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The Geology of Maine's Coastline : A Handbook for Resource Planners, Developers, and Managers

Maine State Planning Office

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Executive Department

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Financial assistance for preparation of this document was provided by the U.S. Department of Commerce, Office of Coastal Zone Management, under the Coastal Zone Management Act of 1972, as amended.

PREFACE

Since 1977, as part of Maine's Coastal Program, the State Planning Office has published a series of handbooks to assist private citizens and developers, as well as members of local planning boards and professional planners, with convenient guides to the management of coastal resources.

These handbooks provide the reader with sufficient technical background to communicate successfully with specialized scientists and technicians when considering developments proposed for shoreline and intertidal sites. They also serve as users' guides to specialized maps displaying coastal data. Non-technical language is used as much as possible without diminishing the accuracy of the information.

This particular handbook, *The Geology of Maine's Coastline,* is the product of work undertaken by the State Planning Office through a contract with the Maine Geological Survey in the Maine Department of Conservation. Barry S. Timson, a geologist formerly with the Maine Geological Survey, did the mapping of the numerous marine geologic units making up the coast and authored the analysis upon which this book is based. Subsequently, his work was reviewed and supplemented by other geologists including Robert Gerber, who added material on planning considerations for various geologic units and the impacts of human activities. The hand drawn illustrations for Chapter 3 were done by artist Jon Luoma. Mary Griffith, a Massachusetts Audubon Society Environmental Intern, edited and circulated various interim and review drafts of the work. Finally, environmental writer, Robert Deis, performed the task of editing the extensive technical text into a shortened version more readily understood by non-geologists.

State Planning Office staff who contributed substantially to the project include: R. Alec Giffen, Director of the Natural Resource Division; Joseph Chaisson who developed the initial concept; Richard Kelly who designed the publication and did the layout; and Harold Kimball who coordinated the publication process.

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Monhegan Island Cliffs

photo Harold Kimball

INTRODUCTION:
THE GEOLOGICAL CONNECTION

In this environmentally-aware era, it has become increasingly obvious to residents of Maine's coastal towns that geological factors can have far reaching effects on their lives and their community. Especially along the coast, the lay of the land, what it is made of and how it is affected by natural processes and human activities determines much more than simply what kinds of plants and animals can live in a given place. Ultimately, these factors determine how people will view, value and utilize that place. For, in very basic ways, the geological aspects of an area both create and limit opportunities for such things as resource use and residential or commercial development.

The existence of a mudflat, for instance, presents you with an opportunity to go clamming—but you wouldn't want to build your house there. Marine sand and silt, the same geologic materials that create a perfect habitat for clams, also limit the possibilities for construction because of their unstable nature and location in an environment flooded daily by the tides. In addition, the effects of construction, even if it were practical, might conflict with the more valuable long-term use of the spot as a commercially harvestable clamflat.

That's a simple example, of course. Many of the interrelationships between people and the geological characteristics of coastal environments are more subtle. Yet, whether subtle or simple, the links are there, and their importance is becoming more and more apparent each year.

Two major needs have resulted from our growing awareness of this "geological connection." First, faced with the complex tasks of long range planning and assessing the feasibility or potential impacts of various activities and projects, coastal planners, developers and residents are feeling an ever greater need for detailed geological information about their towns. The second need follows from the first. In order for nonscientists to use detailed geological information, they must also be given an understanding of what this information means and a working knowledge of its implications.

During the past few years, under the administration of the State Planning Office, Maine's Coastal Program has made substantial progress toward meeting these needs. As a beginning step, it has put together an exhaustive inventory of Maine's coastal resources, including a constantly-expanding data base on the geology of our state's coastline. Equally important, the Coastal Program has gone on to create a continuing series of Coastal Inventory Maps and publications relating to various aspects of resource development or management in Maine's coastal areas.

This handbook is one such publication. Its purpose is to provide the layperson with a general introduction to the geology of Maine's coast and a better understanding of how geological factors figure in resource utilization, development and planning decisions.

As a source of basic information, the book stands on its own. However, it is important to note that this handbook is particularly useful as a complement to a set of Coastal Program resource maps formally titled the Coastal Marine Geologic Environments Maps. Simply put, the Marine Environments maps show the locations of distinct coastal environments, such as a mudflats and beaches. The features and uses of these maps are described in the next section of the handbook, Chapter 1.

In Chapter 3, entitled "The Geologic Environments of Maine's Coast", each of the 55 kinds of environments shown on the maps is described, along with some of the planning considerations relating to them. This is the essential body of information needed to understand just what the individual environments are, why they are important and how human activities may affect them.

To better comprehend coastal geology, however, it is helpful to begin with a broader view—a look at the way all these small geologic units fit together. Such an overview is provided in Chapter 2, called "Perspectives on Maine's Coast." It describes the interesting, complex links between marine environments, explains how natural forces affect coastal landforms, and summarizes some of the changes our coastline has gone through since the last great Ice Age.

Finally, in Chapter 4, a geological phenomenon that has become more and more troublesome to coastal residents in recent years is discussed—shoreline erosion. Our treatment of this special problem begins with some background on how and why shoreline erosion occurs, and then goes on to describe some common and effective ways of dealing with it.

Before going further, it should be explained that since the focus of this handbook is on geology, the amount of information given about the biological aspects of Maine's coast is limited. Only the most relevant or outstanding details about the plants and animals who live in or depend on marine environments are mentioned. For a more thorough look at the diverse biological resources of our state's coast, readers can refer to the companion volume to this book, titled, *A Planner's Handbook for Maine's Intertidal Habitats* (available from the State Planning Office).

By using these two handbooks in conjunction with the Marine Environments maps, coastal residents, developers and planners should gain a clearer idea of what the ultimate benefits and effects of their decisions concerning resource use or development may be. Hopefully, they will also have a better basis for making those decisions in the first place.

Popham Beach, Dune and Marsh System *photo Harold Kimball*

CHAPTER 1: USING THE MARINE ENVIRONMENTS MAPS

As mentioned in the introduction, much of the information in this handbook is particularly useful in conjunction with a set of Coastal Program resource maps called the Coastal Marine Geologic Environments Maps. These maps are not hard to understand. In a number of ways, they are similar to the Soil Conservation Service soil maps with which most land use planners are already familiar.

Soil maps are often used in regional or town planning for purposes such as locating areas suitable for subsurface sewage disposal or sanitary landfill sites and for identifying prime agricultural land. The Marine Environments maps can also be helpful for this kind of generalized planning. In addition, because of their larger scale, they can be used for more detailed planning and environmental impact assessment.

Basically, the Marine Environments maps indicate the size and location of individual geological environments, or "units", (a beach, a mudflat, a tidal channel, etc.) as they occur along the Maine coast. Altogether, 109 maps have been produced, covering land along the state's entire coastline between the nearshore uplands and shallow subtidal depths of about 8-10 meters, or roughly 25-30 feet below the low tide mark. On them, 55 different types of marine environments are distinguished with simple letter codes.

To coastal residents, the most fundamental use of the maps is to determine the geological characteristics of particular sites in their town. Though verification by on-site inspection should always back up any important decision, a quick look at the appropriate map will show with reasonable accuracy what kind of environment exists at any given spot in the shoreland zone. It will show, for example, whether a certain intertidal area is a "coarse-grained flat" or a "seaweed covered flat." Even such relatively similar geologic environments have certain significant differences. Each has its own characteristic sediment composition; each supports a unique set of plant and animal life; and, each has a different potential for meeting human needs. Of equal, perhaps greater, importance is the fact that each reacts differently to various natural or man-made influences.

The pinpointing and identification of these distinct environments is especially advantageous to developers, town planners, industrial researchers and other people for resource utilization planning. For instance, by using the maps, efforts to locate suitable sites for piers, houses, commercial facilities, industrial plants and other developments are made much easier. Places where unstable soils or other geological conditions make a project unfeasible can be quickly identified and ruled out. The proximity of sensitive, ecologically valuable environments to a site can

FIGURE 1 Marine Geologic Environment Map and Legend

MAP SYMBOL	GEOLOGIC ENVIRONMENT
	SUPRATIDAL ENVIRONMENTS
Sd	Dunes & Vegetated Beach Ridges
Sw	Fresh-Brackish Water
Sm	Fresh-Brackish Marsh
Sz	Man-Made Land
Sx	Landslide Excavation & Deposits
	INTERTIDAL ENVIRONMENTS
	Marsh Environments
M1	High Salt Marsh
M2	Low Salt Marsh
M3	Marsh Levee
M4	Salt Pannes & Salt Ponds
	Beaches
B1	Sand Beach
B2	Mixed Sand & Gravel Beach
B3	Gravel Beach
B4	Boulder Beach
B5	Low-Energy Beach
Br	Boulder Ramps
Bw	Washover Fan
Bs	Spits
	Flat Environments
F	Mud Flats
F1	Coarse-Grained Flat
F2	Seaweed-Covered Coarse Flat
F3	Mussel Bar
F4	Channel Levee
F5	Algal Flats
F6	Veneered Ramp
	Miscellaneous Environments
M	Ledge
Mc	Fluvial-Estuarine Channel
Mp	Point or Lateral Bars
Ms	Swash Bars
Mf	Flood-Tidal Delta
Me	Ebb-Tidal Delta
Mb	Fan Delta
Md	Spillover Lobe
	SUBTIDAL ENVIRONMENTS
	Flat Environments
Fm	Mud Flat
Fc	Coarse-Grained Flat
Fe	Eelgrass Flat
Fs	Seaweed Community
Fb	Upper Shoreface
Fp	Lower Shoreface
	Channel Environments
C1	High-Velocity Tidal Channel
C2	Medium-Velocity Tidal Channel
C3	Low-Velocity Tidal Channel
C4	Estuarine Channel
C5	Estuarine Flood Channel
C6	Estuarine Ebb Channel
C7	Inlet Channel
C8	Dredged Channel
Cs	Channel Slope

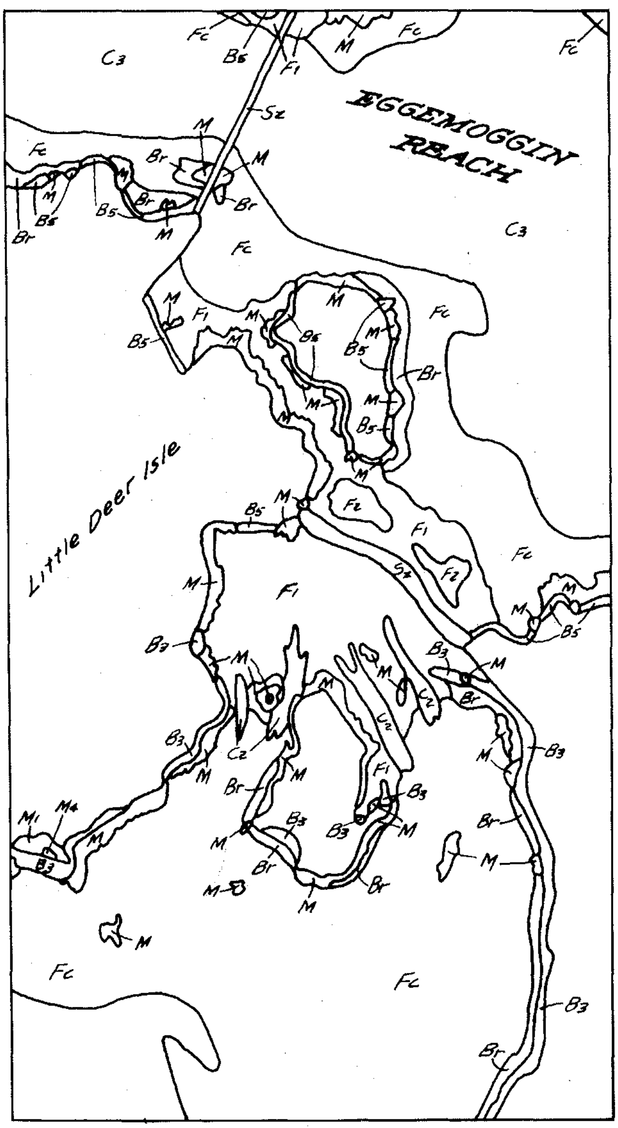
Tidal Creeks

Marsh Drainage Ditch

Unit Boundary

Approximate Unit Boundary

Approximate Transition Boundary Between Estuarine and Marine (30 ppt salinity) Waters and between Estuarine and River (0.5 ppt salinity) Waters.



be noted. And the possibilities for expanding a project in the future can be estimated by looking at the locations, sizes and nature of the environments in the area.

Similarly, the detailed information on the Marine Environments maps can facilitate the location of potential aquaculture sites, commercially harvestable mussel or seaweed beds, and other marine resources. It can help in creating effective strategies to combat shoreline erosion problems, or in the development of zoning guidelines. Recently, the maps have been used to help formulate the clean-up plans that would be implemented in case of a major oil spill off Maine's coast.

Because the differences between individual sites are also crucial in determining the effects an activity or project may have on the environment, another basic use of these maps is for environmental impact assessment. While in many cases professional advice is needed to undertake this type of analysis, it is possible—and often necessary—for the layperson to make judgements about potential environmental impacts for themselves.

Members of municipal planning boards, for example, spend considerable time reviewing developments proposed for their towns, a process that usually involves some kind of environmental impact assessment. For their part, developers generally have to study and report the potential environmental effects of their projects in order to get needed permits and fulfill application requirements.

As a rule, the sophistication of impact assessments varies with the size or expected environmental influence of the project in question, ranging from simple common sense judgements to highly involved computerized simulations and technical studies. Any type of impact assessment, however, should take into consideration the fact that the connections between human

FIGURE 2 Natural Variables Affecting Sedimentation Within an Estuary

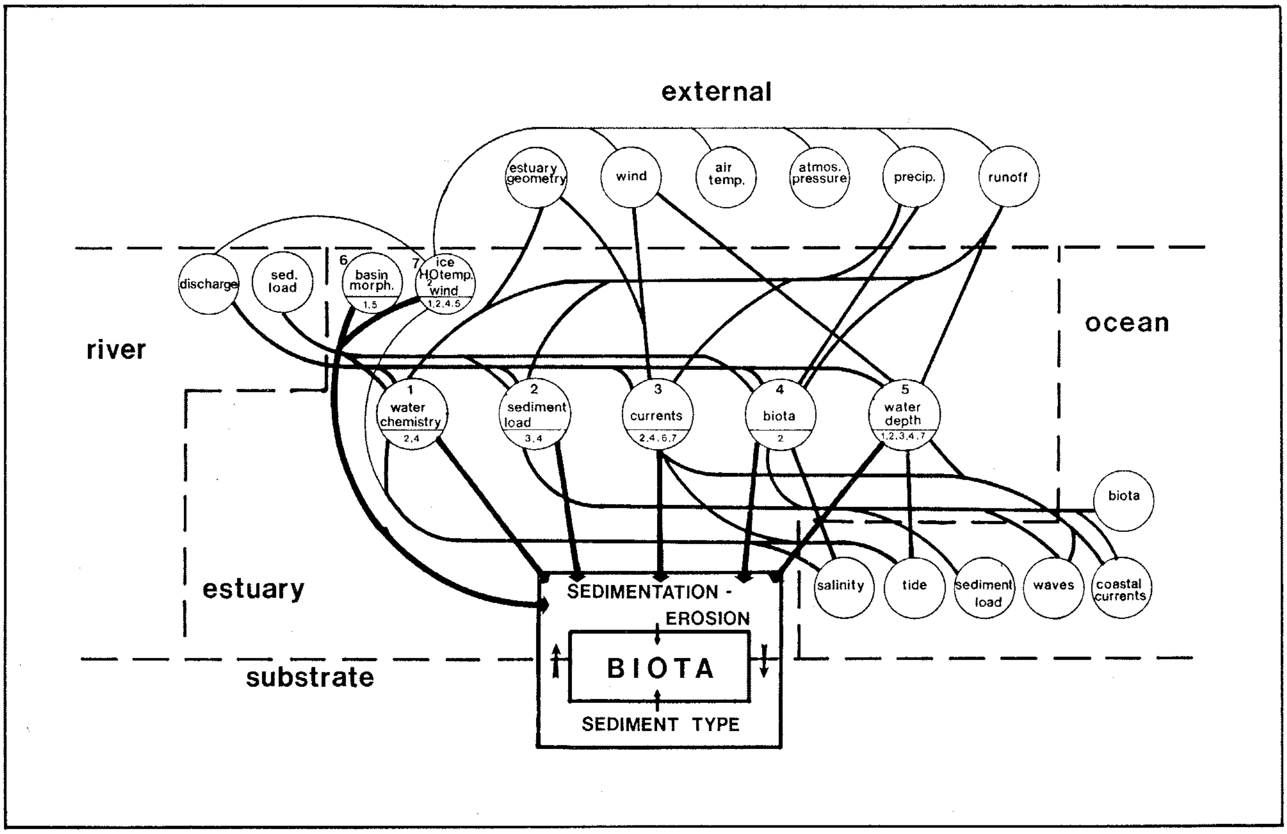


Figure 2 illustrates the complex interactions between factors affecting estuarine biologic organisms. The emphasis is restricted to those factors which affect sediments. The primary factors acting on benthic organisms (those living in or near the bottom) are the processes of sedimentation/erosion and substrate sediment type. These two factors, in turn, are influenced by secondary factors (numbered 1-7) within the estuary. The secondary variables influence each other as indicated by the small numbers within and at the bottom of the secondary factor circles. The secondary factors and tertiary (third level) factors are influenced in turn by those processes within environments adjacent to the estuary itself.

activities and marine environments are extremely complex and that the links between the living and non-living components of those environments are equally intricate.

Figure 2 is a good illustration of this point. It is a "process interaction diagram" showing the interrelationships between the various living and non-living components of a typical Maine estuary (a water body where fresh water mixes with ocean water). Each component is labeled, with plant and animal life combined under the heading of "biota," and each is linked with lines to other components. In theory, if any one of the components is altered in some way due to natural or man-made causes, there will be some effect on the other components it is linked to, and those components in turn will influence another set of components. The basic idea, at least, is plain. Few, if any, environmental systems are simple, and everything in one is intricately connected to many other parts of the system.

In terms of land use planning, particularly with respect to Maine's complex and highly valuable coastal environments, the many interconnections between geological and biological components tend to support the conclusion that the less basic changes made, the better. If not taken to an extreme, this view is generally a sound one. Almost all of Maine's major coastal industries, from commercial fishing to tourism, depend ultimately for their existence on healthy, attractive marine environments.

Changes to the Maine coast are inevitable, in view of the heavy developmental pressures on—and great potential of—our state's coastline. But effective management and careful development that minimizes adverse impacts is both wise and possible. In many ways, the Marine Geologic Environments Maps and an understanding of their implications can be very useful tools in working toward this goal.

Marine Environments Maps may be obtained from The Maine Geological Survey, Department of Conservation, Augusta, ME 04333 (telephone 1-207-289-2801).

Hermit Island and Head Beach, Phippsburg *photo Harold Kimball*

CHAPTER 2: PERSPECTIVES ON THE MAINE COAST

It's often said that Maine has a "rockbound coast," a phrase suggesting shorelines that are massive, solid and unmoveable. But in addition to rugged ledges, the physical structure of our coast is also made up of a significant amount of sediments—accumulations of gravel, sand, silt and clay, or combinations of these particles as well as organic matter. And, in fact, our coastline is constantly being altered and rearranged due to the influence of "process agents," those natural forces of the sea, the earth's weather systems and the general climate of the northwest Atlantic region.

Waves, tides and other process agents move sediments on a daily basis, transporting particles into and out of bays, along beaches and up and down the length of the shoreline. Over longer periods, process agents also affect bedrock ledge. Rock surfaces are weathered by wind and wave; blocks of stone are loosened by the alternate freezing and thawing of moisture in cracks, and may at times be dislodged and moved by storm waves.

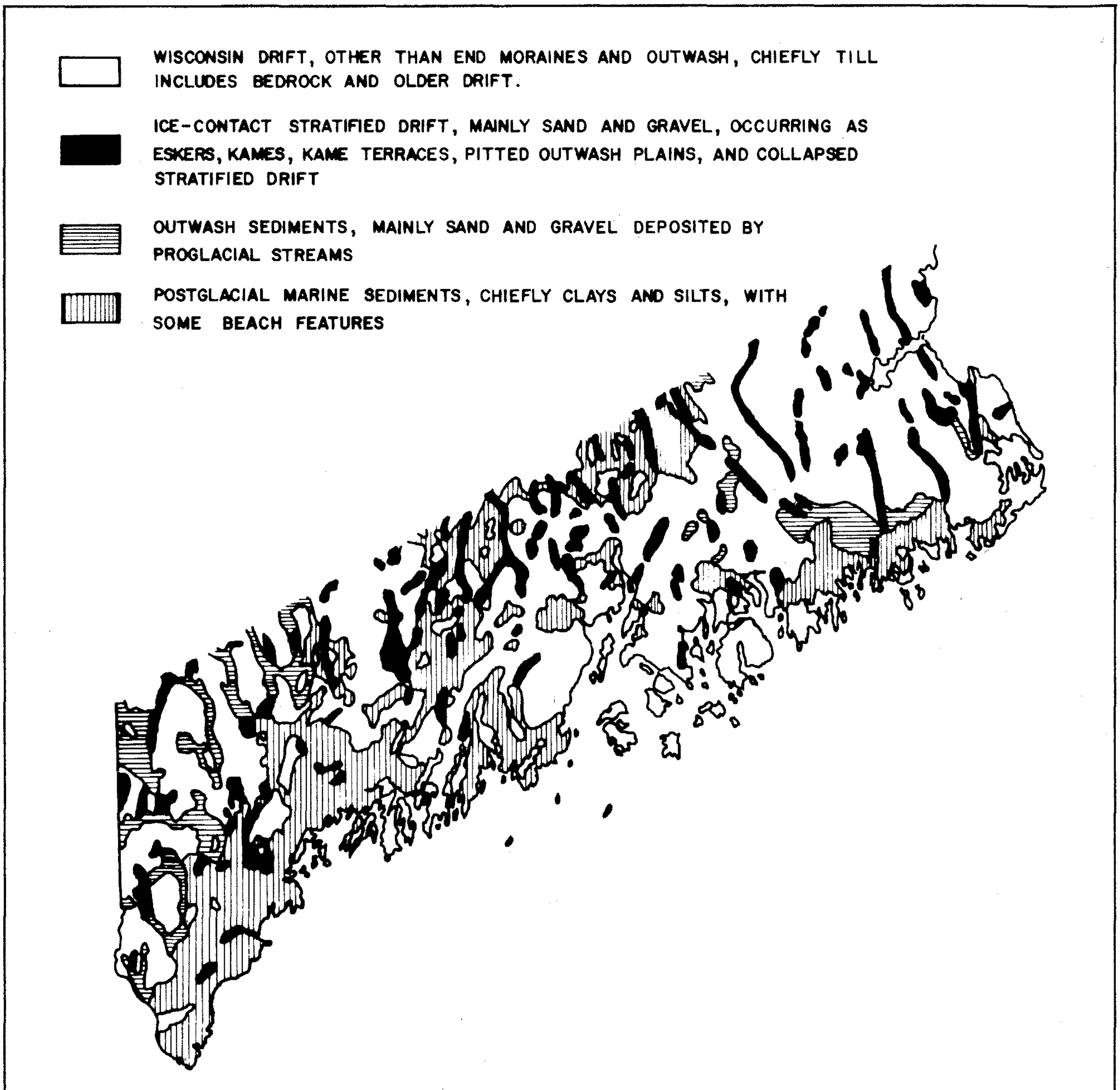
Geological studies show that in the past other natural forces besides those we see now have affected the lay of the land. To describe them all, and all of the changes Maine's coastal geology has gone through, would go far beyond the scope of this book. But before discussing existing process agents in more depth, a brief look at a past force that had particularly significant effects on Maine's landscape is both possible and relevant—the last great glacial advance.

The most recent in a series of continental glaciations that have covered Maine began about 28,000 years ago, during a period when the climate of North America became much cooler than it is today. That cooling trend created a three-mile-thick ice sheet which eventually blanketed all parts of the state and extended out to what are now the Georges Bank fishing grounds on the edge of the present continental shelf.

About 18,000 years ago, the climate began to warm again and the ice began to melt. By 10,000 years ago the glaciers had receded from Maine. The geological effects the ice had during its "life span," however, are primarily responsible for the Maine landscape we see today. For, among other things, the last great ice sheet, known as the Laurentide Advance, actually removed or reworked most of the surficial sediments and soils covering the entire state.

As the glaciers advanced over the land, they became embedded with and carried along enormous loads of sand, gravel, mud and boulders. Over the centuries the ice mass moved slowly southward, transporting more and more surface materials and scouring some areas (such as mountain peaks) all the way down to the bedrock.

FIGURE 3 Surficial Deposits in the Coastal Zone



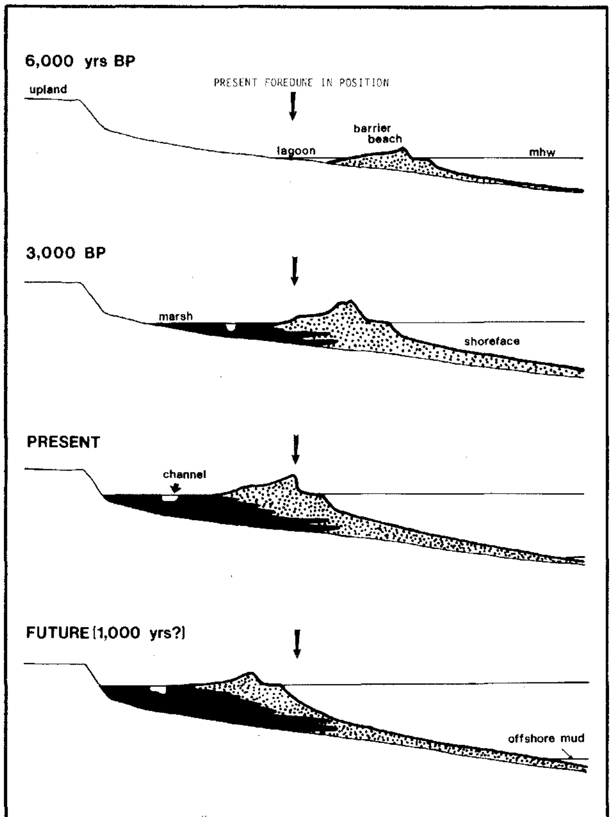
Here and there, the moving ice deposited materials transported from elsewhere, creating new landforms or altering old ones. One common type of glacial deposit is called "glacial till," a mixture of boulders, cobbles, gravel, sand, silt and clay compacted together by the weight of the ice. Another kind of glacial debris is termed "ice contact deposits." These are hill-like sand and gravel formations such as eskers, deltas and moraines, deposited by meltwater streams flowing on, below or adjacent to stagnant or active ice. Outwash deposits of sand and gravel were deposited away from the ice by meltwater streams. (Most of Maine's sand and gravel pits owe their existence to these types of deposits.) A third general type of formation left by the ice is composed of fine-grained sediments like silt and clay, which were deposited in the ocean at the glaciers' seaward margins. These are called "glaciomarine deposits."

Besides changing the topography and makeup of the land, the glaciers also affected our coastline in another very significant way. As the vast ice sheet grew to cover the northern United States, Canada, Europe and northern Asia, it locked up large quantities of the earth's water supplies. This caused a world-wide lowering in sea level height of about 300 feet. At the same time, however, the great weight of the ice mass depressed the earth's surface in many coastal regions, making the drop in sea level less apparent and causing parts of the coast to be flooded.

When the glaciers finally melted, the water they contained was returned to the sea, causing the sea level around the world to rise. But then, with the weight of the ice removed, many areas of the coastline rose rapidly, bringing land that had been under water to a new elevation above the ocean. (Thus, glaciomarine deposits can be found in what are now inland areas.)

Until about 8,500 years ago, the coastline of Maine continued to rise more rapidly than the level of the sea. Since then, sea level has been steadily overtaking land level at an average rate of around one inch per decade. This phenomenon is one of the process agents acting on our coast today. In fact, though the general public hears little about it, the current progressive rise in sea level has a marked influence on shoreline geology.

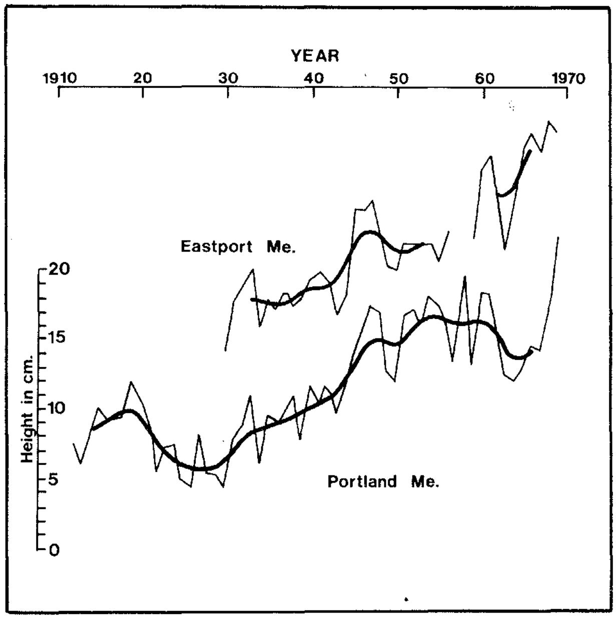
FIGURE 4
Landward Migration of a Barrier Beach



It is the slow rise of the sea level that is responsible for the steady landward migration of coastal environments. As the sea level gets ever higher, the point where the land and sea meet moves further and further inland. So too, do many non-bedrock nearshore environments, such as beaches, marshes and mudflats. In addition, as the sea level continues to rise, waves, tides and other marine process agents are increasingly likely and able to impact upland areas. The results? A slow drowning of the coast, accompanied by increasing shoreline erosion and mounting threats of damage to property and buildings in some areas that are located near the edge of the sea.

Though it may seem paradoxical in view of the effects described above, process agents on the whole are far more beneficial than destructive with respect to Maine's coastal environments. In fact, they are the primary natural forces that maintain the integrity of environments in the nearshore zone. To understand this positive role, it is necessary to look closer at how process agents work. Besides relative sea level rise, the five major process agents that most influence shoreline environments are currents, waves, winds, precipitation, and biological activity. Their effects on coastal geology and relevance to coastal development and planning are the subject of the next section of this chapter.

FIGURE 5 Past Sea-level Variations



GEOLOGIC PROCESS AGENTS

Currents

Currents are one of the most common and most influential process agents affecting the Maine coast. Able to both build and erode, they are extremely important factors in the transport and deposit of sediments from one geological environment to another.

This is particularly true of tidal currents, which result from the twice daily rise and fall of the ocean as it responds to the gravitational pulls of the sun and moon. Tidal currents erode sediments from the bottoms of shoreline environments when tidal flow attains the necessary "current threshold velocity"—the current speed required to pick up and carry away sediments of a given size. As current velocities decrease toward the peak of low or high tide, transport stops and the sediments carried by a current are deposited some distance away from their original position.

The constant moving of sediments that results from tidal current action plays a major role in the maintenance of mudflats, low salt marshes and many other marine environments. And, on the whole, its role is much more constructive than destructive. In fact, in the absence of tidal currents, many intertidal and subtidal areas might quickly become "sediment starved."

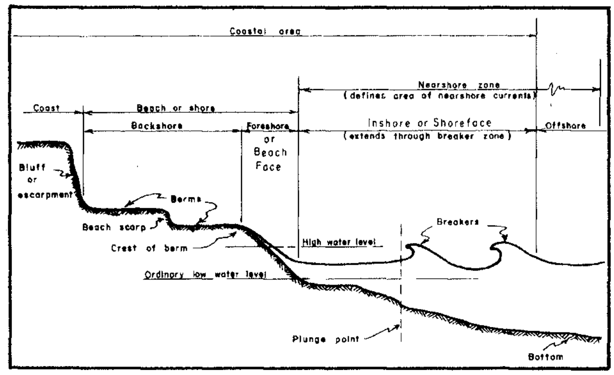
Non-tidal currents may also supply nearshore environments with sediments. Coastal currents generated by large-scale water movements in the Gulf of Maine generally flow southerly along the offshore, transferring river-delivered sediments or suspended sediments eroded from the shallow ocean bottom from one nearshore location to another.

One type of non-tidal current, known as the littoral current, has particularly great influence on the sediment budget of beaches. This current is generated by wave action and usually flows parallel to the coast in the surf zone. Most notably, littoral currents are involved in the distribution of sand along the foreshore, or seaward margin, of beaches. Their movement often determines how wide a beach will be, and where sand eroded from beaches by waves will be carried.

River currents, flowing seaward, also have a significant influence on the sand budget of those beaches located near the mouths of major estuaries (for example, Popham Beach, at the mouth of the Kennebec River). These currents may carry sediments eroded from upland areas to coastal geologic environments. Since the volume of sediment transported varies with the current velocity and volume of water, the amount of sediment delivered to the sea is greatest in spring. However, almost all year round rivers bring sediments that help maintain such environments as mud flats, deltas and marshes.

In terms of coastal planning and development, the role of tidal and non-tidal currents supports the following principle: simply put, any environment that depends for its maintenance on a supply of sediments carried by currents may be threatened with slow destruction if the natural flow of these currents is cut off or altered. Shoreline construction is the activity most likely to have this effect. Thus, in planning the placement of piers, breakwaters, seawalls and other shoreline structures, it is always wise to investigate the flow patterns of local currents in order to avoid future erosion problems.

FIGURE 6 Beach Profile-related Terms

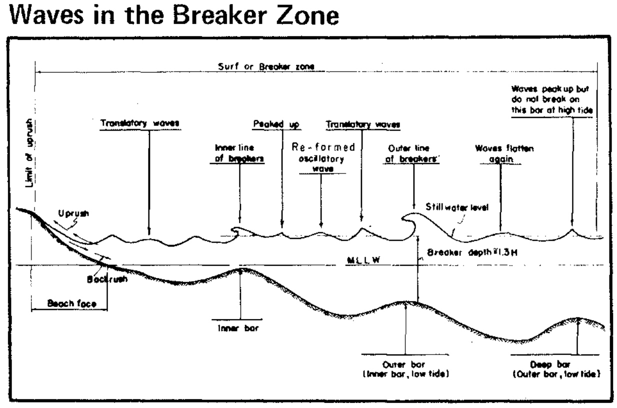


Waves and Winds

The marine process agent that causes the most nearshore erosion and its opposite, deposition, is wave action. And, because waves are primarily generated by the frictional drag of winds, it is appropriate to discuss both of these agents together.

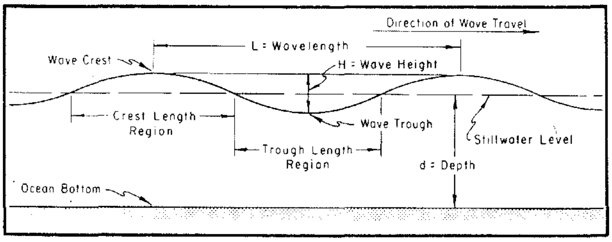
Although wave action is probably best known for its destructive power, waves, like currents, can both build and erode coastal landforms. Studies show, for example, that the stormy conditions of a Maine winter usually result in a net offshore transport of sand from beaches, while the long, low swells prevailing in the summer cause a net landward movement of sand back onto beaches.

FIGURE 7 Schematic Diagram of Waves in the Breaker Zone



Whether waves will build or destroy isn't necessarily related to the time of year. Wave effects are dependent on a complex set of variables including such things as the height and length of the waves, the type of sediments involved, the depth and slope of the ocean floor, and the shape of the shoreline. Another especially important factor is the direction of the wind, which, along Maine's coast, usually comes from one of four general bearings: the south-southeast, the southwest, the northeast, and the northwest.

FIGURE 8 **Wave Terminology**



In Maine, relatively mild south-southeast and southwest winds prevail during the spring, summer and early fall. They are responsible for the formation of low sea waves that tend to carry sediments onshore and are an extremely important factor in the maintenance of beaches. It is under the influence of these winds that the wide seasonal "berms" are built along the seaward margins of Maine's sand beaches.

Northeast winds, on the other hand, are usually associated with heavy storms and are responsible for the most destructive waves affecting the Maine coast. They are generated by the familiar "Nor'easters" which occur primarily in the late fall and winter months. Waves from such storms cause the majority of shoreline erosion problems that occur along our coastline.

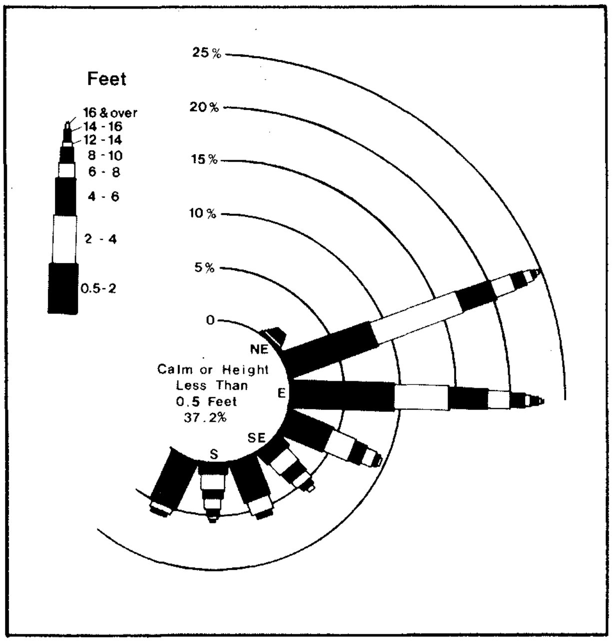
Nor'easters are low pressure systems frequently accompanied by "storm surges"—elevated ocean levels created by a combination of low atmospheric pressure and heavy winds. Northeast storm surges elevate tides an average of one to two feet above the daily predicted height, but during heavy nor'easters surges of four or more feet may occur.

Damage from storm waves and surges is least when a nor'easter strikes the coast during low tides. It is greatest when a storm coincides with high spring tides. If this happens, tide levels may be five or more feet above their normal height, subjecting upland areas to severe wave attack. (This was the case during the record Nor'easter of February 7, 1978, which elevated tide levels up to 5.3 feet above mean high water marks. As most coastal residents remember, that storm caused millions of dollars worth of damage to property and serious shoreline erosion problems along Maine's southern and central coast.)

Overall, the extent of winter erosion along Maine shores, particularly on sand beaches, is roughly proportional to the number of nor'easters that hit the coast that year. Although beaches usually regain sand eroded by storms in a relatively short time as waves and winds return to normal, if two heavy storms pass in rapid succession (less than two weeks), beaches may erode far back into adjacent dunefields.

In the absence of nor'easters, northwest winds usually predominate along our coast in the fall and winter. Under their influence, incoming wave heights are reduced and less able to cause severe erosion. Sand and other sediments tend to move shoreward, and beachfaces are restored. In addition, northwest winds often blow sand from devegetated dunes seaward, onto or across beaches.

FIGURE 9 **Wave Spectrum off Penobscot Bay**



While on the subject of winds and waves, some mention should be made of hurricanes. Though not really common along Maine's coast, they do occur and can have significant effects on shoreline environments.

Hurricanes are heavy storms characterized by their tropical origin and strong counterclockwise wind systems. Waves generated by these winds can cause erosion problems. But because their direction often parallels Maine's coast, they usually lead to much less erosion than storm waves associated with nor'easters.

The greatest danger from hurricanes generally comes, not from waves, but from high winds and "storm surges." The latter effect, resulting from a combination of wind conditions, tide levels and low atmospheric pressure, can pose particularly serious problems for coastal residents. Storm surges created by hurricanes are often two or more feet higher than those generated by the strongest nor'easter and can cause severe coastal flooding.

Fortunately, hurricanes rarely reach Maine, and they are far less frequent than northeast storms. Statistical studies indicate that the average probability of a hurricane hitting our coast annually is less than 5%, while an average of two damaging nor'easters are likely to occur each winter.

Broadly speaking, coastal residents should be aware of two basic planning considerations with respect to winds and waves. On the one hand, because wave and wind action is vital to the maintenance of beaches and certain other marine environments, activities or projects that might interfere with this role should be carefully assessed. This would primarily include development on or near dunes and the construction of shoreline structures. On the other hand, the destructive potential of waves should also be considered in the planning and placement of piers, buildings and any other kind of shoreline development.

One strategy for dealing with the adverse effects of waves is the construction of man-made shoreline protection devices, such as seawalls (discussed in more detail in Chapter 4). In some cases, this can be an effective way of preventing shoreline erosion and property damage. Unfortunately, under certain conditions, seawalls and similar structures can actually make erosion problems worse instead of better, by cutting off the shoreward transport of sediments and intensifying the effects of storm waves on adjacent shore areas. Because of this, and because seawall construction is now subject to State regulations, thorough studies should always be conducted to determine the potential long-range impacts of any shoreline protection device being considered.

A very attractive alternative strategy for dealing with the erosional and destructive power of waves is simply to locate all structures and buildings in the nearshore zone above the area that will be affected by storm waves. Houses, roads and other development situated well behind beaches, marshes, dunes and other nearshore environments are least likely to be in danger during heavy storms, which will continue to impact areas further and further inland as sea level rises. This is a relatively easy, and comparatively inexpensive, tactic to employ. However, since each part of the Maine coast is subject to different conditions, it is best to get expert help in making decisions about just how far away from the shore development should be placed. (See page 74 for more information on this "hazard zoning" strategy.)

Precipitation

Precipitation of all kinds—rain, snow, sleet, hail—has many basic influences on the land. As a process agent affecting geology, it can cause both erosion and deposition. For example, rain and meltwater from snow play important roles in bringing new sediments from upland areas to marine environments. (They also carry along organic nutrients vital to ocean food chains.) On the other hand, heavy rainfall can cause severe erosion when it flows over unvegetated river banks and other sloping terrain lacking in plant cover. In most, but not all, cases, erosion problems develop as a result of human activities that destroy existing vegetation. However, regardless of the cause, severe erosion can also lead to secondary problems resulting from the release of a heavy load of sediments. As these sediments are transported downslope they may cause serious silt pollution of nearby waterways or smother shellfish beds and other valuable marine environments.

Relevant planning considerations can be oriented either to preventing erosion before it occurs or dealing with it afterwards. Severe erosion problems are most likely to develop where soils become denuded of plant life by foot traffic, motor vehicles, development activities (such as bulldozing) or herbicides. They are most easily prevented when the erosional potential of such activities is carefully studied before they take place.

In the case of construction, plans can often be formulated to reduce erosion using various common procedures. But in some instances studies may show that the activity should be sited in a shoreline area less prone to erosion than the one proposed, or even entirely beyond the shoreline area.

In general, solutions to existing erosion problems along the coast are basically the same as those employed inland. Revegetation with an appropriate plant cover, careful management of foot traffic and, if necessary, physical reduction of the degree of slope are the most effective "after the fact" tactics.

It should be noted that not all erosion problems related to precipitation are man-made. High, steep shoreline banks composed of sediments other than bedrock are often prone to steady inland recession. This is due in part to wave action at the toe of the slope, which continually eats away lower bank sediments. At the same time, precipitation weathers away surface sediments at the top and on the face of the bank. These processes can lead to both a steady—or an abrupt—recession of shoreline banks and scarps (depending on the sediment composition). However, though the rate varies from site to site, some recession is almost sure to occur.

In certain cases banks may be stabilized with terracing and vegetation programs. But since shoreline recession is partly an inescapable result of progressive sea level rise, the most basic planning response to this phenomenon is preventative. That is, whenever possible, shoreline development should be placed far enough away from naturally receding embankments to prevent future threats to property or human safety. (See pages 73 for a more thorough discussion of bank recession and related planning considerations.)

Another precipitation-related subject that should be studied by developers and town planners is the hazard of construction on river flood plains. In the spring, rain and snow meltwater swell streams and rivers to levels much higher than common during the rest of the year. Though it may happen only a few times every century, this occasionally leads to severe flooding of the lowlands on either side of a river, a danger to both property and people that might happen to be there. For this reason, any new development in flood-prone areas, as well as the rebuilding of structures damaged by floods, should always be carefully considered. (This is why the federal flood insurance program requires towns to have flood hazard ordinances regulating new construction in flood-prone areas for private property to be eligible for federally-subsidized flood insurance and disaster assistance.)

Ice can also act as a process agent in some coastal environments. Ice plays a minor role, for example, in the transport of intertidal flat and salt marsh sediments when sediments bound up in ice floes are deposited as the floes melt. It can also act as an inhibitor of erosion. This happens when the tiny spaces between sediments are filled with water that then freezes as temperatures drop. The ice "cements" the sediments together, inhibiting erosion on beaches, dunes and some other shoreline environments.

Generally, though, the most important thing coastal residents should keep in mind about ice is its tremendous crushing force. Any piers, wharves or other structures built wholly or partly below the high water mark can be exposed to impacts of 10 to 12 tons per square foot from floating ice, and should be designed accordingly in coastal areas prone to winter icing.

Biological Activity

Just as the physical environment can affect the lives of the plants and animals that live in it, so too can plants and animals affect the physical environment. Probably the best known example of how "biological activity" works as a process agent in terms of coastal geology is the role of vegetation in preventing erosion.

The ability of plant roots to hold unconsolidated soil materials in place is a vital factor in the stability of many geologic environments, and along the coast this function is apparent in environments situated both on uplands and underwater. Salt-tolerant grasses, for example, are crucial to the maintenance of dunefields and salt marshes. Similarly, in some intertidal (between the low and high tide mark) and subtidal (below the low tide mark) environments, aquatic plants play a critical role in preventing drastic erosion by waves and currents.

Interestingly, in dunefields, marshes, vegetated subtidal flats, and certain other shoreline environments, plants not only hold sediments in place, but also facilitate the deposition of new sediments. Their stems and leaves decrease the velocity of winds and waters flowing over them, causing sediments to be deposited—thus, actually building up the plants' own habitat.

Although the role of animal activity as a coastal process agent is not as well known as that of plants, it does affect the deposition and erosion rates of some environments in several ways. Burrowing and bottom-dwelling organisms in sand and mud flats, such as clams, tend to excrete fecal pellets that are bigger than the tiny suspended particulates they ingest while feeding. Because these pellets are relatively large, they are deposited on the bottom rather than being resuspended in the water column. This is one of the best examples of how the biological activities of animals builds and maintains a marine environment.

Certain types of fish and other large organisms that feed on the ocean bottom have the opposite effect. Their feeding habits tend to stir up bottom sediments and cause them to float away in the water. Although this may have the effect of releasing nutrients needed to fuel ocean food chains, it can also accelerate the erosion of fine-grained environments. However, on the whole, biological activity must be considered part of the process that maintains the balance of geological systems.

The geologic function of coastal plants and animals is, of course, only one of the reasons why efforts should be made to minimize adverse effects human activities and projects may have on them. Almost all plant and animal species have some kind of commercial, aesthetic, or ecologic value as well. For coastal residents, many of whose livelihoods depend on fish, shellfish, seaweed and other marine species, the importance of our native flora and fauna is especially apparent. Even so, it cannot be denied that protecting plants and animals from the many threats that exist in the modern world can be difficult.

To prevent devegetation on a sand dune, for instance, a town planner might have to tackle the adverse effects of many different human activities—from the heavy foot traffic of beach goers and direct destruction by development to off road vehicles and the purposeful or accidental spraying of herbicides. To protect the clams, he may have to deal with threats ranging from dredging and upland erosion to overharvesting and pollution by sewage, oil or toxic chemicals.

The companion volume to this handbook, *A Planner's Handbook for Maine's Intertidal Habitats,* is one source of information relating to the planning considerations involved in protecting plants and animals in marine environments. Here, it is possible only to stress that for geologic, economic and ecologic reasons, adverse effects on plant and animal species as a result of human activities and projects should be avoided, or at least minimized, whenever possible.

The Human Factor

Overall, the geological makeup of Maine's coastline has probably affected past and present coastal residents as much or more than those residents have affected coastal geology. Among many other things, it has controlled where people built their homes, how they traveled from one place to another, and how they have made their livings. Unquestionably, the geology of Maine's coast is a basic factor that makes not only our state, but also the people who live here, unique.

But although man's total influence on the shoreline of Maine may be less than the shoreline's influence on Mainers, we have definitely had our effects. Fortunately, they have not been as extensive, on the whole, as those evident in more developed states. Even so, they cannot be discounted or ignored. For better or worse, man has become a kind of process agent. Perhaps not a "natural" one, or a particularly powerful one in comparison to such things as waves or rising sea levels, but one that is just as real.

In many ways, modern coastal residents are still more affected by geology than they affect it. However, as our technology and population has grown, the "geological connection" has increasingly become a two-way affair.

In the beginning, man had very little impact on the geologic conditions along the shoreline. Indian populations were too small to have much effect, and even at its height, early resource utilization during the colonial era by European fur traders and fishermen was minimal, limited to localized areas around scattered trading posts and fishing stations.

When settlers came to Maine in increasing numbers during the 19th century, the human impact on coastal geology began to be more pronounced. As forests were harvested for shipbuilding and agricultural purposes, for example, soil erosion and the movement of sediments from the uplands to marine environments was accelerated. The damming of streams and rivers for industrial power caused further changes in the run-off, sediment transport and coastal depositional processes.

In the present century, industrialization and urbanization, marked by increased resident and seasonal populations, burgeoning construction activity and pollution, have made even more changes in the geology of the shoreline. The coast attracts people, both for its valuable resources and as a place to live. And as almost all coastal residents are aware, solutions to some of the adverse side effects of residential and industrial growth are becoming more and more complex.

Most coastal residents also realize, however, that finding ways to minimize undesirable environmental impacts is extremely important if the resources that made the coast attractive in the first place are to retain their aesthetic and economic value. If the productive potential of the land and ocean are destroyed, if its beauty is marred, we are the ultimate losers. Undoubtedly, to protect this potential and beauty and at the same time meet the growing demands of society is one of the greatest challenges we will face in the coming decades.

The key element in meeting this challenge is knowledge. In order to avoid environmental problems we must understand how the natural world works and how our own activities and projects affect the natural scheme of things. That, of course, is one of the primary purposes of this handbook—to help coastal residents understand how developments may affect the intricate balance among shoreline environments.

Figure 10 is a list of common human activities along with descriptions of how those activities may affect various nearshore geological environments. It should be stressed that these are only *potential* effects. They do not always occur. The list is given not to show what activities are "wrong;" it is given as an aid to planners, developers and others involved in resource utilization and development along the coast of Maine. Hopefully, the information will be useful to them in assessing the possible effects of projects they may be considering. For a more thorough look at how human activities and projects may affect specific coastal environments, readers should refer to the planning considerations described under each of the 55 individual geologic environments discussed in the next chapter. The relative suitability of particular environments for various human activities is summarized in Figure 10.

FIGURE 10 Development Activities – Environmental Suitability Index

ACTIVITIES - ENVIRONMENT SUITABILITY INDEX

X Unsuitable

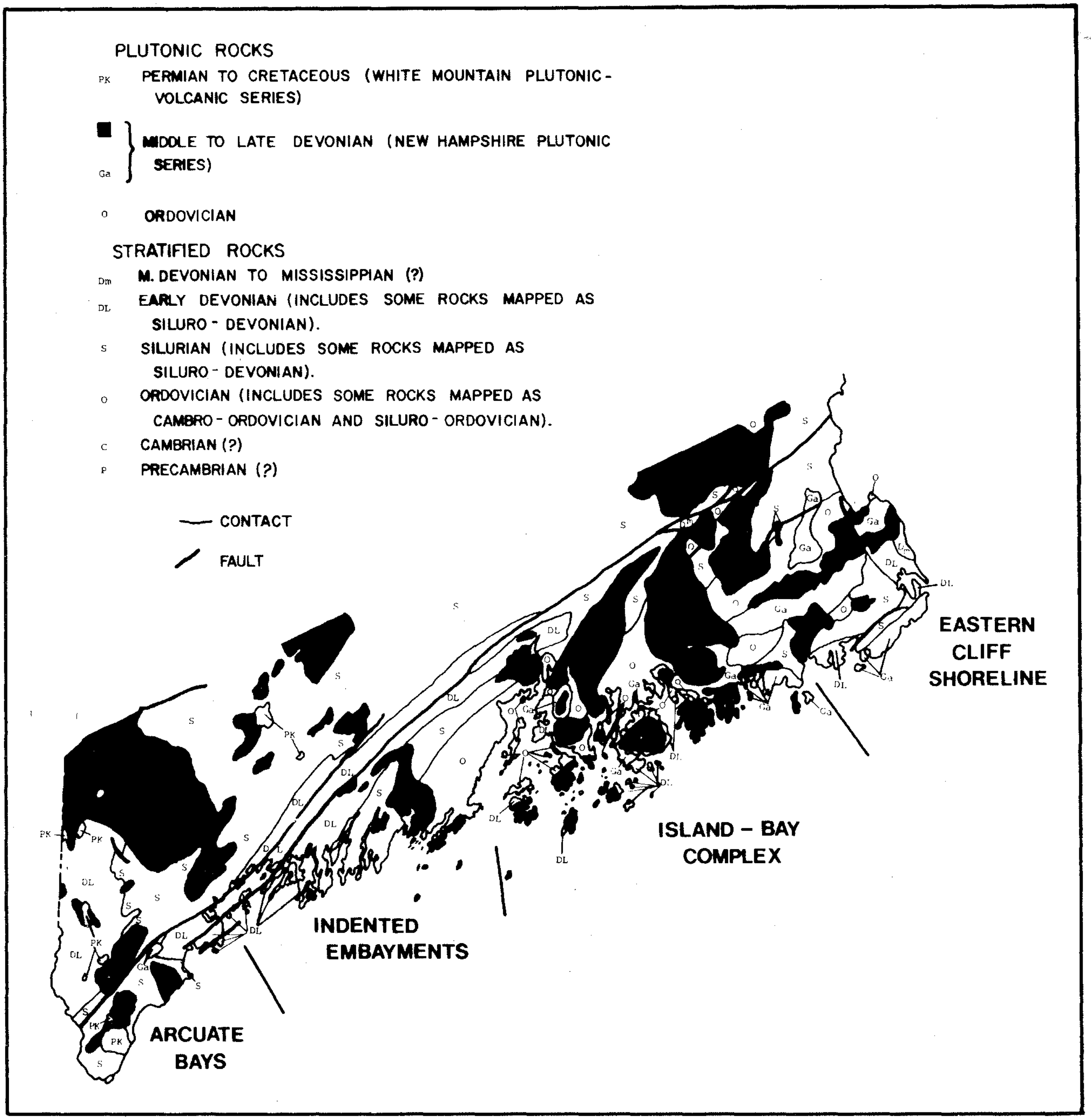
O Suitable only after careful analysis of effects; special engineering and higher costs may result.

S Suitable

COASTAL ZONE ACTIVITIES:

COASTAL MARINE GEOLOGIC ENVIRONMENTS	RECREATION: Recreational Boating	Recreational Swimming	Recreational Fishing & Hunting	Hiking & Walking	Recreational Vehicular Use	NAVIGATION: Commercial Shipping	Channel & Harbor Dredging	COASTAL CONSTRUCTION: Pier, Wharf & Jetty Construction	Roadbuilding	Construction of Storm Barriers	Placement of Pipelines or Subsurface Cables	INLAND CONSTRUCTION: Dam Construction	Light Development	Heavy Development	AGRICULTURE: LAND BASED: Timber Harvesting	Crop Harvesting	WASTE DISPOSAL: Liquid Waste	Solid Waste	Thermal Waste	AQUACULTURE: Impoundment	Clamming & Worming	PEST CONTROL: Wetland Draining	Use of Pesticides, Herbicides & Insecticides	Insect Traps	DEVEGETATION	EXCAVATION	FILLING	COASTAL ZONE OPPORTUNITY ACTIVITIES: Mussel Harvesting	Seaweed Harvesting	Quohog Harvesting
SUPRATIDAL ENVIRONMENTS:																														
Dunes & Vegetated Beach Ridges		X	X	X	X			X	X	X	X	O	X	X	X	X									X	O	O			
Fresh-Brackish Water	O	S	S					O	X		O	O	X	X			X	X	X								X			
Fresh-Brackish Marsh			O	X	X			X	X		X		X	X			X	X	X						X	X	X			
Man-Made Land								S	S	S	S		S	S								X				S	S			
Landslide Excavation & Deposits								X	X	O	X		X	X											X	O	O			
Eolian Flat		X	X	X	X			X	X		X	O	X	X											X	X	X			
Washover Flat			X	X	X				X		X	O	X	X											X	X	X			
Fluvial Tidal Swamp			O					O	O		O		X	X	O	O	X	X	O				O		X	X	X			
INTERTIDAL ENVIRONMENTS:																														
High Salt Marsh		X	O		X			X	X		X		X	X								X	O	O	X	X	X			
Low Salt Marsh			X					X	X		X		X	X				X					O		X	X	X			
Marsh Levee			O	X	X			X	X		X		X	X				O				X	O		X	X	X			
Salt Pannes & Salt Ponds		S							X		X		X	X				X				X	O			X	X			
Sand Beach		S	S	S	O			X	X	X	X	O	X	X												O	O			
Mixed Sand & Gravel Beach		S	S	S	O			X	X	X	X	O	X	X												O	O			
Gravel Beach				S	X			X	X	S	X		X	X												O	O			
Boulder Beach				S				X	X	S	X		X	X												O	O			
Low-Energy Beach		S	S	S	X			O	X	O	X		X	X							S					O	O			
Boulder Ramps								O	X		X		X	X												O	O			
Washover Fan		X	X	X					O		X	O	X	X												O	O			
Spits		S	S	X					X	X	X		X	X												O	O			
Mud Flats								O	X	S	O		O	O	O	O	X	X	X	O	S		O			X	X			
Coarse-Grained Flats			S	O				O	X	S	O			O	O	O	X	X	X		S					X	X	S		
Seaweed-Covered Coarse Flats								O	X		O		O	O			X	X	X							X	X	S	S	
Mussel Bar											X		O	O	O	O	X	X	X				O			X	X	S		
Channel Levee								O	X		O		O	O									O			X	X			
Algal Flats								X	X		O		O	O	O	O	X	X	X	O			O			X	X			
Veneered Ramp								O	S	S	O		O	O			X	X	X				O			X	X			
Ledge			S	S				S	O	S	S		O	O												S	S	S	S	
Fluvial-Estuarine Channel	S		S				X	O	X		O	O	O				O	X	O							O	O			
Point or Lateral Bars		S	S	S	X		X	X	X		X	O	X	X			O	X	X		S		O			O	O			
Vegetated Point or Lateral Bars			S	S	X			O	X		X	O	O	X			O	X	O				O			O	O			
Abandoned Point or Lateral Bars			S	S	S			O	O		O	O	O	X				O					O			S	S			
Swash Bars		X							O		X	O									S					O	O	S		
Flood-Tidal Delta		X	S				X		O		X	O														O	O			
Ebb-Tidal Delta		O	S				X		O		X	O														O	O			
Fan Delta		S	S						O		O	O			O	O										O	O			
Spillover Lobe		X					X		O		X															O	O			
SUBTIDAL ENVIRONMENTS:																														
Mud Flats							O	O			O		O	O			X	X	X	O						X	X			
Coarse-Grained Flats							O	O			O		O	O			X	X	X							X	X			
Eelgrass Flats							X	X			O		O	O			X	X	X	O					X					S
Seaweed Community								O			O							O								X	X		S	
Upper Shoreface							X				O	O		O				X								O	O			S
Lower Shoreface							X				O			O				O								O	O			S
High-Velocity Tidal Channel	S	X	S			O	S	O			O			O			S	O	O	O						O	O			
Medium-Velocity Tidal Channel	S	X	S			S	S	O			O			O			S	O	O	O						O	O			
Low-Velocity Tidal Channel	S	O	S			S	O	O			O			O			O	X	X	O						O	O			
Estuarine Channel	S	X	S			S	O	O			O	O	O	O			O	X	X	O						O	O			
Estuarine Flood Channel	S	X	S				O	O			O	O	O	O			O	X	X	O						O	O			
Estuarine Ebb Channel	S	X	S				O	O			O	O	O	O			O	X	X	O						O	O			
Inlet Channel	S	X	S				X	X			O	O		O			O	O	O							O	O			
Dredged Channel	S	X	S				S	S			O	O		O			O	X	X							O	O			
Channel Slope							S	O			O						O									O	O			
Abandoned Tidal Channel							O		O		O		O	O			X	X	X							O	O			
Tidal Fluvial Channel	S	O	S			S	O	S	O		O	O		O			S	O	O							O	O			
Tidal Creeks	O		O						X		X		O	O	O	O	X	X								O	X			
Marsh Drainage Ditch									X		O						X					X				O	O			

FIGURE 11 Bedrock Control of Shoreline Physiography



COASTAL PHYSIOGRAPHY: THE BIG PICTURE

If you could view the coast of Maine from a point far above the earth—from a satellite, perhaps—you would be able to discern certain broad divisions of the shoreline that geologists call "physiographic subsections." An approximation of this view is provided by your Maine road map. Even a quick glance at it will show you that the Maine coast is not the same along its entire length.

The geographic configuration that you see is a result of two basic factors: the nature and location of bedrock formations, and the past and present effects of the geologic process agents discussed earlier in this chapter.

The cumulative influence of these various elements has created a coastline that can be roughly divided into four large segments. Geologists have given these physiographic subsections names based on their individual characteristics.

They are, going from west to east:
1) The Arcuate Bay Shoreline
2) The Indented Embayments Shoreline
3) The Island-Bay Complex, and
4) The Eastern Cliff Shoreline

Although general physiography is not a primary consideration in all planning decisions, it is the underlying factor in why certain areas have more beaches and others have more rocky shores. Like other geological factors, it is one of the basic influences that both limit and make possible resource utilization or development.

Here, then, in a nutshell, is the "big picture" into which all of the smaller individual segments of Maine's long coastline fit...

The Arcuate Bays Shoreline

The southernmost division of Maine's coast, the Arcuate Bays Shoreline, extends for about 42 miles north-northwest from Kittery to Cape Elizabeth. It includes a series of three bluff headlands separated by two wide, arc-shaped bays widely noted for their fine sand beaches (such as Old Orchard).

The first headland, from Kittery to Ogunquit, and the next, from Kennebunkport to Biddeford Pool, are supported mostly by erosion-resistant types of bedrock. The third headland, at Cape Elizabeth, is underlain by a variety of slow-eroding bedrock types. Along each of these headlands there are a number of small local indentations cut into formations of more easily eroded sedimentary rocks, where isolated sandy or gravelly beach deposits can often be found.

In the two great arcuate bays of this subsection—from Ogunquit to Kennebunkport and from Biddeford Pool to Cape Elizabeth—most of the bedrock surface has been eroded to elevations below present day sea levels and buried beneath beach sands, clay-silts, or glacial till.

The Indented Embayments Shoreline

The Indented Embayments Shoreline extends for about 55 miles east-northeast from Cape Elizabeth to Port Clyde. It is characterized by a continuous series of long, narrow bays, inlets, rivers and estuaries running north and south and separated by numerous bedrock peninsulas and islands extending southward.

The peninsulas, which are commonly 10 to 20 miles long here, closely parallel a layered structure of supporting bedrock chiefly composed of hard crystalline rocks of metamorphic origin. Where sections of these metamorphic rocks are relatively soft, they have been substantially eroded, leaving elongated valleys now flooded by the ocean. Although much of the shoreline in this region is exposed bedrock, there are also a number of small beaches in narrow coves and, at Popham and Reid State Parks, sand beach areas of considerable size.

The Island-Bay Complex Shoreline

The Island-Bay Complex Shoreline section of Maine's coast extends for about 105 miles east-northeast from Port Clyde to Machias Bay. It consists primarily of numerous irregular bays and islands of many sizes. The largest bay is Penobscot Bay, extending for more than 30 miles north-south and up to 20 miles east-west. The largest island is Mt. Desert, with a total area of over 100 square miles.

The scattered distribution of a number of large granite "plutons," or intrusions, is primarily responsible for the hilly physiography of the region. Where such erosion-resistant granite bulges rise high above the surrounding land they form mountains called "monadnocks," the most famous of which in this area is Cadillac Mountain.

The Eastern Cliff Shoreline

Extending for about 23 miles north-easterly from Machias Bay to West Quoddy Head, the Eastern Cliff Shoreline consists primarily of hard volcanic and igneous rocks which rise in cliffs for 30 to 50 meters directly out of the sea. Besides the steep cliffs, this area of shoreline is noted for its relative lack of harbors and inlets. A major northeast-trending fault zone, called the Fundy Fault, passes close offshore. The Fundy Fault is thought to be responsible for the characteristic abruptness of this shoreline.

DEPOSITIONAL SYSTEMS: THE INTERDEPENDENCE OF ENVIRONMENTS

If we look a bit closer at Maine's coastline, focusing on areas smaller than major physiographic subsections but larger than individual geologic environments, we enter a realm many laypeople are unaware of. It's a level at which certain intriguing similarities between geology and the relatively new science of ecology begin to become apparent.

In recent years, the important ecological concept of the interdependence of all living things has come to the attention of the general public through widespread media coverage of various environmental dilemmas. Few people yet realize, however, that most geological environments, or "units," also exist only because of complex interdependent relationships with other units, or that such relationships are especially common along the coast.

Each major coastal feature—a bay, for example—is made up of a group of individual environments (mud flats, beaches, marshes, etc.) linked together by waves, currents, and other process agents. In fact, nearly every coastal environment that consists of mud, sand, gravel or any other "unconsolidated" sediments (as opposed to bedrock) ultimately depends on some other environment for its sediment supply. This interdependence can be traced along the pathways over which process agents carry sediment from one environment to another. These geological networks, marked by the flow of sediments among environments in a nearly equal system of give and take, are termed, "depositional systems."

The depositional systems concept has profound significance to coastal residents, developers and planners. It is both a key to understanding coastal geology and a crucial consideration whenever assessments must be made concerning the potential impacts an activity or project may have on coastal environments. It is the underlying explanation of how and why changes made in one geologic environment can affect other environments in the area. In the next few pages we'll take a closer look at the depositional systems common to Maine's coastline and some of the basic planning considerations relating to them.

FIGURE 12 Depositional Systems Index Map

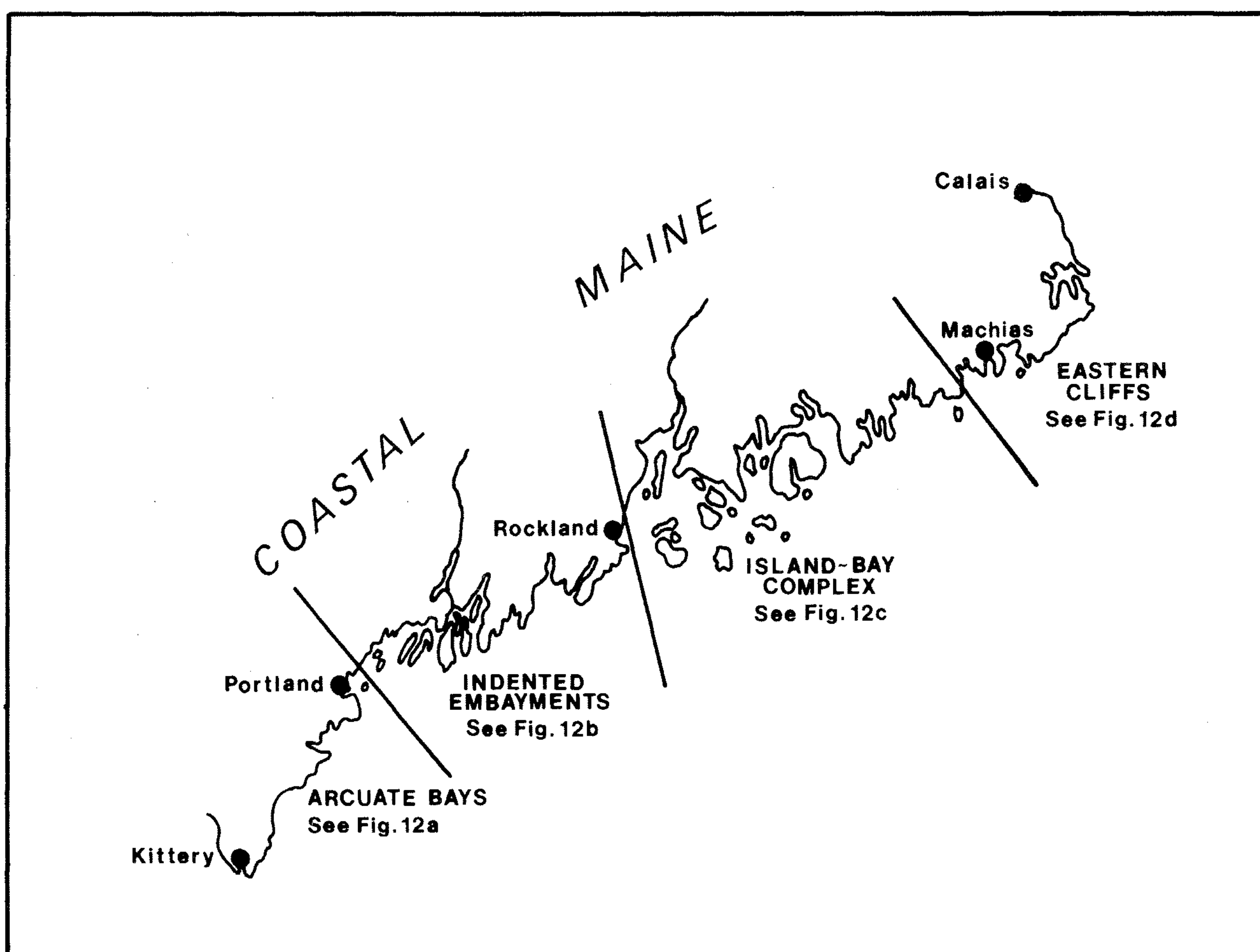
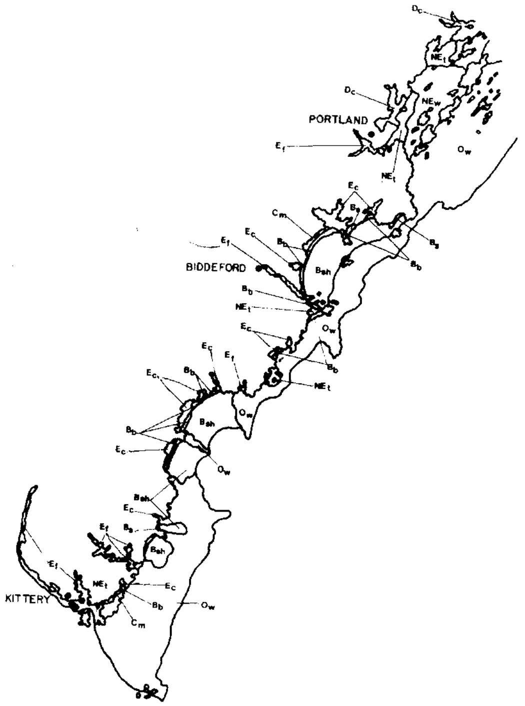


FIGURE 12a The Arcuate Bay Shoreline



LEGEND

BEACH SYSTEMS
- Bb Barrier Beach
- Bs Strand Plain Beach
- Bsh Beach Shoreface

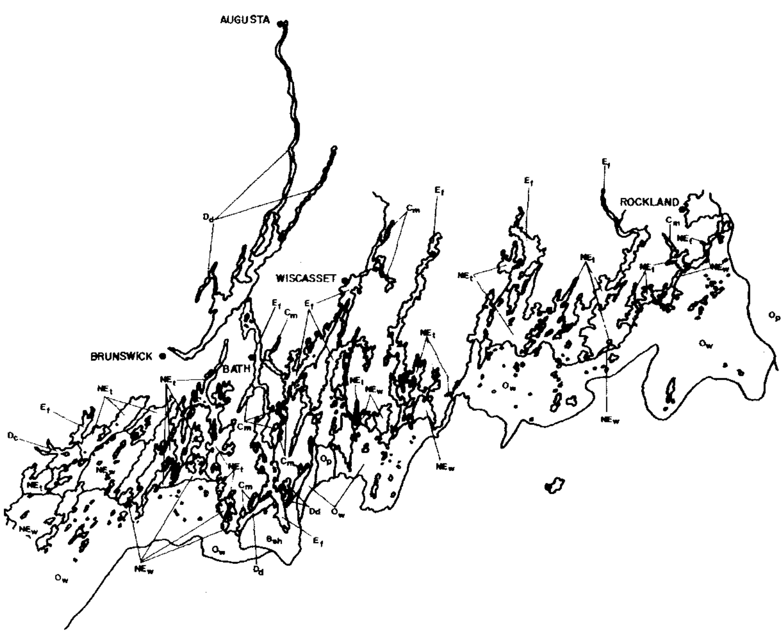
ESTUARINE-NEARSHORE EMBAYMENT SYSTEMS
- Ec Coarse-Grained Estuaries
- Ef Fine-Grained Estuaries
- NEUTRAL EMBAYMENTS:
- NEw Wave-Dominated
- NEt Tide-Dominated

DELTA SYSTEMS
- Dc Constructional
- Dd Destructional
- Df Fan Deltas

OFFSHORE SYSTEMS
- Ow Wave-Shoal Platforms
- Op Platform-Incised Channels

COASTAL MARSH SYSTEMS
- Cm Coastal Marsh

FIGURE 12b The Indented Embayments Shoreline



LEGEND
See Figure 12a

FIGURE 12c The Island-Bay Complex

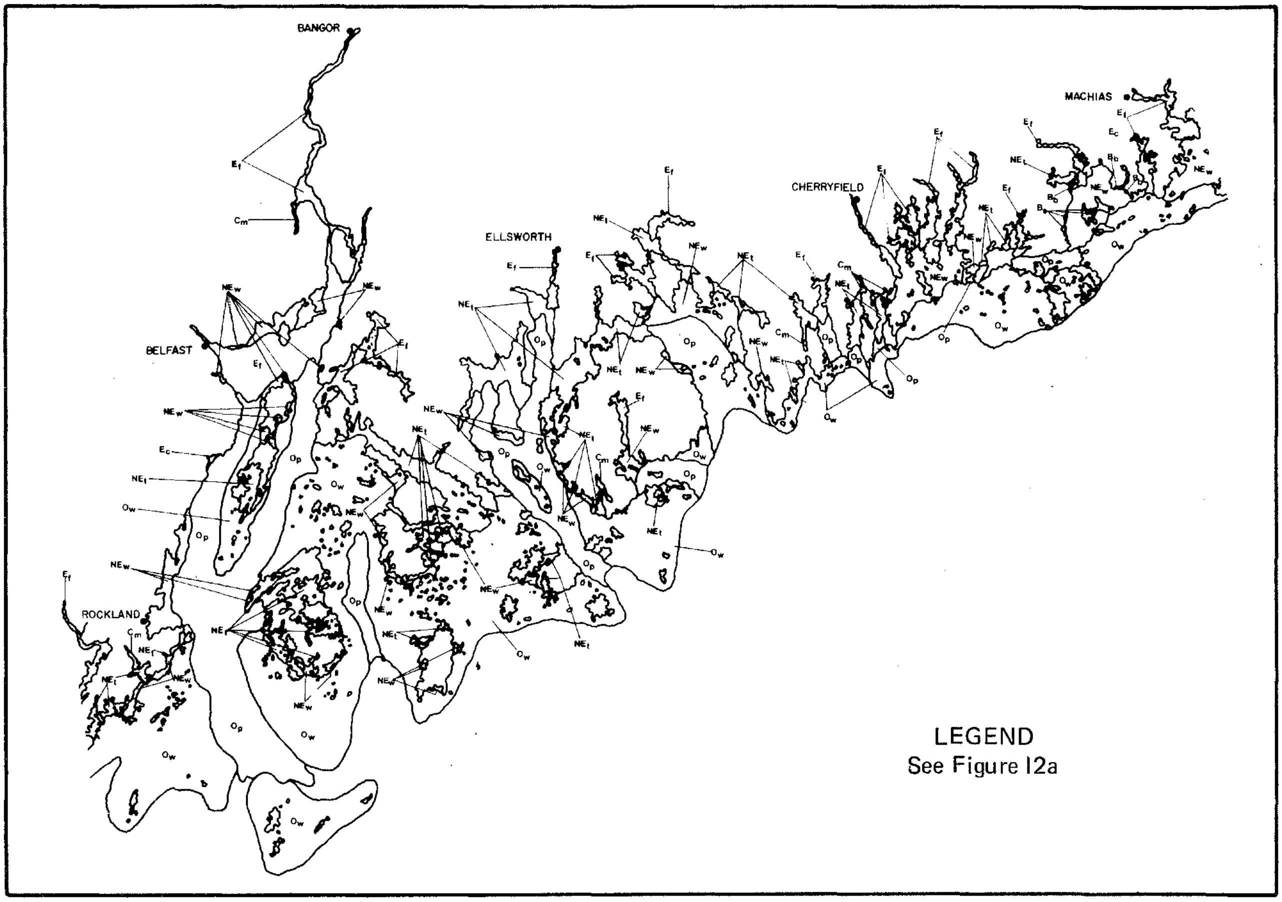
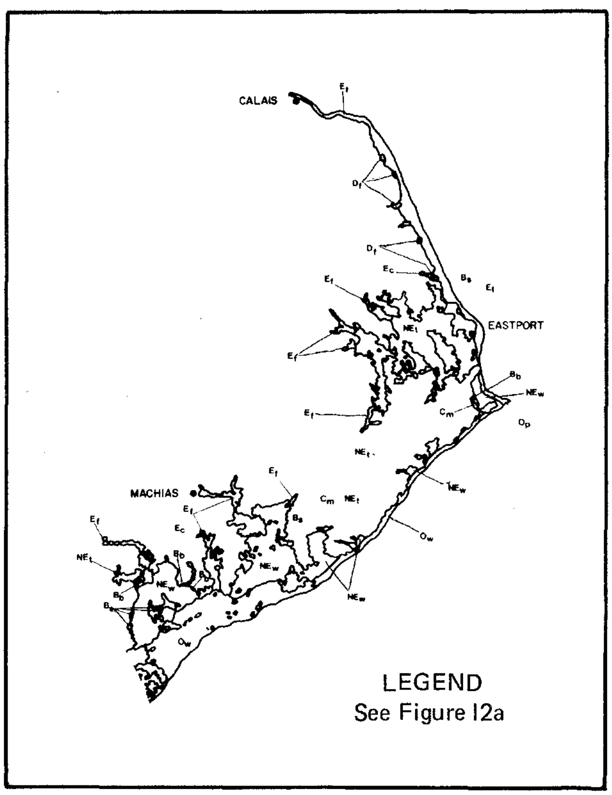


FIGURE 12d The Eastern Cliff Shoreline



The discussion covers the four basic types of depositional systems found along our coast: beach systems, estuarine-nearshore embayment systems, delta systems, and offshore systems. These major categories are further divided into subsystems having their own unique characteristics. Finally, each subsystem can be broken down into groups of the geologic environments that are described in Chapter 3.

Beach Systems

Old Orchard, Popham, Reid—we've all been to a few of Maine's beautiful beaches at one time or another. Yet, very few visitors ever realize how fragile or complex these popular environments are.

In most cases, a beach is part of a larger system of environments characterized by its nearness to the uplands, its dependence on a steady source of sediments, and the importance of waves and winds in its formation and maintenance. Along the Maine coast, two major types of beach systems occur: barrier beaches and strandplain beaches.

Barrier beaches are made up of beaches, dunes (storm ridges, in the case of gravelly beaches), shoreface deposits and other associated features that are completely separated from the upland shore by marshes. Such systems exist where offshore deposits of sand and gravel, now submerged, have provided sufficient sediments for their creation. Less commonly, barrier beaches occur at the mouths of large rivers, where great volumes of sediment have been transported from inland.

All barrier beach systems are maintained primarily by wave and wind (or "eolian") action, the process agents that link together all of the individual environments involved. The low waves and southerly winds of spring, summer and fall transport large quantities of sand and gravel from foreshore deposits onto beaches and dunes. Northwest winds may also carry sand from sand flats behind the beach onto dunefields. Sand thus stockpiled in the frontal dunes and beach area of the system is later removed to the foreshore (subtidal) portions of the beach by winter storms. This process reduces the slope of the beach, causing more of the storm wave energy to be dissipated in the foreshore area rather than on the beach itself. When calmer conditions return, this sand is again gradually transported back onto the beach and frontal dunes, thus completing the cycle.

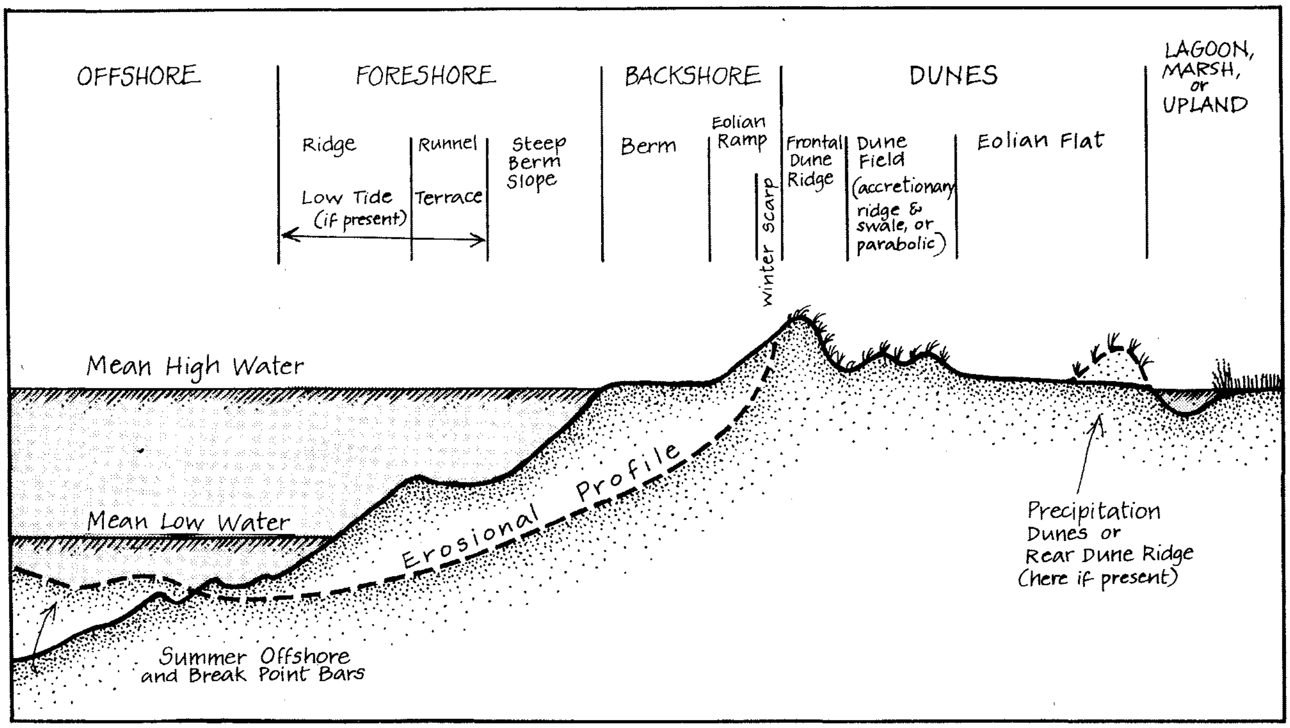
Sand is also transported alongshore by waves. During periods of southerly winds, beach sand is transported in a northeasterly direction. Conversely, nor'easters transport sand in a southerly direction. This bi-directional alongshore movement tends to retain the sand within each beach system (though some sand may be lost by being transported into inlets or along to, and offshore from, headlands where deeper waters occur).

The basic planning consideration relating to the cyclical flow of sediments within barrier beach systems is clear: almost any activity or project that significantly interferes with the normal onshore-offshore transport of a beach system's sediments threatens the continued existence of the entire system.

A classic example is dune devegetation. Thick growths of salt-tolerant grasses and shrubs are crucial to the formation and maintenance of sand dunes. Their stems and leaves slow down and capture wind-transported sand, thus making the dunes higher; their roots hold the sand in place, effectively reducing erosion. When the plant life on dunes is destroyed by heavy foot traffic or construction, the dunes are open to severe erosion by waves and winds. In a short time, this may result in the permanent loss of significant stockpiles of sand needed for the maintenance of the beach systems as a whole, ultimately leading to a sediment-starved, erosion-prone beach.

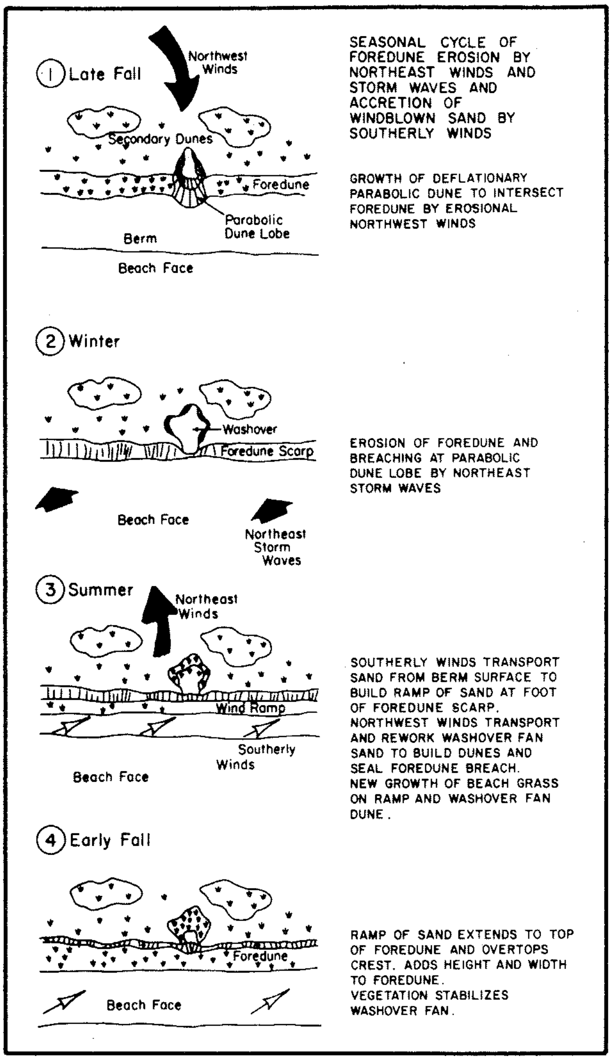
Barrier beach systems may also be threatened if seawalls, revetments or other shoreline structures interfere with the natural cycle of erosion and deposition within the systems. When the

FIGURE 13 Profile View, Beach and Dune Features



seasonal transport of sediments is cut off or altered, severe erosion of beach areas and dunes may result or existing erosion problems may be accelerated. A sediment-starved beach can also result when the flow of sand delivered from inland by a river is restricted by damming, dredging or some other activity.

FIGURE 14
Seasonal Cycle of Foredune Erosion



Another important planning consideration stems from the fact that barrier beaches tend to migrate inland over the years. This slow but steady landward movement is accomplished by washovers during heavy storms and by eolian transport of sand landward over the dune fields. It is usually accompanied by erosion of the frontal beach area and foredunes by storm waves. Thus, as the beach migrates, its width remains fairly constant. (As previously explained, landward migration is a result of the progressive sea level rise occurring along world coastlines.)

The planning response is again clear. Any roads, buildings or other structures built too close to a barrier beach may someday be buried in sand or washed away. This has, in fact, occurred in a number of places, both in Maine and elsewhere along the Atlantic coast. Because the rate of inland movement varies from beach to beach, it is often wise to get expert advice when making decisions about how far away from beach areas development will be allowed. (See Appendix for a list of relevant agencies.)

The basic differences between barrier beaches and *strandplain beaches* is that no marsh or estuary separates the latter from the upland. And, except for the fact that strandplain systems migrate inland at a much slower rate or not at all, general planning considerations are the same.

Estuarine-Nearshore Embayment Systems

Estuarine nearshore embayment systems include two basic types of depositional systems: 1) estuarine embayments, areas of saltwater wetlands and intertidal or subtidal flats where fresh and salt water intermix, and 2) neutral embayments, which though basically similar to estuarine systems in many ways, do not receive substantial volumes of fresh water.

Coarse-grained estuaries are estuarine embayments which develop behind barrier beaches. The major sediment is sand, derived from nearby beach systems or shallow offshore deposits. Among the geological units usually associated with coarse-grained estuaries are salt marshes, estuarine channels, subtidal flats, barrier sand spits, ebb- and flood-tidal deltas, and point or lateral bars. The process agents that most strongly influence this system are tides, rivers, waves and currents.

Flood tides bring sediment from beaches, tidal deltas, or offshore deposits into the estuaries. Ebb tide currents return part of the sediment to the ebb-tidal deltas near the marshes and subsequently back to beaches or offshore deposits. Finer deposits of mud and silt occur in the upper reaches of the estuaries as a result of upland runoff.

A similar type of estuarine embayment system, *fine-grained estuaries,* develop at the mouths of rivers that have moderate to large flows and relatively unprotected mouths at the ocean (such as the Sheepscot River). The basic difference is that major sediments are silt and clay, transported as suspended sediments in the river or brought in by the tide from offshore deposits.

Wave-dominated neutral embayments are shallow, curved bays generally found on the seaward side of estuaries. Here there is little or no fresh water influx and wave action, rather than tidal action, sustains the system.

These embayments are composed primarily of shallow, subtidal environments that receive sediment only from wave erosion of glacial deposits on the shores of islands or the mainland. Fine-grained sediments are usually transported out of the shallow parts of wave-dominated neutral embayments, while coarser sediments tend to remain. The shallowest areas are often exposed at low tide.

Tide-dominated neutral embayments are shallow, very narrow bays in which tidal action is more important than waves in depositional processes. (The exposure to wave action is reduced because of the narrow, sheltered shape of the mouth of such bays.) Tide-dominated embayments receive little or no fresh water discharge. Sedimentation and transport in this system is similar to that in fine-grained estuaries, except that most sediments come from offshore deposits rather than from upland runoff. Tide-dominated embayments characteristically contain a number of different flat environments, estuarine marshes along their landward margins and platform incised channels at their seaward margin.

Many of the geologic environments associated with Maine's estuarine-nearshore embayment systems are extremely valuable, both economically and ecologically. The nutrient-rich saltwater wetland and subtidal or intertidal flat areas, for example, are major feeding, breeding, and "nursery" habitats for our most important fish and shellfish, such as clams, mussels, crabs, striped bass, flounder, alewives and salmon. In fact, most of the commercial fish and shellfish species in the Atlantic are directly dependent on the existence of estuarine embayment systems at some stage of their lives. They also provide crucial habitat to untold thousands of ducks, geese, wading birds and other waterfowl, as well as to a great diversity of game and non-game animals.

Beyond this, the wetland portions of estuarine embayments serve as natural barriers against the erosion of adjacent upland by absorbing the brunt of heavy storm waves. Equally important, marshes help to regulate the flow of runoff from the mainland, storing water and releasing it slowly thus reducing the incidence and severity of coastal flooding. The dense marshland vegetation also acts as a natural water purifier that removes toxic materials from polluted water and traps sediments which might otherwise smother shellfish beds and fill in navigation channels.

Protecting the valuable geologic environments in embayment systems often entails numerous and complex planning considerations. Most of these environments are very sensitive to changes, particularly to any alterations in the volume of water that flows into and out of them. A dam constructed on the river entering an estuary, for example, can prevent sediments from reaching it, leading to a shortage of material needed to replace sediments lost to waves and ebb tides and a lack of nutrients upon which the food chains of the estuary are based. Constructing a breakwater at the mouth of an estuary can cause increased sedimentation in intertidal and subtidal areas, which could cover shellfish beds and block navigation.

Filling for residential or commercial development, ditching, draining, impounding, diking or any other activity that directly destroys an estuarine wetland or interferes with the normal circulation of water in an embayment system can have significant adverse effects on the many commercially valuable species that live, feed or breed there. And even though coastal wetlands can safely soak up a reasonable amount of contaminants, they should be protected from excessive pollution by sewage or toxic chemicals. (Both types of pollutants can also have drastic effects on clam flats and other intertidal or subtidal environments found in embayment systems.)

Mid-Coast and Eastern Coastlines Delta Systems

A number of different kinds of delta systems occur in Maine, each of which has its own particular attributes. *Constructional deltas*, for example, are ever-growing accumulations of sediment found at the mouths of some rivers. Very large constructional deltas, like the one at the mouth of the Mississippi River, don't occur in Maine because our rivers drain much smaller areas and carry much less sediment than the Mississippi. Several smaller examples are found here, however, where rivers carry relatively large amounts of sediment to areas of the shoreline protected from heavy waves. Examples include deltas along the inner portions of Casco Bay and in Merrymeeting Bay. Like other constructional deltas, these are similar to fine-grained estuarine deposits except that the rate of sedimentation is higher.

Destructional deltas are accumulations of sediment at the mouths of rivers that are exposed to relatively high wave and tidal action. As a result, fine sediments are quickly winnowed out of this type of delta leaving mostly coarse-grained sediments such as sand which may be a source of material feeding nearby beaches and river-mouth bars.

Destructional deltas are maintained in a delicate balance depending on levels of sediment supply and the degree of wave and tide energy. Generally, sediments are removed from this system as fast or sometimes faster than new sediments arrive.

A different kind of delta, called a *fan delta*, occurs where a stream delivers sediment to tidal flats in areas where the tidal range (the difference between low and high tide levels) is relatively great. In this delta subsystem, deposition of sediments takes place at the mouths of streams during low tide. Erosion of these sediments then occurs during high tide. The rising tides allow waves to rework delta sediments dumped onto tidal flats, depositing coarse-grained sediments as sandy swash bars and dispersing fine-grained sediments to mud flats at the fan margin.

Because beaches, salt marshes, mud flats and other recreationally or commercially valuable geologic environments are often associated with delta systems, the maintenance or destruction of a delta can have far reaching effects on coastal residents. In terms of planning, one of the most important considerations is that the continued existence of deltas is dependent on the continued delivery of wave-, river- or stream-borne sediments to the delta system. Changes in conditions upriver may cut off crucial supplies of new sediment and threaten the entire system with slow destruction.

Offshore Systems

Offshore systems occur in the outer portions of the nearshore zone and consist of two basic types: wave shoal platform systems and platform incised channels.

Wave shoal platforms are submerged offshore glacial deposits found in water less than 30 meters deep, from which islands may or may not project. The major force acting on this depositional system is intense wave energy, which is continually reworking and transporting the shoal sediments.

Platform incised channels are deeply submerged, low-velocity tidal channels connecting tide-dominated embayments or estuaries to shoreface deposits or subtidal flats. Such channels transport sediments landward and seaward, depending on local conditions.

Both types of offshore systems can be found along Maine's entire coast. Where offshore systems provide habitat, e.g. for lobster or groundfish, location of dredge spoil and other waste disposal is an important planning consideration.

FIGURE 15 Marine Environment Map: Wells, Maine

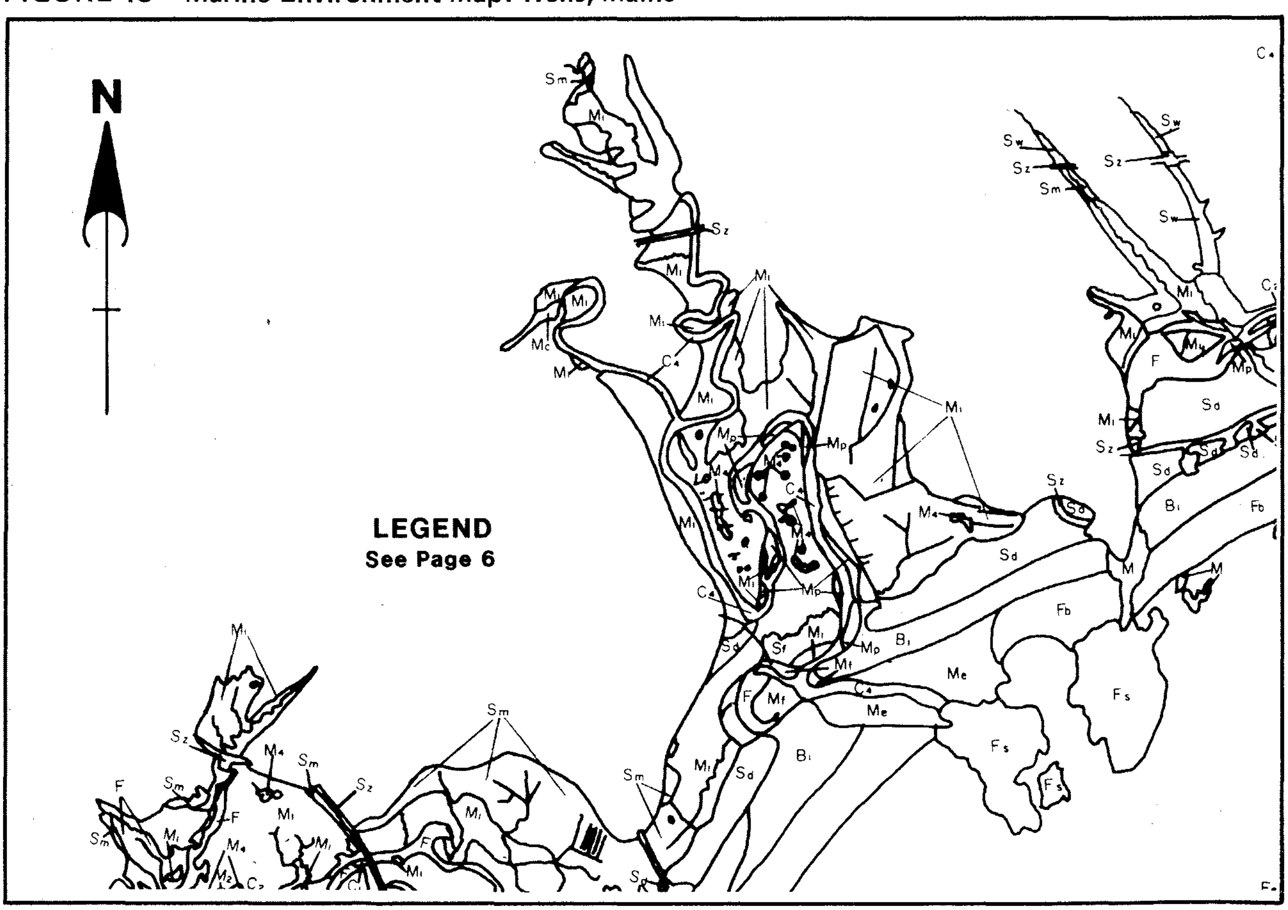


Figure 15. Reproduction of a portion of the coastal marine geologic map of Wells, Maine, illustrating the geologic units associated with the Little River estuary, Drake's Island Beach and Parsons Beach. Figure 16 illustrates schematically the sedimentation processes associated with a barrier beach—coarse-grained estuary system. Large black arrows indicate magnitude and direction of wave transport on flood-tidal delta, ebb-tidal delta, beach, and shoreface. Small black arrows illustrate tidal current transport of sediment; and open arrows indicate wind transport of dessicated sand.

FIGURE 16 Little River: Coarse Grained Estuary Systems

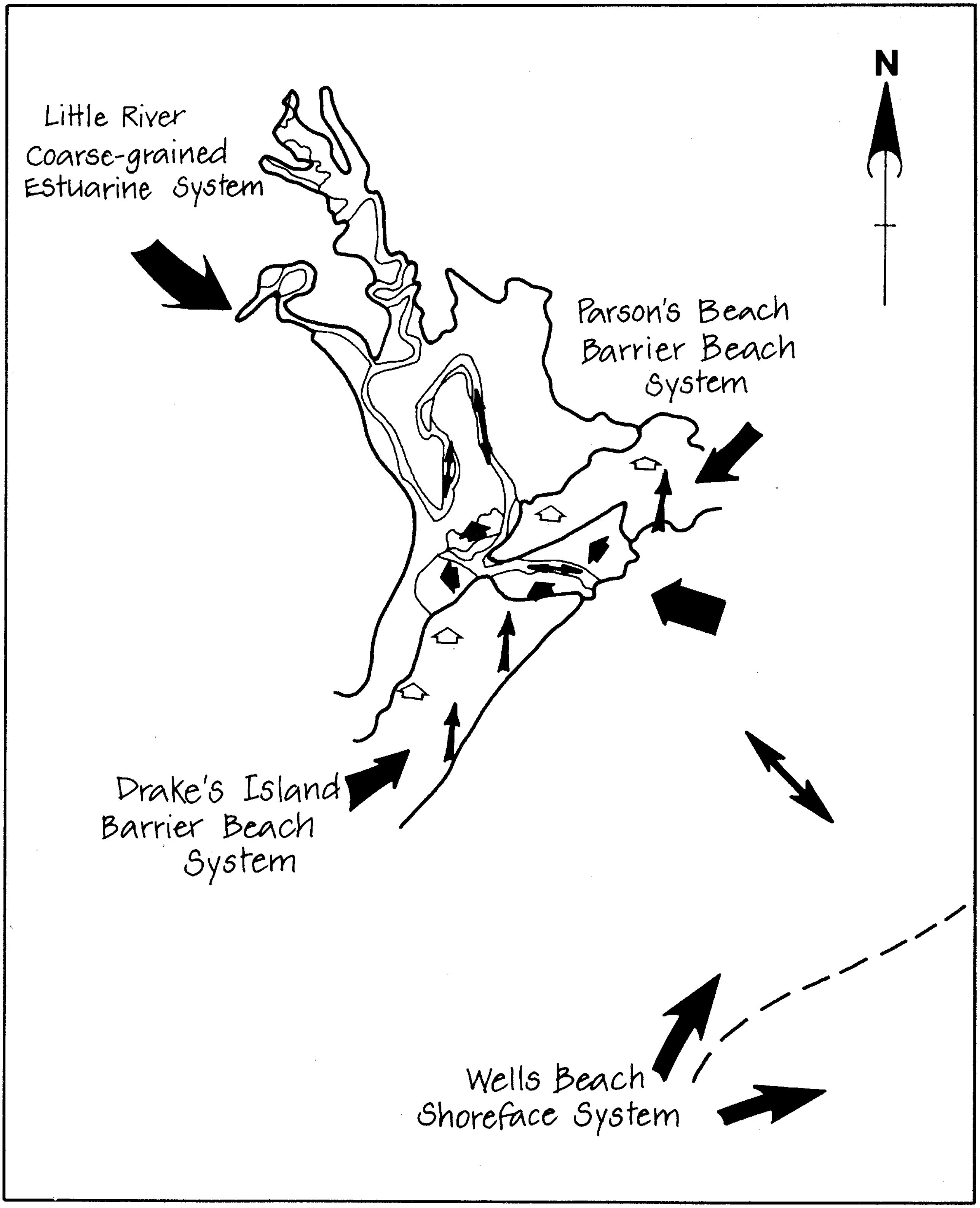
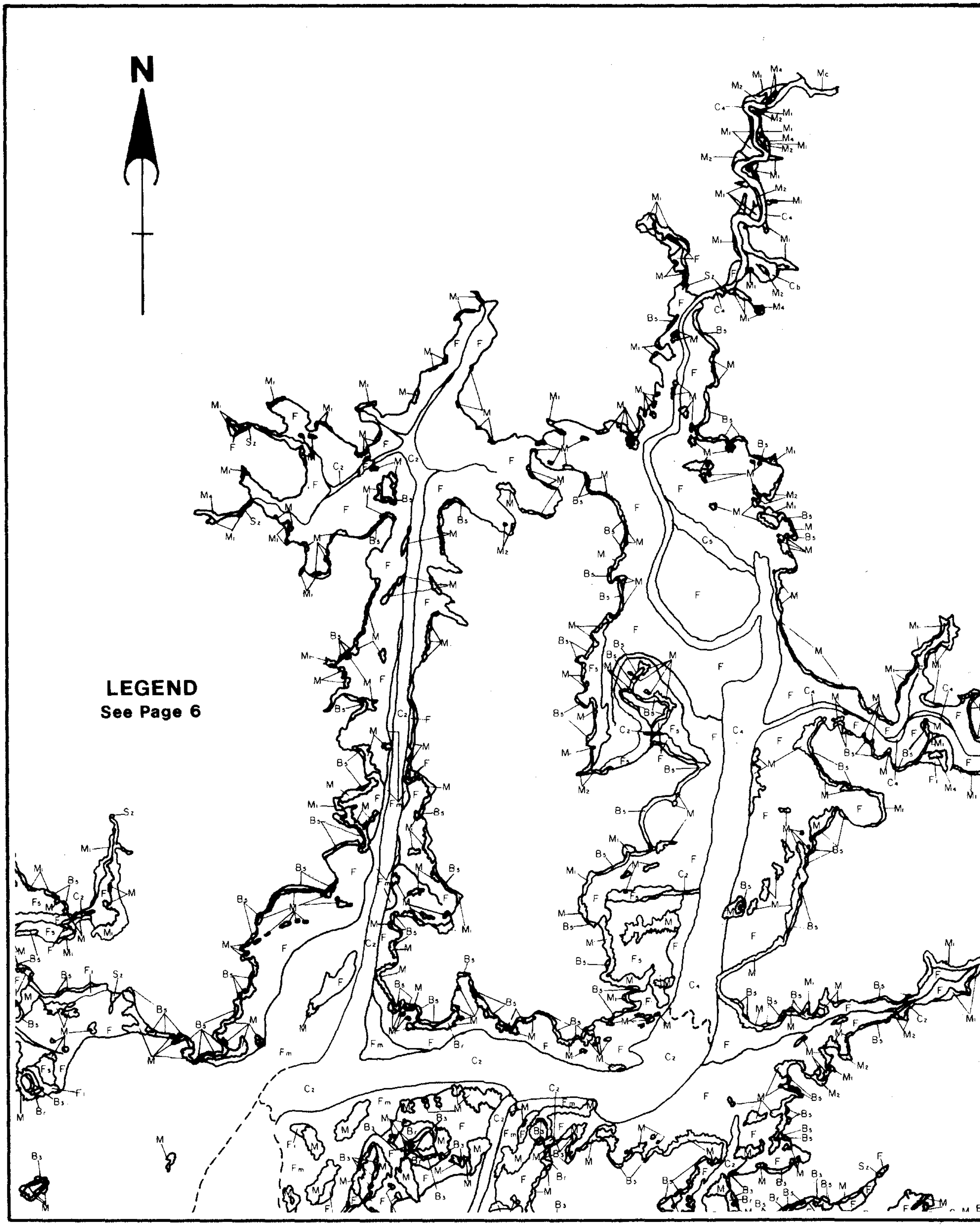


Figure 17. Reproduction of a portion of the coastal marine geologic map of Addison, Me. illustrating the units of the Indian River estuary and the West River embayment.

Figure 18 schematically illustrates depositional conditions and processes. Broad black arrows indicate magnitude and sources of suspended sediment to the systems. Small black arrows indicate estuarine and tidal flow directions. White arrows indicate addition of sediment to the embayments from shoreline erosion.

FIGURE 17 Marine Environment Map: Addison, Maine



White areas are flats of low sedimentation rates; shaded areas — flats of moderate sedimentation rates; vertical-lined areas of high sedimentation and marsh deposition. Slant-lined area is area of estuarine mixing and induced deposition due to estuarine processes. Dotted margin areas are erosional shoreline areas.

FIGURE 18 West River: Wave-dominated Embayment and Indian River Fine-grained Estuary

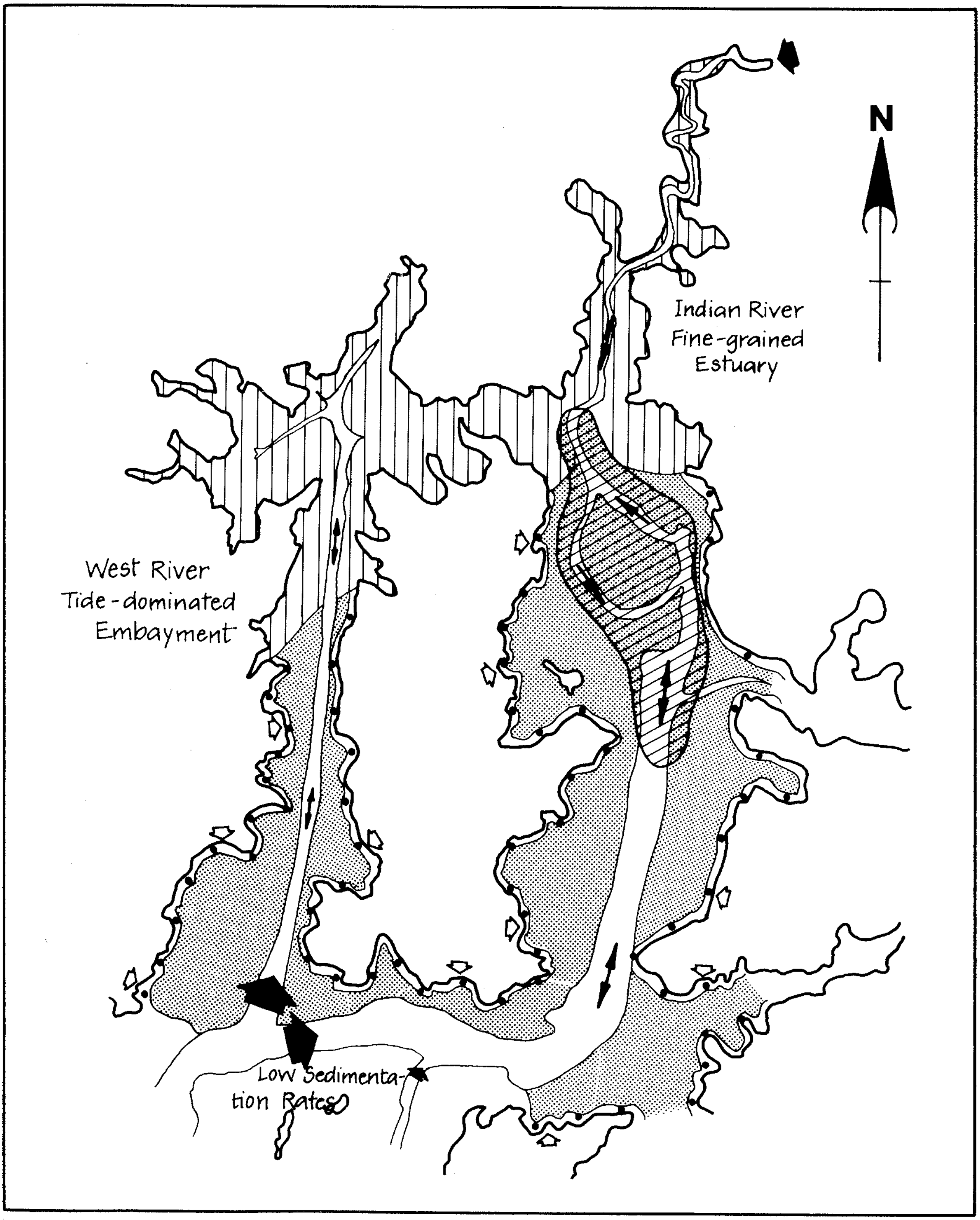
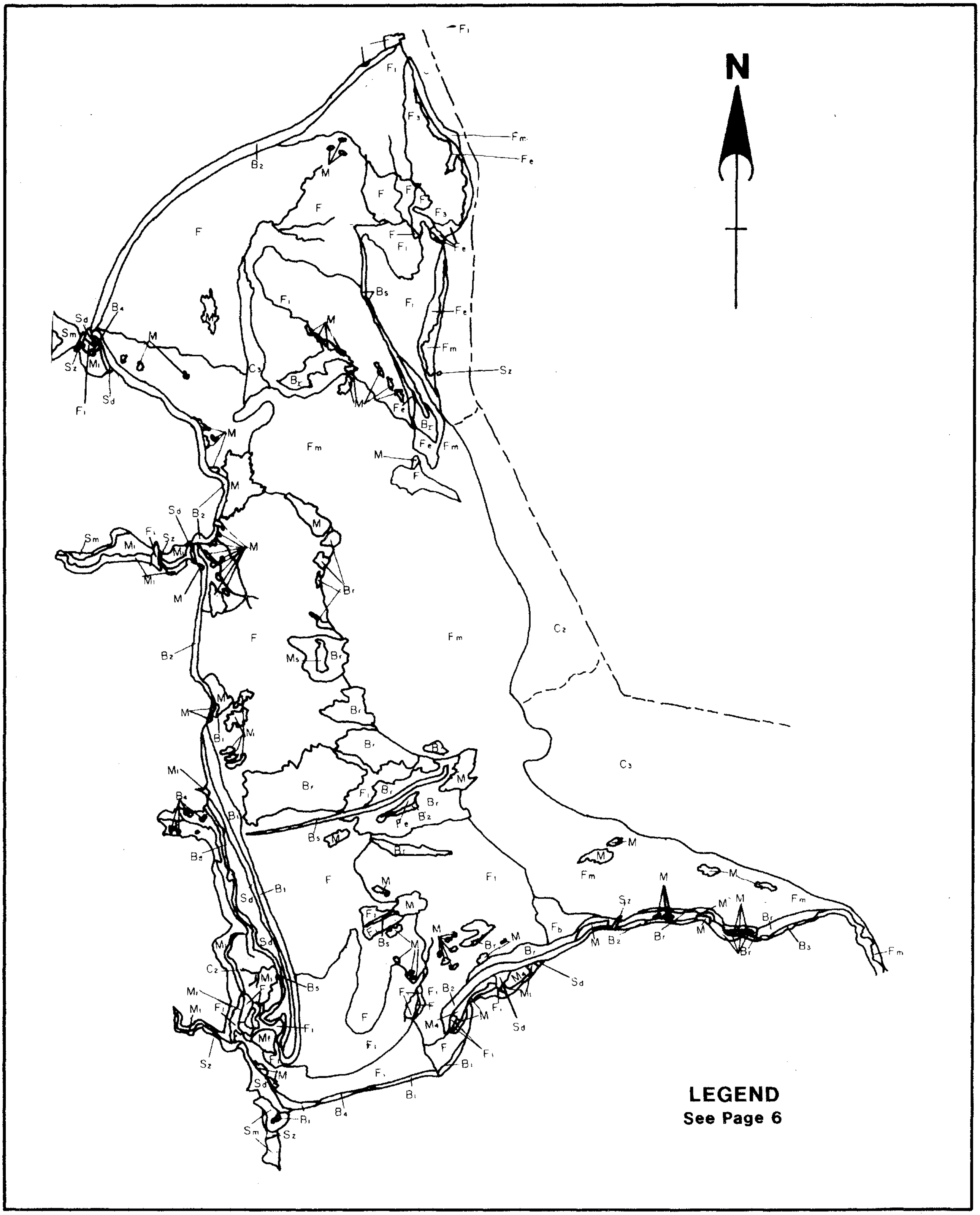


Figure 19. Reproduction of a portion of the coastal marine geologic map of the Lubec, Me. quadrangle illustrating the geologic units of the wave-dominated embayment of South Lubec.

Figure 20 illustrates, schematically, the depositional processes influencing the environments of the bay. Broad black arrows indicate tidal current flow; broad white arrows—magnitude and direction of wave transport. Medium black arrows indicate general sediment dispersal, away from the shoreline;

FIGURE 19 Marine Environment Map: Lubec, Maine



small black arrows along beaches indicate lateral sediment transport by littoral currents. Remaining black arrows indicate tidal transport within the bay.

Shaded areas are accretional barrier beach sub-systems associated with the wave-dominated erosional embayment.

FIGURE 20 So. Lubec: Wave-dominated Embayment

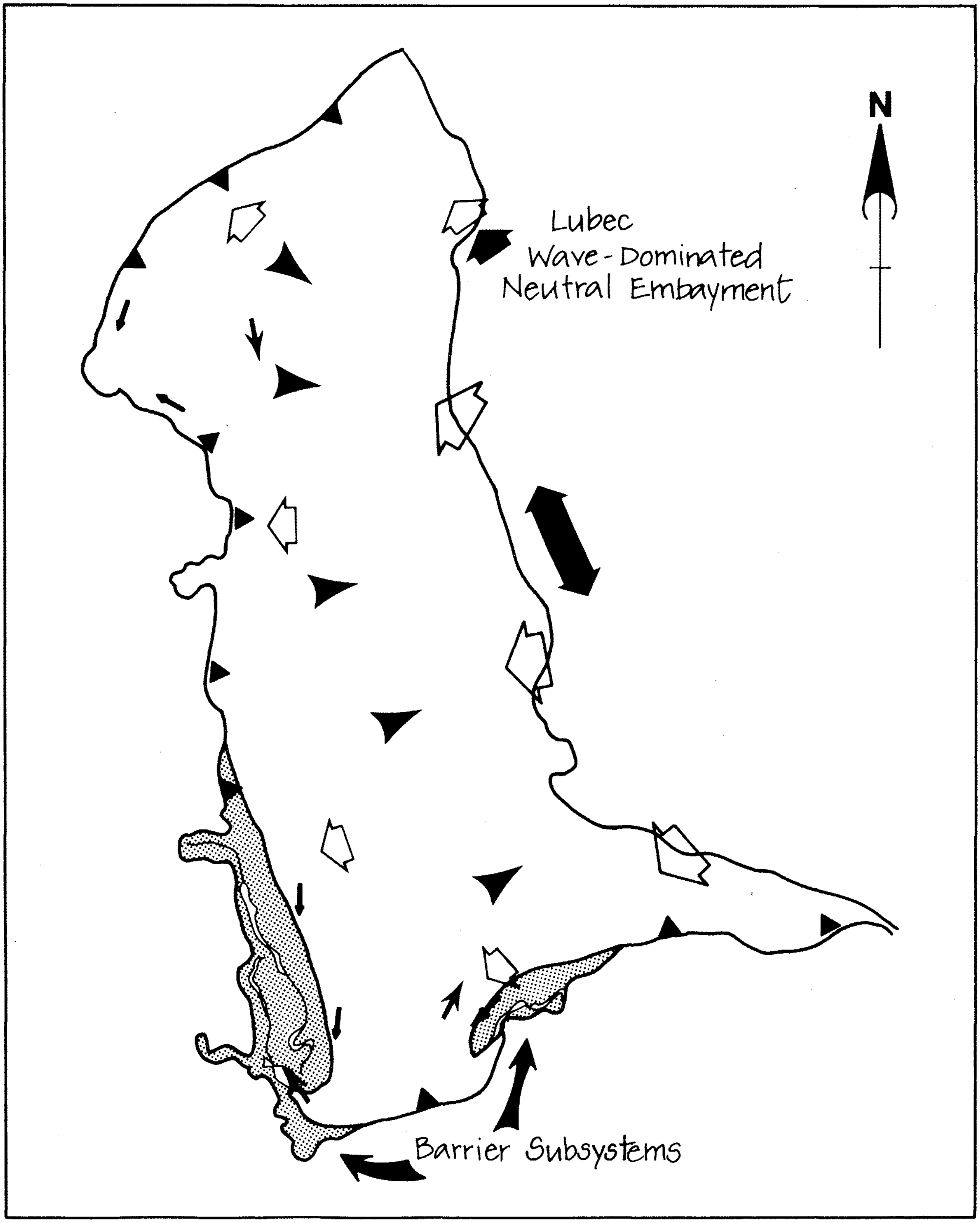
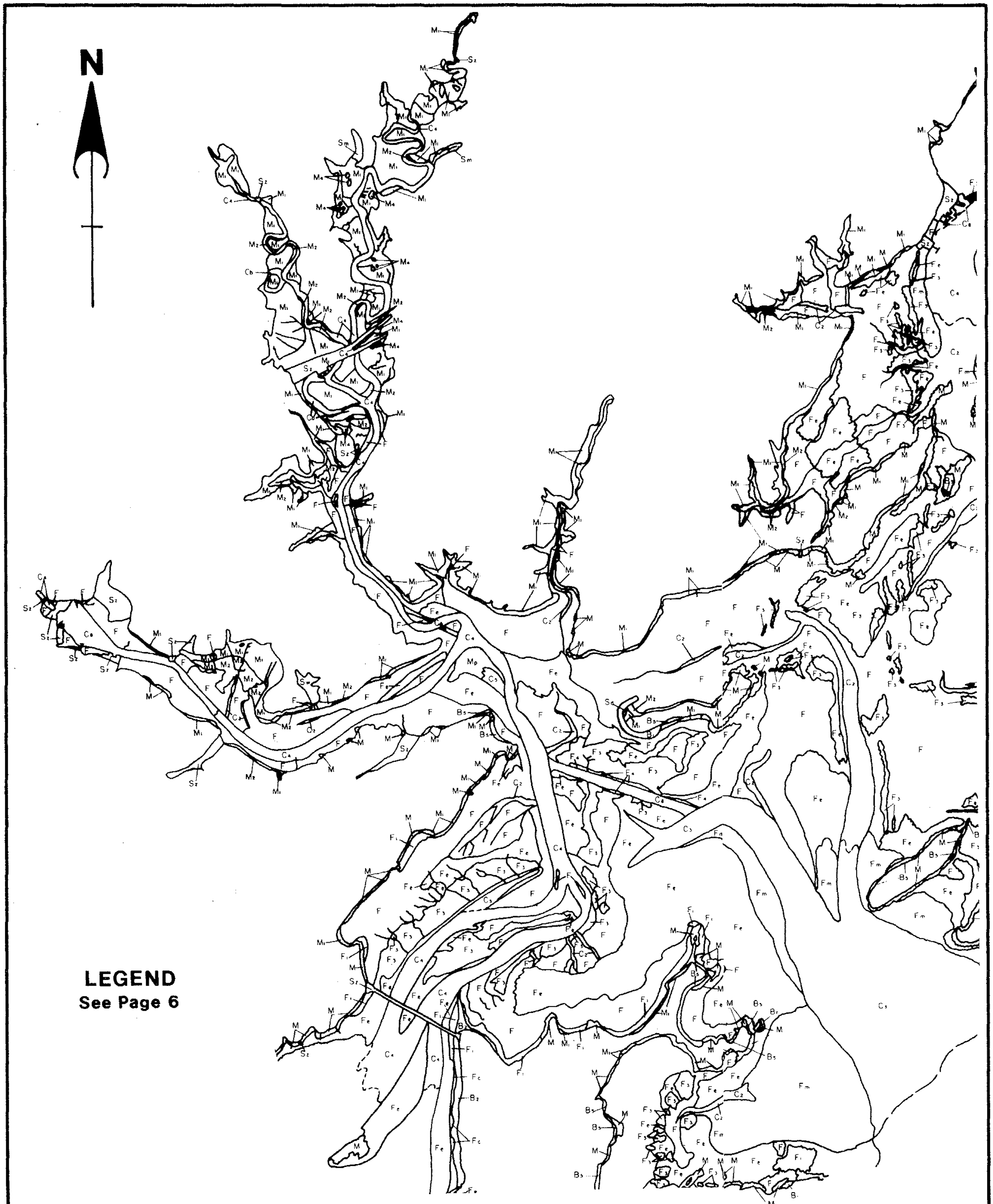


Figure 21. Reproduction of a portion of the coastal marine geologic map of Yarmouth, Me. quadrangle. Figure 22 illustrates the environments of the Royal River constructional delta subsystem at the inner margins of Casco Bay.

Figure 22 illustrates the active processes maintaining the delta. Large, broad black arrow indicates sediment source to the system. Small, broad black arrows indicate suspended sediment dispersal within the basin during spring flooding of the Royal River, while broad white arrows, indicate sediment

FIGURE 21 Marine Environment Map: Yarmouth, Maine



dispersal by flooding tidal currents during normal river flow conditions. Small, narrow black arrows indicate tidal current transport in channels; triangular arrows indicate sediment introduction to the delta system from eroding shorelines.

Shaded areas are constructional portions of the delta plain; slant-lined areas are eroding portions of the delta system. Vertical-lined area is under the influence of processes typical of fine-grained estuaries.

FIGURE 22 **Royal River: Constructional Delta System**

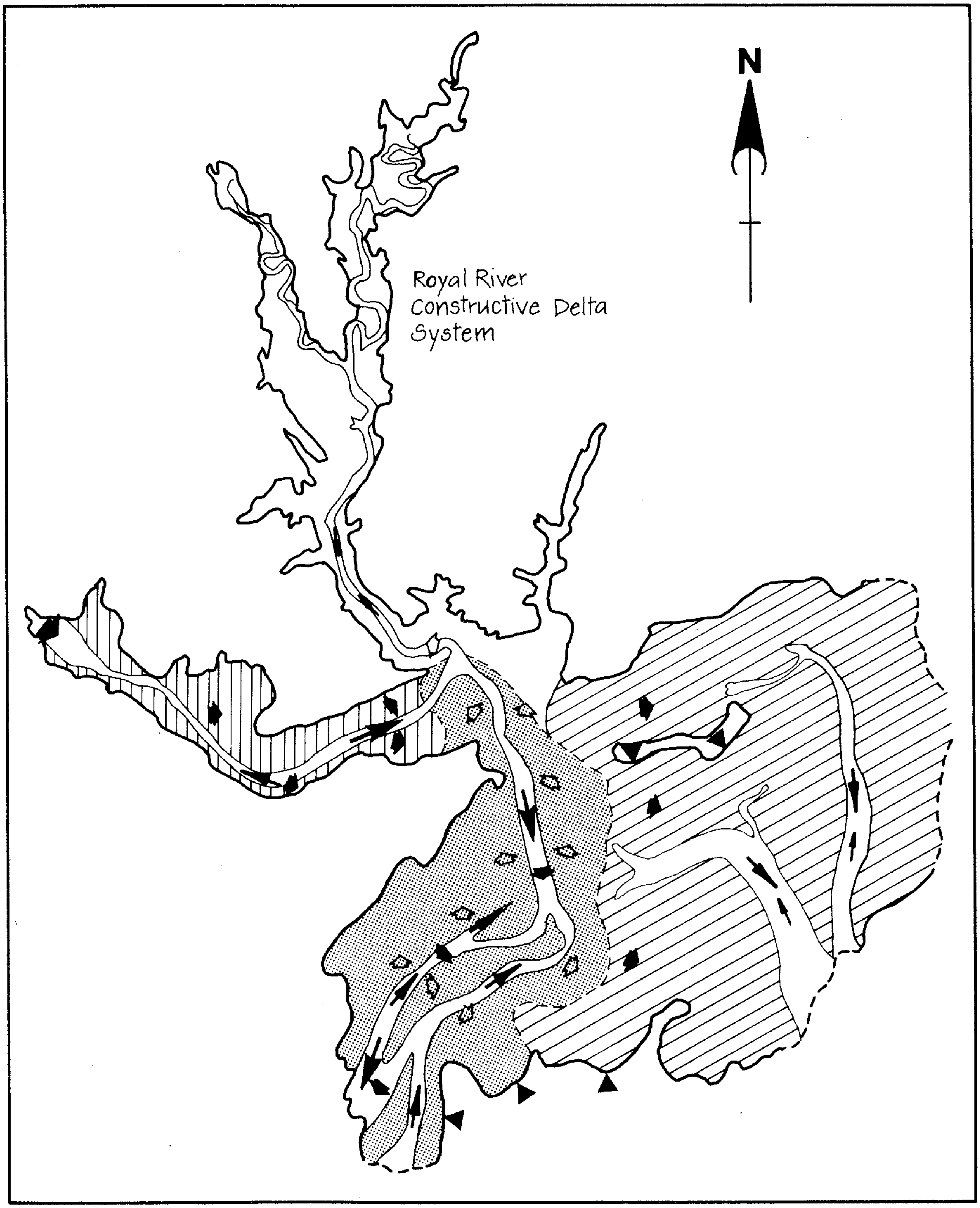
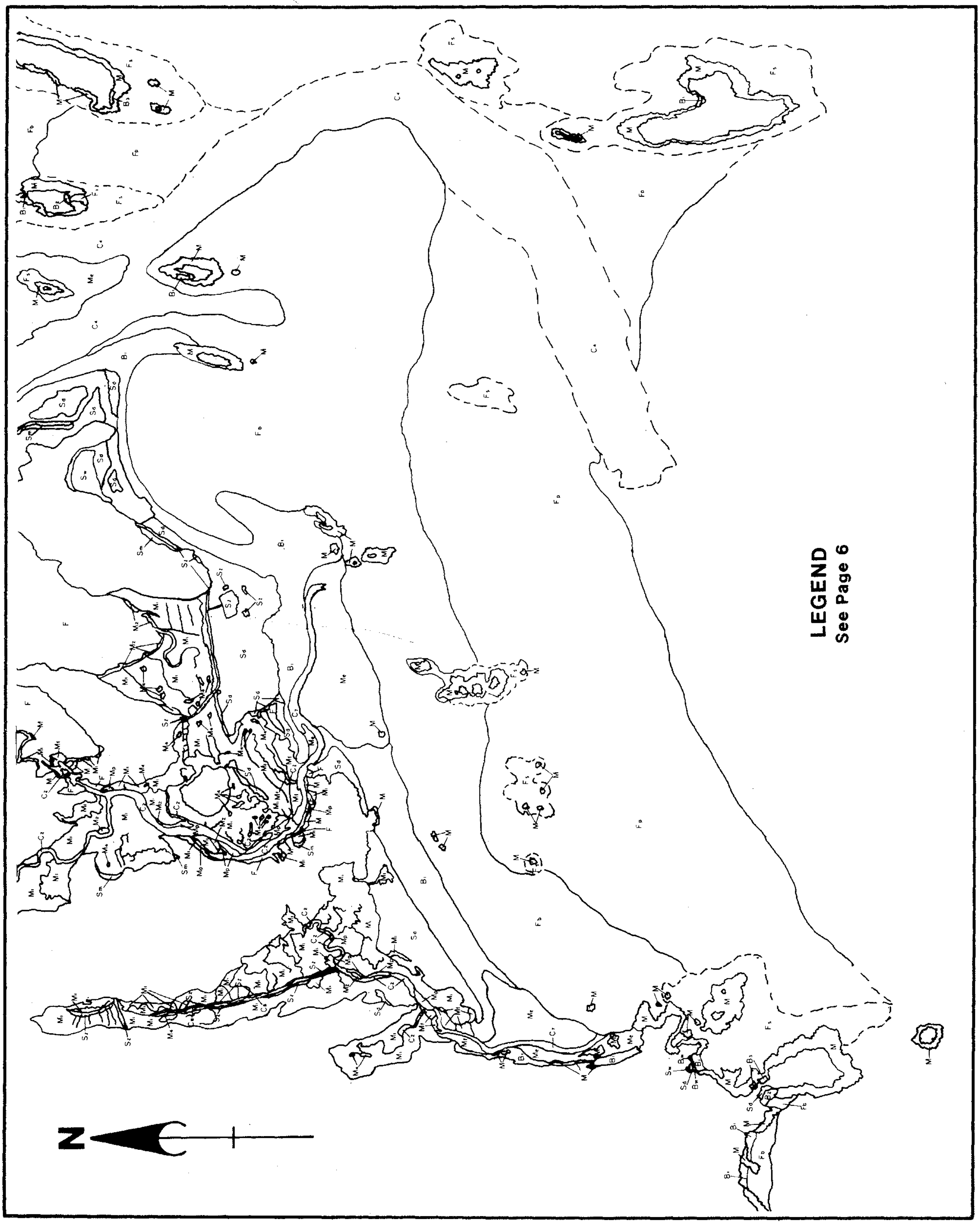


Figure 23. Reproduction of a portion of the Small Point, Me. quadrangle coastal marine geologic map.

Figure 24 illustrates the dominant processes active on the destructional delta system of the Popham Beach area fed by the Kennebec-Androscoggin Rivers systems. Broad black arrows indicate coarse

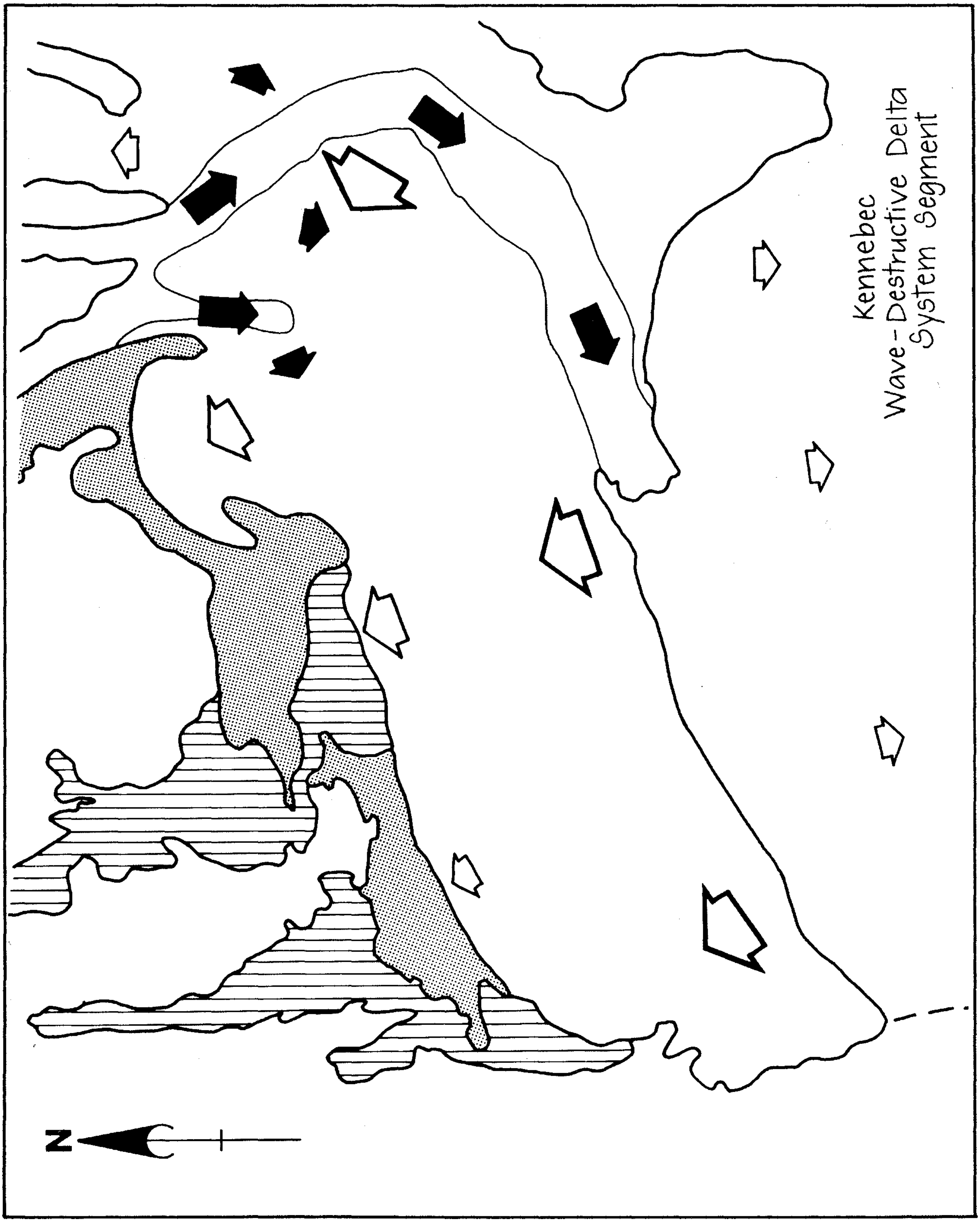
FIGURE 23 Marine Environment Map: Small Point, Maine



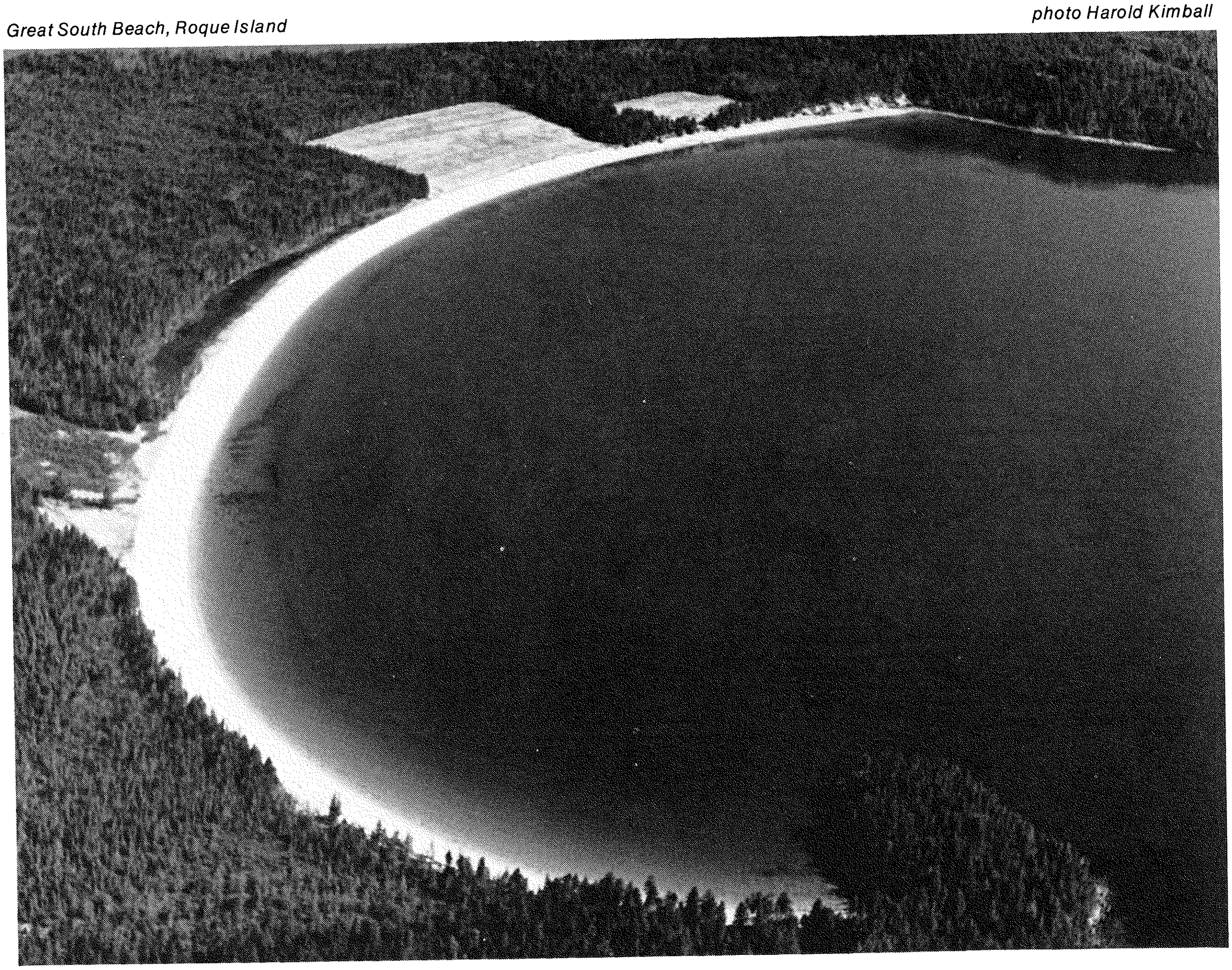
sediment dispersal during spring floods; large white arrows indicate reworking of sediment by wave processes.

Shaded areas are barrier beach systems; vertical-lined areas are associated coarse-grained estuarine systems.

FIGURE 24 Popham Beach Destructional Delta System



Great South Beach, Roque Island *photo Harold Kimball*



CHAPTER 3: THE BUILDING BLOCKS OF MAINE'S COAST

If you were to walk along the coast of Maine from one end to the other, you would travel considerably farther than "the crow flies." Though the distance isn't much more than 200 miles in a straight line, there are well over 4000 miles of shoreline between Kittery and Calais.

This shoreline—the longest of any state bordering the Atlantic—is made up of literally thousands of individual geologic environments, or "units." It is a great patchwork quilt of beaches, mud flats, bedrock ledges, marshes, and many other types of landforms. One system of classification currently in use distinguishes 55 different kinds of coastal environments found along Maine's shores, each characterized by a unique set of attributes.

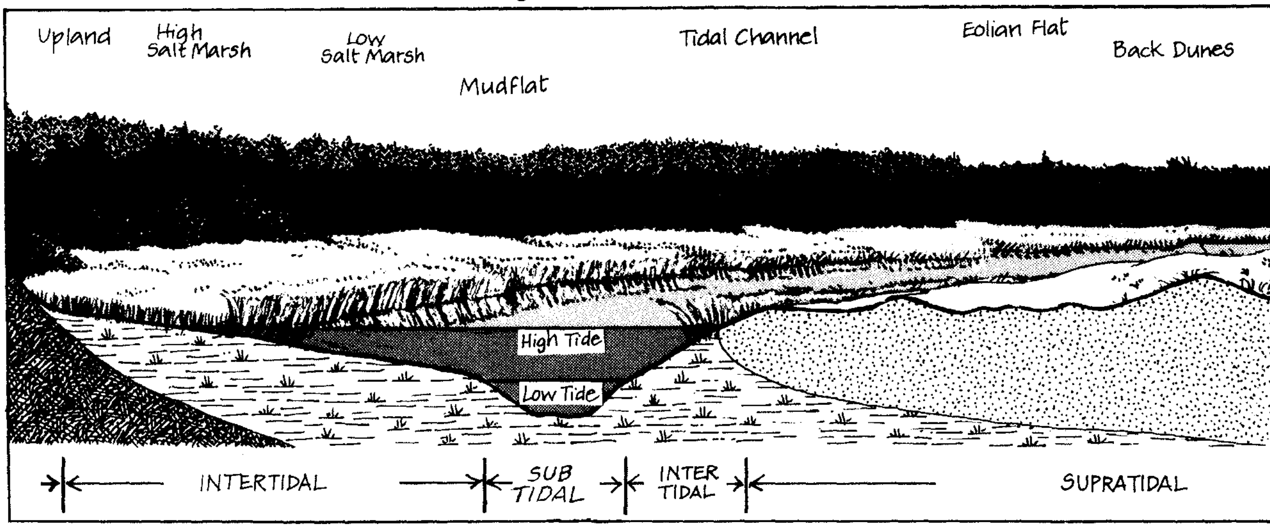
These environments are the subject of this chapter. They are also, as explained in Chapter 1, the basis for the Coastal Program's Marine Geologic Environments Maps. Thus, the information given here is particularly relevant to the substance and use of those maps. It is a basic introduction to each of the 55 units and the geology-related planning considerations pertaining to them.

For this discussion the environments have been sorted into three groups: supratidal environments (those located above the mean high water mark); intertidal environments (those located between the average low and high tide marks), and; subtidal environments (those situated below the mean low tide mark). Readers should realize, however, that in a depositional system, combinations of environments from each of these groups may occur.

It should also be noted that the planning considerations discussed deal primarily with the relationships between people and the *geological* aspects of an environment. For more complete information on how human activities and projects affect marine plants and animals readers are urged, once again, to consult the Coastal Program handbook entitled *A Planner's Handbook for Maine's Intertidal Habitats.*

Finally, a word about the color codes mentioned as part of the description of each environment. The Marine Environments maps are not, themselves, color coded. Geologic units are indicated only by borderlines and letter codes. However, if a planner or developer wants a more graphic delineation of coastal environments for purposes of study, to help in creating zoning maps, for meetings or some other reason, the environments can be hand-colored with "Prismacolor" marking pencils. The appropriate colors are specified so that maps colored by one user can be coordinated with those used by others.

FIGURE 25 Overview of Coastal Geologic Units



SUPRATIDAL ENVIRONMENTS

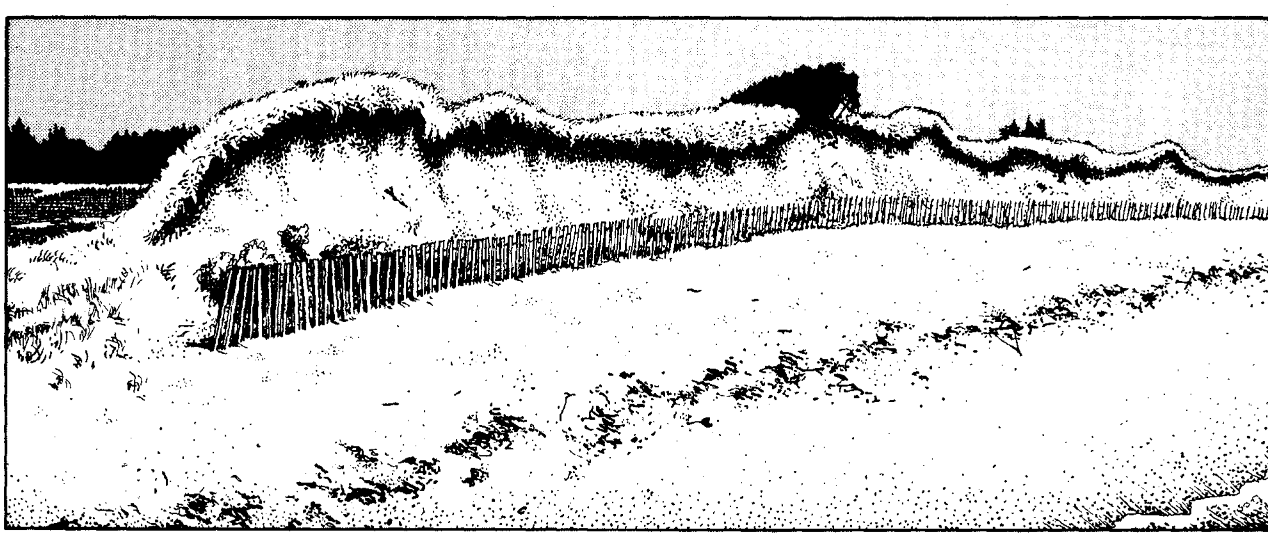
Dunes and Vegetated Beach Ridges

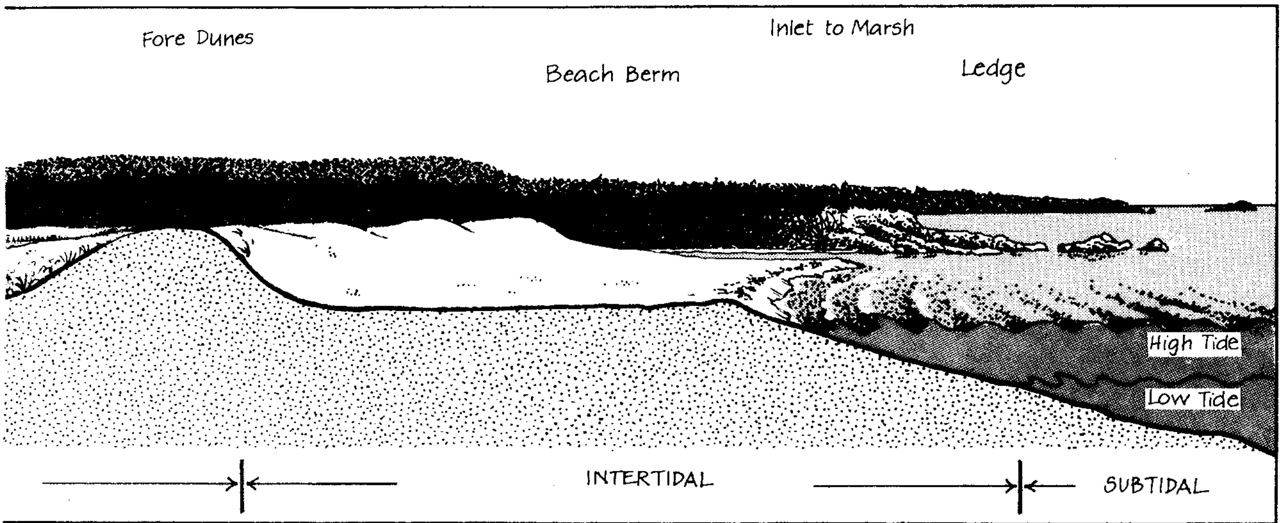
Map Legend — Sd
Color — True Green
Percentage of Total Coast Area Mapped—1.00%

Characteristics: Dunes are vegetated, or in some cases devegetated, mounds of sand or sand and gravel that border the landward margin of sandy beaches. Though they sometimes lack plant life, dunes usually develop and continue to exist only where salt spray-tolerant plants—particularly beach grass—grow thickly enough to act as a "sand trap." The stems and leaves of dune plants slow down and capture windblown beach sand; their interwoven root systems hold the sand in place and resist wind and wave erosion. Where long, continuous lines of dunes form, they are called "vegetated beach ridges." A very rare landform in Maine, the best examples are found at Popham Beach in Phippsburg.

Importance: Dunes play a crucial role in the maintenance of barrier or strandplain beach systems by serving as a major "stockpile" that replenishes the sand beaches lose through storm wave action. They are, in addition, important natural buffers against erosion of adjacent uplands. During a storm, the destructive energy of heavy waves is expended on the dune fields, effectively shielding the land of the upper shore (and any man-made structures located there) from damage. Dunes also provide habitat for a wide variety of plant and animal species. Dune plants include beach grass, Virginia rose, beach plum, bayberry, seaside goldenrod, beach heather, pitch pine and red oak. Among the animals that live or feed among dune fields are the least tern, piping plover, killdeer, sanderling, herring gull, chipmunk, red squirrel, and white-tailed deer. Because some of the species associated with dunes live or breed in no other geologic environment (e.g. the locally rare least tern), and be-

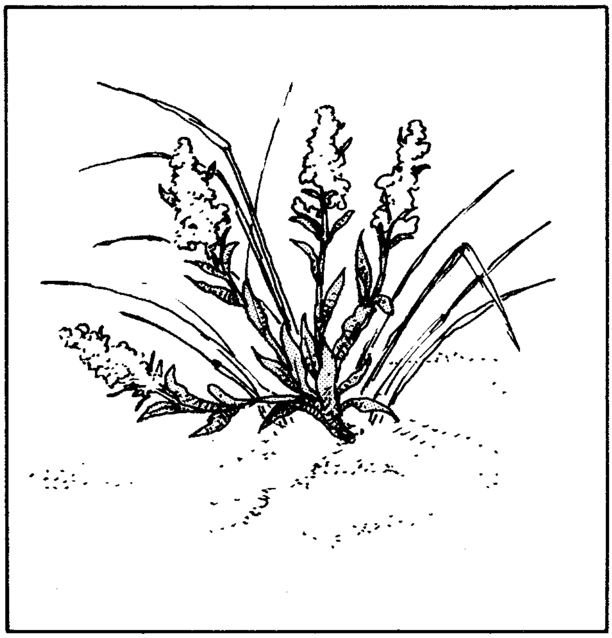
FIGURE 26 Unhealed Frontal Dune Scarp





cause dune fields are relatively uncommon in Maine, this unit is considered to be a very important type of wildlife habitat in our state.

FIGURE 27 Seaside Goldenrod and American Beach Grass



Planning Considerations: Aside from their relative rarity, their beauty, and their function as a wildlife habitat, the role of dunes in maintaining valuable beach areas and in preventing upland storm damage lends considerable weight to arguments for their protection or, when damaged, restoration. Direct destruction for purposes of residential or commercial development has long been one major threat to this goal which should be avoided when possible. Construction of seawalls built to protect beachside structures is another. Scientists have recently determined that seawalls and other man-made shoreline protection structures tend to accelerate rather than slow down beachfront erosion by 1) cutting off supplies of sand that would naturally flow in to rebuild and maintain dune fields from beaches; 2) preventing sand stored in dunes from replacing sand lost to beaches during storms, and; 3) interfering with the influx of new sand to beaches and dunes from offshore deposits. By requiring that all new structures and roads be built well behind dune fields (the exact distance depends on the particular beach system in question), both direct destruction and the need for man-made shoreline protection structures can be avoided. The fact that many beach systems may tend to migrate inland over time provides further reason for keeping buildings and other "improvements" relatively far away from dunes.

FIGURE 28 Beach Pea

Fresh to Brackish Water
Map Legend — Sw
Color — Yellow Ochre
Percentage of Total Coast Area Mapped—2.00%

Characteristics: By definition, this unit includes areas of standing water with a salinity of less than 5 parts per thousand (sea water offshore has a salinity of about 35 ppt). This type of water usually occurs where beach ridges form natural "dams," at the heads of marsh tracts, and behind man-made barriers which have restricted tidal flow.

Importance: Fresh to brackish water bodies temporarily store runoff flood water, thus reducing the effects of flooding on surrounding environments. They are also important habitats in the life cycle of many waterfowl and anadromous fish (e.g. salmon, alewives and shad).

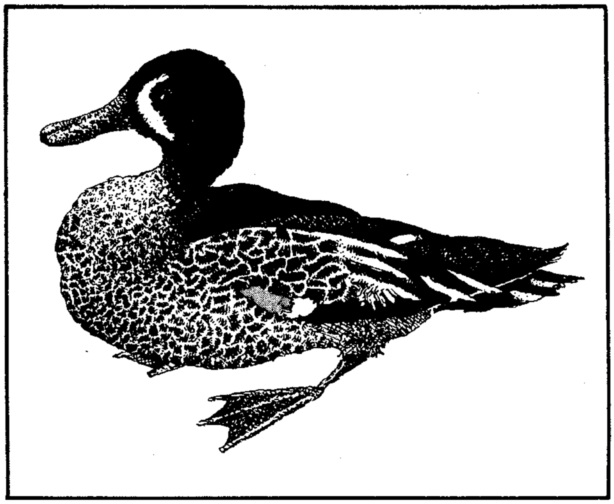
Planning Considerations: The most suitable uses of fresh to brackish water as far as man is concerned are fishing and hunting. After careful analysis of the effects, some types of construction may be suitable (such as piers) though generally this will involve special engineering considerations and higher costs than when undertaken on more appropriate sites. On the whole, most types of light or heavy development, dam construction and filling are considered unsuitable in this environment.

Fresh to Brackish Marsh
Map Legend — Sm
Color — Silver
Percentage of Total Coast Area Mapped—4.00%

FIGURE 29 **Fresh to Brackish Marsh**

Characteristics: Fresh to brackish marshes are wetland adjacent to salt marsh or in coastal impoundments where waters maintain a relatively low salinity of less than 5 parts per thousand. These marshes generally support lush growths of aquatic vegetation and have surfaces which are often several centimeters to one-half meter above the mean high water mark. Fresh-brackish marshes represent a stage between salt marsh and upland, forming where sediment is deposited from mainland drainage or marine flooding. Most tracts are subject to occasional tidal flow and submergence during floods.

FIGURE 30 **Blue Winged Teal**



Importance: Fresh to brackish marshes are an important segment of a number of depositional systems, including coarse- and fine-grained estuaries, tide-dominated neutral embayments, constructional and destructional deltas, and coastal marshes. They provide significant habitat for many species of ducks and other waterfowl and for some valuable game animals, such as beaver and muskrat. Because they are able to temporarily store flood waters, these units help reduce the effects of coastal flooding.

Planning Considerations: Fresh to brackish marshes are generally unsuitable for any kind of development, agricultural use or waste disposal. They are particularly sensitive to drainage, ditching or filling. Though it has been practiced in the past, applications of pesticides or herbicides on fresh-brackish marshes poses a grave threat to their environmental health and can have serious adverse consequences for the valuable wildlife species who live in them. In many cases, however, such marshes can be suitably used for some human activities, most notably, recreational fishing, hunting, and bird watching.

Man-made land
Map legend — Sz
Color — (no color)
Percentage of Total Coast Area Mapped—1.00%

Characteristics: Although man-made land is not a natural feature of the Maine coast, it does exist in a significant number of places and thus must be considered as an environmental unit. It includes all structures and fill that have been placed in the nearshore coastal zone by humans, extending in some cases into the intertidal zone.

Importance: Basically, man-made land is geologically important only in the sense that its creation may alter natural environments or interfere with the maintenance of coastal depositional systems. It can, however, be considered important to people insofar as it provides a place for various human activities, such as development or pier and wharf construction.

Planning Considerations: The creation of new man-made land should always be carefully analyzed to determine impacts on more important geologic units and is, understandably, subject to numerous legal restrictions. Existing man-made lands are often suitable for many types of activities, including pier and storm barrier construction, light or heavy development, and placement of pipelines, though any such undertaking should be carefully examined to avoid adverse effects on nearby environments.

Landslide Excavation and Deposits
Map Legend — Sx
Color — Crimson Red
Percentage of Total Coast Area Mapped—0.01%

Characteristics: This relatively rare unit consists of deposits of upland soil materials that have moved downslope from their original position, causing an excavation of the shoreland by their movement. The deposits are usually subject to further slumping and sliding due to gravity, wave erosion, undercutting and groundwater seepage. Occasionally, portions of landslide deposits and excavations will revegetate with upland grasses and trees, and may stabilize.

Importance: May contribute silt and clay to intertidal mud flats.

Planning Considerations: Obviously, the unstable nature of these units make them unsuitable for any kind of development and for most kinds of coastal construction. They also pose a considerable safety threat to pedestrians. A common method of minimizing the risks associated with landslide excavations and deposits is to classify the area as a "hazard zone." In a few instances, after careful consideration, filling and/or excavation may be suitable activities in these units.

Eolian Flat
Map Legend — Se
Color — Grass Green
Percentage of Total Coast Area Mapped—0.01%

Characteristics: Eolian flats are partly vegetated or devegetated sand flats extending behind coastal sand dunes onto back-barrier marshes or onto coarse-grained estuarine channels where marshes are not present. They originate as either washover fan deposits that are carried over the dune fields by storm waves or as windblown deposits eroded from devegetated dunes.

Importance: Although rare, eolian flats are important to the maintenance of the dune and sand beach systems in which they occur. These systems provide feeding and breeding habitat for terns, sanderlings, piping plovers and other shorebirds.

Planning Considerations: Eolian flats are generally unsuitable for any kind of development or coastal construction. Their role in helping to maintain beach systems also leads to certain other planning considerations similar to those for beaches and dunes (see pages 41 and 49). They can be indirectly affected, for example, by the construction of sea walls nearby. Like other units associated with beach systems, eolian flats tend to migrate landward over time. Thus, any man-made structures should be carefully designed or excluded to avoid future problems.

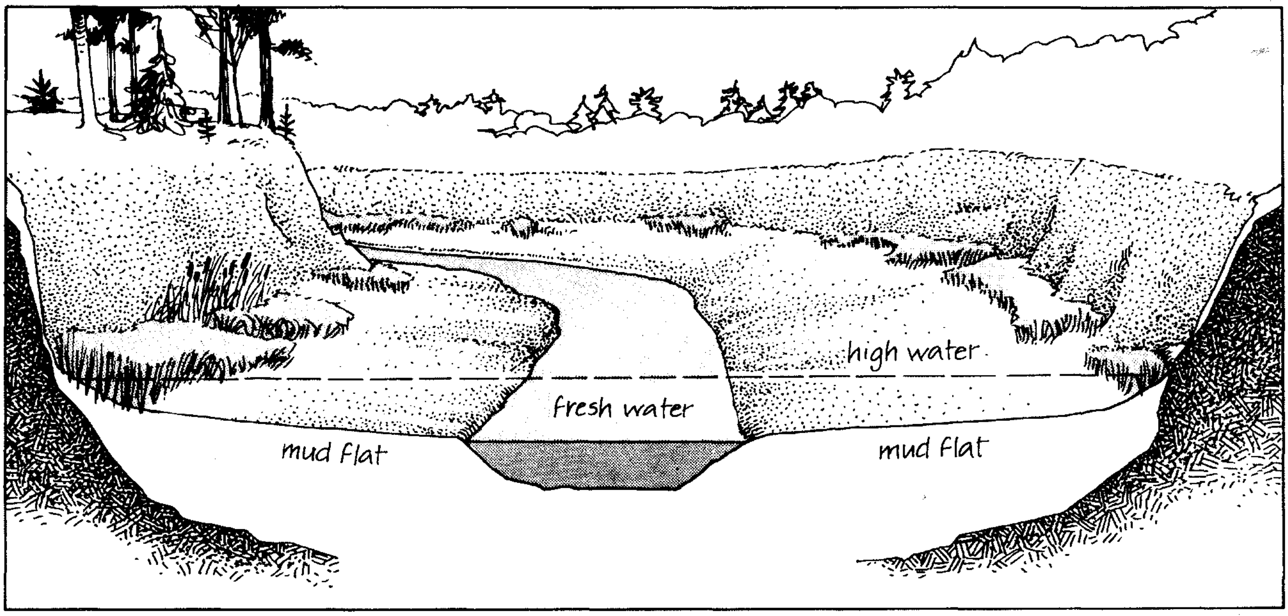
Washover Flat
Map Legend — Sf
Color — Sand
Percentage of Total Coast Area Mapped—0.01%

Characteristics: Washover flats are sand sheets deposited by waves over salt marsh behind inlet mouths and landward of floodtide deltas. They are sometimes inundated by spring tides and storm flood water, as well as by wave shoaling during northeast storms.

Importance: Since these environments are so small in area, they have relatively little significance to either the estuarine systems where they are found or to wildlife.

Planning Considerations: The unstable, flood-prone nature of washover flats and their close association with environmentally-sensitive salt marshes, make them unsuitable for nearly any kind of development or construction.

FIGURE 31 Fluvial Marsh



Fluvial Marsh
Map Legend — Sr
Color — Slate gray
Percentage of Total Coast Area Mapped—1.00%

Characteristics: Fluvial marshes include sparsely-to-moderately vegetated tidal river flats and floodplains of sandy mud or mud. They are subject to flooding twice daily by fresh water backed up by tides, and occasionally by flooding rivers, which deposit the river sediments that make up this unit.

Importance: Fluvial marshes are a significant part of many constructional delta systems, serving as a "storage area" for sediments eventually transported to other geologic environments. They also provide feeding and breeding habitat to various valuable wildlife species, including beaver, muskrat, otter, great blue heron, and numerous ducks and geese.

Planning Considerations: Like other geologic units found in delta systems, fluvial marshes may be adversely affected by the construction of dams on rivers entering them due to a loss of sediments (see page 18). Their role in maintaining delta systems and as important wildlife habitats can also be destroyed by any dredging, filling or draining activities in the area. They may be suitable sites for some types of activities, such as hunting and fishing, pier construction and placement of pipelines after careful consideration of potential impacts. Generally, however, waste disposal and light or heavy development are unsuitable in fluvial marshes.

FIGURE 32 Wild Rice

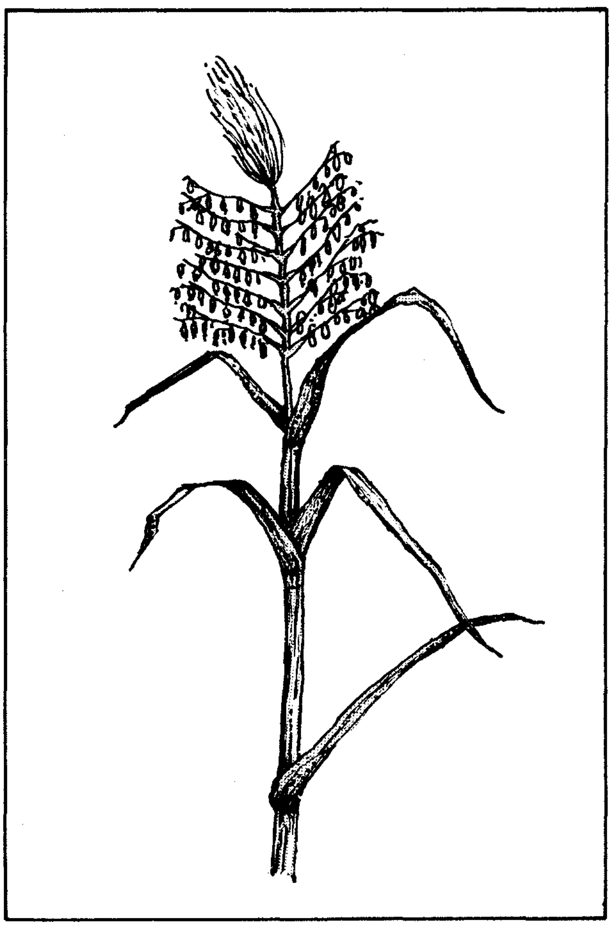
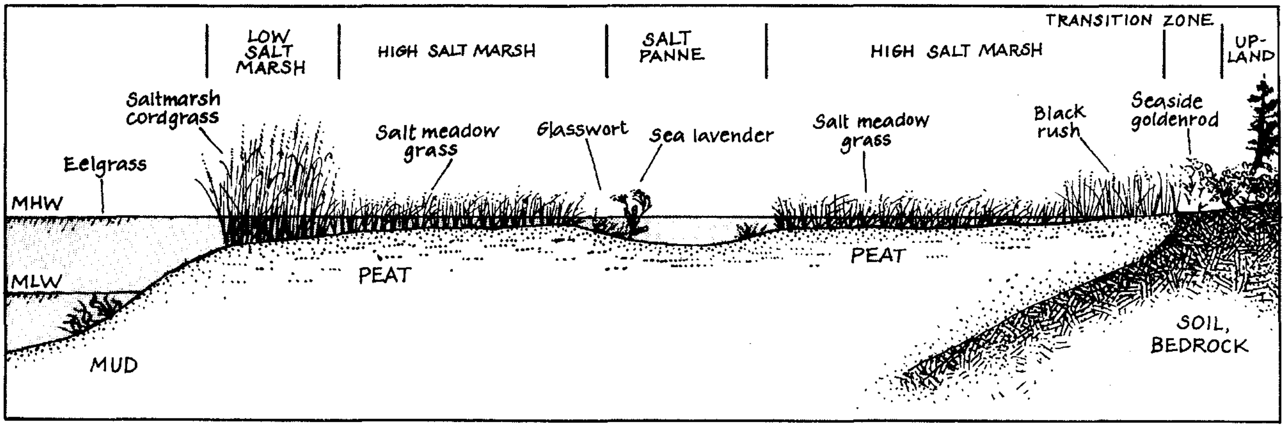


FIGURE 33 Salt Marsh Cross Section



INTERTIDAL ENVIRONMENTS

High Salt Marsh

Map Legend — M1
Color — Peacock Green
Percentage of Total Coast Area Mapped—5.00%

Characteristics: This estuarine environment consists of peat, mud or sand flats densely overgrown with salt-tolerant grasses and situated at or slightly above the mean high water mark. Wetland vegetation plays a key role in the creation and maintenance of a high salt marsh by slowing down and capturing sediments brought in by streams, rivers, and tides. Such marshes commonly occur behind barrier beaches or along and at the mouth of river estuaries. Low salt marsh (Map Legend — M2) becomes high salt marsh as sedimentation builds up on intertidal flats, raising them to the mean high water level. As relative sea level rises (see page 13) coastal salt marshes rise with it, slowly migrating landward.

Importance: The environmental and economic significance of high salt marshes is difficult to overstate. As a wildlife habitat, they are particularly valuable to migratory ducks and geese, numerous shorebird species, many colorful songbirds, ospreys and bald eagles. A great variety of animals important to marine food chains also live here, such as mud snails, copepods and flatworms. Tidal channels and streams running through high salt marshes are breeding and nursery grounds for dozens of commercially important fish and shellfish species. Marsh food chains are heavily dependent on the nutrients and bacteria absorbed and held by marsh vegetation. Beyond its function as a habitat, a high salt marsh temporarily stores flood waters, thus reducing the severity of coastal flooding. Wide bands of marsh in front of upland shores absorb the brunt of heavy storm waves, protecting the mainland from severe erosion. And the dense vegetation that grows here acts as a kind of giant natural water purifier by capturing and holding pollutants and sediments that could otherwise degrade shellfish beds or fill navigational channels.

FIGURE 34 Snowy Egret; Salt Meadow Grass; Salt Marsh Cord Grass; Black Rush

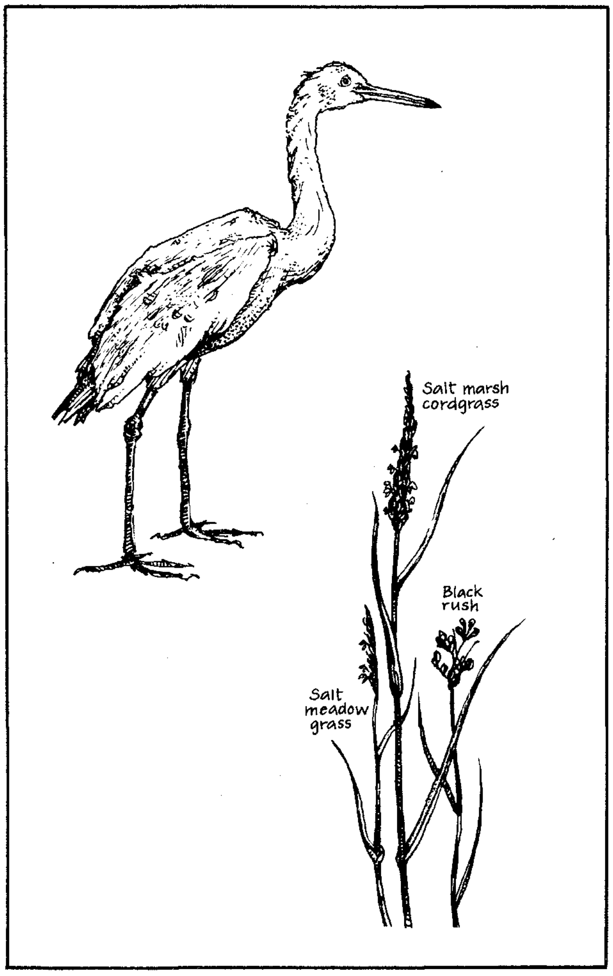
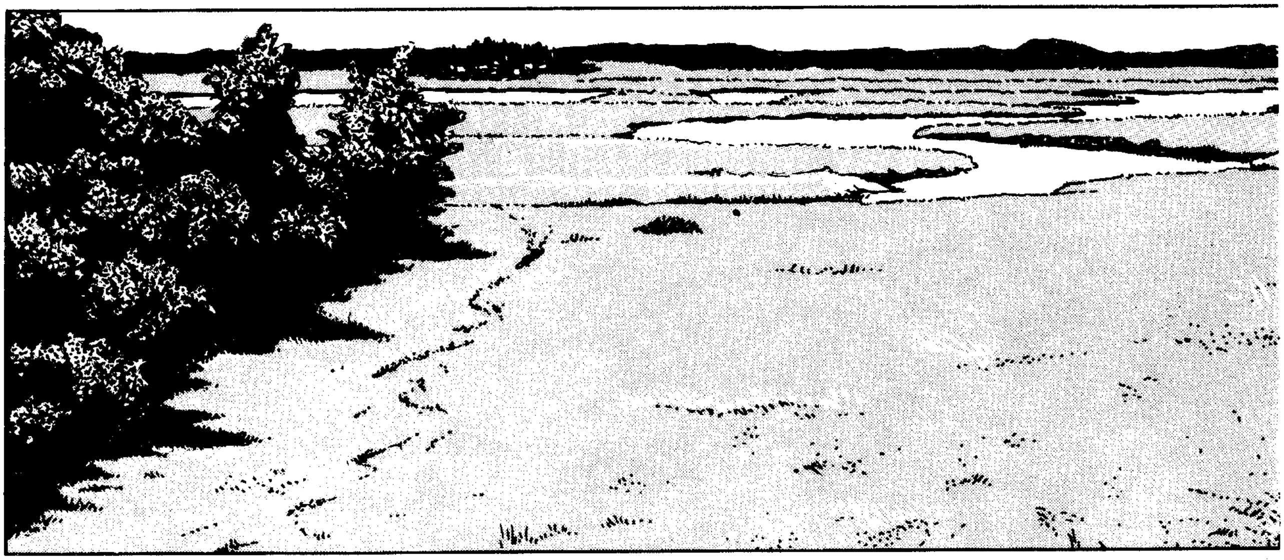


FIGURE 35 Salt Marsh



Planning Considerations: Like other estuarine environments, high salt marshes are very sensitive to changes in the volume of water flowing into or out of them. Any kind of draining, ditching, dredging or filling activities on or near a high salt marsh can have detrimental consequences in terms of the maintenance and productivity of this environment. Light or heavy development, roadbuilding, and most other types of construction are not considered suitable here; nor, despite a high marsh's purifying capabilities, is the disposal of solid or liquid waste. On the whole, the most appropriate human activities in this unit are recreational, such as birdwatching, hunting, and canoeing. Even these activities can have adverse impacts on a high marsh since erosion-prone spots on marsh plots and heavy foot traffic along channel banks can cause devegetation and accelerated bank erosion. In some cases, changes made in nearby environments can affect a high salt marsh significantly. A dam constructed on a river entering a marsh can cut off sustaining sediment supplies; a breakwater constructed offshore can cause increased sedimentation that could smother parts of the marsh surface; and development of adjacent barrier beaches often results in restriction of the tidal channels feeding into marsh systems, leading to a slow destruction of these productive wetlands.

Low Salt Marsh
Map Legend — M2
Color — Peacock Green
Percentage of Total Coast Area Mapped—0.10%

Characteristics: Low salt marshes are sparsely to densely vegetated sand or mud tidal flats located between mean tide and the high water mark. They generally have a slope of from 5° to 20° and lead up to areas of high salt marsh, though isolated strands of low salt marsh are sometimes found. The vegetation here consists solely of salt cord grass (Spartina alterniflora), which grows in stands up to one meter in height. The substrate between stands is bare mud or sand.

Importance: Although they are associated with a variety of coastal depositional systems, including coarse- and fine-grained estuaries, tide-dominated neutral embayments, and constructional deltas, low salt marshes are a relatively scarce geological environment in Maine. They are, nevertheless, one of the most important in terms of economy and ecology because of their crucial role as habitat for numerous commercial fish and shellfish species. Indeed, nearly three-fourths of Maine's fisheries resources are directly or indirectly dependent on the existence of low salt marsh environments as a source of nutrients or as a breeding and nursery ground. Over 60 important commercial species, from clams and crabs to menhaden and flounder, live, feed or grow up in these units.

Planning Considerations: Like the high salt marsh environment, low salt marshes are adversely affected by dredging, draining, filling and any other activity that alters the natural flow of water into and out of them. Dredging of nearby high salt marsh areas can disrupt the natural transport of sediments in a low marsh, increasing turbidity and sedimentation. Dredging on the high marsh can also release chemicals or heavy metals formerly bound up in the high marsh sedi-

ments which may be toxic to the many fish and shellfish species that live in low salt marsh environments, or decrease their commercial value. Pesticides and sewage wastes can have similarly adverse effects on low marsh organisms. Most experts agree that nearly all construction or development is inappropriate here. Even recreation should be limited, since waves caused by power boats, for example, can erode stream banks and increase water turbidity.

FIGURE 36 Plan View; Typical Transition Zone — Salt Marsh to Fluvial Marsh

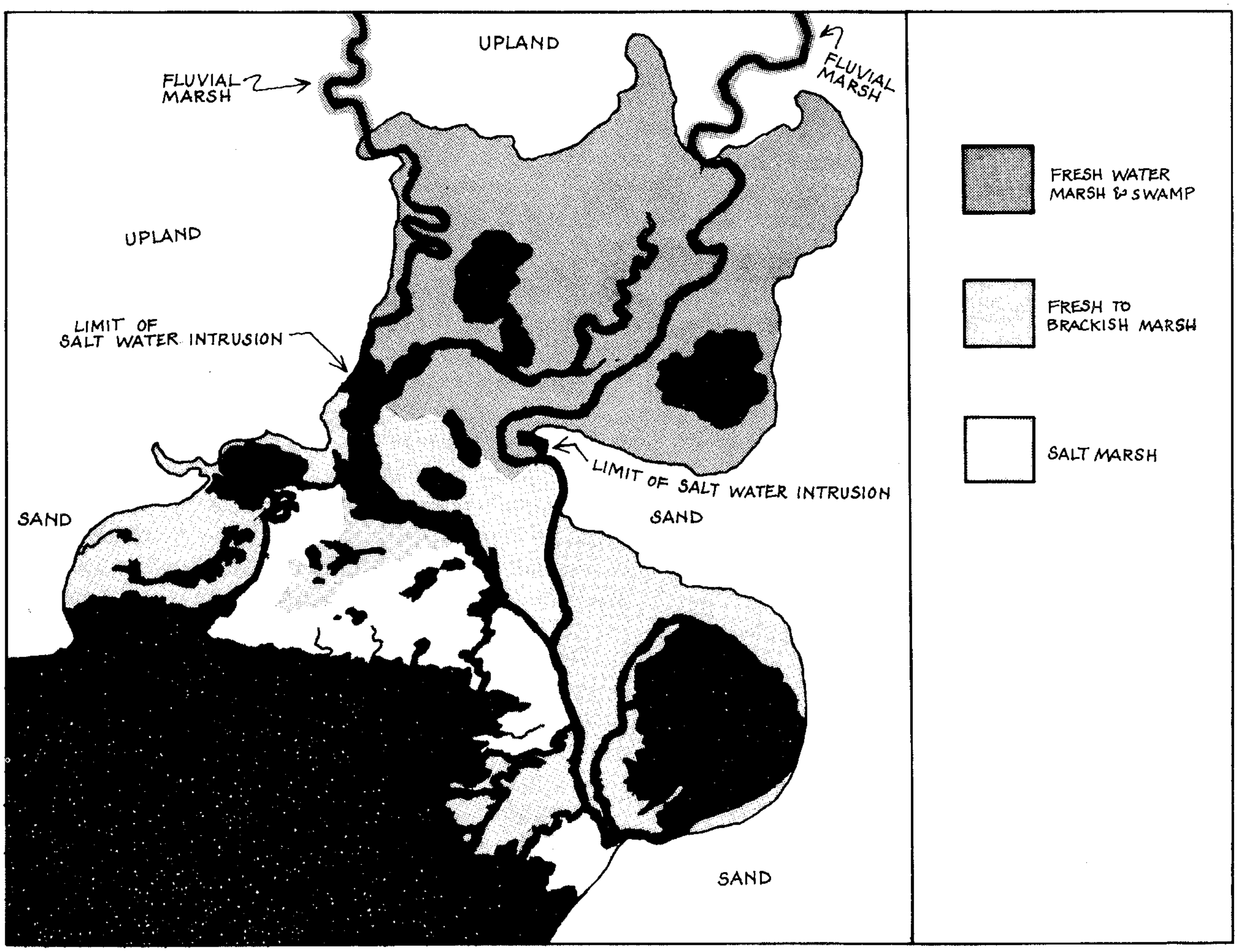
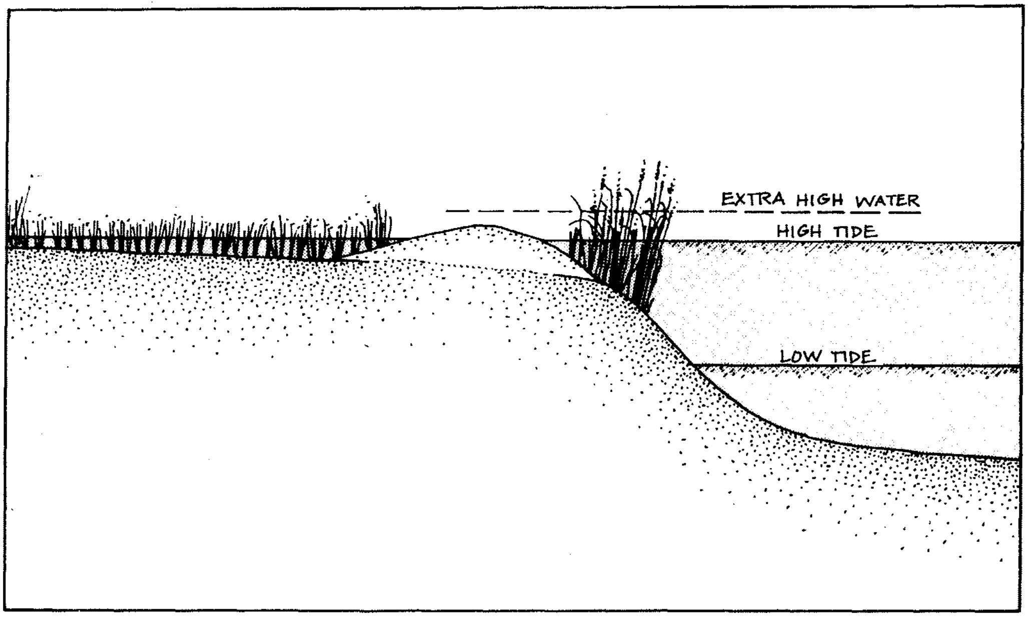
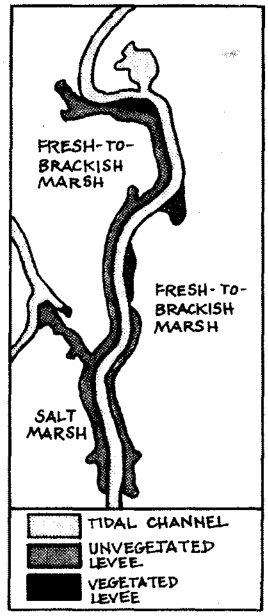


FIGURE 37 Marsh Levee, Two Views





Marsh Levees
Map Legend — M3
Color — Peacock Green
Percentage of Total Coast Area Mapped—0.01%

Characteristics: Marsh levees form as deposits of sand or silt along the margins of tidal channels in high salt marshes. The levee surfaces are generally up to ten centimeters higher than the mean high water mark and surrounding marsh surfaces. These units are created when storm waters overflow channel banks and spread onto the high salt marsh. The sudden reduction of current velocity as the water hits the vegetated marsh surface causes rapid sedimentation of sand and silt, building the marsh levees.

Importance: Marsh levees provide dry walkways through a marsh.

Planning Considerations: There are no special planning considerations associated with marsh levees other than those relating to the maintenance of the high marsh environment as a whole (see page 46).

Salt Pannes and Ponds
Map Legend — M4
Color — True Blue
Percentage of Total Coast Area Mapped—0.05%

Characteristics: Circular unvegetated depressions existing on high salt marsh surfaces are called salt pannes or salt ponds. They are thought to form where bare, rotten spots occur on marshes or in segments of "abandoned" tidal channels. Pannes usually contain seawater from spring tide flooding for a while each year, but during the summer it gradually evaporates, eventually leaving a dry panne covered by mats of algae (the only plants that can grow in this highly saline environment).

Importance: Salt pannes were once used as a source of sea salt.

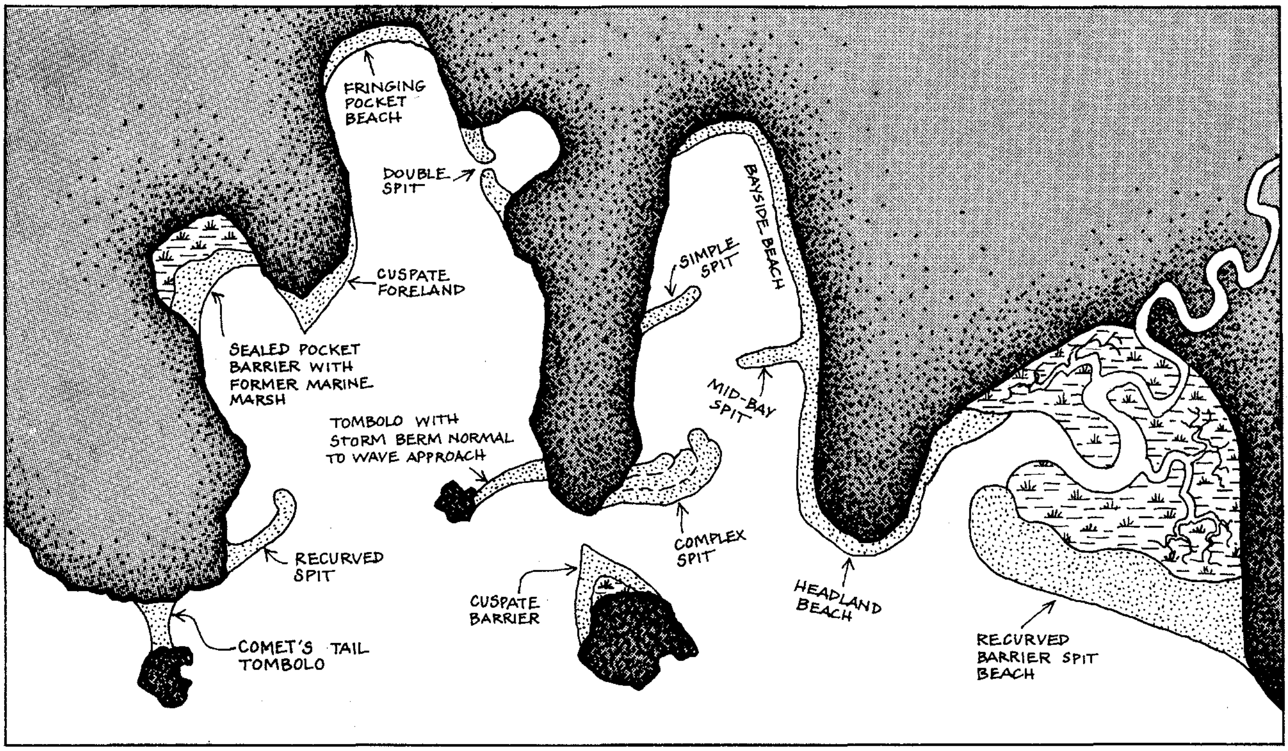
Planning Considerations: None, other than those given for high salt marsh environments.

Sand Beaches
Map Legend — B1
Color — Lemon Yellow
Percentage of Total Coast Area Mapped—1.00%

Characteristics: These are beaches consisting entirely of sand which are exposed to high wave energy. They extend from the mean low water mark to the uplands or to dune fields, where inland vegetation is established. Fine-sand beaches are usually flatter than coarse-sand beaches, and remain more stable when exposed to large waves. Medium-to-coarse grained sand beaches exhibit wide, ridgelike beach "berms" along their lower margins. Sediments involved are generally washed in from offshore deposits of glacial material, transported by river from inland areas, or derived from alongshore erosion of surficial sediments.

Importance: Recreationally, sand beaches are one of Maine's most valuable and most popular environments despite their relative rarity in this state. Many wildlife species feed or live on a

FIGURE 38 Beach Types



beach, including surf clams, sand dollars, striped bass, sand pipers, sanderlings, gulls, terns, and ruddy turnstones. Dune fields are dependent on beaches as a source of sand, in turn acting as a stockpile of sand which replaces material beaches lose to winter storm waves. Barrier beaches form a protective buffer between valuable salt marsh systems and the full force of the ocean.

Planning Considerations: Due to rising sea level beaches tend to move inland over time. Development close to beach areas is therefore not recommended. Residential or commercial development behind sand beaches on dune areas can, in addition, disrupt the natural cyclical transport of sand between beaches and dunes, thus threatening the whole system with sediment "starvation." Seawalls or other shoreline protection structures built to protect beachfront property are another common threat. In many cases, such structures accelerate rather than slow erosion rates on sand beaches. Beaches that depend on river sediments as a source of sand may be adversely impacted by dams built inland. In a similar fashion, seawalls and other retaining walls can prevent the influx of new sand to a beach dependent on offshore deposits transported onto or along the shore by waves, tides and currents. Devegetation and subsequent erosion of adjacent dune fields also lead to erosional problems on sand beaches. (Also see page 70).

Mixed Sand and Gravel Beaches
Map Legend — B2
Color — Yellow Orange
Percentage of Total Coast Area Mapped—1.50%

Characteristics: These are beaches very similar to sand beaches which consist of both sand and gravel deposits. In most cases, gravel is concentrated on the upper portion of such beaches. Beach sediments here originate from wave-reworking of glacial tills or outwash sands and gravels either immediately behind or adjacent to the beach, or from shallow subtidal deposits. Sand and gravel beaches are generally exposed to heavy wave action and are thus classified as "high energy" beaches.

Importance: Like sand beaches, mixed sand and gravel beaches are highly valued as a recreational resource. They also provide habitat for various shellfish and shorebird species, including clams, sanderlings, gulls, and terns.

Planning Considerations: Construction of dwellings and other development on or close behind sand and gravel beaches is generally considered unwise, since they are subject to the effects of progressive sea level rise. This slow but steady inland recession is often accompanied by erosion of scarps backing these beaches, thus development there should be given ample setback from the edge of the bank.

FIGURE 39 Gravel Beach

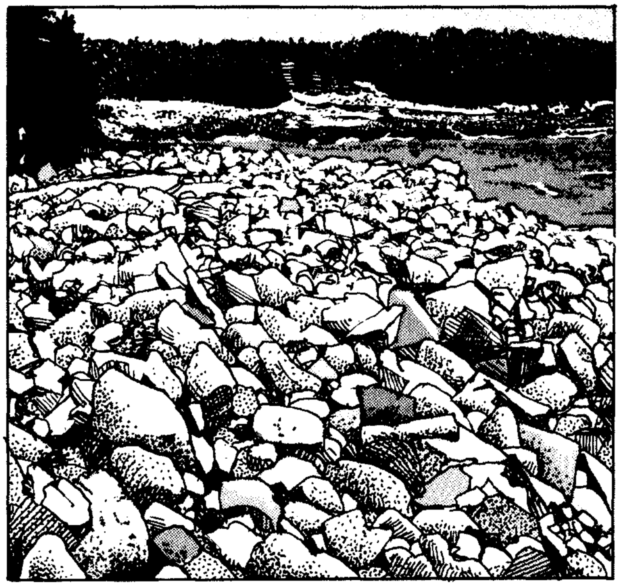
Gravel Beaches
Map Legend — B3
Color — Non-photo Blue
Percentage of Total Coast Area Mapped—3.00%

Characteristics: These are beaches consisting solely of pebbles and boulders which were derived from offshore or shoreline deposits of glacial till or outwash reworked and transported by high-energy waves. Gravel beach faces are usually narrow and steep. The profile generally includes gravel berms, or low ridges, along the lower beach margin and high gravel storm ridges on the landward side. Such beaches occupy shallow indentations of the shoreline where nearby uplands are composed of glacial sediments. They are characteristically small and are backed by either salt marshes or low or high scarps, or banks.

Importance: Though not as sought after as sandy beaches, gravel beaches are often used for recreational purposes and considered very attractive. They also provide habitat for shorebirds, such as gulls and terns, and other wildlife.

Planning Considerations: Gravel beaches are rarely developed except for the construction of roads sometimes built directly behind the storm ridges. Because gravel beaches are subject to landward migration due to progressive sea level rise (see page 13) constant repair of these roads is often necessary due to the effects of continual washover. Thus, when possible, roads or other construction should be set back from gravel beaches and storm ridges far enough to avoid such problems.

FIGURE 40 Boulder Beach



Boulder Beaches
Map Legend — B3
Color — Non-photo Blue
Percentage of Total Coast Area Mapped—0.50%

Characteristics: Boulder beaches consist primarily of boulders derived from glacial till or jointed bedrock ledge exposed to very heavy waves.

Importance and Planning Considerations: (Similar to gravel beaches)

Low Energy Beaches
Map Legend — B5
Color — Magenta
Percentage of Total Coast Area Mapped—4.00%

Characteristics: These are beaches composed of a wide variety of sediment sizes, from mud to gravel, that form in sheltered coves and other parts of the shoreline protected from the force of heavy waves. The sediments are usually derived from wave erosion and weathering of scarps behind the beach. Low energy beaches are narrow and do not exhibit the significant changes in seasonal profiles shown by high energy beaches (see page 66). The lower beach surfaces generally grade seaward into intertidal mud flats and during the summer months salt marsh grasses may grow in some areas.

Importance: Though rarely used for recreational purposes, low energy beaches do provide habitat for a number of wildlife species, such as terns, sandpipers, clams, and marine worms, as well as to juvenile fishes. Finer sediments winnowed from low energy beaches are transported to nearby mud flats, which often harbor valuable shellfish beds.

Planning Considerations: Low energy beaches and banks backing them are subject to some recession due to sea level rise. This occurs, however, at a much slower rate than on high energy beaches. Although development should be set back a reasonable distance, the width of this safety margin need not be as great as in areas where wave energy is heavier.

Boulder Ramp
Map Legend — Br
Color — Non-photo Blue
Percentage of Total Coast Area Mapped—2.00%

Characteristics: A boulder ramp is a gently sloping, boulder-covered surface in the lower intertidal zone that generally occurs seaward of gravel or boulder beaches on shorelines exposed to heavy waves. They develop on top of ledge surfaces or on wave-worked glacial till. In the process of reworking till deposits, waves wash clay and other fine sediments offshore, transporting sand, gravel and boulders onshore to form beaches. Boulder ramps are made up of boulders too large to be moved by average waves.

Importance: Boulder ramps provide habitat for rockweeds and other shoreline plants important to marine food chains, as well as to tenacious animals such as the starfish, barnacle and mussels. To many people they also have an aesthetic value, due to the polished roundness of their boulders and the sounds they make when impacted by waves.

Planning Considerations: Boulder ramps are generally unsuitable for any type of development.

Washover Fans
Map Legend — Bw
Color — Copper
Percentage of Total Coast Area Mapped—0.01%

Characteristics: Washover fans are low, fan-shaped deposits of gravel located behind gravel beach ridges and covering part of the marshes or upland beyond. Washovers sometimes occur on sand beaches but with much less frequency. They are created when high waves overtop gravel or dune ridges, carrying along loads of beach sediment.

Importance: Washover fans constitute part of the stockpile of sediments that will eventually be recycled within the beach system. They are also the major way in which beach systems migrate inland in response to sea level rise.

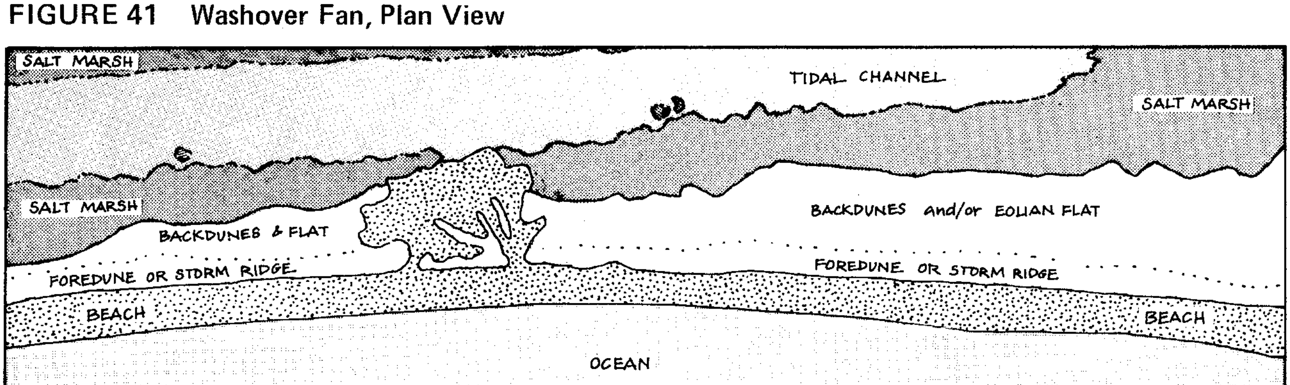
Planning Considerations: Where seawalls or other structures prevent the formation of washover fans beaches may erode at a faster rate. Other considerations are similar to those for dunes and gravel beaches or ridges of which washover fans are a part.

Spits
Map Legend — Bs
Color — Gold
Percentage of Total Coast Area Mapped—0.04%

Characteristics: Spits are sandy beach deposits in the form of a peninsula attached at one end to the shoreline. Those which join islands to the mainland are called tombolos. Spits originate by deposition of sand at the mouths of rivers or where waves approach protruding areas of sandy shoreline from opposite directions.

Importance: Spits are often the forerunners of beaches. Many barrier beaches in Maine, for example, started out long ago as spits. As sand deposition on the original spits continued, they grew, eventually impounding large salt marshes and tidal lagoons behind them. Spits often have

FIGURE 41 Washover Fan, Plan View



rather unstable tips, subject to continual wave reworking, and are favorite nesting sites of the locally rare least tern and piping plover. Where such tern and plover colonies occur in Maine they are usually considered to be critical habitats.

Planning Considerations: Spits are so closely allied to beach environments that planning considerations are much the same as those listed for sand beaches (see page 49). Generally, any changes in the characteristics of impinging waves or the natural transport cycles of sand supplies in the area will alter this unit. Only a few least tern colonies exist in Maine, thus spits on which they nest deserve special protection.

Mussel Bar
Map Legend — F3
Color — Scarlet Red
Percentage of Total Coast Area Mapped—0.04%

Characteristics: Mussel Bars are low mounds or "reefs" of living mussels (Mytilus edulis) and shell debris deposited by wave shoaling. They occur in relatively sheltered areas at the mouths of bays or estuaries not receiving significant freshwater input. The mussels expel sediments they extract from the water in feeding. These sediments settle between individual organisms in the bar, eventually raising the surface of the bar above the level of the surrounding intertidal environments.

Importance: The blue mussels that abound here are an important source of food to marine and bird life. They are also a food source for humans, and as their popularity with seafood lovers continues to increase, the value of mussel bars is likely to become more widely appreciated.

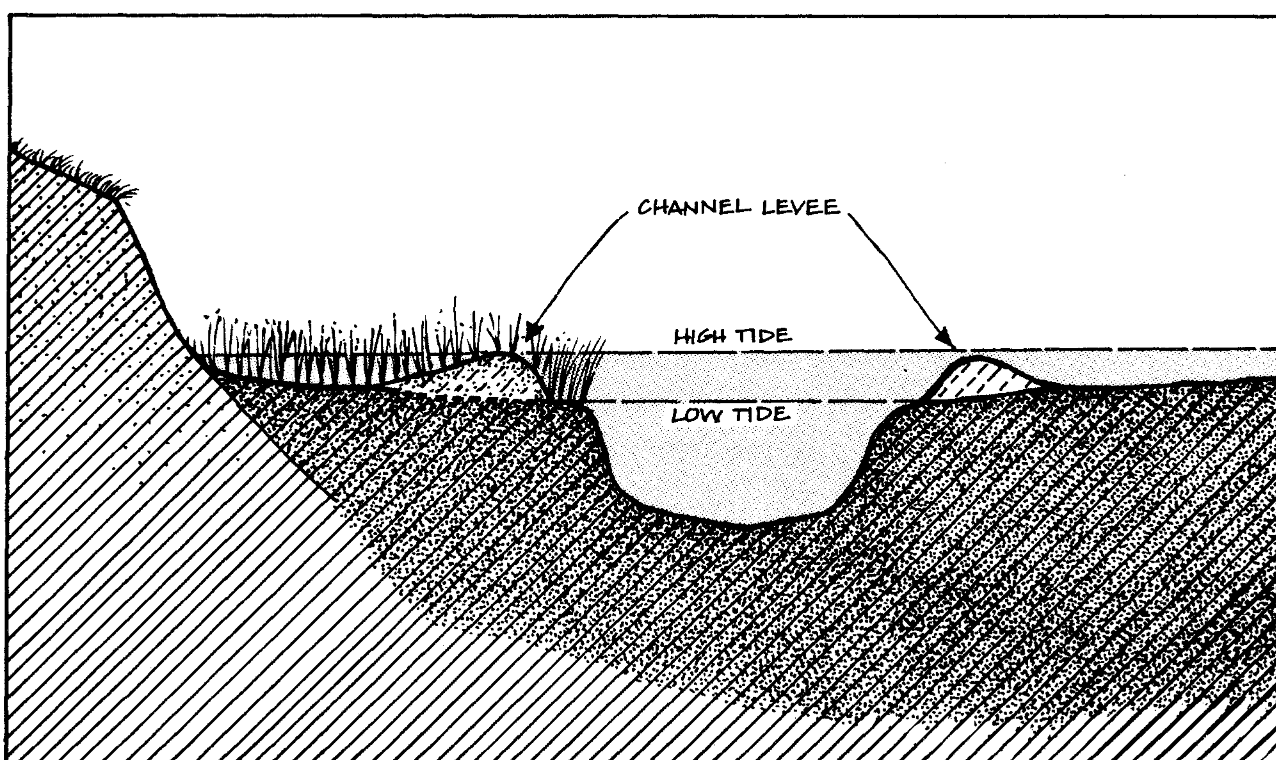
Planning Considerations: Dredging and filling on or near a mussel bar is the most common threat to this unit. A frequent result is increased sedimentation that can smother and kill the mussels or a release of toxic chemicals and heavy metals to which these organisms are very sensitive.

Channel Levee
Map Legend — F4
Color — Cold Dark Grey
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are ridges of fine-grained sediment several tens of centimeters high, deposited along the margins of tidal channels in intertidal flat areas (similar in form to marsh levees).

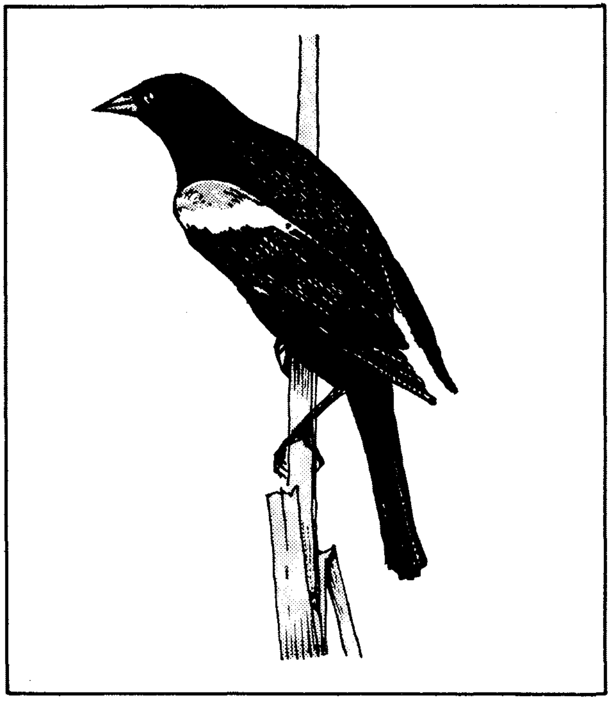
Importance: Channel levees provide habitat for clams, marine worms and other marine species. Many shorebirds, such as the great blue heron and snowy egret feed here. On the whole, the limited size and occurrence of channel levees make them relatively rare intertidal flat environments.

FIGURE 42 **Channel Levee**



Planning Considerations: The most common threats to channel levees are dredging and filling operations, both of which may affect surrounding flats.

FIGURE 43 Red-winged Blackbird (male)

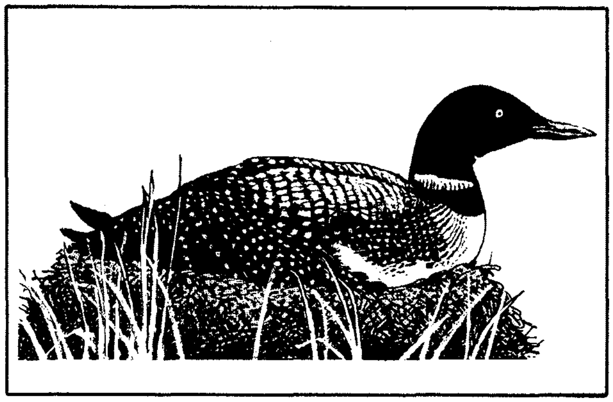


*Mud Flats (Intertidal)
Map Legend — F
Color — Dark Brown
Percentage of Total Coast Area Mapped—
27.00%

Characteristics: These are flat environments situated between the low and high tide lines in relatively sheltered waters. Major sediments are sand, silt and clay, deposited by tidal currents.

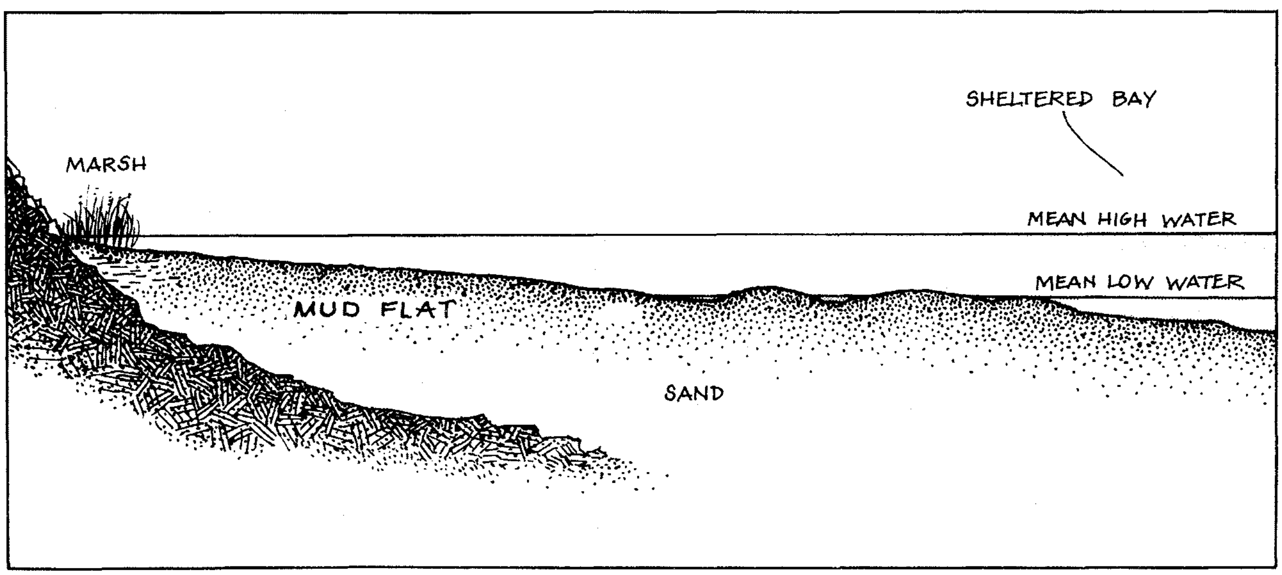
Importance: Mud flats are usually valued most highly for the clam and marine worm populations that abound there. They are the basis of Maine's multi-million dollar clamming and marine worm industries. Mud flats exposed at low tide also provide a rich source of food for great blue herons, snowy egrets, sandpipers and other shorebirds. At high tide, numerous species of waterfowl feed in these environments, including black ducks and loons. Many kinds of fish are dependent on mud flats as a habitat, such as striped bass, alewives, killifish and smelt.

FIGURE 44 Common Loon



Planning Considerations: Mud flats may be disturbed or destroyed by dredging and filling on the flats or on nearby environments. Dredging of adjacent wetlands or agricultural activities and construction on nearby uplands can release an unnatural influx of sediments that may smother shellfish beds and introduce toxic chemicals or heavy metals that are poisonous to clams and marine worms. The commercial usefulness of this environment as a clamming resource can also be destroyed by sewage wastes, a problem all too common along the Maine coast.

FIGURE 45 Mud Flat



Coarse-grained Flat (Intertidal)
Map Legend — F1
Color — Dark Brown
Percentage of Total Coast Area Mapped—4.70%

Characteristics: These are flat environments between low and high tide composed of sand and other sediments coarser than those found on units classified as mud flats. They occur along shorelines exposed to greater tidal and wave energies than fine-grained flats, but often exist in proximity to them. Coarse-grained flats exist at lower elevations than mud flats and are thus subject to longer periods of tidal inundation.

Importance: Like mud flats, coarse-grained flats are important shellfish and marine worm beds, though because of their less stable nature, they are somewhat less productive. They also provide habitat for various commercially important fish species and food sources for waterfowl.

Planning Considerations: (Similar to those for Mud Flats — page 53).

Seaweed-Covered Coarse-grained Flats
Map Legend — F2
Color — Light Green
Percentage of Total Coast Area Mapped—1.00%

Characteristics: These are coarse-grained flats extending into the intertidal and subtidal zones, which support growths of marine algae such as Ulva, Enteromorpha, and Ascophyllum.

Importance: These flats, like others, are productive shellfish habitats and feeding grounds for various waterfowl and fin fish species.

Planning Considerations: (Similar to those for Mud Flats)

Algal Flats
Map Legend — F5
Color — Green Bice
Percentage of Total Coast Area Mapped—0.08%

Characteristics: These are fine-grained flats in the upper intertidal zone that support growths of marine algae. This is a relatively rare flat environment on the Maine coast, occurring mostly north of Frenchman's Bay.

Importance and Planning Considerations: (Similar to Mud Flats).

Veneered Ramp
Map Legend — F6
Color — Dark Brown
Percentage of Total Coast Area Mapped—0.05%

Characteristics: These are boulder ramps or bedrock ledge surfaces shoreward of intertidal flat areas which are covered by a layer of mud several centimeters thick. Veneered ramps result from an increased influx of suspended sediments to tidal bays, typically due to agricultural activity or construction on nearby uplands.

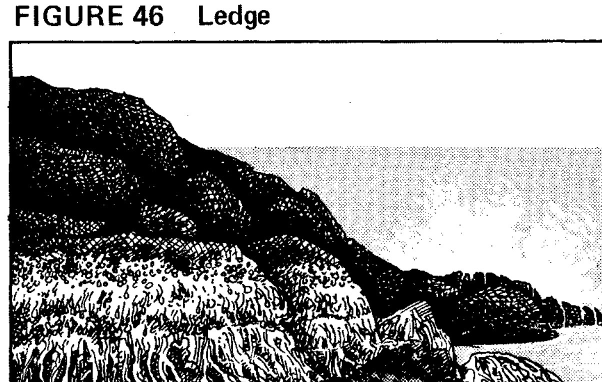
Importance: Though veneered ramps have relatively little importance to natural ecological balances in intertidal environments, they may provide new habitat for a variety of mud-dwelling lifeforms, such as clams and marine worms.

Planning Considerations: Veneered ramps can be suitable sites for certain types of coastal construction, such as piers and retaining walls. It should be noted that although veneered ramps may provide new habitat for shellfish, their appearance is often a sign that human activities on nearby uplands are causing increased sedimentation loads to flow into intertidal areas. This increase in sedimentation may have an adverse effect on more productive environments, such as clam flats, adjacent to the ramps.

Ledge
*Map Legend — M
Color — Warm Light Grey
Percentage of Total Coast Area Mapped—12.00%

Characteristics: The ledge environment consists of bedrock with little or no sediment cover. It is relatively resistant to erosion, although persistent wave action and freeze-thaw cycles may loosen and remove small or large pieces of ledge shoreline. Below the high tide line, rocky shorelines are characteristically covered with dense growths of marine seaweeds and algae.

FIGURE 46 Ledge



Importance: Rocky shores are not only aesthetically pleasing but often superior places for man-made construction. They also support abundant growths of intertidal plants and animals along their lower margins which are important to many marine food chains. Species found here include rockweed, kelp, Irish moss, barnacles, mussels, starfish and periwinkles. Ledge outcrops along the shoreline, which may also be isolated from the mainland as islands, provide feeding and breeding habitat for many higher life forms as well, such as eider ducks, black ducks, and other waterfowl, razorbills, petrels, gulls, terns, and harbor seals.

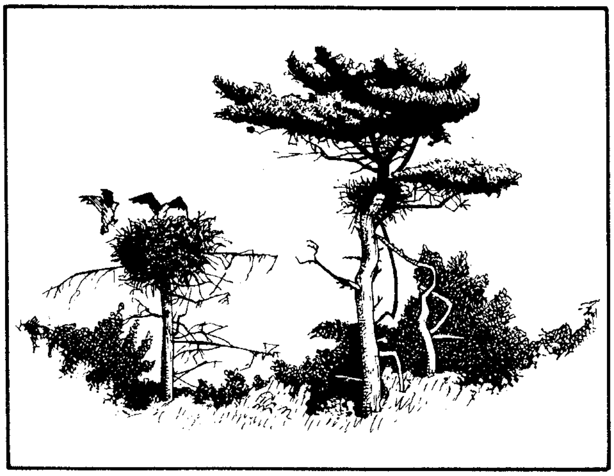
Planning Considerations: Rocky shoreline areas that are not significant breeding areas for birds and seals are some of the best sites for shoreline construction and development (excluding conventional septic systems), since they are both solid and rarely prone to erosion problems. They also offer opportunities for harvesting of mussels and seaweeds, which are commercially important in some areas. One basic threat to these and other ledge-dwelling species is an increased influx of sediments, sometimes caused by agricultural activities or construction on nearby uplands. Such increases in sediment load may smother productive ledge habitats, a problem which can also develop when man-made construction along the shoreline alters current and wave patterns. Pollution by oil or toxic chemicals can also reduce the productivity of ledge environments and their suitability as habitat for birds or seals.

Fluvial-Estuarine Channels
Map Legend — Mc
Color — Lavender
Percentage of Total Coast Area Mapped—0.03%

Characteristics: Fluvial-estuarine channels occupy the upper reaches of an estuary, carrying either river water or estuarine water, depending on the tidal range, river discharge in the area, and incidence of coastal flooding. They are the major link between rivers and estuarine channels, forming a transitional channel through which waters in the estuarine environment flow.

Importance: These channels are an important part of Maine's immensely productive estuarine environments as regulators of outgoing fresh and incoming estuarine waters. Like other estuarine units, they provide crucial habitat for many commercially valuable food fish species. Many shorebirds, loons, waterfowl, bald eagles and osprey forage in and adjacent to the channels.

FIGURE 47 Ospreys

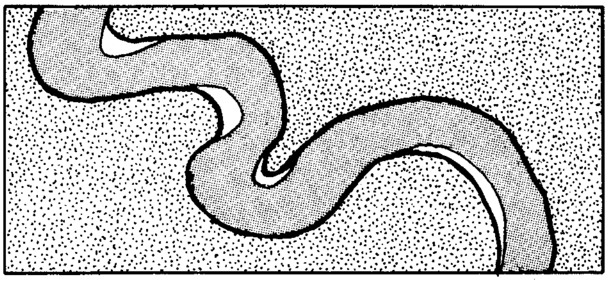


Planning Considerations: Like other parts of estuarine systems, preservation of these channels is important to the productivity of Maine's commercial fishing industry. The basic threats are pollution, dredging, filling, and other activities that disrupt natural water circulation in the area. (For more information on planning considerations relating to estuarine environments see pages 60 and 61).

Vegetated Point or Lateral Bars
Map Legend — My
Color — Dark Green
Percentage of Total Coast Area mapped—0.01%

Characteristics: These are accumulations of sand and mud in tidal or estuarine channels adjacent to channel margins (point bars) or along straight channel segments (lateral bars) which are often stabilized by salt marsh or river bank vegetation during the summer and fall. Sedimentation here is due to deposition of sand and mud as flood-tide currents flow across the surface of the bar.

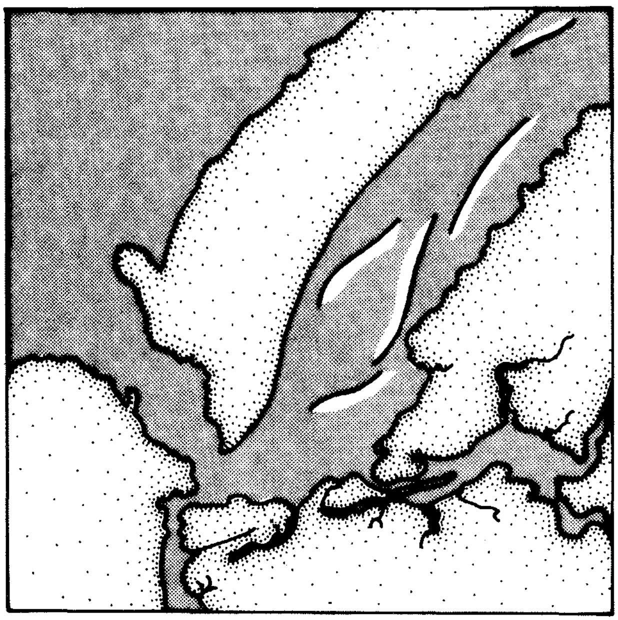
FIGURE 48 Point Bars



Importance: Many valuable wildlife species live or feed on point or lateral bars, including clams, muskrats, raccoons, deer, great blue heron, snowy egrets, ospreys, bald eagles and ducks. They are thus often prime hunting and clamming areas, besides being a very productive part of Maine's important estuarine systems.

Planning Considerations: Besides hunting and clamming, most other human activities, particularly construction or development, are not suitable on these units. Basic threats to the maintenance of point and lateral bars are similar to those to estuarine systems in general (see page 60), including dredging, filling, draining, damming of incoming rivers, increased or decreased sedimentation loads, and pollution.

FIGURE 49 Aerial Perspective; Lateral Bars



Abandoned Point or Lateral Bars
Map Legend — Mt
Color — Sky Blue
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are a type of vegetated point or lateral bars where flood-plain vegetation, including hardwood growth, has succeeded marsh and river bank plants. They occur where accumulations of sand and mud develop in or along the margins of estuarine channels, growing, by continual deposition, beyond the vegetated point or lateral bar stage (see previous unit).

Importance and Planning Considerations: Similar to those for vegetated point and lateral bars and others generally given for estuarine systems (see pages 55 and 26).

Swash Bars
Map Legend — Ms
Color — Light Violet
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are small, transitory sandy bars deposited by waves that are continually moved and reformed by wave action. Swash bars are derived from sediments carried offshore during winter storms. When the long, low waves of summer move this sediment shoreward again, swash bars are formed on ebb-tidal deltas and the margins of intertidal sand flats.

Importance: Sand swash bars are important parts of beach systems, serving to replenish sand lost to beaches during storms. They also help dissipate wave energy that may erode beaches and provide more beach area for recreational use. Swash bars provide habitat for both clams and seaworms which are often abundant enough to be commercially harvested. Shorebirds frequently forage here, including ruddy turnstones, terns, plovers and gulls.

Planning Considerations: Though swash bars are not suitable or commonly used as sites for construction or development, they are an integral part of sand beach systems and can be adversely affected by beachfront development. (See page 49 for other planning considerations relating to beach systems.)

FIGURE 50 Swash Bars

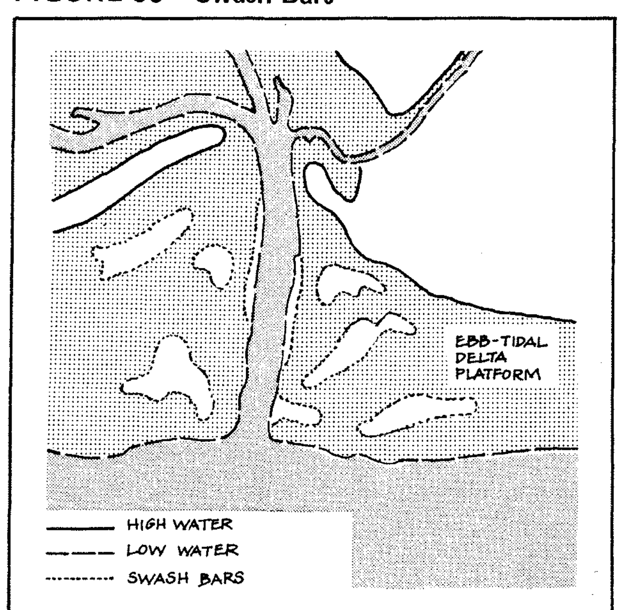
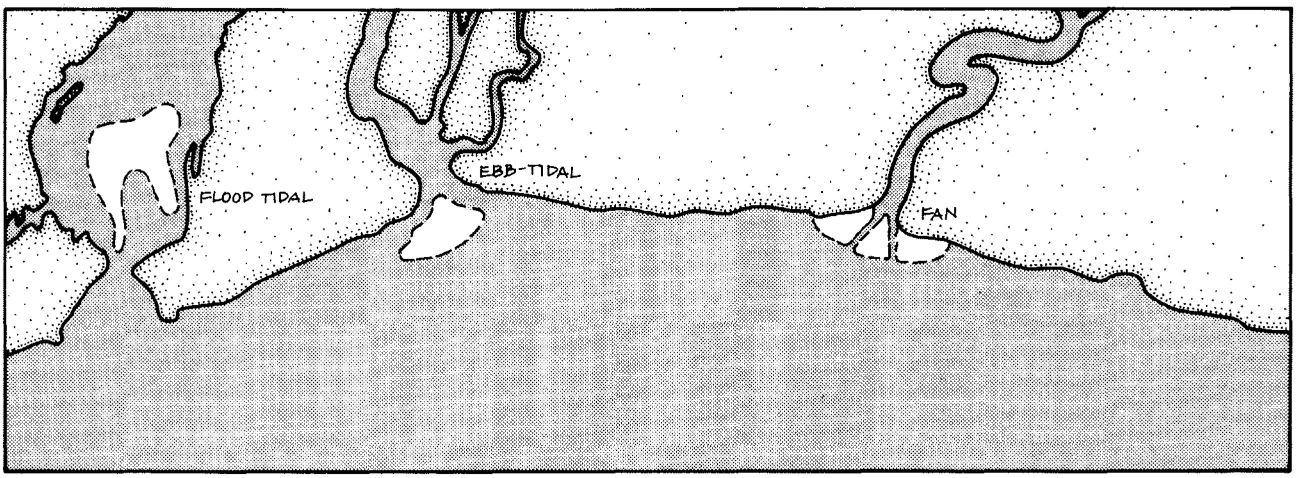


FIGURE 51 Flood Tidal, Ebb Tidal and Fan Deltas



Flood Tidal Deltas
Map Legend — Mf
Color — Flesh
Percentage of Total Coast Area Mapped—0.03%

Characteristics: These are lobate sand bars at the mouths of lagoons or enclosed embayments. During incoming tides sediments are transported from barrier beaches adjacent to the inlet into the estuary. They are deposited as current velocities rapidly decrease where the current enters the still waters of the back barrier estuary. Such deltas are actively reworked by waves and currents, and often show migrating sand "ripples" on their surface.

Importance: Deltas are an integral part of many valuable sand beach systems, due to their involvement in the seasonal transport of sand to and from beaches. They also regulate the flow of water into and out of estuaries. Thus, disturbance of deltas or their sediment sources may affect the productive estuaries with which they are associated by changing the natural flushing time and volume. These units can provide habitat for many beneficial and valuable species, including clams, horseshoe crabs, marine worms, striped bass, sanderlings, terns, eider ducks and loons.

Planning Considerations: Maintenance of deltas is dependent on a continued influx of wave-, current- or river-borne sediments. These sediment supplies can be cut off by dams built upriver or by construction on nearby beaches. The ever-changing nature of deltas and their close association with sensitive beach systems and estuaries make them unsuitable for development or construction, though clamming, hunting and fishing may be appropriate.

Ebb-tidal Deltas
Map Legend — Me
Color — Flesh
Percentage of Total Coast Area Mapped—0.03%

Characteristics: These are similar to flood-tidal deltas except that ebb-tide currents play a larger role in their creation and maintenance. They appear as lobate sand bars seaward of embayment inlet mouths that separate back-barrier beaches from the open ocean. Sediments originate as sand transported out of the estuary by ebb tides or from nearby beaches by littoral transport. Ebb-tidal deltas exhibit swash bars on their surfaces which migrate across the surface and into inlet channels or onto adjacent shores.

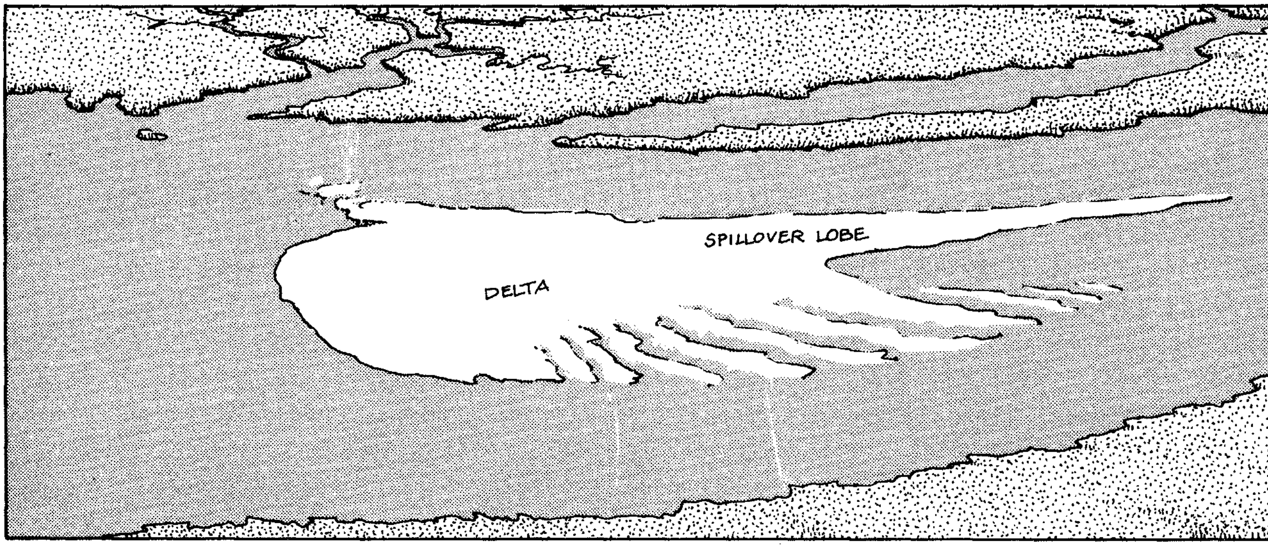
Importance and Planning Considerations: Similar to those for flood-tidal deltas (see above).

Fan Deltas
Map Legend — Mb
Color — Tuscan Red
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are fan-shaped accumulations of sand deposited by streams draining into intertidal areas with high tidal ranges. The apex, or head, of the fan is located at the point where the stream enters the nearshore zone from the upland. Stream water migrates from side to side across the fan surfaces at low tide, and swash bars form on the margins as fan sediment is reworked by waves.

Importance and Planning Considerations: Similar to those for flood-tidal deltas (see above).

FIGURE 52 Oblique Aerial View; Flood Tide Delta and Spillover Lobe

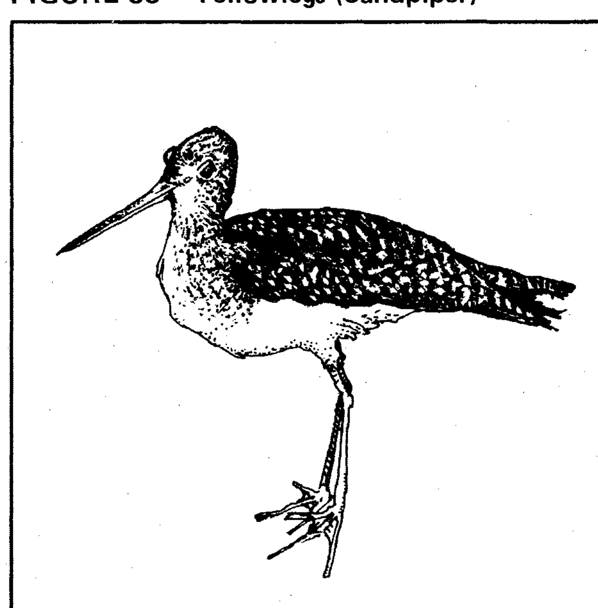


Spillover Lobes
Map Legend — Md
Color — Flesh
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are lobe-shaped sand bars extending from flood-tidal deltas into deeper channels or lagoons along flood-tidal delta margins. Spillover lobes tend to migrate up the estuary and may extend to marsh surfaces, forming washover flats (see page 43).

Importance and Planning Considerations: Similar to those for flood-tidal deltas (see page 57).

FIGURE 53 Yellowlegs (Sandpiper)



SUBTIDAL ENVIRONMENTS

Mud Flats (Subtidal)
Map Legend — Fm
Color — Burnt Ochre
Percentage of Total Coast Area Mapped—9.00%

Characteristics: These are fine-grained flats below the low tide mark that are similar to and usually adjacent to intertidal mud flats. They tend to occur in embayments or other places sheltered from heavy wave action where sediments derived from offshore deposits, river transport and eroding shorelines are brought in by tides and currents.

Importance: Though subtidal flats are often too far underwater to be harvested regularly, they are important habitats for clams and marine worms. As such they comprise a reservoir of these commercially valuable species that provides stock for replenishing heavily utilized intertidal flats. Subtidal flats are also crucial habitat for many of the food fish species caught by Maine fishermen.

Planning Considerations: Like intertidal flats, subtidal flats can be adversely impacted by any dredging or filling operations in the vicinity or by poor farming or construction practices on nearby uplands. Such activities can release an unnatural influx of sediments that may smother shellfish beds and toxic chemicals or heavy metals that are poisonous to marine organisms. Sewage discharges may increase the turbidity and lower the oxygen levels of the water above flats, often reducing the productivity of these environments as habitat for valuable fish and shellfish.

Coarse-grained Subtidal Flats
Map Legend — Fc
Color — Burnt Ochre
Percentage of Total Coast Area Mapped—5.00%

Characteristics: These are coarse-grained flats below the low tide mark that are similar to intertidal coarse-grained flats and often exist adjacent to them or to mud flats. They are formed from submerged glacial deposits reworked by storm waves.

Importance: These units provide habitat for clams, marine worms, fin fish and other valuable marine species, though they are generally less productive than mud flats due to the coarser nature of their sediments.

Planning Considerations: Similar to those for subtidal mud flats (see above).

Eelgrass Flats
Map Legend — Fe
Color — Apple Green
Percentage of Total Coast Area Mapped—3.00%

Characteristics: These are shallow, subtidal flats which support growths of eelgrass, Zostera marina. Eelgrass creates a current baffle, slowing the flow of water and inducing the deposition of fine- to coarse-grained sediments. Most eelgrass in Maine was destroyed by a blight in the 1930's, but in recent years many flats have been recovering, particularly in upper Casco Bay.

Importance: Eelgrass flats provide habitat for commercially exploitable populations of clams and marine worms, as well as for many other bottom-dwelling species. Various species of fish, waterfowl and shorebirds feed here, and the nutrients released by the decay of the eelgrass stands are important to a number of ocean food chains.

Planning Considerations: Similar to those given for subtidal mud flats (see above).

Seaweed Community
Map Legend — Fs
Color — Light Green
Percentage of Total Coast Area Mapped—2.30%

Characteristics: These are subtidal coarse-grained flats and bedrock ledges that support relatively dense growths of seaweeds.

Importance: Seaweed communities thrive with many species of valuable fish and shellfish, such as clams, mussels, and mackerel. In some areas of the state, various types of seaweed are commercially harvested from these environments.

Planning Considerations: Similar to those given for subtidal and flats (see above).

Upper Shoreface
Map Legend — Fb
Color — Sand
Percentage of Total Coast Area Mapped—2.00%

Characteristics: The upper shoreface consists of subtidal sand flats on the seaward margin of large sand beaches, extending from the mean low water mark to depths of about ten meters. It is an environment in which sediments are in constant movement due to wave activity.

Importance: The upper shoreface is a crucial component of sand beach systems, alternately receiving and stockpiling sand lost from beaches during storms and resupplying sand to the beachfront during periods of lower waves. It is also an important habitat for various marine shellfish and fish, including striped bass, surf and razor clams, sand dollars, and quahogs. As Maine's shellfishing industry expands its utilization of clams other than soft-shells, the commercial value of upper shoreface environments is likely to become more widely appreciated. (Further south along the Atlantic coast, surf and razor clams are both intensely harvested by clammers.) These are also prime areas for recreational surf fishing.

Planning Considerations: The upper shoreface is so closely tied to the fate of sand beaches that the planning considerations are identical (see page 48).

Lower Shoreface
Map Legend — Fp
Color — Aquamarine
Percentage of Total Coast Area Mapped—4.00%

Characteristics: The lower shoreface is the deeper, subtidal slope seaward of the upper shoreface beyond sand beaches. It grades from about ten meters below the low tide mark, where sediments are mostly sand, to about twenty meters down, where silt and clay predominate.

Importance and Planning Considerations: Similar to those given for the upper shoreface and subtidal mud flats (see above).

High-Velocity Tidal Channel
Map Legend — C1
Color — Violet
Percentage of Total Coast Area Mapped—0.02%

Characteristics: Tidal channels are low troughs running through intertidal and subtidal environments along which tidal waters flow as a current during ebb and flood tides. They generally develop in river channels submerged by rising sea levels or by headward erosion of currents into subtidal and intertidal flats. High-velocity tidal channels are those in which water velocities exceed two meters per second. They are usually lined with pebbles and cobbles or bedrock.

Importance: Tidal channels play a critical role in carrying salt or mixed salt-and-fresh waters and the organic nutrients suspended in them to and between various nearshore environments, particularly in estuarine systems. Thus, by affecting both salinity levels and nutrient levels, these channels can have profound influences on shellfish and fish productivity in the areas through which they flow. They also provide, in themselves, habitat for many commercially valuable shellfish and fish, including clams, striped bass, alewives, and crabs.

Planning Considerations: The most basic threat to tidal channels is man-made obstruction of the flow of water through them, which can be caused by dams inland, by seawalls and other shoreline structures built along the shores, or by dredging and filling operations.

Medium-Velocity Tidal Channel
Map Legend — C1
Color — Purple
Percentage of Total Coast Area Mapped—0.90%

Characteristics: These are similar to high-velocity tidal channels except that they are usually lined with mud, sand or bedrock and exhibit water flows of between one and two meters per second.

Importance and Planning Considerations: Similar to those given for High-Velocity Tidal Channels (see above).

Low-Velocity Tidal Channels
Map Legend — C3
Color — Pink
Percentage of Total Coast Area Mapped—1.50%

Characteristics: These are similar to high-velocity tidal channels except that they are usually lined with mud and exhibit water flows of less than one meter per second.

Importance and Planning Considerations: Similar to those given for high-velocity tidal channels (see above).

Estuarine Channel
Map Legend — C4
Color — Cream
Percentage of Total Coast Area Mapped—0.70%

Characteristics: These are tidal channels at the mouths of rivers and streams that contain mixed or stratified salt and fresh waters flowing at low or high velocities, depending on the particular conditions.

Importance: Estuarine channels are one of the most important components of our productive estuarine systems, providing feeding, breeding and nursery grounds for dozens of valuable marine species including herring, smelt, flounder, pollack, shad, menhaden, alewives, clams, mussels, lobsters and crabs.

Planning Considerations: Like other environments making up estuarine systems, estuarine channels are very sensitive to alterations in the volume of water flowing into and through them, such as can be caused by dams upriver, seawalls and other structures built along the shoreline, or dredging, filling and draining activities. The productivity of these channels as a habitat for commercially important fish and shellfish may also be imperiled by sewage, chemical and pesticide pollution as well as by increased sediment loads resulting from logging, agricultural activities or construction on nearby uplands.

Estuarine Ebb Channel
Map Legend — C6
Color — Blue Violet
Percentage of Total Coast Area Mapped—0.08%

Characteristics: These are estuarine channels carrying mixed salt-and-fresh waters in which water flow is dominated by ebb-tide currents.

Importance and Planning Considerations: Similar to those given for Estuarine Channels (see above).

Estuarine Flood Channel
Map Legend — C5
Color — Blue Violet
Percentage of Total Coast Area Mapped—0.08%

Characteristics: These are estuarine channels carrying mixed salt-and-fresh waters in which water flow is dominated by flood-tide currents.

Importance and Planning Considerations: Similar to those given for Estuarine Channels (see above).

Inlet Channel
Map Legend — C7
Color — White
Percentage of Total Coast Area Mapped—0.05%

Characteristics: These are high-velocity tidal channels that cut through barrier beaches to connect back barrier marshes or lagoons with the open ocean. Inlet channels terminate landward on flood-tidal deltas and seaward on ebb-tidal deltas. Their shape and width varies with the local tidal, wave and current characteristics; the bottoms are usually lined with sand and gravel.

Importance: Inlet channels maintain sediment transport between coarse-grained estuaries and beach systems. They are an integral part of the beach sediment supply, maintaining equilibrium between sand supplies in the lower estuary and the beach system. They also serve as lanes of travel for estuarine-dependent fish and shellfish species moving between the sea and estuaries or lagoons.

Planning Considerations: Similar to those for estuarine channels (see above).

Dredged Channel
Map Legend — Cs
Color — Purple
Percentage of Total Coast Area Mapped—0.03%

Characteristics: These are man-made or enlarged and deepened inlet, tidal and estuarine channels that exist in their present form as a result of mechanical dredging.

Importance: Most dredged channels are primarily important as navigable waterways, the basic purpose behind such alterations.

Planning Considerations: Dredged channels may have severe adverse effects on surrounding natural environments if they significantly alter sedimentation rates, water flow or other processes. Dredging can be desirable to increase the flushing rate of an embayment; however, before any dredging project is begun, careful investigation of potential environmental side-effects is both wise and legally required.

Abandoned Tidal Channels
Map Legend —Cb
Color — Orange
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are the remains of former tidal channels no longer transporting enough water to erode or maintain the channel boundaries. Some abandoned channels are isolated because of human alterations to the course of the active main channel. They also occur naturally in salt marsh tracts where the main channel has meandered, taking a "short cut" and bypassing a formerly active channel segment.

Importance: If not entirely cut off from the main channel, abandoned tidal channels may provide habitat for juvenile fishes and feeding grounds for wading birds.

Planning Considerations: In time, abandoned channels may become a salt panne or fill in with marsh plants and become part of the surrounding high salt marsh. Either way, they are so closely tied to the high salt marsh that general planning considerations are the same as for that unit (see page 45).

Channel Slope
Map Legend — Cs
Color — Cold Medium Grey
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are moderately sloping margins of subtidal channels which occur where deposition of mud and silt builds up on the sides of a channel. (Most channel walls are too steeply sloping and too erosional to exhibit channel slopes.)

Importance: Channel slopes provide additional habitat for clams, marine worms and other bottom dwelling organisms. Exposed upper slopes provide feeding grounds for great blue herons, snowy egrets and other wading birds.

Planning Considerations: Depend on the type of channel where the channel slope occurs.

Tidal Creeks
(No Map Symbol or Color)
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are small channels or creeks draining intertidal flats and salt marsh areas which are dominated by ebb-tidal flow. Tidal creeks are usually lined with mud or sand.

Importance: Though small in area and extent, tidal creeks provide crucial habitat for many species of juvenile marine fishes (including herring, flounder, pollack, shad, menhaden, and alewives), various shellfish and marine worm species, and feeding grounds for many types of waterfowl, shorebirds and wading birds.

Planning Considerations: Similar to those given for high marsh environments (see page 45).

Tidal Fluvial Channel
Map Legend — Cf
Color — Olive Green
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are tidal channels in the lower segments of rivers entering large estuaries. They are subject to the rise and fall of the tides, but carry only fresh water. (The Kennebec River between Merrymeeting Bay and Augusta is a good example.)

Importance: Tidal fluvial channels provide habitat or feeding grounds for a great variety of wildlife, particularly waterfowl. Black ducks, goldeneye ducks, mergansers, loons, Canada geese, ospreys and eagles are among the many species found here at some time during the year. Such channels are also important to various freshwater and anadromous fish, including alewives, shad and salmon.

Planning Considerations: Dams can block the entrance of anadromous fish to this environment unless fishways are incorporated into them. Another common problem is pollution by sewage effluent, toxic chemicals and pesticides, which can drastically reduce the productivity of tidal fluvial channels and associated estuaries. A particularly insidious effect of pesticides is that they tend to accumulate in the tissue of waterfowl, osprey and eagles, often reducing breeding success.

Marsh Drainage Ditch
(No Map Symbol or Color)
Percentage of Total Coast Area Mapped—0.01%

Characteristics: These are man-made rectilinear channels dug in saltmarsh tracts during the 1930's and 1940's to eliminate mosquito breeding habitat by drying up marsh tracts.

Importance: Undetermined.

Planning Considerations: The practice of draining salt marshes to reduce mosquito populations was generally replaced by pesticide application after WW II. Both methods threaten the productivity of salt marsh environments, upon which Maine's commercial fishing and shellfishing industries ultimately depend (see page 46), and are now subject to strict regulations. In time these ditches will naturally fill in with mud and salt marsh vegetation again, though various tactics can be used to speed up this healing process.

Beach Erosion, Popham—1976 *photo Ken Fink*

CHAPTER 4:
THE DISAPPEARING SHORELINE

The final part of our discussion of Maine's coastal geology deals with a special geology-related problem—shoreline erosion. It is a problem that has affected millions of dollars worth of shorefront property in Maine over the years and one that will probably continue to concern coastal residents for a long time to come.

The primary concern of most coastal residents, of course, is the erosion of shoreline environments that lie above the mean high water mark. Thus, the following discussion is limited to the three basic types of erosional shores common to Maine: beaches, scarped shorelines of unconsolidated materials, and bedrock ledge.

For very useful additional information regarding the erosion of various shoreline types, planners should consult the Coastal Program's "Shoreline Erosion Inventory Maps." This series of twenty-nine 1:48,000 scale maps indicates the various erosional conditions that generally exist along segments of the Maine coast. By revealing the general rates of erosion in a given segment, the maps can be of great help in indicating the scope of erosion problems and in designing site studies of local conditions for solutions that conserve shoreline property, prevent damage to structures, and avoid the unnecessary loss of natural shoreline resources. Like the Marine Environments Maps, they can also be useful for long range planning.

Copies of the Shoreline Erosion Maps may be obtained from the Maine Geological Survey, Department of Conservation, Augusta, ME 04333.

Beach Erosion

The way erosional process agents such as winds and waves will affect a beach depends largely on: 1) the size of the "constituent particles" making up the beach (which can range from tiny sand grains to sizeable boulders), and 2) the amount of wave action that reaches the area. So-called "high energy beaches" are those exposed to the full force of storm waves generated in the Gulf of Maine. These generally consist of sand or gravel and boulders. "Low energy beaches" border relatively protected bays, where wave heights and strengths are far less than those generated in the open Gulf. The makeup of such beaches ranges from pure sand to small-sized gravel or mixtures of both.

In terms of human use, the most valuable Maine beaches are those in which the major sediment is sand. The bulk of our large, recreational sand beaches is found along the state's southwest coast, from the Sheepscot River to Kittery. Most are barrier spits, separating large saltmarshes from the open ocean. Almost all are subject to seasonal erosion and some are more subject to long term erosion.

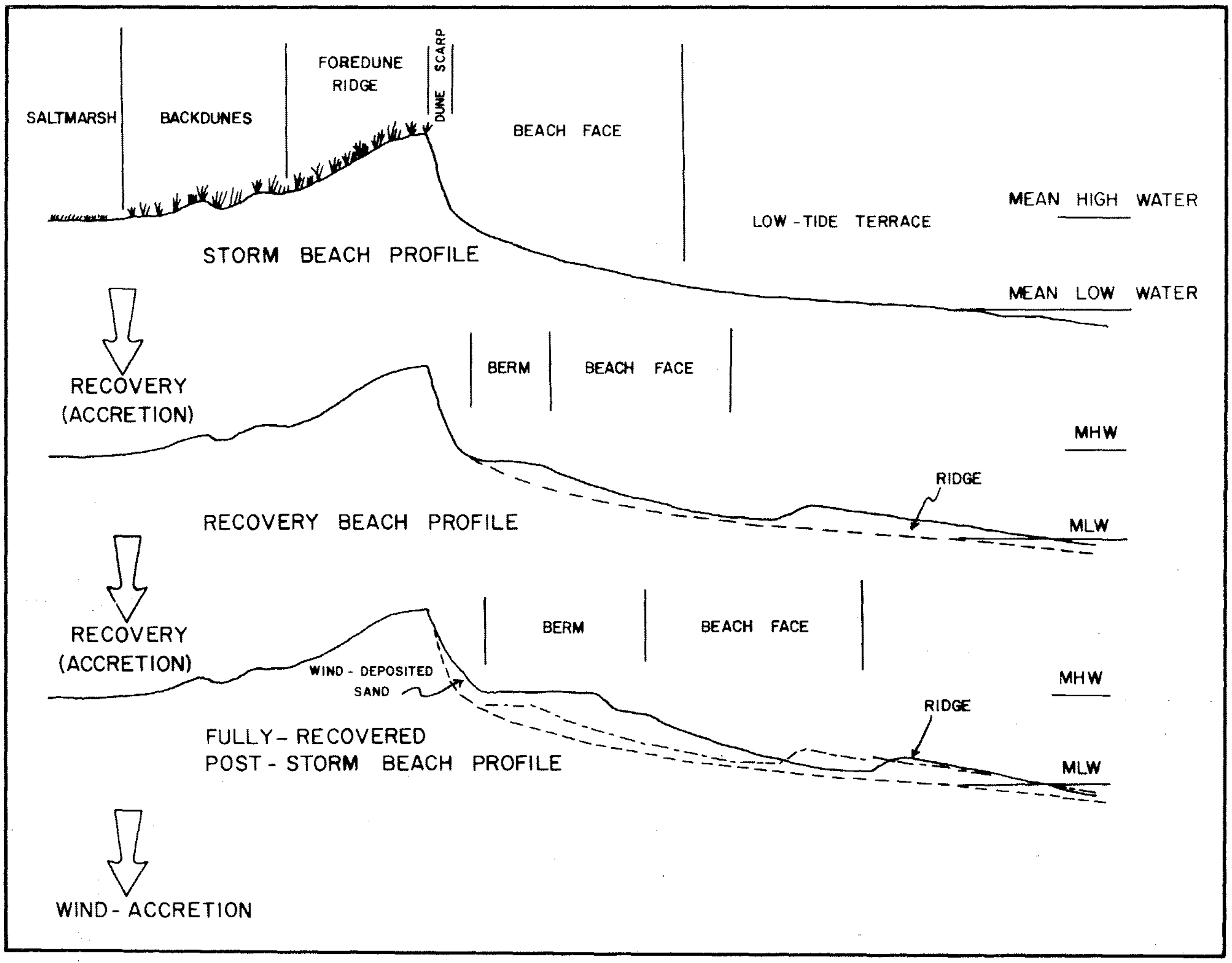
The seasonal variations can be seen by comparing the summer and winter profiles of sand beaches. After a heavy winter storm, sand beaches tend to have a smooth, concave profile. Wave action often cuts a broad scarp, or bank, into the foredune ridges and sand eroded from the beach and dunes is transported a short distance offshore.

Most of the time, the majority of this sand is returned to a beach by the lower wave action of calmer weather when the storm is over. Such "post-storm beach recovery" is usually associated with the building of a berm, or ridgelike strip of sand, on the upper portions of the beach. Renewal of this berm usually takes about two weeks. It is a natural process that works to protect the foredunes from severe erosion, since wave energy from succeeding storms is expended on the renewed berm and not on the dune fields. If a beach has not fully recovered its berm by the time the next storm passes along the coast, much more severe erosion of the foredunes is likely to occur.

During the spring, summer and early fall months, sand beach profiles are built up rather than eroded (or, as scientists would say, they are "accretional" rather than "erosional"). The long, low waves common during the less stormy, warmer months transport sand deposited offshore by winter storms back to the beach. The southerly winds that predominate at this time tend to blow sand from the fully recovered beach and berm onto the foredunes, eventually filling in the characteristic scarp cut by severe winter storms. Soon, if the beach system is a balanced one, the foredunes are widened and heightened back to their pre-winter dimensions.

Beyond this seasonal erosion cycle, there is also long term erosion occurring on Maine beaches as a result of the slow rise in sea level and storm processes. As the sea level rises (at the almost imperceptible rate of about one inch per decade) marine process agents encroach further into the dune-beach system. Sand is removed from the frontal beach and foredunes and is transported by wave washover to the

FIGURE 54 Sand Beach Profiles



back of the dune field, causing a progressive landward migration of the entire system. If this migration is not interfered with by coastal development, the size of the beach and the dune fields remains about the same over time.

To people who have built summer homes or other structures along the beachfront, however, the natural process of landward migration is often viewed as a severe erosion problem that should be stopped. In the past, this has usually led to the construction of seawalls, built in the hope of stabilizing the naturally dynamic dune-beach system.

Unfortunately, scientists have determined that seawalls often speed up beach erosion (see page 71). Thus, landowners who build seawalls to protect their property must realize that, depite their intentions, they are probably accelerating rather than slowing down the loss of valuable sand beaches.

Another serious threat to beach systems is devegetation of dunes. Devegetated dunes are far more vulnerable to erosion by winds and waves than those protected by a thick cover of natural vegetation. And the increased mobility of loose sand raises the chance of its being permanently lost from the beach system.

Although devegetation of dunes sometimes occurs when stands of beach grass die from diseases, unmanaged foot traffic and development are the most common causes. Fortunately, dunes can often be saved by revegetation programs (see page 70) that may involve nothing more complex than restricting pedestrian traffic to controlled access points.

Gravel beaches generally occupy shallow indentations of the shoreline where nearby uplands are composed of glacial sediments, or "till." These beaches are characteristically small and are backed by either saltmarsh or by low or high banks, or scarps.

The profiles and erosional cycles of gravel beaches are much like those of sand beach systems, but the greater size of the constituent particles creates a steeper, narrower beach that responds more quickly to changing wave action. A gravel beach is made up of a storm ridge (similar to the foredune ridge on sand beaches) and the beach proper.

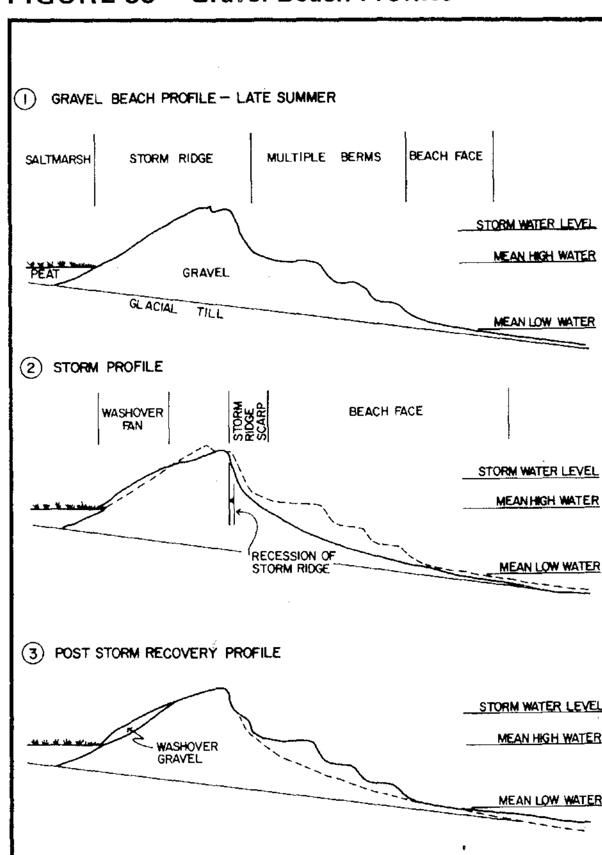
The force of winter storm waves erodes the storm ridge and beach, giving the whole a smooth, concave profile similar to that of dune-beach systems. Within a week after a storm passes, gravel beaches recover to a profile of two to three berms, as most of the gravel removed by storm waves is returned immediately to the beach from offshore. This quick recovery creates an almost instantaneous wave energy barrier, that makes gravel beaches much less prone to severe erosion than sand beaches.

Long term erosion of gravel beaches parallels that of dune-beach systems. As sea level rises, the gravel beach and storm ridge "migrates" inland slowly but steadily. However, washover is far more frequent than on sand beaches.

Although gravel beaches are not often developed by man, roads are sometimes built directly behind storm ridges as a means of access to points of land. The washover phenomenon frequently necessitates constant repair of these roads. Obviously, in planning the locations of future roads and other shoreline structures, problems can be avoided if gravel beaches are given a wide berth.

A similar kind of environment, mixed sand and gravel beaches, occurs just seaward of shoreline margins eroded into thick deposits of glacial sands and gravels where wave energy levels are far less than on the open ocean. The profile of this type of beach responds to seasonal wave action much like gravel beaches do. Storm waves lower the beach profile temporarily, but beach material is soon returned in calmer weather by wave transport as well as by weathering of the scarp, or bank, above the beach.

FIGURE 55 Gravel Beach Profiles



Long term recession of sand and gravel beach-scarp shorelines is accomplished by wave erosion of material at the bottom, or "toe," of the scarp accompanied by erosion of the upper surface due to rain and other weathering processes. As sea level rise continues, so too will shoreline recession in such areas, thus any buildings or other structures built too close to the scarp may someday be in danger of resting on unstable ground.

The last type of beach common to Maine shores are low energy beaches. They occur in relatively protected places where the shoreline intersects unconsolidated surficial deposits of sand and gravel.

Low energy beaches exhibit very low recessional rates. Continued sea level rise and weathering causes some erosion, but it is much slower than on other beaches, since banks bordering low energy beaches are rarely impacted by heavy waves.

Erosion exhibited by Maine beaches in the recent past has varied greatly, at times reaching up to 185 feet of dune line recession annually. Generally, however, low energy beaches recede at a rate of less than one foot per year; occasionally, up to five feet. High energy sand beaches recede at an annual rate of about two feet, though storms may cause recession in high erosion areas to exceed 25 feet annually.

Erosion of Scarped Shorelines

The erosion and subsequent recession of shoreline scarps, or embankments, presents a constant but often unrealized hazard to coastal residents. One reason for this lack of awareness is the fact that the instability of a piece of shoreline property is not always apparent upon cursory inspection by potential buyers or builders. Also, the potential for drastic shoreline bank erosion can increase significantly as an indirect result of development levels in the immediate area.

In the natural scheme, shoreline scarp erosion rates are related to two basic factors: the degree of exposure to heavy waves and the "erodibility" of the material the bank is made of. Generally, the less consolidated the material and the more exposed it is to the open ocean, the faster and more severely it will erode.

Scarps made of loosely packed sand and gravel, for example, are extremely sensitive to gravity and weathering forces. They tend to respond to dislodgement and undercutting by waves very rapidly. Because of particle instability, most sand and gravel scarps are bare of vegetation. There is too much down-slope movement of the substrate for plants to take root and stabilize the slope.

Glacial till escarpments, composed of a compacted mixture of sediments ranging in size from clay particles to boulders, tend to erode at a slower rate than those made of sand and gravel. The cohesiveness of the sediments make such banks more stable, allowing vegetation to take hold and increase stability even further.

Nevertheless, constant undercutting by waves and currents can create unstable conditions on the upper slopes, often causing glacial till banks to recede at rates of one to several feet annually.

Embankments composed of marine clay—the most common type of shoreline scarps in Maine—are also subject to steady erosion and recession. In contrast to other scarps, however, banks of marine clay also exhibit extreme erosion hazard due to occasional small- and large-scale landslides.

Landslides on clay scarps may occur instantaneously and without warning, especially during the wet late winter and spring months. This is usually a response to oversteepening of the lower scarp as a result of wave action.

For example, three days after a late January thaw in 1973, some 75,000 square feet of residential upland abruptly slid into the northern margin of Rockland Harbor when five large blocks of marine clay slumped onto the tidal flats below with no previous warning or obvious sign. Fortunately, no loss of life or damage to buildings occurred. But where one resident once had an expansive back yard of 200 feet between his house and the edge of the bank, he now has less than 50 feet.

The planning considerations that revolve around shoreline scarps made of marine clay are rather evident, and hold true for banks made of sand and gravel of glacial till as well. As a general rule, it is unwise—and possibly dangerous—to build near the edge of scarps, though the safety margin deemed appropriate varies greatly from site to site. (Expert advice should be sought in making such decisions about the appropriate amount of setback.) In the case of extremely unstable or landslide-prone banks, it may even be a good idea to prohibit pedestrian traffic for safety's sake.

Erosion of Rocky Shorelines

Many people think of the rocky shores common to many parts of Maine's coast as shorelines in equilibrium that neither erode nor recede. In actuality, shorelines composed of ledge are weathering and eroding, but at extremely slow rates which pose almost no hazards along the lines of those associated with scarps.

Recession of bedrock shores is primarily dependent on the amount, spacing and direction of fracturing within the bedrock. As ice freezes and expands in these fractures it loosens bedrock fragments, sometimes allowing them to be dislodged and moved by heavy waves. The rate of bedrock recession is so slow, however, that it can usually only be measured over long spans of time—hundreds and thousands of years. Thus, rocky shorelines create erosional hazards requiring a planning response only in extremely rare cases.

DEALING WITH SHORELINE EROSION

In recent decades, efforts to prevent or "mitigate" erosion of shoreline beaches, dunes and scarps have taken many forms. The techniques developed have had varying success. Some have had no success at all. Some have even had the opposite effect of what the builders intended, making erosional problems worse instead of better. The costs involved have also varied greatly.

The techniques described in this section are those which are most commonly used in Maine. They have also been chosen with an eye toward affordability. Each is within the realm of being financed by either private individuals or towns, or is the kind of project for which municipalities can receive financial assistance from federal agencies.

It should be stressed that whether an erosion mitigation technique will be effective depends on the particular conditions existing at each shoreline site. Thus, a very complex array of variables must be taken into consideration in choosing and planning the most appropriate solution for an erosion problem. The reader should also be aware that the implementation of most of these techniques is subject to state regulation.

Near the end of this chapter are lists of state and federal agencies that can provide expert advice and assistance to individuals and towns considering some kind of erosion mitigation program. It is strongly urged that before any of the techniques described—or any others—are tried or even considered, the relevant agencies be contacted.

Some Basic Considerations

Because erosion of the shoreline is a natural and continuing process, it is an extremely important factor to owners or potential owners of shorefront property. In fact, the local rate of shoreline recession is one of the first things that should be investigated by anyone considering the purchase of a piece of land along the shore.

Coastal properties in different areas are subject to different shoreline erosion conditions. They also exhibit different rates of shoreline recession, ranging from negligible on bedrock headlands to extremely variable and unpredictable on beach and dune systems. Severe erosion of beaches and dunes may not occur at a steady, predictable annual rate; more likely, it will occur unexpectedly, as a result of an especially severe winter storm coupled with an unusually high tide. Moreover, a beach and dune system which has been stable or even growing for a number of years may respond to disturbances or changes in its source of sand supplies, in the pattern and strength of littoral currents transporting that sand, or in the shape and location of shoreface deposits, such as sand bars, just offshore. Thus, particularly during a winter storm, the beach's response may be to show severe erosion in places where it has not been evident in the recent past.

The safest course of action for a property owner in this uncertain environment is either to make plans for moving structures of value to more solid ground if necessary, or to be prepared for eventual destruction of their buildings at some unpredictable future time.

Seawalls and other man-made shoreline protection devices are expensive alternative responses, and they may be ineffectual during severe storms when they are needed most. In many cases they accentuate erosion problems. As a result, protective structures must usually be viewed as temporary solutions at best.

Some coastal properties are located on shoreline environments that are eroding at a more constant, and therefore more predictable, rate than beaches and dunes. These rates can be estimated by measuring the distance from a fixed point (the corner of a building or a stake) to the top of the shoreline bank and maintaining an annual record of shorefront recession.

After three to five years, such records will make it possible to estimate the average annual recession rate in feet or inches. Then, the remaining distance between the edge of the shoreline and any buildings can be divided by the annual recession rate to give the approximate number of years before the structures will be threatened by erosion. (The Shoreline Erosion Maps described on page 65 can also be helpful in making these estimates.)

In some cases, various factors may affect the reliability of a property owner's estimates, including any projects in the vicinity that involve shoreline alteration, protection, or dredging. Such projects can accelerate or slow down erosion rates of the shorefront by disrupting natural sediment transport and altering wave effects at the shoreline. As a result, it is wise to get the help of a certified geologist at this stage. A geologist can ascertain the exact type of erosion problem or problems being faced, and confirm the magnitude and rate of the erosion threat. He will also be able to suggest appropriate mitigation techniques and estimate what their side effects on the physical environment might be.

Next, the services of a professional engineer should be obtained if the erosion problem requires the construction of some kind of protective device, like a seawall or revetment. The engineer, working closely with the geologist, may be able to design a structure that is appropriate to the conditions of the site and which will withstand the forces creating the erosion without unnecessary or continual maintenance. However, it is possible that the geologist and engineer will decide that the erosion problem cannot be dealt with in an environmentally or economically acceptable way. In such cases, the owner may have to consider other alternatives: moving his structure back from the shoreline, seeking financial and technical assistance from State or Federal agencies, or—in a few instances—abandoning the property.

If an erosion mitigation technique is attempted by a shorefront property owner, certain steps must be taken in the planning stages. Before any alteration of an intertidal area can be made, permits must be secured from the town in which the project will be located, from the Department of Environmental Protection's Bureau of Land Quality, and from the U.S. Army Corps of Engineers. In making the proper applications, the property owner should be able to describe exactly what he or she proposes to do. It will be necessary to provide information, for example, about the specific nature and dimensions of proposed projects or activities as well as details of any potential environmental side effects. Once again, this suggests the need for expert help.

The interests of owners of property next to development sites, as well as those of the general public, are recognized in existing land use laws. Shoreland zoning, coastal dune and wetland, aquaculture lease and fish weir laws all provide for notice to abutting owners and traditional users through direct notification, public notice and public hearings. Applicants for a permit under these lease or license laws must provide specific information about their plans. Public notices and public hearings provide everyone—particularly neighbors and traditional users of an area—opportunities to present their views and discuss their interests with the board deciding on an application. And under current laws, the burden of proof showing that a project will have no adverse effects on the property of nearby landowners rests with the permit applicant.

Preventing Erosion of Beaches and Dunes

One of the most frequent and frustrating erosion problems facing Maine's coastal residents is the erosion of sand beaches and dunes. Often, it is a problem complicated by the fact that valuable private property and buildings are threatened as the beach system recedes landward, and by the fact that former attempts to slow down erosion have instead accelerated it.

The three most commonly employed techniques of mitigating erosion of this nature are: 1) promoting the growth of dune vegetation; 2) constructing some kind of shoreline protection device, such as a seawall or revetment, and; 3) replenishing the sand lost to erosion with new sand.

PROMOTING DUNE GROWTH

Whenever possible, one of the most attractive and effective ways of preventing shoreline erosion is to take advantage of the natural barriers that already exist—coastal sand dunes. Scientists have determined that beaches, dunes and the sea maintain a delicate balance of give and take. In the natural scheme, the dunes resupply the beaches with sand through wave action, while the sea and wind carries in new sand to restore the dunes. During a storm, the energy of heavy waves is expended on the lower, or foredune, ridges. The upper, or secondary, dune ridges are protected from severe erosion in part by the foredunes and, to an even greater degree by the surprisingly strong, interwoven root mats of the beach grass that grows on them, holding the bulk of the sand firmly in place. these secondary dunes, extending up to twenty feet above the high tide line and fifty feet in width, effectively shield the land of the upper shore from erosion. Equally important, any permanent structures *placed well behind the dune fields* will also be protected.

Unfortunately, this natural barrier cannot permanently prevent wave breaching or continual erosion where sources of sand are lacking or have been cut off by man made obstructions such as seawalls. Nor can they continue to maintain their protective role if the crucial, anchoring growths of beach grass are destroyed. But in areas where development has not completely disrupted the dynamic balance between sea, beach, and dunes, it is possible to successfully work with nature toward forestalling serious shoreline erosion and resulting property damage.

In terms of preventing erosion, the key element in this technique is the promotion of beach grass growth. It can be accomplished most easily over several consecutive summer seasons by installing snow fence around sparsely vegetated dune areas. Snow fencing prevents foot traffic from trampling and eventually killing the grass. At the same time, it allows the wind to blow dry sand from the beaches onto the dunes. Such windblown deposits of sand are very important. They tend to promote beach grass growth, which entraps even more windblown sand, thus heightening and widening the erosion-combating dune ridges.

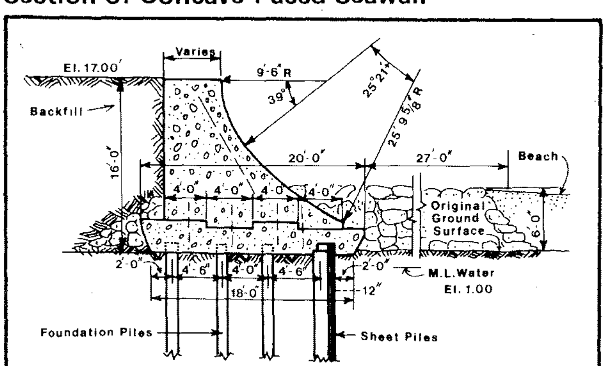
In dune areas where beach grass is nearly or totally absent, it may be necessary to begin the process by planting beach grass "springs." (Springs of beach grass, *Ammophila breviligulata,* are available in quantity from commercial greenhouses in New Jersey. Planning assistance for a dune vegetation program can be obtained from the Maine Geological Survey (State Office Building; Augusta, Maine 04333; Tel. 289-2801), the U.S. Soil Conservation Service (U.S.D.A. Building; Orono, Maine 04473; Tel. 866-2132), and the Ira C. Darling Center (Walpole, Maine 04573; 563-3146).

TECHNIQUE COSTS: from $3.00 per running foot for snow fencing, posts and installation.

Seawalls

In the past, one of the most frequently used tactics aimed at mitigating beach erosion has been the construction of seawalls. Although this can sometimes be an effective technique, seawalls often speed up rather than slow erosion problems (see below). For this reason, it is always wise to study alternative solutions and the specific conditions of the site before planning or building a seawall to make sure it is the best possible response to the situation.

FIGURE 56
Section of Concave Faced Seawall



Seawalls may be vertical or concave-faced walls constructed of poured concrete and reinforcing steel, stone, or stone-filled pile-and-timber cribworks that are situated on the landward margin of the beach in front of any dune fields that might exist. Past experience by the builders of such structures has led to the formation of a number of general guidelines for seawall construction.

Generally, for example, seawalls should extend into the sand below the surface of the beach at least one-and-a-half times farther than the exposed height of the wall. The face of the wall should be smooth, with no protruding corners, angles or buttresses. Irregular faces tend to break down under the force of heavy waves much faster and should be avoided.

When new seawalls are constructed next to existing ones, they should be placed so that the wall faces are oriented in the same direction. Isolated walls should be flanked by "wing walls" extending well back from the front to prevent, or at least reduce, the severe erosion of sand that sometimes takes place at the ends of seawalls.

The shape of the wall face is also important. Straight vertical walls tend to reflect wave energy back over the beach, thereby accelerating erosion in many cases. A concave wall face can diminish wave overtopping, but still focuses wave energy on a small area of the beach. On the whole, vertical planarfaced seawalls are no longer recommended as erosion prevention structures due to their adverse effects on beach systems.

Under some conditions, seawalls and other shoreline protection devices can actually accelerate rather than slow down beach erosion. This unintended side effect may occur for a number of reasons:

1) seawalls can reflect storm waves back over a beach area for second time, causing a greater amount of sediments to be eroded by the same wave;

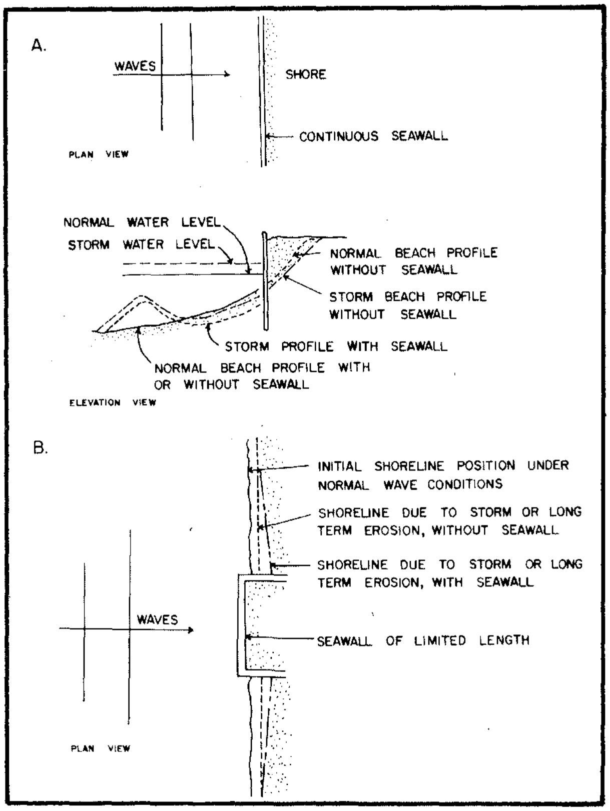
2) seawalls may prevent low summer waves from replenishing the beach with sand from offshore deposits;

3) seawalls constructed at the dune-beach boundary may prevent sand stored in the dunes from replenishing storm-eroded beach sand and keep back beach sand from replacing sand eroded from the dunes by winds or waves; and,

4) isolated seawalls may concentrate storm wave energy at each end of the structure, causing unprotected adjacent areas to erode much faster than if no seawall were present.

Costs: $75-150 per linear foot.

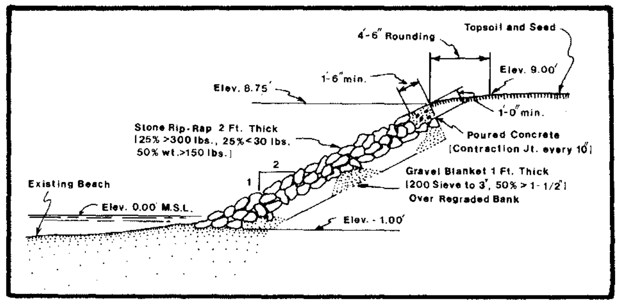
FIGURE 57
How Seawalls Can Accelerate Beach Erosion



Revetments

Revetments—retaining walls built of large stone blocks—are another common structure used to mitigate beach erosion in Maine. This is particularly true along the southern and mid-coast areas due to the availability of large blocks of stone from nearby quarries. Many experts believe stone revetments are a better choice than concrete seawalls in circumstances where a retaining wall is used. they are not only less expensive than concrete walls, but also less prone to reflecting wave energy back over a beach, a phenomenon which can accelerate erosion dramatically.

FIGURE 59 Typical Stone Rip-rap Revetment



The drawbacks of revetments are that they are more susceptible to wave damage, due in part to the tendency for a wall to sink into the sand under its own weight and because individual blocks of stone are sometimes dislodged by intense storm waves.

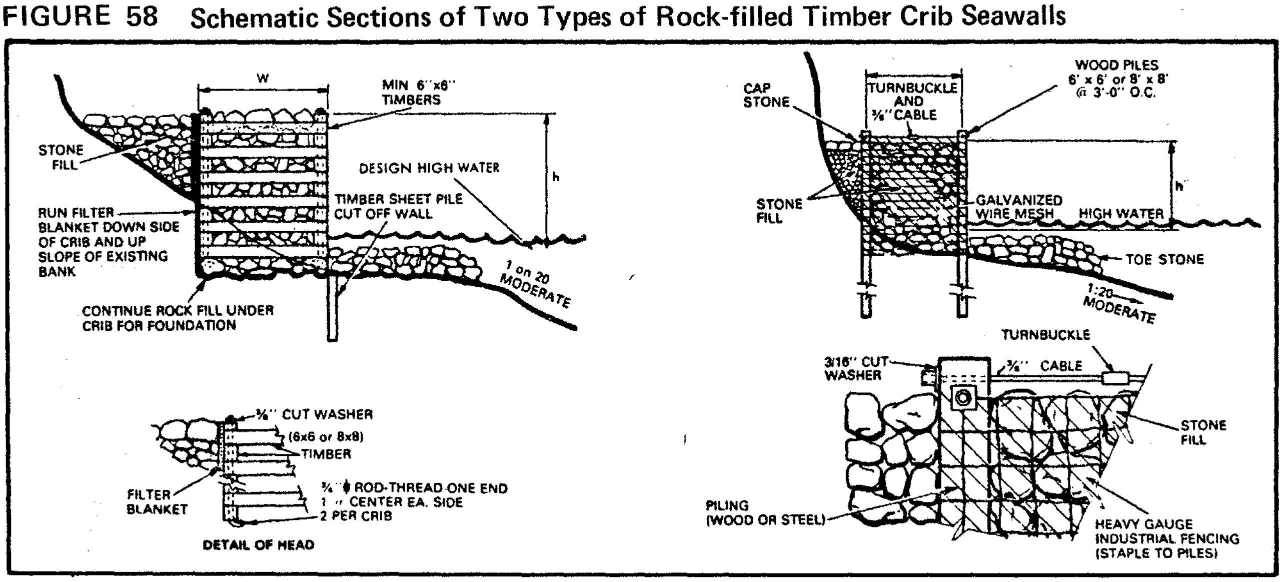
In building a revetment, these drawbacks should be taken into consideration. For example, walls constructed of very large blocks should be buried five to eight feet below the beach surface, and strategic blocks at wall corners should be pinned to prevent dislodgement. As in the case of seawalls, wing walls are also recommended for revetments, extending landward from each end, in order to avoid erosion problems at these points. Finally, the stones used should be of variable size and heavy enough to resist being moved by storm waves. Stones in the 200 to 500 pound range are considered best.

Costs: $75-100 per linear foot

Rock-filled Timber Cribbing

In some parts of Maine, rock-filled timber cribbing has been effectively used as an erosion mitigation technique. This is a type of retaining wall

FIGURE 58 Schematic Sections of Two Types of Rock-filled Timber Crib Seawalls



framed with railroad ties and heavy industrial fencing and filled with rocks ranging in weight from 30 to 50 pounds. Timber cribbing is relatively inexpensive and reasonably attractive. In addition, although the faces are vertical, their boulder-filled walls generally absorb some wave energy, lessening the amount of energy reflected back over the beach.

Costs: $50-75 per linear foot

Beach Replenishment

Beach replenishment is the addition of sand to an existing beach to widen and heighten it. It is based on the concept that the best way of preventing storm damage to shorefront structures is to maintain a wide, "healthy" beach between them and the ocean. Beaches absorb the impact of heavy waves and reduce the amount of wave energy that can reach the uplands and any buildings there.

Though beach replenishment programs can be very effective, they are also quite expensive, usually requiring financial backing by state or federal agencies. The Army Corps of Engineers, in particular, promotes and helps implement this method as the best approach to shoreline protection that at the same time preserves the beach as a recreational resource.

Sand for beach replenishment programs is usually provided by excavating inland glacial deposits, by dredging submerged sand from offshore deposits, or from channel and anchorage dredging in the vicinity of an eroding beach. Before a program begins, temporary protection of backshore structures can be provided by bulldozing sand from the lower beach up against the frontal dunes or a deteriorating seawall. This affords protection, however, only for the duration of one northeast storm in most cases and requires a permit from the Department of Environmental Protection.

Costs: Variable—public assistance funding is usually required.

Preventing Erosion of Channel Banks

Occasionally, due to adverse man-made or natural causes, it may be necessary to employ erosion prevention techniques to stabilize tidal or estuarine channel banks. This is usually accomplished by the construction of retaining walls designed to protect the banks from currents or waves generated by passing power boats.

Channel retaining walls are generally constructed of timber planking and piles or steel bulkheads backfilled with gravel. Most are tied to an anchor post, or "deadman," well behind the wall to help prevent the structure from being destroyed by heavy storm waves.

Although channel retaining walls tend to have fewer adverse side effects than seawalls, some unintended impacts can occur. Such impacts include transportation of backfill material onto nearby environments by marine process agents and the accelerated erosion of adjoining unprotected property. The latter effect is caused when current eddies created at the wall's ends lead to concentrated turbulence on nearby banks.

Fortunately, both of these side effects can usually be avoided, or at least minimized, by: 1) not constructing a channel retaining wall too close to the shore, and 2) adding landward-pointing wing walls at each end of the wall.

Costs: Timber Planking—$75-100 per linear foot
Steel Bulkheading—$300-350 per linear foot

Preventing Erosion of Scarps or Bank Slopes

The erosion of shoreline slopes or scarps by waves and weathering (or "mass wasting") is a problem that can be dealt with in a variety of ways. However, the best technique for mitigating slope erosion at a given site depends on many complex factors, including the nature of the bank deposits, the amount of wave energy impacting the area, and the surface and subsurface drainage patterns in the vicinity.

One of the most common methods of mitigating erosion on scarps composed of compacted glacial sand and gravel is to promote the growth of existing vegetation or to establish such growths where none exists. This is probably the most attractive and least expensive means of slowing the recession of sand and gravel banks. Along protected shorelines, an increased growth of grasses and other plants may be enough in itself to stabilize the scarp. In more open shores, where wave energy is high, revetments or bulkheads may be needed to prevent erosion of the bottom of the slope.

In some states, a slightly more complex technique called "terracing and vegetating" has been shown to be very successful in stabilizing sand and gravel scarps up to eighty feet high. This method employs the following procedures:

1) construction of a low revetment at the toe of the scarp to prevent storm wave erosion of the lower slope;
2) hand-grading of the slope to an angle of less than 45°;
3) terracing of the slope into consecutive levels by means of posts and riser boards;
4) seeding of the slope with both rye grass for quick vegetative cover and American beach grass, which provides a dense root systems to bind and stabilize slope soils in the long term; and

5) shallow burial of dead reed grasses, such as low salt marsh grass (*Spartina alterniflora*) or common reed (*Phragmites communis*) behind the terrace riser boards to provide immediate drainage of runoff water during the period before the grass seeds begin to germinate.

This technique can be very effective in reducing slope runoff and the erosion that it causes. Grading the slope to an angle less than 45° and constructing a revetment to prevent wave erosion at the bottom of the scarp also aids in decreasing the frequency of small-scale landslides, or slumping, of the bank material.

Terracing can be accomplished with a minimum of technical assistance from a geologist, soil scientist or regional soil conservationist. Before trying such a project, interested property owners should request and study the publication *How to Hold Up a Bank* by Giorgina Reid, which is available from A.S. Barnes Inc. & Co., Cranbury, New Jersey.

Costs: For terracing (exclusive of revetment costs)—approximately $400-600 for an 80 foot slope of 200 foot frontage (A vegetation program without terracing will be considerably less expensive, but often less effective.)

Stabilizing scarps composed of marine clay which are subject to small- or large-scale landslides is a very technical operation that should be planned by experts who have a detailed knowledge of sediment engineering properties, subsurface and surface drainage conditions, and ground water hydrostatic conditions. This type of program may require expensive runoff drainage networks and underground pumps to modify ground water tables in the area of the scarp. Thus, mitigation of clay scarp erosion are usually too costly and too complex for individuals or towns without extensive State or Federal financial and technical assistance. Even then, effective erosion mitigation may be too expensive to be worthwhile and alternative tactics, such as geologic hazard zoning (described below) may be more attractive.

Costs: Variable—usually very expensive

Geologic Hazard Zoning

Shoreline areas subject to high rates of erosion often pose a perplexing dilemma to municipalities and individuals. The alternatives are not always attractive: large losses of valuable, taxable property on the one hand and the implementation of costly erosion mitigation programs which may have serious side effects on the environment on the other. Obviously, preventing development on such shorelines before it occurs is a very attractive remedy in avoiding hard choices between losses of property and the spending of large amounts of private or tax money.

This tactic can be accomplished by establishing municipal "geologic hazard zoning." It involves establishing a zoning line a reasonable distance back from a fast-eroding shoreline beyond which little or no development will be permitted. Placement of the line can be arrived at by getting expert help in determining the probable shoreline position 25 to 50 years in the future.

In many cases, zoning an area as a geologic hazard because of erosion does not mean that it cannot be used at all. Often, activities such as low-intensity recreation or agriculture may be safe and appropriate. However, construction of permanent or semi-permanent structures should usually be avoided.

Where dwelling structures are already located near a shoreline threatened by accelerated erosion, a suitable alternative to hazard zoning or the construction of expensive protective devices is simply to move the structure further back from the shoreline. (Assuming, of course, that an adequate amount of property setback is available.)

If relocation seems the best alternative, a thorough analysis of the projected shoreline loss rate should be made first by an engineer or geologist. This will provide a sound setback distance based on the probable future shoreline position. The cost of moving a structure varies, but it is usually under $2000—which is considerably less than the cost of constructing a seawall or revetment.

WHERE TO GO FOR HELP— GOVERNMENT AGENCIES

Individuals or towns involved in or concerned about shoreline erosion mitigation projects should be aware of the assistance offered by various State and Federal agencies. At the State level, most help available will be in the form of information or technical advice. For example, there are a number of State agencies which can provide guidance on permit requirements, general or specific information on shoreline erosion and the techniques used to combat it, and names and addresses of technical experts needed in the planning of erosion mitigation projects. At the Federal level, both the U.S. Army Corps of Engineers and the U.S. Soil Conservation Service can provide technical advice to private individuals and financial and technical assistance to municipalities involved in the protection of publicly-owned shorelines.

The following list includes the most relevant agencies that can be contacted along with a description of the type of assistance they offer.

FEDERAL AGENCIES

Title	Type of information or assistance given
U.S. Army Corps of Engineers New England Division 424 Trapelo Road Waltham, Mass. 02154 Tel. 1-617-894-2400	Technical information on the construction and effects of shoreline erosion mitigation structures Financial assistance for erosion mitigation projects on public shorelands.
U.S. Department of Agriculture Soil Conservation Service U.S.D.A. Building University of Maine at Orono Orono, Maine 04473 Tel. 1-207-866-2132	Technical information about coastal dune erosion and agricultural effects on sediment loads to nearshore environments.
U.S. Soil Conservation Districts (located in each county seat)	Technical information on erosion mitigation techniques. Financial assistance under some circumstances
U.S. Environmental Protection Agency New England Region J.F.K. Building Boston, Mass. 02203 Tel. 1-617-223-7223	General and technical information on the effects of human activities on coastal environments.

STATE AGENCIES

Title	Type of information or assistance given
Maine State Planning Office #38 Natural Resources Division Augusta, Maine 04333 Tel. 1-207-289-3261 or 1-207-289-3155	Land use planning and zoning information Lists of consulting engineers
*Department of Environmental Protection #17 Bureau of Land Quality Control Augusta, Maine 04333 Tel. 1-207-289-2111	Information on environmental problems, permits and impact assessment (Administers the Wetlands Law)
Department of Marine Resources #21 Stevens School Hallowell, Maine 04347 Tel. 1-207-289-2291	Information on impacts of human activities on coastlines Coastal wardens and biologists can offer assistance and enforcement

Department of Conservation #22 Maine Geological Survey Hospital Street Augusta, Maine 04333 Tel. 1-207-289-2801	Information on coastal geology, shoreline erosion, and impacts of human activity on the shoreline. Shoreline Erosion Maps Marine geologic environments maps Lists of consulting geologists
Land Use Regulation Commission (LURC) #22 Hospital Street Augusta, Maine 04333 Tel. 1-207-289-2631	Information on land use standards in Maine's wildlands (unorganized townships)
Department of Inland Fisheries and Wildlife #41 State Street Augusta, Maine 04333 Tel. 1-207-289-2766	Information on impacts of human activities on waterfowl, fish, and other wildlife
University of Maine Ira C. Darling Center Walpole, Maine 04573 Tel. 1-207-563-3146	Information on impacts of human activities on marine ecosystems

*(The DEP through its Citizen's Environmental Assistance Service also provides information concerning general environmental problems and laws—Tel. 1-800-452-1942)

SOME PLANNING CONSIDERATIONS FOR DEVELOPMENT IN COASTAL GEOLOGIC ENVIRONMENT

Land Use Activity	Planning Considerations
RECREATIONAL	
Boating	Mitigating bank and bottom erosion and turbidity from waves, wakes and propellers.
Foot Traffic	Bridges, boardwalks, and traffic patterns can protect dune vegetation and reduce wind/wave erosion.
Fishing & Hunting "All Terrain Vehicles" (ATVs)	Keeping activity levels within tolerance of vegetation/substrate to prevent undue erosion.
DREDGING; PIPELINES & CABLES	Interruption of sediment transport critical to maintenance of geologic units and depositional systems, e.g. beaches; turbidity and sedimentation; spoil disposal and stifling life at the site; release of toxic heavy metals from disturbed sediments; (heavy metals can precipitate naturally or from industrial waste—many shellfish and benthic organisms concentrate toxic metals)

CONSTRUCTION OF MARINE FACILITIES	
Piers, Wharves and Jetties	Alteration of sediment transport by currents; relocating impact of wave energy.
Roads	Location to avoid storm damage; maintaining tidal flows over marshes; preservation of natural erosion controls, eg. vegetation on dunes, steep banks etc.
Seawalls	Locate and design to survive storm damage; avoid accelerating wave erosion; avoid interrupting seasonal sand cycle between dunes and foreshore.
UPLAND CONSTRUCTION	
River Alterations e.g. dams, channelization	Effect on sand supplies for coastal beaches
Light Industry/Residential	Natural shoreline recession rates vs. expected useful life of buildings and roads, sewers, water supply, etc. Likelihood of slumping, accelerated erosion from storm runoff from paved areas, etc.
Heavy Industry	Changes in bay flushing rates due to stratification from freshwater/warm water effluents; sedimentation may be affected by changes in flushing action.
AGRICULTURE	
Timber Harvesting	Removal of trees may upset vegetative stabilizing influence on sand dune areas; logging equipment, operations and roads may cause erosion.
Crop Farming	Increased sedimentation from soil erosion.
WASTE DISPOSAL	
Liquid Effluents (large discharges)	Changes in water quality; scouring and channel cutting; stratification and changes in sedimentation and flushing rates.
Solid Waste (deposited into water bodies)	Erosion from alteration of currents and wave patterns; short term sedimentation and suspended solids.
AQUACULTURE	
Impoundment Aquaculture	Thermal and density stratification; sedimentation.
PEST CONTROL	
Draining Wetlands	Loss of floodwater storage capacity; nutrient transfer to open waters.
Pesticides	Shift in biologic processes.
DEVEGETATION	Erosion; accelerated storm runoff; reduced nutrients from estuaries.
MINING SAND AND GRAVEL	
(In subtidal and intertidal areas)	Beach starvation.
FILLING	Down—current sedimentation; suffocation of vegetation and benthic organisms.

Land Use Laws of Special Interest to Individual Coastal property Owners

This chart summarizes some uses and activities regulated under local, state and federal law in the nearshore coastal area.

Land, wetland, and water areas covered by these particular land use laws are listed, as well as the name and citation of each law, and the administering agency to contact for information.

The administering agency is generally the place to learn the necessary procedures for making applications, obtaining permits, making statements as an interested person at hearings on applications by others, etc.

Not all land use and environmental laws which may apply to a particular proposal are listed. For example, a residential subdivision or any kind of development involving more than 20 acres or disturbing more than 60,000 square feet of land above or below water is subject to the "Site Location Act" (T.38 S. 481-5, 488-90) administered by the Department of Environmental Protection, 1-800-452-1942.

Some Uses and Areas Covered	Law/Citation	Administering Agency
Construction of residences, docks, wharves, roads, sewage systems, beaches, campgrounds, tree clearing, timber harvesting, agricultural operations. Area: Land 250 feet back from normal high water mark.	In municipalities, Shoreland Zoning T. 12 S. 4811-14	Municipal Planning Board Town Office/City Hall
Same as above.	In unorganized and deorganized areas, Land Use Regulation Commission T. 12 S. 681-689	Department of Conservation #22 Land Use Regulation Commission 289-2631
Dredging, draining, filling; construction of a causeway, bridge, marine, wharf, dock, or any other structure; bulldozing, moving, removing, adding to, or building any structure in, on, or over any coastal sand dune. Area: Coastal dunes and wetlands—all tidal and subtidal lands including lowlands subject to storm flowage (except during "maximum storm activity") *also* includes coastal sand dunes above high tide.	Alteration of Coastal Wetlands T. 38 S. 471-6, 478	Department of Environmental Protection #17 Bureau of Land Quality Control 1-800-452-1942; 289-2111

To dredge, fill, or erect permanent causeways, bridges, marinas, wharves, docks or other permanent structures. Area: Submerged lands (beyond mean low water) and intertidal lands owned by the State. Lease required.	Submerged Lands Act T. 12 S. 558; T. 38 S. 1022	Department of Conservation #22 Bureau of Public Lands 289-3061
All overboard (into water) liquid waste discharges including those from residences, seasonal cottages, boats, businesses, industries, municipal and private sewer systems. Area: All Waters—fresh, salt, surface, ground, tidal.	Protection & Improvement of Waters T. 38 Ch. 3	Department of Environmental Protection #17 Bureau of Water Quality Control 1-800-452-1942; 289-2591
Liquid waste/disposal from residential or other land use activity including septic tanks, surface spraying, drainage fields, holding ponds and tanks. Area: All land areas.	Minimum Lot Size (20,000 sq. ft./100 foot shore frontage) T. 12 S. 4807, A,B,C,D,G	Department of Environmental Protection #17 Bureau of Land Quality Control 1-800-452-1942; 289-2111
Wastewater Disposal—all systems other than municipal sewer systems or discharges licensed under line (5) above (overboard liquid waste discharges). Areas: All land areas.	State of Maine Plumbing Code Part II Regulations T. 22 S. 42; T. 30 S. 3221-3225, 4359, 4453, T. 32 S. 3301, 2, 4, 3401-6; 3501, 3504, 3507, T. 20 S. 2361	Department of Human Services #11 Division of Health Engineering 289-3826
Deposit of waste or refuse: A) forest products, e.g. sawdust, bark, slabs, etc., B) potatoes or parts, C) refuse, e.g., junk, sludge, etc. Area: All land and ice which drains or melts into tidal or any other waters of the State.	Dredging/Discharging T. 38 S. 417	Department of Environmental Protection #17 Bureau of Water Quality Control 1-800-452-1942; 289-2591
Siting of all aquacultural (sea-farming) and marine research facilities and related operations, such as raising mussels, oysters, salmon or trout. Area: All tidal waters, all intertidal and subtidal land.	Research and Aquaculture Leases T. 12 S. 6072	Department of Marine Resources #21 289-2291
Construction, extension or maintenance of fishweirs, traps and wharves. Area: Tidewaters within the limits of any city or town.	Wharves and Fish Weirs (Ch 9) T. 38 S. 1021-1026	Municipal Officers Town Office/City Hall
Construction of any marine facilities, e.g. piers, wharves, pipelines, power lines, bridges, breakwaters; dredging or filling; ocean dumping of dredge spoil. Some activities are already covered by nationwide or general permits. Area: All navigable (tidal) waters of the U.S., all tributaries and adjacent wetlands, e.g. marshes, bogs, swamps.	Rivers & Harbors Act 1899; Federal Water Pollution Control Act of 1972; Marine Protection—Research and Sanctuaries Act of 1972 33 CFR Parts 320-329	U. S. Army Corps of Engineers 424 Trapelo Road Waltham, Massachusetts 02154 617-894-2400

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