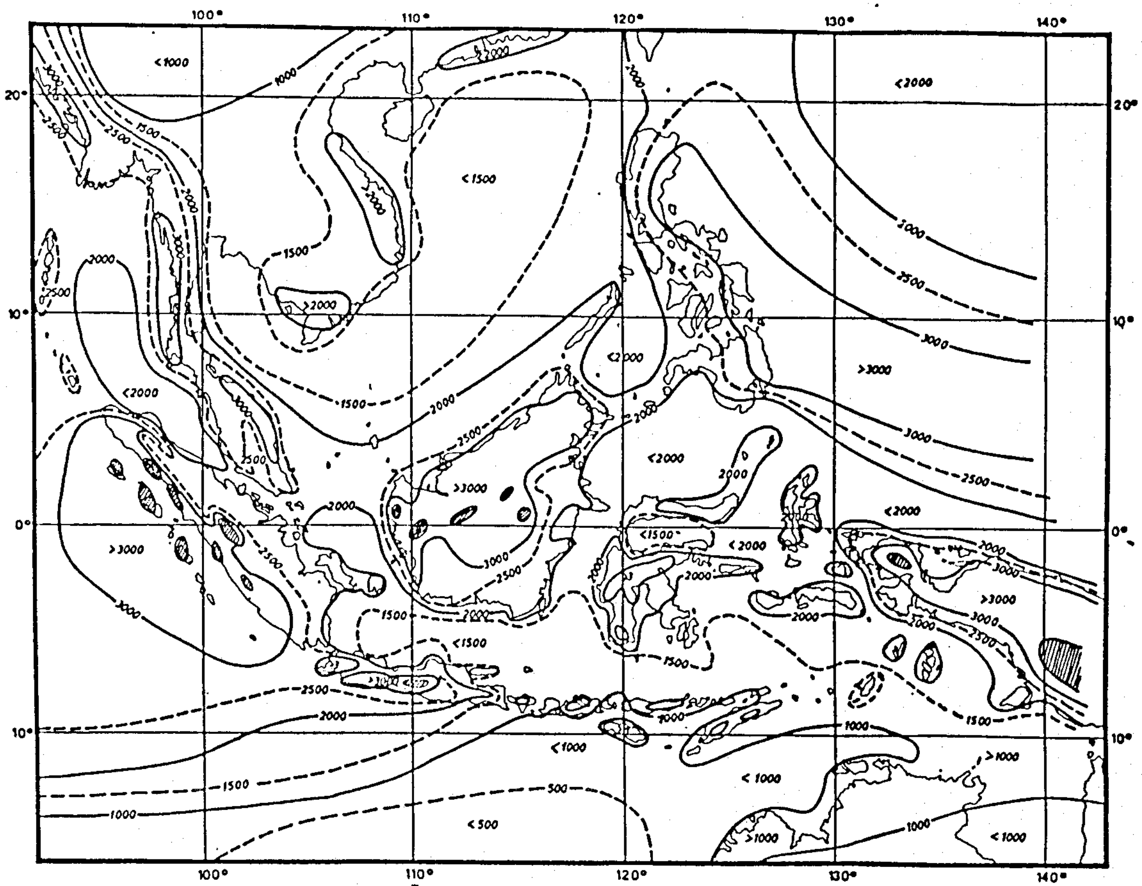

Figure 2. : Average annual rainfall (mm), shaded area is greater than 4000 mm (From Wyrtki, 1961)

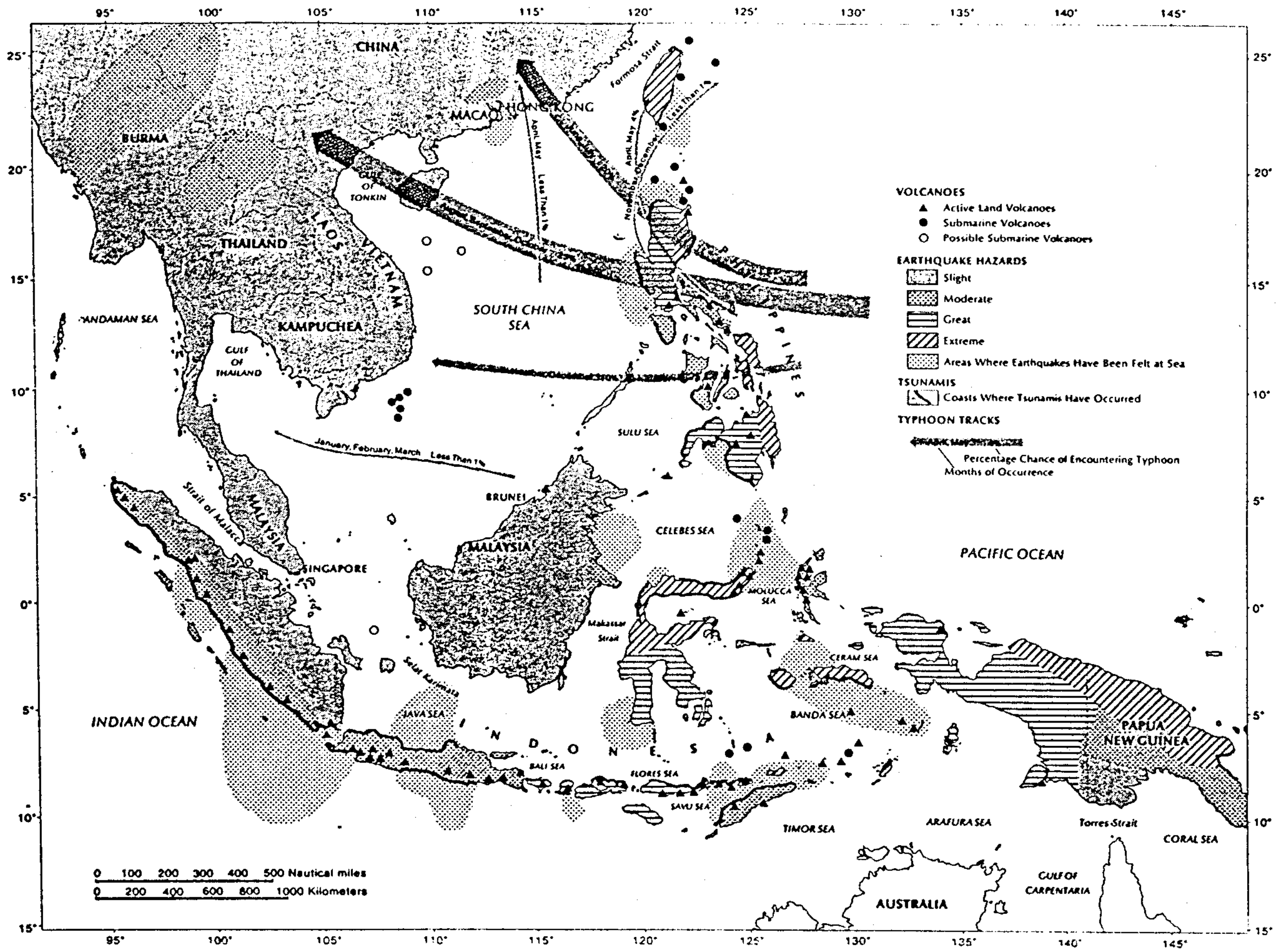

Figure 3. : Natural hazards in Southeast Asia regions(From Kent & Valencia, 1985)

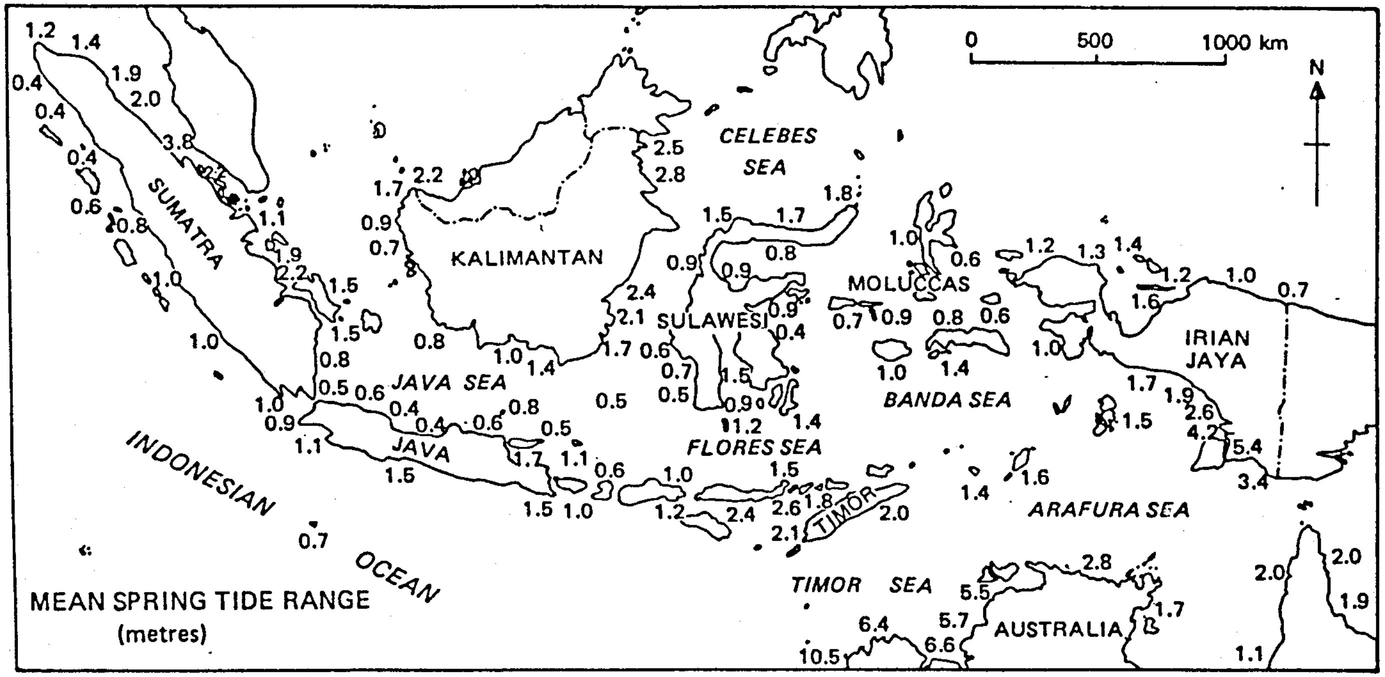

Figure 4. : Average tidal range over Indonesian waters (from Bird and Ongkosongo, 1980)

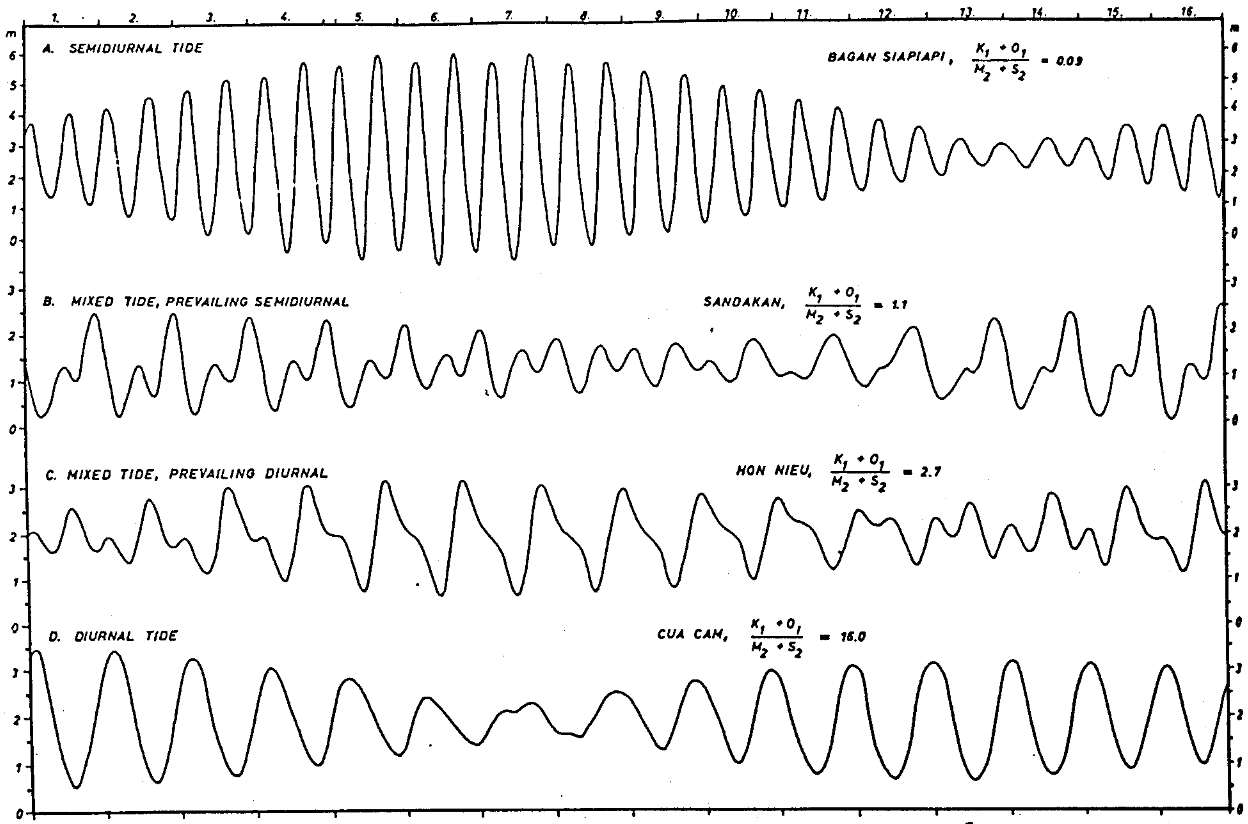

Figure 5. : Typical tidal curves in the Southeast Asian Waters, representing the four typesof tides during a period of 16 days (From Wyrtki, 1961)

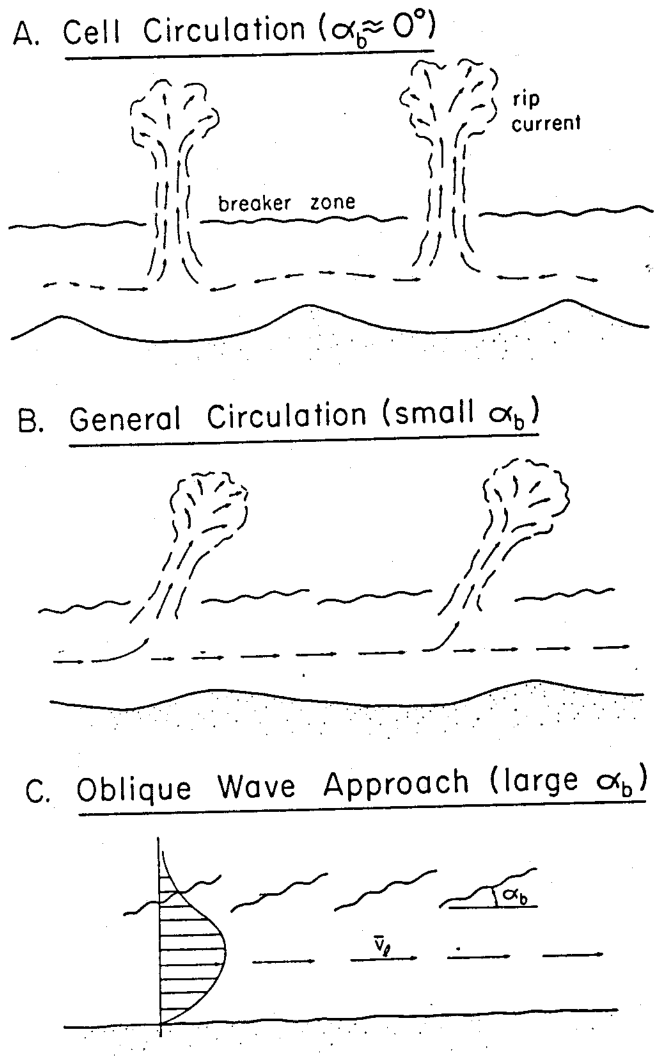

Figure 6. : Different patterns of nearshore currents which depend in large part on the wave approach angle;A) cell circulation with rip currents, B) a combined pattern under intermediate conditions, C) a uniform longshore current when angle is large.

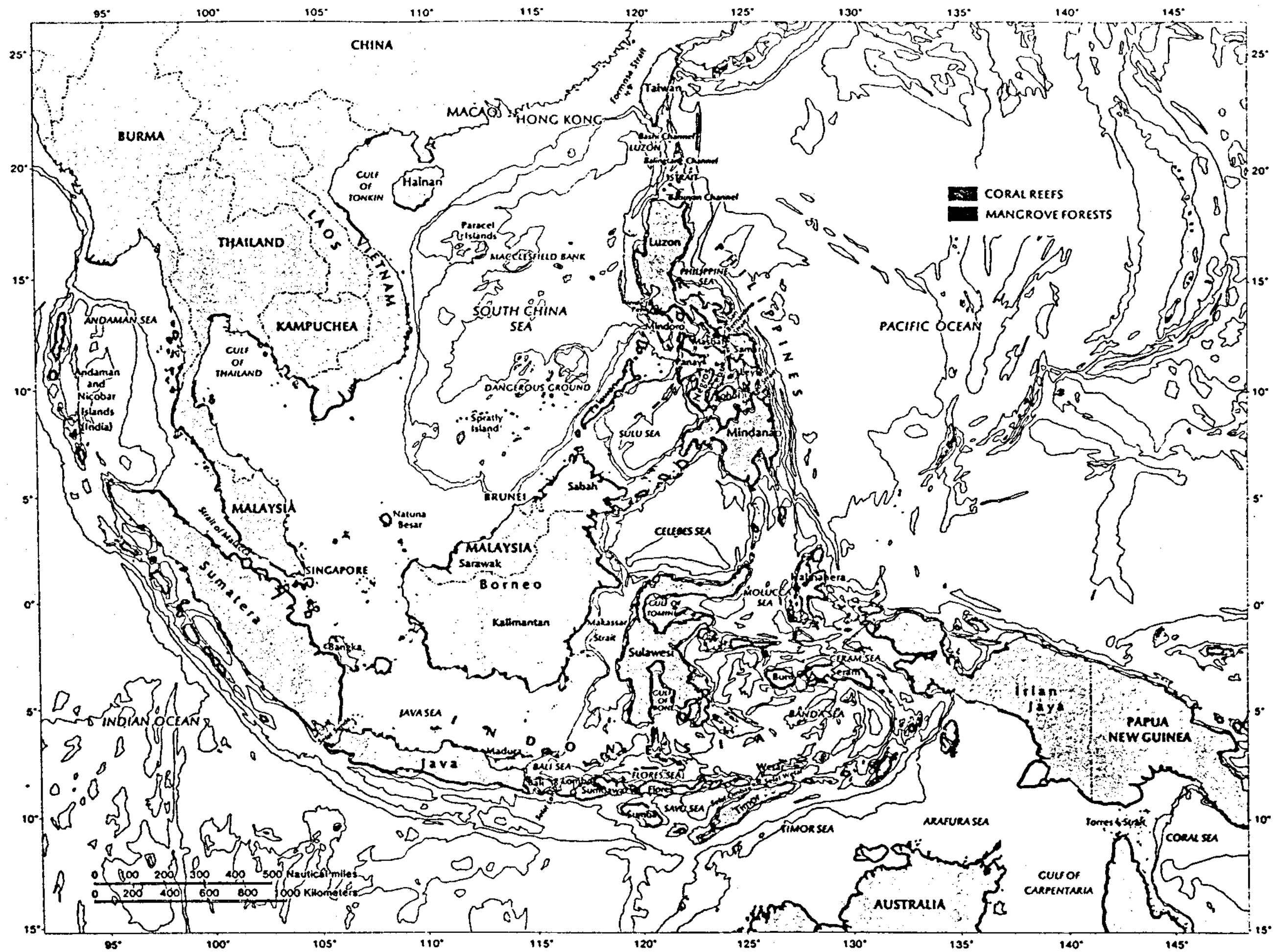

Figure 7. : Distribution of mangrove forest and coral reefs (From Kent and Valencia, 1985).

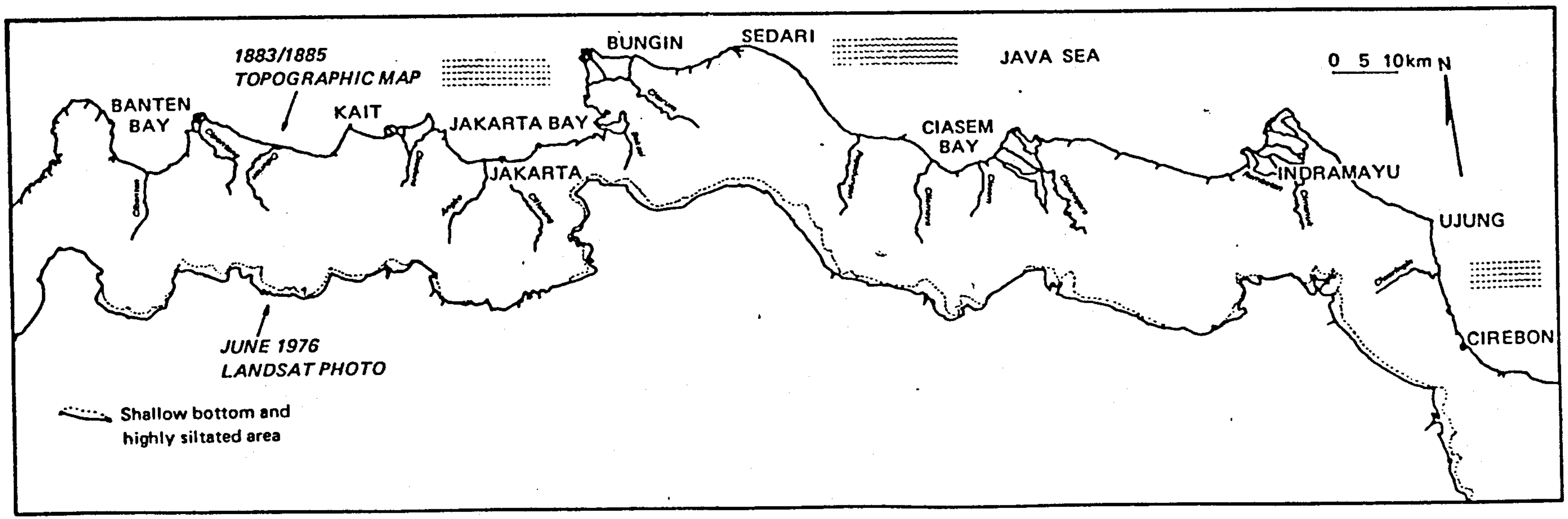

Figure 8. : The coastal outline of northwestern Java as shown on 1883/1885 topographic maps and on 1976 (from Bird and Ongkosongo, 1980)

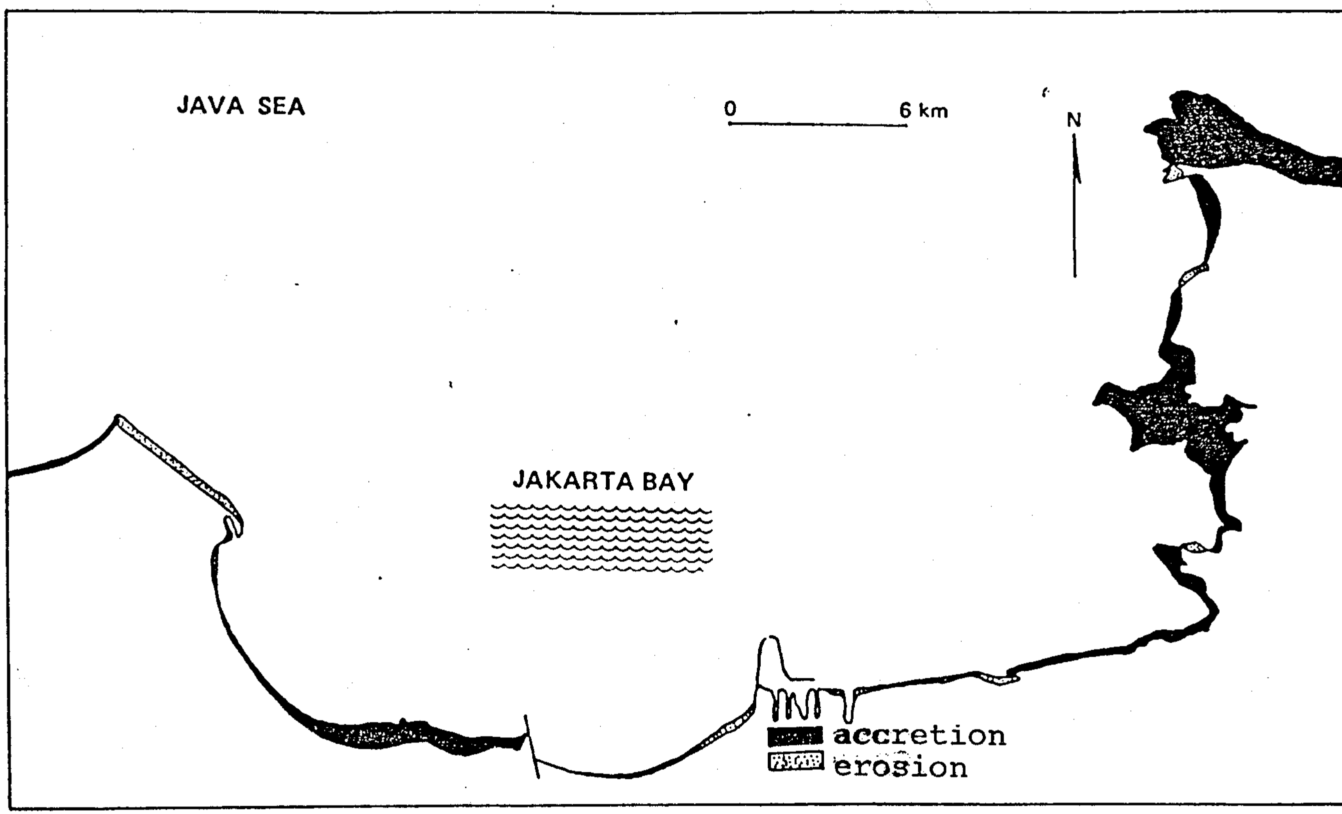

Figure 9. : The extent of Accretion and erosion on the shores of Jakarta Bay in the periods of 1869-1874 and 1936-1940 (from Bird and Ongkosongo, 1980).

Tabel 1. The Indonesian Coastal Zone: Some Statistics

Total island	:	13,667
Land area	:	2,027,083 km2
Land area + 12 n.mile sea	:	3,166,163 km2
Shelf area	:	210,000,000 km2
Length of coastline	:	80,791 km
Area of brackish forest	:	10,000,000 km2
Area of mangrove forest	:	3,100,000 km2
Tambak area	:	183,000 ha
Fishponds	:	40,000 ha

Tabel 2. : Influence of lithology on sediment yields (From Bird and Ongkosong, 1980)

Catchment	Drainage area km^2	Sediment yield $ton/km^2/year$	Source
Volcanic			
Ciliwung	130	250–375	Rutten
Rambut	4.5	532	van Dijk
Banyuputih	225	750–1,000	Rutten
Brantas	10,000	875–1,500	Rutten
Mainly volcanic			
Citarum	73,000	800–1,200	Modified after Soemarwoto
Cimanuk	3,000	1,000–2,000	Rutten
Mixed volc — Sedimentary			
Tandjum	210	750–1,000	Rutten
Cilamaya	225	2,500–3,500	Rutten
Lusi	860	2,500–3,500	Rutten
Serayu	700	3,500–4,500	Rutten
Cilutung		7,500	Nedeco
Sedimentary			
Jragung	101	4,000–6,250	Rutten
Cacaban	7.9	6,600	Rutten
Pengaron	41	9,250–12,500	van Dijk

Tabel 3. : Prevailing wind direction at selected coastal stations in Indonesia (From Bird and Ongkosongo, 1980)

STATION	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Sabang	E	E	E	E	SW	SW	SW	SW	SW	E	E	E
Sibolga	N	N	NW	N	N	NW	NW	W	N	NW	NW	NW
Tabing	W	W	SW	SW	W	W	W	W	W	W	W	W
Tandjung Pinang	N	N	NE	NE	SW	S	S	S	S	S	N	N
Pangkalpinang	N	N	N	NE	S	S	S	S	S	E	E	N
Bengkulu	NE	NE	NE	S	NE	NE	NE	S	S	S	S	S
Pusakenegera	NW	W	W	S	S	SE	SE	SE	SE	SE	SE	SE
Tandjung Priok	NW	NW	SW	NE	NE	NE	NE	NE	NE	NE	NW	NW
Cilacap	SW	W	SW	SE	SE	SE	SE	SE	SE	SE	SE	SE
Semarang-Maritim	W	W	W	NW	E	N	E	SE	E	NW	NW	NW
Tegal	S	S	NW	S	S	SE	SW	SW	SW	SW	SW	SW
Kalianget	W	W	W	E	E	E	E	SE	E	E	SE	N
Surabaya Perak	W	W	W	E	E	E	E	E	E	E	E	N
Supiado-Pontianak	W	N	W	W	E	S	S	S	S	E	W	W
Banjarmasin	W	W	W	W	E	E	S	S	S	E	W	W
Balikpapan	N	N	N	N	N	NW	S	S	S	S	S	N
Denpasar	W	W	W	E	E	E	SE	SE	SE	SE	SE	W
Hasanudin	E	E	NW	NW	E	E	S	NW	NW	NW	SE	E
P.G. Bone Arasoe	N	W	N	N	S	SE	SE	SE	SE	SE	SE	SE
Palu	N	N	N	N	N	N	N	N	N	N	N	N
Rembiga	W	W	W	E	E	SE	SE	SE	SE	SE	W	W
Waingapu	SW	SW	SW	SE	SE	E	E	E	NE	NE	NE	SW
Ambon	N	N	N	N	S	SE	SE	SE	SE	SE	S	S
Kaimana	N	N	N	NW	S	S	S	S	S	S	S	NW
Dili	W	NW	NW	NW	N	N	N	N	NE	NE	N	N