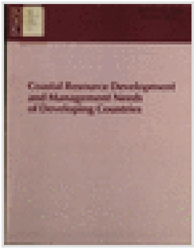

Coastal Resource Development and Management Needs of Developing Countries: Working Discussions (1982)

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Coastal Resource Development and Management Needs of Developing Countries

Working Discussions
Board on Science and Technology for International Development
Office of International Affairs
in cooperation with
Ocean Policy Committee
Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

The coastal regions of the large proportion of developing countries that border on oceans and seas include many of those countries' major population centers. In fact, well over 50 percent of the world's people live either at the coasts or in adjacent coastal lowland areas. Coastal lands and waters also comprise substantial quantities of the nations' agricultural, mineral, and living resources, so that coastal degradation problems such as erosion, decreased water quality, and the destruction of living resources are issues of major concern.

This report evaluates the types of technical assistance in the development and management of coastal resources that the United States might best provide in the context of national programs to encourage and assist international development. It is based principally on the proceedings of a workshop of coastal resource scientists, engineers, and management planners, held in La Jolla, California, on February 8-10, 1982. The workshop was convened by the Board on Science and Technology for International Development (BOSTID), of the National Research Council (NRC), National Academy of Sciences (NAS), in conjunction with the NRC Ocean Policy Committee (OPC), at the request of the Office of Forestry, Environment, and Natural Resources (FNR) of the Agency for International Development (AID).

Workshops and symposia addressing the problems of coastal management in developing countries have been conducted by several international scientific assistance agencies. Findings and recommendations of some of the United Nations Environment Program and UNESCO meetings on coastal environmental monitoring and research programs are referred to in this report. Another series of U.N.-sponsored meetings that is particularly pertinent to the goals of this workshop has been organized by the Ocean Economics and Technology Branch (OETB) of the U.N.

Recognizing the importance of economically productive utilization of natural resources, the OETB workshops have considered development needs and resource protection issues together. Moreover, to increase awareness of the linkages between the various sectors of the environment, land-based and ocean-based aspects of coastal management have been considered as a unified area of concern.

The impetus for the OETB coastal workshops was an interregional seminar, "Development and Management of Coastal Regions," held in West Berlin in 1976. It was co-sponsored by the OETB and the German Foundation for International Development, and attended by representatives of coastal nations worldwide. At this seminar, technical and managerial problems were identified and outlined and it was recommended that follow-up meetings be held to allow more detailed examination of needs in particular geographical areas. Two such regional meetings were held in 1979. The first, the "Workshop on Coastal Area Development and Management in Asia and the Pacific," was held in Manila and jointly coordinated by the OETB and the Environment and Policy Institute of the East-West Center in Hawaii. The second regional meeting, the "Workshop on Coastal Area Management in the Caribbean Region," was held in Mexico City and coordinated by the OETB and the Intergovernmental Oceanographic Commission.

The reports of the two meetings include suggestions for improvements in erosion protection methods and coastal engineering practices, and descriptions of some of the underexploited energy and mineral resources and other commercial development potentials of the regions. The Mexico City report also provides advice about the need for caution due to the possibilities of habitat destruction harming living resources. The Manila workshop proceedings include sections on the mineral resource potentials of the South Pacific and South China Sea regions, discussing not only deep-sea minerals, but also nearshore "bulk" minerals such as construction aggregates that can provide sizeable economic returns for many developing countries. Both reports also strongly endorse the principles of coordinated coastal area management, and conclude that such coordination provides the best means to increase and maintain economic productivity, while simultaneously providing resource protection.

At the 1982 La Jolla workshop on which this report is based, participants suggested the types of scientific knowledge and technology available in the United States that would be most likely to match the needs and capabilities of developing countries for monitoring, managing, and developing their coastal resources. Information in the report is largely drawn from the working group reports of the workshop and from supplementary technical materials provided to BOSTID by meeting participants. Where information from additional sources has been included, bibliographic references are cited. Additional general references for each subject area are recommended in the selected readings list.

SUMMARY OF PRINCIPAL RECOMMENDATIONS

Principal recommendations of scientific and technical approaches to enhance coastal development and meet the coastal resource management needs of developing countries are outlined here. Comments and recommendations in the area of institutional arrangements are given in Appendix A. More specific, technical recommendations are made in Appendixes B to F.

EROSION AND WATERSHED MANAGEMENT

The Problem

Coastal erosion from man-made causes is a critical problem in a large proportion of coastal developing countries. This results in substantial losses of agricultural land, undermining of urban structures, and the stripping away of sand beaches down to the rock or gravel substrate. In addition, the increased occurrence of flooding due to eroded hillsides, or damage to protective features such as barrier beaches and bluffs, has increased the losses of life and property associated with natural coastal disasters (storms, floods, or tsunamis).

Principal factors responsible for increased erosion are:

- devegetation
- dam or harbor construction
- highway or airport construction
- other forms of construction involving inadequately reinforced earth-moving activities, especially on hillsides or at tops of cliffs.

Other causes, often of primary importance in particular locations, include:

- dredging or dynamiting of shore-protecting coral reefs;
- beach sand and gravel mining;

- o groins, bulkheads, or breakwaters built in inappropriate locations;
- o dredging to change the configurations of coastal inlets or channels.

Recommendations

- o Clear-cutting and other forms of excessive devegetation should be avoided. Sustained yield agro-forestry techniques should be instituted if good markets for wood and wood products are available.

- o Sufficient amounts of coral reefs, barrier beaches, wetlands, and vegetation should be identified and left intact to protect shorelines in critical areas.

- o Construction projects, particularly in elevated areas adjacent to the coast, should not be sited in locations where substantial and detrimental erosion is predictably going to result.

- o Development of large civil-works projects such as highways, dams, harbors, and airports must include much increased attention to erosion-minimizing techniques such as re-planting, sediment-bypasses (for harbors or dams), effective retaining walls, or better preliminary analyses of drainage patterns and soil stability (for land projects).

- o Technical information should be obtained to allow accurate decision-making as to what will constitute "sufficient amounts" of natural features to protect a given coastline. These will principally be data concerning sediment types, ocean current directions, locations of offshore features such as reefs, and some estimates of regional river flow and sediment transport levels. Getting such information does not have to involve expensive and elaborate techniques; often simple, low-technology observation and sampling methods will be sufficient.

- o When protective artificial structures such as seawalls, bulkheads, or groins are designed, proper technical advice must be obtained in advance, as these features often have unpredicted effects that actually make matters worse, or create new problems in adjacent locations.

POLLUTION

The Problem

Coastal waters are typically regarded as a convenient dumping site for all types of wastes. In some instances, nontoxic organic wastes, such as domestic sewage or agricultural effluents, will change the aquatic ecosystem, but have no negative or even some slightly positive effects. In most cases, however, as pollutant levels increase in increasingly populated and developed areas, negative effects become apparent in local organisms and environments. The common presence of toxic substances in agricultural, industrial, and even domestic wastes can result in contamination of seafoods and of environmental waters, producing human and animal health problems, and also preventing the use of seafoods for international trade.

Recommendations

- Sewage release sites should be selected in consideration of ocean flushing rates. These depend on current patterns and flow rates, tidal patterns, coastal geography, and bottom depth and topography. Two sites quite near to one another will often have markedly different flow patterns and flushing rates, so that substantial improvemets in pollutant dispersal can be achieved by well-informed site-selection.

- The monitoring of toxic waste levels in seafood supplies and in coastal environments can be most efficiently done by periodic sampling of indicator organisms (usually "biomagnifiers"). The regular collection of tissue samples of animals such as mussels or oysters, for analysis locally or through cooperation with international monitoring efforts such as the "Mussel Watch," is relatively inexpensive. This is also not demanding of very high technology analytical capabilities, as the direct analysis of water contamination levels would be.

- Site-selection for industrial and agro-industrial plants that produce large volumes of organically rich wastewater should include efforts to avoid particularly poorly-flushed locations where eutrophication will create serious pollution problems. (Examples of plant types include, among numerous others, breweries, sugar refineries, canneries, pulp or textile mills, tanneries, and distilleries.)

- Destruction or pollution of the nursery areas for fish, shrimp, and other shellfish decreases the original numbers and probably also the survival rates of young produced in a region, and thus much reduces the reproductive capabilities of the stocks. The numbers of adult fish also typically decrease due to death or migration when an area becomes polluted with wastes or silt. To counteract these effects of coastal degradation, appropriate sections of unpolluted shoreline should be identified and designated as coastal parks or marine life preserves. This is a good method for ameliorating impacts on fish stocks and has the simultaneous advantage of providing natural recreation or wilderness areas.

PRODUCTIVE USE OF AGRICULTURAL WASTES AND SEWAGE

The Present Situation

Large quantities of nutrient-rich waste materials are released into the coastal environment, often creating pollution problems. The organic components of these wastes are energy-rich and could serve as energy sources through a variety of conversion techniques. The nutrient components are also an excellent source of natural fertilizers.

Recommendations

When toxic contaminants are not present, techniques are available for putting organic wastes to use as energy sources, agricultural fertilizers, or aquaculture nutrient supplies. In low-productivity coastal waters, (and usually only if coral reefs are not present), the release of moderate amounts of non-toxic sewage may enhance the productivity of fish or other organisms of economic value. Fairly simple systems may be constructed for the production of biogas fuel through the treatment of sewage or farm effluents. This is only practical, however, when effluents will be available in high-volume and fairly regular supply, as in large farming operations or organized town cooperatives.

PROTECTION OF PRODUCTIVE LIVING RESOURCES

The Resources

Living coastal resources of commercial importance in developing countries include fish, shellfish, commercially important aquatic plants, tropical mangrove forests, and coral reefs. Organisms without direct commercial value are often critical providers of habitat and food supplies for other organisms, as well as being linked to environmental quality by recycling of nutrients and wastes.

Recommendations

- "Sustained-yield" mangrove harvesting methods should be employed in order to support lumber, fuel, and wood-product industries, as well as to protect against erosion. When sustained-yield methods are not applied, the forests can be rapidly destroyed, removing the resource base and thus the potential for continuation of the industry.

- Coral reefs should not be subjected to excessive dredging and mining, or to poisoning and dynamiting incidental to the use of these practices to kill and harvest fish. Sufficient quantities of living reef must be left in each area to support the next generation of fish.

- Corals are often injured or killed when levels of organic wastes (such as sewage), toxic chemicals (especially pesticides), or erosional sediments become too high. When organic effluents are at fault, the placement of sewage outfalls so that effluents are dispersed away from critical reefs has been found to reverse such damage. "Reseeding" of reef areas by coral transplantation is still somewhat experimental, but success has been achieved in areas where silt or pollutant levels had been decreased.

- Fish and shellfish stocks have been decreased by two categories of human activity: the degradation of habitat and associated food supplies as already discussed, and overfishing. Overfishing of nearshore, coastal fisheries, which are typically artisanal fisheries rather than large-scale commercial operations, is not easily monitored or managed due to the diffuse nature of the harvesting and distribution activities. But success can be achieved when managers are able to work effectively with local people to obtain the needed information about any changes in size and composition of catches.

NATURAL DISASTER PROTECTION FOR COASTAL PEOPLE

The Problem

Natural disasters such as floods, hurricanes, or tsunamis are resulting in increasing losses of lives and property as population pressures in developing countries lead to increased migration into exposed coastal areas and floodplains. This is especially true when coastal reclamation or relocation projects encourage settlement in dangerously low-lying areas, or when there has been destruction of protective features such as vegetation, reefs, or barrier beaches.

Recommendations

Disaster preparedness and contingency plans must be developed, and these problems and considerations should be emphasized in all stages of coastal planning and financial allocation. Attempts should be made to identify particularly hazardous areas, so that settlement in those locations can be avoided.

INTRODUCTION

This report describes some of the benefits to be derived from technical improvements in coastal development practices. It also discusses the ways in which many desirable uses of coastal resources can interfere with one another in the absence of sufficiently well-informed coastal management. Consideration is given throughout the report to issues of particular importance to developing countries.

The usefulness of coastal regions as residential, recreational, or tourist areas, and their functions of providing fish, croplands, and healthful waters for coastal peoples has been decreased in many countries as a result of random development.[1] Typical problems include erosion caused by dredging and inappropriate site selection for groins, dams, or harbor breakwaters; toxic contamination of fish or other marine organisms; and sewage and industrial waste contamination of waters and beaches used for recreation or tourism. Also, insufficient marine engineering capabilities can result in inadequate construction of industrial structures, drilling rigs, and other installations to resist currents, surf, and storms; excessive silt deposition in improperly designed harbors; or the flooding or washing out of land fill areas because of inadequately anticipated geological and hydrological factors.

In many of the more densely populated nations, the effects of natural disasters on inhabitants of coastal flatlands are being exacerbated by coastal migrations and related development activities. As population pressures increase rates of migration into exposed flatlands, coastal people become even more susceptible to natural hazards such as floods, typhoons, earthquakes, or tidal waves. This is especially true when land reclamation projects encourage settlement in dangerously low-lying areas, or when land-clearing and other construction activities damage protective vegetation, reefs, or geomorphological barriers.[2] A particularly disastrous example of the loss of life and physical destruction that can result from settlement in unprotected coastal lowlands has occurred in Bangladesh in recent years, where many thousands of lives have been lost in catastrophic coastal floods.

In most tropical coastal regions, fuel-gathering or land-clearance will involve the destruction of mangrove stands that could under proper management provide renewable production of wood and wood products, and that stabilize shorelines and provide nursery grounds for fish and shrimp. In higher latitudes where mangroves do not grow, other forms of wetland vegetation serve equivalent functions, retarding erosion and recycling nutrients into marine food chains. The filling of wetlands and their use as waste dumps is reducing the productive capacities of fish stocks that support artisanal, recreational, and commercial fisheries.

In coral-growing latitudes, reef destruction by mining, dredging, or sewage and silt run-off diminishes coral-associated fish stocks and removes natural protective barriers. Planners and developers have to make decisions involving multiple costs, benefits, and "trade-offs" in almost every coastal development situation. Underexploited coastal resources in many developing countries include living resources such as the many species of fish and shellfish that are not harvested for lack of appropriate processing capabilities or market development, and mineral resources, from the very valuable coastal petroleum resources of some nations to the abundant and often not sufficiently appreciated nearshore materials such as industrial minerals and construction aggregates. Other promising coastal development opportunities not yet fully explored in many countries include mariculture (aquaculture using saltwater animals and plants), innovative ocean energy sources, uses of waste effluents for energy or fertilizer production, or even the encouragement of varied international business operations to establish regional offices or headquarters in some of the particularly attractive locations available in coastal locations.

The impact of rapid and generally unplanned coastal development has created problems for industrialized coastal countries for decades. While total solutions to all of these problems have certainly not been found, considerable progress has been made in finding solutions to a number of specific problems. Substantial technical improvements have been made, for example, in the approaches to the design and siting of coastal structures, in efficient sanitary engineering methods, and methods for predicting and avoiding problems caused by adjacent siting of potentially conflicting facilities (such as industrial plants and tourist hotels).

As development activities proceed in the less industrialized nations, they are experiencing many of the same difficulties. There are, of course, several important differences between U.S. experiences with coastal management (generally called "coastal zone management") and the situation in developing countries. A basic consideration is that the need for development in those countries is an urgent priority. Coastal management is a process which attempts to maximize long-term benefits by means of an analysis of the impacts and benefits of potentially conflicting uses of coastal resources. In developing countries, economic and social costs and benefits will be considered as important or more important than the environmental issues, which have been a major concern for coastal programs in the United States and other developed countries. However, due to factors such as potential human health hazards, and the economic benefits to be derived from preventing the degradation of valuable resources, assessments of coastal evironmental factors will still be of great practical importance in developing countries.[3]

It is particularly appropriate for development assistance agencies (national and international) to increase their efforts to enhance coastal productivity and protect coastal resources from degradation. One reason for this concern is that in some locations, well-intentioned but misapplied or inadequately coordinated assistance activities have resulted in decreased economic value or availability for use of these resources (for example, excessive deforestation, dam construction, land cutting for highways near cliffs or other erosion-sensitive areas, and some wetland reclamation activities). Also, it could be a very effective and productive use of assistance agency resources to apply more effort to the identification and development of the many underexploited resources of developing country coastal areas. The governments and people of many developing countries, influenced in part by the increased worldwide awareness of marine resources created by the extension of national marine jurisdictions and economic zones, now commonly express an increased desire to "turn towards the seas" and learn to use the coastal and open ocean resources that are available to them.

At this NRC workshop, individual working groups identified technical improvements and scientific methods most needed by developing countries to increase and sustain the productivity of their coastal areas. This report describes important needs and problems, with references to some illustrative examples in specific developing country locations. More detailed technical information for each subject area is given in the appendixes that follow the main body of the report.

Recommendations were also made regarding the importance of nontechnical aspects of coastal management, such as institutional arrangements and the coordination of data collection. Some of these recommendations, which grew out of several of the working groups and plenary discussions, are briefly discussed in Appendix A.

PROTECTION OF COASTAL LANDS FROM EROSION

Coastal lands can be damaged when activities such as the building of seawalls, dams, or harbors, or the modification of beaches and coastal wetlands are conducted without sufficient planning or technical capabilities. The relatively gradual processes of natural erosion are often much exacerbated, creating serious problems as land and cliff materials rapidly slump, crumble, slide, or wash away. Of particular concern is the erosion of agricultural lands and beaches, or embankments and other features needed for the protection of residential, agricultural, or commercial land. In Indonesia, for example, erosion of agricultural lands is causing a great deal of concern, and similar problems are occurring throughout much of the rest of Southeast Asia,[4] as well as in the Middle East, West Africa, and portions of Latin America.

Serious erosion results from incorrect site selection or design of harbor entrances, groins, piers, seawalls, or dams on adjacent rivers, or from the dredging of channels, sand mining in inappropriate locations, and dynamiting of offshore coral reefs that had been providing protection from waves and storm surges. Although industrialized countries have done a somewhat better job in these respects, they, too, have had numerous problems with unanticipated coastal erosion effects.

EROSION CAUSED BY DAMS AND OTHER CIVIL WORKS

The damming of rivers almost invariably affects hydrological and sedimentation aspects of coastal areas in the vicinity of outlets to the sea. The amount of disturbance varies greatly, depending on seasonal flow rates and sediment loads of the river and on coastal transport rates and patterns in or near the estuary or open coastal area at the river's mouth. Perhaps the best-known example of changes in the coastal environment created by decrease in river flow and sediment deposition with major implications for fish stocks, saltwater intrusions into freshwater supplies, and human health is the effects of damming the Nile River on the Nile Delta area. The resulting beach erosion problems are of concern to coastal managers in both Egypt and Israel.

Similar changes have occurred in other locations where damming projects may be smaller in scale but the coastal impact is nevertheless serious. For example, damming of the Rio Balsas in Mexico resulted in retreat of the river delta to the extent that a newly constructed factory on deltaic ground had to be abandoned.[5] The Volta River Delta area in Ghana had extensive erosion problems resulting from the completion of the Akosombo Dam in the late 1950s.[6] The shoreline road to Keta, Ghana, has been cut through in a number of places, and severe erosion has occurred within the city itself. More recently, the continuing short supply of sediments in the eastward littoral (coastal current) drift has begun to affect neighboring coastal areas in Togo. The capital of that country, Lome, is threatened with erosion problems because of the loss of Togolese coastal sediments.

Similar problems are beginning to occur in the Niger River Delta area as a result of the completion of the Kainji Dam in the 1960s.[6] Erosion caused by the dam poses particularly difficult management problems in this region, which will be aggravated by the coastal land subsidence caused by oil production. Because this is a "low energy" coast (that is, without strong surf or other high-impact shore processes), it has taken more time for erosion problems caused by the dam to become apparent than on some other coastlines. However, although it occurs at a slower rate, erosion ultimately has the same destructive land-scouring and removal effects on low-energy as on high-energy coasts.

In another West African area, the Senegal River Delta, which forms the Mauritanian-Senegalese coastal border region, erosion problems may be expected to occur because two dams are being planned for the Senegal River.[6] Erosion rates will be rapid here, as this is a high-energy coastline. The city of St. Louis, Senegal, will be particularly jeopardized, since much of it is built on a sandspit at the river mouth.

In many cases, expensive harbor redredging operations could have been avoided, or erosion of economically important croplands and beaches minimized, if adequate technical evaluation of such factors as current patterns, prevailing surf angles, or sediment load levels had been done before coastal structures and facilities were built. (See Appendixes B and D, "Port and Harbor Development" and "Shore Processes.")

EROSION CAUSED BY DEVEGETATION

Destruction of coastal vegetation is a major cause of erosion; for example, the cutting down of mangrove forests, which are normally widespread throughout tropical coastal areas. Problem regions include much of Indonesia and mainland Southeast Asia, the Caribbean islands, Central America, Venezuela, Guyana, and parts of equatorial Africa and western India. (In these last two areas, however, the destruction is frequently caused not by commercial harvesting or clear-cutting for development purposes but by subsistence harvesting for fuel, which may prove to be an unavoidable impact until other energy sources are available.) At present, the annual net world loss of mangrove area is estimated as 200,000-300,000 hectares, about 50 percent of which is considered to be permanent loss.[7]

Coastal forest clearance can result in critical situations in heavily populated areas. Removal for land clearing often causes erosion of topsoil and coastal land. This results in the deposition of silt overloads in coastal waters, which greatly decreases the areas available for feeding and reproduction of coastal fish and shellfish (as well as waters that will support corals). Decrease in abundance of coastal fish in Java, Sumatra, Malaysia, and the Philippines can be, at least in part, directly attributed to sediment overloads in nearshore waters. The indirect evidence is simply that fewer fish are found in silt-loaded waters. Direct evidence is provided by the fact that fish in affected waters at first behave abnormally (by "de-schooling": swimming alone and unnaturally) and then, as silt-loads become worse, gradually disappear from an area.

The ability of coastal wetlands to absorb and reprocess agricultural wastes, domestic sewage, and other organic pollutants is diminished by the loss of their normal plant and animal communities. Further, the original objective of using cleared land for agricultural or other development purposes is often not achieved, and in the absence of soil-retaining mangroves and other plants, the natural impact of rain, streams, and groundwater transport will rapidly remove the essential nutrients and eventually the land itself from cleared areas. UNEP,[8] UNESCO,[9] UNESCO's Man and the Biosphere Program,[10] the U.S. Army Corps of Engineers,[11] and the Office of Coastal Zone Management of the U.S. National Oceanic and Atmospheric Administration[12] have all identified the indiscriminate destruction of coastal forests, and of mangroves in particular, as a widespread and serious problem in a large portion of the world's tropical regions. The negative effects on coastal water quality, estuarine stability, topsoil retention, and fish stocks and other animal resources are not easily, if at all, reversible.

MANGROVE UTILIZATION: SUSTAINED-YIELD HARVESTING

In some tropical coastal areas, it has been found that sustained-yield (as opposed to clear-cutting) harvesting of mangroves is a much more productive use of mangrove lands than clearance and cultivation of rice or other crops in relatively inappropriate soils. Mangrove harvesting, properly managed, can yield a stable supply of timber, charcoal, or other wood products for international trade. In sustained-yield harvesting, selected areas are harvested each season, and others are left to provide future crops. This is successfully practiced in a few Asian and Southeast Asian nations, such as Sri Lanka, Malaysia, and Bangladesh, where it is providing a substantial contribution to the foreign exchange balances. However, this is a relatively untried form of commercial development in the western hemisphere, in most of Africa, and in Oceania, even though the tropical coastal areas of all of these regions have unused or unmanaged mangrove resources. Panama alone, of all western hemisphere countries, is attempting to establish sustained harvesting programs, with a small amount of assistance from the U.N. Food and Agriculture Organization.

Conversion of portions of mangrove areas to well-managed timber harvesting, and protection of this resource from excesses of garbage and other waste dumping and from clear-cutting, provides the dual benefit of enhanced economic productivity and protection of coastal soils and watersheds from damaging erosion.[13]

OCEAN ENGINEERING: CREATING SAFE AND RESILIENT COASTAL STRUCTURES

Whenever structures are built that will be exposed to ocean conditions, there is a need to minimize the destructive impacts of surf and tidal action, currents, surge, and marine weather. Not only offshore structures such as drilling rigs, but also shoreline facilities such as power plants, industrial installations with outfalls or piers, and commercial fishing docks, must be properly designed and constructed. Both routine stress and the impacts of rare but potentially catastrophic events such as typhoons, storm surf, or tsunamis (tidal waves) must be taken into account. Development of safe, sturdy coastal industrial facilities requires the expertise of ocean engineers, scientists, and technicians who can measure surf, tides, and longshore current patterns to plan for proper site selection, materials, and stress-resistance designs.

PORT AND HARBOR DEVELOPMENT AND SHIPPING NEEDS

Port and harbor development (see Appendix B) is a well-established and highly organized branch of civil engineering and municipal planning. Internal port concerns, such as provisions for potentially conflicting activities (for example, transferring fish or other foodstuffs and fuel or industrial chemicals at nearby sites) or the design of facilities to improve efficiency of off-loading and transfer to land transportation, are typically planned by experts trained through the world's many port development and harbor engineering programs.

However, in recent years the capacities of ships (tankers in particular) have increased dramatically. Much larger quantities of oil and other more hazardous products such as liquified natural gas or toxic chemicals and radioactive wastes are being transported along shipping routes everywhere. An extensive literature is developing on oil production and transportation hazards throughout the world. Two areas of particular concern are the waters of Southeast Asia from the Gulf of Thailand through Indonesia and the South China Sea, where the already high volume of oil transported through an area of many narrow straits can be expected to increase,[14] and the Caribbean Sea, where increasing oil pollution hazards pose a special threat to such vulnerable and abundant features as coral reefs and small islands.[15] Plans to reduce seaway congestion by alternative routing of some larger tankers are being developed for the straits of Malacca and Singapore, which are heavily travelled by tankers carrying oil out of the region (from Indonesia and Brunei, for example), and through or into the region (primary sources including Africa, the Middle East, and China). Plans call for liquified natural gas to be transported out of ports in Sumatra (Aran) and Bintulu (Sarawak) to Japan and the United States.[16] A third region where rapid increases in petroleum production and transport make it necessary to plan for the impacts of increased shipping and further deep-water port development is the Gulf of Nigeria. Deep-water port improvement in West Africa will also support the development of fisheries on the very productive fish stocks associated with the nutrient-rich waters and upwelling of the Canary Current region.[17]

It may become difficult for developing nations, with their scarcity of resources for improving facilities and educating engineers, to keep up with the demands put upon modern ports. The ports must be able to handle new transfer volume capabilities. They should also have the contingency planning arrangements needed to cope with operations of supertankers and the attendant hazards of petroleum and toxic substance spills. Consideration should also be given to chronic release hazards. The ability of these countries to profit from modern ocean commerce can be much improved if the levels of marine engineering and coastal science capabilities in each country are increased. Educators and planners should be sensitive to the need for appropriate training programs, and marine technical assistance personnel of foreign nations or international organizations should work with local scientists, engineers, and planners to ensure that appropriate data are collected on factors such as bottom topography, climate, and ocean conditions.

Appendix B describes technical aspects of the three primary areas of consideration in port and harbor development: (1) site selection, (2) design, and (3) environmental impact. Extensive technical information and detailed port development guidelines are available in several series of documents produced by the United Nations and its affiliated Intergovernmental Maritime Consultative Organization.[18]

OFFSHORE MINING AND PETROLEUM PRODUCTION

The proper construction of offshore drilling rigs, pipelines, and shore support facilities for drilling and mining operations requires an advanced level of ocean engineering technology. Oil and gas production, in particular, is an area of applied ocean science that is very highly developed throughout the world. Because of the high profit potential, it may be relatively easy for nations with proven (or likely) extractable petroleum resources to purchase or obtain loans and other forms of financial assistance for complete "technology packages" for this purpose, as well as to hire or train the necessary technical personnel.

In many cases, a concern of developing country planners and administrators will be to consider how plans for reaching long-term development goals of the country can be advanced by the economic advantages conferred by petroleum production for both domestic use and export. An objective for those countries that have experienced considerable technical and economic advancement might be to improve their capabilities for resource surveying, technical evaluations of resource potentials, and deployment of extraction equipment. This would require organized and well-funded training and scientific education programs, and is an area in which development assistance personnel and technical advisors could provide valuable assistance.

There are four stages of offshore development: exploration, development, production, and phase-out. Much information is available on the technology required for each of these stages. However, for many developing countries, identifying and gaining access to sources of information can pose considerable problems. (It was suggested by several participants at the Coastal Resources Management Workshop that the creation of an "information clearinghouse" through a government agency or a marine science research institution would be a particularly worthwhile project for support by one of the U.S. agencies involved in this area.) Regarding offshore oil and mineral production in particular, sources of technical information that are already established in the United States or internationally and that should be able to provide advice or assistance to developing countries, include: the Committee for Coordination of Joint Prospecting for Mineral Resources (headquarters in Barbados and in Fiji), the United Nations Ocean Economics and Technology Branch (office in New York), the East-West Center (Hawaii), the International Association of Drilling Contractors, the International Association of Offshore Supply Operatives, the U.S. Offshore Minerals Management Service (Department of Interior), the International Geophysical Union (which can be contacted through the U.S. National Research Council's Advisory Committee for the International Council of Scientific Unions), and the American Petroleum Institute (a consortium of oil companies, with offices in Washington, D.C.). The East-West Center has recently published a booklet on guidelines for offshore petroleum development, available from their office in Honolulu, Hawaii.[19]

SEWAGE TREATMENT AND WASTE MANAGEMENT

A critical coastal development need in all developing countries is the acquisition of affordable but effective methods for sewage disposal and the handling of toxic industrial and agricultural wastes. Several of the kinds of waste buildup common in densely populated and/or increasingly industrialized developing country coastal areas are creating health problems as well as endangering the wholesomeness and marketability of local agricultural and seafood products.

SEWAGE

In areas of many severely crowded countries such as India, Bangladesh, or Indonesia, there is often an absence of even primary sewage treatment. This contributes to the spread of infectious diseases and to the contamination of locally produced seafood, not only in the vicinity of large cities such as Calcutta but in bays and estuaries of smaller cities and towns as well. Excessive levels of sewage contamination (based on World Health Organization data) exist throughout much of Asia, and Southeast Asia in particular, and in many of the urban coastal regions of South America, including Rio de Janeiro. Effects of this contamination include problems such as eutrophication in Manila Bay, reducing shellfish productivity; oysters off Hong Kong containing fecal bacteria; dysentery being transmitted by cockles in Malaysia; and evidence that typhoid or hepatitis may be linked to coastal water contamination.[20] An excellent up-to-date review of the levels of sewage, and nontoxic organic (measured as biological or biochemical oxygen demand, BOD) and toxic waste pollution in each locality of Southeast Asia is provided by Ruddle.[21] Less information has been collected concerning pollution levels in the Caribbean region. The United Nations Environment Programme, which is coordinating ongoing studies in that region, provides a summary of available information in the 1980 report on wider Caribbean area pollution,[22] produced in conjunction with their "Draft Action Plan for the Wider Caribbean Region."[23] This report states that, although insufficient data exist for the region, it can be concluded that the open waters of the Caribbean Sea are not polluted, but that local coastal waters in a number of localities (for instance, Kingston

Harbour) are polluted with both high BOD and toxic wastes, and that cases of disease transmitted through the consumption of contaminated seafood have occurred. (Public health problems caused by disease microorganism contamination of seafoods are discussed further in Appendix E.)

ORGANIC WASTES: EUTROPHICATION

A less immediately dangerous form of pollution, but one that has serious effects on the productivity and environmental quality of coastal waters (as well as on their attractiveness for recreational use) is eutrophication. This condition of excessive algal blooming produces surface scum or other forms of decaying plant matter, and oxygen depletion, which can result in the death of fish and other animals. The condition is produced by the introduction into fresh or marine waters of excessive amounts of organic material or nutrients from a variety of sources--domestic, agricultural, or industrial. In addition to the obvious desirability of preventing the spread of infectious diseases or the contamination of local food products, many economic benefits can result from improved sewage treatment to maintain the attractiveness and healthfulness of local waters and beaches. Features such as healthy coral reefs and fish populations and waters safe for bathing clearly enhance the development of local recreation and tourist trades, sportfishing, and skin and scuba diving, as well as local artisanal fishing.

Eutrophication problems are worldwide. Examples of well-studied areas include both freshwater (the American Lake Erie) and marine areas (much of the Mediterranean Sea, the New York Bight, and the North Sea). Problems are greatest in small, poorly flushed bodies of water, particularly where the water is shallow or not well mixed vertically, and thus are likely to be more severe in lakes and streams than in most marine environments. However, as urban areas on ocean coasts are often located on protected bays or harbors or behind headlands, urban waters are often not well flushed, and substantial eutrophication does occur adjacent to many coastal cities. Particularly severe eutrophication problems occur in the western Mediterranean; parts of the Persian Gulf; many areas of Pakistan and India; Malaysia, Indonesia, and much of the rest of Southeast Asia; several of the large coastal cities of Brazil and Argentina; and portions of Mexico and Central America.[24] (Less information appears to be available for coastal areas of Africa than for these other regions as to levels of BOD or other measurements of eutrophication.) While this kind of pollution may not be particularly prevalent in some geographical regions, it can be expected to occur in any enclosed bay or harbor where sewage or untreated effluents of other types of organic wastes (for instance, from agricultural processing plants, textile mills, or fertilizer runoff) are released in substantial quantities. Appendix E provides more detailed information on eutrophication causes and effects.

In many cases, local pollution problems can be considerably diminished through the application of simple techniques. The employment of suitable sewage treatment, better outfall design, or better site selection can, in many cases, be accomplished at reasonable cost and can produce substantial long-term benefits. For example, success was achieved in cleaning up polluted Kaneohe Bay in Hawaii simply by moving the location of the outfall pipe to a point outside the coral reef. The reef had prevented the natural flushing action of the coastal currents from dispersing the wastes; once the outfall was moved, the badly eutrophied bay returned to normal, and the coral reef, which had almost died, promptly recovered.[25] Appendix E discusses some of the factors to be considered in designing appropriate sewage and waste management facilities in various types of developing country locations, and some of the benefits of managing, or in some cases putting to productive use, nontoxic organic effluents.

On tropical islands, particularly the atolls that are common in the South Pacific, special care is needed to avoid pollution or sediment buildup in the coral-bounded lagoons as a result of poorly selected sewage release sites. Atoll lagoons tend to be pollutant traps. Corals in numerous locations throughout the Caribbean (for example, in St. Croix, St. Thomas, and Curacao), and also on the mainland (Venezuela) and the South Pacific (Truk and Fiji), as well as in several of the U.S. island territories and possessions[26] are decreasing in productivity or dying, and the numbers of associated fish and other animals are decreasing, because of the impact of sewage, silt, trash, and other forms of waste disposal.

TOXIC WASTES

Even in developed countries, the contamination of coastal waters, organisms, and seafood by toxic wastes such as pesticides, heavy metals, or other industrial chemicals (such as PCBs), is not easily monitored, owing to the relatively high instrument sensitivity needed to detect these substances at the levels they reach in the environment. Nevertheless, efforts to monitor such substances should be made, as even low levels of some of them (PCBs, mercury, some pesticides, and numerous others) in seafoods, and perhaps in waters used for bathing or domestic purposes, can cause human birth defects and serious illnesses, including cancer (see Appendix E for references and specific examples of toxic marine pollution). For many toxic substances, the use of biological monitoring via "indicator organisms" (aquatic animals that concentrate environmental chemicals in their tissues at higher--and thus more easily detectable--concentrations than are found in surrounding waters) will prove to be a practical means of monitoring levels of dangerous pollutants in coastal areas.

MANAGEMENT OF LIVING COASTAL RESOURCES

Living coastal resources, animal and plant, perform a great variety of functions for mankind. They provide food, fuel, and construction materials, offer protection from erosion, flooding, and effects of coastal storms, and contribute to the maintenance of ground- and coastal-water quality by filtering and recycling natural or artificial organic wastes. Living resources are often of special importance in developing countries because of their subsistence value (particularly as food and fuel), and because many of their benefits involve relatively low energy or maintenance costs.

As has been discussed in previous sections of this report, two kinds of tropical biological communities (mangrove forests and coral reefs), which provide much of the ecological foundation for coastal living resources in tropical countries, are especially susceptible to damage caused by activities such as dredge and fill operations, toxic or organic waste discharge, and uncontrolled land clearance and attendant increases of silt in coastal waters. A few of the losses are direct and deliberate (such as the substitution of rice farms or aquaculture ponds for mangroves) and are the result of decisions weighing relative values of various uses of coastal lands and waters. But in many cases, such changes have been undertaken in the absence of any cost-benefit considerations, often with little or no awareness of the types of environmental damage that are likely to occur. Other instances of damage to living resources are more indirect and often unexpected because levels of scientific awareness of developers or planners are insufficient. For instance, there may be little foresight regarding the possible impact of upland clearing or waste disposal practices on coral reefs, or effects of saltwater intrusions on fish populations in river estuary areas.

Failure to consider the importance of living resources, and the absence of econometric techniques for evaluating economic contributions of natural resources, typically result in the failure to account for the very real but poorly measured value of living resources in development planning efforts. It is particularly difficult to evaluate the subsistence values of resources, which if lost may lead to serious hardship or even the destruction of ways of life of poorer people. In many instances, natural systems that provide substantial but poorly quantified multiple benefits for the public at large (such as artisanal fishing[27] or subsistence use of forest products for building or medicinal purposes) are being altered by coastal development activities. They may be replaced by activities that provide fewer but more easily quantifiable benefits (such as short-term lumber production by clear-cutting or production of limestone by dredging coral reefs) that sometimes accrue to a more limited portion of the population. Attempts to achieve short-term gains by exploiting living resources at a rapid rate may result in unexpected long-term losses of resources, such as fish that are normally supplied with nutrition and shelter by coral reefs, or fish, shrimp, and benthic (bottom-dwelling) shellfish dependent on the rich coastal waters associated with mangroves.[28] Local decreases in fish populations owing to increased silt loads are reported in the Philippines, Malaysia, Java, and other parts of southeast Asia. In Qingdao, China,[29] parts of Mexico,[30] and several West African locations (including Nigeria),[31] oil and chemical pollution has contaminated shrimp, fish, and other seafood products and is reported to be affecting survival rates of fish larvae.

As noted earlier, destruction or degradation of organisms such as corals and mangroves, which themselves provide both biological and structural support for other organisms in coastal environments, is often harmful to both economic and ecological concerns. These coastal plant and animal communities all serve as primary food sources for nearshore fish and shellfish. They also are the habitat and food sources for the juvenile stages of many commercially important offshore species. For example, shrimp typically begin life in inshore environments such as estuaries or lagoons. In tropical latitudes, the nutrient-rich, protected waters they need are associated most often with mangrove swamps. The widespread destruction of mangroves by land clearing, fuel collection, dumping, and other human activities along long stretches of tropical coastlines decreases the reproductive success of shrimp populations, which form the basis of very valuable nearshore and offshore fisheries.

The varied assemblages of finfishes captured by the small-scale (artisanal) fisheries of most tropical countries are in large part composed of reef fishes and species that depend on coral reef systems as food sources and, in some cases, as physical refuges. In the protected and highly productive coastal waters of subtropical and higher latitudes, where coral and mangroves are not found, sea-grass beds and wetland vegetation are major coastal sources of water-borne nutrient particles that feed small prey organisms. These environments also serve as principle habitats for young fish.

An example of even indirect habitat destruction affecting local fish populations is given by reef mining off a bay in southern Sri Lanka. There, mining has diminished the reef to the point that it no longer provides protection from surf and surge. The resulting changes in saltwater balance and circulation patterns of the bay and its estuarine area have produced changes in the species of fish present, so that the local fishery is no longer able to harvest its traditional catches.[32]

Other types of alterations of living resources that incur expensive long-term maintenance costs are those related to erosion effects. Such problems result when the dredging of coral reefs or coastal forest clear-cutting lead to increases in erosion that, in turn, necessitate long-term coastal stabilization and restoration activities that may include the building of protective structures.

Major losses of living resources need not invariably result from coastal development activities. In many cases, practical alternatives exist that will avoid or reduce adverse impacts. Where economically desirable activities will unavoidably lead to such losses, the decision to develop should take into account the full value of resources to be lost. Restoration of coastal environments and organisms to more healthy and productive conditions will occur naturally if harmful activities in polluted or denuded coastal areas are curtailed. This is not, unfortunately, the case with dead coral reefs, as corals recolonize and grow very slowly. Even if pollution or other destructive influences are decreased substantially, it will take many years or decades for new live coral to grow in amounts sufficient to support a full community of fish and other organisms. However, as was demonstrated by the Kaneohe Bay incident in Hawaii (referred to in the previous chapter), if a coral reef is not yet dead but is only weakened by pollutant or turbidity levels, improvements in water quality achieved through controls on sewage or silt production may save the reef before it is too late. If this can be done, the reef is quite likely to return to full health and productivity within a few years.

In contrast to coral reefs, wetlands and mangrove systems will often renew themselves quickly if their sites are protected. Where this does not occur naturally within a reasonable time, artificial planting can be used to hasten recovery. Restoration efforts for these systems might be encouraged in the coastal development planning or management process, for example, when dredging or land-filling operations are being considered. Additional information on management of living coastal resources can be found in Appendix C.

COASTAL DEVELOPMENT PLANNING: PUBLIC POLICY, TECHNOLOGY, AND EDUCATION IN SUPPORT OF COMMERCE, INDUSTRY, AND RESOURCE MANAGEMENT

Technological and scientific improvements can be more effectively applied to coastal development activities when there is good communication and coordination of effort among planners, developers, and scientists. Also, as in other technical areas, it will be in the long-term interests of any country to ensure that administrators of science education and technical training programs are kept informed about future national needs in fields relevant to coastal management and development.

The management of coastal areas requires that special care be taken to ensure coordination of effort among technical experts and between them and developers and managers. This is true of coastal management in particular, because it requires the convergence and attention of experts from so many fields. People whose original backgrounds are in various oceanographic and terrestrial fields will be working together. The findings and concerns of ocean engineers, fisheries biologists, or coastal transport experts must be coordinated with those of geologists, farmers, sanitary engineers, or coastal forest and watershed experts, as well as with the needs of businessmen, construction engineers, industrial plant technologists, and others who are part of the general development effort. An example of the sort of planning that has been developed at the municipal level in the United States for the coordination of the work of land- and marine-oriented scientists and planners is furnished by the work program of the Long Island Regional Planning Board.[33] (At the state planning level, which would be equivalent to the size of organization needed for most small or moderately sized countries, state or territory coastal zone management plans would furnish good examples, as discussed below.)

Participants at this workshop on coastal management and development needs of developing countries pointed out that the U.S. experience of more than ten years in the planning and policy aspects of coastal management could be very useful to developing countries. It was noted that the coastal environments and climates, the various types of institutional arrangements, and the mixes of priority issues in individual states, territories, and protectorates are diverse enough to match American experiences with a wide range of the conditions and problems in developing countries. For example, in addition to the many individual state plans, detailed resource surveys and coastal zone management plans have been developed for Puerto Rico,[34] the Virgin Islands,[35] American Samoa,[36] the Northern Mariana Islands,[37] and Guam,[38] each of which shares a great many characteristics and concerns with corresponding tropical island nations of the Caribbean or Pacific.[39]

The coastal planners, scientists, and managers at the workshop further agreed that the U.S. experience demonstrates that successful coastal management programs must be flexible and that failures are likely to result if the system cannot respond to new information or new management priorities. Decisions must be made, although considerable uncertainty exists as to the social, economic, and environmental consequences that a policy or action may bring. A good coastal management system should be capable of evaluating the relative importance of problems and producing decisions, even though there is less information to work with than planners may desire. Perhaps most important, management decisions must be supported by enforcement capabilities strong enough to produce compliance and ensure that essential objectives will be reached.

A major emphasis of this report, reflecting strong consensus among planners, scientists, and coastal managers with experience in both highly industrialized and developing countries, has been on the need to obtain accurate information about local environmental, economic, and social conditions, and to evaluate available technical methods, as early as possible in the development process. Planning alternatives can then be weighed in light of this information. This will encourage well-informed decision making that can promote workable compromises among the many alternative uses of coastal lands, waters, and resources, and that will reinforce each nation's coastal development goals.

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APPENDIXES

APPENDIX A

ADDITIONAL COMMENTS AND RECOMMENDATIONS: INSTITUTIONAL ARRANGEMENTS FOR COASTAL DEVELOPMENT AND MANAGEMENT

In most instances, developing countries will not create new government agencies to develop and implement coastal management programs. Instead, existing agencies will be drawn in and assigned new tasks, and the emphasis will be on promoting effective linkages among agencies. A number of countries have already moved to form interagency coordinating mechanisms specifically for coastal management. Most already have policies in place regarding some of the issues central to coastal management, and many have strong planning laws that could be a vehicle for implementing coastal plans. Developing country governments might be well served by obtaining information about resource management strategies developed by U.S. programs (particularly the coastal zone management plans of the individual coastal states[1]), their success, and the external factors that affect management policies.

The following points should be considered in formulating a strategy for U.S. assistance in coastal management:

- For many countries, management and utilization of 200-mile exclusive economic zones will be the primary focus of coastal and offshore marine resource development programs. The allocation and management of fisheries and continental shelf mineral resources will be major components of their policies, and this will tend to be reflected in the institutional frameworks of their programs.

- Developing countries that are or can become involved in regional or other international resource development programs will benefit from exchanges of information with countries having common coastal characteristics (for example, nations with wide continental margins, island nations, or nations with extensive wetlands and estuarine areas).

- Atlases of coastal areas that show their basic geographic, oceanographic, and biological characteristics are essential for effective coastal planning. Aerial surveys for this purpose can be conducted with small airplanes and quite modest photographic equipment. Ground-truth data collection is also essential.

Satellite mapping will be helpful in those countries with interpretation capabilities. Such capabilities are being developed in a number of countries through training and technical assistance programs held recently or planned for the near future. (Appendix F provides a description of remote sensing technology that is most useful for developing countries.) Examples of coastal atlases are available for many localities within the United States and its possessions.[2]

- o Beyond the necessary basic coastal assessment and mapping purposes, however, additional efforts to inventory resources should address specific problems and aid in evaluating alternative management objectives. Otherwise, the process of developing inventories of coastal resources and collecting data on coastal activities and natural processes can become an expensive and time-consuming process with little relevance to the problems that a country intends to address.

- o The efforts of AID and other U.S. agencies and scientific institutions would be more effective if there were greater coordination among their activities and with those of U.N. organizations, the World Bank, nongovernment organizations such as the Scientific Committee on Protection of the Environment, and the assistance agencies of other nations. In this way, duplication of effort, which is wasteful of economic resources and confusing to personnel in developing countries (and to U.S. technical experts), could be minimized.[3]

- o The United Nations, through its publishing outlet UNIPUB in New York City, distributes handbooks on aspects of coastal development and management, including port and harbor construction, pollution monitoring, and fisheries development. U.S. personnel should be aware of these, and use them whenever appropriate, rather than expending effort on the creation of similar manuals or guidelines for each new problem area.

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was collected by the states of California, Florida, Oregon, and Rhode Island. (Note: This is not intended to be an exhaustive listing, or an evaluation of individual plans; it is only a listing of good starting points for obtaining more detailed practical information.)

2. OCZM/NOAA (c. 1979) American Samoa Coastal Management Program (CMP), pp. 30-34; Northern Mariana Islands CMP, p. 54; U.S. Virgin Islands CMP, pp. 110-111, 117-118; Guam CMP, p. 29; National Oceanic and Atmospheric Administration, Washington, D.C., USA.

3. The need for better coordination of marine technical assistance programs, both within the United States and among the many countries that sponsor development assistance projects, is discussed in: National Research Council (1981) International Cooperation in Marine Technology, Science, and Fisheries: The Future U.S. Role in Development, Proceedings of a Workshop, January 18-22, 1981, La Jolla, California. National Academy Press, Washington, D.C., USA.

APPENDIX B

PORT AND HARBOR DEVELOPMENT

Cost-effective construction and maintenance of ports and harbors must take into account many physical, economic, administrative, and political factors. These development concerns are very site specific, and no single criterion can be used to determine an optimal site for a port or harbor. Some of the physical factors that need to be evaluated are described here. Particular emphasis is given to sediment transport factors, which relate to problems of harbor siltation and erosion in down-current areas. Other factors to be considered include local and regional commercial transportation needs; the siting of features such as fishing grounds or tourist developments that may be impaired by hydrocarbon or sediment pollution in the vicinity of harbors; and the location of offshore mining, drilling, and commercial fishing operations that require convenient port access.

There are three principal categories of physical criteria: (1) site selection criteria, (2) design considerations, and (3) environmental impacts. At any given location, not all of these criteria may be important. The United States has good technical capabilities in all of these areas.

SITE SELECTION

A number of physical factors affect the selection of possible sites for a port or harbor development. Numerous examples throughout the world illustrate the costly and often dangerous consequences of failure to consider one or more of the following elements:

Natural protection at a site. The presence of headlands or interior bays (for example, Guaymas in Sonora, Mexico) makes siting much easier. Similarly, a natural bay may provide a particularly desirable location for a new facility by reducing the need for costly dredging and construction of protective structures.

Exposure to waves. The wave activity at a site will dictate the extent of necessary protective structures. Offshore bathymetry such as submarine canyons and ridges can affect the wave climate; two locations separated by as little as a few kilometers may be unequally suited as harbor sites.

Wind exposure. Directions and intensity of dominant winds can affect the utility of different sites as harbors and can have an impact on design considerations.

Frequency of storms and other natural disasters. The prevalence of features such as storm surge, hurricanes, tsunamis, and earthquakes can influence suitability of sites as effective harbors.

Tidal flows and mean flows. Effects of tidal currents, winds, and other factors on navigation are a major consideration in port or harbor site selection. Strong currents can increase shipping times or create a potential for collisions or grounding, and generally affect the ease of navigation.

Ease of providing deep-water access. Substrate type and bottom stability will influence the ability to create stable, low-maintenance navigation channels. Coral reefs or bedrock outcrops can increase harbor development costs.

Longshore sediment transport. The amount of sediment moving along the shore will affect harbor sediment-trapping behavior. Harbor siltation and downdrift erosion can result from siting harbors in areas of excessive longshore sand transport. The proper positioning and alignment of harbor entrances, and other aspects of design, can minimize siltation and erosion problems.

Local geology. The consolidation state of the surrounding sediment and bedrock (for instance, sandy barrier beach conditions as opposed to a rocky headland) will affect both development costs and the upland influx of sediment and transport through harbor environs.

DESIGN AND CONSTRUCTION CONSIDERATIONS

In addition to construction and engineering concerns, consideration must be given to geologic and oceanographic factors. Principal design considerations are discussed below.

Consideration of local wave and wind conditions. Once an appropriate site has been selected, knowledge of specific local factors is required for structural details of designing harbor protection and loading facilities, as well as for navigation purposes. A harbor entrance should not be directly exposed to incoming storm waves. Effects of prevailing winds on ships entering and leaving the harbor mouth can have major influence on efficiency of harbor operations.

Harbor oscillations. Large-amplitude, low-frequency motions can be amplified by resonance within harbors. The harbor entrance, planform geometry, depth, and size must be carefully designed to eliminate harbor oscillations.

Provisions to maintain navigation channels. Prevention of net influx and building up of sediments is critical to a navigable harbor. Materials from both land and sea must be prevented from entering; or provisions must be made to periodically dredge the harbor. In addition, certain types of bottom sediments may slump or slough into navigation channels, often during times of storm activity. Such slope failure may require particularly frequent maintenance to assure navigability.

Downdrift erosion. Provisions for bypassing sediment need to be made to ensure that downdrift coastal regions do not suffer from loss of sediment input due to harbor construction. Such downdrift starvation can adversely affect coastal stability as well as industry, tourism, and recreation.

Availability of construction materials. Feasibility of development is affected to a large degree by the costs, source locations, and transportation costs of construction materials.

Harbor flushing capability. As harbors commonly trap both pollutants and sediment, careful consideration must be given to the natural flushing potential of a new harbor. When necessary, provisions must be made to increase flushing and to protect water quality.

ENVIRONMENTAL IMPACTS

Port and harbor development can have profound environmental effects. Some possible impacts are listed below.

Effects on land runoff. Harbor development can decrease freshwater availability in coastal areas and change quantities of sediment influx to coastal waters from upland sources. Increases in sediment concentrations have deleterious effects on a large percentage of marine organisms of all kinds: benthic (bottom-dwelling), planktonic (current-borne), and pelagic (free-swimming).

Downdraft starvation. Removal of sediment from the nearshore system through harbor development can affect environmental or ecological factors and make coastal areas less fit for human use by decreasing or altering biological habitats, for instance, or decreasing geological stability through erosion of bluffs.

Increased pollution. The trapping of pollutants such as sewage, industrial wastes, or oil in ports and harbors can increase pollution levels both in harbor waters and in adjacent regions.

Saltwater intrusion due to water table changes. Lowered water tables resulting from coastal development can accelerate saltwater intrusion into freshwater aquifers, reducing potability.

Introduction of alien species. Foreign organisms can be introduced to an area via the release of bilgewater or bilge oils. This may create significant ecological problems in some locations. Research on this subject is not yet conclusive, but the introduction of parasites, and competition with or predation on local species, have been reported in some areas.

Harbor construction. Dredging and filling activities during construction can impair water quality and damage organisms in adjacent areas unless these activities are properly conducted and contained. The disposal of excess dredged materials off site can also cause damage. Disposal at land or sea of spoils from periodic maintenance dredging can also have adverse environmental effects.

APPENDIX C

LIVING RESOURCES AND COASTAL DEVELOPMENT

This appendix reviews important aspects of coastal plant and animal communities, and the ways in which some development activities affect these living resources, and recommends some methods for decreasing or repairing such damage. The final section comments briefly on fisheries and development.

VALUES OF COASTAL BIOLOGICAL COMMUNITIES

- As discussed on pages 4 to 6 and 14 to 16, wetlands, mangrove forests, and coral reefs all produce materials that nourish shellfish and fin fish of the nearshore environment.[1] These are the basis of commercial, subsistence, and sport fisheries.[2] All these communities also serve as nursery areas for many kinds of fish and shellfish.[3]

- These biological communities also afford protection from many kinds of natural disasters. Coral reefs diminish effects of surf, surge, or tsunamis; mangroves reduce coastal erosion and can reduce floods and to some extent high winds; coastal wetlands also retard erosion and ameliorate flooding.[4]

- Wetlands and mangroves process and remove, recycle, or immobilize pollutants such as sewage and excess sediments, unless they are overtaxed by excessive levels of pollution.[5]

- Mangrove forests provide a sustainable source of wood for use in shelter, fuel, household wares, or tools; or for pulp chips, charcoal, and tannin. The leaves and extractives have a number of traditional functions (such as herbal medicinal use) in coastal cultures.

- Mangrove forests and wetlands also support terrestrial wildlife, either for conservation or, when animals are abundant, as a source of food or products for trade. These areas are also extensively used by apiarists in many parts of the world.

- Coral reefs are important tourist attractions. They are also a source of shells and corals for commercial sale (although overharvesting should be avoided).

FACTORS HARMFUL TO LIVING COASTAL RESOURCES

A variety of activities at the coast, or with effects on the coast, are destructive to living coastal resources. Some of the better understood of these are mentioned here.

Dredge and fill impacts. Dredge-spoil dumping and other land-filling operations are directly harmful to all the major types of biological coastal communities (mangroves, wetlands or sea-grass beds, and coral reefs). Disturbances may extend beyond the area of immediate activity. These activities physically disturb and smother organisms and release sediments and pollutants into the water system. Salinity changes can also be produced by dredge and fill operations.

Waste discharge. Discharge of sewage, industrial effluents, and other forms of waste contaminates and physically damages aquatic organisms and environments in many countries. Sometimes recovery from stress can be relatively rapid if the stress is removed. This is not true, however, for organisms such as coral reefs, which take up to several decades to recover. Neither is it true in the case of contamination by toxic wastes that remain in organisms or the environment for long periods. These include, among other materials, heavy metals, polychlorinated biphenyls (PCBs), many radioactive wastes, and some pesticides.

Increases in silt from land runoff. Increased concentrations of suspended sediments in coastal waters, harmful to many types of marine organisms, can be created by activities that alter upland cover and water infiltration characteristics, such as clear-cutting, highway construction, or other construction activities in coastal watersheds. Problems are particularly severe in areas with high adjacent inland elevations, such as continental and high-island coasts. The killing of coral reefs by excessive sedimentation is particularly common around south Pacific high islands, for example, where extensive erosion is caused by land cutting for road construction.

Overharvesting of coastal organisms. As described previously, overharvesting and clear-cutting of mangroves threaten all but the shortest-term uses of that resource. Overfishing of economically or culturally desirable species of fish, shellfish, and other coastal animal resources has become a matter of serious concern in many developing countries where seafood comprises a substantial portion of the diets of coastal peoples. Local custom, cultural traditions, or religious practices in some regions, including much of west Africa or portions of South America inhabited mainly by Indian tribes of inland origin, may result in low levels of seafood consumption. But in many developing countries such as those of coastal Asia and Southeast Asia, most island countries, and numerous other marine coastal locations, fish and shellfish contribute a greater percentage of national protein consumption than is the case in most of the wealthier nations.

Dams and reclamation activities. These create changes in the freshwater and saltwater balance. Of particular concern are water diversion projects such as dams, and drainage for reclamation purposes, or mining of groundwater, that are conducted without consideration of downstream effects. In many locations in Southeast Asia, China, Egypt, other parts of Africa, and Mexico, for example, excessive water diversion has led to changes in coastal salinity (migration of salinity isoplaths), increase in salinity extremes (both fresh and saline extremes), and changes in the hydroperiod (delivery schedules) of freshwater to coastal systems. Often the sources of these problems are distant from affected coastal areas. Yet they can cause direct mortalities of plants and animals or indirect losses through changes in habitat.

Acid conditions created by disturbance of pyritic soils. Another result of water diversion or smaller scale earth moving activities that is localized in impact, but serious where it occurs; is seen in areas with high-sulfate, pyritic soils, such as Thailand and other parts of Southeast Asia. Exposure of buried pyritic soil to air by dredging, pond excavation, or channel building causes oxidation of metallic ions (iron and manganese), resulting in acidic soil and water conditions in watersheds and coastal areas.[6] The high levels of acid are toxic to many plants, including mangroves and most crops other than a few specially developed resistance strains, and to some animals, especially the more sedentary aquatic and intertidal species.

Exotic species. The introduction of exotic species can occur deliberately, by stocking of coastal waters, or accidentally, through escapes from aquaculture ponds, canal construction connecting previously separated waters, or releases in bilgewater. This can result in adverse effects through predation, competition, or disease for native fish species and ecosystems.

Marine mining impacts. Marine mining, especially nearshore dredging for construction materials (sand, gravel, and crushed stone) or placer mining (for shallow-buried minerals) can create major alterations in habitat, especially if there is extensive dumping of dredge spoils or creation of sediment plumes. If widespread, this will have serious effects on local animal or plant populations. Dehais and Wallace[7] give an excellent analysis of impacts of mining for construction aggregates, which is the most common type of marine mining in developing countries.

MITIGATING THE IMPACTS OF DEVELOPMENT ON LIVING RESOURCES

Much is known about protecting the coastal environment from the effects of industrial development. Some of the principal precautions that can be taken are outlined here.

Coral Reef Destruction

Coral mining. Mining should be done only in areas where reefs are not needed for protection of the shore from heavy surf or saltwater intrusion. The mining in each locality should be limited to ensure that sufficient coral remains to provide food and shelter for young and adult fish. If dead reefs already exist, they should be mined in preference to live reefs.

Fishing by dynamiting and carbide bombing. Any other fishing method (except poisoning) should be used instead of this one, which is an example of a short-term gain obtained at the expense of permanent loss. Once a reef area is destroyed, there is nothing to feed and shelter the next generation of fish.

Replacement of damaged reefs. When destruction of reefs is unavoidable, certain measures can be taken to provide at least partial replacement. Artificial reefs can be constructed in some areas, if current and surf conditions permit, to replace coral as a physical protective barrier and fish habitat. Coral reseeding or transplanting, while still experimental, may work in some areas, although required oceanic conditions are not thoroughly known. Efforts may be aided by the addition of substrate materials (rocks, dead coral, or artificial materials).

Industrial Pollution

A series of steps is necessary to combat the effects of pollution.

Environmental monitoring. Data collection is needed to determine whether high levels of toxic pollutants are present in a region's fish or shellfish, sediments, soil, or perhaps water. (Water levels will be the most difficult and expensive to measure directly.) For some substances, techniques may not yet be available for direct water measurement and in many instances, seafood or sediment sampling will suffice for determining the presence of dangerous levels of contaminants.

Identification of sources. Point sources should be identified by analyzing water, sediment, or sessile organism samples from the immediate vicinity of installations or by direct samples of waste or wastewater discharge of plants.

Waste removal. Some pollutants can be removed by wastewater treatment prior to release. When sufficient water purification is not possible for particularly harmful substances, special handling techniques may be needed to avoid release into natural waters. This will require safe toxic waste containers, services for handling them, and provisions for disposal at approved sites. The question of how best to safely dispose of toxic wastes is a difficult one for all nations. Perhaps the best approach at present is for nations to provide safe interim storage while ultimate disposal alternatives are being evaluated.

Sewage Pollution

Outfalls. Construction of longer outfalls will carry effluents farther offshore to water that is likely to be better flushed by currents.

Using current pattern information. Moving release points up- or downcoast may permit locations to be selected where current directions are more favorable for effluent dispersal.

Cost and benefit considerations. Technical and economic factors must be considered before decisions are made as to what level (primary, secondary, or more intensive) and mode (of the several kinds of available biological and chemical methods) of treatment are necessary to keep water quality within acceptable limits. Decisions should be based on local health factors, estimated environmental absorption and dispersion capabilities, existing monitoring data (typically using indicator factors such as Biological Oxygen Demand and coliform bacteria counts), guidelines for pollutant level goals such as those provided by the World Health Organization, and funding and credit availability. (The World Bank and other international development banks may provide credit or other financial assistance for large-scale sanitary engineering projects.)

Silt and Sediment-Loading from Land-Clearing or Dredging Activities

Harvesting management. A sufficient amount of forested area should be left intact in each region to prevent severe erosion (see Appendix D). This is important throughout the watershed area, but is especially needed along river banks and coasts.

Revegetation. Reseeding can be applied in harvested areas, or where alternative uses of cleared land have proved unprofitable (for example, where aquaculture or agriculture projects have failed owing to poor soil, acid leaching into ponds, or erosion).

Informed selection of dumpsites. When mining or dredging operations are conducted, care should be taken to evaluate expected impacts properly, so as to select the least vulnerable or critical areas as dumpsites. For example, identification of particularly important fish nursery areas must be done by biological surveys conducted in appropriate seasons.

Damage to Mangroves and Low-Productivity Exploitation of the Resource

Pollution. Disposal of toxic materials in mangrove areas should be discouraged.

Preventing over-exploitation. Extensive clear-cutting should be avoided. Managed harvesting should be instituted when appropriate (see below), including leaving sufficient stands to prevent erosion.

Promoting productive harvesting. Rationally managed agro-forestry industries should be developed in the many areas where good trade conditions for wood products exist or can be created.

Reducing Acid Soil Problems

Identifying the problem. Soil sampling will be of assistance. Awareness of effects of disturbing pyritic soils should be promoted. Acid production at levels harmful to mangroves and other organisms can be caused by disturbance of soils for numerous purposes, including dikes, drainage ditches, channels, and fish ponds.

Decreasing soil disturbance. Although this problem cannot be avoided altogether, it may be possible to site major earth-disturbing activities to minimize acid production and runoff into critical areas. One way to decrease the production of acid soils is for naturally submerged land, and land used for rice cultivation, to be left submerged and not permitted to become exposed to the oxidative effects of the atmosphere.

Resistance crop strains. A few acid-resistant strains of certain crops have been bred, and perhaps others will be developed in the future. The International Rice Research Institute has develped some resistant rice strains. It is not likely, however, that legumes can be easily adapted to highly acid conditions.[8]

COASTAL FISHERIES AND AQUACULTURE DEVELOPMENT

The production of food from living aquatic resources falls into two categories: capture fisheries, in which wild organisms are harvested from natural populations; and aquaculture, the rearing of aquatic animals and plants in artificial ponds or other controlled environments. Assistance in the management and technical improvement of aquaculture and capture fisheries for developing countries is a major area of endeavor in international development assistance; detailed coverage is beyond the scope of this report. Several monographs and reports on fisheries and aquaculture in developing countries are recommended in the Selected Reading list. Brief comments are given here on a few special characteristics and needs of the fishing and aquaculture industries in developing countries.

Management of Capture Fisheries

It is relatively difficult to institute management by catch quotas for small-scale artisanal fishing activities. Because fishermen and their customers (primarily local) are spread diffusely throughout the entire coastal region, accurate and thorough collection of catch data, dissemination of regulatory information, and regulation enforcement are difficult if not impossible to achieve. Also, when small-scale fishermen harvest for local consumption, the benefit of immediate food provision for needy people may be a factor in considering whether to limit catches by regulation. Even in these circumstances, though, appropriate management regulations can be beneficial. If regulatory measures (such as net mesh-size limits to protect young fish) are successful, small decreases in the present catch should result in substantial increases in catches in following seasons.

Another strategy for avoiding severe overexploitation of particular species by artisanal fisheries is to promote the development of markets for alternative species of fish, shellfish, and aquatic plants. Most marine organisms are edible, and are in fact eaten in some region of the world, and many are exceptionally nutritious and high in protein. Increased dissemination of accurate information on the identification of contaminated shellfish and the small number of toxic marine species is needed to permit the development and expansion of new seafood markets.

In cases where overexploitation of stocks is primarily due to large-scale commercial fishing, one of the various types of quota systems (by limiting catch volumes, seasons, entry permits, or other factors) may be needed and can usually be effectively enforced. This is, however, a complex issue, as immediate economic factors may prove to be important. Substantial employment, often of the poorer segments of the population, may be generated by the commercial fishing activity or its subsidiary activities. Management decisions must be based on an understanding of local economic and political situations, as well as on knowledge of the status of the fish stocks.

Aquaculture Systems

"Aquaculture" is a general term referring to the cultivation of any aquatic organism. The specific term for rearing animals and plants that require seawater or equivalent salinity conditions, such as shrimp, mussels, seaweeds, or marine fish, is "mariculture." Aquaculture and capture fisheries are not, for the most part, operations that compete directly with one another (with the exceptions of the possible introduction of harmful exotic species into the wild, or impacts on wild populations that harvesting of young life stages or reproducing adults for culture-stocking may entail). However, the conversion of land into aquaculture ponds often represents direct competition with agricultural development for land, nutrient, and water supplies. And agriculture may have drastic negative effects on aquaculture ponds if, as is not uncommon, pesticide residues enter water supplies and contaminate ponds.

However, traditional practices have existed for centuries (throughout Asia, for example) in which the cultivation of plants, aquatic animals, and domestic animals, such as pigs and ducks, are made not merely compatible, but even mutually supportive. The animal wastes provide fertilization for plants, and plants provide the food source for animals. In such systems, requirement for supplementary nutrients can be very low.

Some of the most successful new aquaculture systems (including the higher-yield, more energy-demanding "intensive" systems) take advantage of the benefits of the traditional methods of combining plant and animal cultivation. Competition between the two types of food production is thereby lessened. An excellent review of such integrated agriculture-aquaculture systems is provided by the proceedings of a recent conference held at the International Center for Living Aquatic Resource Management (ICLARM). A point of particular interest in that report[9] is the fact that certain kinds of pesticides have been developed that degrade very rapidly under natural conditions to harmless forms. These compounds apparently present no harm to wild organisms (and their consumers) beyond the sites at which they are applied, and they are, in fact, considered safe enough for use in integrated cultivation systems where animals or plants are being raised for human consumption.

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APPENDIX D

SHORE PROCESSES

Erosion, sediment transport, and deposition in nearshore locations are categorized as "shore" or "coastal" processes. Principal generating factors for shore processes are various forms of water movement such as waves, tides, and currents both at an angle to and parallel with the shoreline. In addition, river discharge, wind, and chemical or biological agents may have major effects. Often it is the uncommon, high magnitude events such as storms, high surf conditions, or hurricanes that have the most lasting effects in shaping a coastline from year to year. The effects of these agents vary from one area to another, depending on the types of materials and coastal forms. And all of the processes whereby shorelines advance or retreat, and silt is deposited, suspended, or carried away, may be altered either intentionally or unintentionally by man.

HUMAN MODIFICATION OF THE SHORELINE

Many human activities may alter the distributions of coastal materials and shoreline morphology. Resulting changes may be primarily harmful or beneficial, or may differ in effect according to local environmental characteristics and patterns of use. The following activities and structures are likely to have a significant effect on the shoreline.

Activities generally destructive to coastal resources:

- o Beach sand and gravel mining
- o Dune alteration
- o Reef mining or dredging
- o Dumping of dredge spoils or other wastes into mangrove and coastal marsh areas
- o Inlet and channel straightening by sand removal.

Structures or activities that may have positive, neutral, or negative effects on coastal resources:

- o Breakwaters, jetties, groins, and piers
- o Beach replenishment

- o Coastal highways, railways, airports, and pipelines
- o Harbors
- o Reclamation by land-filling and barrier construction
- o Industrial, commercial, and residential development.

Non-coastal activities that may have indirect effects on the coastal area:

- o Construction of dams on rivers and streams
- o Riverbed mining
- o Offshore sand mining
- o Channel straightening
- o Offshore energy plant construction.

ACTIVITIES THAT TYPICALLY AFFECT COASTAL SYSTEMS

Two of the most common types of artificial intervention into the coastal system--upland dams and bulkheads and groins--are discussed here briefly, along with some of their anticipated impacts and some suggested approaches to problems that may arise. (Another type of coastal engineering project that has major effects on shore processes is port or harbor construction, which is discussed separately in Appendix B.)

Upland Dams

Although the original purposes of dams constructed on rivers far inland (to provide water for irrigation, for instance, or for flood control) may be well served, undesirable side effects often result in these neighboring coastal areas influenced by the river outflow. Frequently these side effects are poorly anticipated, in part because of the considerable distance between the dam site and sites of ultimate coastal impacts, and also because of a lack of awareness of coastal processes on the part of regional planners, engineers, or resource managers.

The drastic reduction of downstream sediment movement caused by most dams decreases sediment supplies to rivermouth deltas, which in turn causes erosion and retreat of deltas, and typically results in substantial losses of sand from downcurrent beaches. Fish populations in a dammed river and in its estuary may suffer from the increased penetration of saltwater upstream. Underground freshwater supplies in lands upstream from the rivermouth may be contaminated by saltwater. In addition, the changes in water flows and associated movements of parasites and microorganisms can lead to an increase in the incidence of waterborne diseases. Because of the reduced flow of water, river navigation will be restricted to vessels of shallower draft than before. Finally, and often significantly for agricultural production, normally fertile farmlands will be denied the influx of rich soils that usually results from the occasional overtopping of a river's banks during periods of high flow.

When the damming of a river is contemplated, an attempt should be made to anticipate in some detail the long-term costs of undesirable side effects. In cases where the need for a dam justifies the direct economic costs and any "external" (side-effect) costs, selection of certain types of dam siting or design may allay some of the more undesirable side effects: for example, dam construction can incorporate mechanisms for increasing flows from bottom or top of the dam to reduce silt trapping or changes in salinity and thermal structure; or "ladders" (stepped waterways) can be built to permit fish to migrate upriver. However, considerable erosional and hydrological impact will probably be unavoidable.

Bulkheads and Groins

A basic rule for shore protection activities is that natural processes should be accommodated or taken advantage of. Unfortunately, this rule is not often followed. The construction of bulkheads and groins along sandy beaches is an example. The most common reason for their construction is to control beach erosion. However, when they are not properly positioned they can have undesirable side effects or may produce the opposite result from that desired. Bulkheads reflect wave energy, increasing scour at their bases or redirecting littoral drift offshore. This can result in sediment deprivation of downdrift beaches. Bulkheads and seawalls may also prevent the exchange of sand between coastal dunes and the beach, and prevent human access to the water.

An understanding of the dynamics of the sediment transport system prior to bulkhead construction will help designers avoid unwanted consequences. Sophisticated instruments are not necessarily required. In fact, the drifting of such buoyant objects as oranges, coconuts, or even empty beer bottles can be observed to obtain useful measurements of nearshore currents.[1] And visual observations made from the beach by a trained observer can provide much of the required information on local coastal processes at relatively low cost.

Aerial photography is the most effective method for mapping and characterizing many aspects of shoreline environments. Mapping based on both aerial and ground-based information concerning the distribution of beaches in relation to headlands or existing groins and jetties provides an integrated picture of sand movement along a stretch of shore. If at all possible, historical records for any area being considered for development should be examined to evaluate longer-term trends in shoreline progression or erosion.

Because wind and waves play an important role in determining variations in the direction and speed of littoral drift, both their typical seasonal and their occasional high-level, storm-generated magnitudes and directions should be evaluated. Ships' logs and coastal weather stations are good sources of data. However, because local time-series data are rarely available when a project begins, theoretical models of wave and current patterns will probably have to be used at first. Routine observation of factors such as waves, sea level, coastal currents, winds, and changes in beaches should be made to develop a supplementary data base for making decisions as coastal development proceeds.

METHODS FOR EVALUATING IMPACTS ON NATURAL SHORE PROCESSES

Primary sources of the sediments carried in coastal waters include rivers, coastal cliffs, coral reefs and other organisms with calcareous or silicious shells or skeletons, and offshore deposits. Estimating the relative importance of these sources may be critical for determining the effect that a seawall at the base of a cliff or a dam across a stream will have on the nearshore environment. Measurement of a river's suspended sediments and discharge rates, possibly taken with simple samplers and current meters, can provide valuable information on the extent to which the shore zone will be deprived of sediment after construction.

A first approximation of local wave characteristics can be made by estimating general features from worldwide wave climate data relevant to the zone in question, and by using numerical models. These determinations should not take more than a few weeks. When necessary, more accurate data often can be obtained by the use of simple equipment such as wave staffs over a period of a year or so. More sophisticated equipment can be quite expensive and may require longer periods of time. However, in some circumstances such equipment will prove cost effective; seawalls constructed after more detailed studies often result in savings owing to factors such as decreases in the amounts of concrete and other building materials originally evaluated as necessary.

As noted above, littoral drift is another parameter that can be determined to a quite useful degree with inexpensive or even minimal equipment. In some cases, monitoring simple drifters, analyzing the morphology of beach forms, and determining the types and particle sizes of beach material along the shoreline will provide much of the information needed in site selection for beach protection structures or other types of coastal modifications.

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APPENDIX E

SEWAGE TREATMENT AND WASTE MANAGEMENT: DECREASING POLLUTION, USING WASTES PRODUCTIVELY

Demographic and industrial growth tends to create pollution problems in all coastal countries, particularly in countries with high population densities near the sea. Coastal waters are often seen as a convenient dumping site for all types of wastes. In some instances, nontoxic organic wastes, such as domestic sewage or agricultural effluents, will not have harmful effects. However, when pollutant levels become too high, as is common in crowded areas and in poorly flushed lagoons and bays, serious health or environmental problems may result.

Insufficient or nonexistent sewage treatment can lead to human health problems resulting from high concentrations of microorganisms such as salmonella, hepatitis viruses, vibrio, or clostridium. The addition of organic material and nutrients can also produce eutrophication, the rapid increases in productivity and concentration ("blooms") of a few species of phytoplankton and larger plants. These plants, which are not typically present in large numbers, are either not consumed at all by the aquatic animal populations, or are not consumed in large enough quantities to prevent the accumulation of decaying plant matter. This creates problems of putrefaction and depleted oxygen levels that kill fish and other animals. Toxic wastes, associated particularly with industrial effluents or chemical waste disposal but also released by agricultural, domestic, or commercial activities, can have serious impacts on the health, productivity, or safety for human consumption of local marine organisms.

SEWAGE

Domestic sewage is a highly concentrated source of organic materials and dissolved nutrients. In high environmental concentrations, these substances will produce undesirable conditions of eutrophication, algal overproduction, and decay. However, under certain specific environmental conditions, the release of nontoxic wastes to natural waters may increase local productivity of marine organisms. And, if an investment is made in technical waste conversion methods, sewage and other organic wastes such as farm effluents can sometimes be put to productive use as fertilizers or energy sources.

Strategies for Disposal in Coastal Waters

Criteria for selection of coastal disposal sites. In order to maximize the flushing and dispersal capabilities of wastewater disposal sites, their selection must be based on a knowledge of prevailing oceanographic conditions, including current patterns and velocities, temperature differentials, underwater topography, and areas of biological significance and sensitivity.

Types of treatment and disposal. Selection of the level and type of wastewater treatment will depend on the discharge method to be used and on available discharge location. A high level of treatment may be dictated by the sensitivity or poor flushing of the local marine environment or because it may be economically sensible to reuse wastewater on shore (for instance, the use of wastewater for agricultural or aquacultural fertilization, as is commonly practiced in much of Asia, provided that water does not contain toxic wastes). In well-flushed, open-coast areas, however, oceanic conditions could permit treatment as minimal as coarse screening, combined with long outfalls to depths and currents that would produce safe dispersal of wastes.

Possible benefits of waste release. Sewage and agricultural and agro-industrial wastes are part of organic and inorganic materials whose nutrient components are stimulants to plant growth, and whose organic components can serve as food for aquatic animals. In coastal zones where nutrient levels are low, productivity of harvested marine organisms may actually be enhanced by the addition of such wastes to levels that are not excessively high. (This does not apply to areas that depend for their productivity on coral reefs, as corals require low-turbidity waters, or to shallow waters where nutrient levels may be naturally very high.) However, areas with deeper waters and no coral may exhibit enhanced productivity when sewage is given minimum treatment on shore, followed by offshore diffusion of wastewaters through properly designed ocean outfalls. Studies along the coast of California by the Southern California Coastal Water Research Project[1] have documented the capacity of municipal wastes to increase the biomass and fish populations of nearshore coastal zones.

Productive Use of Sewage and Other Organic Wastes

When toxic contaminants are not present, techniques are available for putting organic wastes to use as energy sources, agricultural fertilizers, and aquaculture nutrient supplies. Fairly simple systems may be constructed for the production of biogas fuel through the treatment of sewage or farm effluents. This is most practical when effluents are available in high-volume, regular supplies. Fairly large-scale farming operations or organized town sanitation cooperatives are examples of sources of organic effluents which have been very successfully converted into biogas and other fuels and used as fertilizers in a number of developing countries.

Comments on the use of farm animal wastes in connection with aquaculture fertilization are given in the "Aquaculture" section of Appendix C; general references on energy conversion of domestic and farm wastes are given in "Selected Readings."

Eutrophication: Problems Caused by Excessive Organics and Waste Nutrients

For nearshore marine environments in which the principal organisms, such as corals and certain fish, are dependent upon clear water, nutrient additions that increase phytoplankton concentrations and substantially impair light penetration are deleterious. (Corals, although they are animals, require light for the support of their internal symbiotic microorganisms, the zooxanthellae, which are plants.) Nutrient additions also alter the composition of plankton species; even though the nutrients may increase the total plankton productivity, high densities of types of these microscopic plants that are not normally present in a region do not generally lead to enhanced productivity of ecologically and commercially important higher organisms. Instead, the resulting water turbidity and lower oxygen levels due to decay of the overabundant phytoplankton can kill or decrease the reproductive potential of organisms such as fish and shellfish and result in migration of the more mobile species away from this area. Further, the bloom in some areas is likely to consist of "red-tide" phytoplankton, dinoflagellates that produce substances toxic to humans and marine animals. Evaluation of possible negative economic and social impacts should therefore be part of any study of wastewater disposal options.

Monitoring Strategies

Technical evaluations should generally include the determination of prevailing current directions and speeds at the surface and at depth, measurement of temperatures from the surface to depths of about 200 feet, and biological studies to characterize the important components of the benthic and pelagic communities. In order to ensure that samples will adequately represent the actual effects of effluent release on the local ecosystem, the frequency and location of sampling stations must be selected with consideration of the size of the flow and the variability of environmental conditions.

AGRICULTURAL AND INDUSTRIAL WASTES

Nontoxic Substances

Agricultural activities often result in coastal zone pollution, owing to the leaching of materials from land as well as to the direct release of wastes into rivers or coastal waters. The release of organic substances, including animal wastes and discarded materials and effluents from crop harvesting and processing operations (such as sugar refineries, tapioca flour mills, canneries, breweries, or pulp and textile mills), will have impacts similar to those of domestic sewage. Eutrophication is the primary problem with such agricultural or agro-industrial pollution.

As discussed in Appendix D, serious sedimentation problems can also be produced by agricultural activities. The kinds of impacts depend on local soil conditions and agricultural practices. High silt concentrations potentially detrimental to aquatic animals and plants may be introduced into coastal waters by erosion of tilled lands, especially in hilly areas. Also, in areas with pyritic soils (those with high concentrations of iron sulfide and other non-oxidized, acid precursor compounds), a change to dry-land agriculture from submerged-land rice cultivation can have harmful effects on the chemistry of adjacent lands and waters. The earth-moving activities associated with farming may result in enough exposure of these long-buried compounds to the oxygen of the atmosphere to release toxic levels of acid into groundwater, ponds, streams, and nearshore marine waters.

Toxic Wastes

A less visible but potentially more dangerous type of pollution can be caused by the runoff of toxic agricultural chemicals (especially pesticides and herbicides), which may harm coastal organisms directly or make them unfit for human consumption. These effects can also occur through the use of pesticides for nonagricultural insect control in watershed or coastal areas. In addition to chemicals spread or sprayed on crops, some very toxic pesticides are applied externally to livestock and are then washed into streams and carried to coastal waters.

One pesticide that is becoming the subject of serious concern is toxaphene, which is widely used in developing (and some developed) countries in cotton farming, for food crops, and as an insecticide for cattle. Unlike the better-known pesticide DDT, toxaphene--a chlorinated camphene made by adding chlorine to wood residues under ultraviolet (UV) light--has been definitely identified as a carcinogen.[2] Since 1981, several leading environmental chemists have been saying that the possibility of dangerous levels of toxaphene buildup in watersheds, and perhaps in coastal marine waters, is extremely serious,[3] particularly as this pesticide is not degraded in the environment by UV light, as DDT eventually is. Present analytic methods may not be sensitive enough to identify dangerous levels of toxaphene directly in coastal waters, but monitoring could be done through chemical assays of tissues of filter-feeding marine organisms such as mussels or other bivalve molluscs, as discussed below in the section on biological monitoring programs.

As with toxic agricultural wastes, both the direct release of industrial wastes into rivers and coastal waters and the leaching of wastes into aquatic environments from land disposal sites can be harmful to people and coastal organisms. The potential for severe effects from the release of industrial wastes into coastal waters became evident more than two decades ago through the "Minimata incident" in Japan, when many inhabitants became ill or died from eating Minimata Bay fish contaminated by mercury catalyst waste from an acetaldehyde factory.[4]

Chlorinated hydrocarbons (including DDT, PCBs, toxaphene, and mirex), some petroleum hydrocarbons (PHCs), and certain heavy metals such as mercury, are of particular concern because they are "biomagnified" in marine food webs. Thus, organisms at the higher trophic levels, including humans and fish-eating birds and marine mammals, are particularly vulnerable. In developing countries, only a few measurements of levels of such substances in coastal waters, or in the tissues of aquatic organisms, have been done,[5,6] but the data that do exist indicate localized high levels of some of these substances in a number of localities. For example, high mercury levels are found in the Bay of Bangkok and in Manila Bay, and associated with polyvinyl plastic factories near Iligan Bay, Mindanao; petroleum hydrocarbons and pesticides are found in the tissues of marine animals in the harbors of Jamaica and other Caribbean islands; petroleum substances and by-products are suspected of killing fish fry in the waters near Nigerian oil ports.

Strategies for Toxic Waste Disposal

The impact of industrial wastes from point sources can be minimized by treatment of wastes prior to disposal or by confinement in land disposal sites. However, for many countries, waste treatment or effective land-site confinement may prove to be too expensive, and selection of marine disposal sites that maximize dilution and dispersion may be the best available method for minimizing the effects of toxic wastes on living resources. This approach requires knowledge of current patterns and velocities, mixing and flushing rates, and a knowledge of which coastal areas are biologically most productive as harvesting or nursery areas, so that they can be avoided as release sites. The creation of atlases of coastal habitats as recommended in Appendix C will be extremely helpful in selecting disposal sites.

POLLUTION-MONITORING METHODS

Properly designed sampling procedures can often identify primary sources of particular contaminants, thereby enabling control measures to be applied efficiently. This approach has been used for coastal waters near highly developed urban centers in the United States (for example, in the Southern California Bight, the New York Bight, and Chesapeake Bay). However, direct measurement in cases where contaminants are dangerous at low levels requires the development of sensitive analytical capabilities, as discussed below. The use of biological indicators may then be the preferable monitoring method.

Analytical Methods

Importance of instrumentation. Accurate measurement of such highly toxic contaminants as trace metals and chlorinated hydrocarbons requires relatively expensive equipment and the availability of highly trained scientists and technicians. Techniques include atomic absorption spectrophotometry, gas chromatography, and mass spectrometry.

Unfortunately, some of the most widely used and toxic (or carcinogenic) compounds (PCBs, toxaphene, certain metals) are dangerous at such low concentrations that only state-of-the-art analytical techniques are sensitive enough for identification of harmful concentrations in environmental waters. Even after acquisition of the necessary equipment, methods for accurately measuring concentrations of elements and organic compounds in environmental samples (sediments, water, and biota) are beset by difficulties with sample contamination, matrix (surrounding material) interferences, and detection limits. Further, maintenance personnel must be available for routine and emergency services. These factors may pose major problems in a developing country and should be considered before analytical equipment is purchased.

Even in developed countries, direct measurement of pollutant levels in the water will not always be possible or practical. However, measurement of contaminant levels in the tissues of organisms, where concentrations may be greater by factors of a thousand or more, is often possible. Where local analytic capabilities are limited, it may be possible for tissue samples of organisms such as mussels or oysters (exceptionally good "bio-magnifiers") or fish to be shipped frozen to laboratories in other regions. (A program to do just this, the "International Mussel Watch Program,"[7] has been under way for several years, with very promising results, in developing countries throughout much of the world. Coastal countries not involved in Mussel Watch may want to contact participants in order to evaluate the benefits of joining this worldwide monitoring, training, and management effort.)

Intercalibration procedures. The ability of a laboratory to make consistently accurate measurements requires the use of standard reference materials and routine participation in intercalibration exercises with other analytical laboratories. Standard reference material of biological tissue and sediments can be obtained from the U.S. National Bureau of Standards or from the International Laboratory of Marine Radioactivity in Monaco. Interlaboratory calibration exercises with technologically more advanced countries can be arranged through several international organizations. For example, the Intergovernmental Oceanographic Commission (IOC) of UNESCO sponsors a program titled "Global Investigation of Pollution in the Marine Environment" and maintains a group of experts on methodology and intercalibration that conducts intercalibration exercises among IOC member states for a variety of marine contaminants.

Training. There are several ways for individuals in developing countries to learn the techniques of monitoring marine contamination. In some instances, it is possible for trainees to spend about six months to a year at a foreign laboratory with analytical capability for the contaminant(s) of interest. The success of these programs will usually depend on the availability of supervisory individuals who are prepared to provide both technical information and consistent guidance for the trainees. Another approach is to take advantage of international training programs provided by UNESCO through the IOC's Training, Education, and Mutual Assistance Program. It is also important that the experience and educational backgrounds of trainees be considered so that they can be placed in appropriate training courses.

Establishment of Biological Monitoring Programs

Marine pollution monitoring programs may measure concentrations of pollutants in sediments, in water, or in the tissues of plants and animals. There are advantages and disadvantages in measuring each of these components of the coastal ecosystem. However, the use of organisms, which function to varying degrees as integrators of environmental pollutant levels as well as concentrating many contaminants in their tissues, has become increasingly popular. As mentioned above, this is often the least expensive and most practical approach.

In establishing a biological monitoring program for marine pollutants, two approaches, one for human health factors and one for environmental factors, are needed. The first approach is to monitor pollutant levels in seafood organisms important in the diet of local populations. This is obviously critical in areas where there is a heavy dependence on marine organisms for local food supplies. The second, complementary, approach involves selection of a "sentinel" or "indicator" organism to monitor changes in environmental levels of a pollutant. Normally, a relatively immobile species, usually a filter-feeder such as a mussel or oyster, is selected. The population is then sampled routinely to obtain an indication of long-term changes in pollutant levels.

The following factors must be taken into account for the establishment of biological monitoring programs:

- Concentrations of pollutants in organisms can vary substantially within and among populations. This natural variability must be compensated for by using sufficiently large sample sizes.

- Trace metals exist naturally in the environment and in plant and animal tissues, so estimates of the normal, uncontaminated, range of concentrations must be established for each organism before the degree of pollution can be assessed.

- Hydrocarbons similar to those present in various types of petroleum can be synthesized by marine organisms. The analyst must be able to distinguish between these biosynthesized hydrocarbons and chemically related ones assimilated from petroleum pollution sources.

- Some organic pollutants, once accumulated, will be metabolized and altered in chemical structure, making identification of the compound that was originally accumulated difficult. Information on this and related problems may be obtained in the current literature on environmental chemistry; summary information on some topics will also be available from UNESCO or the IOC.

INTERNATIONAL POLLUTION-MONITORING PROGRAMS

The workshop sponsored by the U.S. Environmental Protection Agency and National Academy of Sciences, the International Mussel Watch (1980), brought together experts to assess strengths and weaknesses of biological monitoring programs of chemical pollutants and to identify research needed to improve this approach. The report of that workshop contains detailed information for initiating a biological monitoring program in almost any coastal area.[7]

A number of the major international technical assistance organizations are developing marine pollution-monitoring programs throughout much of the world. At present, there are two regional monitoring programs for chemical pollutants being developed by the Intergovernmental Oceanographic Commission for its Caribbean region (IOCARIBE) and for the Western Pacific Region (WESTPAC). Marine science studies coordinated by UNESCO for each region of the world (including a series on coastal lagoons whose most recent session was a symposium in Bordeaux, France, in September 1981; and a workshop on mangroves, sea grasses, and coral reefs held in St. Croix, U.S. Virgin Islands, in May 1982) often include the collection or coordination of data directly or indirectly related to coastal pollution impacts. The U.N. Environment Programme (UNEP) plans to conduct large-scale marine pollution monitoring programs that will attempt to coordinate the collection of data on a regional basis throughout the world. UNEP programs will generally include other major aspects of marine resource management as well, such as living marine resource management plans, natural hazard protection programs, oil spill contingency plans, and environmental education projects. Work on several of these "Regional Seas Programmes" (such as one for the Mediterranean sea) is quite far advanced while others are still in the planning stages. A useful source of information on their work in progress, upcoming meetings, and coastal management in general is the small, informal journal of the programme, The Siren, available from UNEP (see "Selected Readings"). The nongovernmental Scientific Committee on Problems of the Environment (SCOPE) has conducted several marine pollution studies and has the advantage of being able to respond more quickly than the larger international organizations to critical problems as they are identified.[8]

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APPENDIX F

REMOTE SENSING OF COASTAL AND MARINE POLLUTANTS

Remote sensors on aircraft and satellites are being used with considerable success for the following purposes in the marine and coastal environment:

- Mapping coastal vegetation, its biomass, and stress induced by pollutants
- Monitoring man-made and natural changes in the coastal zone, including land-use change
- Hydrographic charting and geomorphic mapping, including coastline erosion
- Charting current circulation, waves, and other dynamic properties influencing coastal erosion and pollutant dispersion
- Detecting freshwater springs in highly saline coastal waters
- Monitoring the effects of dredging and the dispersal of ocean-dumped dredge spoils
- Tracking the drift and dispersion of organic and inorganic pollutants, including oil slicks, sewage sludge, and industrial wastes
- Mapping chlorophyll and nutrient-rich waters in various stages of eutrophication.

These applications of remote sensing require a wide assortment of data analysis techniques, including visual photo-interpretation of aerial film for coastline erosion mapping; standard digital techniques for thermal current charting; multispectral analysis methods for biomass studies; and sophisticated principal component analysis for quantitative determination of pollutant concentration in water. Many of these applications also require a small number of water samples obtained from boats during satellite overpass for analysis and calibration of remotely sensed data.

Many developing countries have not yet acquired the ability to digitally process remotely sensed data or to analyze water samples for some of the more difficult pollutants, such as heavy metals. Therefore, in preparing plans for monitoring marine and coastal pollutants in those countries, simpler, less expensive techniques must be employed.[1]

In bays and coastal waters, a small aircraft can be used in conjunction with a small boat (20 m) to track certain common pollutants. The aircraft requires two 70 mm or 35 mm cameras. The first camera should contain color film and the second panchromatic film with special filters to enhance suspended sediment plumes and certain pollutants. For oil slick detection, the blue or ultraviolet bands are most effective with film cameras from low altitudes (1,000 m). Red filters enhance suspended sediments and green filters help delineate algae. The aircraft must be in radio communication with the boats, guide the boat to proper stations, and record on film the exact location where the boat takes its samples (from medium altitudes of 3,000 m, to include land features for positioning or navigation).[2,3]

Water samples obtained by the boat crew can be analyzed at any suitable laboratory for concentrations of suspended sediments, chlorophyll, and important pollutants. If a relationship can be found between pollutants and water turbidity, then remote sensors can monitor pollutant distributions at frequent time intervals even when boats are not available.[4,5]

Inexpensive drogue and dye techniques can be used to predict pollutant drift and dispersion in coastal waters. Simple drogues can easily be built using common materials such as PVC tubing and fabric.[6]

Several times during each season (rainy and dry), a small boat (about 20 m) can be used with a small aircraft to track current drogues and map the turbidity distribution patterns from which current circulation can be deduced. Thus, suspended sediment is used as a natural tracer. As for pollutant studies, two cameras are used, one with color film and one with panchromatic film and special filters. Filters in this case should be selected to enhance the colors of the dyes or the drogues. If the thermal scanner is available, it may provide additional information on circulation patterns in the area.

Current drogues can be deployed from the boat and tracked by the aircraft over one complete tidal cycle during each of the field experiments. The aircraft must take high-altitude photos to locate the drogue cluster with respect to the shoreline and low altitude photos to show the dispersion (spreading) of the current drogues. The drogues are usually color-coded and measure currents at the surface and at a depth of one meter.[7,8]

Changes in coastal land use, including mangrove losses or degradation, can be mapped from small aircraft containing two 70 mm cameras with color and color infrared film. These techniques are described in detail in References 9 and 10. For discriminating and mapping vegetation types, visual photo-interpretation techniques are sufficient. For mapping vegetative stress or biomass, digital multispectral methods must be employed.[11]

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