COBSEA

COORDINATING BODY ON
THE SEAS OF EAST ASIA

A Regional Approach to the Sustainable and Ecosystem-Based Management of Coastal Erosion in the East Asian Seas Region: A Resource Document

October 17, 2011

UNEP

Regional Seas

UNEP

A Regional Approach to the Sustainable and Ecosystem-Based Management of Coastal Erosion in the East Asian Seas Region: A Resource Document

Acknowledgements: This Report was prepared for the Coordinating Body on the Seas of East Asia (COBSEA) of the United Nations Environment Programme (UNEP).

UNEP/COBSEA is grateful to W.F. Baird and Associates Coastal Engineers Ltd. (Canada), their project manager Mr. Peter Zuzek and to Dr. Larry P. Hildebrand (Canada) for developing the project.

UNEP thanks the following peer reviewers for their contributions, on which this report is based:

Peer reviewers:
Dr. WONG Poh Poh (National University of Singapore)
Dr. David G. Aubry (Chairman and Chief Executive Officer Woods Hole Group)
Dr. Klaus Schwartzer (Institute of Geosciences, University of Kiel, Germany)

UNEP also acknowledges the COBSEA National Focal Points and Dr. Ellik Adler (COBSEA coordinator) for their constructive comments and inputs.

For bibliographic purposes, this document may be cited as:
UNEP/COBSEA, 2011. A Regional Approach to the Sustainable and Ecosystem-Based Management of Coastal Erosion in the East Asian Seas Region: A Resource Document.
COBSEA Secretariat
Bangkok, Thailand
ISBN: 978-92-807-3251-51

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on 100% recycled paper, using vegetable – based inks and other eco-friendly practices. Our distribution policy aims to reduce UNEP's carbon footprint.

TABLE OF CONTENTS

TABLE OF CONTENTS *(continued)*

Page

EXECUTIVE SUMMARY

Coastal erosion is an issue of emerging concern in the littoral countries of the East Asian Seas (EAS) Region. This issue was highlighted at the 20th Intergovernmental Meeting of the Coordinating Body on the Seas of East Asia (COBSEA; the UNEP Regional Seas Programme for South East Asia) member countries in November 2009.

In response to this shared concern, COBSEA commissioned the preparation of this Resource Document to provide a regional framework and practical guidance to assist countries at the national, sub-national and local levels to address coastal erosion. The approach is based on the principle of ecosystem-based management, which recognizes that the coastal zone is a dynamic system of interconnected ecosystems and that human interventions such as erosion protection must be considered in a holistic context to fully evaluate the benefits and cumulative impacts.

All EAS countries are affected to some degree by coastal erosion, some quite severely. In addition, the focus on coastal erosion is increasing as climate-change related sea-level rise and changes to storm intensity and frequency are occurring. The purpose of this document is to provide guidance for the effective management of coastal erosion in the EAS region, with a view to improving coastal resilience and thereby reducing the impacts on ecosystems, the economy, and the safety, health, and livelihoods of the peoples of the region. Knowledge of coastal sediment, including coastal sediment-cell boundaries, sediment balance, favourable sediment status, and sediment reservoirs are all key concepts to address coastal erosion in a sustainable manner. Fundamentally, erosion mitigation should be undertaken in a sustainable manner within a comprehensive Integrated Coastal Zone Management framework.

It is important to understand and appreciate that coastal erosion is a natural and dynamic long-term process. Erosion is necessary to produce new sediment and sustain vital coastal systems and the people that depend on them. Yet while coastal erosion is a natural phenomenon, it is frequently exacerbated by human interventions. These interventions may include coastal engineering structures that impede the natural long-shore transport of sediment, and the degradation or loss of naturally resilient coastal ecosystems such as mangrove forests, coral reefs and beaches. Sand mining and the damming of sediment-rich rivers also have a negative impact on the overall coastal sediment budget which is critical in maintaining the resilience of the coast.

While several EAS nations are taking progressive measures to address coastal erosion and combining “soft” engineering approaches such as mangrove re-planting and beach nourishment, with traditional “hard” structures such as breakwaters and seawalls, there is little to no specific guidance that would assist member countries in managing this issue strategically or in sharing the experience, lessons learned and best practice that several member nations have already developed. National coastal databases are also required to organize and freely disseminate the temporal and geo-spatial data required for comprehensive technical investigations.

This Regional Resource Document builds on the current understanding of coastal erosion processes and policy responses from the region and around the world. It provides EAS member countries with a two-step process to develop a logical approach for addressing this important issue in both a regional and country-specific context as follows:

Step 1 – Setting the Policy Framework: The first activity in Step 1 is the development of a "statement of political intent" that clearly outlines the direction the nation plans to take for the management and protection of its coastal zone. The second part of Step 1 is a policy statement on values and functions of the coast. Here, the aspects of the coastal zone that are the most valued and will be preserved with appropriate policy are outlined.

Step 2 – Develop Objectives and Erosion Mitigation Options: Once the policy framework has been established, Step 2 focuses on developing objectives and erosion mitigation alternatives as follows:

- Formulate Strategic Objectives for the Coast
- Develop Coastal State Indicators
- Benchmarking to Establish Thresholds
- Develop Tactical Options (erosion mitigation alternatives)
- Evaluate Alternatives and Select a Preferred Approach

This Resource Document should be considered the starting point for EAS countries in addressing their coastal erosion challenges within an ecosystem-based framework. To be effective, the principles and approaches outlined in this document must be tailored to each coastal country and coastline condition. Finally, the specific human, institutional and/or legal capacity necessary to address this issue in each country must be identified and enhanced.

The UNEP/COBSEA would like to thank the Government of the Republic of Korea through the Korea Maritime Institute and the Ministry of Land Transport and Maritime Affairs for their kind support which made possible the development of this Regional Resource Document. This Resource Document which was discussed and approved by a Regional Meeting of Experts and National Authorities from the COBSEA countries (Bangkok, April 2011) will serve as a base for a regional policy and activities to address coastal erosion that will be carried out in the region during 2012 to 2014, again with the kind support of the Yeosu Project of the Government of the Republic of Korea.

1.0 INTRODUCTION AND BACKGROUND

Coastal erosion was identified as an "issue of emerging concern" at the 20th Intergovernmental Meeting of COBSEA (the Coordinating Body on the Seas of East Asia; the UNEP Regional Seas Programme for South East Asia) in 2009. Refer to Annex 1 in Appendix A. The growing frequency, severity and impacts of coastal erosion in the littoral countries of the East Asian Seas (EAS) Region and the often unsustainable results following many short-term and reactive responses to coastal erosion have inspired these nations to call for the development of a regional approach for coastal erosion management and guidance at national and local levels to assist their efforts in dealing with erosion.

The challenge in dealing with coastal erosion, as it is for most of the major issues in the EAS region, is to deal with it not in isolation or its symptoms only, but, as the terms of reference for this project clearly call for, to do so as an intricate component of a dynamic and complex coastal environment that has physical, ecological, cultural, political and socio-economic dimensions. The critical role and the goods and services that the region's coastal systems provide, such as natural protection and sediment management by mangroves, beaches, seagrass beds and coral reefs are not often enough given priority consideration, despite the agreed-upon priority placed on them in all UNEP/COBSEA and other regional bodies' (e.g., PEMSEA) guidance documents and agreements.

Many of the documents that set principles for and guide the sustainable development of the EAS region, give scant attention to the issue of coastal erosion. At best, it is mentioned, often in passing, in lists of environmental and socio-economic development pressures and threats. Yet a growing, but still limited and incomplete body of research in the region indicates that all EAS member states are to some degree affected by coastal erosion, some quite severely. Erosion hotspots continue to retreat; some of them in spite of the installation of coastal protection works. Additional investment in shore protection is prohibitive in some communities. Loss of property, infrastructure and beach width annually causes millions of dollars worth of economic damage, and these loses represent significant management challenges. Refer to Figure 1.1 for an example of extreme erosion and flooding in Bangkok.

Figure 1.1 Coastal Erosion Impacts in Bangkok, Thailand

Both coastal and river bank erosion are problems of increasing concern throughout the EAS region, particularly over the last few years. Refer to an example in Figure 1.2 for an example from the Philippines. It is anticipated to worsen over the coming decade. This change in the structure of coastlines and river banks is often a result of human activities, whether directly or indirectly. Some activities actually result in new sources of sediment to the coast, which change the coastal environment profoundly, and can lead to the overall degradation of the coast. Predictions for the effects of climate change suggest that the scale of coastal erosion will increase, thus there will be consequential costs for both protection and relocation.

Figure 1.2 Erosion Impacts on the South Bank of the Bucao River Mouth, Botolan, Zambales, Philippines

While several EAS nations are taking progressive measures to address coastal erosion and combining "soft" engineering approaches (e.g., beach nourishment, barrier-island and mangrove protection) in concert with traditional "hard" structures (e.g., breakwaters, groins, seawalls, shore hardening), there is little to no specific guidance that would assist member countries in managing this issue strategically or in sharing the experience, lessons learned and best practice that several member nations have developed. There are significant benefits in doing so and the guidance outlined in this report is designed to support such an approach. An example of a hard engineering protection (offshore breakwaters) is provided in Figure 1.3.

Figure 1.3 Hard Engineering Structures to Mitigate Erosion and Restore Beaches, Thailand

Coastal erosion and accretion is a natural process that has and continues to shape the physical, ecological and human development patterns that characterize the EAS region and sustain its socio-economic character. The coastal ecosystems of the Seas of East Asia are among the most productive, sensitive, populated and threatened regions of the world. This is where the majority of the region's almost two billion people live and derive their livelihood. It is also where mangroves, beach systems, mudflats, intertidal areas, seagrass beds and coral reefs thrive naturally and provide vital goods and services, and where the growing impacts of climate change-related sea-level rise are and will be felt most profoundly. An example of a coastal village threatened by sea-level rise is provided in Figure 1.4.

Figure 1.4 Coastal Village in Cambodia Susceptible to Erosion and Sea-Level Rise

This document advocates strongly for recognizing and respecting coastal erosion as a largely natural process, but one severely exacerbated by human expectations and interventions. These pressures include, *inter alia*: human settlement patterns and densities, in both urban mega-cities built on deltas and rural natural resource-dependent coastal communities; rapid and pervasive industrial development; land reclamation; dredging; river-flow regulation (especially dams); coastal tourism infrastructure and impacts such as loss of beaches; aquaculture practices that clear natural defences such as mangroves and wetlands; and hard-engineering structures for protection.

Although coastal erosion is often perceived in short timeframes, typically hours-to-days and related to storm events, it is in fact a dynamic long-term process that is necessary to produce new sediment and sustain these vital coastal systems and the people that depend on them. Problems emerge when we build engineering structures or react to coastal erosion without fully understanding its dynamic spatial and temporal nature and the principles that underlie sediment dynamics. For example, downdrift erosion followed the construction of the International airport runway extension in Kuta Bali, Indonesia (runway extension seen in Figure 1.5, downdrift erosion is not visible). The objective of this regional guidance document is to improve "coastal resilience", that is, the inherent ability of the coast to accommodate changes induced by human settlement, development, extreme events and sea-level rise, while maintaining the functions fulfilled by the coastal system in the long-term. We must work "with" natural processes such as coastal erosion, and not against them.

Figure 1.5 Ngurah Rai International Airport Runway Extension that Caused Downdrift Erosion, Kuta Bali, Indonesia

Coastal erosion becomes a problem along developed coastlines when there is no room to accommodate change. A highly urbanized coastal zone will certainly face difficulties with coastal erosion, such as the example seen in Figure 1.6 for a section of the Malaysian coast. The question is how much room is needed and what human uses are compatible with a dynamic coastline? Unless we know the natural behaviour of the coast, we cannot formulate a sustainable, ecosystem-based, economically rational and socially acceptable coastal management strategy.

Figure 1.6 High Density Urban Development, Malaysia

While it is virtually impossible to do away with natural hazards such as coastal erosion, it is possible to – eliminate those that we cause, minimize those that we exacerbate, and to reduce vulnerability to most. Doing so requires a comprehensive and holistic approach to coastal management that maximizes the health and resilience of communities and ecosystems. The integration of coastal erosion management into Integrated Coastal Zone Management – which is founded on an ecosystem-based approach and has sustainability as its highest goal – is a promising avenue to achieve this. This is particularly true, since many EAS countries have or are developing ICZM frameworks and programmes and have already taken many of the proactive steps that are necessary to accommodate the broader consideration of coastal erosion in the sustainable and ecosystem-based management of the region's coastal systems.

The purpose of this resource document is to provide EAS member countries with a general but sufficient understanding of coastal erosion drivers and processes and a logical framework and approach for addressing this important issue in both a regional and a country-specific context. While the general principles and components of the recommended approach will apply throughout the EAS region, their application must be tailored to the specific conditions and needs in member countries and often the site-specific erosion challenges that are being faced on different types of coastlines, under varying densities of urban and industrial development, and in the context of the health of local ecosystems.

There is abundant information available on coastal erosion from around the world, but it often exists in diverse sources, buried in the grey literature and in languages other than English. A reference list of some of these key resources, updated to 2011, is provided at the end of this report and regional references are included throughout the text where appropriate.

2.0 THE EAST ASIAN SEAS REGION

2.1 Regional Governance

Several regional organizations related to marine and coastal management and sustainable development are operating in the EAS region. The more significant ones are described below.

COBSEA consists of ten member countries: Australia, Cambodia, the People's Republic of China, Indonesia, the Republic of Korea, Malaysia, the Philippines, Singapore, Thailand and Viet Nam. Refer to Figure 2.1 for a map of the region. COBSEA was formed in 1981 as a UNEP Regional Seas Programme Unlike some UNEP Regional Seas Programmes, COBSEA does not operate within the framework of a legally binding convention. Instead, COBSEA's operation is based on the implementation of the "Action Plan for the Protection and Sustainable Development of the Marine and Coastal Areas of the East Asian Seas Region", commonly referred to as the East Asian Seas Action Plan, which was approved in 1983 and revised in 1994. In 2008 COBSEA has adopted the New Strategic Direction for COBSEA 2008-2012, which is based on four interlinked strategic elements: (1) Information management; (2) National capacity building; (3) Strategic and emerging issues; and (4) Regional cooperation. The New Strategic Direction also outlines COBSEA's three priority thematic areas: (i) Marine- and land-based pollution; (ii) Coastal and marine habitat conservation; and (iii) Management and response to coastal disasters. The COBSEA Secretariat is located in the UN Building in Bangkok, Thailand.

Another regional organization working in support of the EAS region's pursuit of sustainable development is the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA). PEMSEA, as an EAS-regional body promotes regional cooperation through the implementation of the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA), as a framework for policy and programme development at the national and local levels. This regional framework document provides direction for policy development in key areas such as integrated coastal zone management, habitat and biodiversity protection, the control of land-based sources of pollution, and the unsustainable harvesting of marine resources.

ASEAN Working Group on Coastal and Marine Environment (AWGCME) is another important regional organization. In line with its mandate as the regional intergovernmental organization, ASEAN has in place the institutional framework and policy framework to promote regional coordination for the integrated protection and management of coastal zones and marine waters. The AWGCME oversees the technical and implementation issues, while the ASEAN Environment Ministers and the ASEAN Senior Officials on the Environment provide policy and strategic guidance for its work. Currently work is focused in the following priority areas: coral reef, sea grass and mangroves; tanker sludge and ballast water; solid, liquid and hazardous waste management; coastal erosion; ecotourism; coastal wetlands, including protected marine areas; and clean technology.

2.2 Socio-Economic Development

East Asia's economic growth is accelerating together with coastal industrialization and increasing exploitation of the region's coastal and marine resources. The region as a whole is highly urbanized, with populations fast transforming from rural to urban. In 1980, about 42 per cent of EAS countries' population lived in urban areas. This proportion is estimated to grow to 69 per cent (a regional total of 1.5 billion people) by 2030, a rate of increase that is about 9 per cent higher than the global average. Currently, at least

50 per cent of the combined population of Singapore, Australia, Republic of Korea, Malaysia and the Philippines live in urban areas, with Indonesia and China projected to join this list by 2030. Although coastal zones do not usually constitute a large proportion of total land area, they tend to be the most urbanized, with the country's largest cities typically located near the sea, along a river bank, or in a delta. With increasing migration from rural to urban areas, the number and density of coastal urban cities are also projected to increase. Coastal settlements that have developed into major EAS cities are among the most populated in the world. Five of the 21 global megacities (cities in excess of 10 million inhabitants) are located in the region and it is estimated that more cities will achieve this status within the next five decades.

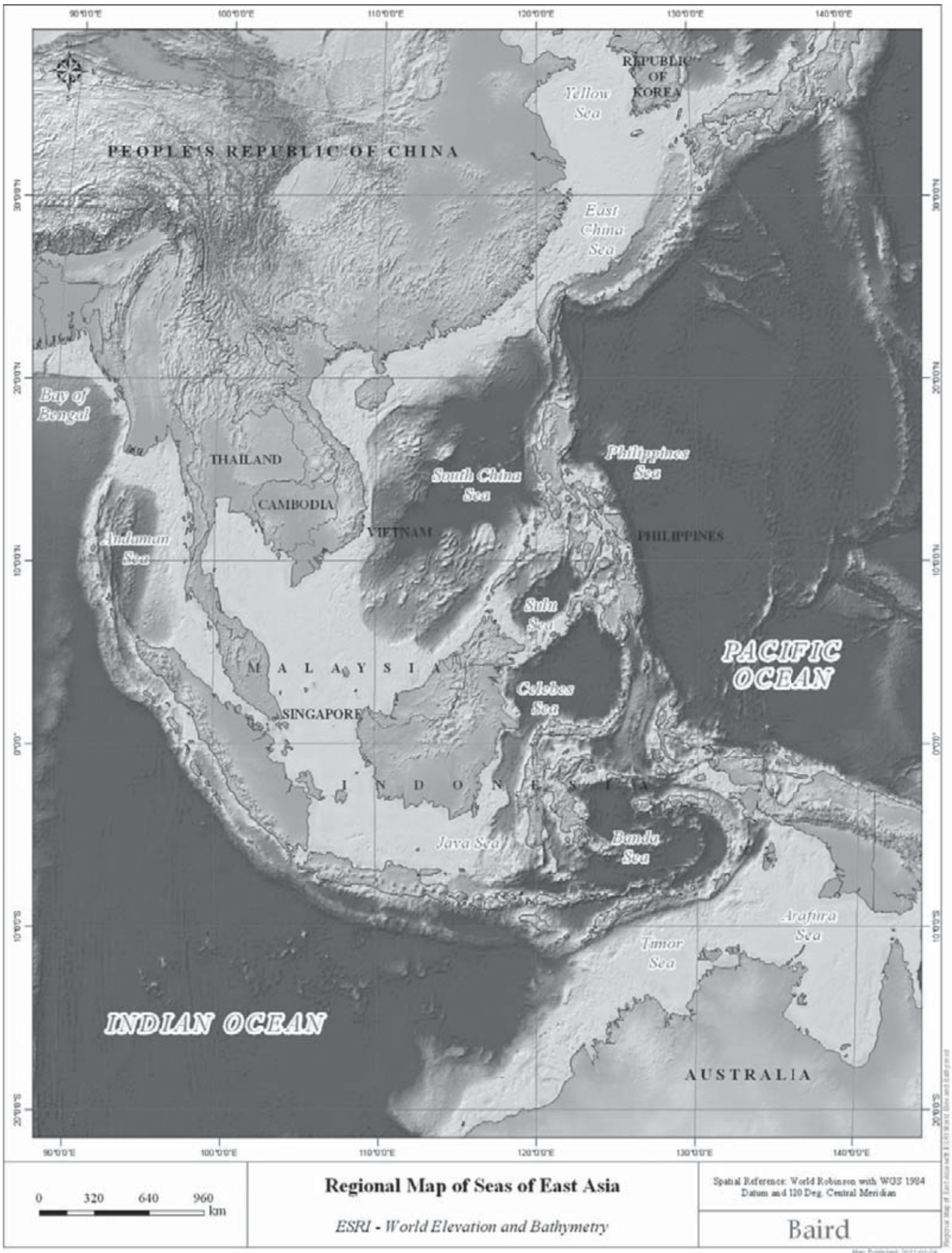


Figure 2.1 Regional Map of the Seas of East Asia

2.3 The Coastal and Marine Environment of the Seas of East Asia

2.3.1 The EAS Region

The East Asian Seas (EAS) region accounts for 14 of the world's 64 semi-enclosed and interconnected Large Marine Ecosystems (LMEs). Seven are distributed along the borders of Cambodia, China, Indonesia, Republic of Korea, Malaysia, Philippines, Singapore, Thailand and Viet Nam, and another seven along that of Australia. They are globally-significant, rich in natural resources, extensively linked by large-scale atmospheric, oceanic and biological processes such as ocean currents and species migration, and of great ecological, social and economic importance to the region.

2.3.2 Coastal Geology

Most of the EAS region is geologically active; it is part of the Pacific "ring of fire" and earthquakes and volcanic eruptions continue to shape the coast and the risks inherent in living there. The shores of East Asia largely follow the tectonically active zones where the Pacific and Indian Ocean plates collide with the mainland Asia plate. Along many stretches of coast, structural trends are generally parallel to the coast. Outside these areas, away from the tectonically-active collision zones, the coastal regions are generally more stable and the structural trends are usually not parallel to the coast; this is the case along most of the Asian mainland from Thailand to northern Asia.

Different coastal types may also be classified according to plate tectonics, particularly the movements and interaction of these plates, which may result in collisions, trailing edges and marginal sea coasts. Coastlines of the EAS region are considered to be mostly either collision coasts or trailing-edge coasts. Collision coasts are typically characterized by the delivery of coarse sediments from montane catchments to coastal zones. Along this type of coastline, it is usual to find narrow continental shelves and deep waters relatively close to shore. Other features of this coastline category include rocky shores with poor beach or reef development as is observed in Indonesia. Trailing-edge coastlines, on the other hand, are often fed by large river drainage systems and contribute huge volumes of fine sediments to wide, low gradient, continental shelves. The geomorphology of Viet Nam for example, is dominated by its extensive deltaic regions. These regions exemplify the trailing-edge category of coastline, with their broad littoral zones, relatively shallow waters, gentle slopes and tidal amplitudes of approximately 4.5 m. More specific details for the individual countries can be found in Bird (2010).

2.3.3 The Coastlines of the EAS Region

Bleakley and Wells (1995) provide a good description of the coastlines of the EAS region. The extent of coastlines varies greatly among the ten EAS countries. Singapore has the shortest coastline of 246 km and the Indonesian archipelago the longest at 95,181 km (Table 2.1). The extensive coastal areas of the region are conducive to settlement and livelihood. There are Hundreds of natural harbours and some have become among the most important ports in the world. Refer to a Korean example of a large port in Figure 2.2.

Figure 2.2 Large Harbour and Port Facilities in Korea

According to recent estimates, close to 75 per cent of the region's human population of almost 2 billion live in the coastal areas. Cambodia and China have the lowest proportion of coastal populations at 24 per cent each, while for the Philippines, Republic of Korea and Singapore, the entire population lives within 100 km of the coast.

Table 2.1 Coastline extent and percentage of population living within 100 km of the coast (COBSEA countries and globally)

	Coastline Extent (km)	Coastal Population (percentage within 100 km of coast)
Australia	59,736	89.8
Cambodia	455	23.8
China	32,000	24
Indonesia	95,181	95.9
Republic of Korea	12,750	100
Malaysia	4,809	98
Philippines	36,289	100
Singapore	246	100
Thailand	3,148	38.7
Viet Nam	3,260	82.8
EAS Countries	**247,874**	**73.7**
World	**1,634,700**	**39**

Sources: UNEP/COBSEA, 2010. State of the Marine Environment for the East Asian Seas and corrective statistics provided by member countries.

Comparatively straight coasts, situated along mountain chains, sometimes with river deltas and local alluvial foreland, are found mainly in western Sumatra, southern Java and northern Viet Nam. A drowned, older topography with irregular coastline is present in parts of southern Viet Nam, the mainland coast north of the Red River, on the islands of eastern Indonesia, on northern Kalimantan (Borneo) and the Philippines. Elsewhere, the coast is predominantly depositional, consisting of beaches, spits, barriers, tombolos, mudflats, coral reefs, and mangrove forests and estuaries, such as those seen in Figure 2.3.

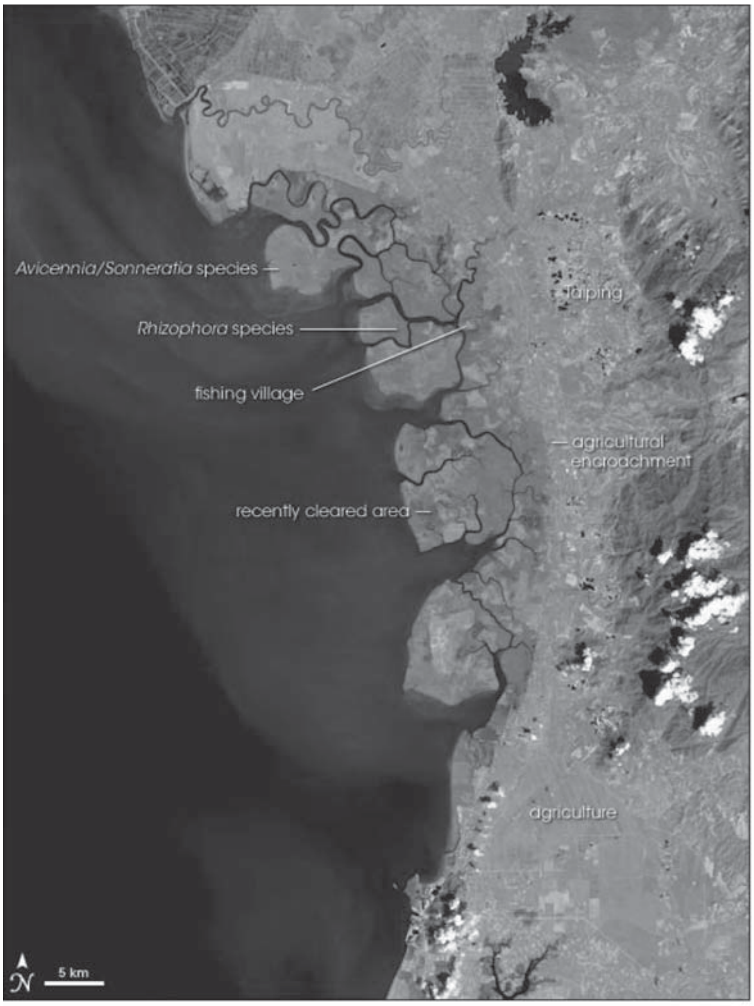


Figure 2.3 Matang Estuary and Mangrove Forest, Malaysia

The EAS marine region includes the extensive archipelagos of Indonesia and the Philippines (the two largest archipelagos in the world); Indonesia alone has 17,480 islands. There are also numerous islands off the coast of mainland Asia. Island types range from coral cays to raised limestone, volcanic and continental islands such as Java and Borneo.

Rocky shores occur on the coasts of many East Asian islands, such as the west coast of Thailand (Figure 2.4). In addition, the southwest cost of Sumatra and the Pacific coastline of the Philippines and Sulawesi have extensive rocky topographies. Smaller rocky outcrops and boulder formations are common above coral reef flats and on headlands bordering sandy bays. Wave erosion of limestone creates sheer or fissured cliffs with little to no beach formation.

Figure 2.4 Rocky Coastline near Ko Lanta Yai, Thailand

Sandy beaches occur extensively on the shores of coral islands and are interspersed among other shore formations throughout continental Asia. Refer to Figure 2.5 for an example from Viet Nam. Steep beaches of coarse sand are built up on ocean-facing coasts exposed to strong surf. Intertidal flats of mixed sediments, with a narrow sand fringe at high-water mark, develop on more protected shores. Marine turtles nest on the sandy beaches throughout many areas of the East Asian Seas.

Figure 2.5 Sandy Beach, Quang Binh Province, Viet Nam

2.3.4 Meteorological and Oceanographic Factors

The EAS region is strongly influenced by monsoons and typhoons. One of the important characteristics of any ocean system is the degree of energy transfer from the atmosphere to the ocean surface, which essentially corresponds to the scale of wave development. Different wave types in the EAS region are storm waves, west-coast swell, east-coast swell, and tropical cyclone-influenced waves (Viles and Spencer, 1995). Surface waters in the region have high temperatures and are of low density and salinity (average 34 ppt). Annual temperature variations in surface waters are small (26-30^{o}C).

Tides are another vital component of coastal dynamics, in that they generate strong currents, transport sediment, influence the zonation and ecology of coastal organisms, and ultimately shape the geomorphology of coastlines (especially for muddy coastlines). Tidal ranges in the EAS region vary from meso-tidal (a tidal range of 2-4 m) for most coastlines, to macro-tidal (in excess of 4 m) in the far north (China and Republic of Korea) and far south (Australia).

There are a variety of geohazards in the EAS region which can cause extensive economic damage and human tragedy. Floods appear to be the more dominant natural disaster throughout Asia, affecting 60 per cent of the total number of people exposed to all types of natural disasters. The region’s vulnerability was demonstrated by the tragic events surrounding the tsunami that struck the coastlines of several EAS countries in December of 2004. Many corals were affected, particularly adjacent to the intertidal zone. The enormous rebuilding effort, that started after the disaster and continues to this day, offers an opportunity to plan the placement of roads, walls, resorts, hotels, houses and aquaculture installations more wisely. The replanting of mangroves is considered essential, such as the efforts seen in Figure 2.6 in Thailand. The devastating effects of the tsunami highlighted the need for an increased focus on disaster prevention and response, especially in coastal areas. Improved and integrated coastal development planning and the strengthened implementation of policies and plans to prevent and respond to coastal natural disasters are now being given increasing priority by EAS countries.

Figure 2.6 Mangrove Restoration for Erosion Mitigation, Thailand

2.3.5 The EAS Catchment Areas

The upstream river basins that are the catchment areas of the Seas of East Asia cover a total area of about 6.25 million km^2 and accommodate about 1.5 billion people. Therefore, the health of the EAS region is significantly impacted by these river basins and related human activities (PEMSEA, 2003).

Erosion of inland soils provides considerable amounts of terrestrial sediments to the coast in some areas. The levels of suspended solids in Asia's rivers have quadrupled since the late 1970s (ADB, 2001) and two-thirds of the world's total sediment transport to oceans occur in Southeast Asia (UNEP, 1999a). These sediments, together with those derived from coastal features (e.g., eroding cliffs and marine sand banks) can provide essential material for the development of offshore reefs, mudflats, salt marshes, sand beaches, sand dunes and transitional marshes. In turn, these coastal habitats provide a wide range of outstanding benefits including locations for economic and recreational activities, reduction in eutrophication of coastal waters, nesting and hatching of fauna species, such as marine turtles, and importantly, protection from flooding in low-lying areas and absorption of wave energy during storm surges. There can also be negative ecological problems associated with too much sediment or sediment with poor environmental quality. More importantly, the widespread damming of many of these sediment-laden rivers has severely reduced the sediment supply to the coast, thus further exacerbating coastal erosion (Saito, 2007).

2.4 Critical Ecosystems

The EAS region covers a large geographic region and it is not possible to describe all of the coastal zone ecosystems found within the region. The following sections summarize general information about the four most widespread ecosystems found within the region: coral reefs, mangroves, seagrass beds and beaches.

2.4.1 Coral Reefs

The EAS region contains almost half of the world's coral reefs (Wilkinson, 2008). Refer to Table 2.2 for details. Coral reefs are among the most biologically rich and productive ecosystems on earth. Coral reefs provide jobs, livelihoods, food and shelter, generate the sand on tourist beaches and provide protection for coastal communities and the shorelines along which they live. Coral reefs typically mitigate 75 to 95 per cent of wave energy, but are less effective for large waves or storm surges during storm events. Fringing reefs are most common and are present around most small-to-medium-sized islands. Reefs are less common on mainland coasts and on larger islands, particularly around rivers. The Philippines and Indonesia support the most extensive areas of coral reef in the region (84 per cent). Well-developed reefs are also found off the southern coasts of Thailand, on the offshore islands of Viet Nam, on the east coasts of Peninsular Malaysia and off Sabah.

Table 2.2 Summary of the Three Major Coastal and Marine Ecosystems in EAS Countries

	Habitats (thousands of km^2)		
	Mangroves	**Seagrasses**	**Coral Reefs**
Australia	14.5	96.3	49.0
Cambodia	0.73	N/A	0.05
China	0.22	0.02	1.51
Indonesia	30.6	30.0	51.0
Republic of Korea	N/A	0.07	N/A
Malaysia	5.65	0.003	3.6
Philippines	2.47	0.98	25.1
Singapore	0.005	<0.001	0.05
Thailand	2.44	0.094	2.13
Viet Nam	1.58	0.44	1.27
EAS Total	**58.2**	**128**	**132.5**
Global Total	**157.1**	**177**	**284.8**
EAS as % of Global Total	**37.1%**	**72.3%**	**46.9%**

Source: State of the Marine Environment …

The coral reefs of the broader Southeast Asia region alone are estimated to generate goods and services valued at US$ 112.5 billion annually (PEMSEA, 2003). Beyond their biological value, the physical structures of coral reefs dissipate wave energy, thus reducing routine erosion and lessening inundation and wave damage during storms. Unfortunately, reefs today are facing multiple threats from both local and global pressures, chief among them being warming and acidifying seas. Mass coral bleaching is becoming more widespread and frequent. According to UNEP, in the last 70 years, nearly 70 per cent of the original coral reefs bordering the South China Sea have been destroyed with a resultant loss of biodiversity and ecological goods and services that coral reefs provide, such as fish habitat and wave attenuation. The coral reefs of South East Asia are the most threatened of any region in the world; the recently released report “Reefs at Risk Revisited” (2011) indicates that nearly 95 per cent of these reefs are threatened and about 50 per cent are in the high or very high threat category. Indonesia has the largest area of threatened reef, followed by the Philippines. Overfishing and destructive fishing pressure (such as blast and poison fishing) drive much of the local threat in this region, followed by watershed-based pollution and coastal development. The continuing degradation and loss of coral reefs, which provide essential services such as shoreline protection, will make the job of protecting coasts and managing coastal erosion, all the more difficult in the future. The resilience of the coasts of the EAS region is being diminished.

2.4.2 Mangroves

About 35 per cent of the world’s mangroves occur in the EAS region. Indonesia has the greatest area of mangroves (3,060,000 ha), followed by Malaysia, with 565,000 ha, Thailand and Philippines with about 250,000 ha each, and Viet Nam with 158,000 ha. Refer to Table 2.2 for a summary and Figure 2.7 below for the spatial coverage.

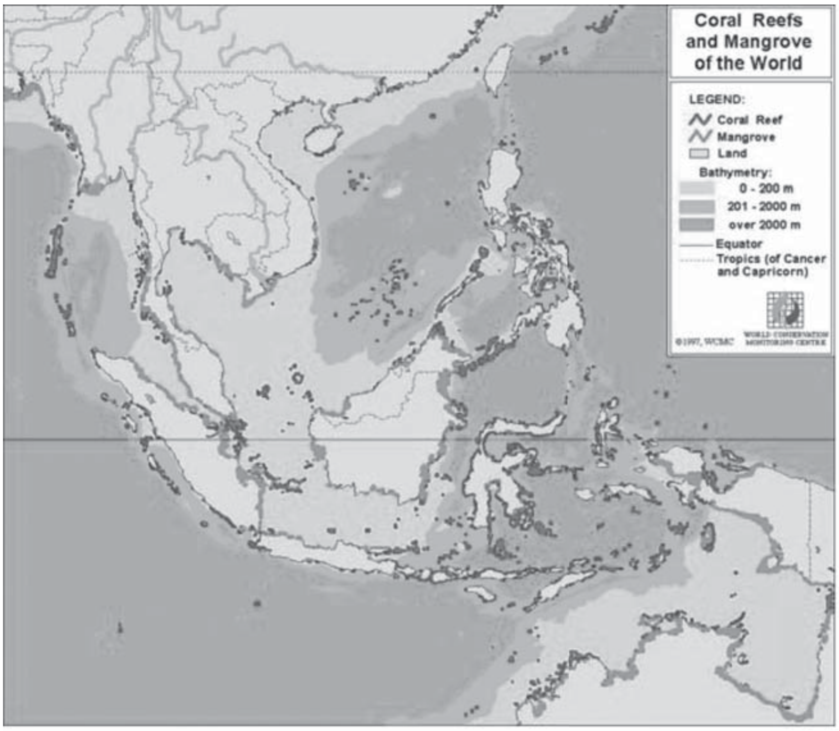


Figure 2.7 Coral Reefs and Mangroves in the SEA Region

Mangroves protect the coast from storms and typhoons, serve as flood control and mitigate the effects of siltation on coral reefs and sea-bed communities. An oblique aerial view of a mangrove forest in Malaysia is provided in Figure 2.8. They are extremely important habitats, maintaining coastal integrity and supporting vast amounts of wildlife, many of which are of high commercial importance. However, mangroves do not grow naturally on sites with strong erosion. Economic assessments provide some of the most powerful arguments in favour of mangrove management, protection or restoration. Studies estimate that mangroves generate between US$ 2,000-9,000 per hectare annually, considerably more than alternative uses such as aquaculture or agriculture.

Figure 2.8 Coastal Mangrove Forest, Malaysia

The recently released UNEP World Mangrove Atlas[1] details extraordinary synergies between people and forests:

> *Mangrove forests help prevent erosion and mitigate natural hazards from cyclones to tsunamis – these are natural coastal defences whose importance will only grow as sea-level rise becomes a reality around the world. Given their value, there can be no justification for further mangrove loss.*

Despite their importance, mangroves are threatened habitats mainly from reclamation and pollution; clearing, illegal cutting and conversion for expansion of aquaculture has been cited as a major cause of the destruction of over 3 million hectares of Southeast Asia's mangrove forests. In Viet Nam, mangrove cover has decreased by about 50 per cent since 1943. There was a 25 per cent decrease in mangrove cover between 1979 and 1987 in Thailand and in the Philippines, mangroves are estimated to cover about 20 per cent of that present in 1920s and about half the remaining forest is composed of secondary growth. Figure 2.9 provides an aerial view of mangrove clearing for agriculture in the Philippines.

Figure 2.9 Mangrove Clearing for Aquaculture and Community Development, Roxas City, Philippines

Encouragingly, many EAS countries are now embarking on major restorations, a positive signal upon which to build and accelerate a definitive response. Mangroves have been actively planted or encouraged to grow in Indonesia, the Philippines, Thailand and Viet Nam. There are no mangroves in Korea. Mangroves are recognized as an important greenbelt that protects the coastal areas from natural disasters such as tsunamis, cyclones and erosion resulting from sea-level rise, especially in small-island countries. There is good evidence that mangroves even reduced the impact of the 2004 Indian Ocean tsunami in a number of locations.

[1] World Mangrove Atlas http://www.fao.org/forestry/7003-1-0.pdf.

By way of example of how mangroves can be employed in coastal protection, and also their limitations, more than 3,000 ha of mangroves have been planted along the coast of Soc Trang (Mekong Delta, Viet Nam) since 1993, with the aim of protecting the sea-dyke and coast from erosion and the land from storms. But in areas of high erosion energy, some of these forests have been completely destroyed, along with the earth dyke that protects people and farmland. The project – Management of Natural Resources in the Coastal Zone of Soc Trang Province (Albers and von Lieberman, 2011) – therefore decided to set up an erosion control model which combines breakwaters and mangroves (i.e., "hard" and "soft" solutions) to reduce erosion and stimulate sedimentation. When properly designed in the right environmental conditions, mangroves are a promising green engineering solution to erosion.

2.4.3 Seagrasses

Seagrasses typically form dense beds which cover large areas of coastal waters and perform a wide spectrum of biological and physical functions. Refer to an example from South Sulawesi, Indonesia in Figure 2.10. They support marine food webs and provide essential habitat for many coastal species, playing a critical role in the equilibrium of coastal ecosystems and human livelihoods. The value of ecosystem services of seagrasses has been estimated at US$ 34,000 per hectare per year (Constanza et al., 1997). The complex root structure of seagrass beds secures and stabilizes sediments, providing essential shoreline protection and reduction of coastal erosion from extreme storm events. Seagrasses are considered the world's most widespread shallow marine ecosystem and the EAS region has 72 per cent of the world's total seagrass areas, yet it is the least studied of the three major ecosystems regionally. Several studies have indicated that seagrass habitat is declining worldwide (Short et al., 2011). Coastal development (land reclamation, dredging and shoreline hardening) as well as water quality degradation (eutrophication) are considered the greatest threats to seagrass ecosystems all over the world, with those in the EAS region among the most threatened.

Figure 2.10 Seagrass Bed in Bone Batang, South Sulawesi, Indonesia

2.4.4 Beaches

Given the vast geographic area of the EAS region, it features a wide variety of beach types from gently sloping fine grained muddy shorelines to coarse grained steep rocky beaches, often in areas that feature bedrock outcrops. Carbonate sand beaches are common along coastlines that are fringed with coral reefs and highly dependent on healthy coral ecosystems to produce new beach building material. Regardless of their sediment characteristics, beaches are an important ecosystem in the EAS region for ecological and societal reasons. For example, beaches provide the critical transition from coral reefs and seagrass beds to upland terrestrial ecosystems. They are also often a focal point for coastal communities, providing access for fishing vessels, recreational pursuits and other community activities. Beaches are dynamic by nature and most resilient to erosion and sea-level rise when left in a natural state. However, when a negative sediment budget develops in a coastal cell, erosion often occurs and the beaches degrade. They are also threatened by engineered shoreline protection when built on eroding beaches, which further degrades the quality of the habitat they provide.

2.5 Climate Change Considerations

The State of the Marine Environment Report for the EAS region (2010) highlights that climate change has already begun to affect the coastal areas of the EAS region, particularly its deltas and estuaries. The evolution of the major deltas depends on changes in both ocean processes and sediment flux. Rising sea-levels and the increasing number of extreme weather events, often generating storm surges, increase the coastal erosion of deltas (which is often further exacerbated by the excessive pumping of groundwater). Storm surge heights could also increase as a result of stronger winds, higher sea-surface temperatures and the low pressures associated with tropical storms, resulting in an increased risk of coastal disasters. Climate change can also have an impact on the timing and magnitude of rainfall, which affects run-off characteristics of a region. Overall, trends indicate both rising temperatures and also an increase in rainfall variability. Saltwater intrusion into estuaries may be pushed 10-20 km further inland in some areas by rising sea-levels. Projected increases in the frequency and intensity of extreme weather events would exert adverse impacts on estuarine flora distribution which plays an important role in coastal protection.

The projected rise in sea-levels would have serious impacts on the coastal areas of the EAS region. Rising sea-levels will inundate low-lying coastal wetlands, other flat and low-elevation coastal areas and coastal cities, resulting in land loss, population displacement and socio-economic impacts that affect a number of sectors, such as agriculture, coastal aquaculture and coastal tourism. The cost of response measures to reduce the impact of sea-level rise is potentially immense. Land migration of mangroves and tidal wetlands is expected to be constrained by human infrastructure and human activities in many areas. Protection of low-lying areas will be weakened by past removal of natural buffers such as mangrove forests.

The current rate of sea-level rise (SLR) in the EAS region is 1-2 mm/yr, which is marginally higher than the global average (Cruz et al., 2007). However, in East Asia specifically, the rate of SLR has varied considerably from 1.5-4.4 mm/yr, due to regional variation in land surface movement. The potentially catastrophic consequences of even a small rise in sea-levels are obvious. In some coastal areas, a 30 cm SLR could result in 45 m of landward erosion (Cruz et al., 2007). Even with a conservative SLR estimate of 40 cm by 2100, nearly 19 million people living in low-lying coastal areas of the region would be flooded annually, with Thailand, Viet Nam, Indonesia, Cambodia and the Philippines hardest hit, particularly their deltaic areas. In China alone, a SLR of just 30 cm would inundate more than 80,000 km^2 of coastal lowland. Many megacities in the EAS region are located in low-lying coastal deltas and are therefore especially vulnerable to threats by climate change, sea-level rise and extreme events. Sea-level rise on low elevation coastal zones is estimated to affect as much as 55 per cent of the population of Viet Nam, 26 per cent in Thailand, 18 per cent in the Philippines, and 11 per cent in China (McGranaham et al., 2007).

In more severe predictions, a SLR of 1 m would affect Viet Nam and the Philippines significantly. In this scenario, 5,000 km^2 of the Red River delta and 15,000-20,000 km^2 of the Mekong river delta would be inundated. Roughly 2,500 km^2 of mangroves would be lost and 1,000 km^2 of cultivated farmland and agriculture would become salt marshes. The number of people living in the Mekong Delta area that would lose their homes is projected to be around 14 million (WGCCD, 2007). In the Philippines, a recent study concluded that a SLR of 1 m would affect 64 out of 81 provinces, inundating almost 700 km^2.

Relative sea-level rise in China has been recorded at about 2-3 mm/yr for the past 50 years. It is expected that by 2050, the sea-level will have risen by almost 0.5 m in certain areas, such as Huanghe Delta, making storm surges a major challenge. For Indonesia, it has been estimated that sea-level rise may result in 2,000 small islands being lost by 2030, up to 160 km^2 of northern Jakarta being flooded by 2050, and a total land loss of more than 90,000 km^2 by 2100. Sea-level rise along Thailand's coastline could result in significant saltwater intrusion up rivers, threatening the country's most fertile agricultural areas.

As socio-economic conditions vary widely within the EAS region, climate change has potentially varying impacts on the coastal and marine environments of its constituent countries. Significantly, the rural poor in coastal areas are the most vulnerable, as they have very few resources to protect themselves from the potential impacts of climate change. A highly vulnerable coastal community in Matnog, Sorsogon, the Philippines is presented in Figure 2.11.

Figure 2.11 Erosion Threatens a Coastal Community, Matnog, Sorsogon, Philippines

EAS countries vary widely in the extent to which they are integrating adaptation into their national planning and also in their prioritization of coastal areas in adaptation strategies. Already, national and local laws have been written and enacted to protect the coastal environment. Future measures include: new standards for raising dikes; improved coastal rehabilitation; and the establishment of marine protected areas. Viet Nam is focusing on its deltaic area and has adopted the IPCC adaptation framework, combining three strategic options – full protection, adaptation and withdrawal. Thailand has incorporated adaptation options into the wider framework of their coastal hazard management strategy and Malaysia utilizes an ICM framework based on five measures: defend, accommodate, retreat, counter-attack, and coastal land buy-back. Coastal defence remains a high priority in Indonesia where ICM is usually used as a short-term strategy only, although a long-term adaptation strategy for coastal areas has also been adopted.

Table 2.3 summarizes some possible impacts to coastal areas associated with sea-level rise, identifies adaptation strategies and the relative cost of these measures. These findings were adapted from Maribus (2010) and are not an exhaustive list of potential impacts to the East Asian Seas Region, nor does it identify all the potential adaptive measures. However, the table does provide a useful framework to consider the types of impacts that sea-level rise will have within the region, and review the types of management solutions and associated costs.

Table 2.3 Summary of Possible Sea-Level Rise Effects, Adaptive Measures and Costs

Effects of Sea-level Rise on Natural Coastal Systems		Possible Protective/ Adaptive Measures Protective-[P] Adaptive-[A] Retreat-[R]	Relative Costs
Flooding of low-lying areas and resultant damage	Storm tides	Dykes and flood barriers **[P]**	Very high (construction, maintenance)
	Backwater in estuaries	Artificial dwelling mounds, flood-proof building (standards) **[A]**	Medium to high
		Identification of risk zones **[A/R]**	Low to medium (enforce)
		Adapted land-use and landscape planning **[A/R]**	Medium (recurrent)
Loss of or changes to coastal wetlands and mangroves		Adapted land development planning **[A/R]**	Low to medium (on-going)
		Dyke relocation **[A/R]**	Very high (one-off)
		Foreshore reclamation **[P/A]**	High (recurrent)
		Beach nourishment, sediment protection **[P]**	Medium/Low (on-going)
Direct and indirect morphological changes, particularly erosion of beaches and bluffs		Construction of groynes, bank protection, sea walls **[P]**	Medium to high (construction)
		Beach nourishment, dune protection **[P]**	Medium to high (on-going)
		Underwater reefs, breakwaters **[P]**	Medium to high (construction)
		Development-free zones **[R]**	Low to high (enforce)

Effects of Sea-level Rise on Natural Coastal Systems		Possible Protective/ Adaptive Measures Protective-[P] Adaptive-[A] Retreat-[R]	Relative Costs
Intrusion of saltwater	Into surface water	Dams and tide gates to prevent influx of saltwater **[P]**	High (construction, maintenance)
	Into ground water	Adapted/reduced withdrawal of water **[A/R]**	Low to medium (on-going)
		Pumping in of freshwater **[P]**	Medium (recurrent)
		Adapted withdrawal of water **[A/R]**	Low (permanent)
Higher (ground) water levels and limited soil drainage		Soil/land drainage improvement **[P]**	High (on-going)
		Construction of pumping stations **[P]**	Very high (construction, maintenance)
		Altered land use **[A]**	Low to medium (enforce)
		Designation of flood/high-risk areas **[A/R]**	Low to medium (enforce)

A detailed review of adaptation strategies for coastal erosion and flooding was also generated in Chapter 4 of a recent UNEP report entitled “Technologies for Climate Change Adaptation” (Zhu, 2010). For example, the report describes the technical advantages and disadvantages, institutional requirements, costs, barriers for implementation and a relevant case study for each strategy. The strategies are listed in Table 2.4, which was reproduced from the UNEP report, along with a ranking of the knowledge requirements to successfully implement each strategy.

Table 2.4 Knowledge Requirements for 13 Coastal Erosion and Flooding Adaptation Strategies

(dark shading)	**Essential**
(light shading)	**Secondary**
(no shading)	**Irrelevant**

	Beach Nourishment	Artificial Dunes and Dune Rehabilitation	Seawalls	Sea Dikes	Storm Surge Barriers and Closure Dams	Land Claim[1]	Flood Proofing	Wetland Restoration	Floating Agricultural Systems	Flood Hazard Mapping	Flood Warnings	Managed Realignment[2]	Coastal Setbacks
RSLR scenarios	Secondary	Secondary	Essential	Essential	Essential	Essential	Essential	Secondary	Secondary	Essential	Secondary	Secondary	Secondary
Extreme water levels[3]	Secondary	Essential	Essential	Essential	Essential	Essential	Essential		Secondary	Essential			Secondary
Wave climate[3]	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential		Essential	Secondary	Secondary	Secondary
Nearshore bathymetry	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Secondary		Essential	Essential		Secondary
Tidal regime[4]	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Essential	Secondary	Secondary	Secondary	Essential	Secondary
Historic flood information	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary		Secondary	Secondary	Secondary	Secondary
Land cover										Essential	Essential	Secondary	Secondary
Coastal topography							Essential	Essential		Essential	Essential	Essential	Secondary
Level of coastal protection							Essential			Essential	Essential		Secondary
Settlement[5]	Secondary	Secondary	Secondary	Essential		Essential							
Sediment characteristics	Essential	Essential	Secondary	Secondary	Secondary	Secondary		Essential				Essential	
Availability of suitable dredge sites[5]	Essential	Essential 7				Essential 8		Secondary					
Local sediment budget	Essential	Essential	Secondary	Secondary	Secondary	Secondary		Secondary					
Desired dry beach width	Essential	Secondary											
Historic erosion rates	Essential												Secondary 10
Historic habitat distribution and cause of decline		Essential						Essential				Secondary	
Vegetation	Secondary	Essential						Essential				Essential	
Floodwater velocity							Essential			Secondary	Secondary		
River discharge[3]					Essential 11						Essential		
Meteorological observations/forecasts					Essential 11						Essential		
Effective warning dissemination											Essential		
Warning threshold					Essential 11						Essential		
Construction of floating beds									Essential				
Cropping patterns									Essential				

3.0 A REGIONAL APPROACH TO THE SUSTAINABLE AND ECOSYSTEM-BASED MANAGEMENT OF COASTAL EROSION IN THE EAS REGION

The obvious interconnectivity between land and sea activities, the regional economy, social well-being and functional ecosystems makes it essential to adopt a new paradigm in coastal governance and in dealing holistically with coastal erosion.

3.1 Goal

The terms of reference for this project are based on a growing body of observational and scientific evidence that coastal erosion is a significant and increasingly important threat confronting the EAS Region and its member countries, peoples, economies and societies. The focus is becoming even sharper as the growing threat of climate-change related sea-level rise and increased storminess is predicted to and is already having serious impacts throughout the region. The call for more "protection against coastal erosion" at regional, national and local levels is natural, but often leads us to reactive, short-term and typically engineered responses. We do so without necessarily considering the dynamic land-sea nature of coasts and that the eroding and accreting sediments we are worried about are but one dimension of a broader and inter-connected human, social, economic and ecological system that provides essential goods and services that sustain us. Therefore, and within this broader perspective on coastal erosion, the goal for the EAS Region and its member countries should be:

> *To facilitate and provide guidance for the effective management of coastal erosion in the Seas of East Asia region and member nations, with a view to improving coastal resilience and thereby reducing the impacts on ecosystems, the economy and the safety, health, quality of life and livelihoods of the peoples of the region. This will be done in an ecosystem-based and sustainable manner, within an Integrated Coastal Zone Management Framework.*

3.2 Framing Questions

As a starting point, and to frame this approach to coastal erosion management, we must answer the following basic questions: (i) What is vulnerability? (ii) What is vulnerable in the EAS region? (iii) Where is it vulnerable? (iv) Who is vulnerable? (v) How have they become vulnerable? and (vi) What are the right approaches to reduce vulnerability?

These important questions were addressed and discussed at some length during a COBSEA-sponsored workshop on climate change, sea-level rise and coastal erosion held in Bangkok, Thailand on 25-27 April 2011. Presentations made on country-specific conditions in Cambodia, Indonesia, Korea, Malaysia, the Philippines, Thailand and Viet Nam provide detailed insights on the specific nature of those countries' vulnerability, some of the impacts they are experiencing and the measures taken to date to address the issue. Examples from these countries are included throughout the following sections.

What is vulnerability?

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability or extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its ability to adapt. The opposite of vulnerability is resilience, or the ability to resist and/or recover from damage.

What is vulnerable?

The people, infrastructure, ecosystems and livelihoods of the EAS region are vulnerable to a variety of pressures and risks, including coastal erosion. Refer to the eroding coastal village in X, Malaysia in Figure 3.1. These threaten the socio-economic objectives of sustainable development that have been embraced for the region. This is true in the major urban centres of the region and for the rural poor, both of whom aggregate in a very narrow strip of land along the sea. It is equally true for the coastal natural resources of the region that provide the foundation for human benefits. As the natural protective resources of the coast continue to be degraded and lost (e.g., mangroves, unrestricted beach systems, seagrass beds, wetlands and coral reefs), the overall health of the people, economy and society also decline.

Figure 3.1 Erosion Destroys Coastal Community in Pantai Sabak, Kelantan, Malaysia

The traditional resource-based activities such as coastal fisheries, aquaculture, forestry and agriculture are found side-by-side throughout the EAS region with activities such as shipping, tourism and industrial activities such as refineries, petrochemical manufacturing, food processing, shipbuilding and repair. Refer to the large port in Figure 3.2. Another natural resource issue anticipated to worsen in the coming decade is that related to over-exploitation of mineral resources, primarily sea sand. Many EAS countries are currently alert to the impact of current and projected rates of resource extraction, and are attempting to find sustainable ways of exploiting these resources in the future.

Figure 3.2 Large Industrial Complex Constructed in the Coastal Zone, Thailand

Where is it vulnerable?

Vulnerability exists coast-wide in the EAS region, although to varying degrees dependent on the type of coastline in question, the level, pattern and density of human development and the degree to which natural protective features are intact. We must gain a more detailed understanding of where in the region coastal erosion is occurring, the factors that create vulnerability or exacerbate the threat, and the best way of responding to its impacts today and planning strategically for what is predicted to come.

By way of example, Bangkok is one of the most vulnerable cities to sea-level rise in the whole of Asia. Bang Khun Thain (the only district in Bangkok province that is located on the coast), has a coastline of 4.7 km where coastal erosion is taking place at a rate of 20-25 m per annum near one village. A sample of dramatic coastal erosion is provided in Figure 3.3. A recent study conducted to determine household adaptation strategies for coastal erosion and flooding in this district (Jarungrattanapong and Manasboonphempool, 2008) determined that thirty years of individual effort to protect their shrimp ponds through the application of stone breakwaters, bamboo revetments, dyke heightening, inland retreat and renovating after flooding, cost on average US$ 3,130 per household (roughly 23 per cent of an average household income) and negatively affected their neighbours when they did not act as a group. The study recommended that protection measures should be planned for the entire upper Gulf of Thailand and not individually for small coastal area by the local government.

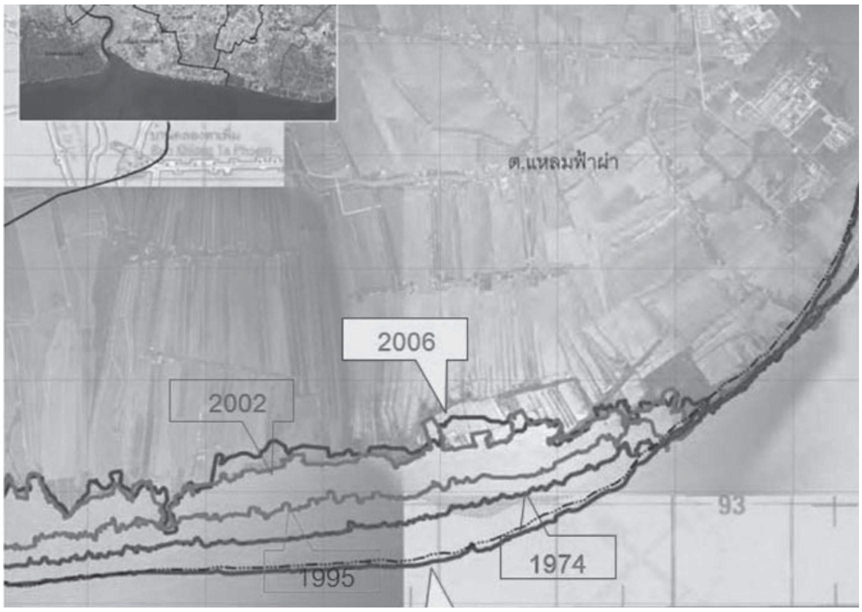


Figure 3.3 Coastal Erosion Impacts in Bangkok, Thailand

Who is vulnerable?

Both urban residents in densely populated mega-cities and rural coastal communities are vulnerable to the impacts of coastal erosion. Urban coastal populations are vulnerable most often because of where and how intensively they have built, the development benefits they derive from locating there, and the reduction of options for adaptation. Rural, or less densely-populated coastal communities, which are often poor and not necessarily sharing in the region's development benefits, are also less capable of dealing with the on-the-ground impacts of coastal erosion events. We must imagine and implement different strategies for reducing vulnerability for different types of coastal communities and coastline types. Being the region worst affected by natural disasters, combined with high population densities and the large number of people living on flood plains and low-lying coastal areas, the vulnerability of the people of East Asia is high.

How have they become vulnerable?

While coastal erosion is a natural phenomenon, it is frequently exacerbated by human interventions. This may result from building too close or too intensively in high-risk coastal areas; removing, degrading or interfering with natural protective features such as mangroves; building "hard" protective infrastructure that reduces or removes adaptive capacity; or simply being located in low-lying areas that will feel the impacts of a changing climate. The development pattern in the EAS region is clear, so the challenge and opportunity is to better understand our levels of current and emerging risk, to take a more holistic view of how the coast functions and interacts with human systems and expectations, and place coastal erosion into a broader framework of integrated ecosystem-based management.

The traditional response to coastal erosion has been to build coastal structures such as groins, piers and jetties to prevent beach sediment loss or stabilize navigation channels. Figure 3.4 presents an example of breakwaters protecting a river mouth in Malaysia used for navigation. However, these structures also delay the littoral drift of sand naturally caused by long-shore currents, resulting in a change to the coastal sediment budget. This may result in the gradual formation of a new coastline altogether, with degradation in some coastal areas and progradation in others. Viet Nam has identified an increasing number of areas already suffering from sand deficits (roughly 284 km^2), the landscapes of which have been dramatically impacted. Human settlements affected by sand deficits or a negative sediment budget may have to be relocated due to coastal erosion.

Figure 3.4 Shore-connected Breakwaters at Marang River Mouth, Malaysia

Coastal development in West Java Indonesia, which involved the deforestation of mangroves, resulted in changed coastal dynamics which caused extensive erosion along that coastline, estimated to retreat 1-10 m annually. However, a number of other factors are implicated. Firstly, a large part of that coast's sediment budget has historically been supplied by nearby rivers, but many of these have now been dammed for flood control purposes and water catchments, resulting in a decreased amount of sediment supplied to the coast. Additionally, many countries are practicing coastal sand mining, usually for the purpose of land reclamation, which may change beach gradient and hasten coastline erosion. An example of sand mining is provided in Figure 3.5.

Figure 3.5 Sand Mining in the Coastal Zone

What are the right approaches to reduce vulnerability?

In order to reduce vulnerability of populations, infrastructure and livelihoods, it is necessary to look at coastal erosion, not in isolation, but as one factor that continues to shape and threaten the people and ecosystems of the region. The following sections will outline the challenges, principles, and concepts that will allow for a sustainable and ecosystem-based approach to deal with coastal erosion in the EAS region.

3.3 Challenges/Constraints

An analysis of recent research on the coastal areas of the EAS region and the material presented by national focal points and experts at the April 2011 COBSEA workshop on climate change, sea-level rise and coastal erosion, identified a number of challenges and constraints related to the management of coastal erosion:

- There is limited and incomplete information on the causes, extent, severity and trends of coastal erosion on a regional, national and local level;

- With increasing urbanization of the EAS coasts, the demand for coastline defences and erosion control also increases. This could lead to a self-reinforcing effect as additional property and economic activities require further and often more robust defences. Short-term economic gain often stimulates this development, without taking into account erosion risk and potential downdrift impacts of sea defences. These developments all lead to reduced coastal resilience since the coastline has nowhere to move;

- There is a widespread perception that coastal erosion is always irreversible, especially for example, immediately after a storm event when erosion if more evident. This sometimes results in a call from both local residents and political representatives for hard engineering works to be constructed. There is little public awareness of the physics behind coastal processes that cause the difference between structural and episodic erosion. For example, erosion can be followed by coastal accretion when boundary conditions change, either at a seasonal, annual or much longer, geological time scale;

- Understanding coastal erosion processes requires an insight into all the factors that interact along the coastline and an awareness of different time scales. Over many decades and even centuries, coastal evolution in sedimentary environments is governed by the demand and supply of sediments. Sediment *demand* of a coast is determined by the rate of relative sea-level rise and the morphology of the coastal plain. Sediment *supply* is determined by the availability of sediment and by the transport capacity of wind-generated waves and currents. The balance between sediment demand and supply drives the evolution of the coast: when supply is greater than demand, the coast will grow seaward; when demand equals supply, the coast will stay in place; and when the supply is insufficient, the coast will tend to retreat (the frequency of this scenario will increase in the future due to sea-level rise);

- Climate change will probably lead to an increase in coastal erosion. In terms of the main drivers for accelerated erosion, the relative sea-level is the most important. A rising sea-level implies an increase in sediment demand, which if not supplied, results in coastal retreat. Higher sea-levels will raise extreme water levels, allow waves to break nearer to the coast and transmit more wave energy to the coastline. This will promote erosion and coastal retreat at sediment-starved locations. Sea-level rise is therefore likely to cause an inland migration of beaches and the loss of up to 20 per cent of coastal wetlands;

- Other drivers that may exacerbate erosion rates are increased storminess, larger waves and changes in prevalent wind directions. The condition and performance of existing coastal defence structures may also deteriorate through interactions with rising sea-level, larger waves, more severe storm surges and changes in the shape of the coastline. Several recent studies indicate that coastal protection strategies and changes in the behaviour or frequency of storms may be more important than the projected acceleration of sea-level rise in determining future coastal erosion rates;

- With sea-level rise, sediment supply will exert a major influence on coastal evolution in the future. With a positive sediment supply, shorelines may be stable or even accrete seaward. Conversely, for low gradient shorelines (gentle slopes), the future trend will be retreat due to submergence even without a long-term erosion trend;

- Many traditional hard-engineered structures are not providing the intended level of protection and many of these structures are failing or are at serious risk of doing so;

- There appears to be a shortage of adequately trained personnel (managers, scientists, coastal geomorphologists, technical experts) and facilities that can be marshalled to respond comprehensively to coastal erosion;

- In general, existing institutional arrangements do not consider or facilitate the management of coastal erosion;

- Any response to coastal erosion, whether hard engineered interventions or softer protective measures, are expensive. Countries struggling with their national economies and other priorities find it difficult to invest the resources required to build and maintain these interventions;

- The political will to make the required policy, programme and investment changes for dealing with coastal erosion in a more holistic manner is yet to be tested. While expressions of commitment to the principles inherent in sustainable ecosystem-based management have been made at regional and national levels, governments may be challenged to implement this approach when the affected stakeholder pressure for immediate and visible responses, often in the form of engineering structures, following erosion events; and

- Investment in a more holistic and ecosystem-based approach to coastal erosion management, particularly those received from donor agencies and governments, must be, and seen to be, dedicated to the priorities identified in this Resource Document. Governments will be challenged to make these transactions and investments both transparent and accountable, particularly where management institutions are struggling to meet many competing demands by society. Private sector interests and responsible authorities must work together to ensure that decisions regarding development patterns and mitigation alternatives are made in an open and inclusive manner, and in consideration of the underlying principles for coastal erosion management outlined in this document.

These constraints form the basis of the elements of this coastal erosion guidance document, outlined in Section 4.0 of this report.

3.4 Principles

A sound approach to coastal erosion management must start from a recognition of and grounding in fundamental principles (guiding values). Many of the following principles are found in or based on the strategic documents of UNEP, PEMSEA, COBSEA and its member nations. They provide the foundation for addressing coastal erosion, not only as an issue in isolation, but as an integral part of an integrated approach to coastal zone management and the broader regional objectives of safety, health, productivity and resilience of coastal ecosystems and populations.

On the relationship among economic, social and environmental objectives, COBSEA member countries have determined:

- Economic and social development are of vital local, national and regional importance;
- Environmental protection and economic development are compatible. That is, in order to achieve the region's stated goal of sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it; and
- Market mechanisms which internalize environmental costs and benefits promote long-term economic growth.

These principles speak directly to the economic and social objectives and reality in the EAS region, which is that the region must and will continue to develop. They also recognize this development cannot come at the cost of the ecological foundation of the region's coastal areas and resources and that both sides of this equation must be balanced. They also speak to national and regional responsibility to assume these costs in their decisions about on-going sustainable development of the region and their responses to coastal erosion.

Many of the principles of good ICZM are relevant to the implementation of a sustainable and ecosystem-based approach to coastal erosion management. ICZM focuses on maintaining the integrity of ecosystems by managing human activities and their impacts on ecosystems. Therefore:

- Management plans for coastal erosion should be part of a broader policy, structure and perspective on ICZM, both regionally and nationally;
- Approaches should be ecosystem-based, that is, recognize the coast as a dynamic physical system, but one intricately linked to the ecological, social and economic character and structure of the region;
- Management of coastal resources and the activities affecting them shall be science-based and respect natural processes and systems;
- Coastal erosion will only be addressed comprehensively and sustainably if those responsible for and dependent on the coast are aware of their vulnerability, have the information, tools and resources to respond in informed ways, and take steps to modify their institutional and personal behaviours and responses to respect and accommodate the dynamic process of coastal erosion; and
- All relevant stakeholders must be engaged in this management process if it is to be well informed, broadly accepted and effectively implemented by all concerned.

In addressing coastal erosion as an issue that is poorly understood and often compels short-term and reactive responses, it is necessary for member countries to:

- Take a long-term perspective. Coastal erosion can be both episodic and a long-term process and responses to its impacts must be both agile and strategic;
- Understand and work within natural processes;
- Work toward achieving and maintaining coastal resilience; and
- Recognize and respond to local specificity. There are a variety of coastline types in the region and a wide spectrum of development intensities and uses.

3.5 Key Concepts

At the core of the principles and approaches advocated in this guidance document for dealing effectively with coastal erosion, is the central concept (technical theories or approach) of ecosystem-based management.[2] There is a broad and rich literature on this subject and its specific application in coastal and marine systems has been adopted in principle through COBSEA and PEMSEA regional agreements and frameworks. An excellent new Introductory Guide – Taking Steps toward Marine and Coastal Ecosystem-based Management – was released by UNEP in June 2011, and should be used as a key reference in understanding this fundamental concept.

Ecosystem-based management, or EBM, is an approach that goes beyond examining single issues, species, or ecosystem functions in isolation. Instead it recognizes ecological systems for what they are: a rich mix of elements that interact with each other in important ways. This is particularly important for oceans and coasts. Because humans depend on an array of ocean and coastal functions for our well-being – protecting coastal settlements from erosion, for example – EBM recognizes that our welfare and the health of the environment are linked. Put another way, marine and coastal systems provide valuable natural services, or “ecosystem services”, for human communities. Therefore, to protect our long-term well-being, we need to make sure marine and coastal ecosystem functions and productivity are managed sustainably. This means managing them in a way that acknowledges the complexity of marine and coastal ecosystems, the connections among them, their links with land and freshwater, and how people interact with them.

EBM is as much a process as an end point. It does not require a single giant leap from traditional, sectoral management to fully integrated, comprehensive management. Instead, EBM can be achieved in a step-by-step, incremental, and adaptive process. Ecosystem-based management builds on existing knowledge and management structures and develops these further. It is not about throwing out what we have and replacing it with something else. It is an ‘adaptive’ management approach that continues to evolve with new information and experience with programme implementation.

Turning now specifically to the issue of coastal erosion, five well established coastal science and engineering concepts and one additional ecological maxim are proposed as key elements of the coastal erosion management framework for the EAS region. They are based on working “with” natural processes and not against them. These concepts

[2] The terms “ecosystem-based management” and “ecosystem approach” (EA) are often used interchangeably, and they mean generally the same thing.

are inter-linked through coastal processes but they also have policy and management dimensions. These concepts are well described in a recently released report from a comprehensive European study on coastal erosion management (Marchand, 2010).[3]

1. Coastal Resilience

Coastal resilience is the inherent ability of the coast to accommodate changes induced by human interventions, extreme events and sea-level rise, while maintaining the functions fulfilled by the coastal system in the long-term. Because resilience is based on natural processes, it varies between different coastal types. For instance, a beach-dune coast is more resilient than a cliff coast because of the self-restoring capacity of dunes (that is, where they are not lost, degraded or constrained). It is important to note that this definition does not require a coastline to remain in an equilibrium state. Especially on longer time scales, most coasts are evolving systems and are not necessarily in a state of static equilibrium. Coastal resilience therefore should refer to coastal functions: compatibility and adaptability of uses to coastal erosion management which allows natural fluctuations of the coastline. This concept links strongly with an adaptive management approach and the need to prioritize the health and resilience of natural coastal systems.

2. Coastal Sediments

An abundant natural supply of sediment, whether fine or coarse grained, is a critical component for healthy and resilient coastlines. The concept of “coastal sediment cells” provides a useful spatial framework for the investigation of sediment supply, transport pathways and depositional patterns along the coast, all of which in turn can influence erosion. The role of sediment balance or favourable sediment status along is critical concept to understand erosion trends and patterns. And finally, when sediment budget investigations determine the sediment balance is negative, strategic sediment reservoirs are required to re-nourish our coastlines and increase their resilience to threats such as sea-level rise. These concepts are further described in the following sections.

Coastal Sediment Cell

A coastal sediment cell is defined as a relatively self-contained coastal compartment that defines critical sediment processes, including generation of new supplies (i.e., sources), transport paths and sinks (i.e., deposition). The cell boundaries delineate the geographical area within which the budget of sediment is determined, providing the framework for the quantitative analysis of coastal erosion and accretion. Refer to the conceptual diagram in Figure 3.6.

In this respect, coastal sediment cells constitute the most appropriate units for investigating and working towards the objective of favourable sediment status and hence, coastal resilience. Delineating coastal cells requires field work, geomorphic analysis and computer modeling. Cell boundaries can be natural, such as headlands, capes or dramatic changes in coastline/island orientation relative to the dominant wave direction, or artificial, such as large engineered port structures created by land reclamation, construction of navigation channel jetties or erosion mitigation structures such as long groins.

[3] Marchand M. (Ed.), 2010. Concepts and Science for Coastal Erosion Management. Concise Report for Policy Makers. Deltares, Delft.

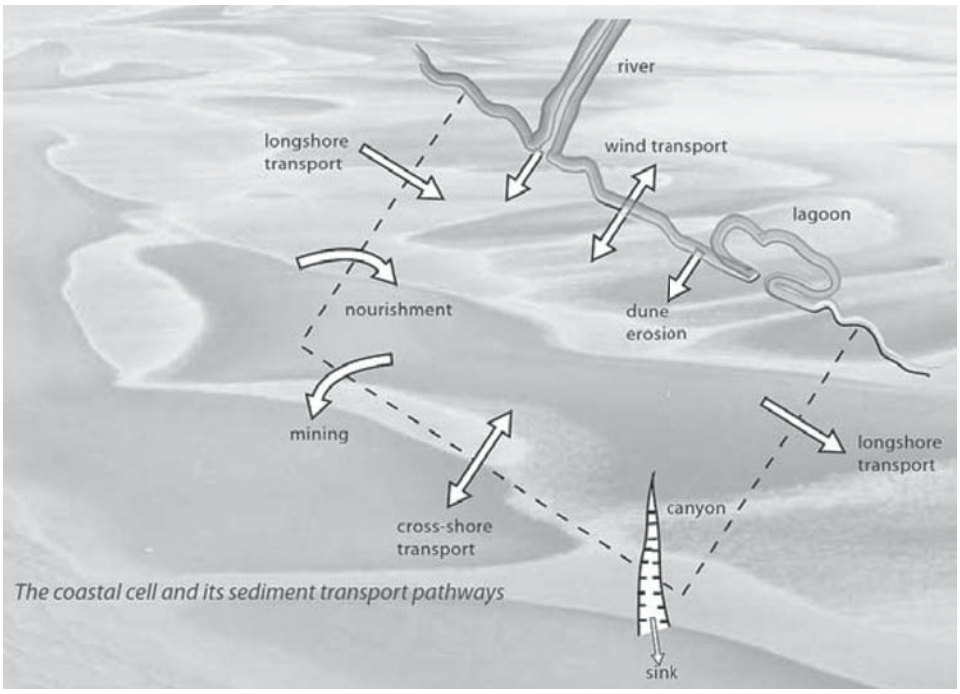


Figure 3.6 Conceptual Diagram of Coastal Sediment Cell (from Marchand, 2010)

The application of coastal sediment cells requires the establishment of a sediment budget for a coastal area, that is, a mass-balance of inputs and outputs of sediment within the cell. This provides insight into the relative importance of the various sediment sources and losses, resulting in deposition and erosion patterns. Coasts should be managed on a sediment-cell basis, which often requires participation across political or jurisdictional boundaries.

The primary sources of sediment in a coastal cell include riverine supply, inputs from sections of the coastline that erode naturally, onshore transport of sediment from offshore marine deposits, and carbonate sand inputs from coral reefs/shell fragments. Human intervention through, for example, beach nourishment (the artificial deposition of sediment from either dredging of adjacent offshore areas or supplied from upland sources) may also form an important input. The coastal cell also loses material in various ways, including trapping in deep offshore channels and submarine canyons, accumulation adjacent to large engineered structures such as ports, sand mining for the aggregate industry or dredging and disposal beyond the zone of active sediment transport (i.e., in deep water). Sediment may be transported to estuaries, lagoons and inner seas and by wind to beaches and dunes from where it may only return through further erosion during severe storms.

Longshore currents also transport sediment to new regions of the coastal cell. The net balance between losses from and inputs to a coastal cell determines, to a large extent, what portion of a coastline is eroding, stable or accreting, especially in the longer term. It is clear that any human interference in these processes, such as the blocking of sediment transport by building a jetty (refer to Figure 3.7), breakwater or harbour, or reductions in new sediment inputs due to dam construction on rivers could have repercussions on the delicate natural sediment balance within the cell and thus alter previous natural erosion and sedimentation patterns.

Figure 3.7 Updrift Deposition and Downdrift Erosion at a Jetty, Philippines

Sediment Balance and Favourable Sediment Status

Favourable sediment status occurs when the present volume of coastal sediments promote coastal resilience and allows coastlines to respond dynamically to storms and other severe events. To describe the sediment balance as “favourable” depends on the objectives for erosion management. A neutral or positive sediment balance is often required to arrive at this favourable status. We can expect that the impact of sea-level rise will result in higher demand for sediment, which, if not supplied, will lead to coastline retreat. Favourable sediment status should be the target for sustainable coastline management in EAS countries. A positive sediment balance for the coastal zone can be achieved for each coastal cell by preserving existing sediment and natural processes that re-distribute sediment, designation of strategic sediment reservoirs, and the addition of new sediment via beach nourishment projects. These measures in combination with spatial planning, building regulations and stakeholder education (see COBSEA report on Spatial Planning in the Coastal Zone) will ensure a positive sediment balance is maintained in coastal sediment cells.

Strategic Sediment Reservoirs and Sediment Bypassing

Strategic sediment reservoirs are supplies of sediment of “appropriate” characteristics that are available for replenishment in the coastal zone, either temporarily (to compensate for losses due to extreme storms) or in the long-term (multiple decades or longer). They can be identified offshore, in the coastal zone (both above and below low water), in the hinterland (above high tide), or adjacent to engineering structures (e.g., beneficial re-use of material dredged from navigation channels). Many coastal erosion problems are caused by human-induced imbalance in the sediment budget when natural sediment sources are depleted by sand mining activities, trapped in river reservoirs upstream or adjacent to coastal engineering structures. Restoring this balance will require the understanding of critical sediment processes, and locations where strategic sediment reservoirs can be mined to restore the natural balance. For example, when sediment accumulates adjacent to structures that disrupt longshore sediment transport, such as jetties, it can be mechanically bypassed downdrift to restore the natural sediment supply.

3. Erosion Protection

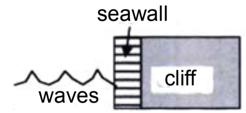
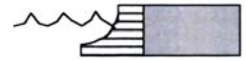
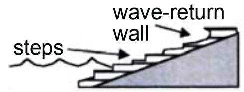
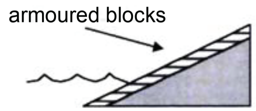
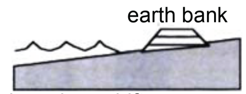
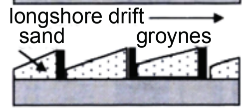
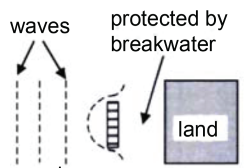
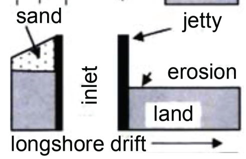
In some coastal sediment cells or portions of the cell, restoring favourable sediment status alone will not be sufficient to increase the coasts resilience to extreme erosion hazards, such as cyclones and tsunamis. In these cases, additional human intervention may be required in the form of natural erosion mitigation (e.g., mangrove reforestation) or the construction of engineering structures, such as seawalls and dykes. Further information on coastal protection options is provided below.

Engineered Erosion Protection

In highly urbanized or industrialized coastal areas, where critical infrastructure and populations are at imminent risk to erosion hazards and there is little to no physical space in which re-locate, engineered protection with appropriate mitigation measures should be considered. Simply put, there will be some places society has to protect at all costs and these areas will require engineering structures designed as part of a comprehensive investigation that ensures the level of protection is sufficient to protect the resource and local/downdrift ecological impacts are mitigated. For example, wherever possible, these impacts to the sediment supply, physical processes, the marine ecosystem or the species that utilize the area should be properly mitigated and the proponent should pay for the mitigation costs.

The spatial extent for the erosion mitigation structures and potential downdrift impacts should be evaluated within the framework of the coastal sediment cell. For each unique shore type, a range of engineered options will exist and should be examined. For example, as outlined in Haslett (2000), eroding cliffs can be protected with shore parallel protection such as vertical walls, stepped walls and revetments. Careful consideration should be given to the geologic properties of the soils and the potential for the seabed to erode at the toe of the structures. Refer to the schematic in Figure 3.8. Eroding beaches, on the other hand, can be stabilized with groynes and offshore structures, such as submerged or emergent breakwaters. Refer to Appendix B for additional erosion mitigation alternatives.

Table 3.1 Summary of Typical Erosion Problems, Potential Engineering Solutions and Limitations (from Haslett, 2000)

Management issue	Engineered solution(s)	Types	Description	Problems	Illustration
Cliff erosion	Seawalls	Vertical wall	A wall constructed out of rock blocks, or bulkheads of wood or steel, or simply semi-vertical mounds of rubble in front of a cliff	Rock walls are highly reflective, bulkheads less so. Loose rubble however, absorbs wave energy	
		Curved wall	A concrete constructed concave wall	Quite reflective, but the concave structure introduces a dissipative element	
		Stepped	A rectilinear stepped hard structure, as gently sloping as possible, often with a curved wave-return wall at the top	The scarps of the steps are reflective, but overall the structure is quite dissipative	
		Revetment	A sloping rectilinear armoured structure constructed with less reflective material, such as interlocking blocks (tetrapods), rock-filled gabions, and asphalt	The slope and loose material ensure maximum dissipation of wave energy	
Coastal inundation	Seawalls	Earth banks	A free-standing bank of earth and loose material, often at the landward edge of coastal wetlands	May be susceptible to erosion, and overtopped during extreme high-water events	
	Tidal barriers		Barriers built across estuaries with sluice gates that may be closed when threatened by storm surge	Extremely costly, and relies on reliable storm surge warning system (e.g., Thames Barrier)	
Beach stabilization	Groynes		Shore-normal walls of mainly wood, built across beaches to trap drifting sediment	Starve down-drift beaches of sediment	
	Beach nourishment		Adding sediment to a beach to maintain beach levels and dimensions	Sediment is often rapidly removed through erosion and needs regular replenishing; often sourced by dredging coastal waters	
Offshore protection	Breakwaters		Structures situated offshore that intercept waves before they reach the shore. Constructed with concrete and/or rubble	Very costly and often suffer damage during storms	
Tidal inlet management	Jetties		Walls built to line the banks of tidal inlets or river outlets in order to stablise the waterway for navigation	The jetties protrude into the sea and promote sediment deposition on the updrift side, but also sediment starvation and erosion on the down-drift side	

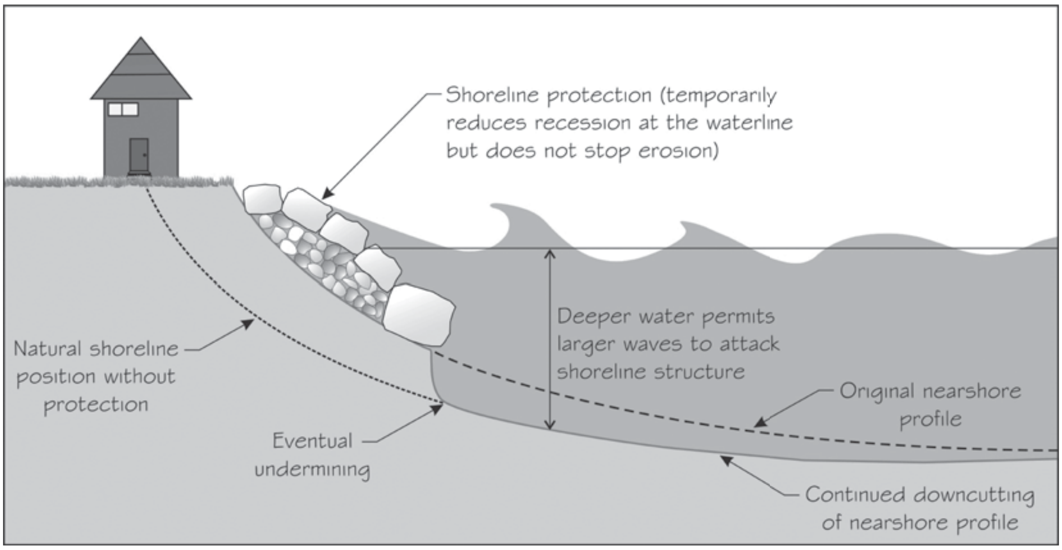


Figure 3.8 Downcutting Process at the Toe of a Shore Parallel Structure

Natural Erosion Protection

While the preceding concepts refer specifically to sediment and the natural physics of coastal areas and the physical interventions that can and should be taken to deal with coastal erosion, there is also the 'living' component of coastal systems that must be actively considered. The EAS region is blessed with abundant natural protection – in mangrove forests, coral reefs, wetlands, barrier beaches and seagrass beds. Any effective and sustainable approach to coastal erosion management must include protection, enhancement and strategic application of these natural living resources (i.e., 'soft engineering' or 'bio-belting') to make coastal erosion management fully effective. Refer to the geotube breakwaters and mangrove reforestation in Sungai Haji Dorani, Sabak Bernam, Selangor, Malaysia in Figure 3.9. Coral reef ecosystems are another example of natural erosion protection, since healthy reefs provide a continuous supply of carbonate sand that nourishes beaches naturally.

Figure 3.9 Geotube Breakwaters (in background at waterline) and Mangrove Reforestation in Malaysia

Additional references for books and manuals on coastal erosion are provided in Appendix B.

These key concepts can be considered the building blocks for an effective approach to coastal erosion management and they lead us into the strategic and tactical options that are described in the following sections.

3.6 Additiional Management Tools, Data Collection and Training

In addition to the concepts of coastal resilience, coastal sediments and erosion protection, there are several key management tools, data and training requirements that should be part of the long-term strategy to mitigate coastal erosion impacts. Comments on integrated coastal zone management, zoning for coastal hazards, adaptive management, training and capacity building, and national data repositories are provided below.

3.6.1 Integrated Coastal Zone Management Plans for Sediment Cells

Integrated Coastal Zone Management Plans will be a useful framework to outline objectives and priorities at the country/local level, and should be consulted when considering mitigation alternatives for coastal erosion. When developed for individual coastal sediment cells, rather than political or jurisdictional boundaries, they provide the ideal framework for evaluating the resiliency of the coastline, favourable sediment status, and locating strategic sediment reservoirs. When erosion mitigation is required in the form of engineered protection or natural options, ICZM plans can help stakeholders make holistic decisions within an ecosystem-based management framework. Additional comments will be provided in Section 4.0 on the applicability of ICZM plans when developing a regional programme on coastal erosion.

3.6.2 Zoning for Coastal Hazards

When considering coastal hazards, one of the approaches taken could be to divide the coastal areas into two or more general zones. Zone A for instance, could be designated as important terrestrial and marine habitat for healthy ecosystems and the dynamic coastal processes (erosion and sedimentation). Here, different philosophies could be conceived for urban and non-urban areas. For urban areas, there could be a minimum (e.g., 100 m) setback rule from high tide for future development. All local and downdrift impacts of shore protection structures to mitigate erosion, flooding, and vulnerability to sea-level rise constructed in this zone would be evaluated in a holistic ecosystem-based decision framework. Additionally, to minimize human and property loss, residential developments in these areas would be highly restricted (or not permitted) in favour of natural protection (bio-belting) or more public-domain facilities such as gardens, parks and recreational space. This shift in focus from high intensity development to something more natural and accessible for communities is something increasingly called for by the residents of the EAS region. Importantly, areas identified from risk maps as high vulnerability for coastal storms, tsunamis, landslides and seismicity and volcanism, are designated as either “not allowed to build” or “substantial hazard mitigation required prior to development”. A sample of an existing zoning map from Malaysia is provided in Figure 3.10.

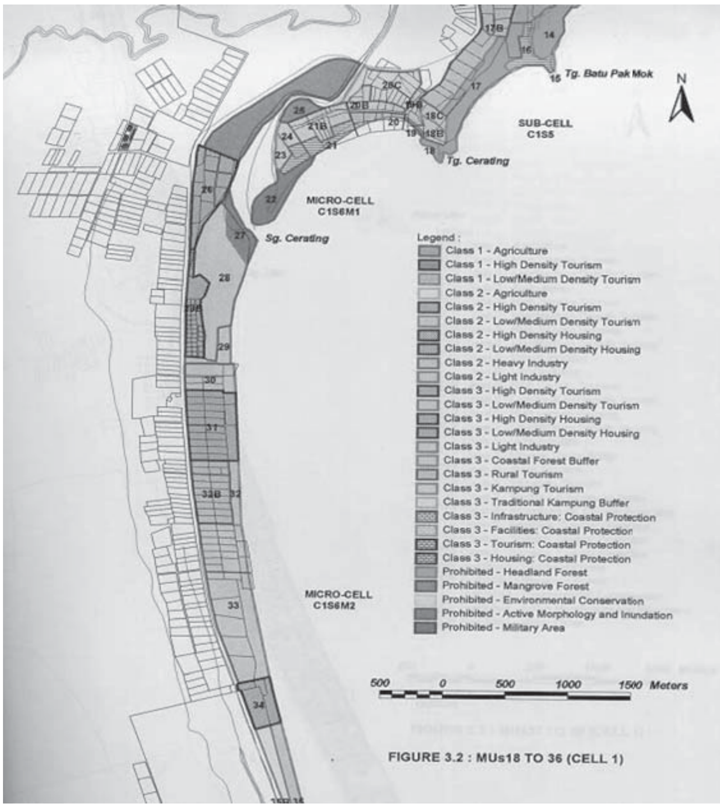


Figure 3.10 Zoning Map from Integrated Shoreline Management Plan, Pahang, Malaysia

For non-urban areas, Zone A could be left as natural habitat where coastal and ecosystem processes govern (no active intervention). Zone B would be designated for areas of the coastal zone not impacted by coastal hazards or beyond the zone of dynamic coastal processes that require the more stringent regulations. Development would be permitted in Zone B.

This study has not explored the use of set-back lines or zoning as a management tool in any detail, as the Sida-sponsored study on spatial planning, being conducted in parallel to this project, will be addressing this issue comprehensively. It is important, therefore, to bring the findings and recommendations of these two studies together to form a more comprehensive package of guidance for the coastal nations of the EAS region.

3.6.3 Adaptive Management

Adaptive management recognizes that our coastal environments are dynamic ecosystems that respond to natural and human forcing functions. Our attempt at developing policy frameworks and management protocols for coastal erosion are based on our best available data and information at present. As additional monitoring data is collected and we learn from practical applications in the future, our knowledge of best practices, impacts and opportunities will improve. Further, with the on-going uncertainty about our future climate due to global warming, the frequency and magnitude of the forcing functions that shape our coastal zones is unknown. What is clear is that stationarity (normal or average conditions) for these forcing functions is not likely and the policy framework presented in this document will require updating over time. Adaptive Management provides the ideal framework to deal with this future uncertainty for coastal erosion management.

3.6.4 Training and Capacity Building

The fields of coastal science, coastal engineering and coastal zone management/planning are highly specialized technical fields and many of the COBSEA member countries will require training and capacity building in these disciplines and others to effectively develop and implement a long-term regional programme for coastal erosion management. Building in-country expertise will be a critical requirement in the future and should commence in the near-term. Additional recommendations on training and capacity building are provided in Section 5.4.

3.6.5 National Coastal Data Repository and Future Data Collection

The coastal zone is a dynamic environment and decision-making on erosion mitigation alternatives within an ecosystem based management framework requires extensive information, including: oceanographic and meteorological data, bathymetric and topographic data, marine geophysical information, tidal data including sea-level rise projections, historical wave climate in deep and shallow water, historical and modern satellite coverage and aerial photography, land-use and marine classifications of surficial geology and sea bed characteristics, terrestrial and aquatic habitat, migratory corridors and spawning areas, to mention just a few.

Although some of these datasets exist in some regions, there is typically no centralized national archive or clearinghouse for these critical geo-spatial and temporal datasets that are necessary for scientific investigations and evidenced based coastal zone planning. The establishment of an online clearinghouse for the archive and distribution of all data related to coastal zones should be a national priority for each country in the COBSEA region, as it will be essential to develop sustainable long-term solutions to coastal erosion and sea-level rise. Finally, this information should be freely available.

In the future, some sites will require sophisticated data collection with state-of-the-art marine vessels and instruments based on the level of risk to people and infrastructure. In other instances, monitoring programmes can be implemented by training local stakeholders to collect valuable coastal data without complicated instruments. These programmes engage local stakeholders, education the community, and build a sense of ownership in the project site.

4.0 POLICY FRAMEWORK AND ELEMENTS OF THE APPROACH

The question has been asked by EAS nations and through their regional partnership: What should a sustainable and ecosystem-based coastal erosion management process for the East Asia Seas Region look like? There are a number of inter-related and sequential steps in such a process that must begin at the highest policy levels and provide increasing levels of detail and guidance as one moves closer to the ground and the particular coastal erosion issue at hand.

COBSEA and PEMSEA strategic documents that identify approaches to challenges such as coastal erosion were used to develop four inter-linked strategies: (i) information management (e.g., establish a one-stop-shop or knowledgebase to provide stakeholders with information on programmes and projects and the state of the coastal and marine environment); (ii) national capacity building (strengthen its member countries' capacities in responding to the growing pressures exerted on the coastal and marine environment and the increasing need for sustainable management of their natural resources); (iii) regional cooperation to prevent duplication of efforts, manage at the coastal sediment-cell scale, develop sustainably and protect large marine ecosystems on a regional scale; and (iv) assisting its member countries in identifying and addressing upcoming issues of priority to the region.

With the above-noted priority and agreement to work cooperatively and within each nation's own interests and capacity, a three-step process was developed that: (1) defines the goals of the programme and provides guidance on the approach (completed in April 2011 Workshop); (2) establishes the political intent and policy framework; and (3) provides the framework for the evaluation of erosion mitigation alternatives and implementation of the preferred option.

At the core of the framework is the evaluation of erosion mitigation alternatives within the framework of Integrated Coastal Zone Management. In other words, a holistic ecosystem approach to evaluating options to address coastal erosion is adopted. The framework requires a series of political and policy statements to define objectives. These high-level statements must come from the most senior levels of government; it is not for technical experts, scientists or engineers to determine these. These declarations of a nation's desired values and functions of the coast (e.g., maintaining ecological integrity, ensuring public safety), its desired type and intensity of coastal development, and the amount of time and money governments are willing and able to invest in managing coastal erosion, are for the politicians to determine and clearly communicate as guidance in the technical approaches that will be employed.

4.1 Step 1 – Setting the Policy Framework

There are two critical initial steps required to establishing a regional policy framework: (1) A Statement of Political Intent; and (2) Policy Statements about the Values and Functions of the Coasts. The activities in these two steps are further described in the following sections and presented schematically in Figure 4.1.

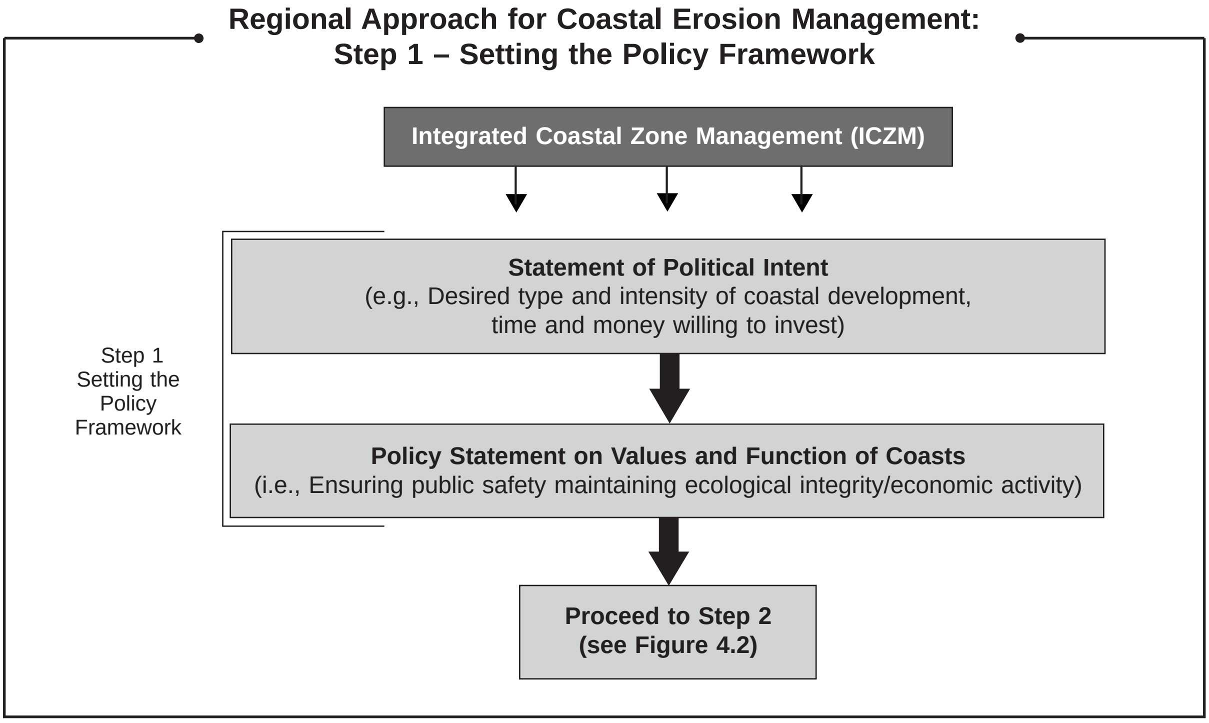


Figure 4.1 Policy Framework for Coastal Erosion Management

4.1.1 Statements of Political Intent

Well before any consideration of coastal erosion and how to deal with it, political decisions are taken and communicated at both national and regional levels, about the desired type and intensity of development of the coast and how much effort (time and money) society is willing to spend on reaching or maintaining this desired state. From various UNEP, PEMSEA, COBSEA and member-country policy and strategic documents, we know that further sustainable development of the region is a shared priority and that member countries will prioritize holistic approaches to their coastal zones. These statements of political intent must be tested and refined in the lead-up to and during the next phases of this initiative where participating policy leaders can more explicitly articulate their intent about development and investment effort.

4.1.2 Policy Statements about the Values and Functions of the Coast

Within the above political context, clear policy statements about the values and functions of the coast are established. These may include ensuring public safety, or maintaining ecological integrity. These have been articulated in many of the COBSEA and other documents at the regional level and require clear national statements of policy for each member nation. Stated policies must also be specific to different coastline types (e.g., rocky, mangrove, beach) and level of development (urban and rural).

4.2 Step 2 – Developing Objectives and Erosion Mitigation Options

With the political and policy context set, the technical and scientific dimensions of national and regional responses to coastal erosion can be initiated in Step 2. The key steps are outlined and described in Figure 4.2.

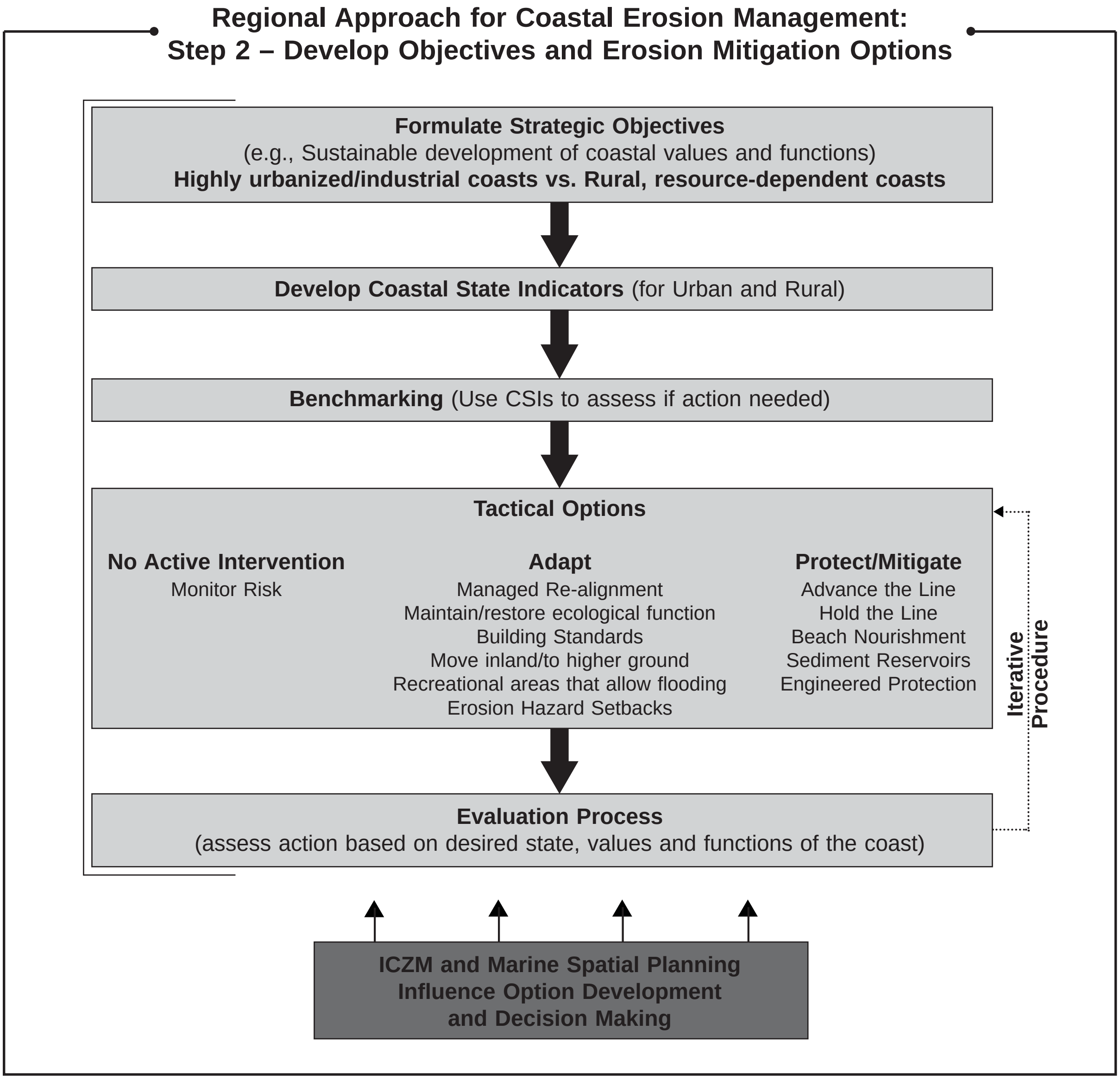


Figure 4.2 Development of Objectives and Erosion Mitigation Alternatives

4.2.1 Formulate Strategic Objectives

From the stated long-term vision about the prioritized values and desired development of the coast, a strategic objective is formulated. The COBSEA partnership has already embraced sustainable development and the recognition of the interdependency of the ecological and socio-economic systems as fundamental objectives. This is a strong foundation. An example of a possible strategic objective for the EAS Region would be "the sustainable development of coastal zones while maintaining ecological functions and native biodiversity". These objectives must be more clearly articulated by each member country. This step requires clear communication and good dialogue among the political and technical actors.

The next step focuses on implementation, which includes the development of coastal state indicators (CSI), benchmarking and evaluation of tactical options. The evaluation of tactical options to address coastal erosion hazards is iterative and will rely on the CSI and the results of the benchmarking analysis. Additional information on Step 3 is provided in the following sections.

4.2.2 Develop Coastal State Indicators

CSIs are used to identify and quantify critical indicators for the overall ecosystem health and biodiversity of the coastal zone. They do not quantify all functions and linkages within the coastal ecosystem; rather, they represent key species and environmental factors that can be used to evaluate the overall health of the coastal zone. Examples of physical CSIs relevant to beaches and coastal erosion include dune health, barrier beach width, backshore width, dune zone width, total barrier beach volume, nearshore slope, etc. On a national scale, the percentage of natural versus altered or engineering coastline could also be a CSI.

4.2.3 Benchmarking

Benchmarking is used to establish critical thresholds or tipping points for the various CSI. For example, once the overall area (spatial extent) or health of the protective coral reef or mangroves ecosystems drops below a minimum threshold, then tactical options are considered.

4.2.4 Tactical Options

At the next level, one or more "tactical" options are formulated, describing in more detail what has to be carried out in order to achieve the strategic objective. If, for instance, at a strategic level the objective formulated is "sustainable development of coastal values and functions", then at the tactical level, we have to choose between different options. Examples might include maintaining the coastline at its current position (i.e., not allowing erosion), or allowing certain variability in coastline position. Three general categories for the coastal erosion tactical options were developed, including:

- **No Active Intervention** – decision not to invest in constructing new or maintaining existing sea defences. Evaluate hazard level (i.e., risks) and monitor coastal evolution;

- **Adapt** – a series of options exist, including (but not limited to) managed re-alignment, move infrastructure inland, change the land use to something that can sustain erosion and flooding, or adopt erosion hazard setbacks to regulate new development in the coastal zone; and

- **Protect and/or Mitigate** – maintain or upgrade the level of protection provided by existing coastal defences, advance the line, construct new erosion protection, beach nourishment and bio-engineering alternatives (e.g., enhance coral reef development and bio-belting). A conceptual diagram of a beach nourishment project is provided in Figure 4.3.

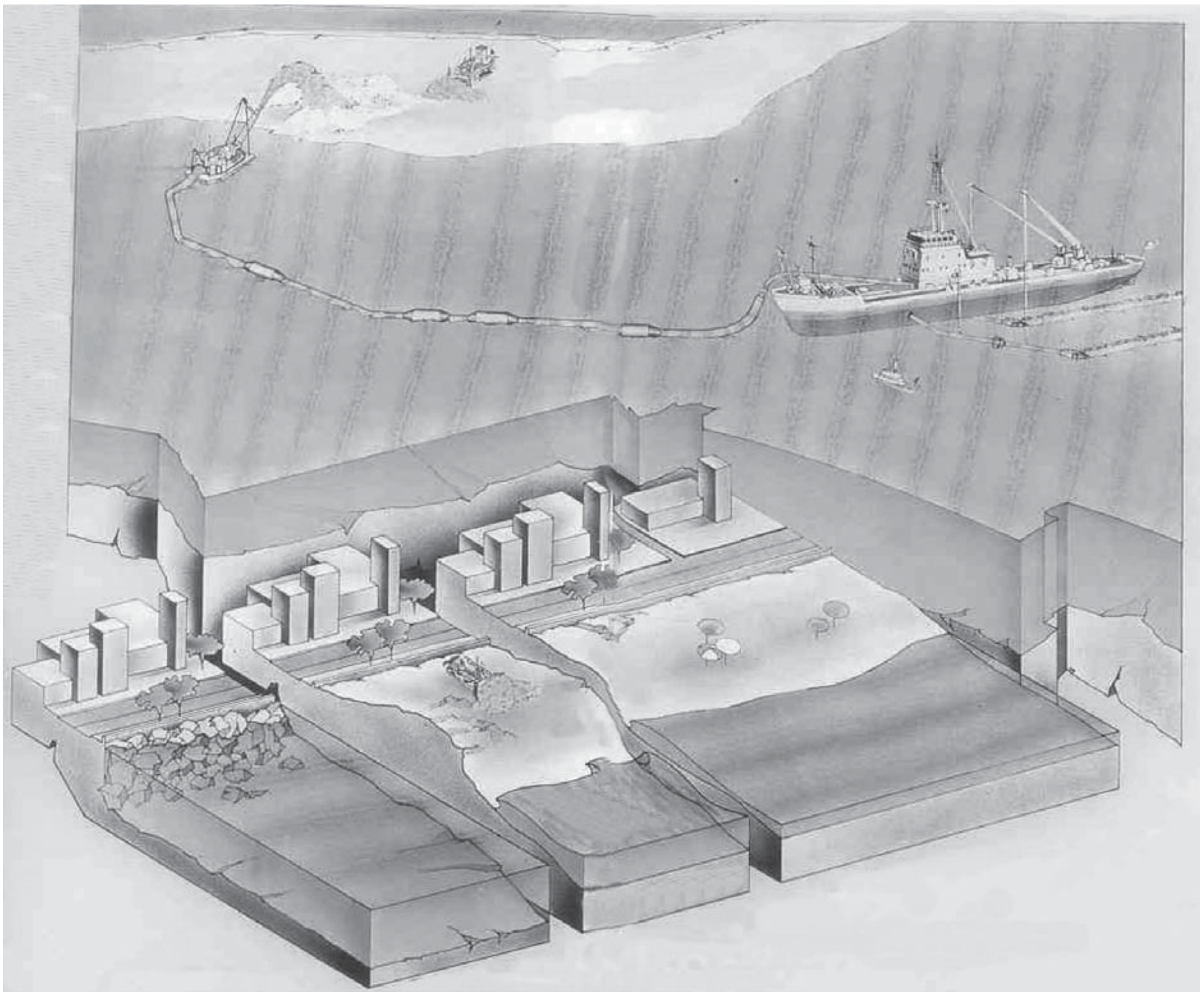
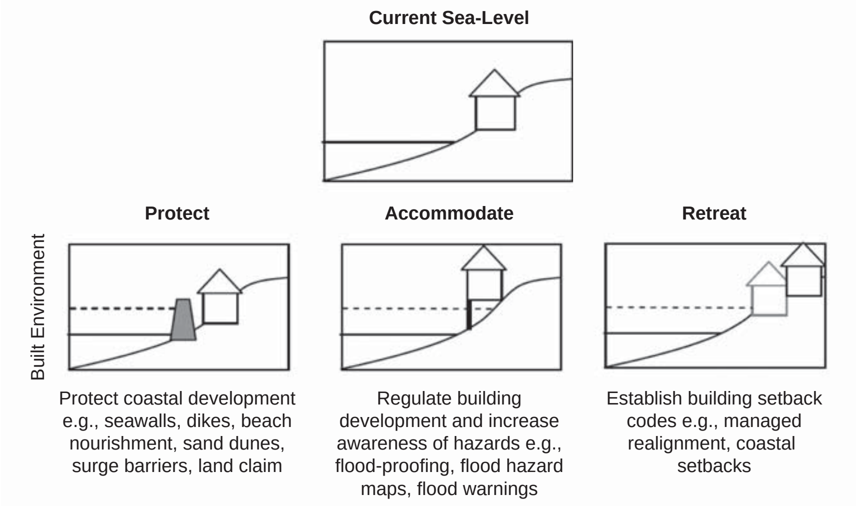


Figure 4.3 Conceptual Diagram of a Beach Nourishment Project to Mitigate Erosion and Restore Beaches (existing conditions on bottom left, nourished beach on bottom right)

Additional examples for the three main tactical options are listed in Figure 4.2. Additional reference material on erosion mitigation alternatives is provided in Appendix B. It is also important to emphasize the need for ongoing and long-term monitoring of the coastal system under various scenarios so that an adaptive management approach can be used in the future.

A new Guidebook – ***Technologies for Climate Change Adaptation-Coastal Erosion and Flooding*** (Zhu (Ed.) 2010) – was recently released by the UNEP RISØ Centre. This important publication covers thirteen of the most widely used and discussed adaptation technologies – grouped under the "protect", "accommodate" and "retreat" approaches – that can reduce the impacts of coastal erosion and flooding due to climate change. Refer to the Conceptual Sketch below reproduced from the Guidebook for additional information. These technologies can be sub-divided into approaches involving: (1) capital goods such as dykes, seawalls, storm-surge barriers and flood proofing; and (2) technologies focusing on information, capacity building, institutional arrangements and policy and strategy development. This Guidebook (copies of which were provided to participants of the April 2011 Coastal Erosion workshop in Bangkok) can be used by policy-makers and coastal zone project planners in the EAS countries as practical best-practice guidance in assessing their evolving adaptation needs and help them to prepare actions plans for adapting to climate change in their coastal zone.

It is important to note that adaptation consists of more than simply implementing a specific technology. As a result, this guidebook also considers the wider process within which adaptation technologies are implemented – including information collection and dissemination, awareness building, design, implementation and monitoring – ideally within an Integrated Coastal Zone Management context.



Conceptual Sketch of the Protect/Accommodate/Retreat Options (from Zhu, 2010)

4.2.5 Evaluation Process

Once the CSI, benchmarking and a series of conceptual tactical options have been developed, the actual evaluation process regarding interventions can be completed during the following four steps:

- **Coastal State Indicators** – define/predict how the erosion mitigation alternatives will impact the coastal state indicators that characterize the overall health, biodiversity and sustainability of the coastal zone in question;
- **Benchmarking** – assessing whether or not benchmark values or threshold would be exceeded for the coastal state indicators if the erosion mitigation alternatives were constructed;
- **Compare Tactical Options** – compare the various conceptual alternatives to address the erosion hazard and rank them based on their anticipated effectiveness, impact to coastal state indicators, and other factors noted in the local Coastal Zone Management Plan for the sediment cell. A short list of viable alternatives is generated; and
- **Select Preferred Alternative** – based on the comparison of impacts to the coastal state indicators and other important local factors, select a preferred erosion mitigation strategy.

5.0 FUTURE REGIONAL, NATIONAL AND LOCAL ACTIONS

Recommendations have been developed for three different governance levels to advance the development of a regional programme in the future:

(i) The policy-makers at the EAS level (regional);

(ii) Decision-makers and Policy-makers at national levels; and

(iii) Coastal practitioners at sub-national and local levels.

Building on the regional framework presented in Section 4.0, these actions can be grouped into several logical categories where individual tasks can be outlined:

1. National Policy and Framework Development

2. Programme Objectives

3. Implementation

4. Training/Capacity Building

5. Sharing Best Practices

The following tables, organized by each of the above categories, set out the actions needed to move towards a sustainable and ecosystem-based approach to the management of coastal erosion in the EAS region.

5.1 National Policy and Framework Development

Any interventions to deal with coastal erosion, whether at the regional, national or local level, must be taken in the context of established policy priorities and constraints. These political expressions about the desired values and ultimate state of coastal areas must be clearly communicated to those tasked with determining vulnerability, assessing risk and recommending adaptation options. If, for example, a national policy prioritizes aggressive coastal development and community safety, then more emphasis will be placed on protecting assets and human lives, most likely with engineered structures. On the other hand, if the priority is to emphasize the maintenance and restoration of coastal ecosystems as natural defence systems, then this will have direct implications on land-use planning decisions and an approach that accommodates a dynamic coastline. Table 5.1 highlights the main policy considerations and steps that should be taken at regional, national and sub-national/local levels in the EAS region.

Table 5.1 Policy Considerations at the Regional, National and Local Level

Regional EAS Level	National Level	Sub-national/Local Level
Declare clear statements of political intent about the desired state of the **region's** coasts	Integrate clear statements of political intent about the desired state of **respective nations'** coasts into policy and legislation	Municipal or regional governments should translate the policy priorities articulated at the EAS and national levels into practical, on-the-ground application, within the coastal sediment cells
Declare clear statements about the desired type and intensity of development of the region's coasts	Integrate clear statements about the desired type and intensity of development of the nation's coasts into Integrated Coastal Zone Management Plans at the coastal sediment cell scale	
Indicate how much effort – time and money – **the regional partnership** and its external supporters are willing to spend on reaching or maintaining expressed desired state	Indicate how much effort – time and money – **the nation** is willing and able to spend on reaching or maintaining declared desired state	
Use these political and policy statements to refine the structure and emphasis of the ICZM programmes to include coastal erosion[4]	Use these political and policy statements to inform the structure and priorities of national ICZM programmes	
Recognize the growing threat from climate change and build in adaptive planning and capacity everywhere possible	Assess the regulatory and institutional frameworks at national level to identify gaps and inconsistencies and development of recommendations to address constraints	
Ensure that policies developed to address coastal erosion are ecosystem-based and sustainable	Develop strategic objectives that respond to coastal erosion and support desired state	
Develop strategic objectives that respond to coastal erosion and support desired state of the coast	Make effective arrangements with respect to the budgetary requirements of coastal erosion management. Accountability for actions that are detrimental to the favourable sediment status should be part of such arrangements, even if the down-drift impacts are beyond national boundaries	
Encourage the protection and restoration of natural protective features where they traditionally existed or could thrive – mangroves, wetlands, seagrass beds and coral reefs	Define coastal sediment cells for each nation and learn from those that already have	
Promote the designation of strategic sediment reservoirs throughout the EAS region and manage the use of this shared resource for the benefit of member countries. This could be a tangible expression of international cooperation on the management and strategic use of a shared regional resource	Formulate national coastal erosion policies both for short-term (event-hours-to-days) and long-term (climate change – decades to century) time scales	

[4] The ICZM framework is already being used in China, Indonesia, Korea, Malaysia, Philippines and Viet Nam and can be easily adapted to incorporate coastal erosion management and climate change adaptation.

5.2 Programme Objectives

Moving from the policy level to the establishment of programme objectives will take the decision-maker to the more practical steps of information collection and management, delineation of management boundaries and the selection of appropriate tools. It is important to re-emphasize here that these decisions must be made within the above-established policy context. The management context (i.e., programme objectives) will flow from the policy level and must be supportive of achieving those goals. Table 5.2 outlines some of the important steps that can be taken in this regard at the regional, national and sub-national/local levels.

Table 5.2 Management Objectives that Support National Policies

Regional EAS Level	National Level	Sub-national/Local Level
Improve the information base on the causes, extent, severity and trends of coastal erosion throughout the EAS region	Improve the information base on the causes, extent, severity and trends of coastal erosion in each member nation[5]	Enhance ecological risk assessment in relation to coastal function as natural defence system. Develop hazard maps in conjunction with socio-economic indicators
Delineate coastal sediment cell boundaries and restore a positive sediment balance where possible	Delineate and map areas currently and potentially affected by coastal erosion and undertake research to understand the controlling factors[6]	
Promote the use of setback lines and zoning in urban and rural areas	Nations use the four basic steps – define coastal state indicators, establish benchmarks for intervention, develop tactical options and assess impacts	

5.3 Implementation

Once the policy and programme objectives have been articulated, processes can be put in motion to bring technical detail to the desired approach. The suggested options outlined in Table 5.3 will produce the capacity and specific detail necessary to plan and ultimately implement appropriate responses to coastal erosion.

[5] For example, a coastal geological mapping project was recently undertaken in Penang, Malaysia, developing a geohazards mapping methodology for the coastal areas with regard to the effects of tsunamis and cliff instabilities around the backshore areas. Other methods included sediment sampling, photo documentation and the gathering of historical and anecdotal accounts.

[6] Many COBSEA member countries are currently undertaking research to delineate and map areas potentially affected by erosion and determine the controlling factors, as well as establishing relevant guidelines to minimize its extent and severity. Many of these studies use remote sensing, such as comparing temporally-spaced aerial photos, and also include sea-floor topography, beach profiling and sediment sampling. These approaches should be shared.

Table 5.3 Implementation of Actions at the Various Governance Levels

Regional EAS Level	National Level	Sub-national/Local Level
Establish a Regional Working Group on coastal erosion under COBSEA	Conduct national vulnerability assessments of each nation's coasts[7]	Formulate Coastal State Indicators (CSIs) in order to enable benchmarking and monitoring
Incorporate the results and guidance from the Coastal Spatial Planning project conducted for the Region	Assess current resilience of coastal systems within sediment cells	Promote information and education campaigns amongst the general populace of coastal regions to build a greater public awareness regarding coastal hazards and the recommended preventive and mitigation measures available
	Establish sediment budgets for each nation's coasts	Produce coastal and marine geohazards survey maps, which indicate the degree of vulnerability or susceptibility of each coastal area to a particular geohazards
	Establish National Working Groups on coastal erosion in participating countries, comprising representatives from all relevant stakeholders to coordinate activities at national level	Place emphasis on the specific conditions and needs within each coastal sediment cell, rather than taking a general, formulaic approach
	Build the required information base, including a national level geo-spatial clearinghouse for the types of data outlined in Section 3.6.5	Promote a consistent approach to monitoring of coastal erosion and sedimentation within the coastal sediment cells
	Incorporate the results and guidance from the Coastal Spatial Planning project	Empower communities and stakeholders to participate more actively in vulnerability assessments and adaptation implementation

5.4 Training/Capacity Building

The State of the Marine Environment Report highlighted that the condition of coastal areas and capacity to deal with the region's problems differs widely because of varying socio-economic situations. There is great potential for regional capacity development and transfer as the experiences gained across the region are varied and valuable to all. National efforts can then be consolidated and combined to strengthen the region's capacity to address coastal erosion with long-term sustainability alternatives. Refer to Table 5.4 for recommended actions.

[7] Various international and regional organizations have already begun adaptation programmes or projects that include some of the COBSEA countries. For example, UNFCCC has developed a compendium of methodologies for assessing vulnerability and adaptation, and a database on existing local strategies for coping with climate change variability and hazards

Table 5.4 Training and Capacity Building Activities

Regional EAS Level	National Level	Sub-national/local level
At the outset of the programme, a detailed training needs analysis should be undertaken to provide the basis for the development of a training and technical support programme to address these needs. The analysis should include identification of appropriate coastal academies or other potential training and research institutes in each country of the region	Train experts in all relevant government agencies in the principles and approaches of sustainable and ecosystem-based coastal erosion management	Train communities and stakeholders to participate in vulnerability assessment and adaptation planning in their local community
Assess existing capacity of adequately trained personnel (managers, scientists, coastal geomorphologists, coastal engineers, technical experts) in the region that can be marshalled to respond comprehensively to coastal erosion	Assess existing capacity of adequately trained personnel (managers, scientists, coastal geomorphologists, coastal engineers, technical experts) in the nation that can be marshalled to respond comprehensively to coastal erosion	
Establish regional research teams and initiatives and develop complementary scientific expertise in the region in the fields of coastal geomorphology, coastal engineering, ecology and coastal planning		

5.5 Sharing Best Practices

The implementation of this proposed approach puts a high demand on the knowledge of coastal processes, which in turn requires large quantities of technical information and stakeholder involvement. There is a direct need for applied research and collaboration between experts and managers to close the gap in the science-policy interface. Then, key "best practice" concepts to improve the sustainable management of coastal erosion can be formulated, implemented into policy, and executed. Table 5.5 provides some initial thoughts on knowledge sharing on coastal erosion mitigation.

Table 5.5 Sample of Knowledge Sharing on Best Practices

Regional EAS Level	National Level	Sub-national/local level
Include coastal erosion data in the EAS Knowledgebase[8]	Share research and experiences learned within each member nation with those responsible for aspects of coastal management and ICZM generally	Conduct study tours of successful and unsuccessful coastal erosion management projects
Enhance implementation of best practice through COBSEA-sponsored workshops		Assess current pilot studies; learn from these, initiate more pilots with approaches advocated in their policy frameworks, to test and refine approaches
Share experience, lessons learned and best practice from member nations		Conduct cost-benefit analyses – traditional vs. new approaches to identify the most efficient and effective approaches

6.0 THE PATH FORWARD

Section 6.0 provides several recommendations for the path forward and ultimately the development of a regional programme to address coastal erosion in the EAS region.

6.1 Engage COBSEA Member Countries

A COBSEA-sponsored regional workshop on Climate Change, Sea-level Rise and Coastal Erosion was convened in Bangkok, Thailand from 25-27 April 2011. At this workshop, an earlier draft of this resource document was presented, reviewed and discussed among the seven attending EAS countries (Cambodia, Indonesia, Korea, Malaysia, Philippines, Thailand, Viet Nam) and representatives of other regional organizations. National presentations were made on the coastal erosion challenge and responses to date and this material has been used to update and enrich the final version of this resource document. The COBSEA member countries will approve the final document in the future.

6.2 Further Consultation with the COBSEA Member Countries

The next phase of this initiative will include further individual consultations with the COBSEA member countries to evaluate their specific needs to develop a Coastal Erosion Programme. This may include support with Steps 1 and 2 of the policy framework, training, capacity building or other country specific requirements.

6.3 Comments on Integration with the Marine Spatial Planning Study

Another emerging issue (beyond coastal erosion), identified in the “New Strategic Directions for COBSEA, 2008-2012”, under the thematic area of management and response of coastal disasters, highlighted by the series of natural disasters in the region over the past years, concerns the need for improved spatial planning in the coastal zone to address disaster prevention and carry out environmentally sustainable development.

The project “Spatial Planning in the Coastal Zone – Disaster Prevention and Sustainable Development” was developed by the COBSEA Secretariat as a post-tsunami project during 2006 and submitted to the Swedish International Development Cooperation Agency (Sida). In early 2009, the project proposal was approved for funding by Sida.

At the request of Sida concepts of climate change adaptation, sea-level rise, ecosystem approach and results-based management were integrated into the project. In addition, it was also agreed with Sida that all seven COBSEA developing countries (Cambodia, China, Indonesia, Malaysia, Philippines, Thailand and Viet Nam) will be included in the project.

The 3-year project focuses on spatial planning in coastal areas with an overall goal to prevent/reduce the impacts from natural disasters, climate change and sea-level rise, and to promote sustainable development of the coastal areas through the application of spatial planning.

The project will be implemented in the following three phases over a period of three years:

(i) Producing Regional Guidance for the development and implementation of coastal spatial planning and coastal setback lines;

(ii) Meet individually with participating EAS nations to determine their training and capacity-building needs; and

(iii) Field application of the National Guidance and strengthening of national capacities through demonstration sites to undertake sustainable integrated coastal zone planning.

A draft of the regional report ”Bringing New Emerging Issues into Spatial Planning in the Coastal Zone” was developed and reviewed at a regional workshop in November 2010 and peer-reviewed by three experts. The report is currently being finalized.

The Regional Guidance will be a step-by-step operational tutorial on how to actually do spatial planning in the coastal zone for mid-level planners including the “check list” of things that need to be taken into account to mitigate or adapt to the sea-level rise and coastal disasters.

7.0 REFERENCES

Albers, T. and N. von Lieberman, 2011. Current and Erosion Modelling Survey: Management of Natural Resources in the Coastal Zone of Soc Trang Province (Viet Nam). Germany.

Armitage, D., M. Marschke and T. Van Tuyen, 2011. Early-stage Transformation of Coastal Marine Governance in Viet Nam? Marine Policy 35: 703-711.

Asian Development Bank, 1995. Proceedings of the Coastal and Marine Environmental Management. Manila. 331 p.

Asian Development Bank, 2009. The Economics of Climate Change in Southeast Asia: A Regional Review. Manila. 208 p.

Asian Development Bank, 2011. Climate Change and Migration in Asia and the Pacific. Manila.

Bleakley, C. and S. Wells, 1995. Marine Region 13: East Asian Seas: A Global Representative System of Marine Protected Areas – Great Barrier Reef Marine Park. The World Bank and the World Conservation Union (IUCN). Washington, D.C. USA. 212 p.

Burke, L., K. Reytar, M. Spalding and A. Perry, 2011. Reefs at Risk Revisited. World Resources Institute. Washington.

California Coastal Sediment Management Workgroup, 2009. The California Coastal Sediment Master Plan: Status Report.

California Coastal Sediment Management Workgroup, 2010. California Beach Erosion Assessment Survey 2010.

Chaimanee, 1997. The vulnerability of geohazards in the coastal lowland of Thailand, p. 35-46. In Kato, H. and Y. Shimazaki (Eds.). Report of EANHMP: An approach to Natural Hazards in Eastern Asia. Geological Survey of Japan, Tsukuba.

Coastal Science and Engineering, 2011. Coastal Erosion and Solutions: A Primer (2nd Edition). Columbia, South Carolina.

Conservation International, 2008. Economic Values of Coral Reefs, Mangroves and Seagrasses: A Global Compilation. Center for Applied Biodiversity Science, Conservation International, Arlington, Virginia, USA.

Costanza, R. et al., 1997. The Value of the World's Ecosystem Services and Natural Capital. Nature 387: 253-260.

Cruz, R.V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li, and N. Huu Ninh, 2007. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p. 469-506. In Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds.). Asia Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, UK.

Bird, E.C.F., 2010. Encyclopedia of the World's Coastal Landforms. Published by Springer.

Dodds, W., J.A.G. Cooper and J. McKenna, 2010. Flood and Coastal Erosion Risk Management Policy Evolution in Northern Ireland: "Incremental or Leapfrogging?" Ocean and Coastal Management 53: 779-786.

Eurosion, 2004. Living with coastal erosion in Europe: Sediment and space for sustainability. A guide to coastal erosion management practices in Europe. Brussels. Directorate General Environment. European Commission.

Farhan, A.R. and S. Lim, 2011. Resilience Assessment on Coastline Changes and Urban Settlements: A Case Study in Seribu Islands, Indonesia. Ocean and Coastal Management 54: 391-400.

Feagin, R.A., M.L. Martinez, G. Mendoza-Gonzalez and R. Constanza, 2010. Salt Marsh Zone Migration and Ecosystem Service Change in Response to Global Sea-Level Rise: A Case Study from an Urban Region. Ecology and Society 15(4):14.

Friesinger, S. and P. Bernatchez, 2010. Perceptions of Gulf of St. Lawrence Coastal Communities Confronting Environmental Change: Hazards and Adaptation, Quebec, Canada. Ocean and Coastal Management 53: 669-678.

Global Commons Institute, 2011. Climate Uncertainty and Policymaking: A Policy Maker's View. Report Prepared for the All Party Parliamentary Group on Climate Change. London.

Intergovernmental Panel on Climate Change, 2007. Fourth Assessment Report of the United Nations Intergovernmental Panel for Climate Change.

Jarungrattanapong, R. and A. Manasboonphempool, 2008. Adaptation Strategies for Coastal Erosion/Flooding: A Case Study of Two Communities in Bang Khun Thian District, Bangkok. TDRI Quarterly: March 2008: 21(1). Pp 11-18.

Joffre, O., 2010. Mangrove Dynamics in Soc Trang Province (Viet Nam) 1889-1965. Management of Natural Resources in the Coastal Zone of Soc Trang Province. GTZ.

Kellon, D. and J. Arvai, 2011. Five Propositions for Improving Decision Making About the Environment in Developing Countries: Insights from the Decision Sciences. Journal of Environmental Management 92, 363-371.

Khazai, B., J.C. Ingram and D.S. Saah, 2007. The Protective Role of Natural and Engineered Defence Systems in Coastal Hazards. Literature Review Report prepared by Spatial Informatics Group for the State of Hawai'i.

Kirwan, M.L., G.R. Guntenspergen, A.D'Alpaos, J.T. Morris, S.M. Mudd and S. Temmerman, 2010. Limits on the Adaptability of Coastal Marshes to Rising Sea-Level. Geophysical Research Letters, Vol. 37.

Landry, C.E., 2011. Coastal Erosion as a Natural Resource Management Problem: An Economic Perspective. Coastal Management, 39: 259-281.

Latif, Z.A., 2010. Challenges of the Malysian Coast – Integrated Shoreline Management. Second International Conference on Coastal Zone Engineering and Management (Arabian Coast 2010), 1-3 November 2010, Muscat, Oman.

Marchand M. (Ed.), 2010. Concepts and Science for Coastal Erosion Management. Concise report for policy makers. Deltares, Delft.

Maribus, 2010. World Ocean Review.

McKenna, J., J.A.G. Cooper and A.M. O'Hagan, 2009. Coastal Erosion Management and the European Principles of ICZM: Local versus Strategic Perspectives. J. Coast Conserv 13: 165-173.

McGranahan, G., D. Balk and B. Anderson, 2007. The Rising Tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization: 19, 17-37.

Mercer LLC., Carbon Trust and International Finance Corporation, 2011. Climate Change Scenarios – Implications for Strategic Asses Allocation. Public Report.

Partnerships in Environmental Management for the Seas of East Asia, 2009. Achieving Sustainable Development Targets in a Changing Climate: How Can ICM Help? Policy Brief, The East Asian Seas Congress 2009.

Partnerships in Environmental Management for the Seas of East Asia, 2003. Sustainable Development Strategy for the Seas of East Asia: Regional Implementation of the World Summit on Sustainable Development Requirements for the Coasts and Oceans. PEMSEA, Quezon City, Philippines. 116 p.

Pijnappels, M, F. de Pater and O. Van Steenis (Eds.), 2011. Deltas in Times of Climate Change: Connecting World Science and Deltas. Meeting Report, International Conference, Rotterdam, the Netherlands, 29 September – 1 October 2010.

Saito, Y. et al., 2007. Shrinking Megadeltas in Asia: Sea-level Rise and Sediment Reduction Impacts from Case Study of the Chao Phraya Delta. Prepared for INPRINT.

Short, F.T. et al., 2011. Extinction Risk Assessment of the Worlds' Seagras Species. Biological Conservation 144: 1961-1971.

Trisirisatayawong, I., M. Naeije, W. Simons and L. Fenoglio-Marc. (in press). Sea-Level Change in the Gulf of Thailand from GPS-corrected Tidal Guage Data and Multi-satellite Altimetry. Global and Planetary Change. 2011.

United Nations Environment Programme, 2011. Taking Steps toward Marine and Coastal Ecosystem-Based Management – An Introductory Guide.

United Nations Environment Programme, 2008. New Strategic Directions for COBSEA (2008-2012). COBSEA Secretariat, United Nations Environment Programme. Bangkok. 23 p.

United Nations Environment Programme, 2009. Report of the Twentieth Intergovernmental Meeting of the Coordinating Body on the Seas of East Asia (COBSEA). 2-5 November 2009. Ha Long City, Viet Nam. 36 p.

United Nations Environment Programme, 2007. Strategic Action Programme for the South China Sea. UNEP/GEF/SCS Technical Publication No. 16.

UNEP/COBSEA, 2010. State of the Marine Environment Report for the East Asian Seas 2009. Ed. Chou, L.M., COBSEA Secretariat, Bangkok. 156 p.

Viles, H. and T. Spencer, 1995. Coastal Problems. John Wiley and Son Inc. New York. 350 p.

Wilkinson, C.R. (Ed.), 2008. Status of Coral Reefs of the World: 2008. Australian Institute of Marine Science. Townsville.

WGCCD (Working Group on Climate Change and Development) 2007. Up in Smoke? Asia and the Pacific: The Threat from Climate Change to Human Development and the Environment. New Economics Foundation and IIED. 92 p.

World Bank, 2010. Climate Risks and Adaptation in Asian Coastal Megacities: A Synthesis Report. Washington, D.C.

World Mangrove Atlas http://www.fao.org/forestry/7003-1-0.pdf.

Zhu, X. (Ed.), 2010. Technologies for Climate Change Adaptation – Coastal Flooding and Erosion. UNEP RISØ Centre on Energy, Climate and Sustainable Development/GEF. Denmark.

Appendix A:

EXTRACT FROM THE FINAL REPORT OF THE 20TH MEETING OF THE COORDINATING BODY OF THE SEAS OF EAST ASIA

Annex 1:

EXTRACT FROM THE FINAL REPORT OF THE 20TH MEETING OF THE COORDINATING BODY OF THE SEAS OF EAST ASIA

Coastal erosion is caused by, among others, *natural* factors such as waves, winds, storms, tidal currents and, lately, by climate change-induced sea-level rise caused by thermal expansion and also by *human-induced factors* such as construction of hard coastal defences, land reclamation, dredging, river-flow regulation, vegetation clearing, etc., is taking its toll and causing serious impact.

The protection against coastal erosion and adaptation to sea-level rise is important as climate change will increase the frequency of natural hazards such as tidal surges and storms. There is a need to establish regional, national and local frameworks for the management of coastal erosion. Policies, strategies and implementing guidelines for government and decision-makers would be necessary to address this emerging problem of coastal erosion in the EAS region.

The 20th Intergovernmental Meeting of COBSEA (Halong City, Viet Nam, November 2009) has identified coastal erosion as an emerging priority for the region, and requested COBSEA Secretariat to develop a regional programme to address the problem. It also directed the Secretariat to identify external funding sources to implement the programme. In this regard, with the kind support of Korea Maritime Institute, the development of a regional programme has been initiated.

The development of the Regional Programme to address coastal erosion in the East Asian Seas is currently underway through consultancy services hired by COBSEA Secretariat. As a follow-up to this initiative, of developing the draft Regional Programme, a regional workshop is planned with the aim of exploring and discussing the scope and magnitude of this issue and refining the draft Regional Programme of Action on the Sustainable and Ecosystem-based Management of Coastal Erosion in the East Asian Region.

Coastal Erosion Management Techniques (Principals and Limits of Application)

(from http://www.eurosion.org/reports-online/part4.pdf)

Techniques	Principles	Limits of Application
Hard Techniques		
Breakwater	Breakwaters are protective structures placed offshore, generally in hard materials such as concrete or rocks, which aim at absorbing the wave energy before the waves reach the shore.	Breakwaters reflect or diffract wave energy in destructive ways or concentrate it in local hot spots. Erosion problems and the scouring effects of the misdirected energy lead to the loss of beach/coastline and undermine the structures that were meant to be protected.
Gabion	The gabion is a metal cage filled with rocks, about 1 metre by 1 metre square. Gabions are stacked to form a simple wall.	They are used to protect a cliff or area in the short-term only, since they are easily damaged by powerful storm waves and the cages tend to rust quite quickly. Gabions have the advantage of ease of use and are relatively cheap but their life span is short.
Geotextiles	Geotextiles are permeable fabrics which are able to hold back materials while water flows through. Geosynthetic tubes are large tubes consisting of a woven geotextile material filled with a slurry-mix. The mix usually consists of dredged material (e.g., sand) from the nearby area but can also be a mortar or concrete mix.	Geotextiles are relatively recent but provided good results to prevent beach from retreating. Plus they are very flexible and can be re-arranged if their configuration does not provide good results.
Groin fields	Groins are structures that extend perpendicularly from the shore. Usually constructed in groups called groin fields, their purpose is to trap and retain sand, nourishing the beach compartments between them. Groins may be made of wooden or rocky materials. They interrupt the longshore transport of littoral drift. When a well designed groin field fills to capacity with sand, longshore transport continues at about the same rate as before the groins were built, and a stable beach is maintained.	Sand accumulated between groins contributes to a sediment deficit down-drift. Coastal erosion problems are then shifted to other locations. Thus, to be effective, groins should be limited to those cases where longshore transport is predominantly in one direction, and where their action will not cause unacceptable erosion of the down-drift shore.
Revetments	Revetment is a sloping feature which breaks up or absorbs the energy of the waves but may let water and sediment pass through. The older wooden revetment consists of posts fixed into the beach with wooden slats between. Modern revetments have concrete or shaped blocks of stone laid on top of a layer of finer material. Rock armour or riprap consists of layers of very hard rock with the largest, often weighing several tonnes, on the top. Riprap has the advantage of good permeability and looks more natural.	Revetments are adapted to foreshore with a gentle slope. It has the same adverse effect as seawalls though with a reduced intensity. It also results in changing the nature of the sea frontage which may lead to further changes in the foreshore ecosystems.
Seawall	Bulkheads and seawalls protect banks and bluffs by completely separating land from water. Bulkheads act as retaining walls, keeping the earth of sand behind them from crumbling or slumping. Seawalls are primarily used to resist wave action. Design considerations for these types of structures are similar. These structures do not protect the shore in front of them, however.	When bulkheads and seawalls are used in areas where there is significant wave action, they may accelerate beach erosion (much of the energy of the waves breaking on the structure is redirected downward to the toe). Bulkheads and seawalls are most appropriate where fishing and boating are the primary uses of the shore and gently sloping areas for sunbathing or shallow-water swimming are not essential. They are also critical when risks associated to coastal erosion are imminent.
Soft Techniques		
Artificial reef creation	Building an artificial reef which absorbs the wave energy (thus providing coastal defence), while providing a natural habitat for marine biodiversity and opportunities for recreational activities.	Only few examples of artificial reef creation exist in Europe (in Sea Palling, UK mainly), but seems to provide good results.
Beach drainage	Beach drainage decreases the volume of surface water during backwash by allowing water to percolate into the beach, thus reducing the seaward movement of sediment. Beach drainage also leads to drier and "gold" coloured sand, more appreciated for recreational activities.	The technique is relatively new and experience lacks to assess its performance. It has to be noted however that beach drainage is adapted when erosion mainly occurs cross-shore (non-significant long-shore drift).
Sand supply or nourishment	Artificial increase of sand volumes in the foreshore via the supply of exogenous sand. Sand supply may be achieved through the direct placement of sediment on the beach, through trickle charging (placing sediments at a single point), or through pumping. It can be also take place in the emerged part of the foreshore ("beach nourishment") or under the water line ("underwater nourishment") which is generally cheaper.	Beach and underwater nourishment as been very popular in the North because of the availability of sediments which has similar properties as the beach sediment. When sediment is not available and has to be imported from another region, beach nourishment may not be the best decision. Nourishment schemes have also to be carefully designed as they may alter the biota (both on the beach and in the dredging area).

Techniques	Principles	Limits of Application
Soft Techniques		
Beach scraping	Artificial re-profiling of the beach when sediment losses are not severe enough to warrant the importation of large volumes of sediments. Re-profiling is achieved using existing beach sediment.	Beach scraping is among the cheapest techniques as it does not require importing sand. However, the process may have to be carried out several times before the right profile is found. It is also restricted to those beaches where cross-shore erosion is dominant and storms not heavy.
Cliff drainage	Reduction of pore pressure by piping water out of the cliff and therefore preventing accumulation of water at rock boundaries.	May not be applicable for all types of cliffs.
Cliff profiling	Change of cliff face angle to increase cliff stability. The angle at which cliff become stable is a function of rock type, geologic structure and water content.	May not be applicable for all types of cliffs, and the techniques requires a fairly good knowledge of the cliff geologic structure and watering process.
Cliff toe protection	Protection of the cliff base by placing blocks at the foot of potential failure surface.	This technique is easy to achieved but do not stop erosion completely. It may therefore be adapted in those case where further loss of lands is still acceptable.
Creation of stable bays	Increasing the length of the coastline to dilute wave energy per unit length of coast. While some coastline segments are protected, erosion continues between these hard points leading to the formation of embayments.	This technique is almost not used in Europe and is still experimental. However, it has been envisaged for a number of sites (especially the Holland coast).
Dune regeneration	Wind blown accumulation of drifted sand located in the supra-tidal zone. Wind velocity is reduced by way of porous fences made of wood, geo-textile, plants, which encourages sand deposition.	Adapted for those cases where wind plays an important role.
Marsh creation	Planting of mudflats with pioneer marsh species, such as *Spartina sp*. Marsh vegetation increases the stability of sediment due to the binding effects of the roots, increasing shear strength and decreasing erodability. Marshes also provides cost-effective protection against flooding by absorbing wave energy.	Marsh creation is particularly popular in United Kingdom. However, the technique may be jeopardized by accelerated sea-level rise. In this case, the accumulation of fine sediments necessary to the marsh creation may not occur in the proper way and the marsh finally collapse.
Mudflat recharge	Supply of existing mudflats with cohesive sediments. This is achieved via trickle charging (see beach feeding), rainbow charging, and polders.	Such as marsh creation, mudflat recharge may be jeopardized by accelerated sea-level rise.
Rock pinning	Prevention of slippage in seawards dipping rocks by bolting layers together to increase cohesion and stability. Does not prevent wave attack at the cliff base, but does reduce the threat of mass movement and thus reduces net erosion rates.	May not be applicable for all types of cliffs.
Sand by-passing	Reactivation of sediment transport processes by pumping sediments accumulated up-drift by coastal infrastructure normal to the coastline and injecting them down-drift. A variant of sand by-passing is to use materials dredged for navigational purposes to reactivate the sediment transport.	This technique has been implemented by a number of harbour authorities (or dams authorities) in Europe as volumes of sand trapped by harbour breakwaters (resp. dams) are generally considerable. When sediments are trapped by a series of groins (or consecutive dams) the technique might not be cost effective anymore. It has to be noted that in the case of dams, accumulated sediment may be contaminated may not be re-injected in the sediment transport system.
Vegetation planting and/or stabilization	Colonization of coastal soils by vegetation whose roots bind sediment, making it more resistant to wind erosion. Vegetation also interrupt wind flow thus enhancing dune growth. As for cliffs, vegetation increases cohesion of surface soils on cliff slopes to prevent downhill slumping and sliding.	Vegetation adapted to dune (e.g., Marram grass) is generally very fragile and require integral protection and daily care to the dune system.

Appendix B:

EROSION MITIGATION ALTERNATIVES AND GENERAL REFERENCES

Measures for Responding to Sea-Level Rise (Objective and Environmental Effects)
(from http://epa.gov/climatechange/effects/coastal/pdfs/CCSP_chapter6.pdf)

Response Measure	Method for Protection or Retreat	Key Environmental Effects
Shoreline armoring that interferes with waves and currents		
Breakwater	Reduces erosion	May attract marine life; down-drift erosion
Groin	Reduces erosion	May attract marine life; down-drift erosion
Shoreline armoring used to define a shoreline		
Seawall	Reduces erosion, protects against flood and wave overtopping	Elimination of beach; scour and deepening in front of wall; erosion exacerbated at terminus
Bulkhead	Reduces erosion, protects new landfill	Prevents inland migration of wetlands and beaches; wave reflection erodes bay bottom, preventing submerged aquatic vegetation; prevents amphibious movement from water to land
Revetment	Reduces erosion, protects land from storm waves, protects new landfill	Prevents inland migration of wetlands and beaches; traps horseshoe crabs and prevents amphibious movement; may create habitat for oysters and refuge for some species
Shoreline armoring used to protect against floods and/or permanent inundation		
Dike	Prevents flooding and permanent inundation (when combined with a drainage system)	Prevents wetlands from migrating inland; thwarts ecological benefits of floods (e.g., annual sedimentation, higher water tables, habitat during migrations, productivity transfers)
Tide gate	Reduces tidal range by draining water at low tide and closing at high tide	Restricts fish movement; reduced tidal range reduces intertidal habitat; may convert saline habitat to freshwater habitat
Storm surge barrier	Eliminates storm surge flooding; could protect against all floods if operated on a tidal schedule	Necessary storm surge flooding in salt marshes is eliminated
Elevoting land		
Dune	Protects inland areas from storm waves; provides a source of sand during storms to offset erosion	Can provide habitat; can set up habitat for secondary dune colonization behind it
Beachfill	Reverses shore erosion, and provides some protection from storm waves	Short-term loss of shallow marine habitat; could provide beach and dune habitat
Elevate land and structures	Avoids flooding and inundation from sea-level rise by elevating everything as much as sea rises	Deepening of estuary unless bay bottoms are elevated as well
Retreat		
Setback	Delay the need for shore protection by keeping develoment out of the most vulnerable lands	Impacts of shore protection delayed until shore erodes up to the setback line; impacts of development also reduced
Rolling easement	Prohibit shore protection structures	Impacts of shore protection structures avoided
Density or size restriction	Reduce the benefits of shore protection and thereby make it less likely	Depends on whether owners of large lots decide to protect shore; impacts of intense development reduced

Manuals and Books

Albers, T. and N. von Lieberman, 2011. Current and Erosion Modelling Survey: Management of Natural Resources in the Coastal Zone of Soc Trang Province (Viet Nam). Germany. (information on the use of bamboo stakes in Viet Nam)

CSE (Coastal Science and Engineering) 2011. *Coastal Erosion and Solutions – A Primer*. 2nd edition.http://www.coastalscience.com/.

GDENV European Commission, 2004. *Development of a Guidance Document on Strategic Environmental Assessment (SEA) and Coastal Erosion*. Final Report. http://ec.europa.eu/environment/iczm/pdf/coastal_erosion_fin_rep.pdf.

EUROSION, 2004. *Living with Coastal Erosion in Europe: Sediment and Space for Sustainability. A Guide to Coastal Erosion Management Practices in Europe. (Shoreline Management Guide* – SMG). Brussels. Directorate General Environment. European Commission. 164 pp. http://www.eurosion.org/reports-online/reports.html.

Haslett, S., 2008. *Coastal systems*. 2nd edition. Routledge.

INTERREG IIIC, 2006. *Engineering the Shoreline – Introducing Environmentally Friendly Engineering Techniques Throughout the World*. EU. http://www.interreg-messina.org/documents/CoastalToolkit/MESSINA%20-%20Practical%20Guide%20-%20Engineering%20the%20Shoreline.pdf

Jarungrattanapong, R. and Manasboonphempool, A. *Adaptation Strategies to Address Coastal Erosion/Flooding: A Case Study of the Communities in Bang Khun Thian District, Bangkok, Thailand*. Prepared for the Economy and Environment Program for Southeast Asia.

Linham, M. and R.J. Nicholls, 2010 (X. Zhu ed.). *Technologies for Climate Change Adaptation*. UNEP Risø Centre on Energy, Climate and Sustainable Development, Denmark. http://tech-action.org/Guidebooks/TNAhandbook_CoastalErosionFlooding.pdf

Mangor, K., 2004. *Shoreline Management Guidelines*. DHI, Hørsholm, Denmark.

USACE (US Army Corps of Engineers), 2008. *Coastal Engineering Manual* (CEM) Parts 1-5. (See Part V, chapter 3 on shore protection projects). http://publications.usace.army.mil/publications/eng-manuals/

Internet Sites

Encora – Coastal portal (maintained by some members of EU)
http://www.coastalwiki.org/coastalwiki/Protection_against_coastal_erosion
(see protection against coastal erosion: entries on hard measures and soft measures)

2. EUROSION
http://www.eurosion.org/index.html
(click on Shoreline Management, then click Table to see 60 examples of coastal type, policy and measure used in European Union).