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Anticipatory Planning For Sea-Level Rise Along The Coast Of Maine

This report is a joint effort in cooperation with the State of Maine's State Planning Office.

The cover photo shows conditions at Camp Ellis in Saco, Maine, after a December 5, 1990 storm that was classified as a relatively "modest" 25-year event. The storm, which took place during a proxigean spring tide, combined with high tides (more than one foot over normal spring tide conditions) and 45 mile per hour winds to cause a wind-driven storm surge of 2 feet.

Anticipatory Planning for Sea-Level Rise Along the Coast of Maine

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EXECUTIVE SUMMARY

A. PROJECTED RATES OF SEA-LEVEL RISE

The present configuration of Maine's coast is attributable to a rise in sea level over the past 10,000 years. Scientists have been able to verify that sea level has continued a gradual rise in all of Maine's major coastal municipalities during at least the last fifty years.[1] Geologists and climate modelers project that this rise will continue, although there is not total agreement on the projected rate of rise.

A continuation of the historic rate of sea-level rise of around 2 mm/year (20 cm/100 years) places many shoreline properties in jeopardy from coastal erosion and inundation. However, several consensus reports of the international scientific community over the last decade project an **accelerated rate of sea-level rise** as a result of global climate change associated with the **greenhouse effect**. For example, the Intergovernmental Panel on Climate Change (IPCC) predicts that by the year 2100, there will be a global rise in sea level in the range of 33 to 110 cm, with a most likely rise of 66 cm.[2] If these predictions are accurate, coastal areas of Maine will face even more extensive threats to natural and built resources than would occur with a continuation of the past rate of sea-level rise.

B. PLANNING FOR SEA-LEVEL RISE

This report constitutes Maine's first systematic assessment of its vulnerability to a change in shoreline position as a result of accelerated sea-level rise associated with global climate change. Because there is still a great deal of uncertainty associated with projections of global climate change, this report should be considered as merely the first cut at assessing vulnerability and identifying options for an anticipatory response strategy. Due to the projected gradual onset, there will be time to make some corrections as more scientific certainty is achieved. However, despite the uncertainty and gradual onset, it is important for Maine to begin to address these issues now. As expressed by a consensus of international coastal zone managers:

> It is urgent for coastal nations to begin the process of adapting to sea level rise not because there is an impending catastrophe, but because *there are opportunities to avoid adverse impacts by acting now,* opportunities that may be lost if the process is delayed.

> This is also consistent with good coastal zone management practice irrespective of whether climate change occurs or not.[3]

While this statement is directed at coastal nations, in the United States, states have primary authority over land use controls, are the primary entities engaged in coastal zone management, and will be primarily responsible for mitigating physical impacts of sea-level rise. To take maximum advantage of opportunities to avoid adverse impacts, it is important for individual states to begin now to plan for possible sea-level rise.

This report asserts that meaningful preparations can take place now, despite scientific uncertainty, by carefully building upon what is already known. It utilizes the following approach:

- Start by identifying historic sea-level trends in Maine, by understanding global climate change theories, and by focusing on four of the projected physical impacts of global climate change which are most likely to be experienced in Maine: change in shoreline position, accelerated erosion/inundation of dunes and beaches, inundation of wetlands and lowlands, and loss of natural coastal protection systems.
- Utilize a range of likely sea-level rise scenarios to project the change in shoreline position and to assess vulnerability rather than limiting the analysis to a single projection.
- Seek "no regrets" strategies, which the State will not regret implementing even if there is no acceleration in the rate of sea-level rise, and which recognize that sea-level rise is just one factor affecting coastal land loss.
- Continue to participate in appropriate national and international emission reduction strategies to reduce the magnitude of future impacts of global climate change, including accelerated sea-level rise.
- As a component of natural resource, land use, and coastal zone management responsibilities, acknowledge that State governments will have primary responsibility for developing strategies to mitigate the impacts of accelerated sea-level rise.

C. SEA-LEVEL RISE SCENARIOS FOR VULNERABILITY ASSESSMENT

Maine's research team used a range of sea-level rise scenarios derived from national studies to assess vulnerability to projected changes in shoreline position. This study did not make any independent scientific judgment as to the probable predictive accuracy of those scenarios.

The United States Environmental Protection Agency and the Intergovernmental Panel on Climate Change (IPCC) recommend that coastal zone managers evaluate impacts based on consideration of at least a 1.0 meter rise scenario, even though the actual projections for 2100 are lower. The use of a one meter scenario builds in a precautionary margin for error. If possible, lower scenarios should also be evaluated to more closely approximate what scientists currently project to be most likely. Higher scenarios can also be evaluated to project impacts

beyond 2100 or to identify areas which are at some, but slight, risk of inundation within the next century based on current projections.

To encompass a range of possible outcomes and to allow decision-makers to assess different levels of risk, Maine's researchers opted to map and evaluate the impact of shoreline change resulting from sea levels 0.5 m, 1.0 m and 2.0 m greater than today, but 100 years hence. The 0.5 m scenario is close to what some scientists are projecting as likely by 2100. The 1.0 m scenario is less likely by 2100, but may appropriately be selected as the planning standard because it acknowledges scientific uncertainty and builds in a margin for safety should sea level rise faster than is currently projected. The 2.0 m scenario is very unlikely to be realized by 2100, but EPA projects it will eventually happen in the very long run and it is useful to identify sites that are at even slight risk of inundation by 2100.

D. STUDY SITES FOR VULNERABILITY ASSESSMENT

Researchers focused on study sites within Casco Bay and Saco Bay, adjacent Maine embayments, drawn from three types of environmental settings: salt marshes, bluffs and sand beaches. Specifically, the sites studied were Gilsland Farm, a Maine Audubon sanctuary with bluffs and salt marshes in Falmouth; Bungunac Bluff and Wharton Bluff, two bluff areas in Brunswick developed with single-family residences; Winnocks Neck, an area of single-family residences in Scarborough abutting a salt marsh; Pine Point, another residential area in Scarborough abutting an accreting beach; central Old Orchard Beach, an intensely developed seasonal resort/commercial shorefront with no natural dune system; and Camp Ellis, a portion of Saco with small residences immediately adjacent to an eroding beach.

E. FINDINGS OF MAPPING AND IMPACT ASSESSMENT

Studies of shoreline change and coastal erosion project that Maine's coastal sand dune systems, coastal wetlands, and coastal eroding bluffs face the prospect of significant coastal erosion and inundation even without accelerated sea-level rise, just based on historic rates of change.[4] For beaches and coastal wetlands, that erosion and inundation would be exacerbated by an accelerated rate of sea-level rise associated with global climate change. The findings of projected change in shoreline position by 2100 under the different scenarios for these specific study sites are summarized in Table S.1.

Table S.1. **Composite Result for Study Sites by Environmental Setting**

Environmental Setting	Sea-Level Rise Scenarios Projected Shoreline Change, Retreat in Meters		
	0.5 m	1.0 m	2.0 m
Salt Marsh	3-35	8-50	17-100
Bluff	15-45	15-45	15-45
Beach	50-150	100-300	200-600

1. Sand Beaches

The most profound changes as a consequence of accelerated sea-level rise will probably be experienced by **sand beaches**. This is of particular concern because sand beaches are scarce in Maine, with sand and cobble beaches comprising less than 10% of Maine's shoreline. In addition, areas adjacent to Maine's sand beaches tend to be more intensely developed than inland sites. A change in shoreline position may inundate relatively intensely developed areas immediately adjacent to the beach. Similarly, if sand dune systems are not protected from adjacent development which would inhibit its ability to migrate inland (e.g. sea walls or other structures), the inland movement of the shoreline might also result in the loss of the dry sand portion of the beach and have a very significant impact on coastal tourism, recreation, and the local economy.

While shoreline change in these beach areas is more difficult to evaluate than other environments for many reasons, the study concluded that a shoreline retreat of hundreds of meters seems likely. Far more observational data and modeling would be required to provide more precise projections of future shoreline positions for sand beaches in Casco and Saco Bays. For example, there is as yet no quantitative understanding of the volume of sand contributed by the Saco River, and this study did not consider that sand eroded from one part of the beach would likely contribute sand to other areas and lessen their erosion. However, noting these limitations, for purposes of planning for future sea-level rise, this study made preliminary projections of landward movement in shoreline position ranging from 50 to 600 meters (150 to 2,000 feet) during the next 100 years, based on a sea-level rise ranging from .5 to 2 meters over that same period.

The site specific vulnerability assessment projected only minimal changes at Pine Point because it is currently accreting. However, under these projections, Old Orchard Beach and Camp Ellis are expected to experience major impacts, even at the 50 cm scenario.

Of the three sand beaches included in this analysis, the Camp Ellis/Ferry Beach case study contained the most quantitative assessment of anticipated impacts. Under the worst case scenario, 260 acres of upland would be inundated along with more than 350 structures and public roads, utility lines, a municipal service facility, and heavily used state and municipal recreational beaches. Under the 100 cm scenario, 133 acres of upland currently developed with 334 structures would be inundated. The 50 cm scenario projects 71 acres of upland currently developed with 210 structures would be affected. The level of private investment at risk in Camp Ellis/Ferry Beach ranges from almost $38 million to over $61 million, depending upon the sea-level rise scenario.

For central Old Orchard Beach, projections based on the 50 cm sea-level rise scenario indicate a loss of 80 acres of upland, including beachfront development and development along Grand Avenue landward to the railroad tracks. This area includes an amusement park, arcades, retail shops, motels, restaurants, high density residential structures, sewer lines and a new stormwater outfall. Since 1991, about $3.9 million has been channeled into public improvements in waterfront and downtown areas which are potentially at risk, and other significant investments are planned in this area as part of ongoing revitalization efforts.

2. Wetlands

The analysis projects that significant impacts will also be felt by **tidally influenced wetlands**, with the projected landward movement in shoreline position for "fringe" wetlands along bay shores ranging from 10 to 350 feet, depending upon the sea-level rise scenario. A change in shoreline position along coastal wetlands is of concern because, absent appropriate planning, it may result in a substantial loss of critical wetlands. Improved scientific understanding of wetlands over the last two decades has resulted in a national recognition of their important ecological and natural resource functions, including providing essential nesting and feeding habitat for waterfowl and other wildlife; serving as habitat for many rare and endangered species; providing nursery and spawning areas for many commercially-valued fisheries; contributing to the enhancement of water quality; and contributing essential natural flood control services.

Many factors will affect whether a change in shoreline position will result in a loss of coastal wetlands. Salt marshes have the ability to migrate landward in equilibrium with a sea-level rise induced change in shoreline position if conditions are ideal.[5] They can expand inland and toward the water, and increase in elevation through accumulation of sediments and plant biomass. If sedimentation balances submergence, they will maintain themselves. However, if sediment supply and accretion is less than the rate of coastal submergence, the marshes will drown. The sediment supply will be influenced by the steepness of the slope of the adjacent uplands, the composition of adjacent uplands (e.g., whether they are bedrock), the presence of coastal engineering structures, and the armoring of bluffs and banks (e.g., building bulkheads). Regardless of sediment supply, marshes will be unable to migrate inland and will drown if they encounter hard upland barriers, either natural or built.

There are more than 5,000 acres of salt marsh in the combined Casco and Saco Bay regions; they comprise roughly 20% of the regions' coastline. It was beyond the scope of this study to conduct expensive, site-specific studies of potential migration of coastal marshes, but researchers did utilize regional estimates from nationwide vulnerability assessments.[6] Projecting from these national studies, researchers estimated that the Saco/Casco Bay area could lose 300 to 500 acres of coastal wetlands if only already-developed areas were armored, and between 800 to 900 acres if all coastal wetland shorelines were protected by bulkheads or similar armoring. These national studies suggest 50 to 250 acres of coastal wetlands could be lost in Saco and Casco Bay even if marshes are allowed to migrate freely.

3. Eroding Bluffs

Researchers also found that **eroding bluffs** are vulnerable to coastal erosion, but that the rate of erosion is driven more by coastal storms than by a rise in sea level. Shoreline retreat rates in the range of 50 to 150 feet are projected over the next century. Coastal bluffs make up only about 3% of the Casco/Saco Bay region, so the impacts will be more localized. In the mapped study sites, continued shoreline erosion was found to threaten five homes situated on about 18 acres of upland. Over the 100-year study period, roughly 200 existing homes adjacent to bluffs in the Falmouth-Freeport area and on the Casco Bay islands may be threatened.

4. Urban Engineered Waterfronts

Based on a preliminary assessment, researchers also concluded that **urban engineered waterfronts** in the study area are not likely to experience a change in shoreline position due to an increase in sea level within the .5 to 2 meter scenarios because most structures are currently designed to accommodate seas which are approximately 6 feet higher than current mean high tide. However, additional research is needed to assess the probable increased geographic extent and frequency of flooding of low-lying urban areas from storm surges. Further study may identify the need to improve existing waterfront facilities.

5. Rocky Shorelines

Not surprisingly, **rocky shorelines** are not particularly vulnerable to a change in sea level. The change in shoreline position will vary with the slope of the adjacent land, but since erosion is not anticipated, any impacts are expected to be minimal.

6. Summary

There is already significant development in or adjacent to the areas most threatened by continued or accelerated sea-level rise — sand beaches, coastal wetlands and eroding bluffs. Future actions, such as continued development in these areas or construction of engineered "solutions" to "protect" upland areas, may increase the investment at risk. These future actions may also reduce the capacity of natural coastal systems to adjust to a change in sea level in ways which maintain critical wetland functions or preserve valued sand beaches.

F. POLICY RESPONSE OPTIONS

The second part of the report analyzes possible *adaptive response strategies* the State of Maine might adopt to mitigate the negative impacts of a change in shoreline position and associated impacts of global climate change. Regardless of the progress made by the State, the nation and the international community in emission reduction efforts, Maine needs to develop an adaptive response strategy because scientists predict that even if greenhouse gas emissions were controlled immediately, the atmospheric concentration of these gases would still increase for many years, and the rate of sea-level rise would still accelerate during the next century. And even if those scientists are wrong and the *rate* of sea-level rise does not accelerate, a continuation of sea-level rise in Maine at observed historic rates is projected to result in significant property damage along the soft coast.

This report is not itself a formal plan. It provides background information and a set of preliminary recommendations to facilitate the future development of a more formal plan to promote adaptation of Maine's coastal resources to relative sea-level rise as a result of global climate change. The report's conclusions and recommendations reflect the opinions of the members of the study team, but do not yet represent the official position of any specific state agency. They constitute a starting place for further discussion and policy refinement by coastal managers and decision-makers.

It should be noted that *emission reduction strategies* constitute a second type of response to global climate change (e.g., multi-party agreements to limit greenhouse gas emissions, development of cleaner energy sources and technologies, and expansion of forested areas).

The State of Maine should also assess how it can contribute to greenhouse gas emission reduction strategies, but that analysis is beyond the scope of this report.

This study analyzes possible adaptive response strategies from several different angles:

- the relative **costs and benefits of selected preliminary response strategies** for one specific case study area (Chapter Four);
- the **responsiveness of existing State and Federal laws and policies** to address the most significant negative impacts on coastal resources identified by the vulnerability assessment (Chapter Five);
- the **legal considerations for Maine's policy response** including potential legal challenges to regulatory tools (Chapter Six); and
- **approaches already adopted or evaluated by other states** for coastal erosion or coastal hazard mitigation (Appendix B).

The study's conclusions and recommendations, based on the mapping, vulnerability assessment, cost-benefit analysis, evaluation of existing State and Federal laws, and legal assessment of strategic policy response options, are contained in Chapter Seven. The following sections briefly summarize the findings of Chapters Four, Five, and Six, which should be consulted for a more complete discussion of assumptions and analysis.

1. Cost-Benefit Analysis of Response Strategies

The cost/benefit analysis conducted for one specific study site (Camp Ellis, Chapter Four) concluded that it was more cost-effective to adopt a strategy to retreat from the shoreline as sea level rises rather than a strategy to attempt to protect development and maintain the shoreline in its current position. Four different response strategies were evaluated (two using protection and two using rolling easements) which represent a range of possible policy options.

The first protection strategy analyzed (Option 1, reactive protection) involved a combination of beach nourishment along sand beaches, maintenance of existing bulkheads and construction of new bulkheads along wetlands to prevent inland migration. Using assumptions explained in detail in Chapter Four, for this reactive protection strategy, the cost-benefit analysis found costs would exceed benefits for the 0, 50, 100 and 200 cm sea-level rise scenarios. The ratio by which the costs would exceed the benefits ranged from a low of 1.1:1 for the 0 cm rise scenario to a high of 1.6:1 for the 200 cm rise scenario. This finding is directly attributable to the fact that beach nourishment is very expensive, and that even under a zero cm sea-level rise scenario, a substantial amount of beach nourishment would be needed over the next century to protect the existing structures by maintaining the current shoreline position.

The second protection strategy analyzed, Option 2, was a variation on Option 1. It differed from Option 1 only in the addition of an initial buy-out and abandonment of the structures which are currently most vulnerable. This buyout was coupled with the same reactive protection strategy as under Option 1 for the remaining structures through beach nourishment and bulkheads. The distinguishing characteristic of this "compensated setback" strategy is that it would postpone beach nourishment costs by abandoning selected structures and secure a volume of sand to protect the next tier of structures from the encroaching

shoreline. The amount of sand needed for beach nourishment would drop to zero for a number of years, depending on the rate of sea-level rise.

Once again, costs were found to exceed benefits for the 50, 100 and 200 cm sea-level rise scenarios. The ratio by which the costs exceeded the benefits ranged from a low of 1.1:1 for the 50 cm rise scenario to a high of 1.8:1 for the 200 cm rise scenario. Under the 50, 100 and 200 cm sea-level rise scenarios it was estimated that the compensated setback policy would eliminate the need for beach nourishment for 20, 10 or 5 years, respectively. There was only one case in which benefits were found to exceed costs; Option 2 was found to provide slight net benefits (1.16) if one assumed that there would be no rise in sea level. However, the assumption of a 0 cm rise would be completely contrary to historic trends and recent coastal erosion mapping at this site. It is also interesting to note that the use of the compensated setback strategy assumed in Option 2 actually resulted in a less favorable benefit/cost ratio than the reactive protection of all structures assumed in Option 1 for the 100 and 200 cm rise scenarios. The reason is that with a more rapid sea-level rise scenario, the savings in sand for beach nourishment provided by the compensated setback program is quickly consumed and does not last long enough to offset the relatively high present value of purchasing the properties upfront.

In contrast, the two retreat strategies assessed in Options 3 and 4 were found to be more cost-effective, with benefits exceeding costs for all sea-level rise scenarios. Option 3 assumed regulations would prohibit all new development within the area expected to be affected by a change in shoreline position within the next 100 years. It also assumed that any existing development would be subject to a "rolling easement" which would require removal of development and restoration of the site to its natural condition as the shoreline position moves inland to affect that development. The ratio by which the benefits exceeded costs were 1.4:1 for a 50 cm rise, 1.1:1 for the 100 cm rise, and 1.2:1 for a 200 cm rise.

Option 4 assumed that rolling easements would apply to both existing and new development. New development would be allowed on sites expected to be affected by projected sea-level rise but it would have to be removed if the site becomes inundated by the sea. The ratio by which the benefits exceeded costs were 1.7:1 for a 50 cm rise, 1.3:1 for a 100 cm rise and 1.5:1 for a 200 cm rise, in all cases, more favorable than the Option 3 values. The distinguishing aspect between Option 3 and Option 4 is the setback policy of prohibiting all new development in the zone of anticipated sea-level rise.

This analysis shows that on a cost-benefit basis, using the articulated assumptions, the present value of prohibiting all new development outweighs the cost of allowing the new development to occur and then removing it should the sea-level rise. The opportunity costs of Option 3 would be particularly high if development is prohibited in a zone and sea-level rise does not occur or occurs to a lesser degree than assumed by the setback policy.

This simplified cost-benefit analysis lends quantitative support to the position that the best course of action is to retreat from the shoreline in the face of rising sea level. The underlying reason for this is that in present value terms, it is far less costly to allow development to occur, and then remove structures and components of the infrastructure which would be affected by sea-level rise over the next 100 years than it would be to incur the continual

annual expense of beach nourishment and bulkheading. This conclusion holds true under all studied scenarios.

While this cost-benefit analysis is specific to Camp Ellis, it has implications for similar beachfront development in Maine. Clearly, this cost-benefit analysis does not address all type of coastal development. For example, there might be atypical sites in Maine where the current level of development and/or an existing heavily engineered shoreline (e.g., very valuable, high intensity structures such as along the Portland Harbor waterfront) might justify reactive protection as a more cost-effective strategy than retreat.

This simplified economic assessment provides policy makers with some information about costs, economic efficiency and performance under uncertainty. In addition, policy makers need to consider other criteria, which exceed the scope of cost-benefit analysis, including equity, political/institutional feasibility, value to be placed on unique or critical resources, and consistency with other State goals and laws.

2. Responsiveness of Existing State and Federal Laws to Sea-Level Rise

Researchers determined that federal programs provide some limited incentives and technical assistance for states to engage in sea-level rise and erosion mitigation planning. For example, the Coastal Zone Management Act has been amended to recognize rising seas as a critical area for anticipatory planning and now provides financial assistance for programmatic changes through enhancement Grants. Other federal research programs, such as EPA/s Climate Change program, also provide valuable technical assistance to states. However, the federal programs are not intended to be a comprehensive response to sea-level rise, and primary responsibility remains with the States to engage in the requisite coastal management planning.

Researchers concluded (Chapter Five) that the policies already in place for Maine's sand dune systems, established by the Sand Dune Rules of the Natural Resources Protection Act, form a very solid base for an appropriate adaptation strategy. In fact, Maine's sand dune regulations have received national recognition as an exemplary coastal erosion response strategy. The Sand Dune Rules should be retained and enforced. Key elements include:

- a prohibition on new or expanded seawalls;
- a requirement that new, large developments only be allowed on sites that will remain stable assuming a 3-foot rise in sea level over the next century;
- a requirement that new, small developments be adequately set back so that they are not expected to be damaged by coastal erosion or a change in shoreline position over the next century;
- a prohibition on rebuilding (unless it can meet new construction standards) if a structure is damaged by more than 50% of the appraised market value; and
- a requirement that if the shoreline recedes such that tidal lands extend to any part of the structure (including support posts) for six months or more, then the structure shall be removed and the site restored to natural conditions.

The State should avoid granting any piecemeal exceptions to specific landowners. Only minor modifications are recommended to clarify the means of determining likely site stability when reviewing smaller structures proposed for that area which is expected to remain stable over the next century given a continuation of historic rates but which would be affected by an accelerated rate of sea-level rise.

However, researchers recommend more extensive modifications to regulations applicable to salt marshes and eroding bluffs to extend the philosophy of the Sand Dune Rules to the other components of the soft coast. The laws governing development in these locations need to be revised to anticipate a non-static shoreline and to protect the capacity for the shoreline to migrate landward without compromising the functioning of the natural system.

To protect irreplaceable wetland resources and their ecological functions along the Maine coast, this study recommends steps should be taken to protect the capacity for landward migration. The first step should be to make a policy decision about which, if any, wetlands the State is willing to lose when sea level rises. If it opts to continue to allow the hardening of the upland edge of wetlands to protect certain types of land or structures (e.g., to protect land already developed to a certain intensity), wetland migration will be precluded in those areas. To retain the other wetlands, the State should adopt provisions, either through the Natural Resources Protection Act or mandatory minimum provisions for shoreland zoning ordinances, to prevent the hardening of the upland edge. Specific provisions should include setback provisions based on projected changes in the shoreline, with new, large structure setbacks based on an assumed 100 cm rise over 100 years, and new, small structure setbacks based on historic rates; all new development would be conditioned on retreat if actual changes in the shoreline resulted in the interference with the natural migration of salt marsh vegetation or tidal flows of water.

To prevent development on eroding coastal bluffs, researchers recommend that these natural features should be incorporated into the Natural Resources Protection Act and regulations should be adopted which would parallel the Sand Dune Rules. In addition, or in the alternative, protection under local shoreland zoning ordinances should be substantially increased. These rules should limit new development, prevent the construction of bluff stabilization devices designed to protect existing structures, and would establish a retreat policy in the event of future bluff erosion.

With respect to engineered urban shorelines, researchers concluded that stronger land use controls could help minimize damage from sea-level rise. The primary action would be to strengthen use restrictions so that new uses would be restricted to those that require a shorefront location in order to function, sometimes referred to as "water dependent uses." Such controls would further other important state interests and leave property owners with numerous economically beneficial uses.

3. Legal Considerations for Maine's Policy Response

The foregoing measures to protect sand dune systems, wetlands and eroding bluffs were the focus of an assessment of potential legal challenges (Chapter Six). That analysis concluded that the current standards for the protection of private property do not pose insurmountable hurdles to carefully drawn regulatory approaches to the problem of sea-level rise. The Maine Law Court has already upheld significant restrictions under the current Sand

Dune Rules. This indicates a belief that such regulations do advance a legitimate state interest and do so in a manner that does not deprive land owners of their property rights in violation of constitutional guarantees. The terseness of the leading State opinion, however, and the recent efforts of the federal courts to expand the protection of private property subject to governmental regulation may encourage other land owners to mount similar challenges to further regulation aimed at sea-level rise. In that event, the smaller the area of a parcel that is affected by the restriction, the more likely it is to be upheld.

If Maine chooses to pursue one or more of the regulatory options outlined previously, this study recommends that it should develop and promulgate them as soon as possible. The earlier that the public is on notice of the likelihood of rising sea level and the policy choice of a retreat strategy, the more likely the regulations are to withstand legal challenge. Property that is purchased after the regulations are adopted will be bought subject to the expectations that the development restrictions will be applied in light of sea-level rise. The promulgation of regulations that require a wetland migration area on the upland margin or which prohibit the future construction of bulkheads that would block such migration will help to clarify the expectations of land owners. When these expectations are clarified, if it is necessary to carry out removal conditions or enforce revised coastal setbacks, the effect will be a minimal disruption of settled expectations.

4. Conclusions and Recommendations

The key premises underlying the recommendation are:

THE STATE SHOULD PROTECT AND STRENGTHEN THE ABILITY OF NATURAL SYSTEMS TO ADJUST TO CHANGES IN SHORELINE POSITION

and

THE STATE SHOULD PREVENT NEW DEVELOPMENT WHICH IS LIKELY TO INTERFERE WITH THE ABILITY OF NATURAL SYSTEMS TO ADJUST TO CHANGES IN SHORELINE POSITION.

In Chapter Seven, the report recommends three different types of actions: 1) concrete anticipatory policies and design standards to guide public investment in buildings, roads and similar infrastructure; 2) specific planning and regulatory policies; and 3) longer range strategic assessment, research and educational actions. The specific recommendations, developed in more detail throughout the report, are summarized as follows:

a. Anticipatory Action

1) Review all new coastal public works projects to determine if minor, cost-effective changes can be made in design or siting to accommodate a changed shoreline position or more intense storms;

2) Discourage an irreversible commitment of public resources for new infrastructure or structures in areas likely to be affected by accelerated sea-level rise, except as necessary to support continued economic viability and efficient functioning of water-dependent uses;

3) Increase the amount of publicly-owned or controlled upland area adjacent to public waterfront access areas to allow for landward movement;

4) Expand coastal nature preserves and acquire key undeveloped coastal wetlands and adjacent conservation areas to provide sufficient upland buffer areas for wetland migration;

b. Planning and Regulatory Policies

5) Halt attempts to stabilize the shoreline within or adjacent to the soft coasts and maintain/restore the ability for coastal sand dune systems, coastal wetlands and eroding bluffs to migrate inland.

6) Along all soft coasts, establish setbacks for all structures (including walls and bulkheads) based on projected shoreline position assuming a 100 cm rise in sea level over the next century to protect the natural systems.

7) As a limited exception to #6, in those areas expected to remain stable over the next 100 years assuming a continuation of historic sea-level rise, allow construction of new, small, easily-movable structures (excluding seawalls or bulkheads) built at low densities adjacent to sand beaches or marshes on the condition that they be removed if they begin to interfere with coastal processes.

8) As a limited exception to #6, allow new structures for functionally water-dependent uses which meet certain performance standards.

9) Treat existing development within the area threatened by erosion or inundation from a sea-level rise of 100 cm over the next century as non-conforming structures, prohibit expansion or intensification of use, but allow ordinary maintenance and repair so long as not damaged by more than 50% of its value. To the extent legally feasible, require the owner to remove the structure if it is damaged by more than 50% of its value, if the structure becomes located on public land, or becomes a public nuisance.

10) On any site unlikely to be affected by a 100 cm rise but likely to affected by a 100 to 200 cm rise over the next century, allow new subdivision development only if it meets performance standards for cluster development designed to minimize the costs of protection.

11) Supplement State regulatory procedures by encouraging/requiring other agencies and municipalities to consider the probability of future increased rates of sea-level rise in making investment, development and permitting decisions.

c. Strategic Assessments, Research and Education

12) Designate one State agency as the lead agency for monitoring issues associated with global climate change and sea-level rise.

13) The lead State agency and cooperating State agencies should undertake additional research to document coastal erosion and to determine how revised global or regional projections of particular impacts of global climate change may affect Maine.

14) Undertake a substantial education effort aimed at local officials, code enforcement officers, other State agencies, current and potential coastal landowners and the general public to focus on the hazards of coastal erosion and inundation, possible impacts of accelerated sea-level rise, the costs of engineered "solutions" and the benefits of conserving the soft coasts as a resilient natural system.

15) As funding permits, undertake supplemental studies on related impacts, specifically including the impacts of coastal flooding/storm surges and salinization/saltwater intrusion with accelerated sea-level rise. In addition, continue to assess policy response options, particularly rolling easements or other market-based approaches, to supplement the use of regulatory setbacks.

The study makes the most detailed recommendations with regard to modification of regulatory strategies. However, researchers also recommend additional evaluation of policy options, including market-based approaches such as the acquisition of rolling easements, to facilitate planning for even longer time frames (beyond 100 years) or higher than projected sea-level rise (greater than 100 cm by 2100).

There are opportunities for the State to demonstrate leadership in non-regulatory spheres in preparing for the possibility of an accelerated rate of sea-level rise. For example, it should illustrate sound economic analysis by incorporating an awareness of sea-level rise projections into its decisions about public works projects, capital investments, public waterfront access siting, and acquisition of conservation areas.

State agencies should also provide leadership through the development and transfer of technical information. Maine Geological Survey and other State agencies should continue to monitor national global climate change projections, analyze the implications of national projections for the State of Maine, and provide technical assistance to municipalities about coastal erosion, historic rates of sea-level rise, and local impacts of projected accelerated rates of change.

The State should also undertake a widespread public education effort to emphasize the non-static nature of the shoreline and the benefits to other shoreline owners, the community and the State of protecting the ability of natural systems to adjust to changes in shoreline position. It is particularly critical to convey information about anticipated shoreline change, coastal processes, and related regulatory constraints to current and potential coastal landowners so that they do not harbor any unrealistic expectations about being able to interfere with natural coastal processes.

Finally, it is important for the State to continue to be an active participant in anticipatory planning for sea-level rise and global climate change. For example, the State should contribute to efforts to mitigate the global and local impacts of greenhouse gasses by participating in appropriate emission reduction efforts. Through a designated lead agency, the State should also keep abreast of scientific developments and evolving legal tools. It should plan to revisit its adaptive response strategy on a periodic basis, perhaps on a ten year schedule. This iterative approach will allow the State to incorporate evolving scientific information, evaluate emerging legal tools, and refine its approach based on the best information available at that time.

G. ENDNOTES

1. JOSEPH KELLEY, ET AL., LIVING WITH THE COAST OF MAINE (Durham, NC: Duke University Press, 1989).

2. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, WORKING GROUP I, 1992 IPCC SUPPLEMENT: SCIENTIFIC ASSESSMENT OF CLIMATE CHANGE 4 (J.T. Houghton, et al., eds., 1992).

3. *Appendix A: Conclusions from the 1990 IPCC First Assessment Report, in* GLOBAL CLIMATE CHANGE AND THE RISING CHALLENGE OF THE SEA (L. Bijlsma, J. O'Callaghan, et al., eds., Rijkswaterstaat, The Netherlands, Report of the Coastal Zone Management Subgroup, IPCC Global Response Strategies Working Group, May 1992).

4. KELLEY, *supra* note 1.

5. See discussion and references cited, Chapter 2, 2-15 to -16.

6. T.V. Armentano, R.A. Park, and C.L. Cloonan, *Impacts on coastal wetlands throughout the United States, in* GREENHOUSE EFFECT, SEA-LEVEL RISE AND COASTAL WETLANDS 87-128 (J.G. Titus, ed., Wash., DC: EPA, 1988).

Chapter One

PLANNING FOR SEA-LEVEL RISE

The threat of global climate change is one of the major issues confronting the world as it enters the 21st century. We are faced with a variety of predictions that indicate that the human race cannot continue to use up the earth's non-renewable resources at the current pace with impunity. Some experts hypothesize that the current pattern of resource consumption has set into motion a series of interactions which are causing global warming. One of the possible projected impacts of this human-induced global climate change is an accelerated rise in global sea level.

A very substantial international scientific research effort has been conducted during the last decade to try to verify the phenomenon and project the impacts of global climate change. Meanwhile, policy makers familiar with various impact projections are anxious to move beyond the problem-recognition stage to begin to develop constructive responses.

The critical issue is how best to develop specific responses when many scientific issues remain unresolved. This report asserts that meaningful preparations can take place now, despite scientific uncertainty, by carefully building upon what is already known. It utilizes the following approach:

- **at the outset, clearly identify what we know about sea-level trends in Maine**, what we know **about global climate change** and associated global sea-level change, and what we believe to be **the most likely impacts** associated with accelerated sea-level rise;
- **seek "no regrets" strategies** (which we will not regret even if there is no acceleration in the rate of sea-level rise) **which also address known threats and recognize that sea-level rise is just one factor affecting land loss.**
- **use a range of likely sea-level rise scenarios** to evaluate vulnerability and develop response strategies rather than limiting the analysis to a single projection;
- continue to **participate in appropriate emission reduction strategies** in an attempt to mitigate likely impacts;
- **assume that State and/or local governments will have primary responsibility** for mitigating local impacts of accelerated sea-level rise;

- build into the process **periodic review and adjustment** of anticipatory sea-level rise response strategies.

Each step in this approach is discussed in more detail below.

A. REVIEW WHAT WE KNOW ABOUT SEA-LEVEL TRENDS IN MAINE, GLOBAL CLIMATE CHANGE AND ASSOCIATED IMPACTS

1. Historical Rates of Sea-Level Rise in Maine

Sea level varies significantly in both its vertical and spatial position over time. Much of the variation, such as that caused by the tides, results in no net change in the position of the shoreline. However, geologists have recorded vertical movement of the sea between 25,000 years ago and the present greater than 100 meters as a result of the waxing and waning of continental glaciers.[1]

During the last fifty years, geodesists have observed tide gauges record a rise of the sea which has averaged 2.4 mm/yr in New England.[2] The exact reasons for this rise are still uncertain, but may be caused by melting of small glaciers,[3] thermal expansion of warming sea-surface water,[4] land subsidence,[5] or a combination of all of these factors.[6]

The Maine Geological Survey has used National Ocean Survey tide-gauge readings to estimate that Maine's rate of sea-level rise between 1940 and 1980 ranged from 1.1 mm per year in Kittery, to 2.3 mm per year in Portland, to 3.2 mm per year in Eastport.[7] If that rate continues unchanged into the future, it translates to increases *per century* of 11 cm (4 inches) in Kittery, 23 cm (9 inches) in Portland, and 32 cm (12 inches) in Eastport. Maine's coast is currently experiencing significant local submergence (decreased land elevation) due to lingering effects possibly caused by loading and unloading of receding ice sheets.[8] The rate of sea-level rise is supposed to be greatest in the Eastport area because of more rapid land subsidence in that area;[9] but this conclusion remains controversial.[10]

To keep this information about changes in sea-level in perspective, it is important to understand that a vertical increase of 11 to 32 cm (4 to 12 inches) in the level of the ocean will translate to a much larger horizontal migration of the high water line landward, depending upon the slope of the adjacent land surface and the type of shoreline. (*See Figure 1.1*) At a minimum, with a one foot rise, the shoreline will move at least as far inland as the previous one-foot topographic contour line. On a very gently sloping coast, that contour line will be much farther inland than on a steep coast.

However, while this simple method of estimating land loss from the slope of the land surface may be useful for sheltered estuaries or wetlands, it greatly underestimates land loss along eroding coastal bluffs or sandy shorelines. Coastal bluffs retreat at highly variable rates, depending on complex factors.[11] Sandy shorelines are also characterized by complex migration processes which result in land loss many times greater than the vertical rise in sea level;[12] some studies have estimated the landward movement of the shoreline per century to be in the magnitude of 100 to 300 times the vertical rise over that same period.[13] So, for example, a 23 cm (9 inch) vertical rise in sea level over the next century along a sand beach

could translate into a movement of the shoreline landward in the magnitude of 23 to 69 meters (75 to 225 feet) per century.

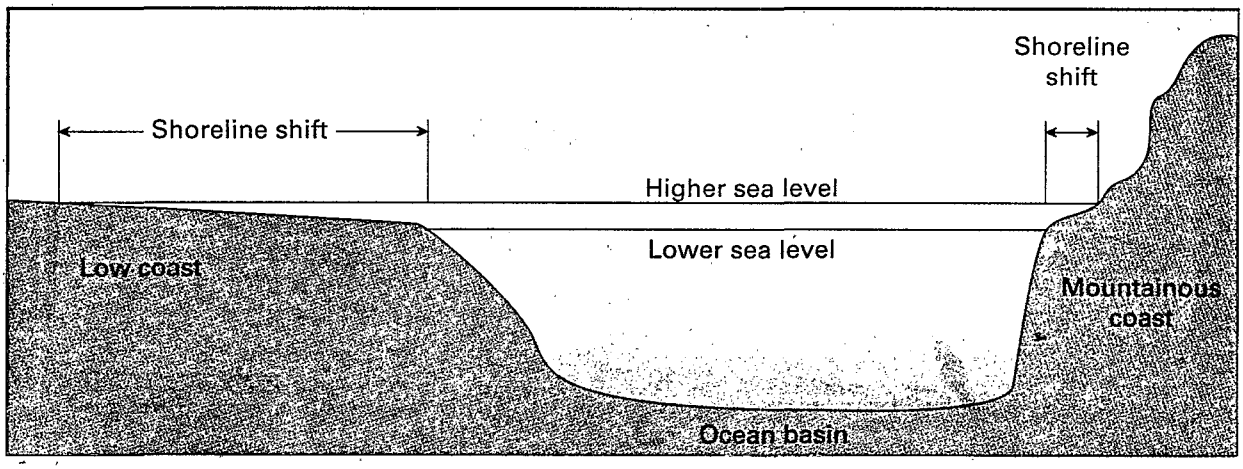

Figure 1.1. Small vertical changes in water level shift coastlines dramatically on gently sloping coasts but cause only minor shifts on steep coasts. Source: U.S. Geological Survey, COASTS IN CRISIS, Washington, DC (1990).

2. Accelerated Sea-Level Rise as a Result of Global Climate Change

The continued rise of the sea at the present rate (discussed immediately above) poses many problems along developed shorelines.[14] However, even greater concern has been raised for the potential impact of a still more rapid rise of the ocean than is presently occurring. Some scientists are predicting that the rate of sea-level rise will accelerate as a result of global climate change associated with the "greenhouse effect."[15]

The greenhouse effect, also referred to as *global warming*, is described as the presence of increased concentrations of human-induced gases, such as carbon dioxide and methane, in the atmosphere. These gases trap heat re-radiating from the earth's surface and raise the earth's atmospheric temperature. This, in turn, could increase the rate of sea-level rise due to further expansion of the sea's surface layer and glacial melting.[16] Thus to accurately project sea-level rise under conditions of global climate change, an additional increment must be added to local historical rates to reflect a *global* increase in ocean volume.

Scientific knowledge about possible global climate change and the associated increase in sea level is still at a very rudimentary stage. Recent studies tend to assume that best projections indicate a rise of approximately 1 to 3 feet by 2100, while earlier studies assumed a rise of 2 to 7 feet by 2100.[17] One of the more recent estimates put a "best guess" at 48 cm (approximately 1.5 feet) higher than present by the year 2100.[18] *(See Figure 1.2)*

Because there is still a wide range of uncertainty associated with projections of global climate change and resulting sea-level rise, scientists cannot provide coastal managers with a single number which represents the projected accelerated sea-level rise attributable to global warming. Instead, to assess possible impacts, coastal planners have to use a range of scenarios designed to be broad enough to encompass the range of likely outcomes. These scenarios are discussed in more detail in section C of this chapter.

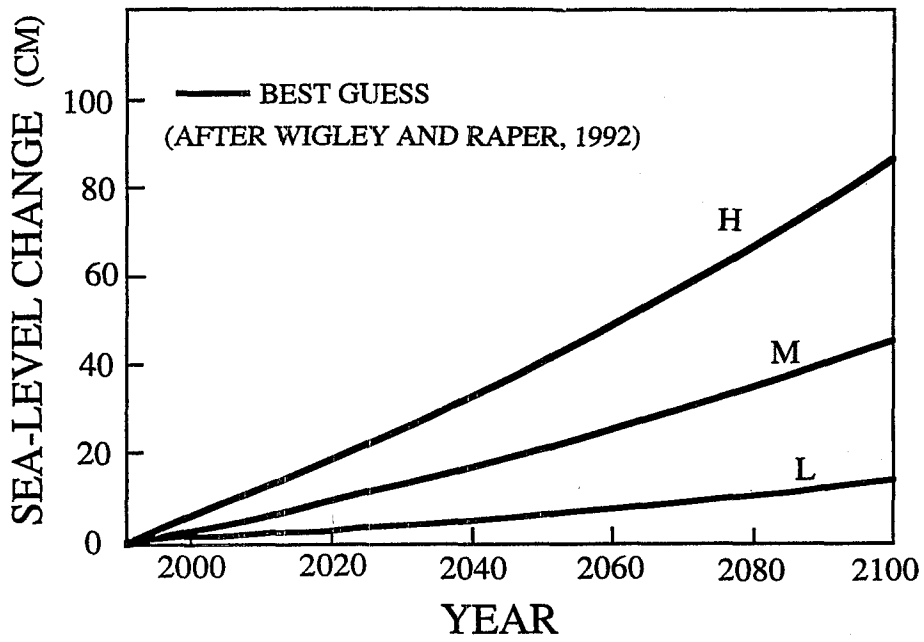

Figure 1.2. Estimates of future sea-level rise (modified from Wigley and Raper, 1992). L, M, and H refer to low, medium and high estimates of future sea levels.

3. Possible Impacts of Accelerated Sea-Level Rise

Given projected increases in sea level due to a combination of local and global changes, the next step of the analysis is to try to integrate possible scenarios with information about probable impacts. It is not yet possible to make precise predictions of the magnitude and specific array of future impacts of global warming.[19] However, researchers have begun to develop lists of possible impacts, and have begun to separate the probable from the merely possible. They have also begun to recognize that the baseline health of the coastal zone may have significant bearing on the ability of the region to adjust to a change in sea level.

During the last several decades, coastal regions of Maine have experienced very significant growth in the number of residents and recreational visitors.[20] This development pattern has resulted in a variety of problems including the degradation of coastal habitats, user conflicts resulting from spatial limitations, coastal pollution due to increasing volumes of municipal wastes and other point and nonpoint sources of water pollution, and coastal erosion and flooding due to insufficient allowance for natural coastal processes. Accelerated sea-level rise will tax those natural systems which provide protection against the sea (e.g., sand dune systems, wetlands) and will accentuate problems caused by or symptomatic of degradation of those systems.

In addition, depending upon the degree of sea-level rise and local conditions, scientists predict that new problems will be added to those already caused by intensive use of coastal areas. These new problems may include:

1) changes in the location of the terrestrial-aquatic boundary;
2) increased frequency and inland extent of flooding;
3) loss of coastal wetlands;
4) accelerated dune and beach erosion;
5) loss of significant habitat for commercially important species;
6) saltwater intrusion into groundwater; and
7) greater upstream intrusion of salt-water wedges.

In turn, these impacts on the natural environment may also:

1) destroy or undermine structures in developed areas;
2) damage the infrastructure; and
3) disrupt the local economy, particularly natural resource-dependent sectors.

The vulnerability to these possible impacts is assessed in greater detail in Chapters Two and Three of this report.

B. SEEK "NO REGRETS" STRATEGIES WHICH ALSO ADDRESS KNOWN THREATS AND RECOGNIZE THAT SEA-LEVEL RISE IS JUST ONE FACTOR AFFECTING LAND LOSS

Representatives of the United States Environmental Protection Agency, the United Nations Environment Programme, the World Meteorological Organization, and the international Intergovernmental Panel on Climate Change (IPCC), assert that despite scientific uncertainty about the global climate change, the magnitude of the potential negative impacts makes it incumbent upon governments to develop response strategies without waiting for conclusive proof of causation or complete unanimity in the scientific community. For example, the IPCC Coastal Zone Management Subgroup has adopted the following statement:

> It is urgent for coastal nations to begin the process of adapting to sea level rise not because there is an impending catastrophe, but because *there are opportunities to avoid adverse impacts by acting now*, opportunities that may be lost if the process is delayed. This is also consistent with good coastal zone management practice irrespective of whether climate change occurs or not.[21]

Due to the scientific uncertainty about global climate change and lag time before most impacts will be felt (if they occur at all) most of these representatives are not advocating immediate concrete steps to armor the shoreline or otherwise get ready for a change in sea level. Rather they emphasize relatively low-cost strategies which not only make sense to minimize any adverse impacts of accelerated sea-level rise, but which would also make sense (e.g., which the government would not regret taking) even if sea level does not rise at an accelerated rate. For example, these strategies may be justified because they increase the ability to survive coastal storm events of the intensity currently experienced with less damage or because they strengthen the resiliency of coastal resources. The focus of this report is on identifying these types of "no regrets" strategies.

In seeking these "no regrets" strategies, it is important to recognize that there are many interacting variables that can lead to coastal land loss. *(See Figure 1.3)* Projections of

shoreline change as a result of sea-level rise caused by global climate change represent just one variable. The local impact will depend on the interactions of all of these variables. Furthermore, even if projections are wrong and global climate change does not cause a substantial rise in sea level, the other factors may cause significant land loss.

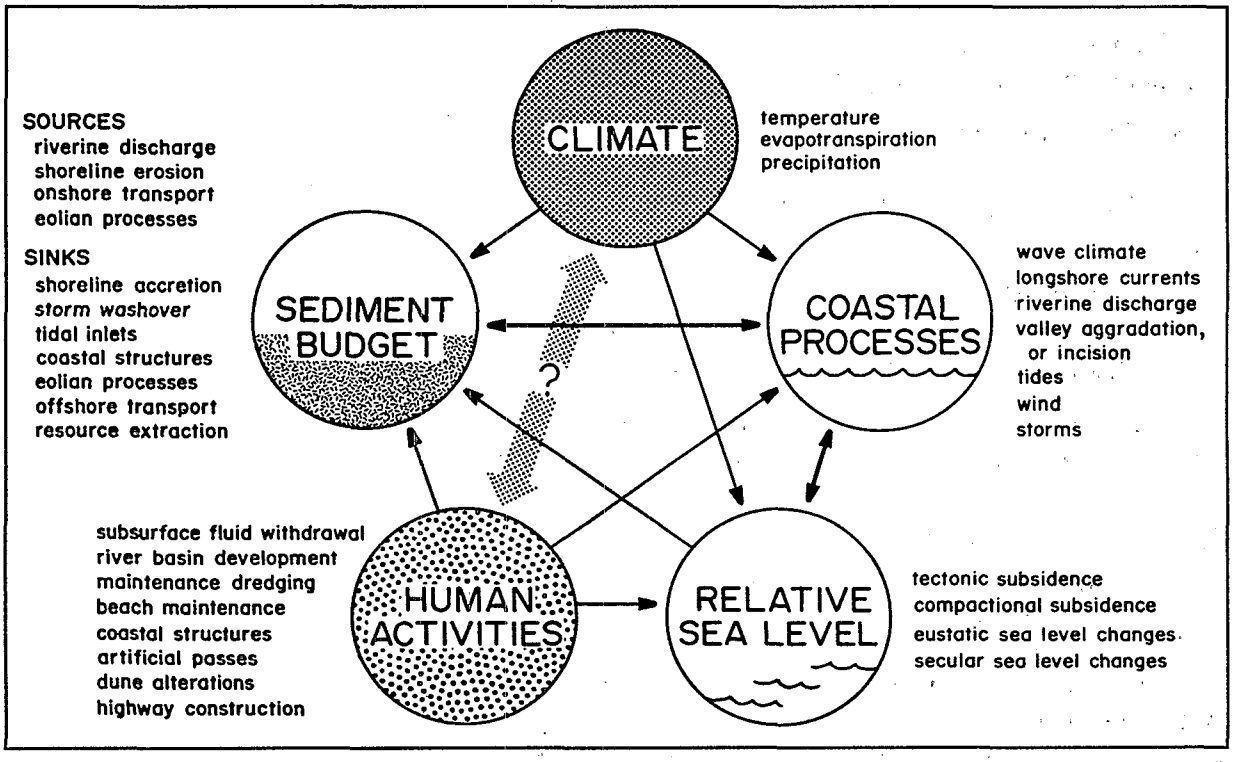

Figure 1.3. Interaction of agents affecting land loss. Arrows point toward the dependent variables. The number of arrows originating from or terminating at a particular agent indicates the relative degree to independence or interaction. For example, human activities are independent of other agents, but they affect sediment budget, coastal processes, relative sea level conditions, and perhaps climate (from Morton [1977]).

Source: O.H. PILKEY, ET AL. COASTAL LAND LOSS. (Wash., DC: American Geophysical Union, 1989) at 6.

The factors affecting land loss are identified as:

1) **relative sea-level changes** (including not only eustatic (world-wide) sea-level changes which might be attributable to global climate change, but also tectonic and compactional subsidence and oceanographic sea-level changes);

2) **coastal processes** (waves and currents, with highest and most intense levels of wave and current energy affecting the coast during intense storms such as hurricanes and northeasters);

3) **alterations in the sediment budget** (affecting sandy shores, with supplies from coastal rivers interrupted by natural decreases, river containment or diversion, dam construction);

4) **climate** (temperature and precipitation indirectly influencing land loss by affecting decomposition of rocks, vegetated cover, and upland runoff); and

5) **human activities** (such as coastal construction projects, fluid production, and resource extraction promoting alterations and imbalances in the sediment budget, coastal processes and relative sea level).[22]

The multi-factored, interactive nature of the land loss process highlights two important considerations in any anticipatory planning process:

- Coastal land loss is a natural phenomenon, perhaps increasingly exacerbated by human activities. It does not become a "problem" until humans try to hold back natural processes of land migration.
- Coastal land loss may result from factors other than eustatic sea-level rise attributable to global climate change, with coastal storms and human activities which disrupt the sediment budget being prime factors. Thus, it is important that any anticipatory plan be responsive to these land loss factors as well.

Since these factors are so interrelated, it may be possible to develop "no regrets" strategies which address sea-level rise, but will also minimize coastal land loss from other factors.

C. COMPENSATE FOR SCIENTIFIC UNCERTAINTY BY USING A RANGE OF SEA-LEVEL RISE SCENARIOS

While the scientific models and current knowledge are sufficiently developed to identify a potential problem on a global scale, they can not yet accurately predict the timing and magnitude of sea-level rise on a local scale.[23] It is thus prudent to use a range of possible scenarios to assess vulnerability and evaluate response options.

For at least the last decade, the international research community has used an assumption of a one meter rise in sea level over the next century to study possible impacts. During that time, specific research projects have developed other high, medium and low scenarios, illustrated in Figure 1.2 (p. 1-4) and Figure 1.4, on the following page.

In its sea-level rise studies, the U.S. Environmental Protection Agency (EPA) has generally continued analyzing the National Research Council's 1985 scenarios of a rise of 50, 100 and 200 cm (½, 1 and 2 meters) by 2100. According to the EPA, the primary reason for using the 50, 100 and 200 cm scenarios is not that it expects these precise results to unfold, but rather that they are "round numbers" that seem to "bracket the range" and serve its goal of being a bit wider of the mark so they cover every contingency.[24] EPA asserts that the extra-high scenario (200 cm) is useful to project what might happen in the very long run (perhaps 200 years or longer) since there is no reason to expect the effects of global warming to stop in 2100. EPA suggests that the extra-high scenario is also useful for identifying which areas are at any risk, even though small, of being affected by accelerated sea-level rise over the next century to assist with siting facilities that would be severely impacted by coastal erosion, such as a hazardous waste disposal facility.

EPA does not equate these scenarios with projections of the most likely outcomes. Recent EPA uncertainty analyses, now cite the 50 cm scenario as the median estimate by 2100. This

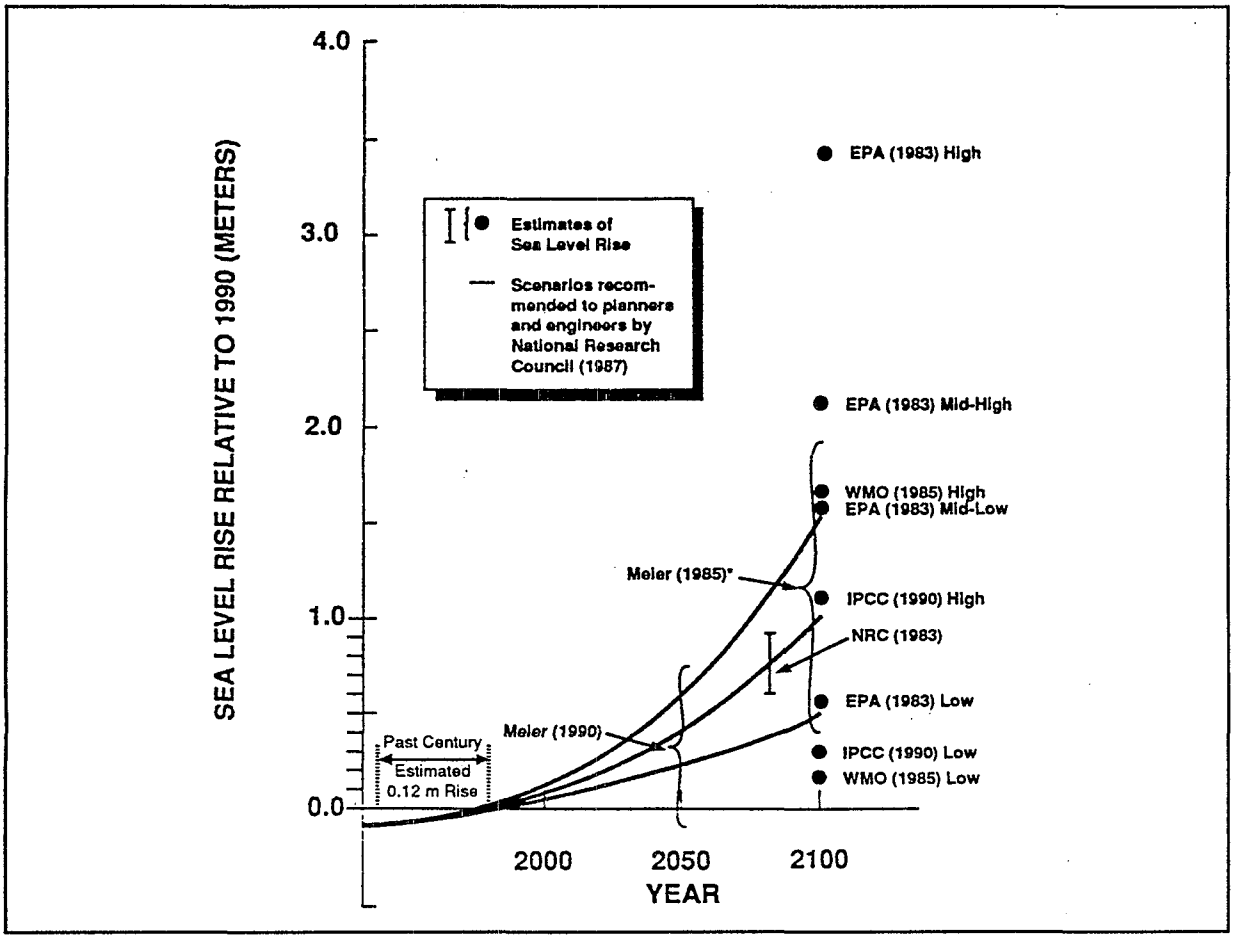

Figure 1.4. Estimate of future sea level rise. Source: J.G. Titus, et al., *Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea* 19 COASTAL MANAGEMENT 171-204 (1991) at 176.

analysis gives 200 cm a less than 0.5% chance of happening by the year 2100 and a 10% chance of happening by 2200. The mid-level 100 cm scenario is given a 5% chance of happening by 2100, but a 50% chance of happening by 2200.[25]

Despite these probabilities, the EPA continues to advocate that all areas examine their sensitivity to at least the one meter rise scenario, because that builds in some precautionary room for error and probably has the effect of extending the analysis beyond 2100. EPA has recommended that communities add the local historical rate of sea-level change (positive or negative) attributable to subsidence to the 50, 100 or 200 cm adjust for local conditions.

In 1990, the Intergovernmental Panel on Climate Change (IPCC) reaffirmed this general approach when it developed its best estimates of future sea-level rise. It predicted that by the year 2100 there will be a global rise in sea level in the range of 33 to 110 cm, with a most likely rise of 66 cm.[26]

Other researchers have subsequently made adjustments to these sea-level rise projections based on revised International Panel on Climate Change emissions scenarios. These revisions

place the global low-, mid- and high-level scenarios at 15 centimeters, 48 centimeters and 90 centimeters, respectively.[27]

Table 1.1 summarizes historical change and various scenarios or projections, using a measured historical rise in Portland as the base. Thus, depending on the assumptions used, sea-level rise predictions or scenarios combining both local subsidence and global change range from a low of 24 to 59 cm, to a high of 104 to 214 cm, with a mid range of 60 to 112 cm.

***Table 1.1.* Predicted Sea-Level Rise in Portland, Maine, 2100**

	Low	Mid	High
Historical (Maine Geological Survey)	21 cm	24 cm	26 cm
Local Historical (historical less eustatic rise component)	9 cm	12 cm	14 cm
Global Sea-Level Rise Scenarios	50 cm	100 cm	200 cm
Forecast Rise 1 (local historical plus global scenarios)	59 cm	112 cm	214 cm
1990 IPCC Sea-Level Rise Estimate	33 cm	66 cm	110 cm
Forecast Rise 2 (local historical plus 1990 IPCC estimate)	42 cm	78 cm	124 cm
Adjusted IPCC After Revised Emissions	15 cm	48 cm	90 cm
Forecast Rise 3 (local historical plus adjusted IPCC)	24 cm	60 cm	104 cm

Source: Adapted from Maine Geological Survey, First Year Report on Hazard Mapping Project, 1993.[28]

In mapping shoreline change based on accelerated sea-level rise scenarios, this project opted to map scenarios of sea level of 50, 100, and 200 cm above present sea level in the year 2100. This was the equivalent of using typical global scenarios without adding an additional increment for local change. For the low- and mid-level scenarios, it was substantially equivalent to using 1990 IPCC projections of global change plus local change. While recognizing the importance of local change as a factor, the project opted not to add local change to global scenarios for purposes of mapping change in shoreline position because: 1) local historical sea-level rise varies over the study area; 2) local change is relatively small in relation to the global scenarios; and 3) adding local historical change to the global scenarios would cause the mapped assumptions to deviate even more from IPCC 1990 projections and later revised projections of sea-level rise based on revised emission projections. It was felt that use of these 50, 100 and 200 cm scenarios incorporated the requisite margin for error and worst-case scenarios that must be factored in when planning to mitigate severe adverse coastal impacts.

D. Participate in Appropriate Emission Reduction Strategies

While the emphasis of the preceding discussion has been on adaptation strategies, the State should not lose sight of the fact that one way to reduce the extent of sea-level rise is to reduce emission of greenhouse gases. Clearly the problem of increased concentrations of greenhouse gases is global in scope. International attempts are being made to negotiate reductions in emissions of particular trace gases. While hopes are high for a joint international agreement, similar efforts suggest that progress will probably be slow and incomplete.

But the State of Maine does not have to wait for a coordinated international response. In the United States, a variety of state and local governments have developed their own partial emission reduction strategies. For example, responses have included:

- comprehensive studies/plans to reduce greenhouse gas emissions and per capita nonrenewable energy consumption;
- utility regulation strategies (e.g., choices regarding fuels, conservation initiatives, preference to conservation, and demand-side management measures);
- building codes (e.g., requiring buyers to make conservation investments when they purchase a house);
- small scale demonstration projects (e.g., reduced energy use by state agencies, transportation policies to reduce automotive use, efficiency investment in new buildings);
- attempts to incorporate environmental costs of nonrenewable energy sources into prices through tax policies; and
- participation in EPA's Green Lights program to install energy efficient equipment when it is profitable and does not compromise lighting quality.[29]

Admittedly, these state and local programs can only make a small incremental contribution to reducing the global emission problem. But adaptation planning and emission reduction efforts should both be pursued by the State.

E. ASSUME STATE/LOCAL GOVERNMENTS WILL HAVE THE PRIMARY RESPONSIBILITY FOR MITIGATION OF SEA-LEVEL RISE IMPACTS

With emission reduction strategies, there is a misguided, but nevertheless strong, temptation to wait for national or international bodies to adopt the laws or negotiate the treaties that will put in place a coordinated global response. In contrast, whether it likes it or not, the State will probably bear the burden and the responsibility to formulate the local, adaptive response to this global problem. The impacts of global climate change will be felt locally, the costs will generally be borne locally and, in the United States, since land use controls are generally a function of state or local governments, the responsibility for much of the response planning will fall on those governments.[30] Thus, even if state and local governments have little direct control over reducing global greenhouse gas emissions, they will have a major responsibility for planning to adapt to potential adverse impacts.

F. UTILIZE A PROCESS WHICH INCORPORATES PERIODIC REVIEW AND UPDATING OF THE ADAPTIVE RESPONSE STRATEGY

Given scientific uncertainty and rapidly evolving scientific knowledge, coastal managers are not in a position to make decisions now about a definitive adaptive response strategy for the next century. Rather policy decisions will have to be made now based on the best available knowledge, with the express intent of reviewing these policies periodically (e.g.,

every five to ten years) as scientists refine their predictions. It will be an iterative process.

Despite the scientific uncertainty and complexities discussed above, there are certain affirmative statements that can be posited as a starting point for Maine's anticipatory planning for sea-level rise:

1. Despite some scientific uncertainty about causation and extent of global climate change, the magnitude of the potential negative impacts makes it incumbent upon governments to develop response strategies without waiting for conclusive proof of causation or unanimity in the scientific community;

2. Even though negotiations are being conducted to reduce emissions of greenhouse gases, due to forces already set into motion, it is essential to simultaneously develop local adaptation strategies in preparation for potential impacts of future global climate change;

3. In coastal communities, adaptation strategies should first focus on the possible impacts of sea-level rise associated with global climate change since that will have the most direct impact on natural resources and human development.

4. In the United States, it is appropriate for States to take the lead in developing local sea-level rise adaptation strategies since they will be most directly responsible for coping with the local impacts. States already possess a range of land use, zoning, development regulation, public investment, economic incentive, and similar tools to use in developing anticipatory strategies.

5. Due to the inherent complexities of predicting impacts of global climate change and the first, second, and higher order impacts of relative sea-level change, and the interconnections between those impacts, the initial analysis should be a first-cut at determining the most likely impacts and the general magnitude of those impacts within very broad parameters. If further refinement of the assessment of vulnerability of particular localities or resources is needed to develop adaptation strategies, additional detailed scientific studies will be required.

6. Developing adaptive response strategies will be an iterative process that will require decisions to be based on the best available information at the time. Anticipatory response plans should be reviewed and updated as scientific knowledge increases, projections of magnitude of global sea-level rise are refined, and experience with governmental response strategies increases.

7. The State should retain and improve on existing policies (supplemented as necessary by new policies) which strengthen the State's position with regard to the known, measurable threats already posed by a continuation of the historical rate of sea-level rise, but are also sufficiently flexible to respond to accelerated sea-level rise, if it occurs. These "no regrets" strategies will be justified (and the State will not regret implementing them) even if the global warming theories are incorrect and the State does not experience any change in the rate of coastal erosion or change in shoreline position attributable to the greenhouse effect.

The detailed results of the mapping and vulnerability assessment components are contained in the next two chapters. The remaining chapters explore anticipatory response options from economic and legal perspectives.

G. ENDNOTES

1. R.G. Fairbanks, *A 17,000 Year Glacio-Eustatic Sea-Level Record: Influence of Glacial Melting Rates on the Younger Dryas Event and Deep-Ocean Circulation*, 342 NATURE 637-642 (1989) and J.T. Kelley, S.M. Dickson, D.F. Belknap & R. Stuckenrath, *Sea-Level Change and the Introduction of Late Quaternary Sediment to the Southern Maine Inner Continental Shelf, in* QUATERNARY COASTS OF THE UNITED STATES, at 23-24 (J. Wehmiller & C. Fletcher, eds., Soc. Econ. Paleo. and Mineralogists, Spec. Pap. 48, 1992).

2. S.D. Lyles, L.E. Hickman, & H.A. Debaugh, SEA-LEVEL VARIATIONS FOR THE UNITED STATES 1855-1986 (National Ocean Services, National Oceanic and Atmospheric Administration, Office of Oceanography and Marine Assessment, Rockville, MD, 1988).

3. M.F. Meier, *Contribution of Small Glaciers to Global Sea Level*, 226 SCIENCE 1418-1421 (1984).

4. D. Reommich, *Ocean Warming and Sea-Level Rise Along the Southwest U.S. Coast,* 257 SCIENCE 373-375 (1992).

5. D. AUBREY & K.O. EMERY, SEA LEVELS, LAND LEVELS, AND TIDE GAUGES, (New York, NY: Springer Verlag 1990).

6. W.R. Peltier, *Global Sea Level and Earth Rotation*, 240 SCIENCE 148-1421 (1988).

7. D.F. Belknap, B. Andersen, et al., LATE QUATERNARY SEA-LEVEL CHANGES IN MAINE, at 71-75 (Soc. Econ. Paleo. and Mineralogists, Spec. Publ. 41, 1987).

8. W.R. Gehrels & D.F. Belknap, *Neotectonic History of Eastern Maine Evaluated from Historic Sea-Level Data and C-14 Dates on Salt-Marsh Peat*, 21 GEOLOGY 615-618 (1993).

9. W.A. Anderson, et al., *Crustal Warping in Coastal Maine*, 12 GEOLOGY 677-680 (1984).

10. R. Reilinger, *Reanalysis of Crustal Warping in Maine*, 15 GEOLOGY 998-961 (1987); W.R. Gehrels & D.F. Belknap, *supra* note 8, at 615-618.

11. HANDBOOK OF COASTAL PROCESSES AND EROSION (P.D. Komar ed., Boca Raton, FL: CRC Press 1983).

12. O.H. PILKEY, R.A. MORTON, J.T. KELLEY & S. PENLAND, COASTAL LAND LOSS, (Wash., DC: American Geophysical Union 1989).

13. NATIONAL RESEARCH COUNCIL, MANAGING COASTAL EROSION (Wash., DC: National Academy Press 1990).

14. W. KAUFMANN & O. PILKEY, THE BEACHES ARE MOVING: THE DROWNING OF AMERICA'S SHORELINE (Duke Univ. Press 1983) (1979); J.T. KELLEY, A.R. KELLEY & O.H. PILKEY, LIVING WITH THE COAST OF MAINE (Duke University Press, 1989); and O.H. Pilkey, J.T. Kelley, R.A. Morton & S. Penland, *supra* note 12.

15. There are two basic indicators of global climate change: global mean temperatures and global mean sea level. Evidence exists that global mean surface temperatures have increased by 0.3 to 0.6°

C over the last 100 years. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, WORKING GROUP I, 1992 IPCC SUPPLEMENT: SCIENTIFIC ASSESSMENT OF CLIMATE CHANGE 4 (J.T. Houghton, et al., eds., 1992) [hereinafter 1992 IPCC SUPPLEMENT]. Global mean sea level is correlated with temperature and has apparently increased by 10 to 20 cm during the last century as well. V. Gornitz, S. Lebedeff & J. Hansen, *Global Sea Level Trend in the Last Century*, 215 SCIENCE 1611-1614 (1982).

One theory advanced to explain the observed global warming is that the measurable increase in greenhouse gas concentrations during the last century has trapped solar heat. Scientists theorize that these trace gases (such as carbon dioxide and methane) which are believed to result in large part from human activities (e.g., burning of fossil fuels, deforestation, certain agricultural practices) delay the escape of infrared radiation from the earth's atmosphere. This trapped heat causes a warming of temperatures. According to this theory, it also causes a rise in sea level due to the thermal expansion of sea-surface water and, melting of small glaciers. M.F. Meier, *Contribution of Small Glaciers to Global Sea Level*, 226 SCIENCE 1418-1421 (1984); W. Peltier, *supra* note 6, at 895-901.

Changes in global surface temperature and concentrations of greenhouse gases that were observed during recent years are consistent with the greenhouse theory, but most scientists take the position that a definitive cause/effect relationship has not yet been demonstrated. Too few and too widely dispersed temperature observations, and sea-level measurements biased by a concentration of tide gauges in subsiding, formerly-glaciated regions preclude definitive statements yet on the status of global climate change.

In addition while most scientists acknowledge that the greenhouse gas theory is consistent with the evidence of global temperature changes and changes in mean sea level, most scientists agree that another viable theory exists which also explains those temperature and sea-level rise observations: natural internal variability. P. Stone, *Global Climate Change: Causes, Evidence and Prediction in* AIP CONFERENCE PROCEEDINGS: THE WORLD AT RISK: NATURAL HAZARDS AND CLIMATE CHANGE SYMPOSIUM (Rafale Bras, ed., Cambridge, MA: MIT Center for Global Change Science and Industrial Liaison Program, 1992) [hereinafter THE WORLD AT RISK] and 1992 IPCC SUPPLEMENT, *supra* at 4. These scientists note that the observed global warming is still within the range that could be explained by natural variations in climate based on historical natural climate variations. Until the data proves that the observations exceed historical variations, the greenhouse gas theory cannot be validated. It is not expected that observations which support the theory of enhanced greenhouse effects will provide unequivocal information for at least a decade. 1992 IPCC SUPPLEMENT, *supra* at 4.

16. J.G. Titus, *Greenhouse Effect, Sea-Level Rise and Barrier Islands*, 18 COASTAL MANAGEMENT 1-20 (1990). An increase in sea level may result through one or more of the following: 1) thermal expansion of ocean water (the same amount of water takes up more space as its temperature increases above 4° C); 2) increased melting of mountain glaciers; 3) melting of Greenland glaciers; and 4) introduction of portions of massive Antarctic glaciers into the ocean. W.R. Peltier, *supra* note 6.

17. THE POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE ON THE UNITED STATES, (J.B. Smith & D.A. Tirpak, eds., Wash., D.C.: Hemisphere Publishing Corporation, 1990) and J.G. Titus, *The Cost of Holding Back the Sea*, 19 COASTAL MANAGEMENT 171 (1991).

18. T.M.L. Wigley & S.C.B. Raper, *Implications for Climate and Sea Level of Revised IPCC Emission Scenarios*, 357 NATURE 293-300 (1992).

19. There are several reasons for a lack of precision in predicting the range and magnitude of impacts. These include the inherent unpredictability of climate, the unpredictability of other events that could affect the global climate (e.g., volcanic activity, solar emissions), the unpredictability of rates of increases in greenhouse gases which may be driving the warming (e.g., negotiated reductions in emissions, public education altering emissions), and inherent limitations of current climate models.

P.H. Stone, *Forecast Cloudy: The Limits of Global Warming Models*, THE WORLD AT RISK *supra* note 15, at 143-149. There is also continuing debate over the list of expected impacts. Small differences in assumptions make major differences in projected impacts. Nevertheless, it is important to note that sea-level rise is one of the major impacts of global climate change that is projected with a relatively high level of confidence. If the planet is in fact experiencing human-induced global climate change, global sea-level rise is one of the most likely impacts. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE: THE IPCC SCIENTIFIC ASSESSMENT (J.T. Houghton, G.J. Jenkins & J.J. Ephraums, eds., Cambridge University Press, 1990). Since it is one of the less speculative impacts, this report focuses on sea-level rise. Some other projected impacts with potential bearing on the coastal region are mentioned in the report as well.

20. J.R. KELLEY, A.R. KELLEY & O. PILKEY, LIVING WITH THE COAST OF MAINE (Duke University Press 1989).

21. *Appendix A: Conclusions from the 1990 IPCC First Assessment Report, in* GLOBAL CLIMATE CHANGE AND THE RISING CHALLENGE OF THE SEA (L. Bijlsma, J. O'Callaghan, et al., eds., Rijkswaterstaat, The Netherlands, Report of the Coastal Zone Management Subgroup, Intergovernmental Panel on Climate Change, Response Strategies Working Group, May 1992).

22. O.H. PILKEY, R.A. MORTON, J.T. KELLEY & S. PENLAND, *supra* note 12.

23. There is a significant discrepancy in the scales used by scientists and the needs of the local policy makers. Modelers of climate change are usually working on a scale of thousands of miles. Policy makers, in contrast, are often hoping to narrow the findings to a particular municipality, county or state. While some scientists have attempted to use scientific methodologies to convert from a regional global circulation model to local predictions, the effort is very complex and results can suffer from significant limitations. J.P. Hughes, D.P. Lettenmaier & E.F. Wood, *An Approach for Assessing the Sensitivity of Floods to Regional Climate Change, in* THE WORLD AT RISK, *supra note 15, at 112.* Even though some impacts are predicted on a global scale, they will affect different parts of the world differently. For example, increased global mean temperature is a change that is predictable with some degree of certainty, but the extent of the increase is still the subject of much debate. Attempts to move from the global scale to the local scale to predict changes in local air temperature have not been successful because local air temperatures will be affected by changes in rainfall and wind patterns (among other things). While able to give a general indication of the likely direction of change on a larger regional scale, global circulation models are not yet able to predict changes in rainfall and winds with accuracy on a local scale. J.C. Pernetta & D.L. Elder, *Climate, Sea Level Rise and the Coastal Zone: Management and Planning for Global Changes*, 18 OCEAN AND COASTAL MANAGEMENT 1, 136 (1992).

24. Correspondence from James G. Titus, Office of Policy, Planning and Evaluation, United States Environmental Protection Agency, June 6, 1994, on file with the Maine State Planning Office.

25. *Id.*

26. *E.g.*, a rise of 13 to 43 inches, with a most likely rise of 26 inches. 1992 IPCC SUPPLEMENT, *supra* note 15.

27. T.M.L. Wigley & S.C.B. Raper, *supra* note 18.

28. Historical rates based on tide gauge readings were uniformly adjusted to find "local change" by subtracting 12 cm. This amount was subtracted to account for the portion of the historical change attributable to a eustatic (worldwide) rise in sea level because the historical change already includes a past rise in worldwide sea levels. The figure of 12 cm is an estimate only, based on other estimates ranging from 10 to 18 cm. Titus, *supra* note 24.

29. P. Wexler & S. Conbere, *States Fight Global Warming*, 18 EPA JOURNAL 4, 18 (Sept./Oct. 1992).

30. J. Nigg, *Societal Response to Global Climate Change: Prospects for Natural Hazard Reduction, in* THE WORLD AT RISK, *supra* note 15, at 289.

Chapter Two

VULNERABILITY OF MAINE SITES TO ACCELERATED SEA-LEVEL RISE

Based on the analysis in Chapter One, it is clear that Maine faces a strong probability of a future with a higher-than-present level of the sea. The critical questions are:

1) how a higher sea level is likely to impact the coastal area if no steps are taken to respond to the threat; and

2) what efforts need to be undertaken to prevent any disasters, minimize the risk, and manage the consequences.

To assist with answering these questions, coastal managers and decision-makers need information about the potential magnitude of the problem, and the implications of the threat for both natural and socio-economic systems.

This information is typically developed in a study called a *vulnerability assessment*. It provides decision makers with an understanding of the susceptibility of the shoreline to rising sea-level, clarifies the need for advanced planning, and provides information for priority setting between specific coastal areas and/or economic sectors within the State.

A. DESIGNATION OF CASE STUDY AREAS AND SEA-LEVEL RISE SCENARIOS

The first step in the vulnerability assessment was to delineate case study areas and to specify the sea-level rise scenarios to be assumed when mapping the future position of the shoreline at representative locations. The research team identified seven representative southern Maine study sites in Casco and Saco Bays, adjoining estuaries along the western margin of the Gulf of Maine. *(See Figure 2.1)* The two bays have differing geological histories (described in more detail in "Setting of Study" in Appendix C) and typically have different land use patterns as well. Portland, Maine's largest city, is located on the southwestern edge of Casco Bay. Commerce and industry dominate its portion of the bay, with suburban residences spread out away from it. Only in the northern portions of the bay and on the islands can one find rural development (Kelley et al., 1989a). Representative Casco Bay study sites were: Gilsland Farm (Falmouth), Bungunac Bluff (Brunswick) and Wharton Bluff (Brunswick).

Saco Bay is dominated by Old Orchard Beach, Maine's largest resort beach. Motels and commercial establishments cover the former sand dunes along the central part of the main beach, while summer residences are often set back behind sand dunes elsewhere. Similar, but less intense development has occurred along other Saco Bay beaches as well. Along the landward margins of the large salt marshes, residential development has begun to occur. Representative Saco Bay study sites were Winnocks Neck (Scarborough), Pine Point (Scarborough), Old Orchard Beach, and Camp Ellis (Saco). (For additional background on the Casco Bay/Saco Bay region, see Appendix C.)

These study sites represent three different types of environmental settings: salt marsh, bluff and beach. A Gilsland Farm site and the Winnocks Neck study area are primarily on or adjacent to salt marshes. A second Gilsland Farm site, Bungunac Bluff and Wharton Bluff are located on eroding bluffs. Old Orchard Beach and Camp Ellis are located on or adjacent to sand beaches.

As discussed in Chapter One, due to scientific uncertainty about future impacts of global climate change, the study opted to use three different sea-level rise scenarios in assessing impacts. This study evaluated the future position of the shoreline at these representative locations in Casco and Saco Bays using scenarios of sea level 50, 100 and 200 cm above present sea level in the year 2100.

B. PREDICTION OF FUTURE SHORELINE POSITIONS

In the next step in the vulnerability assessment, Maine Geological Survey predicted future shoreline positions for each study site, assuming the different sea level rise scenarios. Three different methods were employed to predict future shoreline positions in differing coastal environments. The first method considered only simple submergence of the coast by the rising ocean to the predicted elevations (0.5 m, 1.0 m, and 2.0 m). To determine the distance from present mean high water to the predicted levels along a traverse, the elevation was evaluated by leveling and the distance by measuring tape. The distance from present mean high water to the predicted locations was transferred to maps (1:24,000) which depict contemporary coastal environments (Timson, 1977).

This technique was used in low-energy areas where tidal marshes border the upland (Gilsland Farm, Winnocks Neck). Three or more traverses were made at each study site, and three measurements were averaged parallel to each traverse. Erosion was not observed along the ocean-upland contact, and it was inferred that rising sea level would permit colonization of the upland by salt marsh plants. Cores from marshes like these show a landward-thinning deposit of peat reflecting the slow upward growth of the marsh with rising sea level (Kelley et al., 1988; Belknap et al., 1989).

Where an eroding bluff occurred at the high-tide line, an historical analysis of the rate of bluff retreat was made. In two locations (Bungunac and Gilsland Farm) the bluff had been resurveyed several times in the 1980's (Smith, 1990) and these measurements of bluff retreat were used to project the future shoreline position of the sea, assuming that the retreat rate remained constant. Historic photographs from 1940, 1972, and 1985 were also traced onto mylar under a zoom transfer scope, and the resulting maps digitized for comparison with the

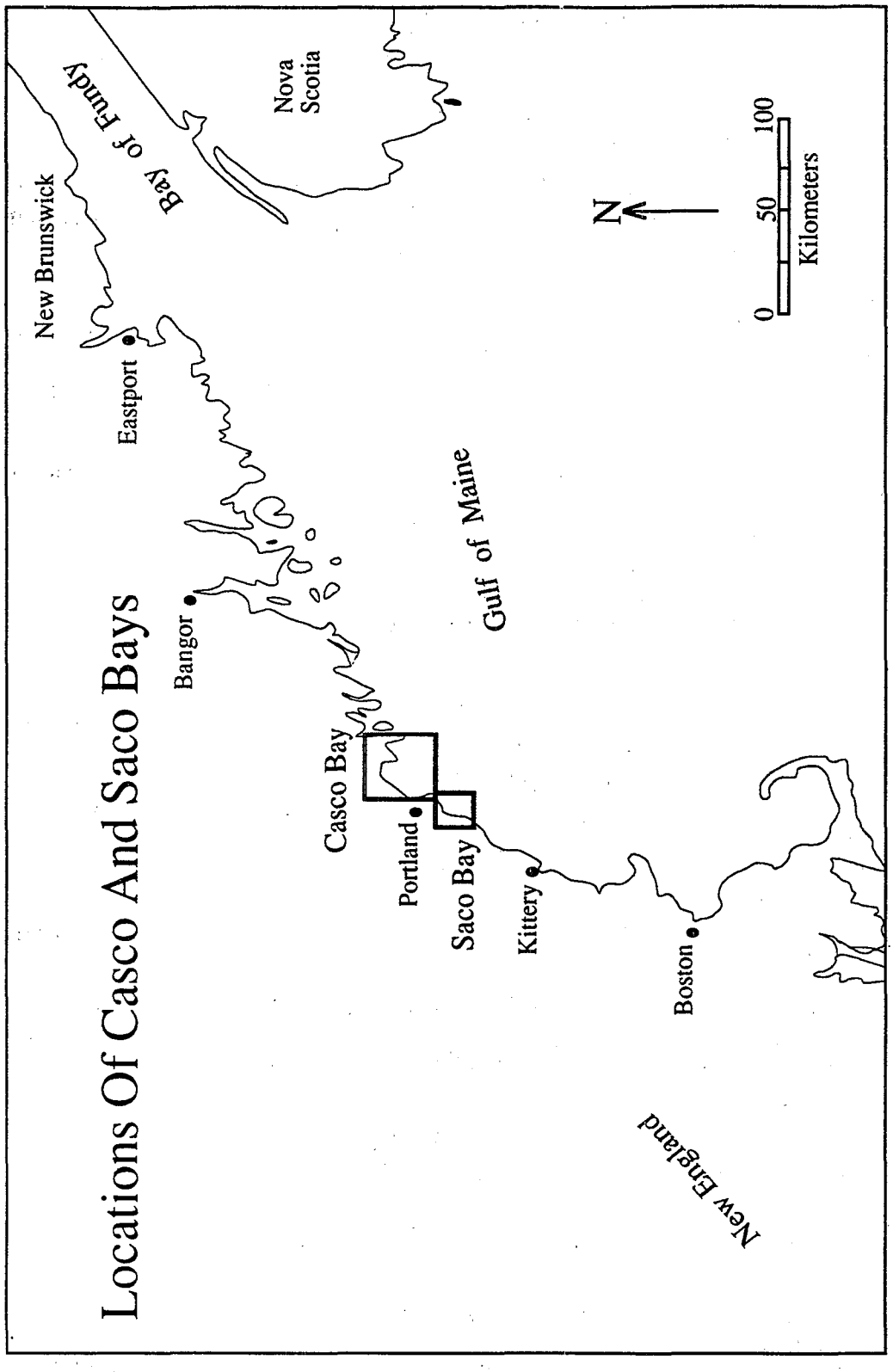

Figure 2.1. Location of Casco and Saco Bays in relation to New England and the Gulf of Maine.

measured rates. The "long-term" rate of retreat evaluated by remote sensing was comparable to that evaluated directly by surveying in the "short term".

The bluffs considered by this method are retreating because waves break against them at high tide. In a study of the factors controlling the rate of bluff retreat in Maine (Smith, 1990), bluffs in three bays (Casco Bay, Machias Bay, Damariscotta River Estuary) with differing rates of sea-level rise were compared. In each bay several bluffs were surveyed and evaluated, and at each bluff site, several traverses were made. An analysis of variance (ANOVA) could not discern a difference in the rate of bluff retreat between the three bays with differing rates of sea-level rise because there was so much local variability at a specific site (Smith, 1990). The reason for this is that many other factors influence the susceptibility of bluffs to erosion (orientation of the bluff, height, composition, rate of slumped debris removal etc.). It is assumed that the bluffs will continue to retreat at their present rates regardless of the rate or amount of sea-level rise, or even whether sea level rises. Although one might argue that a 2 m higher-than-present level of the sea would allow waves more time to act on already eroding bluffs, the limiting factor affecting bluff retreat appears to be the rate of removal of eroded sediment, which would not be directly related to a higher sea-level (Kelley et al., 1989a). Thus, only one 100 year shoreline position is shown for bluff-coasts, and it is based on the current rate of bluff retreat.

Prediction of future shoreline positions in Saco Bay is more complex than for the other shoreline types because the area has not behaved uniformly during the historic period. At the southern end of the bay (Camp Ellis), erosion and accretion have each occurred in the past and have been significantly impacted by engineering structures and dredging and spoils disposal activities at the adjacent river mouth (Nelson, 1979, USACOE, 1992). Based on the past record of aerial photographs and ground surveys, the United States Army Corps of Engineers has published predicted retreat rates for the area (USACOE, 1992).

Along most of the central portion of the beach (Ferry Beach and Old Orchard) the shoreline has fluctuated over the years across a very wide littoral zone, and few, if any, landmarks have ever been removed by erosion despite the rise in sea level of about 0.3 m in this century (Nelson, 1979). It is possible that this region has received sand eroded from the south in sufficient quantities to prevent erosion. Alternatively, erosion may have claimed some of the beach, but it is more than 100 m wide, and the amount of erosion is not quantitatively measurable (there are no vegetated sand dunes with which to evaluate shoreline retreat).

At the northern end of the beach (Pine Point), significant accretion has occurred because of spoils disposal and construction of a jetty (Nelson, 1979). This area is also at the depositional end of the longshore current system of the beach, and accumulates sand lost from other places in the bay.

To project future shoreline positions in such a complex bay, a geo-historical approach was utilized, and the long-term behavior of the beach system was evaluated. Approximately 10,000 years ago sea level was 15 km seaward of the present coast (Kelley et al., 1992; Shipp et al., 1991). The estimated depth of this lowstand shoreline varies from 50-65 m below present sea level, with 50 m being a conservative figure. To reach its present location, the shoreline must have retreated at an average rate of 1.5 m/yr (Kelley et al., 1992). The rate of sea-level rise was not constant during this time period, but averaged 0.5 m/century, the

same value as the low estimate for the next century's rate of rise. If the system behaves as it did in the past, the beach will retreat 150 m during the next 100 years if sea level rises 0.5 m. If sea level doubles or quadruples its rate of rise to 1.0 m/yr or 2.0 m/yr, respectively, it is assumed that the retreat will double or quadruple as well. Thus, 300 meters of retreat are assumed if sea level rises 1.0 m and 600 meters of retreat if sea level rises 2.0 m by the year 2100.

These values are broadly in line with estimates that would result from employment of Weggel's (1979) calculation: $r = b/(d + s) \times h$, where r is the amount of retreat, d is the dune height, s is the offshore depth of no-sediment motion, and h is the amount of sea-level rise. This equation excessively generalizes a very complex beach and assumes the existence of a profile of equilibrium that recent literature debunks (Pilkey et al., 1993, List, et al., 1991). The extreme rates of longshore sand transport in the Old Orchard Beach system generally negate use of Bruun's (1962) two-dimensional model on the Saco Bay system. Nevertheless, values of b from 5 to 15 km, values of s from 10 to 50 and values of d from 1 to 5 yield retreat distances between 300 m and 600 m for sea-level rise scenarios up to 2 m greater than present.

These estimates of beach response to rising sea level are much less precise, much more uncertain, than predictions based on the historic retreat rates of bluffs or of land submergence. There is as yet no quantitative understanding of the volume of sand contributed by the Saco River, and no consideration is given here to where sand eroded from one part of the beach might go. Any change in the role of the Saco River as a source of sand to the bay would probably be significant to the behavior of the beaches. Similarly, a large amount of erosion from one part of the beach would likely contribute sand to other areas and lessen their erosion. To provide more quantitative information on future shoreline positions for Saco Bay, far more observational data and modelling is required. For the purpose of planning for future rises in sea level, the 150 m, 300 m and 600 m values of land retreat projected are adequate.

The detailed results of the mapping effort are discussed for each study site, beginning on page 7 of this chapter (and for Camp Ellis, on page 1 of Chapter Three). For each site, Maine Geological Survey describes the setting and summarizes its projections of future shoreline position. The mapping section is followed by a Maine State Planning Office assessment of physical changes and natural system responses, as discussed in section C, below.

The Maine Geological Survey results are summarized in Table 2.1. It is important to keep these findings in context. The rise in sea level over the past 10,000 years is responsible for the present configuration of the Maine coast. A continuation of the historic rate of sea-level rise of around 2 mm/yr (20 cm/100 years) places many properties in jeopardy. An increase in the rate of sea-level rise may occur, however. In this study, shoreline changes resulting from sea levels 0.5 m, 1.0 m, and 2.0 m greater than today, but 100 years hence, were evaluated. As described in greater detail below, the retreat of unconsolidated bluffs is not expected to change as a result of a more rapid rise in the sea, but such bluffs would continue to pose a threat to property even at their present rate of retreat (up to 0.5 m/yr). Salt marshes would passively drown upland sites, but the steepness of the bedrock-dominated coastal region will result in a much smaller area of new marsh creation (drowning) than would occur in

non-rocky regions of the United States' Coastal Plain. Beaches would probably experience the most profound changes as a consequence of accelerated sea-level rise. These areas are more difficult to evaluate than other environments for many reasons, but still a retreat of hundreds of meters seems likely.

Table 2.1. **Projected Shoreline Changes for Casco and Saco Bays, Maine**

RETREAT DISTANCE IN METERS

Location	Environmental Setting	Method	Sea-Level Rise Scenarios 0.5	1.0	2.0
Gilsland Farm (1-3)	A	1	3-18	8-36	17-75
Gisland Farm (4)	B	2	15	15	15
Bungunac Bluff	B	2	45	45	45
Wharton Bluff	B	2	26	26	26
Winnocks Neck (1-3)	A	1	4-35	23-50	33-100
Camp Ellis	C	3	60-100	60-100	60-100
Camp Ellis	C	4	150	300	600
Old Orchard Beach	C	5	18	18	18
Old Orchard Beach	C	4	150	300	600
Pine Point	C	4	+100*	50	200

Environmental Setting: A) Salt Marsh; B) Bluff; C) Beach.

Method: 1) Flooding; 2) Surveyed Rate; 3) Army Historic Photo Analysis; 4) Geo-Historical; 5) Historical Fluctuations.

* Beach Growth, Not Retreat

Location, environmental setting, methodology and retreat distance estimated for the three scenarios of future sea-level rise. Bluffs are assumed to retreat the same distance under all scenarios as well as under a continuation of the existing sea-level rise rate because they are already reached daily by ocean waves. We cannot accurately predict the behavior of marshes which respond both to sea-level rise and sediment supply. Under present rates of sea-level rise: 1) Pine Point is growing seaward because of sand introduced from erosion at Camp Ellis; 2) Old Orchard Beach is fluctuating in shoreline position due to varying inputs of sand from Camp Ellis; and 3) Camp Ellis has been eroding at rates from 0.6 to 1.0 m per year according to an Army analysis.

C. ASSESSMENT OF PHYSICAL CHANGES AND NATURAL SYSTEM RESPONSES

The next step in the vulnerability assessment was for the Maine State Planning Office to inventory study area characteristics, identify relevant development factors and assess physical changes and natural system responses given the shoreline positions predicted by Maine Geological Survey. This portion of the analysis is not intended as a precise quantitative analysis of the vulnerability of Maine's coastline to accelerated sea-level rise. It is more accurately characterized as a planning exercise to identify the types of problems Maine is likely to experience and the potential location of these impacts. This preliminary assessment should form the basis for further discussion and evaluation of possible actions.

Scientists have compiled multiple lists of a myriad of possible impacts on the coastal zone related to global climate change (Stewart, 1990, Pernetta and Elder, 1992); they vary according to the assumptions made and the extent to which secondary impacts are included. In assessing the vulnerability of the selected sites to the impacts of global climate change, the research team tried to emphasize the *likely* over the *merely possible*. Following the lead of the first nationwide vulnerability assessments in the United States (Titus, et al., 1991), this study attempted to consider as many factors as possible, but concentrated on developing estimates of loss of dryland and wetlands for three sea-level rise scenarios. Specifically, researchers focused on four physical impacts likely to be experienced in Maine: change in shoreline position, accelerated erosion/inundation of dunes and beaches, inundation of wetlands and lowlands, and loss of natural coastal protection systems.

The research team believes this focus was appropriate for this initial study. These four impacts generally need to be studied prior to work on other physical changes, are more direct, and the resulting impacts tend to be more amenable to mitigation through governmental action. Additional studies will be required to assess the impact of other likely physical changes such as increased risk of coastal flooding and storm surges, alteration of tidal ranges, and increased potential for salt water intrusion.

The following assessments describe, in as much detail as readily available information would allow, the anticipated physical and natural systems responses to accelerated sea-level rise anticipated in each of the six study sites in Saco and Casco Bays. Whenever possible, the assessment also discusses potential impact for the Saco and Casco Bay region as a whole. (*See also* Appendix C)

An assessment of five of the six study sites is included in this chapter. The sixth site assessment, Camp Ellis, is presented separately in Chapter Three as an example of the level of analysis that could be developed for each location if additional staff time and a more detailed data base were available. The State Planning Office went beyond readily available information for Camp Ellis to develop the data necessary for a rough economic assessment of the costs and benefits of selected response strategies, presented in Chapter Four.

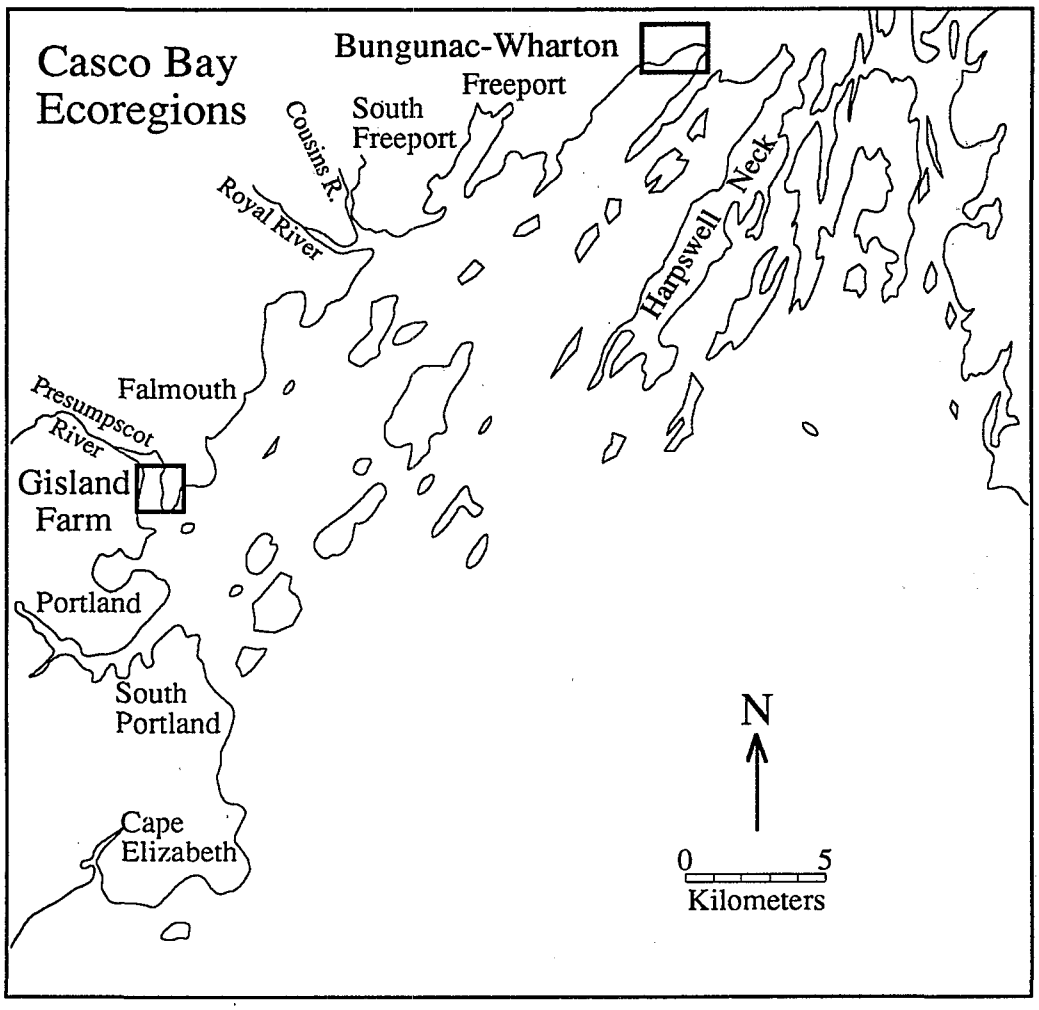

Figure 2.2. Map of Casco Bay with location of study sites enclosed by boxes.

D. RESULTS

1. Gilsland Farm

a. Shoreline Position

Gilsland Farm is located in western Casco Bay near the mouth of the Presumpscot River. (*Figure 2.2*) Bluffs of glacial-marine sediment abut the river in the western portion of the study site, while a salt marsh fills a small valley to the north. *(Figure 2.3)* The bluff rises 9 m above higher high water and large trees and blocks of sediment are actively slumping down parts of its face. (*Figures 2.4, 2.5*) The surveyed erosion rate here between 1985 and 1988 was 0.15 m/yr with a standard deviation of 0.2 (Smith, 1990). Historic air photo analyses yield retreat rates of 0.12 m/yr between 1940 and 1972, and 0.04 between 1972 and 1986, with standard deviations of 0.3 and 0.05, respectively. The large standard deviations result from the episodic erosion along the face of the bluff over time (Sunamura, 1983). The air photos were difficult to interpret because falling trees and slumping blocks partially

obscurred the toe of the bluff. For this reason, the surveyed value of 0.15 m/yr was extrapolated to a retreat distance of 15 m by 2100. (*Table 2.1*) (*Figure 2.3*)

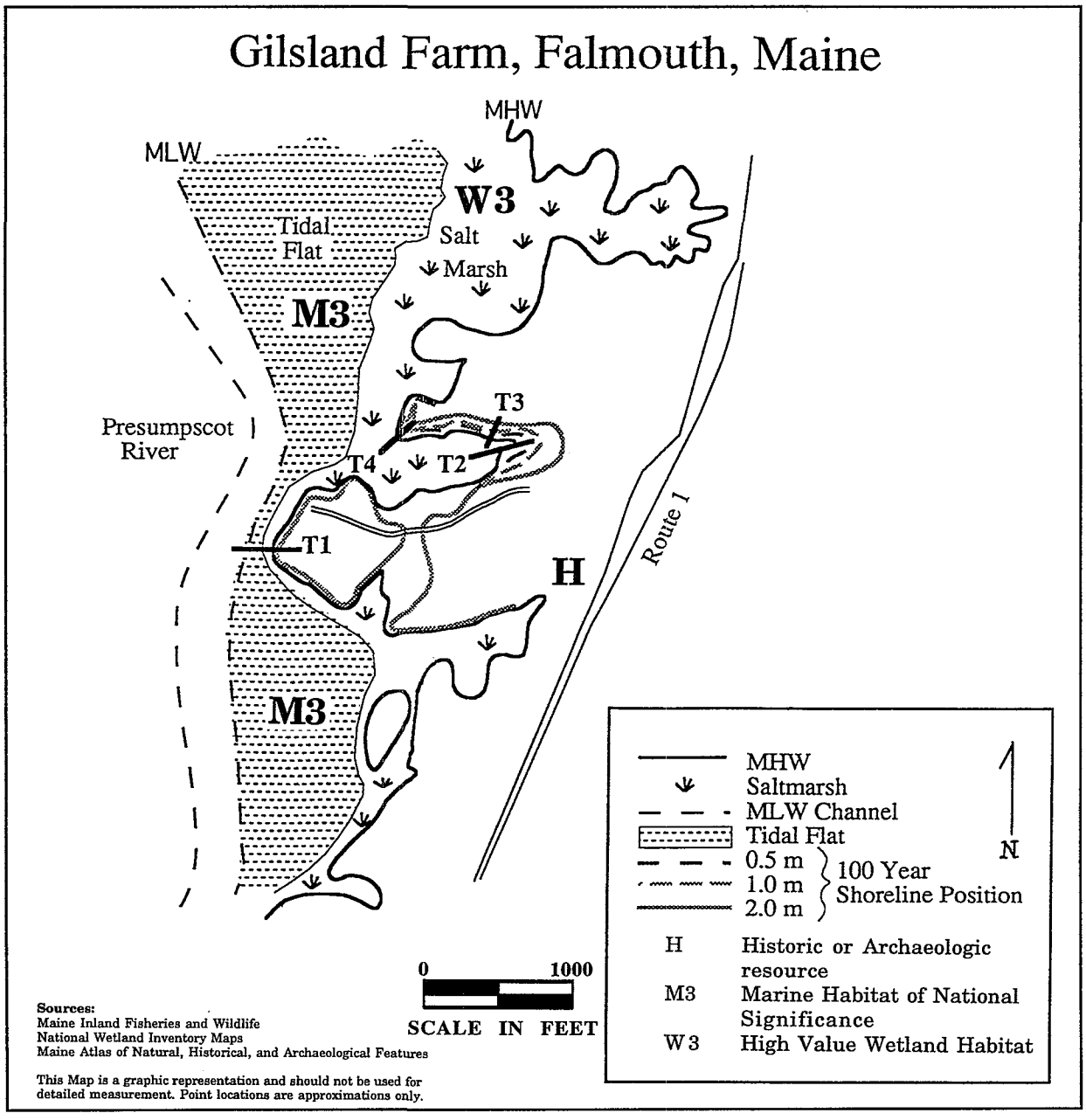

Figure 2.3. Projected shoreline change at Gilsland Farm, Falmouth, Maine. Mapping was limited to the area surrounding Gilsland Farm, although the surrounding area is also depicted. Coastal environments after Timson (1977).

Figure 2.4. Photograph of Gilsland Farm. Site of Traverse 1.

Although the salt marsh is also eroding in front of the bluff, to the north the marsh appears more stable. A *Spartina alterniflora* marsh (low marsh) grades into wetland dominated *Spartina patens* (high marsh) followed by *Typha sp., Solidago sp.* (freshwater marsh), and then upland plants. The transition from halophytes to freshwater plants was gradual, so survey traverse 2 was begun at the contact between the wetland and a mowed field. This traverse was aligned directly up the axis of the valley, the gentlest slope in the area. As a result, the distances to the 0.5 m, 1.0 m and 2.0 m elevations were more than 3 times that observed in traverses 3 and 4, along the steeper western wall of the valley. (*Figures 2.3, 2.6, 2.7, 2.8*) The greatest extent of submergence over dry upland is estimated at almost 75 m up the valley axis. (*Table 2.1*)

Because of irregularities in the slope of the land, a range of distances to the three elevations were observed and recorded. (*Table 2.1*)

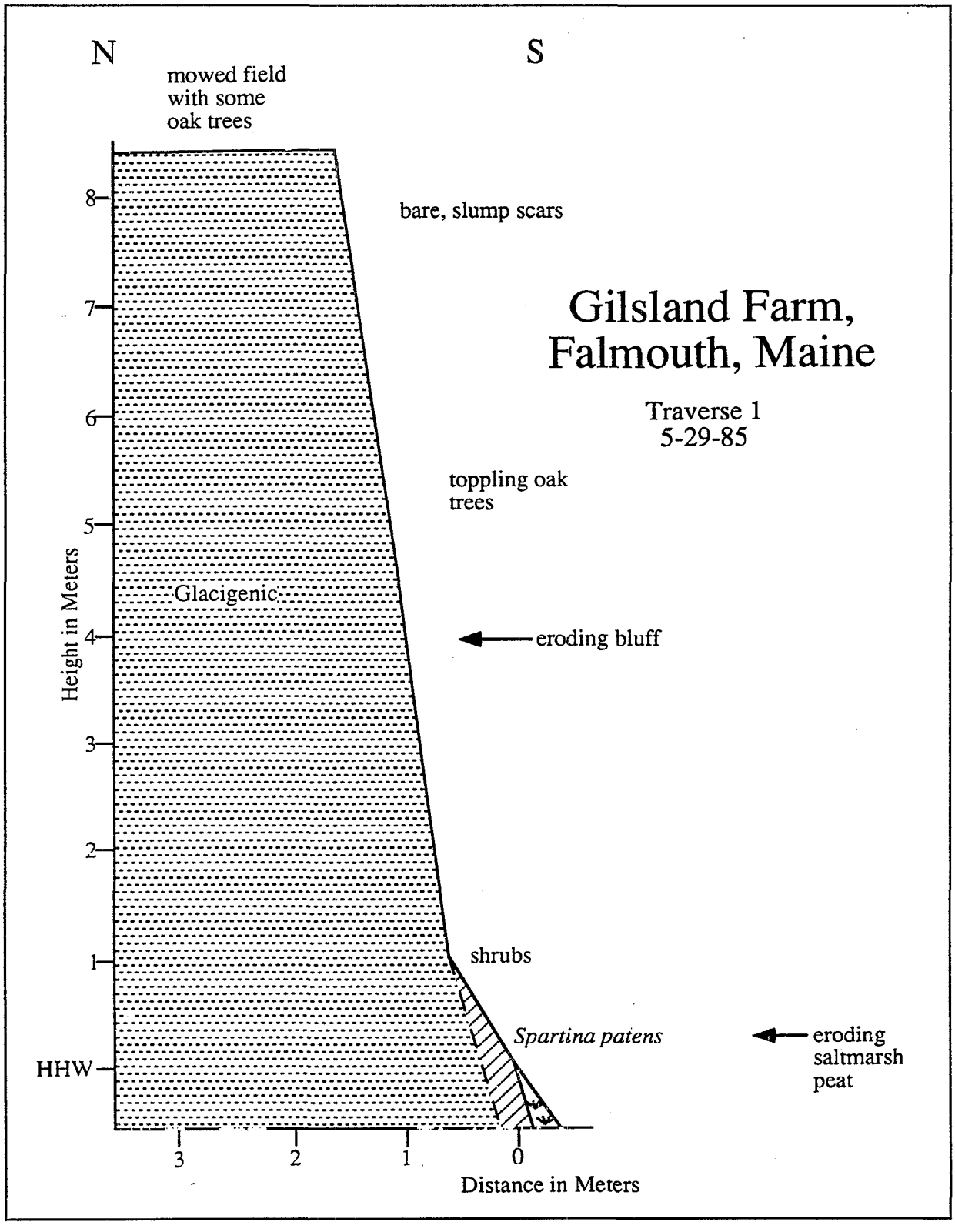

Figure 2.5. Traverse 1, Gilsland Farm. Traverse 1 is located on Figure 2.3.

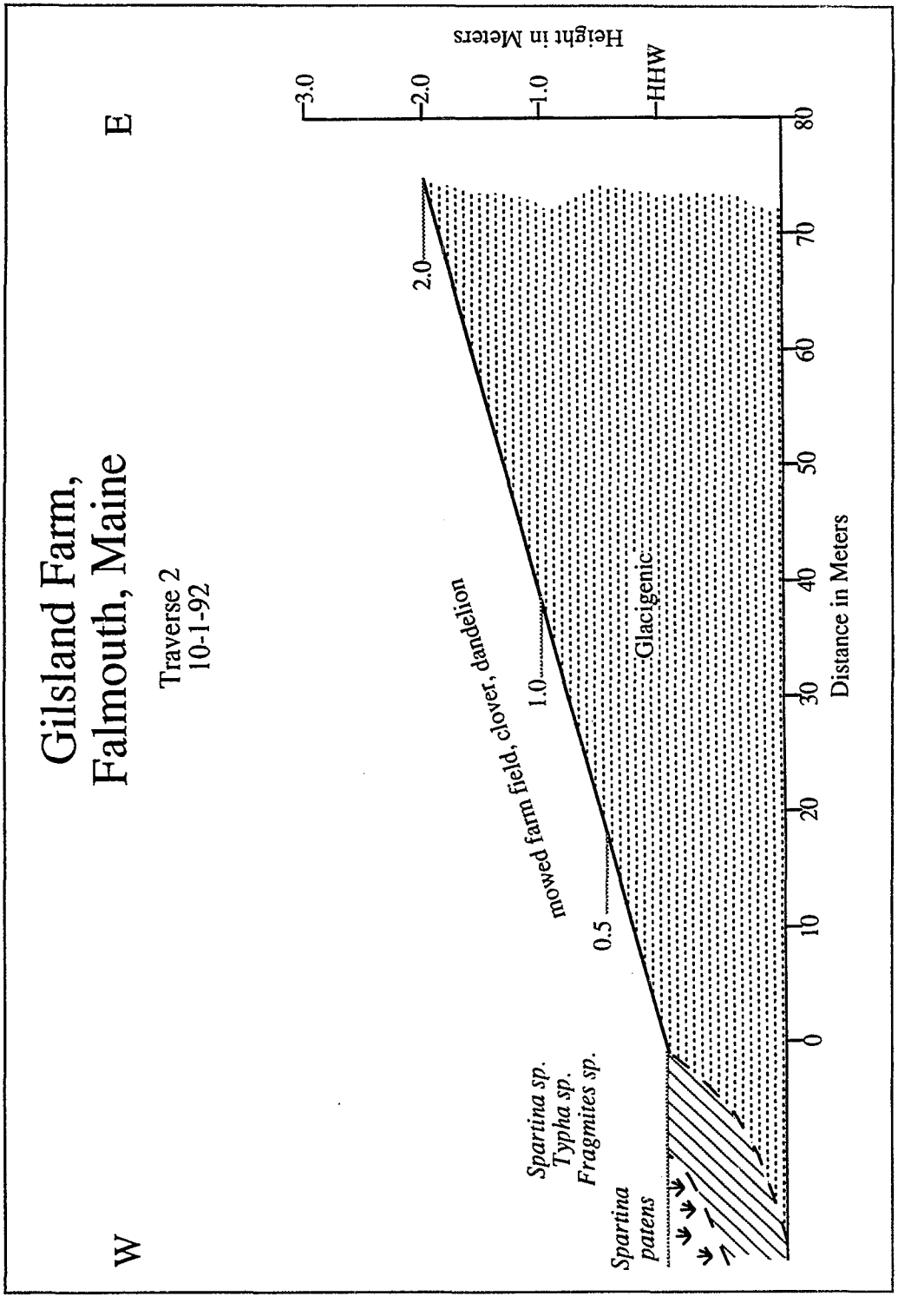

Figure 2.6. Traverse 2, Gilsland Farm. Traverse 2 is located on Figure 2.3.

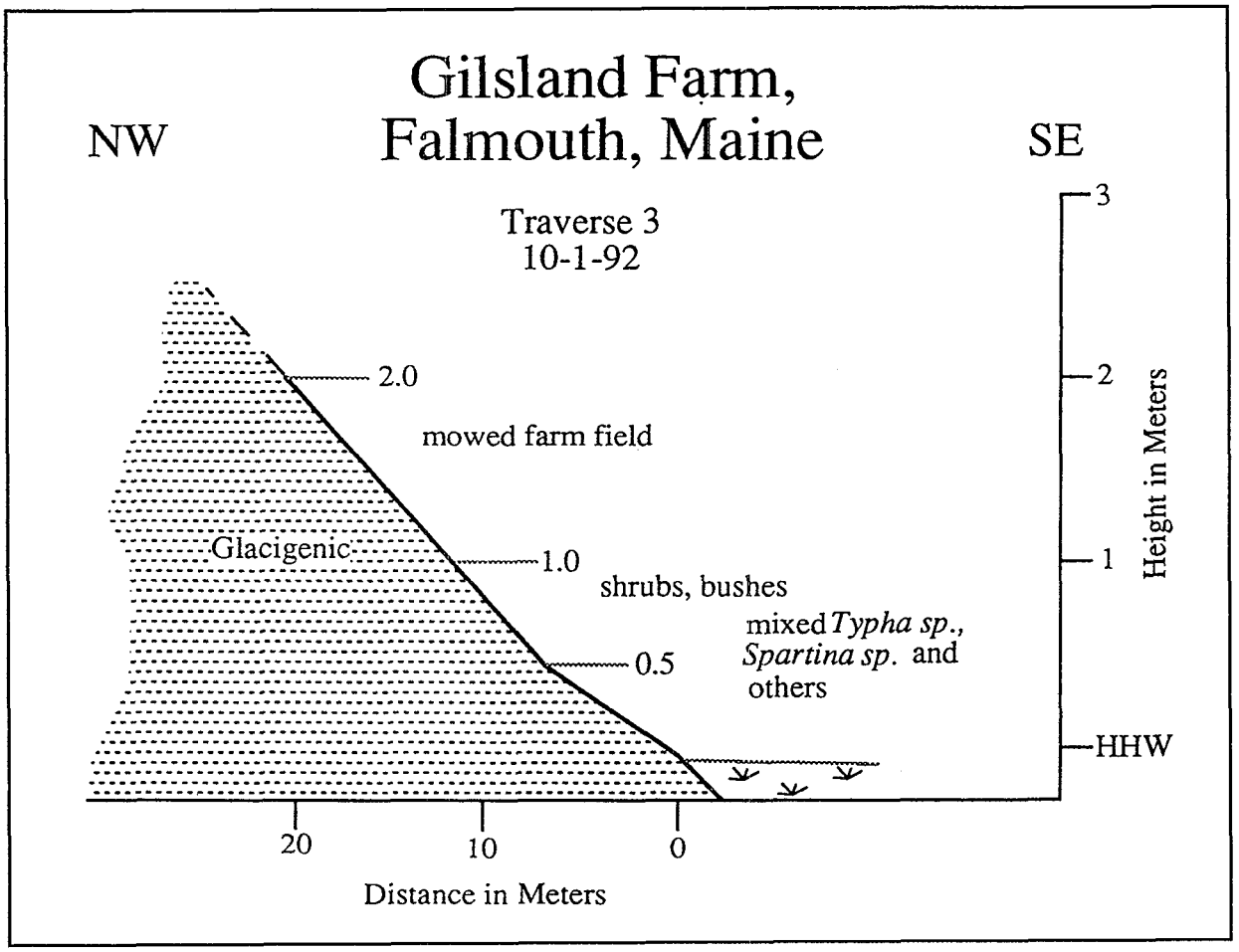

Figure 2.7. Traverse 3, Gilsland Farm. Traverse 3 is located on Figure 2.3.

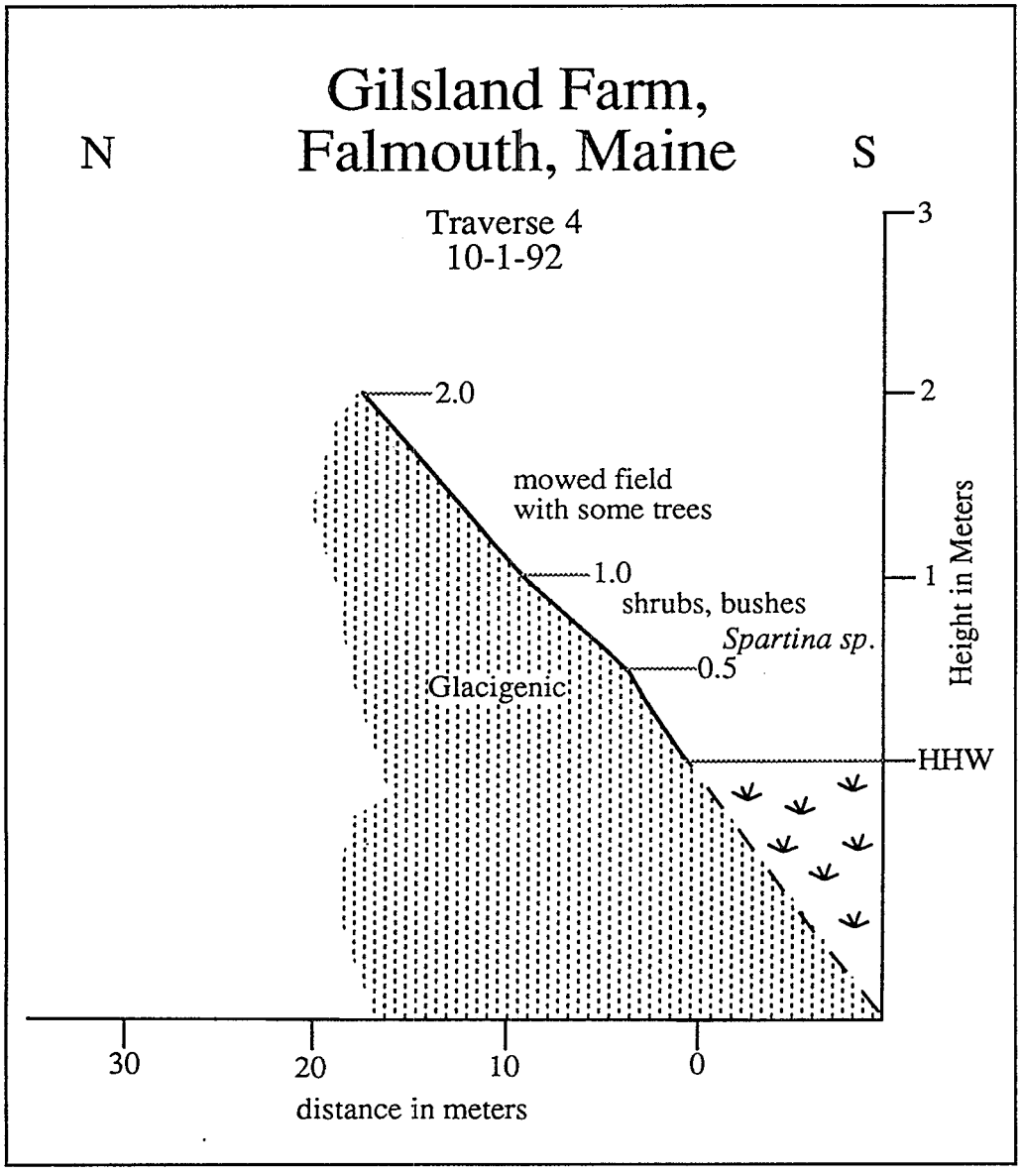

Figure 2.8. Traverse 4, Gilsland Farm. Traverse 4 is located on Figure 2.3.

b. Impact Assessment

1) Upland Impacts

The mapped study area at Gilsland Farm included approximately 50 acres of dryland, 25 acres of adjacent salt marsh and a large expanse of tidal flats. Estimates of the loss of upland according to sea-level rise scenarios are as follows:

	.5 m rise	1.0 m rise	2.0 m. rise
Dryland Lost	3 acres	5 acres	14 acres

2) Value of Land/Structures

A quantitative analysis of the monetary value of anticipated losses at this site was not possible. This site is unlike the others considered in this analysis in that it is not developed, and is owned and operated by Maine Audubon as a sanctuary and field office. Gilsland Farm has extreme local, regional, and possibly statewide significance as a recreational, educational, historic/cultural, and pristine resource. It was selected as a study site because of its accessibility for field investigations, and is illustrative of probable impacts on similar, developed sites.

3) Wetland Impacts

Wetland and marine habitats of high quality and national significance exist at this site, part of a large system of wetlands and tidal flats that comprise the Presumpscot River Estuary. The US Environmental Protection Agency (USEPA) has been a leader in studying the possible effects of sea-level rise on salt marshes (Titus, 1987, USEPA, 1989). Drawing on those studies, researchers understand that salt marshes adjust to sea-level rise by expanding inland and towards the water and increasing in elevation through accumulation of sediments and plant biomass. In general, marshes will expand when sedimentation exceeds submergence, will maintain if sedimentation balances submergence, and will drown when sediment supply and accretion is less than the rate of coastal submergence (Sea-level plus subsidence). Besides the natural availability of sediment, other factors such as slope of adjacent uplands, the presence of coastal engineering structures, the armoring of bluffs and banks limiting the amount of available sediment, and the rate of sea-level rise all affect the ability of marshes to migrate landward to keep pace with accelerated sea-level rise. In addition, marshes that have been fragmented by land development or otherwise degraded by human influences will have diminished ability to migrate (U.S. Congress, Office of Technology Assessment, October 1993.) *Figure 2.9* (Titus, 1986) illustrates these various scenarios of wetland change.

The USEPA has sponsored numerous studies which modelled anticipated wetland changes due to global warming in different regions (Barth and Titus, 1984, Park et al., 1989, Titus and Greene, 1989, USEPA, 1989). In different areas of the country, studies have documented that marshes have been able to keep pace with more gradual, historic rates of sea-level rise (e.g. 2.4 mm/yr in Charleston, South Carolina, 1 cm/yr in Louisiana). One study (Park, et al. 1989) concluded that many of New England's wetlands developed on poorly drained glacial tills and occur at elevations above those that could be inundated by sea-level rise in the

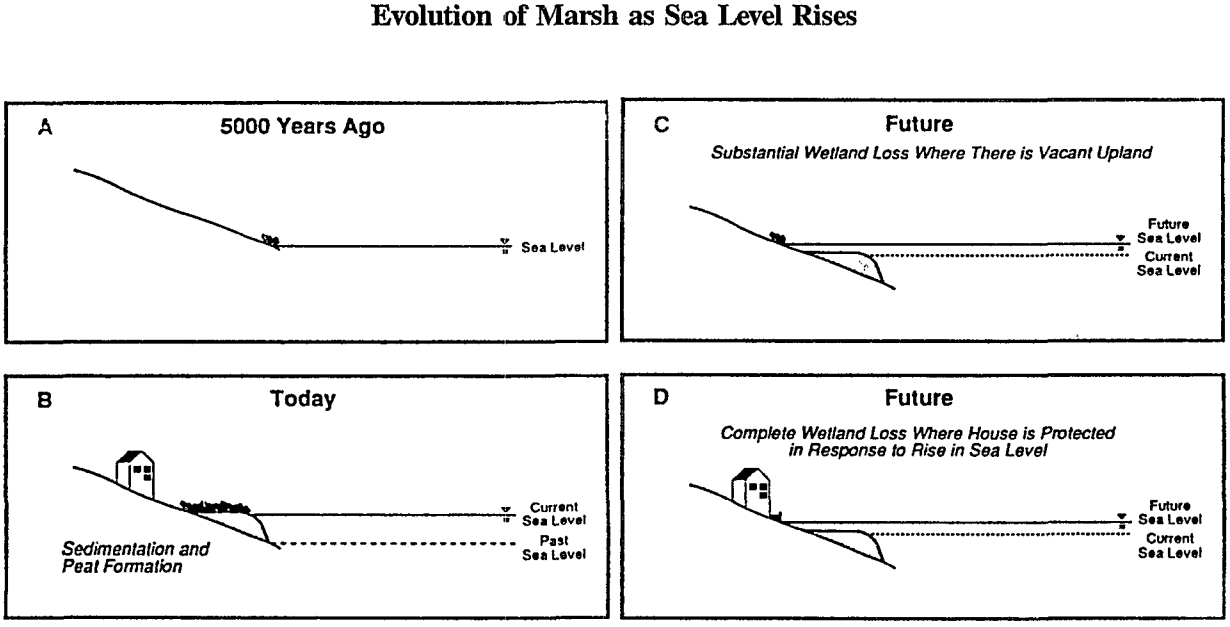

Figure 2.9. Coastal wetlands have kept pace with the slow rate of sea level rise that has characterized the last several thousand years. Thus, the area of wetlands increased as new lands were inundated. If in the future sea level rises faster than the ability of the wetlands to keep pace, the wetland area will decline. Construction of bulkheads or dikes to protect developed areas would prevent new wetlands from forming inland, resulting in a total loss in some areas.

Source: Titus (1986).

next century. Researchers (Armentano and Park et al., in Titus, 1987) concluded that under a scenario of accelerated sea-level rise of 1.4 m by 2100, the general response of New England wetlands would be expansion into freshwater areas, or expansion onto unprotected adjacent undeveloped lowland, dunes or beaches (especially in areas less than 3.5 m or 10 ft. in elevation). In this modelling exercise, losses of marsh due to expansion of tidal flats were small or compensated for by expansion of the salt marsh. In contrast under the high scenario of accelerated sea-level rise of 2.2 m by 2100, in sheltered places with steep slopes and cliffs (such as one of Park's study sites in Jonesport, Maine), the projected rise inundated salt marshes. In these areas, despite Maine's high tidal range, which favors the maintenance of marshes, there is little lowland to be inundated and colonized by marshes. A relatively low rate of accretion (2mm/yr), typical of New England salt marshes was assumed in these studies.

Given the information discussed above, and lacking the ability to conduct expensive, site specific studies of coastal marshes in Maine, this study assumes that (provided there are no physical constraints to landward movement and excepting areas of steep slope), the marsh surrounding Gilsland Farm (and other salt marshes covered in this study) will migrate inland in equilibrium with the .5 meter and 1.0 meter levels of accelerated sea-level rise. Under the extreme case of a projected 2.0 meter rise by 2100, losses of coastal wetlands might be anticipated. However, as noted above, Maine's coastline is more typically relatively steep and bedrock-dominated, thus, due to physical constraints and steep slopes, it is expected that a change in shoreline position will frequently result in a much smaller area of new marsh

creation. No assumptions were made about the quality of the habitat provided by the newly created wetlands.

4) Extent of Similarly Situated Land in the Region

Salt marshes with associated mudflats make up more than 20% of the coastline of the larger Saco Bay/Casco Bay region. NOAA estimates that there are 2,900 acres of salt marsh in the Saco Bay estuary and 2,400 acres within the Casco Bay estuary (U.S. Department of Commerce, 1991).

A more accurate assessment of wetland impacts for the region would require more site specific analysis of different slope conditions, sediment availability, and the extent of shoreline armoring, because protection of private lands by construction of shoreline protective measures will preclude migration and result in wetland losses. However, national studies, broken down by region, have been prepared which may provide additional information. Titus and Greene (in USEPA, 1989) expanding upon Park's assessment of New England wetland losses (Park et al., 1989), estimated that between 15% and 17% of coastal wetlands could be lost if all of the shoreline was protected with bulkheads or similar structures; similarly they estimated between 6% and 10% of New England's coastal wetlands could be lost if only already developed shoreline areas were protected. If shorelines are able to retreat naturally, losses would be smaller, and in certain conditions, there might be a possible net gain of wetlands.

Using these estimates, wetland losses for the Casco and Saco Bay region, would be projected as follows:

Table 2.2. **Range* of Potential Wetland Losses for Region**

	Natural Migration (1-5% loss)	**Developed Areas Protected** (6-10% loss)	**All Shores Protected** (15-17% loss)
Saco Bay	29-145 ac.	174-290 ac.	435-493 ac.
Casco Bay	24-120 ac.	144-240 ac.	360-408 ac.

* Range represents estimates for .5 meter, 1.0 meter, 2.0 meter sea-level rise scenarios.

5) Analysis

This site highlights the importance of protecting the ability of marshes to migrate to keep pace with rising sea level. In developed areas, there will be pressure to harden the shoreline to protect public and private investment. Much more research is needed on the relationship of marshes to sea-level rise in Maine. According to a recent newsletter of the Wells Estuarine Research Reserve (Dionne, 1993), marshes in the northeast are beginning to show signs of changes in zonation from high marsh to low marsh, indicating impacts by changing water levels and variations in available mud supplies.

Gilsland Farm is also one of the two mapped sites in the study area to contain eroding bluffs. If this were a developed site, a projected bluff retreat of .15 meters per year (about .5 ft/yr) or 15 meters by 2100 (49.2 ft) would be cause for concern.

2. Bungunac Bluff-Wharton Point

a. Shoreline Position

The coastline from Bungunac Bluff to Wharton Point forms the northwestern corner of Casco Bay. (*Figure 2.2*) Bluffs of glacial-marine sediment greater than 10 m high are common at Bungunac Bluff and decrease to a gentle slope covered by salt marsh north of Wharton Point. Where they are exposed to waves from the southwest, the bluffs are fronted by a mudflat and are very unstable. (*Figures 2.10, 2.11*) As at Gilsland Farm, large trees and blocks of slumping debris are common along the bluff face. (*Figure 2.12*) The surveyed retreat rate between 1985 and 1988 averaged 0.45 m/yr with a standard deviation of 0.16 (Smith, 1990). This compares favorably with rates evaluated from historic photographs of 0.52 m/yr between 1940 and 1972, and 0.89 m/yr between 1972 and 1986, with standard deviations of 0.28 and 0.58, respectively (Smith, 1990). The predicted shoreline reflects the surveyed retreat rate of 45 m for the year 2100. (*Table 2.1*)

To the northeast of Bungunac Bluff, wave exposure is reduced, and a salt marsh protects bluffs from direct wave attack. (*Figures 2.10, 2.14*) Here, the surveyed retreat rate was 0.26 m/yr with a standard deviation of 0.26. In historic photographs the bluff was obscurred by shadows from overhanging trees and no longer-term evaluation was possible (Smith, 1990). The projected retreat distance here is 26 m. (*Table 2.1*)

At Wharton Point no bluff erosion is occurring, and the salt marsh is locally expanding out across the tidal flat (Smith, 1990). (*Figure 2.13*) This is likely to continue into the next century because mud eroded from eleswhere in the bay is apparently collecting at the upper end of Maquoit Bay (Hay, 1988).

b. Impact Assessment

1) Upland Impacts

The mapped study area in Maquoit Bay included about 100 acres of dryland and 25 acres of wetland. Extensive tidal flats also occur all along this shoreline. The mapped 100 year shoreline position results in a loss of about 18 acres of upland.

2) Value of Land/Structures

While the area affected by slumping bluffs is usually small and localized, individual property owners can be greatly impacted by shifting shorelines. In the Bunganuc Point study area, two properties are currently experiencing land loss. Five homes may be impacted over the study period. Town of Brunswick 1988 assessment records value the Bunganuc Landing Road properties (five acre lots with substantial homes) at between $140,200 to $310,100. Two properties at Wharton Point mapped transect are valued at $199,600 and $248,500.

3) Wetland Impacts

Mudflats and wetlands in Maquoit Bay are among the most productive in the region, and are rated of national significance with high habitat values. In Bunganuc Point, there will be slight wetland losses, as slump material from bluffs is periodically dumped on the marshes. At Wharton Point, marshes are growing seaward into mud flats due to transport of Maquoit Bay mud supplies to this area.

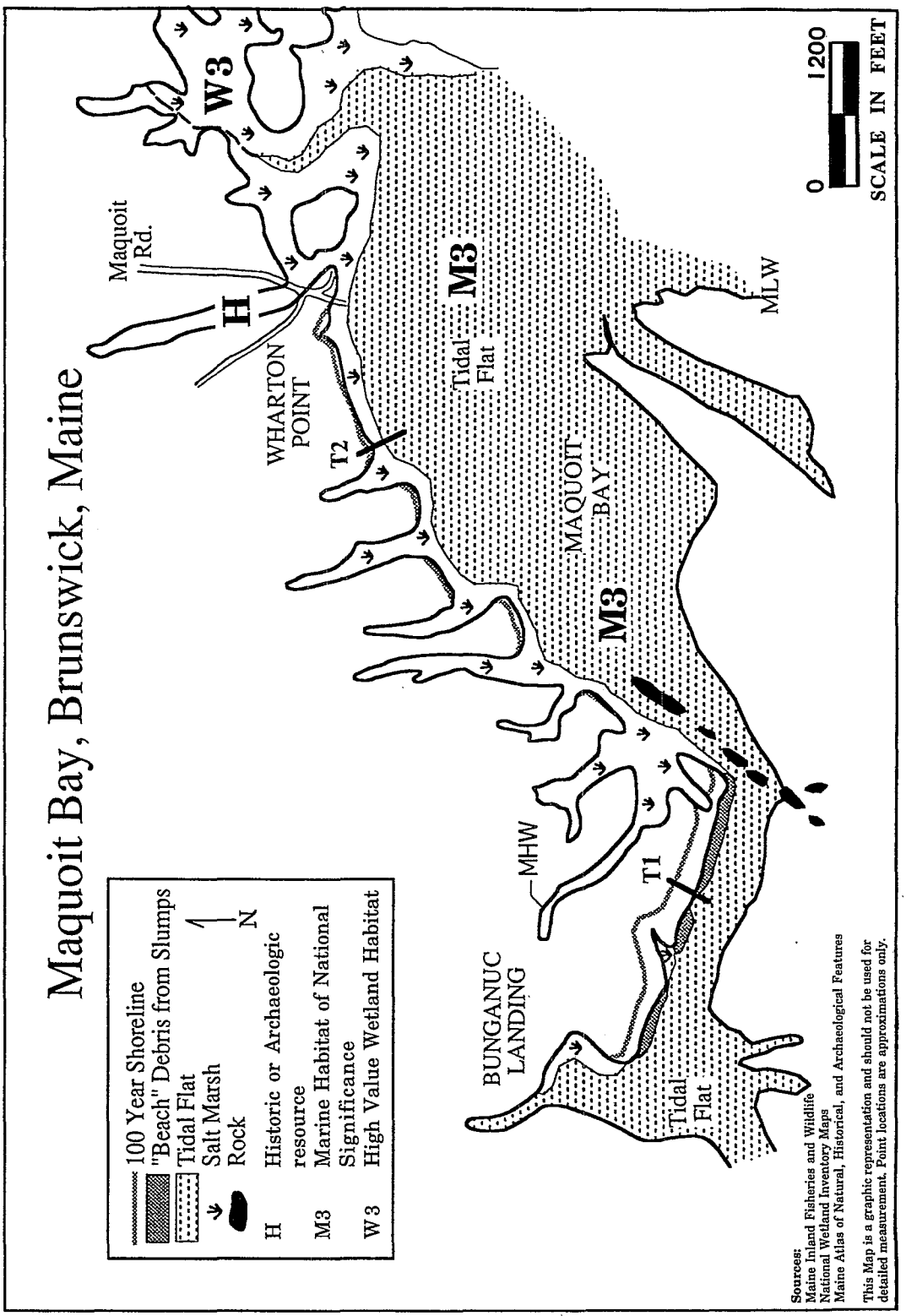

Figure 2.10. Projected shoreline change map at upper Maquoit Bay, Maine. Coastal Environments after Timson (1977).

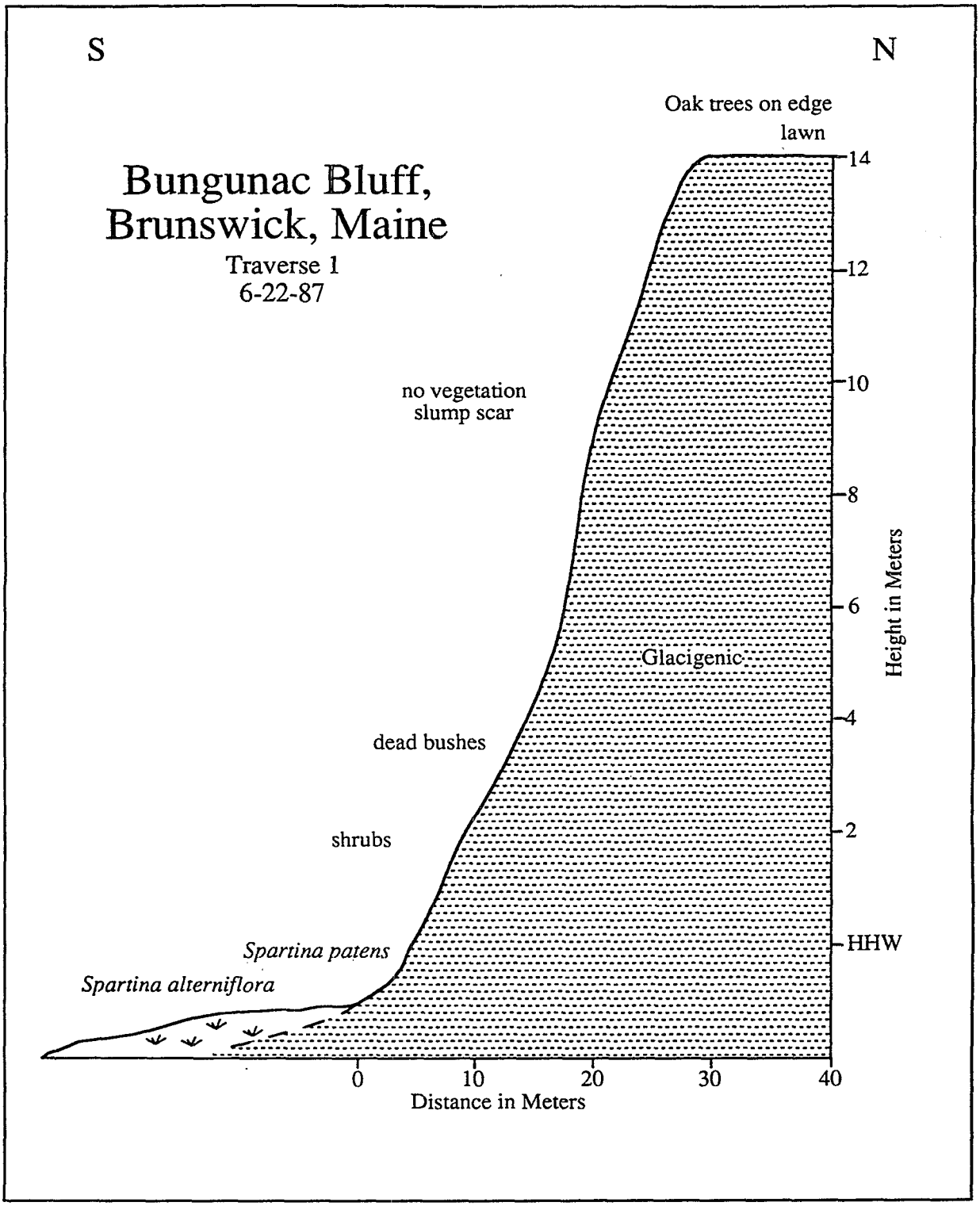

Figure 2.11. Traverse 1, Bungunac Bluff, Brunswick, Maine. Traverse 1 is located on Figure 2.10.

Figure 2.12. Photograph of Maquoit Bay shoreline. Site of Traverse 1.

Figure 2.13. Photograph of Maquoit Bay shoreline. Site of Traverse 2 is located in forested area in distance.

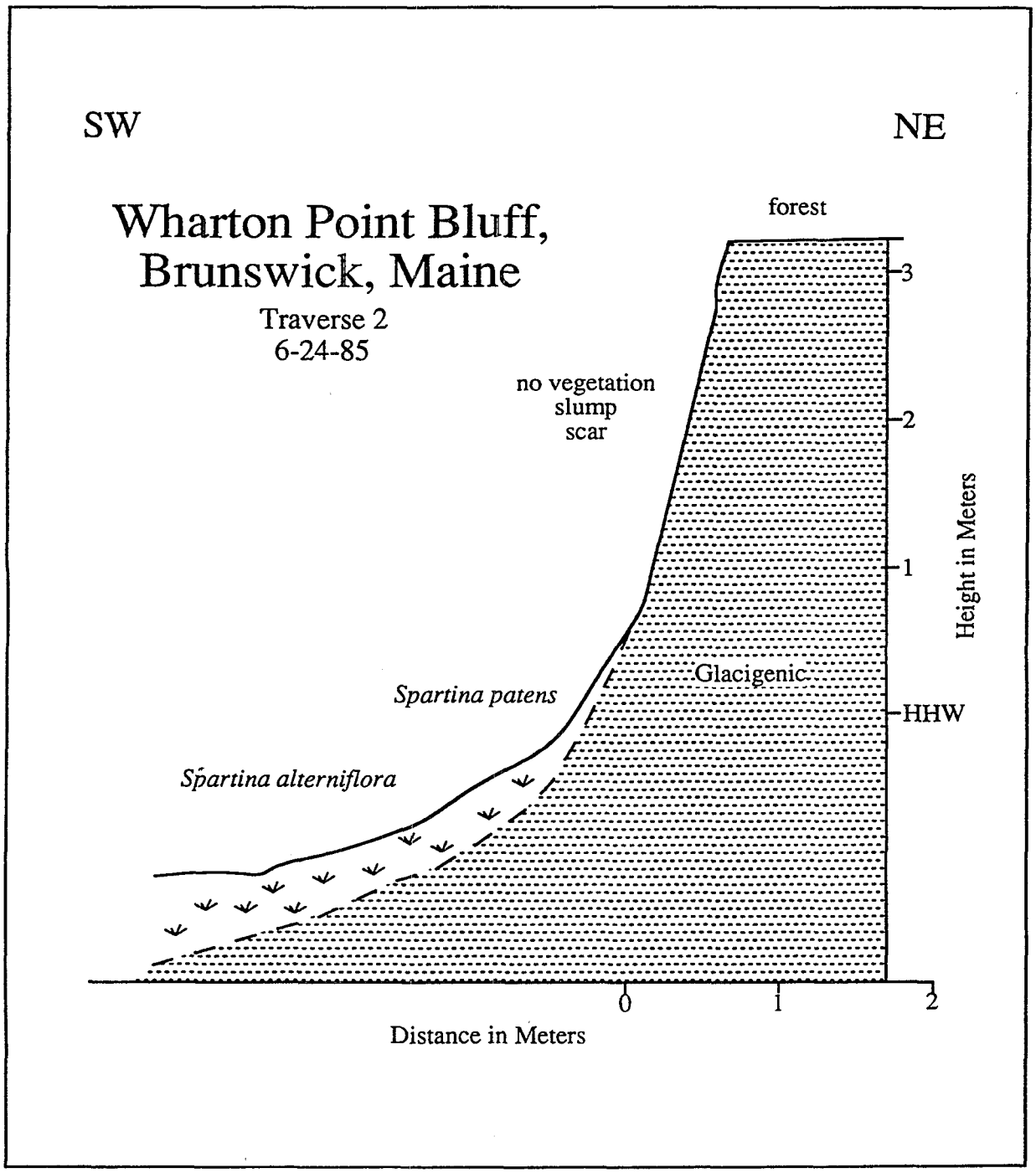

Figure 2.14. Traverse 2, Wharton Bluff, Brunswick, Maine. Traverse 2 is located on Figure 2.10.

4) Extent of Similarly Situated Land in the Region

Although bluffs make up only about 3% of the total shoreline of the region, much of the area's suburban shoreline from the Presumpscot River in Falmouth to the Harraseeket River in Freeport is supported by bluffs of sand or mud. Mackworth Island, Brunswick, and the Casco Bay islands also have isolated bluff areas.

Impacts associated with eroding bluffs are confined to a smaller area than the widespread inundation associated with the impact of rising seas on other coastal environments. Typically, impacts will be experienced only by adjacent landowners who have built close to the bluff line. There are no known major built features other than residences threatened by bluff erosion in the region.

However, as many as 200 homes in the region may be affected by the range of shoreline positions projected during the study period. Property assessment data was not gathered for the region, but the average value of individual properties in the Bunganuc Landing area may provide a useful comparison for the region.

5) Analysis

The Bunganuc area highlights the fact that bluff environments, while not directly affected by rising sea level, are unstable and dynamic areas. Clearing vegetation to improve views or attempting to stabilize the slopes with gravel or other materials increases the threat of erosion.

Relatively recent development has occurred in these areas despite the existence of local and state land use and environmental regulations. This points to possible inadequacies in those laws, lack of knowledge about bluff shoreline processes, the need for more data on bluff behavior, and the need for public education about shoreline processes and slope maintenance.

It is generally not feasible to stabilize eroding bluffs; a retreat from the affected area is usually the only solution. Homes that are currently threatened have experienced loss of usable yard space and have moved septic systems away from the eroding bluff edge. Soft technologies such as the planting of vegetation at the base of the bluff only slow rates of erosion. Due to the steepness of some of these areas, hard structures, such as riprap, to protect individual properties would be prohibitively expensive. Use of hard structures to stabilize bluffs would also have significant environmental costs due to the interference with transfer of sediment from bluffs to coastal wetlands.

3. Winnocks Neck

a. Shoreline Position

Winnocks Neck, Scarborough is a peninsula extending into the Scarborough River salt marsh. (*Figure 2.15*) The Neck is bounded by the Nonesuch River and Mill Brook to the east and west, and by the Scarborough River to the south. (*Figure 2.16*) The peninsula is supported by bedrock more than 30 m high (90 feet) which is mantled by till and glacial-marine sediment. Within the marsh many small "islands" of glacigenic material (like Plummer Island) project above the marsh surface and are being slowly drowned by the marsh as it grows upward with rising sea level. (*Figure 2.18*)

Three traverses were selected to evaluate changes in the shoreline as a consequence of future submergence. Traverse 1 extends west from the Nonesuch Marsh and parallel to the Plummer Island Rd. There is a distinct topographic and vegetative break from a *Spartina patens*-dominated high marsh to a freshwater marsh with *Typha sp* which was used as higher high water. (*Figure 2.17*) The 0.5 m elevation averaged 26 m from higher high water, but most of this distance was across the freshwater marsh. (*Table 2.1*) The 1.0 and 2.0 elevations were relatively closer to higher high water because the traverse steepened up a partly mowed hillside. (*Figure 2.18*)

Traverse 2 passes over a narrower part of the peninsula where the topographic relief was less. (*Figure 2.20*) Although the distance to the 0.5 m elevation was less than at traverse 1, the land flattened out and the distance to the 2.0 elevation was twice as far as at traverse 1. If the traverse were extended along a road into a small subdivision, the distance to the 2.0 m elevation was greater than if the traverse (*Figure 2.19*) went through the more uneven ground of the adjacent forest. (*Table 2.1*).

Traverse 3 extends up the western side of the peninsula from the Mill Brook marsh. (*Figures 2.16, 2.21*) There is a distinct topographic break at the landward edge of the *Spartina patens* salt marsh which is considered higher high water. The upland beyond this is forested, but relatively steep as in traverse 1. The 2.0 m elevation occurs near Sandy Point Road, and a hill with houses on it rises on the opposite side of the road. (*Table 2.1*)

Because of irregularities in the slope of the land, a range of distances to the three elevations were observed and recorded. (*Table 2.1*)

b. Impact Assessment

1) Upland Impacts

The mapped study area at Winnock's Neck included about 275 acres of developed upland and adjacent salt marsh. Upland losses are projected as follows:

	.5 m rise	1.0 m rise	2.0 m. rise
Dryland Lost	23 acres	43 acres	66 acres

Most of the area is developed with large-lot, "upscale", single family structures, whose backyards gradually fade into the adjacent marsh. The low and medium sea-level rise scenarios would inundate the shores at greater or lesser levels depending on the steepness of the slope. Because sea-level is predicted to rise over a prolonged period of time, impact on these properties will also be gradual, as the wetland-upland edge migrates inland, resulting in a net loss of usable backyard area for these homeowners, and over time, complete conversion of the affected area to salt marsh. Under each of the sea-level rise scenarios, the most apparent changes in shoreline position occur at the terminus of the peninsula. The 2.0 meter rise boundary breeches the road that provides access to the end of the peninsula. Over the very long term, Winnock's Neck will become an island surrounded by marsh, similar to the existing pattern of small islands scattered throughout the marsh.

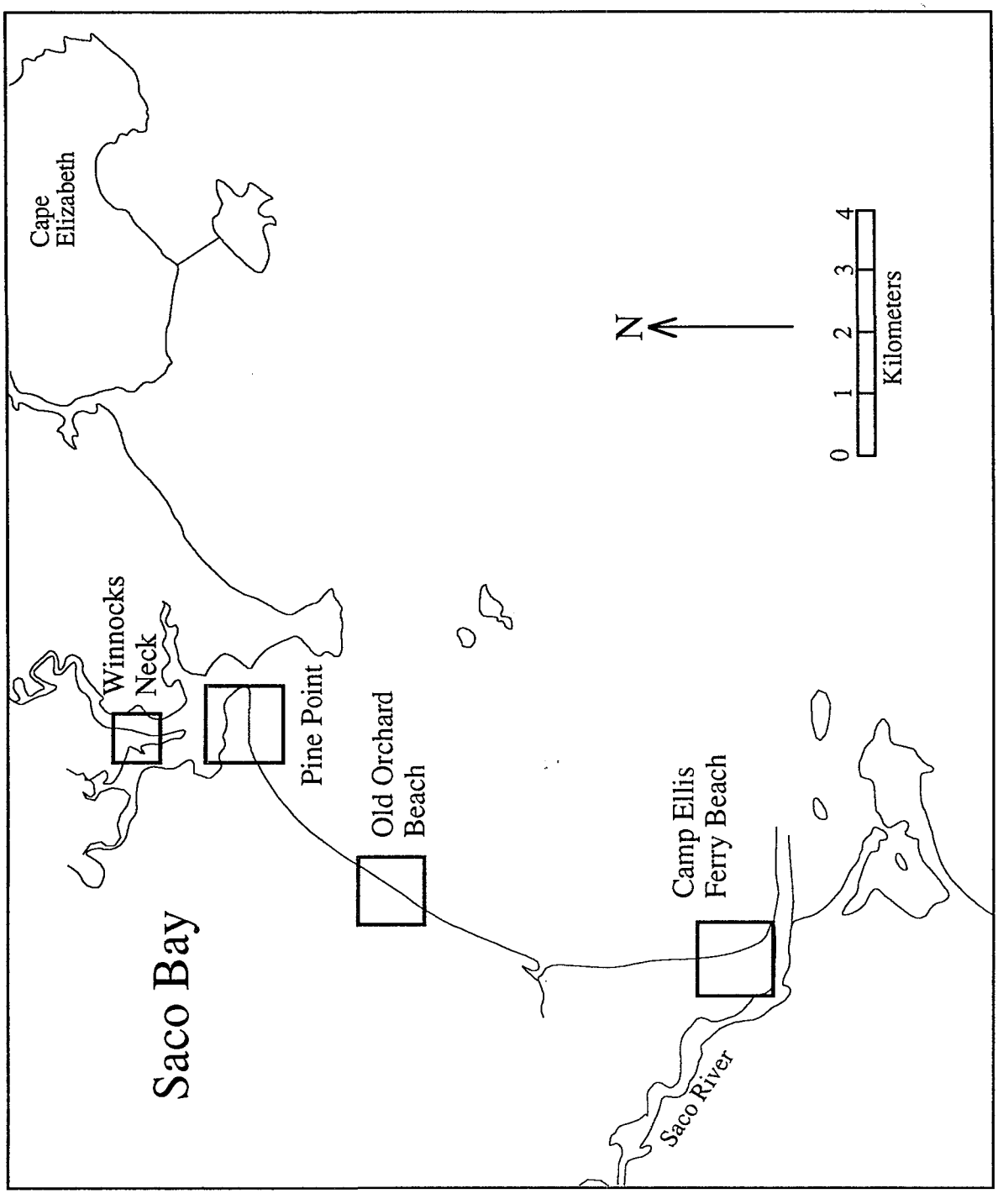

Figure 2.15. Map of Saco Bay with location of study sites enclosed by boxes.

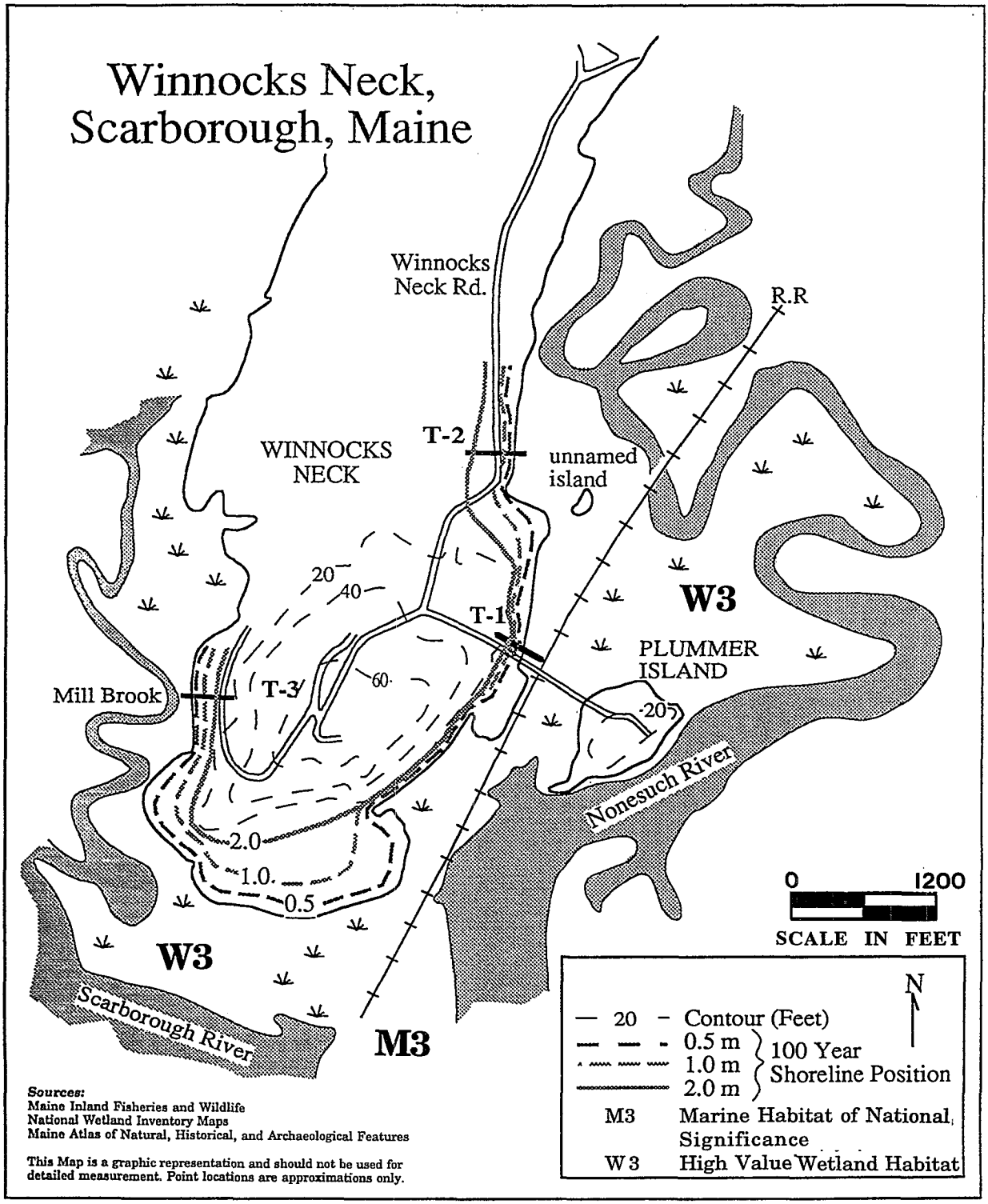

Figure 2.16. Projected shoreline change map for Winnocks Neck. Mapping was limited to the area surrounding Winnocks Neck, although the surrounding area is also depicted. Coastal environments after Timson (1977).

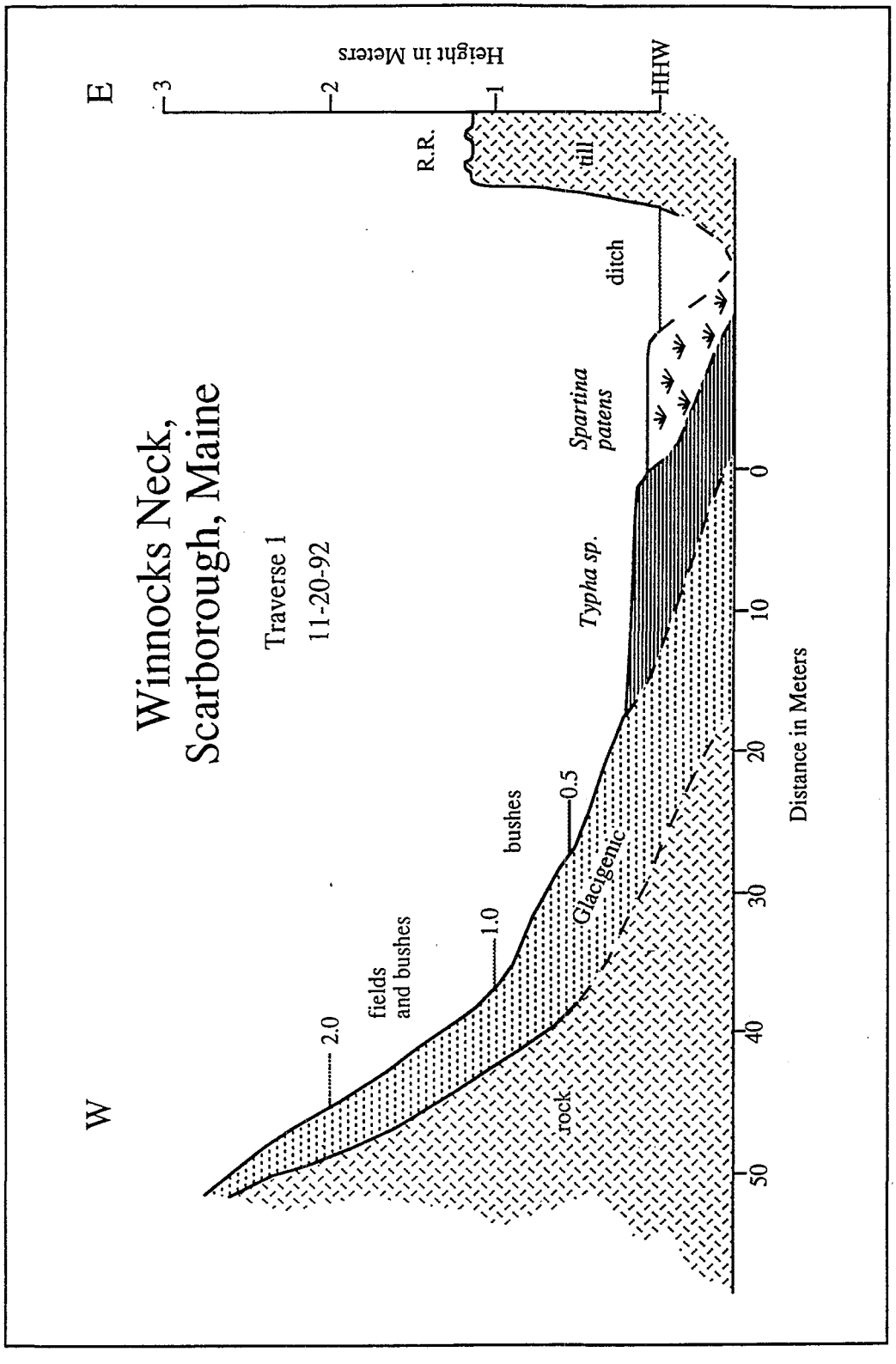

Figure 2.17. Traverse 1, Winnocks Neck. Traverse 1 is located on Figure 2.16.

Figure 2.18. Photograph of Winnocks Neck. View toward north at Traverse 1.

Figure 2.19. Photograph of Winnocks Neck. View down road into subdivision at Traverse 2.

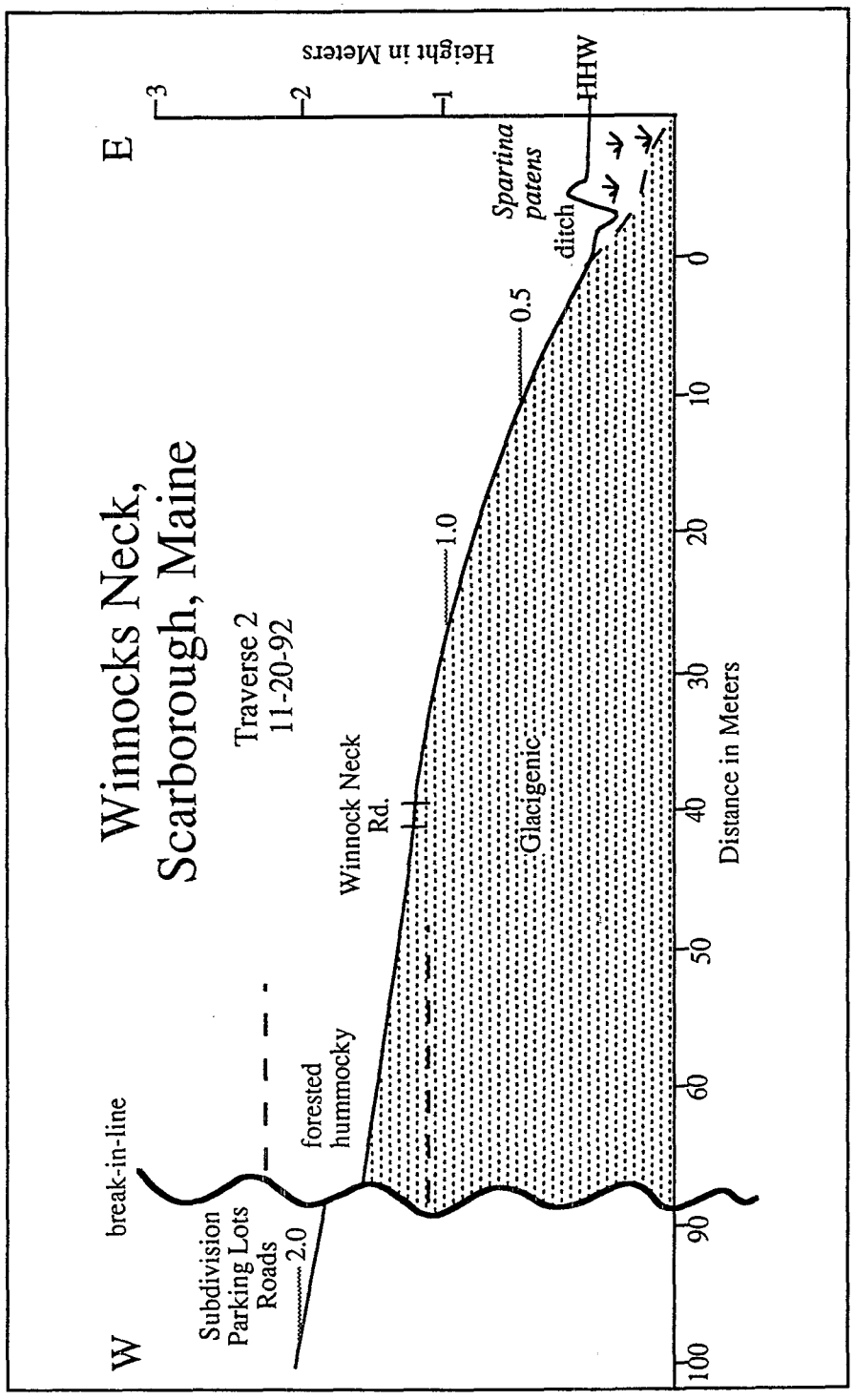

Figure 2.20. Traverse 2, Winnocks Neck. Traverse 2 is located on Figure 2.16. The dark wavy line indicates a break in the section. If the traverse were extended down a paved road and into a subdivision it would be farther to the 2.0 m elevation than if the traverse went through woods. Even within the woods there is considerable relief indicated by the dashed, parallel lines.

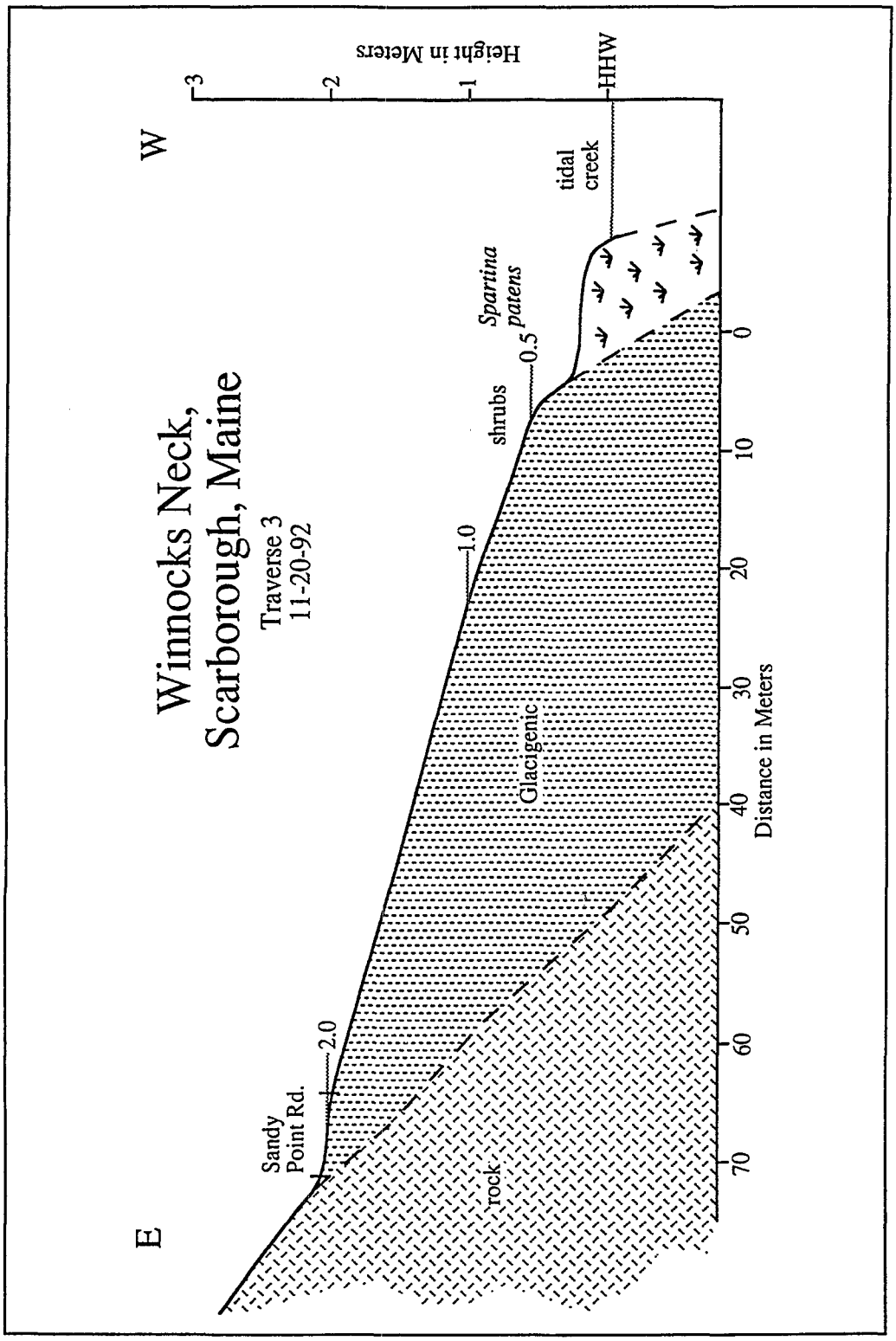

Figure 2.21. Traverse 3, Winnocks Neck. Traverse 3 is located on Figure 2.16.

2) Value of Properties

The majority of properties at risk are located at the terminus of the Winnock's Neck peninsula, where shoreline slopes are more gradual, and a network of cul-de-sacs (not shown) wind through developed lots. According to Scarborough assessor's records, the value of land and buildings in this area is about $7.2 million. The assessed value of structures (excluding land) in the area ranges from $100,000 to $180,000, while lots range in value from $78,000 to $110,000.

3) Wetland Impacts

The predominant natural feature in Winnock's Neck is the valuable marsh land surrounding the peninsula at the confluence of the Scarborough River and the Nonesuch Rivers. Marine habitat in this area is rated of national significance, while wetland habitats are also of high value. For a summary of potential wetland impacts, see the discussion under the Gilsland Farm study area.

4) Extent of Similarly Situated Land in the Region

(*See* discussion under Gilsland Farm study area.)

5) Analysis

Winnock's Neck illustrates the dilemma of migrating marshlands. In order to allow wetlands to survive an accelerated rise in sea-level, they must be allowed to migrate inland. This causes a conflict in wetland edge areas that have been developed. Adjacent property owners will be tempted to keep wetlands at bay by hardening of their shoreline.

Recent debates concerning state-mandated shoreland zoning have included disagreement over what is considered an adequate width of protective buffer between wetlands and adjacent development. Wetland setbacks have typically been static boundaries based on that "critical edge" required to preserve the wetland's value for wildlife habitat. In order to preserve valuable wetlands (for a variety of functions, habitat, flood retention, etc.) and to minimize future property losses accruing from migrating wetlands, zoning and subdivision standards should begin to consider wetlands as dynamic systems, with setbacks sufficient to accommodate anticipated changes in shoreline position.

4. Old Orchard Beach

a. Shoreline Position

Old Orchard Beach is located between Saco and Scarborough on the longest unbroken stretch of beach in Maine. (*Figures 2.15, 2.22*) The beach possesses a wide berm and low-tide terrace, but most of the original sand dunes were leveled in the 19th century to construct hotels. (*Figures 2.23, 2.24*) Landward of the former dunes are a mixture of lowlands and higher rocky areas, and occasionally rock outcrops are observed on the beach.

The 0.5 m, 1.0 m, and 2.0 m shoreline positions at 150 m, 300 m, and 600 m, respectively, reflect the uneven back-barrier terrain by projecting into the swampy areas and outward at the rocky hill. (*Table 2.1*) This depiction assumes that no new land from the Saco

River or elsewhere within the system is supplied to the beach in the next century, and neglects the impact of the two 1.3 m diameter sewage pipes under the dunes.

In addition to the shorelines predicted on the basis of the modified historical method, a 100 year shoreline supplied by the Town of Old Orchard Beach is depicted. It was produced as part of a permit application to locate a stormwater pipeline beneath the beach. Since there has been no more than 18 m of shoreline fluctuation mapped with certainty over the past century, this line is drawn 18 m landward of the high water line.

b. Impact Assessment

1) Upland Impacts

Development along Old Orchard's coast today is quite varied; high density, high rise condominium structures are intermixed with cottage style homes, commercial establishments, and seasonal dwellings. The mapped study area includes the heart of OOB's development district, including The Pier, the East Grand Avenue (Route 9) business strip (motels, restaurants, amusements), numerous Town facilities and part of the downtown area.

The mapped study area included about 270 acres of upland. Projected losses of dryland are as follows:

	.5 m rise	1.0 m rise	2.0 m. rise
Dryland Losses	80 acres	135 acres	169 acres

The .5 meter scenario potentially inundates all beachfront development and Grand Avenue to the railroad tracks. This area includes an amusement park, arcades, retail shops, motels, restaurants, and high density residential structures. Other built features at risk under this scenario include the network of sewer lines and the new stormwater outfall.

In addition to the development inundated by the .5 meter rise described above, the 2.0 meter rise scenarios would threaten town facilities such as a small park, tennis court, library, public restrooms, and parking lots. This area has been targeted for public and private improvements as part of an ongoing community revitalization, and discussed in further detail in the following section. Additionally, the 2.0 meter rise would also impact a small, lowlying area of moderate density residential development to the north. Due to the small difference in the land area covered by the 1.0 and 2.0 meter scenarios, impacts associated with the 1.0 meter rise were not analyzed separately, but most impacts identified with a 2.0 meter rise would also occur with a 1.0 meter rise.

2) Value of Land/Structures

According to information provided by the Old Orchard Planning Office, the value of land and buildings within the mapped .5 meter inundation area is about $32.4 million. It should be kept in mind however, that the mapped study site includes only a portion of Old Orchard's developed shoreline. If a .5 meter sea-level rise scenario was anticipated all along Old Orchard's shoreline, the value of potential property losses would greatly increase. For example, to the north of the mapped study area towards Pine Point, there are 6 high-rise condominium structures containing a total of 251 units (7-8 stories high, 28-55 units each)

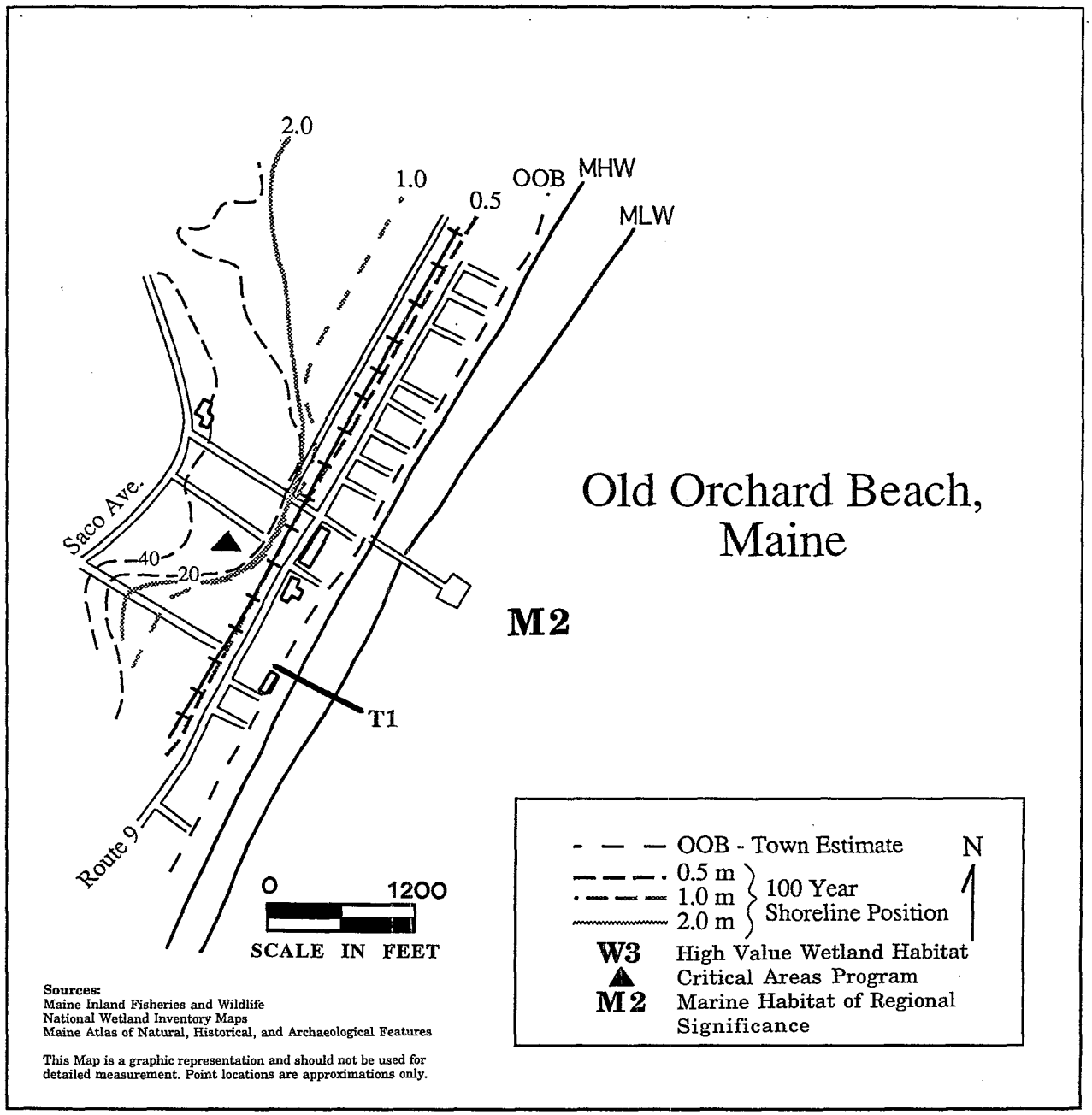

Figure 2.22. Projected shoreline change map for Old Orchard Beach. The projections from this study are compared with that of the Town (Timson et al., 1992).

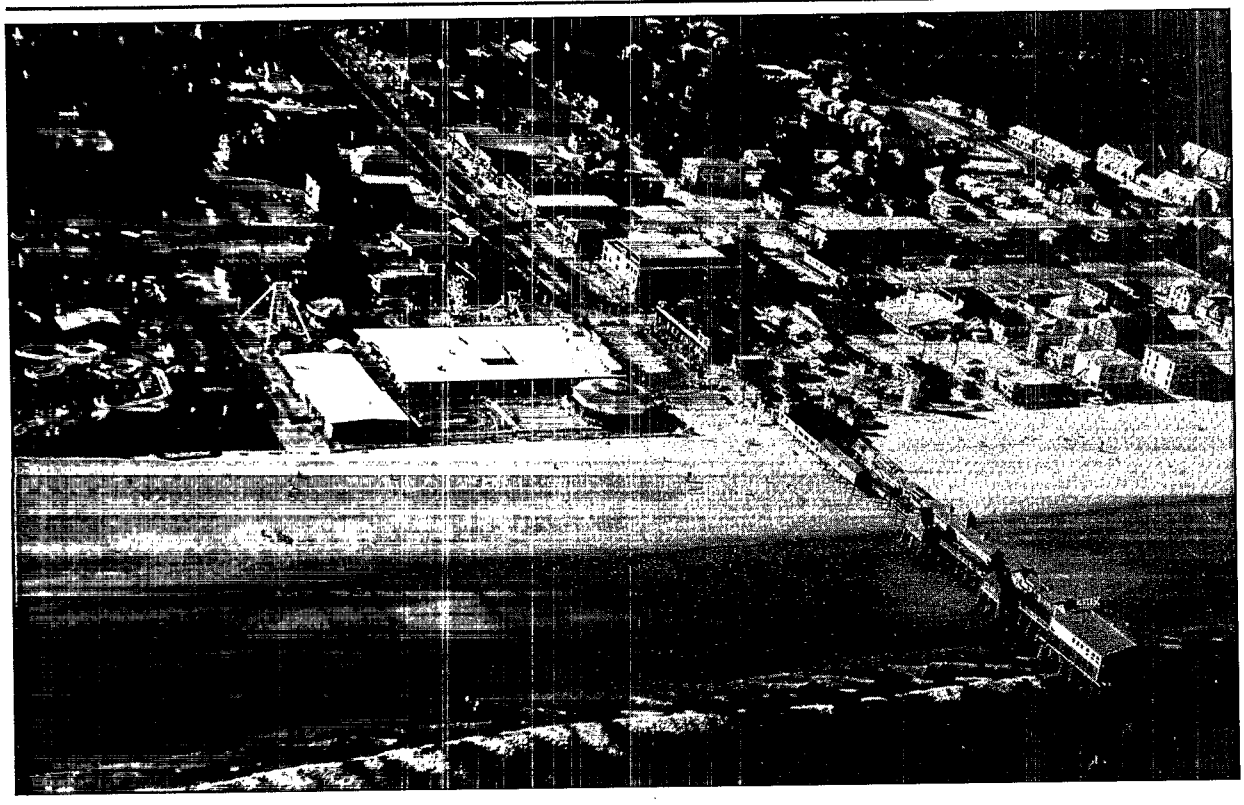

Figure 2.23. Photograph of the Old Orchard Beach area. Aerial photography of the study area.

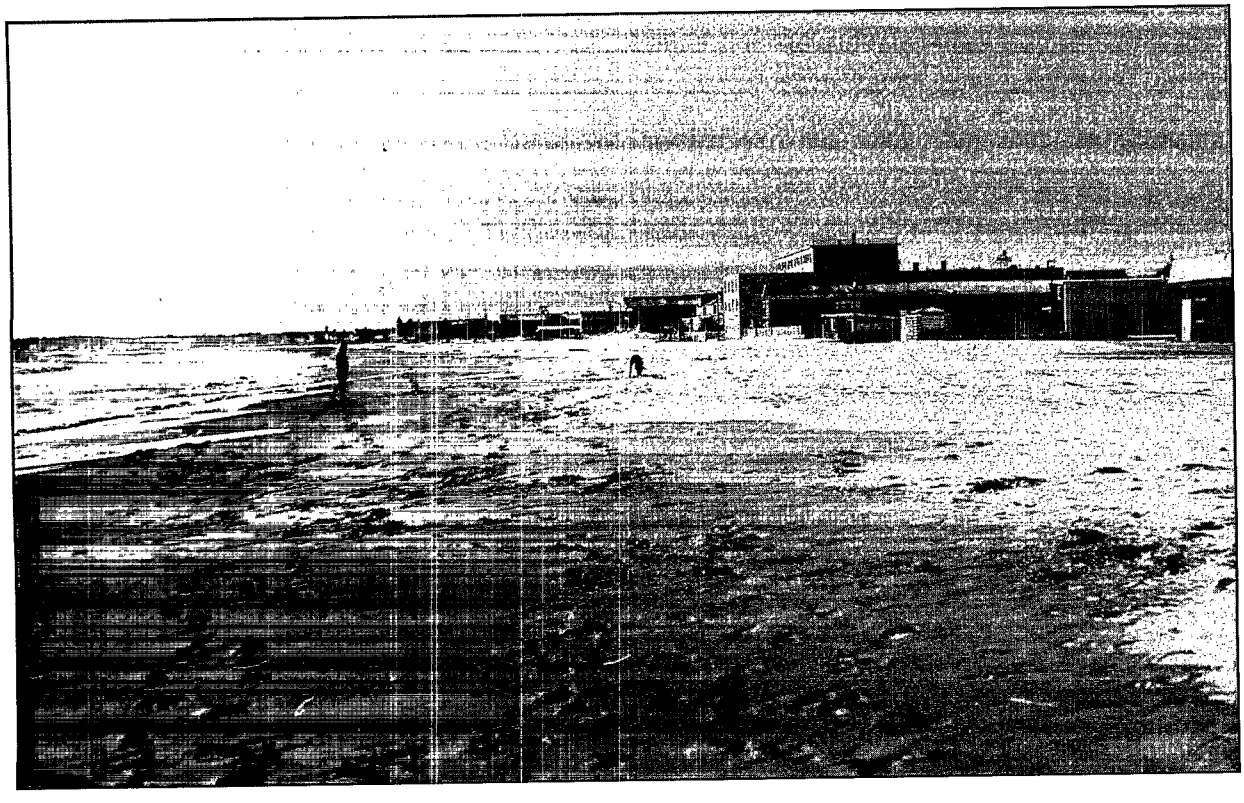

Figure 2.24. Photograph of the Old Orchard Beach area. Ground plot from near the study area.

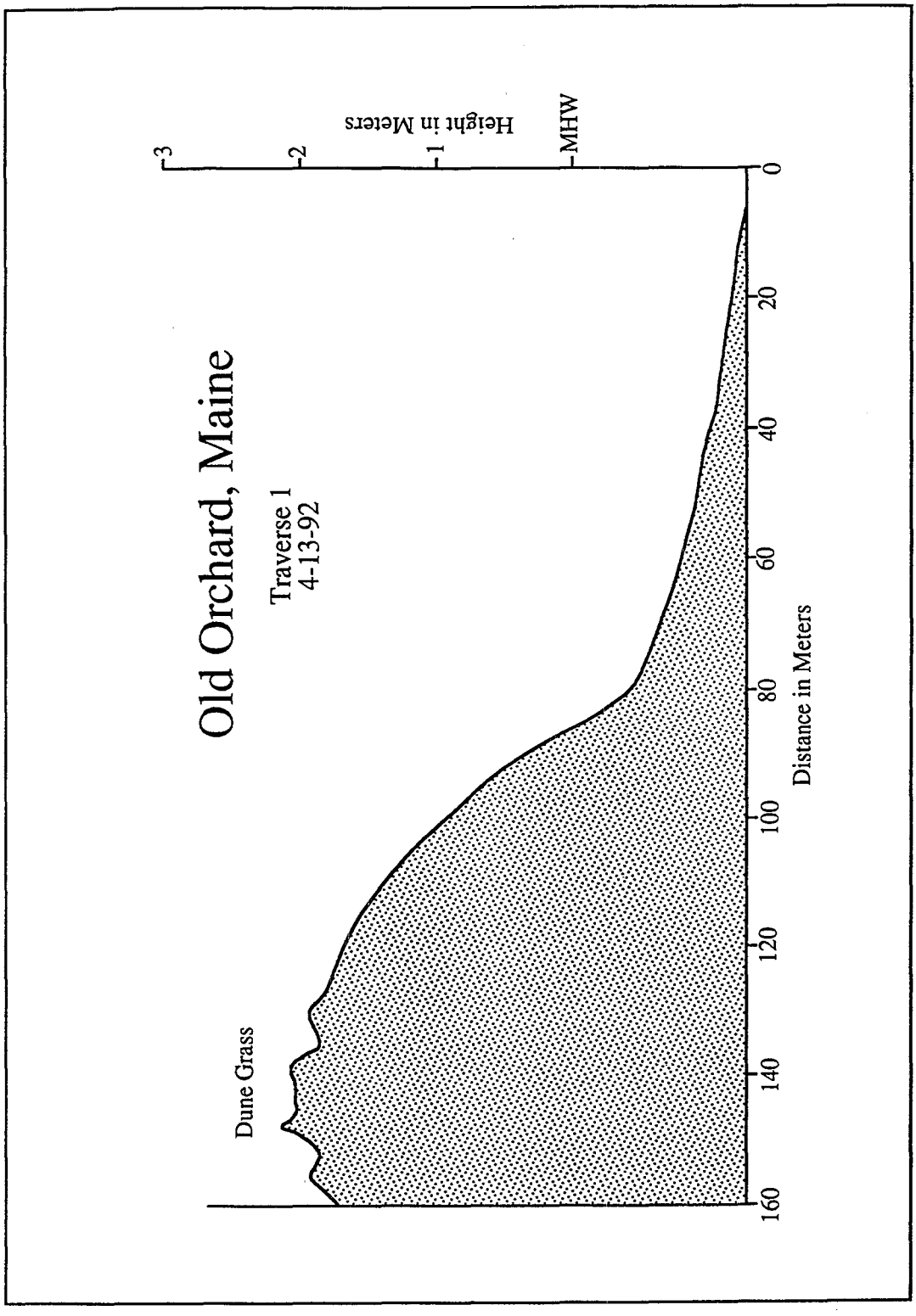

Figure 2.25. Traverse 1, Old Orchard Beach, Saco Bay. Modified from Timson et al., 1992).

located directly on the beachfront. A current value assessment for these properties is $35,347,600.

The 2.0 meter scenario potentially impacts an additional area of mostly residential development, assessed at $6.9 million. Because the 1.0 meter boundary was substantially similar to the 2.0 meter boundary in high-density areas, data on assessed value of these properties was not separated from figures gathered for the 2.0 meter analysis.

According to the Old Orchard Beach Planning Office, recent public improvements in the waterfront and downtown area represent about $3.9 million in investment (*see Table 2.3 below*).

Table 2.3. **Recent Public Improvements—Old Orchard Beach**

Project	Year Completed	Source of Funds	Cost
1. Pumping Station	1991/2	Local	$1,100,000
2. Stormwater Outfall	1993	Local	$800,000
3. Tax Increment Finance District Improvements	1993	Local, MDOT, Job Bond	$2,000,000
TOTAL PUBLIC INVESTMENT			$3,900,000

Of the public improvements listed in Table 2.3, the first two projects listed would be potentially affected by the .5 meter sea-level rise scenario. Also at risk under this scenario, is the network of sewer lines constructed under the dune system in the 1980's. No costs were available for the sewer project. The tax increment finance district investments listed above were completed throughout the downtown development district. Only a portion of these improvements will be threatened by the .5 meter rise scenario.

Table 2.4. **Tentative Public and Private Improvements—Old Orchard Beach**

Project	Anticipated Completion	Possible Sources of Funds	Cost
1. Ocean Outfall/Sewer Treatment	NA	Local, federal	$4,500,000
2. Train Station	1994/5	Federal	$200,000
3. Proposed New Pier	NA	Private	NA
4. Boardwalk	1995/6	Fed., MDOT, Local	NA
5. Retail Complex	NA	NA	NA
6. Memorial Park Improvements	NA	NA	NA
7. Construction of New Chamber Building	NA	Private	NA

NA = Information not available.

Table 2.4 provides a list of tentative projects that are currently under *preliminary discussion* in the Old Orchard downtown and shorefront area. Note that funding sources for these projects are not secure, in some cases voter approval of bond issues will be necessary.

Of the public and private projects under discussion, listed in Table 2.4, the ocean outfall/sewer treatment improvements, the pier, and the boardwalk would be potentially affected under the .5 meter sea-level rise scenario. Improvements associated with the downtown revitalization effort (Depot Square Area redevelopment), including the passenger train station, infill retail development, park improvements and new construction to house the Chamber of Commerce fall within the 1.0 and 2.0 meter sea-level rise boundaries.

3) Wetland Impacts

A series of small wetlands are just outside of the 2.0 meter rise boundary.

4) Extent of Similarly Situated Land in the Region

(See discussion under Camp Ellis/Ferry Beach, Chapter Three.)

5) Analysis

Of all the sites covered in this analysis, the potential impacts of sea-level rise in this study area are perhaps the greatest. Given the nature of the existing development, and the reliance on beach-related tourism, sea-level rise potentially threatens the basis of the local/regional economy and the roots of the cultural identity of Old Orchard. The level of public and private investment here may test the State's determination to adhere to its retreat policy and current ban on construction of seawalls.

This site illustrates the extreme danger associated with eliminating natural protective features and building within the sand dune system without appropriate setbacks from high hazard areas. It also highlights the dilemma associated with allowing public investment in infrastructure in unprotected beach environments. A sewer line was located in the sand dune system in 1980's to serve existing and planned development—development that now appears to be threatened within the 100 year study horizon.

This site also illustrates the need for provision of reliable data concerning coastal hazards to local and state decisionmakers, and agreement regarding what methodologies are acceptable for projecting future shoreline positions. Old Orchard Beach's estimate of the 100-year shoreline position (based on the maximum amount of shoreline fluctuation that had been mapped with certainty over the previous century) is quite different than the shoreline position mapped for this analysis using a geo-historical approach.

5. Pine Point

a. Shoreline Position

Pine Point is a northward-projecting spit bordering the Scarborough River inlet. (*Figures 2.15, 2.26*) This spit was formerly a barrier island before the railroad line closed the tidal inlet in the 19th century (Farrell, 1972). Possibly because of sand by-passing that inlet, the Scarborough River inlet began to narrow and fill with sand, and the COE constructed a jetty at the inlet entrance in the 1960's. That jetty now traps sand derived from the south, and

sandy spoils from the dredging of the tidal channel have also been placed on Pine Point. For these reasons the beach has grown seaward at a rate averaging 2.5 m/yr between 1976 and 1991. (*Figure 2.26*) Beach growth has been greater near the influence of the jetty than to the south, where little growth has occurred. Because of the growth of this beach residential development also grew since the 1960's, and the entire area is covered with residences and commercial buildings. (*Figure 2.27*)

If the assumption of continued beach progradation due to an influx of sand from the south holds, a 0.5 m rise in sea level will not result in any retreat of the shoreline, rather in a 100 m advance at Traverse 1. Growth will be less to the south. Even a 1.0 m rise in sea level will only result in 50 m of retreat at Traverse 1 if sand sources to the south persist. A 1.0 m rise of the sea, however, will lead to a breach in the barrier at the southern end of Pine Point where growth is not presently occurring. An extreme rise of the sea by 2.0 m will lead to 350 m of retreat at Traverse 1, and complete destruction of Pine Point. A hypothetical realignment of the beach is depicted as the 2.0 m shoreline. (*Figure 2.25*)

b. Impact Assessment

1) Upland Impacts

The Pine Point study area included about 630 acres of land, with dryland accounting for approximately one-half of that total, and the Scarborough Marsh accounting for the balance of the site. Loss of dryland associated with various rates of sea-level rise at Pine Point are projected as follows:

	.5 m rise	1.0 m rise	2.0 m. rise
Dryland Lost (gained)	(25 acres)	83 acres	315 acres

2) Value of Land/Structures

According to the Town of Scarborough's assessor's records, the value of properties inundated in the 1.0 meter rise scenario is estimated at roughly $32 million. In addition to properties lost, costs associated with 1.0 meter sea-level rise would also include bridge/road improvements to maintain access to Pine Point. At the 2.0 meter rise, the value of land and buildings at risk in the Pine Point study area would be $50.2 million.

3) Wetland Impacts

Natural features that could potentially be affected by rising sea-level and changes in Pine Point's shoreline position include nationally significant marine habitats, and the high value wetland habitat associated with Scarborough Marsh. Given the study assumptions described earlier in this chapter, Scarborough Marsh would probably not suffer any net loss immediately (assuming that the marsh could migrate landward unimpeded). Scarborough Marsh, because of its large contiguous mass and healthy state would probably migrate more easily than smaller, fragmented wetlands. Higher rates of sea-level rise (i.e. 2.0 meters) could lead to wetland drowning.

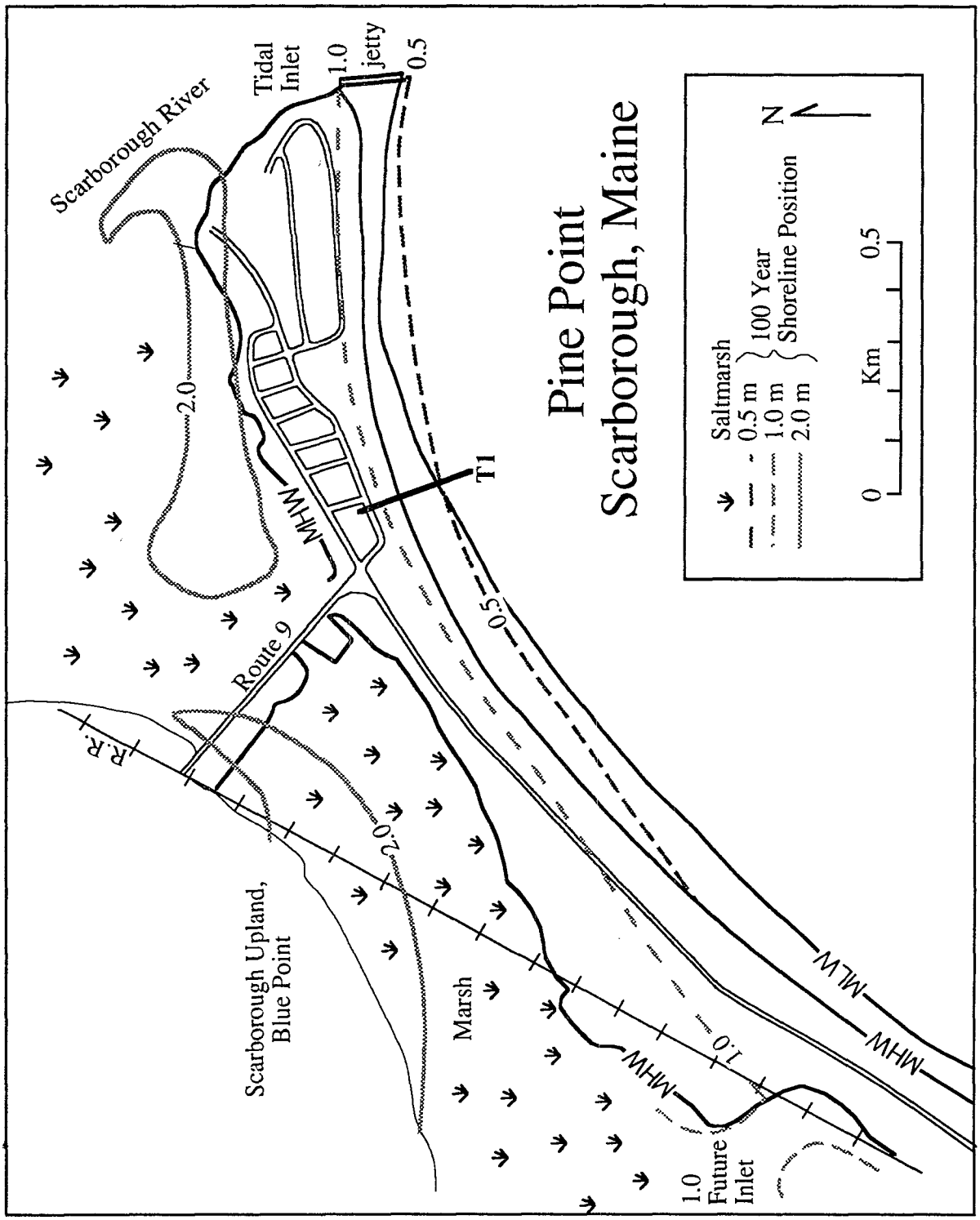

Figure 2.26. Projected shoreline change map for Pine Point, Saco Bay. Note that the barrier beach may be breached by a tidal inlet at the 1.0 m projected shoreline. At the projected 2.0 m shoreline, the entire barrier is profoundly altered, and the shape of the shoreline projection is highly speculative. Coastal environments after Timson (1977).

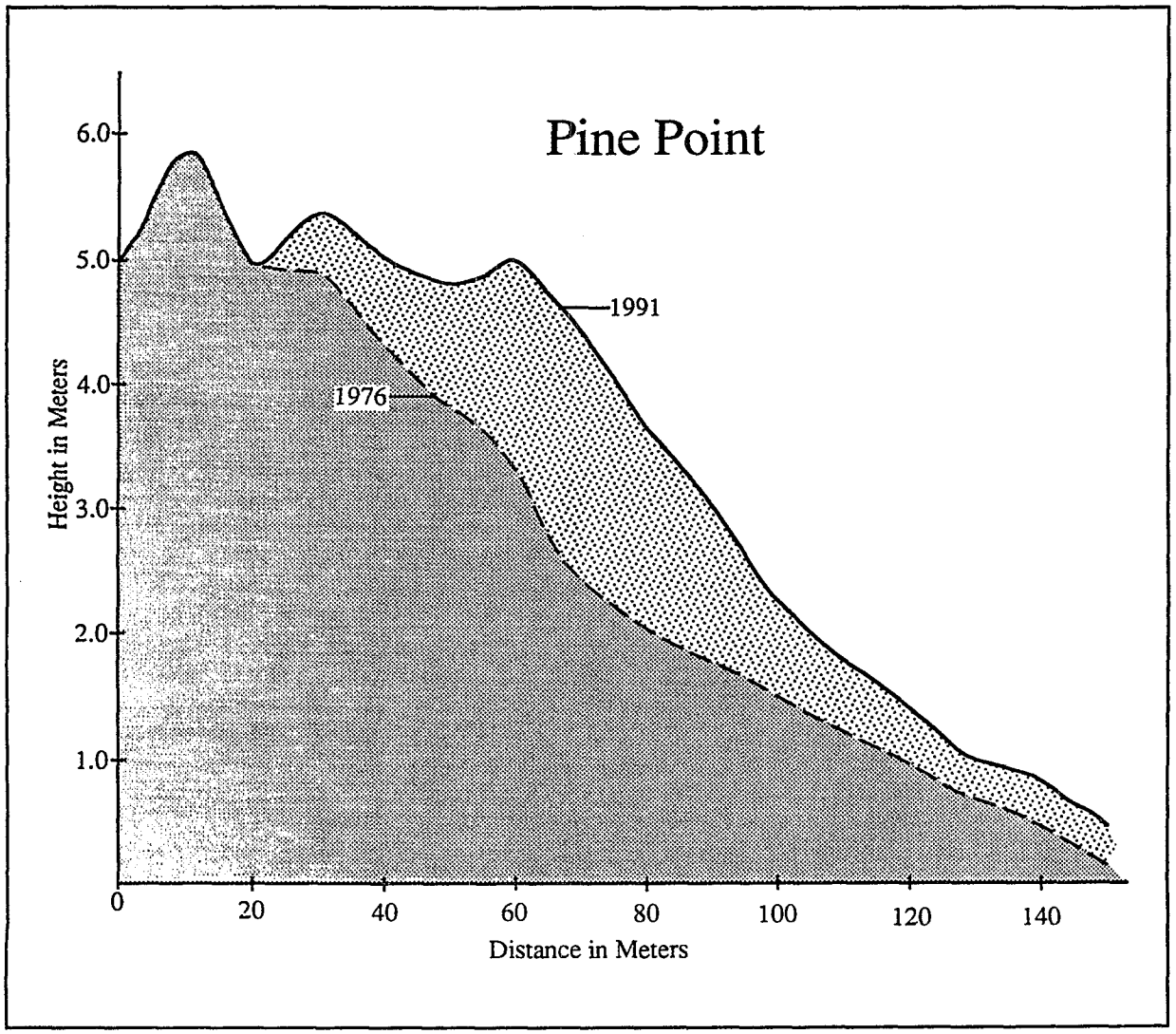

Figure 2.27. Traverse 1, Pine Point, Saco Bay. Survey line from Fink (personal communication 1992).

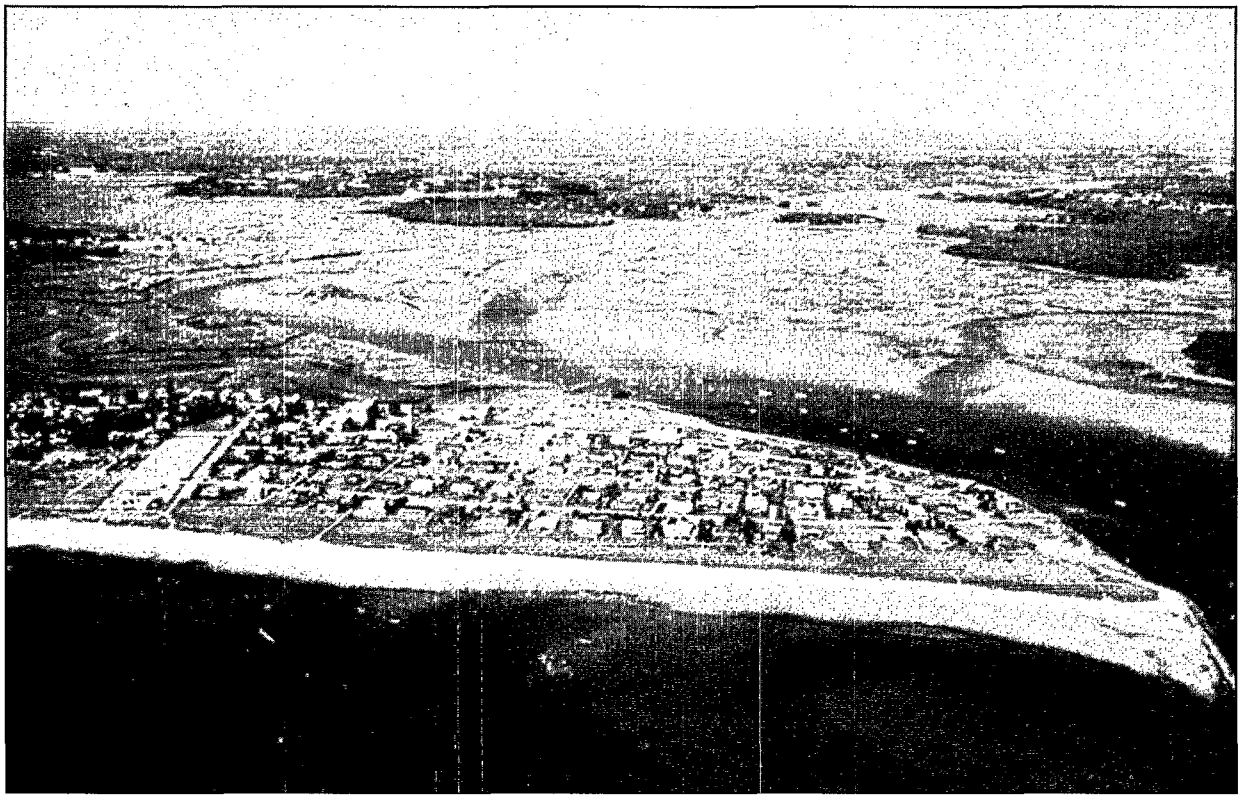

Figure 2.28. Photograph of the Pine Point area. Aerial photography of the Pine Point area.

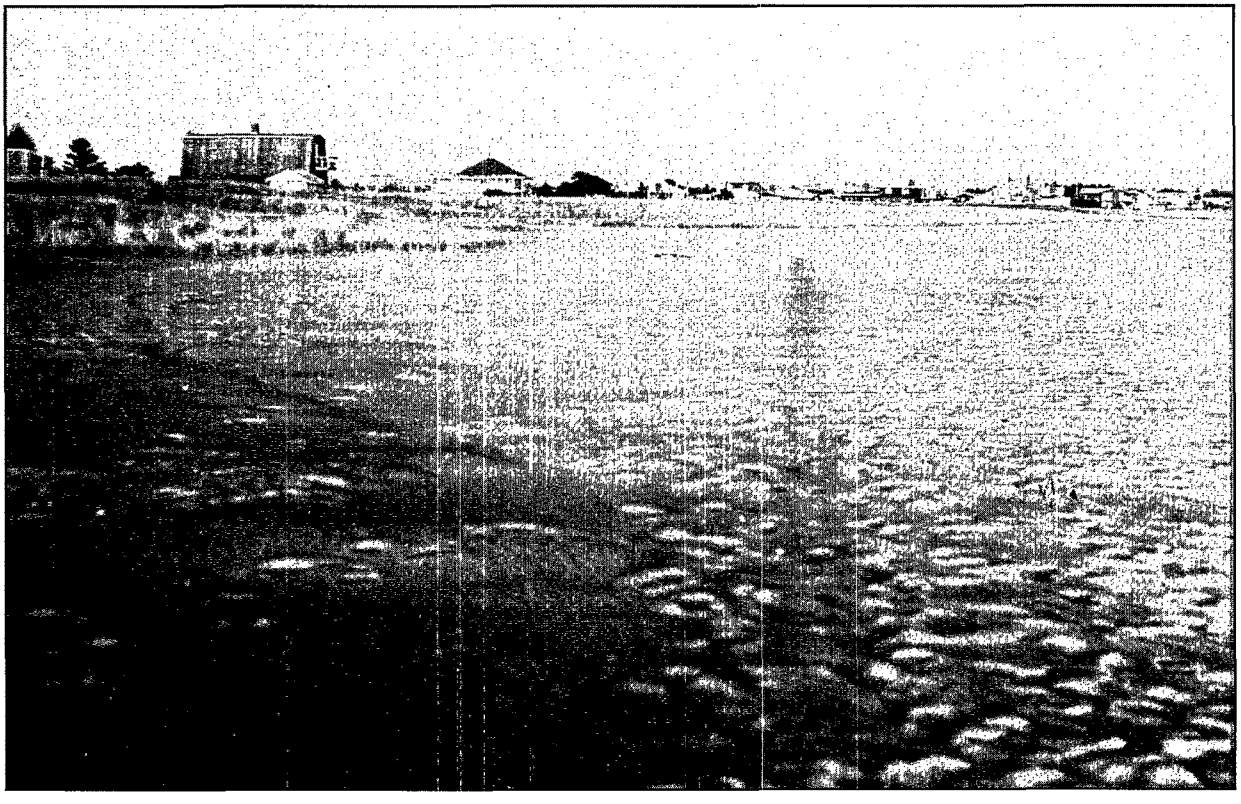

Figure 2.29. Photograph of the Pine Point area. Ground photograph of the study area at Pine Point.

4) Extent of Similarly Situated Land

(*See* discussion under Camp Ellis/Ferry Beach section of this chapter.)

5) Analysis

Since lots sizes in Pine Point have been increasing substantially due to accretion, theoretically, there could be a corresponding change in the allowable density for those accreting lots, allowing for redevelopment to multi-family units. Thus, the Pine Point site analysis raises the question of how to treat areas along Maine's shoreline that are accreting in the short term, when geologists suspect that these areas are subject to change over the long term. Maine's Sand Dune Rules attempt to deal with this issue by requiring analysis of possible shoreline changes over a 100 year planning horizon.

6. Other Predominant Coastal Types

Two other coastal types are characteristic of portions of the shoreline of Maine, but were not mapped for this study by Maine Geological Survey: urban engineered shorelines and rocky shores. Expected impacts are discussed briefly, below.

a. Urban Engineered Shorelines

1) Upland Impacts

The Fore River section of the Portland waterfront was also evaluated for possible impacts of accelerated sea-level rise, although site features were not mapped. Since the engineered shoreline in this area is built up to 2 meters above mean high water in most locations, sea-level rise alone probably will not affect the shoreline position along the Portland waterfront. As has been the case in the past, property owners will probably continue to raise the height of their shoreline structures gradually over time, or in response to crisis flooding.

2) Extent of Similarly Situated Land

Only 5% of the region's shoreline consists of urban, engineered waterfront. In the region, only the Portland/South Portland waterfront, and a small area in South Freeport have urban, "unmovable" shorelines.

Water dependent businesses (those that must be located on, or adjacent to oceans, bays, and estuaries) are prevalent in this area and include fisheries, fish processors, ship builders, water transportation support facilities and others that rely on a waterfront (or in-water) location. These businesses and industries stand to be affected by sea-level rise in at least two ways: by changes in the productivity of marine habitats and wetlands, and by impacts on waterfront infrastructure. Bigford (1991) notes that typical ports with low-lying structures can expect impacts such as: increased stress on pilings, piers, docks and elevated structures; loss of access to waterfront landings; flooded utility lines; and loss of coastal lands for water dependent structures and uses. In Casco Bay, Colgan (1990) estimated that more than 2000 employees worked in "coast dependent" industries/businesses, with the value of that sector's output estimated at more than $104 million.

Urban services such as sewer treatment and stormwater drainage also may be affected by rising sea-level. In the case of sewer plants and outfalls, sea-level rise may result in inundation of plants, transmission of untreated sewage into area waters, and may result in delays getting plants back into operation. Every municipality in the region has outfalls that may be affected by rising sea-level.

No attempt was made to project costs of worst case property losses or costs associated with protection strategies for urban waterfronts.

3) Analysis

Although major impacts from a change in shoreline position due to sea-level rise are not anticipated along Portland's Fore River shoreline, the potential effects of storm surges and the potential for increased and more widespread flooding along engineered shorelines should be investigated. A study of potential effects of sea-level rise in Saint John, New Brunswick (Martec Limited, 1987) found that under a 1 meter rise, what is now the 100 year floodplain would become the 20 year floodplain. Kana, in studies of the physical impacts of sea-level rise in Charleston, South Carolina (in Barth and Titus, 1984) concluded that a five-foot rise in sea-level would double the size of the ten-year floodplain to the approximate size of the hundred-year floodplain unless additional levees and seawalls were built. Similarly, Leatherman (in Barth and Titus, 1984) studied changes in storm surge levels and inland inundation as a result of projected rates of sea-level rise in Galveston Bay, Texas. Leatherman concluded that a .4 meter rise in sea-level by 2025 would convert a 75-year storm into a 100-year storm. Under the high scenario of sea-level rise, flooding associated with a 100 year storm would occur at a 10 year frequency by the year 2075, resulting in catastrophic damage to the study area. Implications of this research for Maine's urbanized low-lying areas should be further researched. Further studies may reveal the need to make improvements to existing bulkheads, docks, etc. and may indicate the need for low-lying industries to floodproof machinery.

b. Rocky Shoreline

Although not considered as a specific coastal environment type investigated in this study, rocky shores (dotted with occasional, pocket, gravel beaches) comprise more than half of the Casco/Saco Bay region shoreline. It is not anticipated that accelerated sea-level rise will have a significant impact on shoreline position along rocky shores. Further study would be needed to determine the shoreline retreat rates associated with gravel pocket beaches.

7. Summary/Conclusions

Prior studies of shoreline change and coastal erosion in Maine have determined that the components of Maine's *soft coast*—coastal sand dune systems, coastal wetlands, and coastal eroding bluffs—may experience significant coastal erosion and inundation with a continuation of the historical rate of change. Along sand beaches and coastal wetlands, that erosion and inundation would be exacerbated by an accelerated rate of sea-level rise associated with global climate change. The findings of projected change in shoreline position by 2100 under the different scenarios for the study sites, grouped by environmental setting, are summarized in Table 2.5.

Table 2.5. **Composite Result for Study Sites by Environmental Setting**

Environmental Setting	Sea-Level Rise Scenarios Projected Shoreline Change, Retreat in Meters		
	0.5 m	1.0 m	2.0 m
Salt Marsh	3-35	8-50	17-100
Bluff	15-45	15-45	15-45
Beach	50-150	100-300	200-600

The preceding assessment of the vulnerability of selected mapped areas in Casco and Saco Bays to accelerated sea-level rise leads to the following general observations:

- Estimates of shoreline change portrayed in this report by the three mapped scenarios are more substantial than previous estimates, which simply projected historic rates of sea-level rise over a 100 year period. Coastal managers need to understand and appreciate the differences in the assumptions used in each type of projection.
- The areas most threatened by accelerated sea-level rise are sand beaches and salt marshes; eroding coastal bluffs are also faced with significant impacts from a continuation of current erosion.
- There is already significant development in threatened areas. Population projections and economic forecasts suggest that pressure for coastal development will continue.
- Existing and projected levels of public and private investment, and the value of recreational beaches may lead to attempts at extensive "solutions" to "control" sea-level rise.
- The extent of development in unstable areas, and the probable impacts associated with accelerated sea-level rise in the study area, suggest that current land use and environmental laws may be inadequate to deal with issues such as wetland migration and eroding bluffs.
- There is a need for additional study on: the potential impacts on fisheries and habitat associated with accelerated sea-level rise, wetland migration, and storm surges/flooding.
- There is a need for increased public education for local officials and existing and future residents on the topic of shoreline dynamics and methods for developing and living safely in coastal environments.

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Chapter Three

CASE STUDY: CAMP ELLIS/FERRY BEACH

A. INTRODUCTION

The analysis in the preceding chapter presents a rough estimate of impacts of a change in shoreline position for several sites, using readily available information. Clearly, more quantitative assessments of impacts would be possible given additional data or staff resources. As an illustration of the potential for more detailed analysis, the research team opted to undertake a more quantitative assessment of the features at risk from accelerated sea-level rise for the Camp Ellis area. This type of more quantitative assessment was made possible by the availability of existing data on a Geographic Information System (GIS). The information presented in this chapter serves as the foundation for the cost-benefit analysis of alternative response strategies for Camp Ellis, presented in Chapter Four.

B. SHORELINE POSITION

Camp Ellis is a spit which projects southward into the Saco River in the City of Saco. To the north it becomes attached to the mainland and is called Ferry Beach. (*Figures 2.15, 3.1*). The area, with the exception of a small state park, is highly developed. Residences are set back among extensive sand dunes near Ferry Beach, but commercial structures as well as residences cover the former dunes and crowd onto the beach at Camp Ellis (Kelley et al., 1989). (*Figures 3.2, 3.3*)

This area has experienced both progradation and erosion in the course of the past century. Following the initial dredging of the Saco River, and construction of a jetty at Camp Ellis, the beach grew seaward. This may have been a response to the placement of dredged spoils on the beach, because in the early 20th century, the new land eroded along with many buildings and a railroad line (USACOE, 1992).

The USACOE has predicted a retreat rate of about 1 m (3 feet) per year for that portion of Camp Ellis lacking an integrated seawall, and 0.6 m (2 feet) per year for the area behind a massive granite seawall fronting Surf Street (USACOE, 1992). (*Figure 3.4*) These predictions are based on examination of historical maps and aerial photographs. To date the predictions have been relatively accurate for the area lacking massive engineering structures,

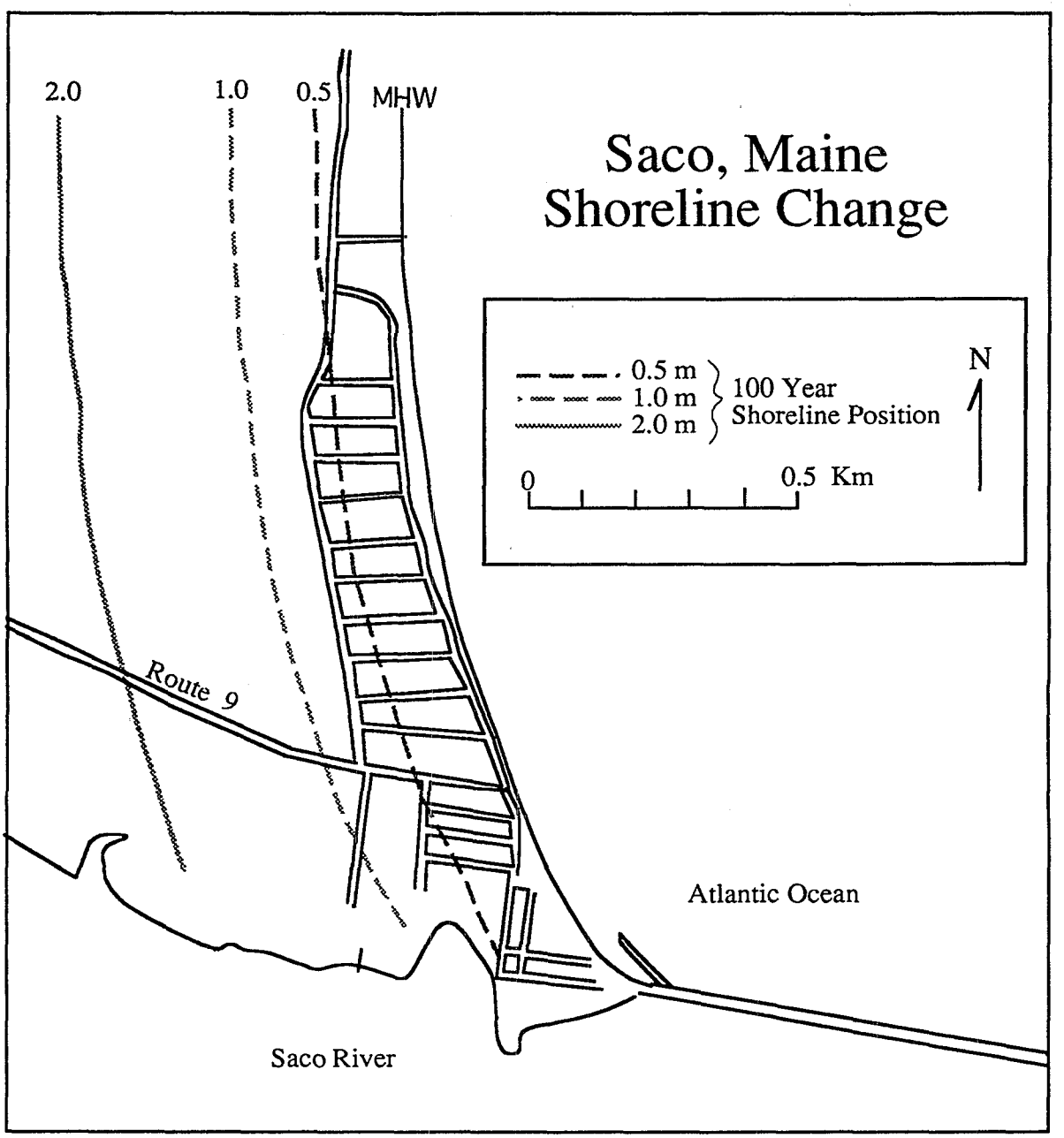

Figure 3.1. Projected shoreline change map for Camp Ellis. Mapped shorelines consider only erosion from the ocean side, not from the Saco River side. Mapped shorelines do not consider the addition of new sand from the Saco River.

Figure 3.2. Photograph of the Camp Ellis-Ferry Beach area. Development on beach at Camp Ellis.

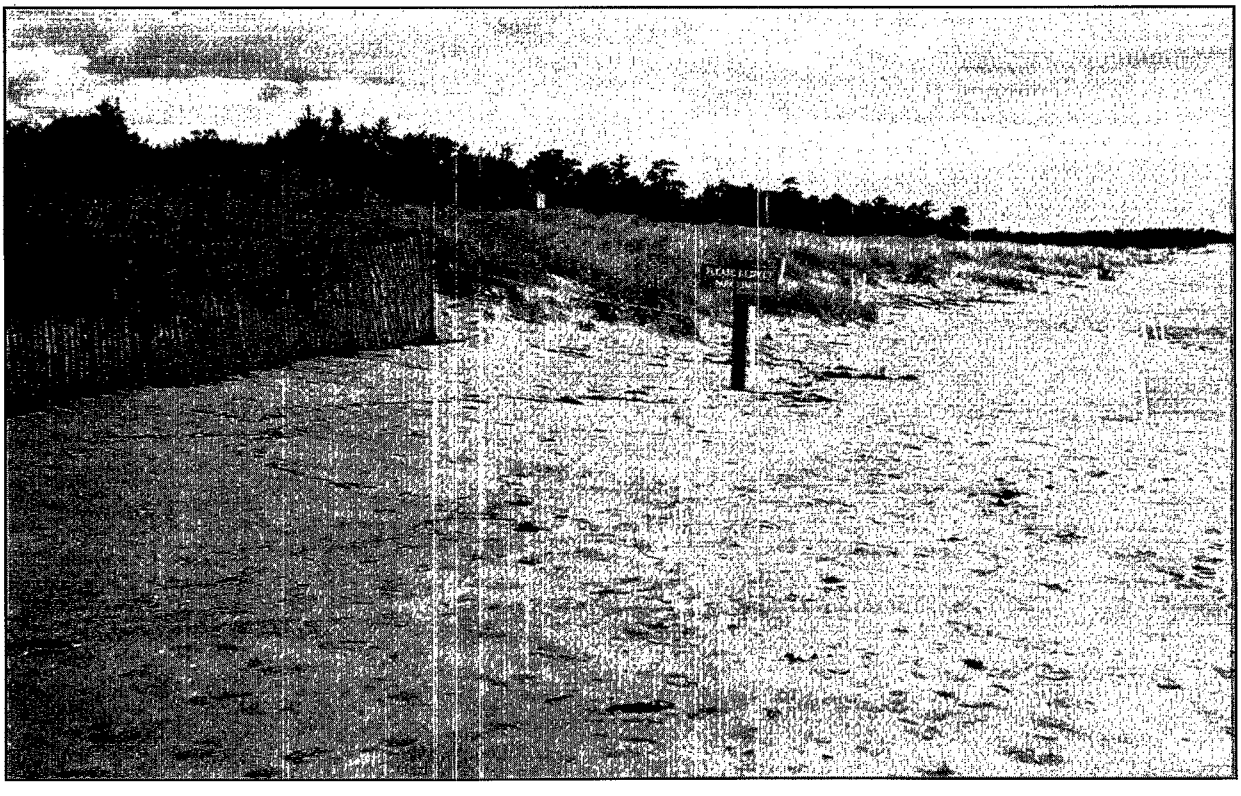

Figure 3.3. Photograph of the Camp Ellis-Ferry Beach area. Undeveloped back dune at Ferry Beach State Park.

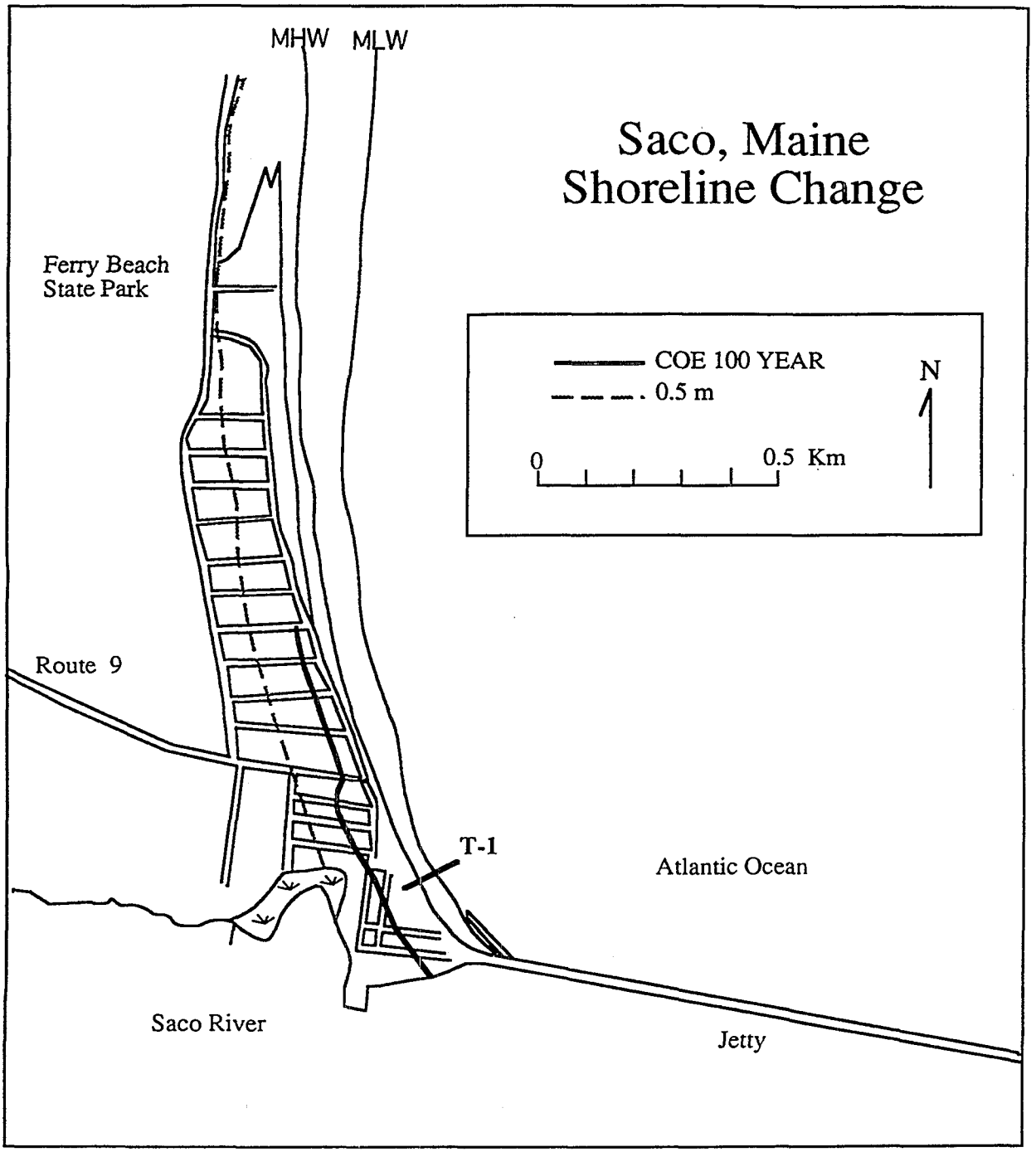

Figure 3.4. Shoreline change map of Camp Ellis comparing 0.5 m shoreline from this study with U.S. Army Corps of Engineers predictions. The Army prediction is a continuation of trends up until 1955.

and one or more houses per year have been lost to the sea. The large seawall on Surf Street has repeatedly been destroyed by storms also, but has been rebuilt in the same place, and so no erosion of the land behind it has occurred. There is no longer a beach in front of the wall, however, except at low tide (Kelley et al., 1989).

The USACOE's data do not apply to Ferry Beach, and their predictions are only shown to the end of the Surf Street seawall. (*Figure 3.4*) Although the height of most of the private seawalls as well as the Surf Street seawall is greater than 2 m above higher high water (*Figure 3.8*), in a dynamic beach setting the walls are likely to be undermined or destroyed by waves in the future, and it is reasonable to assume the beach will retreat. The 150 m, 300 m and 600 m predicted shorelines associated with the 0.5 m, 1.0 m, and 2.0 m higher sea levels, respectively, reflect this assumption. (*Figure 3.1*, *Table 2.1*) No consideration is given to the impact of sand redistribution as a result of the projected sea-level rise, nor of the effect of paved roads, sewer lines and parking lots.

C. IMPACT ASSESSMENT

1. Upland Impacts

Substantial impacts are projected on natural and built features. Figures 3.6, 3.7 and 3.8 show the projected sea-level rise scenarios along with settlement patterns, land use, location of natural features, and infrastructure. It should be noted that mapped shorelines consider only erosion from the ocean side, not from the Saco River side. There has been insufficient study of the impact of sea-level rise on rivers to project shoreline change along the river.

The projected .5 meter sea-level rise boundary is about 150 meters (500 ft.) landward of current mean high water. Under this scenario, public and private properties at risk include the following:

- 71 acres of land developed with 210 structures
- 2.4 miles of public roads
- 2.3 miles of water lines
- 1.8 miles of sewer lines
- Municipal fire sub-station
- State Park lands

The 1.0 meter sea-level rise projection creates a new land/sea boundary about 300 meters (1,000 ft) from current mean high water. Features at risk under this scenario include the following:

- 133 acres of land, developed with 334 structures
- 4.25 miles of public roads
- 3.6 miles of water lines
- 3.4 miles of sewer lines
- Fire sub-station
- State Park lands

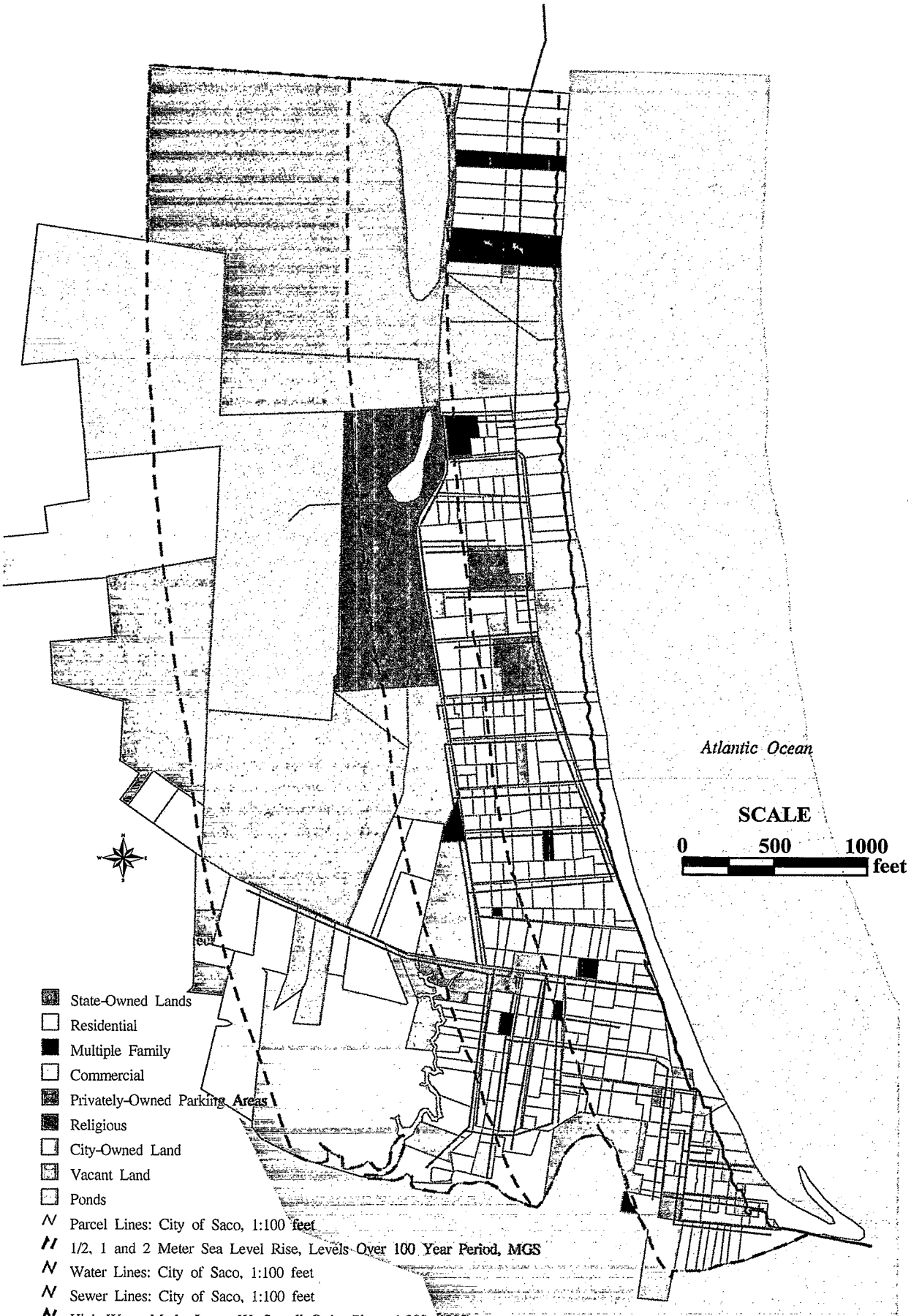

Figure 3.5. Camp Ellis, Saco, Maine. Settlement patterns and wetlands.

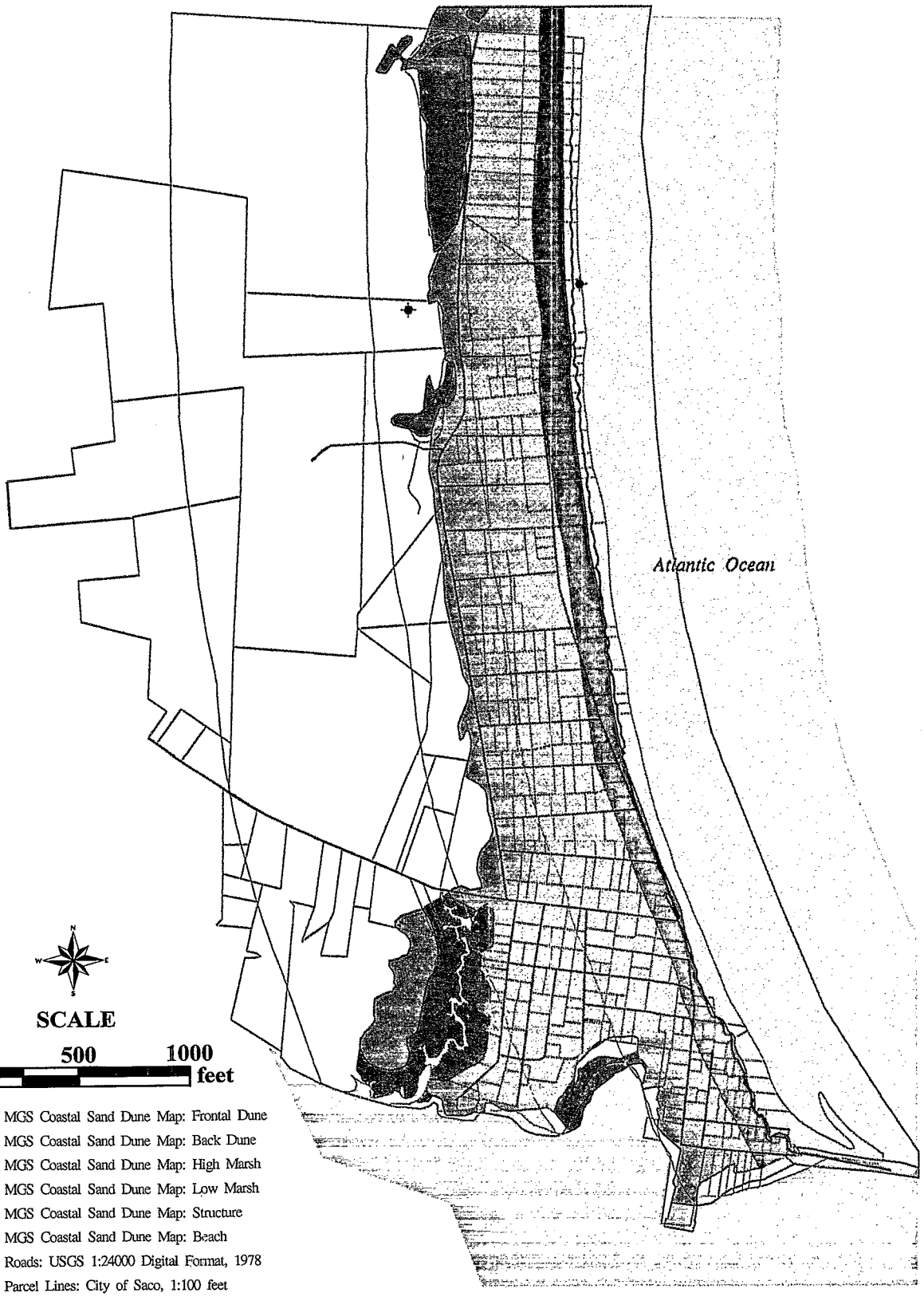

Figure 3.6. Camp Ellis, Saco, Maine. Sand dunes and critical areas.

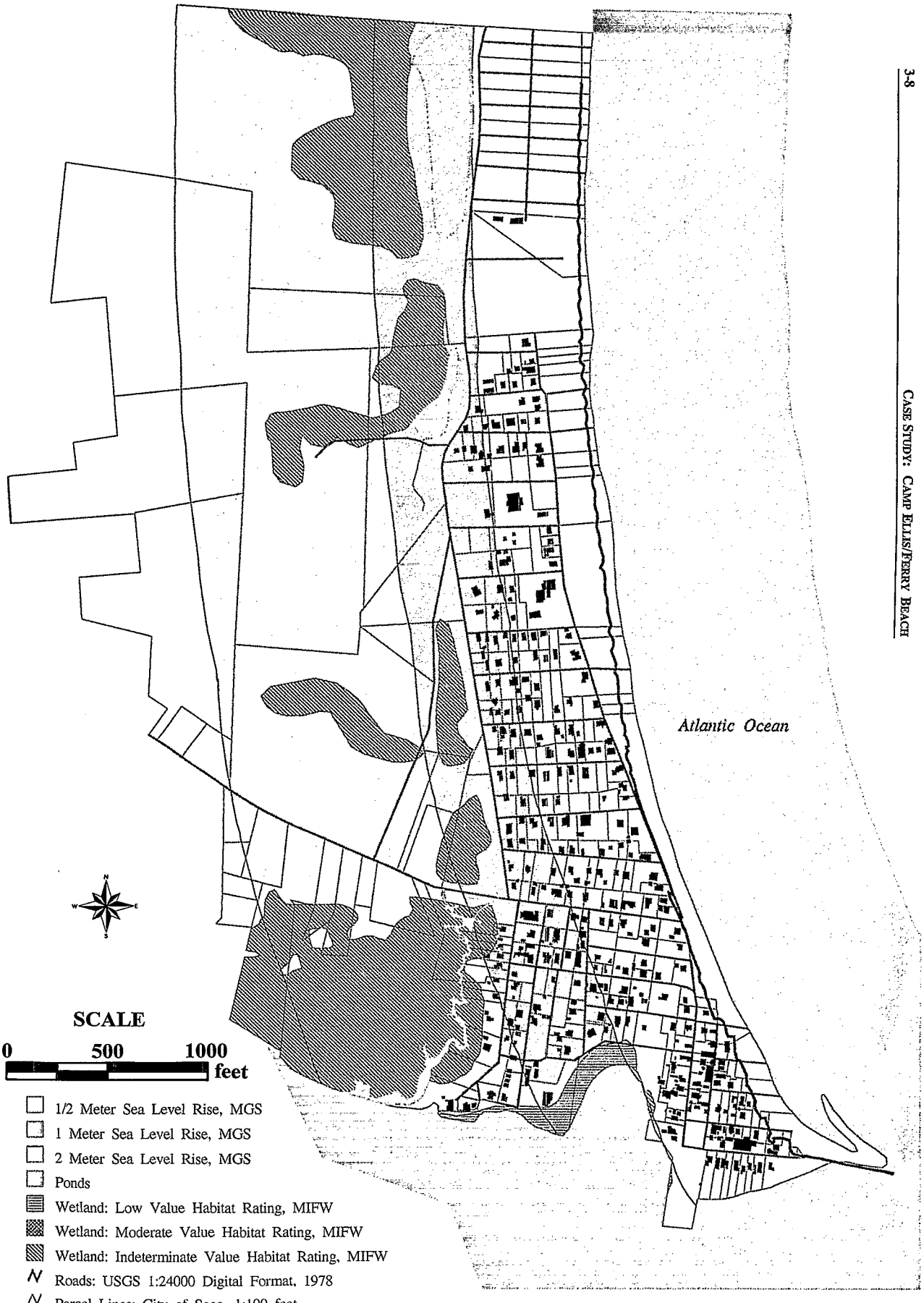

Figure 3.7. Camp Ellis, Saco, Maine. Land use and public infrastructure.

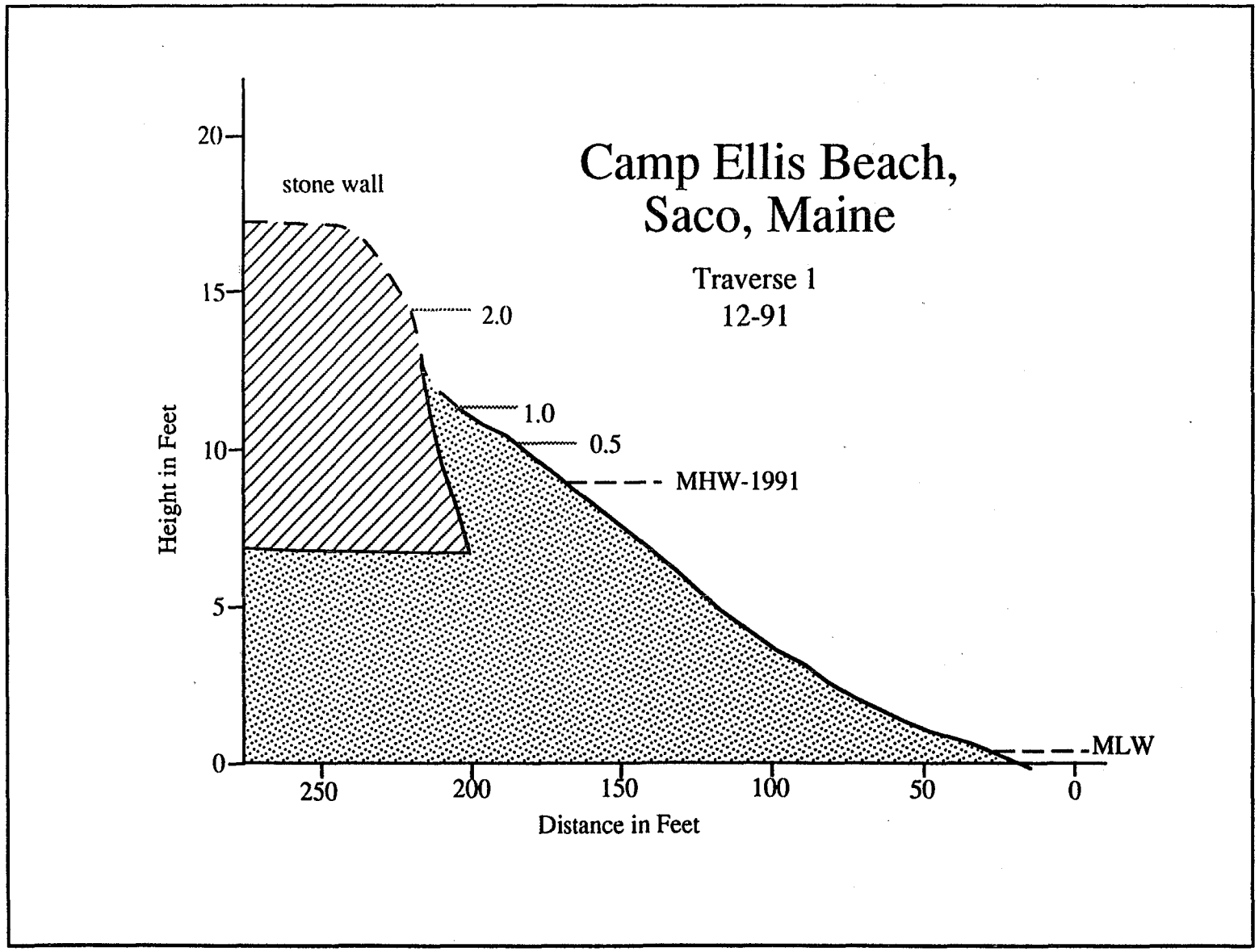

Figure 3.8. Traverse 1, Camp Ellis, Saco Bay. Modified from U.S. Army Corps of Engineers, 1992.

The 2.0 meter sea-level rise boundary is 600 meters (2,000 ft.) inland from current mean high water. Features at risk under this scenario include:

- 260 acres of land developed with 364 structures
- 4.7 miles of public roads
- about 4 miles of water lines
- 3.6 miles of sewer lines
- Fire sub-station
- State Park lands

2. Value of Land and Structures

According to City of Saco assessors records, property values in the .5 meter rise area total about $37.6 million. The value of properties inundated under the 1.0 meter sea-level rise scenario is roughly $55.2 million. Under the 2.0 meter rise, the value of land and buildings inundated reaches about $61.3 million. The difference between the value of properties affected under the 1.0 and 2.0 meter rise is not that sizable, due to the largely undeveloped nature of the land within the 2.0 meter band, and the presence of wetlands.

3. Wetland Impacts

Wetland acreages that may be impacted by rising sea-level in the Camp Ellis/Ferry Beach area are as follows:

	.5 meter	1.0 meter	2.0 meters
Wetland Acreages	< 1 acre	21 acres	57 acres

Most of the wetlands in the Camp Ellis site are tidally influenced freshwater wetlands. All are classified as having low, moderate or indeterminate value for habitat. It was beyond the scope of this study to determine how freshwater wetlands might react to rising sea-level. However, it should be noted that it is expected that they would undergo slow conversion to salt marsh, and would probably be inundated during the 2.0 meter rise.

4. Extent of Similarly Situated Land in the Region

Roughly 10% of shoreline of the Casco and Saco Bay regions is made up of sand beaches. As explained previously in Chapter Two, potential shoreline changes in sand beach areas of between 50-600 meters (175 ft.-2,000 ft.) can be anticipated, depending on the sea-level rise scenario being considered.

While the mapped sites described in this and the preceding chapter (Camp Ellis/Ferry Beach, Old Orchard Beach and Pine Point) are the largest beaches in the study area and probably provide the best examples of how developed beach areas may be affected, other sand beaches in the study region may be similarly affected. Scarborough Beach, Higgins Beach, Crescent Beach and Willard Beach, because of their moderate slopes, may experience shoreline changes similar to those mapped for Old Orchard and Camp Ellis. The coastal lands

adjacent to East End Beach and Mackworth Island beaches, having much steeper slopes, will experience less dramatic movement of the shoreline.

Sand beaches also occur on Casco Bay's larger islands. Again, slope conditions on the adjacent shoreline will help to determine the landward extent of sea-level rise in these areas.

In addition to being heavily used for public recreation, the majority of the sand beaches in the mainland portion of the study area are developed in residential uses. Even where state park status protects an area of sandy beach, the actual area of state ownership typically is small, and developed areas surround park lands. Since densities of development around the region's sand beaches vary, Camp Ellis/Ferry Beach, with its mix of high density cottages and moderate density estates may provide a useful comparison of potential property losses.

In addition to property losses, recreational value must be considered when evaluating potential impacts of sea-level rise on sand beaches. Using available statistics for state park usage in the region and Colgan's (1990) estimates of the value of the recreational experience, the recreational value of three sand beaches mapped in the study area would be between $.5 million and $4.25 million each year. Visitor estimates at municipal beaches and privately owned areas would have to be added to these figures to determine a total value for the region.

5. Analysis

There continues to be ongoing debate and discussion surrounding the fate of Camp Ellis. Shorefront landowners, concerned about saving their property from the sea, have banded together under the umbrella of "Save Our Shores." Upland owners are more concerned about the costs to the town taxpayers of continuing to fight a losing battle with the sea. The City of Saco is currently considering abandoning Surf Street, the street that is continually undermined during coastal storms. Some others are concerned about the proper role for local, state, and federal agencies. Presently, the U.S. Army Corps of Engineers is studying the possible relationship between the jetty and coastal erosion, while the City and State are discussing a potential buyout of shorefront properties. This controversy is illustrative of the questions other communities will face if coastal erosion accelerates.

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Chapter Four

COSTS AND BENEFITS OF SELECTED POLICY RESPONSE OPTIONS

A. SETTING PRIORITIES FOR ADAPTIVE RESPONSE STRATEGIES

The preceding vulnerability assessment has identified several types of resources at risk of negative impacts from accelerated sea-level rise. It suggests that there will be impacts on unmanaged ecosystems and on human settlement. If sea-level rise predictions are realized, some, but clearly not all of these impacts, are amenable to mitigation through adaptation strategies.

State and local governments are faced with two choices on the timing of mitigation strategies: 1) they can wait to take any action until the consequences of sea-level rise are established or 2) they can begin now to develop strategic responses. If they opt for inaction (either by acknowledging the risk but choosing not to act yet or by entirely ignoring the risk), they may actually increase the risk of loss or the magnitude of the loss. For example, if they take no action to regulate new development in hazard areas or if they allow significant degradation of natural coastal systems, their vulnerability to sea-level rise may increase over time. On the other hand, if state and local governments acknowledge the threat and begin advanced planning, they may be able to avoid increasing their vulnerability, and may in fact even be able to reduce the risk of negative impacts or the magnitude of loss in the future.

In general terms, these decisions about response strategies and mitigation will be investment decisions, both private and public, which will be partially guided by projecting the future rate of the return on such investments. However, due to the uncertainties about the extent of global climate change and the time frame over which impacts may become apparent, estimating the return on the investment will require resolving (or at least making assumptions about) a series of complex issues.

One issue is how to value particular outcomes when estimating economic benefits. For example, what value should be placed on reduction of loss of life or retention of wetlands in evaluating the return on the investment?

Another issue concerns what assumptions to use when predicting how people will respond to impacts over time. Should analysts assume that people will continue to act as they always have (e.g., continued greenhouse gas emissions, continued attempts to build on the shoreline,

etc.) until the government takes action? Or will people begin to change their behavior by responding to emerging impacts without waiting for governmental intervention?

A third issue concerns how to factor scientific uncertainty and the time lag in feeling effects into any mitigation program. In many instances, it will not make sense to rush to implement policies or to build structures to protect against the high-range rise in sea level projected for 100 years from now. James Titus, Director of the EPA Sea Level Rise Project posits that:

> [t]he need to respond today depends on the likelihood of global warming; the magnitude of the impacts; and the potential for anticipatory measures to reduce adverse impacts of sea level rises or climate changes as expected, *without imposing substantial costs if the changes do not unfold.*[1]

He encourages state and local governments undertake today only those actions which would significantly reduce adverse impacts of sea-level rise but would also not be ill-advised if projected effects of global warming fail to materialize. These have been described as *no regrets* policies.

These actions could consist of a combination of *concrete measures or physical changes* (e.g., making siting decisions or modifying designs for current construction projects to incorporate features responsive to sea-level rise projections), *planning, amending regulations or "changing the rules of the game"* (e.g., adopting new land use restrictions in advance of development pressures, modifying conventions of property ownership) and *research and education* (achieving more certainty in projections and educating people to the need for response measures).[2]

To assist with this assessment of beneficial/"no regrets" policies, Titus has suggested the following criteria for policy makers to consider in evaluating potential response strategies:

- Economic efficiency: Will the initiative yield benefits substantially greater than if the resources were applied elsewhere?
- Performance under uncertainty: Is the strategy reasonable for the entire range of possible changes in temperatures, precipitation, and sea level?
- Urgency: Would the strategy be successful if implementation were delayed 10 or 20 years? Is the opportunity to solve the problem likely to vanish if no action is taken soon?
- Low cost: Does the strategy require minimal resources?
- Equity: Does the strategy avoid the problem of unfairly helping some at the expense of other regions, generations, and economic classes? Does it give people ample time to adjust?
- Institutional feasibility: Is the strategy acceptable to the public? Can it be implemented with existing institutions under existing laws?
- Unique or critical resources: Would the strategy decrease the risk of losing unique environmental or cultural resources?

- Health and safety: Would the proposed strategy decrease (or at least avoid increasing) the risk of disease or injury?
- Consistency: Does the policy support other national, state, community or private goals?
- Private vs. public sector: Does the strategy minimize governmental interference with decisions best made by the private sector?[3]

Some of these criteria such as economic efficiency, performance under uncertainty, and cost can be evaluated in more depth using cost-benefit analysis. The balance of this chapter develops a very rough cost-benefit analysis as an initial attempt to use this tool in setting priorities. It evaluates four different response options as applied to one of the case study sites, Camp Ellis.

The other criteria, i.e., institutional feasibility (including legal defensibility), equity, and consistency with other goals, do not lend themselves to a cost-benefit analysis but are critical components in any decision about appropriate adaptation strategies for Maine. They are the focus of the analysis in Chapters Five and Six.

B. COST-BENEFIT ANALYSIS

1. Selection of Case Study Site

In order to develop a quantitative assessment of alternative policy response options, it was necessary to focus on one small area with relatively uniform topography for which there existed sufficient data to allow a comparison of benefits and costs of a set of parallel response strategies. Due to the currently available information and the apparent magnitude of the threat posed by sea-level rise, this detailed case study focuses on a sand beach setting—Camp Ellis. Clearly, no one response is appropriate for the entire shoreline. Responses may differ significantly, depending on the topography, level of development, land use and unique natural features. However, as a first attempt to quantify costs and benefits in one type of setting, a sand beach site was selected due to the much higher projected magnitude of change in shoreline position for beaches; the relative scarcity of sand beaches in Maine; the value of the resource to the State's economy, particularly the tourism industry; the greater magnitude of vulnerability of built resources to a change in shoreline position along the beach, and the likelihood of forthcoming substantial policy debates concerning alternative response strategies.

2. Description of Camp Ellis/Ferry Beach

Camp Ellis is a densely settled area within the City of Saco, developed primarily in cottage-type year-round and seasonal single family residences. Several restaurants, a fish pier, and a few tourist-oriented shops comprise the small waterfront business district. Ferry Beach, adjacent to Camp Ellis, is also included in the case study area. Ferry Beach is also primarily "built out," but with larger dwellings on bigger lots.

Camp Ellis is known for experiencing very high erosion rates, and numerous properties have been destroyed during coastal storms. The City of Saco faces ongoing expenditures for road repairs, maintenance and clean-up associated with coastal storms. Ferry Beach is a more

stable area, protected by a healthy dune system. The entire area is served by municipal water and sewer, and includes a network of public roads.

a. Shoreline Positions/Impact on Built Features

Figures 3.6, 3.7 and 3.8 in Chapter Three show the projected sea-level rise scenarios along with settlement patterns, land use, location of natural features, and infrastructure.

As reported in Chapter Three, for the projected .5 meter sea-level rise boundary, 150 meters (500 ft.) landward of current mean high water, public and private properties at risk include:

- 71 acres of land (assessed value $28.2 million);
- 210 structures (assessed value $9.4 million);
- 2.4 miles of public roads;
- 2.3 miles of water lines;
- 1.8 miles of sewer lines;
- Municipal fire sub-station;
- State Park lands.

The projected 1.0 meter sea-level rise shoreline boundary, about 300 meters (1,000 ft.) from current mean high water, puts the following features at risk:

- 133 acres of land, with an assessed value of $41.2 million;
- 334 structures, valued at $14 million;
- 4.25 miles of public roads;
- 3.6 miles of water lines;
- 3.4 miles of sewer lines;
- Municipal Fire sub-station;
- State Park lands.

The projected 2.0 meter sea-level rise boundary, approximately 600 meters (2,000 ft.) inland from current mean high water, includes the following features at risk:

- 260 acres of land, assessed value of $46 million;
- 364 structures valued at $15.3 million;
- 4.7 miles of public roads;
- about 4 miles of water lines;
- 3.6 miles of sewer lines;
- Municipal Fire sub-station;
- State Park lands.

The difference between the value of properties affected under the 1.0 and 2.0 meter rise is not that sizable, due to the presence of significant wetlands and therefore the less developed nature of the land within the 2.0 meter band.

b. Natural Features

Natural features in the Camp Ellis/Ferry Beach area (refer back to maps in Chapter Three) that may be impacted under the three sea-level rise scenarios include:

1) Wetlands/Ponds
   - less than an acre of salt marsh under the .5 meter scenario;
   - slightly over 21 acres of freshwater wetlands under the 1.0 meter scenario;
   - 56.5 acres of freshwater wetlands under the 2.0 meter scenario;
   - 2 freshwater ponds under the 1.0 and 2.0 meter scenarios.
2) Sand Beach
   - Sand beach system, including Ferry Beach State Park (27,739 visitors for a two year period from 1991-2), and numerous other public access points.
3) Marine Habitat
   - Marine habitat for shorebird feeding and roosting, seal haul-outs and nesting sea bird sites (regional and national significance).
4) Other
   - two registered critical areas under the 1.0 meter scenario, 4 critical areas under the 2.0 meter scenario.

c. Wetlands

The vulnerability analysis in Chapter Three identified acres of wetlands at risk in Camp Ellis/Ferry Beach under the various sea-level rise scenarios. The majority of mapped wetlands in the case study area are tidally influenced freshwater wetlands. It was beyond the scope of this study to determine how those wetlands might react to rising sea level. However, it is likely that they would undergo slow conversion to salt marsh, and would probably be inundated during the 2.0 meter rise.

The first two response strategies explored in this cost-benefit analysis include consideration of protection of developed properties from migrating wetlands through the construction of bulkheads. Because it was uncertain what the effects on freshwater wetlands would be, the cost-benefit analysis portrays a worst case scenario of constructing bulkheads around the total perimeter of the case study's wetland acreage.

d. Growth Trends and Potential for New Development in the Case Study Area

When sewer lines were extended to the Camp Ellis/Ferry Beach area in recent years, it was speculated that the area would undergo massive redevelopment, that substandard buildings would be replaced by higher density dwellings and that marine business zoning might spur expansion/redevelopment of the existing small mixed use commercial and fishing village. Combined with a downturn in the economy, continuous storm damage and ongoing erosion have caused people to be cautious about making property improvements or investing in new ventures. Few properties are selling. Of course, these earlier expectations could easily be revived in a more robust period of sustained growth in the region's economy.

The cost-benefit analysis of different response options required an estimate of the amount of new development anticipated in Camp Ellis/Ferry Beach over the study period (2100). While the population of the City of Saco as a whole may grow at a rate of .7% per year (based on recent trends, Maine State Planning Office, 1994), growth in the Camp Ellis/Ferry Beach area will be limited to redevelopment of existing lots and subdivision of relatively small quantities of vacant land. Under each sea-level rise boundary area, the amount of vacant land and land with potential for redevelopment was analyzed in light of current zoning regulations. Vacant land and "underutilized" properties (i.e. those that could accommodate additional units under current zoning) were targeted as areas where new development and redevelopment (at higher densities) would be likely. Wetland areas and state park lands were not considered as part of the available vacant land supply, but current ownership patterns were not considered in determining whether the remaining privately held land would be developed in the future. An allocation of area needed for new roads and parking was considered when analyzing vacant land. Within the shorefront area having the .5 meter sea-level rise shoreline position as its upland boundary, between 25 and 261 new units could, at least in theory, be constructed. Within the same area but with the 1.0 meter sea-level rise shorefront position as its upland boundary, between 35 units and 317 new units could be developed. Within the shorefront area with the 2.0 meter sea-level rise shoreline position as the upland boundary, between 60 and 462 new units could be constructed. Within each anticipated sea-level rise boundary a midrange estimate was assumed as the most likely level of redevelopment potential; 51, 72, and 127 units respectively within the 0.5, 1.0, and 2.0 meter sea-level rise boundaries.

3. Selection of Four Policy Response Options

The intent of this analysis is to compare costs and benefits of the most basic alternative policy response options. This should assist with the evaluation of the advisability of taking particular actions at all at this time. The four options reflect specific public investments and regulatory/planning/"changing the rules of the game" types of responses. Clearly different concrete measures, physical changes, nonregulatory incentives, education and research also have a role to play in an integrated strategy. Similarly, one could easily conceive of different public investment or regulatory strategies than the ones chosen here for comparison. By no means are these the only policy options available, but they are illustrative of the basic cost differences between retreat and reactive protection strategies on developed shorelines.

The following alternative policy response options were evaluated:

Option 1: Reactive Protection for both developed and undeveloped properties.

This policy is defined as not taking specific steps ahead of time to alter the anticipated development pattern (assuming a buildout of current trends) but then later, as sea level rises, protecting the development that has occurred with **beach nourishment** along sandy beaches and **bulkheads** along developed wetland shores to protect all developed land.

Option 2: Reactive Protection for both developed and undeveloped properties, combined with a compensated setbacks for the currently threatened structures.

This policy is defined as encouraging a modified development pattern so that a smaller area will need to be protected through the same beach nourishment along sandy beaches and same

bulkheads along developed wetland shores as in Option 1, but using an initial public buyout of selected currently threatened properties to improve economic efficiency.

Option 3: Rolling Easements for developed properties, regulatory setbacks for all undeveloped properties.

This option assumes regulations would prohibit all new development within all of the area expected to be affected by a change in the shoreline position within the next 100 years, with the area varying for each scenario. In addition, any existing development would be required to retreat if waters rise to touch the structure for six consecutive months. It is assumed this retreat requirement would be enforced through a type of "rolling easement" which would require development removal and restoration of the site to its natural condition as the shoreline position moves inland. No effort would be made to hold the current shoreline position, thus all beaches and wetlands would be allowed to migrate inland.

Option 4: Rolling Easements for both developed and undeveloped properties.

This option, a variation on Option 3, eliminates the setback requirement for new construction and utilizes a "rolling easement" to control the impacts of both new and existing development. New development would be allowed in areas expected to be affected by a change in the shoreline position within the next 100 years, both new and existing development would be required to retreat if the building sustains damage to the extent of 50% or more of the building's appraised value or if the shoreline recedes so that any part of the structure is within the coastal wetland for six months or more. Under the "rolling easement," when the structure on a site is partially inundated by a migrating shoreline, the structure must be removed and the site must be restored to its natural condition.

4. Discussion of Methodology

a. Overview:

The general methodology applied through the quantitative portion of the economic analysis is to determine if "the benefits to whomsoever they may accrue are in excess of the estimated costs."[4] Distributional aspects of how the share of costs or benefits would be allocated among various parties were not addressed in the quantitative analysis. The methodology used in this analysis attempts to compute the aggregate social cost for each of the four proposed policy response strategies based on the available data, using simple linear assumptions for the timing of events.

Comprehensive data on property values, both land and structures, in the affected area were collected from the local town offices. These data were summarized and cumulated by sea level rise zone (0.5, 1.0, and 2.0 meter) through the use of a GIS (Geographical Information System). The quantity of wetland loss, infrastructure loss, and new bulkheads needed under each sea-level rise scenario were also computed and categorized within each sea-level rise zone, by the GIS.

The economic value of waterfront land at risk in the 0.5 meter sea-level rise zone is computed using nearshore (not shoreline) land values. Nearshore land is characterized for the purpose of this study as land in the 0.5-1.0 meter elevation band.[5]

All benefits and costs were converted to present value equivalents using the fiscal year 1992 interest rate for federal water resources projects of 8.5 percent.

Table 4.1 contains the aggregate quantities that were used to compute the costs and benefits for each aspect of a particular policy. Table 4.2 contains the price and value assumptions that were applied to the quantities in Table 4.1 to compute the cost and benefit totals for each policy strategy, under each sea-level rise scenario.

A fundamental assumption for computing the costs and benefit implications under each sea-level rise scenario was that sea level is assumed to rise at a constant rate through the 100 year study period (1995-2094). In other words, it is assumed that in the 100th year the level of the sea would just reach the total extent of rise expected under each scenario (either 50 cm, 100 cm, or 200 cm); it is also assumed that the sea would get to that level by rising equal increments in each individual year (a straight line estimation approach). The volume of wetlands and the value of structures and infrastructures was assumed to be equally spread throughout each of the three sea-level rise zones. Therefore the volume of wetland loss; the value of property and infrastructure loss; and the need to construct new bulkheads were also assumed to be spread in equal increments throughout the 100 year period.

Because of these simplifying linear estimates and assumptions regarding the timing of natural events the quantitative portion of this study should be viewed as a "rough analysis". No good data were available to vary the rate of sea-level rise over the next century, and a dynamic model to quantify the effects of a centimeter by centimeter sea-level rise was not constructed. Although it is unlikely that either the potential sea-level rise (or the damages resulting from it) will be so linear, it is not unreasonable to make such simplifying assumptions in order to quantify and compare basic strategies as long as such assumptions are clearly stated and held constant under each policy option.

b. Detailed Methodology Used to Compute the Benefit and Cost of Each Policy Response Option

Option 1: This option assumes a reactive protection strategy for both the developed and the less than fully developed lots in the study area. Policy Option 1's response strategy is simply to use beach nourishment to maintain the existing beach frontage and recreational usage and to protect the remaining development by the building of bulkheads to prevent an inward migration of wetlands wherever they are necessary.

This strategy would provide complete and equal protection to any new structures on the less than fully developed land at no additional cost. This is because at the Camp Ellis site the only potential new development is redevelopment of existing structures and underdeveloped lots, or the development of undeveloped lots that are interspersed within the developed area. There is no undeveloped area at Camp Ellis that would require separate or additional bulkheads or beach nourishment beyond that which the existing development would already require if the sea-level were to rise.

This absence of any significant area of undeveloped land in Camp Ellis is one of the limitations of using the Camp Ellis site as an example for other sites that may have substantial tracts of undeveloped land. At sites with significant undeveloped tracts of land there could be a significant variation in the potential future costs of a reactive protection policy based on

the regulatory rules for undeveloped land. For example, new development could be required to cluster in areas most easily defended from rising sea level. In addition, if there were large tracts of undeveloped land, it might be possible to develop different types of response policies for discrete coastal areas. For example, an "expensive" protection strategy could be evaluated for already developed portions of the shoreline, but a retreat policy could be applied to undeveloped areas. Developing a different policy for large areas of undeveloped land could significantly affect the future amount of beach nourishment or bulkhead construction that would be required or permissible.

In contrast, since Camp Ellis does not have large tracts of undeveloped land, further restrictions on the the development of underdeveloped land will have no impact there on the aggregate future cost of either beach nourishment or the building of bulkheads. Under a reactive protection policy for the developed area, the aggregate future cost for building bulkheads and applying beach nourishment will be totally independent of what happens to the underdeveloped or undeveloped lots. In fact, any redevelopment to increase the number of units within current zoning regulations would actually lower the per unit cost to protect the existing structures using a reactive protection strategy of beach nourishment and bulkhead building.

To compute the costs of Option 1 the present value of the annual cost of adding sand, maintaining existing bulkheads, and building new bulkheads were added to the present value of the wetland volume that would be lost under each sea-level rise scenario over the next 100 years. The benefit of Option 1 was computed as the present value of both the estimated recreation value[6] and property value that would be saved over the next 100 years by pursuing this strategy.

It should be noted that under each sea-level rise scenario evaluated using the policy strategy specified by Option 1, the costs exceeded the benefits. This unappealing economic situation can be directly attributed to the simple fact that beach nourishment is very expensive, and that even under a zero centimeter sea-level rise scenario a substantial amount of beach nourishment will be needed over the next century to protect the existing structures by maintaining the current shoreline. The ratio by which the costs exceeded the benefits ranged from a low of 1.1:1 for the zero cm rise scenario to a high of 1.6:1 for the 200 cm rise scenario.

Option 2: This option uses the same basic policy response strategy as Option 1, with the only addition being a compensated setback program to be implemented for a number of properties that are already being seriously threatened by sea-level rise. Since these properties are built directly on top of the frontal dunes, in effect what this policy does is simply move the position of the shoreline that will be defended slightly furthur back to a more easily defended (and less costly) position, given the current sea level. Otherwise this policy option utilizes the exact same techniques as Option 1 to protect the remaining development. (Elsewhere in this study the compensated setback program may also be referred to as an "anticipatory protection" policy.)

The compensated setback program is estimated to cost 110% of the current appraised property values of those already threatened properties to be acquired. The 10% premium is

included to give the owners an incentive to facilitate and ease the transition of ownership from private to public hands.

The major benefit of the compensated setback policy is that by vacating the portion of shoreline that is currently under the most stress from sea-level rise, coastal erosion and storm surges, a volume of sand will be provided to buffer the next tier of structures that are further setback from the encroaching shoreline. This means that the amount of sand needed for beach nourishment to maintain the current shoreline position will drop to zero for a number of years, depending on the rate of sea-level rise. If, contrary to observed historical trends, sea level does not rise at all, it is estimated that the compensated setback program would provide enough sand to eliminate the need for beach nourishment for the entire 100 year period. Alternatively, if sea-level rises at a rate of 50, 100, or 200 cm over the 100 year period it is estimated that the compensated setback policy would only eliminate the need for beach nourishment to protect the remaining structures and maintain the current shoreline position for 20, 10, or 5 years, respectively.

Because the cost of sand for beach nourishment is very high, the compensated setback program provides a savings that is large enough to substantially improve the benefit/cost ratio for a reactive protection strategy under both the zero and fifty centimeter sea-level rise scenarios. In fact under the zero centimeter sea-level rise scenario it changes the ratio from being less than one, to being greater than one, which makes this scenario the only variation on a reactive protection strategy evaluated by this study that yields a benefit/cost ratio greater than 1.0. However, it is also important to note that a zero centimeter sea-level rise over the next century is highly unlikely, because it would be inconsistent with projections of sea-level rise based on historical rates of change in Maine, and would also be inconsistent with Maine Geological Survey's coastal hazard mapping for Camp Ellis.[7]

This analysis suggests that if policy makers believe they must protect existing development and if they are advised that a 0-50 cm sea-level rise is the most probable scenario over the next century, the use of a compensated setback program in conjunction with a reactive protection policy can improve the benefit/cost ratio.

However, under higher sea-level rise scenarios (100 or 200 cm) the compensated setback policy actually reduces the benefit/cost ratio, and makes it more expensive to pursue than a pure reactive protection policy on it's own, because of the combination of two factors. First, the upfront cost of acquiring the most threatened properties has a high present value that is added to the cost of the policy, while the amount of property being protected is diminished because after the buyout there is less property to protect. Second, under a more rapid sea-level rise scenario the savings in sand for beach nourishment provided by the compensated setback program is quickly consumed and does not last long enough to offset the relatively high present value of purchasing the properties upfront at the inflated value of 110%.

Option 3: Policy Option 3 establishes a rolling easement strategy[8] for all current development, and would implement a setback policy to exclude any further new development or redevelopment from occuring in either the anticipated 50, 100, or 200 cm sea-level rise zones.

The economic cost of prohibiting development according to a setback policy within each band of anticipated sea-level rise are estimated based on the number of new units that could

be added by redevelopment within each band. A mid-range estimate of the redevelopment potential that would occur by the year 2100 under existing zoning regulations is assumed. The value of the lost development potential within a band is then calculated using the current average per unit value within each band, multiplied by the potential number of new units within each band. The mid-range estimates of the number of potential new units and the average development value per unit in each band are listed in Tables 4.1 and 4.2.

The economic costs associated with the rolling easement aspect of this policy option are calculated based on cumulative estimates for removal and relocation of all existing structures and infrastructure components; plus the cost of site restoration within each band of the anticipated range of sea-level rise scenarios. All values and quantities used to compute the costs and benefits are listed in Tables 4.1, 4.2, and 4.3. As mentioned earlier all estimates for the timing of natural events (such as the incremental rise in sea-level) as well as the distribution of the economic value of structures and infrastructure within an anticipated zone of sea-level rise are assumed to be strictly linear, to simplify the analysis.

The cost-benefit analysis for this policy option shows that benefits exceed costs under the 50, 100 and 200 cm sea-level rise scenarios. For the 50 cm rise scenario the ratio the ratio is 1.41, for the 100 cm rise scenario the ratio if 1.14 and for the 200 cm rise scenario the ratio is 1.23. The variation in the ratios is a function of the number of structures and infrastructure components in each zone, plus the amount of redevelopment potential in each zone. The reason the ratio falls for the 100 cm scenario, but then rises again for the 200 cm scenario is because of the disproportionately low number of structures and minimal infrastructure components in the 200 cm band.

Option 4: Under this option the economic costs are estimated for implementing a rolling easement policy on both existing and yet to be developed structures, exactly as they are in Option 3 for the existing structures. The same mid-range estimates used to estimate the amount of prohibited development in each sea-level rise zone of Option 3, are used here to estimate the costs of relocating the yet to be built structures that will eventually have to be moved.

The cost-benefit analysis for this policy option shows that benefits exceed costs for each sea-level rise scenario by a wider margin than in Option 3. Under the 50 cm rise scenario the ratio is 1.72, for the 100 cm rise scenario the ratio is 1.34, and for the 200 cm rise scenario the ratio is 1.55. As in Option 3, the fluctuation in the ratios is also attributable to the disproportionatly low number of structures and infrastructure components in the 200 cm band. Comparing Option 4 to Option 3 it can be inferred that using a rolling easement policy rather than a setback policy for underdeveloped sites increases the cost-benefit ratio in all cases. Therefore, at the Camp Ellis site, given the alternatives considered, it can be concluded that applying a rolling easement policy to both developed and underdeveloped sites is the most economically efficient policy choice.

Table 4.1

RAW DATA: Camp Ellis Case Study (aggregate quantities used to compute costs & benefits)			**Sea Level Rise Scenarios:**			
			0 cm.	50 cm.	100 cm.	200 cm.
Strategies:		**UNITS:**				
OPTION #1:						
Developed Area: Reactive Protection						
Undeveloped Area: Reactive Protection						
costs:	Beach Nourishment	(# cubic yds./yr.)	100,000	200,000	400,000	800,000
	Maintenance of Existing Bulkhead	(# feet)	5,280	5,280	5,280	5,280
	Wetland loss	(# acres)	-	0.24	21.32	51.65
	New Bulkheads Needed	(# feet)	-	682.5	14,362.5	30,574.5
benefits:	Recreation Value	(# people/yr.)	98,869	98,869	98,869	98,869
	Value of Structures	(total $'s)	-	$9,419,900	$13,979,100	$15,258,200
	Aggregate Value of Land	(total $'s)	-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk	(total $'s)		$14,933,174	$27,963,374	$32,790,274
OPTION #2:						
Developed Area: Compensated Setbacks + Reactive Protection						
Undeveloped Area: Reactive Protection						
costs:	Beach Nourishment	(# cubic yds/yr)	0	200,000-20yrs.	400,000-10yrs.	800,000-5yrs.
	Cost of Modified Development	(total $'s)	$5,591,300	$5,591,300	$5,591,300	$5,591,300
	Maintenance of Existing Bulkhead	($/yr.)	5,280	5,280	5,280	5,280
	Wetland loss	(# acres)	-	0.24	21.32	51.65
	New Bulkheads Needed	(# feet)	-	682.5	14,362.5	30,574.5
benefits:	Recreation Value	(# people/yr.)	98,869	98,869	98,869	98,869
	Value of Structures	(total $'s)	-	$8,146,314	$12,705,514	$13,984,614
	Aggregate Value of Land	(total $'s)	-	$24,366,386	$37,396,586	$42,223,486
	Economic Value of Land @ Risk	(total $'s)	-	$12,914,185	$25,944,385	$30,771,285
OPTION #3:						
Developed Area: Rolling Easements						
Undeveloped Area: Setbacks						
costs:	Amount of Land at Risk	(# acres)	-	71	133	260
	Aggregate Value of Land	(total $'s)	-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk	(total $'s)	-	$14,933,174	$27,963,374	$32,790,274
	roads at risk:	(# feet)	-	12,778	22,440	24,922
	sewer lines at risk:	(# feet)	-	9,617	17,767	18,951
	water lines at risk:	(# feet)	-	12,201	19,118	21,105
	Prohibited Development	(# units)	-	51	72	127
	Removal of Existing Develop.	(# structures)	-	210	334	364
	Site Restoration	(# sites)	-	210	334	364
benefits:	Cost of Reactive Protection: Opt. #1	(see above description of costs avoided under Option #1)				
OPTION #4:						
Developed Area: Rolling Easements						
Undeveloped Area: Rolling Easements						
costs:	Amount of Land at Risk	(# acres)	-	71	133	260
	Aggregate Value of Land	(total $'s)	-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk	(total $'s)	-	$14,933,174	$27,963,374	$32,790,274
	roads at risk:	(# feet)	-	12,778	22,440	24,922
	sewer lines at risk:	(# feet)	-	9,617	17,767	18,951
	water lines at risk:	(# feet)	-	12,201	19,118	21,105
	Removal of New Development	(# structures)	-	51	72	127
	Removal of Existing Develop.	(# structures)	-	210	334	364
	Site Restoration	(# sites)	-	261	406	491
benefits:	Cost of Reactive Protection: Opt. #1	(see above description of costs avoided under Option #1)				

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Table 4.2

RAW DATA: Camp Ellis Case Study

(PRICE & VALUE Assumptions Used to Compute Cost Benefit Analysis)

Replacement of roads or utilities	($/linear foot)	$200.0
Wetland mitigation	($/acre)	$30,000.0
Sand for beach nourishment (upland source)	($/cubic yard)	$7.0
Concrete block seawall construction	($/linear foot)	$755.0
Annual maintenance of seawall (estimated at 5% per year)	($/linear foot)	$37.8
Average building relocation cost	($/structure)	$78,795.0
Average cost of land to relocate	($/site)	$52,500
Average site restoration cost	($/site)	$5,000
Beach recreational value (Range from Colgan study on recreational values)		
low:	($/person-day)	$6.00
high:	($/person-day)	$50.14
Development Value ($/undeveloped unit):		
0.5 meter zone:	($/undeveloped unit)	$44,857
1.0 meter zone:	($/undeveloped unit)	$36,768
2.0 meter zone:	($/undeveloped unit)	$42,637
FY92 interest rate for federal water resources projects (as cited in the US Army Corps of Engineers, Camp Ellis Beach Reconnaissance Report)		8.5%

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Table 4.3

COST-BENEFIT ANALYSIS: Camp Ellis			Sea Level Rise Scenarios:			
			0 cm.	50 cm.	100 cm.	200 cm.
Strategies:		**UNITS:**				
OPTION #1:						
Developed Area: Reactive Protection						
Undeveloped Area: Reactive Protection						
costs:	Beach Nourishment	(total $'s)	$8,232,935	$9,199,159	$11,131,606	$14,996,501
	Maintenance of Existing Bulkhead	(total $'s)	$2,347,374	$2,347,374	$2,347,374	$2,347,374
	Subtotal Costs:	(total $'s)	$10,580,310	$11,546,533	$13,478,981	$17,343,876
	Wetland loss	(total $'s)	-	$847	$75,226	$182,242
	New Bulkheads Needed	(total $'s)	-	$67,036	$1,410,696	$3,003,052
	TOTAL COSTS:	(total $'s)	**$10,580,310**	**$11,614,416**	**$14,964,903**	**$20,529,170**
benefits:	Recreation Value	(total $'s)	$6,976,989	$6,976,989	$6,976,989	$6,976,989
	Value of Property Protected	(total $'s)	$2,864,247	$2,864,247	$4,932,995	$5,651,142
	TOTAL BENEFITS:	(total $'s)	**$9,841,236**	**$9,841,236**	**$11,909,985**	**$12,628,132**
OPTION #2:						
Developed Area: Compensated Setbacks + Reactive Protection						
Undeveloped Area: Reactive Protection						
costs:	Beach Nourishment	(total $'s)	$0	$1,845,764	$5,076,322	$10,253,968
	Buyout Plan	(total $'s)	$5,591,300	$5,591,300	$5,591,300	$5,591,300
	Maintenance of Existing Bulkhead	(total $'s)	$2,347,374	$2,347,374	$2,347,374	$2,347,374
	Subtotal Costs:	(total $'s)	$7,938,674	$9,784,439	$13,014,996	$18,192,643
	Wetland loss	(total $'s)	-	$847	$75,226	$182,242
	New Bulkheads Needed	(total $'s)	-	$67,036	$1,410,696	$3,003,052
	TOTAL COSTS:	(total $'s)	**$7,938,674**	**$9,852,321**	**$14,500,918**	**$21,377,937**
benefits:	Recreation Value	(total $'s)	$6,976,989	$6,976,989	$6,976,989	$6,976,989
	Value of Property Protected	(total $'s)	$2,266,418	$2,266,418	$4,335,167	$5,053,314
	TOTAL BENEFITS:	(total $'s)	**$9,243,407**	**$9,243,407**	**$11,312,156**	**$12,030,303**
OPTION #3:						
Developed Area: Rolling Easements						
Undeveloped Area: Setbacks						
costs:	Value of Land at Risk	(total $'s)	-	$1,756,341	$3,288,866	$3,856,574
	Value of Infrastructure at Risk:					
	roads:	(total $'s)	-	$300,573	$527,849	$586,232
	sewers:	(total $'s)	-	$226,218	$417,927	$445,778
	water:	(total $'s)	-	$287,000	$449,706	$496,375
	Prohibited Development	(total $'s)	-	$2,287,690	$3,059,813	$5,404,829
	Removal of Existing Development	(total $'s)	-	$1,946,142	$3,095,293	$3,373,313
	Purchase of Land to Relocate	(total $'s)	-	$1,296,687	$2,062,350	$2,247,591
	Site Restoration	(total $'s)	-	$123,494	$196,414	$214,056
	TOTAL COSTS:	(total $'s)	**-**	**$8,224,145**	**$13,098,219**	**$16,624,750**
benefits:	**TOTAL BENEFITS = Cost of Opt #1:**	(total $'s)	**-**	**$11,614,416**	**$14,964,903**	**$20,529,170**
OPTION #4:						
Developed Area: Rolling Easements						
Undeveloped Area: Rolling Easements						
costs:	Value of Land at Risk	(total $'s)	-	$1,756,341	$3,288,866	$3,856,574
	Value of Infrastructure at Risk:					
	roads:	(total $'s)	-	$300,573	$527,849	$586,232
	sewers:	(total $'s)	-	$226,218	$417,927	$445,778
	water:	(total $'s)	-	$287,000	$449,706	$496,375
	Removal of New Development	(total $'s)	-	$472,635	$667,249	$1,176,953
	Removal of Existing Development	(total $'s)	-	$1,946,142	$3,095,293	$3,373,313
	Purchase of Land to Relocate	(total $'s)	-	$1,611,597	$2,506,929	$3,031,778
	Site Restoration	(total $'s)	-	$153,485	$238,755	$288,741
	TOTAL COSTS:	(total $'s)	**-**	**$6,753,991**	**$11,192,575**	**$13,255,745**
benefits:	**TOTAL BENEFITS = Cost of Opt #1:**	(total $'s)	**-**	**$11,614,416**	**$14,964,903**	**$20,529,170**

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COST-BENEFIT ANALYSIS: Camp Ellis *Summary Table: Benefit to Cost Ratios*		Sea Level Rise Scenarios: 0 cm.	50 cm.	100 cm.	200 cm.
Strategies:					
OPTION #1:					
Developed Area: Reactive Protection					
Undeveloped Area: Reactive Protection	costs:	$10,580,310	$11,614,416	$14,964,903	$20,529,170
	benefits:	$9,841,236	$9,841,236	$11,909,985	$12,628,132
	ratio B/C:	0.93	0.85	0.80	0.62
OPTION #2:					
Developed Area: Compensated Setbacks					
+ Reactive Protection	costs:	$7,938,674	$9,852,321	$14,500,918	$21,377,937
Undeveloped Area: Reactive Protection					
	benefits:	$9,243,407	$9,243,407	$11,312,156	$12,030,303
	ratio B/C:	1.16	0.94	0.78	0.56
OPTION #3:					
Developed Area: Rolling Easements					
Undeveloped Area: Setbacks	costs:	-	$8,224,145	$13,098,219	$16,624,750
	benefits:	-	$11,614,416	$14,964,903	$20,529,170
	ratio B/C:	-	1.41	1.14	1.23
OPTION #4:					
Developed Area: Rolling Easements					
Undeveloped Area: Rolling Easements	costs:	-	$6,753,991	$11,192,575	$13,255,745
	benefits:	-	$11,614,416	$14,964,903	$20,529,170
	ratio B/C:	-	1.72	1.34	1.55

M. Montagna, Maine State Planning Office (August 1994)

Table 4.4

5. Economic Strengths and Weaknesses of Policy Response Options

By far the single most significant cost or benefit under any of the four response options is the cost of beach nourishment. This particular beach is currently experiencing significant erosion. At current erosion rates the beach would require 100,000 cubic yards of sand annually to maintain the shoreline at its current position, which computes to $700,000 annually. Under the stresses of a sea level 200 cm higher than the current level it is estimated that it would take 8 times the current amount, or 800,000 cubic yards of sand annually, to maintain the shoreline at its current position. (The intervening sea-level rise scenarios of 50 cm and 100 cm would require an estimated annual 200,000 and 400,000 cubic yards of sand, respectively, to maintain the shoreline at its current position.) These assumptions for beach nourishment at these annual rates are worst-case assumptions. It is likely that some quantity of sand would not leave the system and would remain available to nourish the beach. But determining how much sand would remain in the system is beyond the scope of this study.

The reason that the cost of beach nourishment far outweighs the other items in the cost-benefit analysis is because the expense is relatively high and is increasing over time for all but the 0 cm rise scenario. Only under the 0 cm rise scenario does the cost come close to the combined benefits of protecting the recreational values of the beach and the property.

The distinguishing aspect between Option 1 (pure reactive protection) and Option 2 (reactive protection plus compensated setbacks) is the proposed public buyout of those structures which are currently threatened. Option 2 with compensated setbacks would be slightly more economically efficient under a 50 or 100 cm sea-level rise scenario than Option 1, while the pure reactive protection (Option 1) would be slightly more efficient if a 200 cm rise were to occur over the next century. The basic reason is that the $5.6 million cost to enact the compensated setback plan is all upfront, while the increasing costs of beach nourishment are spread out over time and therefore reduced in present value terms. Not until the sea rises at a rate of 2 centimeters per year (under the 200 cm scenario) is the saving of beach nourishment costs in the early years, from implementing the buyout, exceeded by the additional cost of beach nourishment that will be needed in the later years.

The distinguishing aspect between Option 3 and Option 4 is the setback policy of prohibiting all new development in the zone of anticipated sea-level rise. This analysis shows that on a cost-benefit basis the present value of prohibiting all new development outweighs the cost of allowing the new development to occur and then having to remove the new development should the sea-level rise, identical to the removal requirements for existing development. The opportunity cost of this policy (Option 3) would be particularly high if development is prohibited in either the 50 cm, 100 cm, or 200 cm elevation zones, and sea-level rise does not occur or occurs to a lesser degree. The analysis shows that even if sea-level eventually rises to the anticipated level and requires removal of all new development, the present value of the lost development rights today is higher than the present value of the future removal and future site restoration costs since those would be spread over the next 100 years.

C. CONCLUSION

Because the volume of sand needed for beach nourishment at Camp Ellis is a significant factor in determining both the costs of Options 1 and 2 and conversely the benefits of Options 3 and 4, any variation in this price would significantly affect the Benefit/Cost Ratios in Table 4.4. Any increase in the cost of sand would increase the overall favorability of Options 3 and 4, while a decrease in the cost of sand would make either pursuing Option 1 or 2 more economically favorable than they currently appear.

The other significant basic assumption worth questioning is the annual interest rate of 8.5% used to compute the present value of pursuing each strategy over the 100 year time period. Because the amount of beach nourishment that is required to maintain the shoreline at its current position is increasing over time (for all but the 0 cm scenario) and the incremental amount of property that is threatened with each 1 cm rise in sea level is constant, any change in the interest rate will not be neutral to its effect on the relative difference between costs and benefits. If a lower interest rate was assumed it would make the benefit/cost ratio of either of the rolling easement strategies (Options 3 and 4) look even more favorable. Meanwhile if a higher interest rate were assumed in the analysis it would increase the benefit/cost ratio for the two reactive protection strategies (Options 1 and 2) and call into question whether that basic strategy is more economically efficient in the long-run.

Option 4 (rolling easements for both developed and undeveloped properties) comes out the most favorable in terms of a benefit to cost ratio under each of the three sea-level rise scenarios. *(See Table 4.4)* Therefore if sea level is expected to rise, the conclusion of this quantitative analysis (in terms of economic efficiency) would be to support Option 4 over the three alternative strategies based on the assumptions stated in this overview.

The underlying reason for this is that in present value terms it is far less costly to remove whatever structures and infrastructure would be affected as a result of sea-level rise over the next 100 years, than it would be to incur the continual annual expense of beach nourishment. This conclusion holds true even under both high and low sea-level rise scenarios. Similarly, the opportunity cost associated with keeping land undeveloped or less than fully developed (Option 3) even when it is not yet threatened, exceeds the cost of having to remove new development when the time comes. This is because the value of an upfront loss of development rights exceeds the present value of future removal costs that would be spread out over the next century.

While the general conclusion favors Option 4, it should be noted that there are risks associated with Option 4 which are not reflected in this analysis. It assumes the only costs associated with removal are the costs of purchasing relocation land, physically moving the structure, and restoring the site. However, if development is allowed, it is realistic to assume that no matter how much prior notice is given of the impending retreat requirement, people will not willingly abandon that new development without trying to change the retreat policy. The amount of effort expended to try to reverse the policy is likely to be in some proportion to the value of the development facing removal. If there is a failure of political will to enforce the rolling easement policy, the community may incur costs similar to, or even exceeding, those for reactive protection. This is because the protection costs could be higher than those reflected in this analysis if the community delays in committing to a protection strategy until

after the failure of the retreat strategy. If a genuine commitment to follow through with Option 4's retreat requirements is lacking, Option 3 could be more favorable. Alternatively, other variations on these retreat strategies are possible. For example, a strategy could limit new development in the threatened area to only small, movable structures. This might minimize the risk of backsliding when it comes time to enforce the removal requirements, while at the same time reducing the opportunity costs that would have been incurred with a total prohibition on all development in threatened areas.

D. ENDNOTES

1. Titus, James G., *Strategies for Adapting to the Greenhouse Effect*, APA JOURNAL, Summer 1990, at 311 (emphasis added).

2. *Id.* at 315-321.

3. Adapted from *id.* at 313.

4. United States Code (Flood Control Act of June 22, 1936), 1940 ed. (Washington, D.C.:U.S. Government Printing Office) at 2964.

5. Reconnaissance Report (Camp Ellis Beach, Saco, Maine), U.S. Army Corps of Engineers, May 1992.

6. Colgan, Charles S. and Frances Lake, 1992. "The Economic Value of Casco Bay" prepared for the Maine Coastal Program by the Edmund S. Muskie Institute of Public Affairs, University of Southern Maine. Maine State Planning Office, Augusta, Maine.

7. Stephen M. Dickson, Shoreline Erosion Management Project—Phase I, Protect Completion Report, Maine Geological Survey, July 1993, at 8.

8. Titus, James G. 1991. *Greenhouse Effect and Coastal Wetland Policy: How Americans Could Abandon an Area the Size of Massachusetts at Minimum Cost.*" 15 ENVIRONMENTAL MANAGEMENT 1, at 39-58.

Chapter Five

RESPONSIVENESS OF EXISTING STATE AND FEDERAL LAWS TO SEA-LEVEL RISE

A. INTRODUCTION

The vulnerability assessment (Chapters Two and Three) concluded that the areas most threatened by the prospect of accelerated sea-level rise are sand beaches and salt marshes. Eroding coastal bluffs are also faced with significant impacts from a continuation of current erosion.

In some of the mapped sites, substantial development is already located in threatened areas. For example, in central Old Orchard Beach, a rise of 50 cm by 2100 would inundate all of the commercial development on both sides of Route 9, back to the railroad tracks. In Camp Ellis, a similar rise in sea level would inundate 71 acres of land already developed with 210 structures.

In these intensely developed areas there is no question that private investment is on a collision course with coastal erosion and inundation. Public investments (e.g., roads, sewer systems and public open space), coastal beach-based recreation and tourism (e.g., sand beaches and public shoreline access areas), and marine resource industries (e.g., critical wetland habitat for commercially valuable species, commercial water dependent uses and commercial access to public waters) may also be heavily impacted by sea-level rise.

Governmental policies, laws and regulations will be instrumental in determining to what extent new public investment and new private development will take place in areas projected to be subject to coastal erosion and inundation as a result of sea-level rise. They will also establish the rules for treatment of existing development as the development is threatened by a change in shoreline position and as that same development threatens to interfere with natural coastal processes. This chapter analyzes existing state and federal laws to evaluate the extent to which they are already prepared to minimize adverse impacts of accelerated sea-level rise, and the extent to which they can be modified to respond to an anticipated change in shoreline position.

In evaluating existing laws and policies, this chapter **posits that a retreat strategy is generally preferable to a protection strategy**. Where the coastal processes and land development are on a collision course, the preferable option will be for the land development

to move back from the shoreline. Only in very limited circumstances (e.g., the commercial port area of the Portland/South Portland harbor) might it make economic sense to deviate from this policy; in limited areas the already disturbed character of the shoreline and the nature and intensity of the threatened development might justify protective engineered solutions, such as seawalls, to keep the shoreline from migrating.

The very simplified cost/benefit analysis of alternative policy response options for one developed, extremely vulnerable site (Camp Ellis, Chapter Four) supports preference for a retreat strategy. It found that the relative costs and benefits of protection and retreat favor the latter in that setting.

Similarly, a survey of innovative policy responses to sea-level rise and coastal erosion in selected coastal states (*See* Appendix B) verified that these states are beginning to embrace a retreat strategy as well, at least as a strategic response to a continuation of historical patterns of shoreline change. While these state approaches vary significantly in detail and in the extent to which they have been able to translate broad policy goals into implementing laws, there are **notable shared themes that Maine's policies should also embrace as guiding principles:**

1. Respect the dynamic nature of coastal systems;
2. Strive to preserve/enhance the resiliency of natural systems;
3. Acknowledge as underlying premises that the public should not be subsidizing private development in hazard areas and that private development in hazard areas can constitute a public nuisance;
4. To maximize political acceptance, build on and strengthen existing coastal policies rather than developing a separate set of sea-level rise policies;
5. Utilize state or regional oversight of local decisions regulating coastal development to facilitate integrated management of coastal systems and to better reflect the state-wide interests in this public resource;
6. Develop an integrated approach to control impacts on beaches, eroding bluffs and migrating wetlands recognizing that they are parts of an interconnected natural system;
7. Acknowledge that no one technique will be sufficient for the entire shoreline; incorporate sufficient flexibility to respond to differences in coastal topography, varying intensity of development, and land use (e.g., water dependent uses);
8. Utilize coastal setback requirements to minimize new development in hazardous coastal areas;
9. Supplement coastal setbacks with a variety of additional regulatory, tax, acquisition and planning strategies.

These premises inform the following analysis of Maine's laws and regulations.

B. MAINE'S LAWS AND REGULATIONS RELEVANT TO SEA-LEVEL RISE

The laws and regulations currently in place in Maine constitute the State's de facto response to the threat of sea-level rise. A few of the laws specifically anticipate the possibility of sea-level rise; other laws address a range of possible coastal hazards which could include sea-level rise. The laws and regulations with primary impact are summarized in Appendix A, with specific focus on their relevance to possible sea-level rise. It may be consulted for more detailed discussion of each law. The analysis in this chapter draws upon that review to identify strengths and weaknesses in existing laws.

This chapter first reviews the general laws and policies which provide the mandate or enabling legislation to plan for sea-level rise. Then, because the regulatory needs are different for each type of coastline (sand beach, marsh/flat, bluff, and engineered shoreline) this chapter analyzes the specific portions of existing laws and regulations most likely to influence development along each type of shoreline.

1. Background Law: Coastal Management Policies Act

The 1986 Coastal Management Policies Act[1] is a statement of policies to guide the State in balancing competing coastal uses. The Act establishes nine policies and directs that state, local, and certain federal agencies with responsibility for regulating, planning, developing, or managing coastal resources conduct their activities in a way which is consistent with the nine policies.

The policy relating most directly to sea-level rise is Policy Four which states:

> **Hazard area development.** Discourage growth and new development in coastal areas where, because of coastal storms, flooding, landslides or **sea-level rise,** it is hazardous to human health and safety[.] (emphasis added)

The accompanying illustrative Guidelines[2] express the rationale for the policy, noting that coastal floodplains, sand dunes, and wetlands in their natural state provide storm protection and support a variety of important plants and wildlife. Citing the extensive damage to natural and man-made features visited by coastal storms and the direct and indirect costs to governments of repairing this damage, the Guidelines establish the objective of discouraging development and redevelopment in areas that present threats to public safety or that threaten property damage which will be costly to public entities.

The Guidelines recommend that affected agencies govern themselves in accordance with the following policies:

- Government agency decisions will not support new infrastructure or related facilities in hazardous areas;
- Public funds available for improvements, renovations, or repair to existing infrastructure or other public facilities in hazard areas will give priority to their relocation out of hazardous areas.
- Government agencies will require new and modified structures/facilities to be adequately setback to protect them from erosion for 100 years.

- Government agencies will include scientific projections of sea-level rise in regulatory and management decisions affecting the shoreline.[3]

The Coastal Management Policy Act does not contain any provisions providing sanctions for violating the Act. By Executive Order, state agencies were directed to examine all their programs affecting the coast and to incorporate changes to make them consistent with the Policies before December 31, 1987. This Order was tackled with varying levels of agency enthusiasm and resources, resulting in uneven and unsystematic responses. It is fair to say that the December 31, 1987 goal was not met, but work is continuing on an incremental basis in some agencies to bring the State closer to the goals expressed in the Coastal Policies.[4]

As mentioned, the Act also encouraged federal and local agencies to review their programs for compliance with these Coastal Management Policies, but without establishing any deadlines. For municipalities, the primary land use regulatory entity in Maine, these policies were eventually given greater relevance through provisions in the Growth Management Act[5] and the Shoreland Zoning Act,[6] both of which require the resulting comprehensive plans, comprehensive land use ordinances, and shoreland zoning ordinances adopted by coastal municipalities to "address" the Coastal Management Policies. Coastal Policy Four may be furthered through voluntary comprehensive planning efforts, through state review of local plans for compliance with the Coastal Policies as a condition of awarding implementation grants, through continuing state technical assistance, through state consistency certification for preference for certain funds, and through the long-range restriction that a municipality will not be able to enforce any local land use ordinances (beyond the minimum shoreland zoning requirements) if it has not adopted a comprehensive plan which is consistent with the Act (including furthering its goals and the Coastal Management Policies) by 1998 or 2003.

The possibilities for encouraging municipal compliance under the Shoreland Zoning Act, as currently enforced, are more limited. While the Act recites that each coastal municipality is required to address all of the coastal management policies in its shoreland zoning ordinance, assessing compliance with these policies has not been a high-priority on the part of municipalities or the Department of Environmental Protection. If a municipality meets the minimum Guidelines for Shoreland Zoning Ordinances, it is not independently evaluated to ascertain whether it has addressed the coastal management policies.

In summary, Coastal Management Policy Four and the associated Guidance provisions appear to be sound policy statements as far as they go, but they provide just the merest shadow of an outline for a comprehensive, enforceable strategy. The policy statements and guidelines are very general. They do not shed any light on the weight to be accorded hazards posed by storm-driven erosion, local subsidence, and the threat of sea-level rise as a result of global climate change. Finally, the Act relies on essentially voluntary implementation by affected local, state, and federal agencies. Policy Four of the Coastal Management Policies Act is probably most important as an expression of public purpose which can be invoked by various governmental entities as they adopt statutes, rules, and ordinances which flesh out a detailed response strategy.

The following sections explore in more detail how existing laws currently address the Policy Four goal of discouraging growth and new development in coastal areas where, because

of sea-level rise, that type of growth and new development would be hazardous to human health and safety.

2. Sand Beaches

a. Character of Development

Sand beaches in Maine are primarily located in the southern part of the state in the Saco Bay and Wells embayments. The northern beaches are more typically composed of cobble. Statewide, beaches (both sand and cobble) constitute only about 10% of the 3,300 mile tidal shoreline.

Many of the southern beach areas first developed as summer resorts. During this century, development spread to cover almost every available space on large beaches and much of the area adjacent to smaller, frequently less stable strandlines as well.[7] These communities of seasonal single family residences are increasingly seeing summer homes converted for year-round residences.

While most of the land adjacent to these southern beaches is already developed to some extent, absent governmental restrictions on the location and intensity of new development, pressure is building for a new generation of higher intensity development on land currently occupied by lower-intensity uses. For example, summer camps have been bought and razed to make way for larger year-round homes. And developers contemplating high-rise residences eye sites currently occupied by small businesses and old motels. Whether this type of development will actually come to pass depends primarily upon economic conditions and upon the limits imposed by state and local land use regulations, including whether the review authorities will have the political will to enforce those restrictions.

As discussed in more detail in Chapter Two, the mapping of selected areas for this project using 50, 100 and 200 cm scenarios projected that the shoreline along sand beaches would move in the magnitude of 50-150 meters (150-500 feet) landward over the next 100 years assuming a 50 cm (1.6 foot) rise in sea level; 100-300 meters (300-1,000 feet) landward over the next 100 years assuming a 100 cm (3.3 foot) rise in sea level; and 200-600 meters (650-2,000 feet) landward over the next 100 years assuming a 200 cm (6.5 foot) rise in sea level. The 50 cm scenario by the year 2100 is the most likely of the three scenarios, but hazard mitigation planning theory suggests that it makes sense to evaluate the higher scenarios as well.

b. Natural Resources Protection Act and Sand Dune Rules

The primary law controlling development in sand beach areas is the Natural Resources Protection Act (NRPA)[8] as further fleshed out in the Coastal Sand Dune Rules.[9] The NRPA requires that all proposed construction affecting critical natural resources meet various standards prior to receiving a permit. The Rules further articulate the standards and other requirements a proposal must meet to be deemed in compliance with NRPA. Together the statute and rules establish policies which prohibit new construction in certain portions of the sand dune system, restrict the intensity of development where it is not prohibited, and require mobility or retreat for new and existing structures in the face of migrating coastal systems.

The Sand Dune Rules articulate the basis for these policies, noting that there is evidence that sea level is currently rising, that "theories have been developed which predict this rise to accelerate in the future,"[10] and that any rise will increase the "rate of shoreline erosion and flooding, and the risk of damage to coastal property."[11] The rules further state:

> The extent to which sea level will change in the future is uncertain. However, under any scenario of increasing sea level, the extensive development of sand dune areas and the construction of structures which are not practical to move increase the risk of harm, both to the sand dune system and to the structures themselves.

Therefore, in order to protect the natural supply and movement of sand, and to prevent creation of flood hazards, the Board will evaluate proposed developments with consideration given to future sea-level rise and will impose restrictions on the density and location of development, and on the size of structures.[12]

A permit is generally required for any construction, repair, or alteration of any permanent structure in a coastal sand dune system (defined to include beach berms, frontal dunes, dune ridges, back dunes,[13] and other sand areas deposited by wave or wind action).[14] An applicant is required to demonstrate that the proposed action meets statutory standards for review, which for activities on or adjacent to a sand dune require that the activity "not unreasonably interfere with the natural supply or movement of sand within or to the sand dune system or unreasonably increase the erosion hazard to the sand dune system."[15]

Additional minimum standards are articulated in the Rules which must be satisfied before a permit will issue, including:

> Projects shall not be permitted if, within 100 years, the project may reasonably be expected to be damaged as a result of changes in the shoreline.[16]

The Rules are extensive and complex, but generally establish two sets of restrictions—one applicable to existing structures and the other applicable to new structures. Buildings which have been damaged to greater than 50% of their appraised value due to an ocean storm cannot be reconstructed or replaced and additions to existing structures are not allowed unless they can meet the requirements for new structures.

c. Existing Structures

No State permit is required for the maintenance and *minor* repair of existing structures above the high water line causing no additional intrusion into a sand dune. But a State permit is required for:

- The restoration or replacement of a building which is damaged to greater than 50% of the building's appraised market value by an ocean storm;
- The repair of a seawall if the repair cannot be done with hand tools, or if there will be any increase in dimensions, or if the building behind the seawall has been severely damaged by an ocean storm and the damage exceeds 50% of the building's appraised value;

- Any repair, rehabilitation, or other improvement of a building, the cost of which exceeds 50% of the appraised market value of the building before the start of construction;
- Any work done to enlarge an existing building; and
- Reconstruction or replacement of an existing building.

The owner of a structure damaged by a coastal storm or coastal erosion will be unable to rebuild either the structure or any seawall in front of it without a permit if the structure is damaged by more than 50% of its value. In applying these regulations, no distinction is made based on the source of the damage, such as whether it was caused by a 100-year storm, a 5-year storm, or gradual erosion. To rebuild, the owner must apply for a permit within one year of the damage, and must meet all of the standards for new buildings (except maximum size and view protection provisions). It is unlikely that such a permit to rebuild would be granted since the extent of the recent damage would make it difficult for the applicant to satisfy the minimum standards, including the standard requiring no unreasonable interference with the natural supply or movement of sand within or to the sand dune system. It might also be considered a flood hazard to itself.

However, until damaged to 50% of its value, existing structures can be maintained, repaired (if the repairs are not so extensive that they actually enlarge, reconstruct or replace the structure), and improved. As written, the allowed "improvement" is rather broad. It can cost up to half of the appraised value of the existing building prior to the start of construction and (except in V-zones) may involve the construction of a second story or dormers.

In summary, these provisions allow existing buildings to not only remain in beach areas which are threatened by sea-level rise, but also in some cases, to be enlarged within the existing footprint (second story, dormers). Substantial improvements can be made until a building is damaged by more than 50% of its value. However, at that point, a permit is required for repairs or rebuilding and a structure cannot be rebuilt unless it can meet the standards for new construction (see below). It is unlikely that an applicant would be able to secure such a permit; the owner of the damaged property would be required to abandon it and retreat to less vulnerable land.

To date, the provisions prohibiting rebuilding if a structure has been damaged by more than 50% of its value have been applied in numerous instances, with only one litigated challenge to the no rebuilding provision. That case involved an after-the-fact permit application (permit applied for after the seasonal cottage was already substantially built) for a post-erosion damage replacement structure at Popham Beach. The Maine Supreme Court upheld the BEP's denial of a sand dune permit, finding that it was supported by substantial evidence. One of the BEP's grounds for denial was that the applicants had failed to meet their burden to show that the project would not reasonably be expected to be damaged within 100 years as a result of changes in the shoreline.[17] The applicants subsequently claimed that denial of a sand dune permit constituted a regulatory taking of property without compensation in violation of the Maine Constitution. The Maine Supreme Court held that no taking had occurred because "beneficial and valuable uses of their property remain."[18]

d. New Construction

The standards for new construction in or on a coastal sand dune system are similarly rigorous. They limit areas and types of structures. New structures are prohibited in V-zones (velocity zones or that portion of the land that would be inundated by wave surges superimposed on a flood) and on or seaward of frontal dunes.

The Maine Supreme Court has been asked to rule on this provision twice. In one case, it upheld the BEP denial of an after-the-fact permit and denial of a variance to build a house addition on Hunnewell Beach in Phippsburg because it was on a frontal dune.[19] A second case involved denial of a permit to build a new residence on a narrow sand dune between a salt marsh and the ocean on the only remaining vacant lot in Horseshoe Cove, Biddeford.[20] Again, accepting Maine Geological Survey's determination that the house would be located on a frontal sand dune, the Supreme Court found that the evidence in the record amply supported the Board's denial of the initial application and of the variance request. The Court did not, however, reach the applicants' claim that denial of a permit would constitute a regulatory taking under the Maine and United States Constitutions.[21]

New seawalls are prohibited outright, regardless of whether they would be in front of new or existing structures. Property owners have sought relief from this provision through special legislative amendment twice. In one instance in 1987, a few Pine Point property owners succeeded in obtaining an amendment to allow permits to issue for bulkheads along the Scarborough River from the jetty to the town landing. The resulting permits are, however, subject to the requirements that the applicants maintain the bulkheads and also repair any damage to the frontal sand dune between the end of the bulkhead and the town landing.[22] But in 1994, a similar request for legislative amendment by Biddeford property owners was defeated in committee; committee members expressed their determination to maintain the integrity of the Sand Dune Rules by refusing to grant piecemeal exceptions.

In areas where development is not prohibited outright, its intensity is restricted. Developed areas (including driveways, parking, lawns, septic systems, buildings, etc.) are limited to 40% of the site, and no more than 20% of the lot may be covered by buildings.

For larger buildings, the rules establish a more stringent criterion by specifically requiring the permit reviewer to assume that sea level will rise 3 feet over the next 100 years. Specifically, no new building may be more than 35 feet in height or have a footprint of more than 2,500 square feet unless the applicant "demonstrates by clear and convincing evidence that the site will remain stable *after allowing for a three foot rise in sea level over 100 years*" (emphasis added). This is the only provision in the Rules which makes any express assumption of a particular rate of sea-level rise over a specific period of years. The applicant may not rely on the existence of a seawall as evidence of site stability. The applicant may not propose to build a seawall or engage in beach nourishment as a means of stabilizing the site.

In addition to these restrictions on intensity of development, as with existing structures, the regulations establish a policy of retreat if sea level rises. All new, reconstructed, or replacement structures approved after the effective date of the rules[23] are subject to the following conditions:

1) No seawall shall be constructed or expanded on the property.

2) If the shoreline recedes such that the coastal wetland ... [including tidal and subtidal lands] extends to any part of the structure, including support posts, for a period of six months or more, then the approved structure, along with appurtenant facilities, shall be removed and the site shall be restored to natural conditions within one year.

3) Any debris or other remains from damaged structures on the property shall be removed from the sand dune system.

4) No structure shall be relocated within the sand dune system without approval of the Maine Department of Environmental Protection.

These rules are justified within the text of the Rules by findings by the Department of Environmental Protection that sea level is rising, seawalls interfere with the supply and movement of sand and accelerate erosion, and structures in a coastal wetland interfere with the natural supply and movement of sand and create an unreasonable flood hazard.

These Rules effectively prohibit the strategy of building "floodproofed" structures on pilings with the intent to maintain the structure after the beach has eroded out from under it. These retreat conditions maintain flexibility on when they will kick in; if sea level rises more quickly than anticipated they will require retreat sooner than 100 years, but if the rate of rise is less than projected, they will allow the structure to remain longer.

This policy of retreat is enforceable against these new, reconstructed and replaced structures through express conditions of approval. In addition, the Rules state that the Department will record sand dune orders containing any of these conditions with the Registry of Deeds. If this is done, it puts all subsequent owners on notice of these conditions prior to any purchase of the property.

In summary, pursuant to these rules (which only control development along less than 10% of the State's shoreline) new construction in or adjacent to sand dune systems is tightly regulated, and those new, reconstructed, or replacement structures which are allowed are subject to retreat requirements if the shoreline recedes so that any part of the structure is affected by tidal waters for 6 months or more. Similarly, once constructed, if they are damaged by a coastal storm by more than 50%, they would probably be unable to rebuild.

The provision dealing with construction of larger structures requires reviewers to evaluate site stability assuming that sea level will rise 3 feet over the next 100 years. For smaller structures, assessment of site stability must be made on a case-by-case basis guided by the policy that projects will not be permitted if, within 100 years, the project may reasonably be expected to be damaged as a result of changes in the shoreline.[24] No rate of change is specified; typically the DEP and BEP have considered a continuation of the historical rate of change rather than an accelerated rate of change as a result of global climate change. The Rules use an accelerated rate (3 feet over 100 years) for reviewing larger structures but an historical rate for reviewing smaller structures based on the assumption that the smaller structures are movable, and would be moved if threatened by coastal erosion.

e. Other Laws Affecting Sand Beaches

Development on or along sand beaches is also controlled by several other land development regulations which are general in focus, including the Mandatory Shoreland Zoning Act and corresponding local shoreland zoning ordinances,[25] the Site Location of Development Act if the proposed development exceeds certain size/intensity thresholds,[26] the Subdivision Law,[27] and the State Floodplain Management Program.[28] They are much less detailed than the NRPA Sand Dune Rules, but do add a few specific setback requirements and review standards which might supplement the Rules in particular instances.

In addition, the State's Coastal Barrier Resources System Act[29] prohibits the expenditure of state funds or the granting of state financial assistance for development activities within the designated coastal barrier resource system.[30] Proscribed development activities include construction or purchase of structures, construction of roads, airports, boat-landing facilities, bridges or causeways, and erosion prevention projects.

Maine's statute and the parallel federal law are designed to protect and conserve coastal barriers and the adjacent wetlands, marshes, estuaries, inlets, and nearshore waters by discouraging development on and adjacent to those barriers. To date, only a small fraction of Maine's undeveloped areas (e.g., 32 coves, beaches, islands, points) are designated for inclusion in the coastal barrier system. This law provides limited, though important, protection for these undeveloped areas by prohibiting expenditure of state funds in support of development. It does not restrict private investment.

f. Opportunities to Strengthen Controls on Development

One of the problems with the sand dune permitting system as currently administered is that it requires an individual assessment of site stability, potential interference with the natural supply or movement of sand, and erosion hazard for each application. Advanced designations are currently used only to designate locations of frontal dunes, back dunes, and flood hazard zones through computerized sand dune maps which have been prepared for certain areas of sand dune systems in southern Maine.[31] While the designation of these maps as "best available information" for purposes of establishing these existing zones is important to rule out certain types of development in specific areas, they address only part of the issue. These maps show only existing conditions; they do not project hazards posed by beach erosion, by formation or migration of inlet and marsh channels, by engineered shorelines, or by sea-level rise.

The Maine Coastal Program has identified the need to refine the regulations so that the State makes more advanced judgments about where development should be prohibited based on projections of future hazards. In theory, the advanced designation of hazard areas will not only guide private investment decisions and lend consistency to permitting decisions under NRPA, but will also be useful to guide government agencies in making public infrastructure decisions and will provide important information about natural geologic processes to municipalities for integration into their comprehensive plans and land use regulations.

To accomplish this end, the Maine Geological Survey (MGS) and the Department of Economic and Community Development (DECD) are currently involved in a two-phase Shoreline Erosion Management Project to enhance the sand dune maps so they convey more

information about historical shoreline change and the vulnerability to future shoreline retreat. The first phase of the project is to calculate shoreline change rates for three priority hazard areas based on change in shoreline position over time. The second phase will expand the coverage of "coastal hazard maps" to include approximately 30 additional beach systems throughout the state. A Geographic Information System (GIS) system will allow these maps to display information about the existing built environment, locations of frontal and back dunes, past shoreline changes, wave washover and flood zones, erosion rates for selected points, and a shoreline hazard rating. The MGS GIS is able to display information about shoreline change in great detail, since the grid size can be as small as one square meter.

Completing the measurement of historical erosion and developing these increasingly detailed maps of coastal hazards along beach systems throughout the state will give the State the ability to consider adopting different setback lines for each beach or segment of beach based on historical average annual erosion rates. These setbacks could vary based on local historical shoreline change/erosion rates. These area-specific setback lines would reflect significant differences which occur along the coast based on different types of beach systems (type of shoreline (sheltered or exposed), composition (sand to cobbles), off-shore profile, and other relevant characteristics).

The preliminary assessment of policy directions suggests that this information could be used to establish setback distances based on the erosion rate of a particular beach or beach segment using a setback line based on 100 times the historical average annual rate. These maps would give much more explicit guidance in applying the policy already articulated in the Sand Dune Regulations that "projects shall not be permitted if, within 100 years, the project may reasonably be expected to be damaged as a result of changes in the shoreline."[32]

This 100-year policy would place Maine in the forefront of states with state-imposed setback requirements. Several other states use variations on a 30-year/60-year standard for small and large structures.[33] This lower standard has been criticized as being too low to reflect the life expectancy of modern structures.[34] The National Research Council Committee on Coastal Erosion Zone Management in its 1990 report recommended that state and local erosion management programs should be encouraged to adopt stricter erosion standards such as a 50-year/100-year standard for small and large structures.[35] Maine's adoption of a 100-year setback standard for all buildings would be consistent with this recommendation.[36]

However, it should be noted that while substantial public benefits should be expected from enforcing setbacks based on a 100-year erosion projection based on historical erosion rates, these setback lines may still significantly underestimate the area vulnerable to coastal erosion. These new setback maps would determine the mandatory setback from erosion-prone shorelines by assuming that the past average annual erosion rate will continue unchanged into the future. The problem with using historical rates is that it makes no allowance for forecasts of global climate change.

Maine Geological Survey, based on tide gauge readings over fifty years and assuming a continuation of the historical rate of change, predicts that seas in Portland will be 21 to 26 centimeters higher in 2100.[37] Sea level increases based on this historical tide gauge data are projected to be slightly higher in Eastport (27-31 cm) and slightly lower in Kittery (11 cm).

Establishing setback lines based on an assumption of a continuation of past erosion rates incorporates an assumption of a continuation of the historical rate of sea level change as well.

However, more recent forecasts of global sea-level rise based on revised International Panel on Climate Change emissions scenarios place the global low-, mid-, and high-level forecasts at 15 cm, 48 cm, and 90 cm respectively.[38] Those numbers have to be increased to reflect local subsidence (based on historical change less historical global rise of approximately 12 cm per century) to project total sea-level change in the local area. Using the revised forecasts, this would result in a forecast rise in Portland by the year 2100 of 24 cm (low), 60 cm (mid), and 104 cm (high). If these scenarios for accelerated global sea-level rise are borne out, the resulting increase in locally-experienced sea-level rise will be approximately 14% (low), 150% (mid), or 300% (high) greater than the increase in sea level assumed by projecting a continuation of historical rates.

In the phase I completion report for the Shoreline Erosion Management Project, the Maine Geological Survey discusses the possibility of global sea-level rise as a result of global warming, and acknowledges that "erosion rates determined in this study are possibly conservative when calculating future beach changes."[39] The basis for this conclusion is that "it is quite likely that an acceleration in the rate of sea level rise will cause an increase in the erosion rates."

In summary, the Shoreline Erosion Management Project assumes a continuation of an historical rate of change without projecting a future, accelerated rate of erosion based on accelerated sea-level rise as a result of global climate change. Thus, the State must still confront the policy issue of how to integrate projections of accelerated sea-level rise into any revised coastal hazard mitigation strategy. Due to the scientific uncertainties currently surrounding those global change projections, the State may be justifiably apprehensive about basing mandatory setback requirements for *all* development on projections of historical erosion *plus* erosion anticipated as a result of accelerated sea-level rise due to global climate change. However, the State should consider using more stringent setback requirements which include assumptions about an accelerated rate of sea-level rise in certain conditions.

For example, the State could further articulate a two-tiered system, similar to the one it uses now, in which some uses are subject to a setback based on 100 times the historical annual average erosion rate for that beach and other uses are subject to a setback based on projections assuming a specified accelerated rise in sea level (e.g., a rise of 3 feet or 100 cm over 100 years). The Sand Dune Regulations as currently applied make this distinction with regard to small and large new development; for all development, the Rules direct that no permit shall be granted if, within 100 years, the project may reasonably be expected to be damaged as a result of changes in the shoreline.[40] For small development, while the means of measurement is not specified, 100 years of stability is assessed using a projected continuation of historical rates. In contrast, the Rules specifically state that 100 years of stability for larger projects is to be assessed assuming a rise in sea level of 3 feet over the 100 years. It would be a good idea to make this distinction more explicit if that is what is intended. With the completion of the maps being developed under the Erosion Management Project, setback requirements for smaller structures could be designated in advance, based on historical change. For larger development, the regulations could continue to contain a setback requirement which requires applicants to assume a 3-foot rise in sea-level over the next 100 years.[41]

Another variation on this system would be to designate particular favored uses (such as water-dependent uses or uses supportive of commercial water-dependent uses) which would be subject to setbacks ranging from 0 feet (if functionally required) to rates based on historical change. The less favored uses (such as non-water dependent commercial and residential structures) would be subject to the requirement that they show the site will be stable assuming a specified accelerated rate of change (e.g., 3 feet over 100 years).

In proposing these setbacks as a component of an anticipatory sea-level rise response strategy, it is assumed that it is rational to continue use of current setback requirements, which are based on 100 times an historical or accelerated sea-level rise rate (using the mid-level 100 cm or approximately 3 foot scenario), particularly since they have been in place for more than a decade. Many current owners of shoreline property, particularly those purchasing during the boom years of the mid-1980s, have assumed ownership with no investment backed expectation of being able to build closer than these setbacks.

However, as yet unresolved Maine litigation may hold that even though the BEP has the power to deny sand dune permits and variances on frontal dunes and forward of these setback lines, the application in a particular fact situations may constitute a taking of private property requiring compensation.[42] This possibility is discussed in more detail in the following chapter.

In evaluating the appropriateness of using setback provisions which incorporate assumptions about accelerated sea-level rise, decision-makers should be cognizant of the EPA's uncertainty analysis. According to EPA, a rise of at least 100 cm has a 5% chance by 2100 and 50% chance by 2200. Assuming these EPA projections are correct, using a setback based on a 3 foot/100 cm rise scenario for larger structures would mean that the State would have a 95% probability of successfully keeping large new structures from interfering with coastal processes for the next 100 years. At the same time, given the uncertainty, it also means that there is a 50% probability that those large structures would not have been affected by a change in shoreline position for 150 to 200 years and could in fact have been built closer to the shoreline with no innundation by 2100.

Policy makers must balance the risk of harm to structures and the natural systems against the chance that they will unnecessarily restrict the use of the property. Factors supporting a cautious approach for larger structures (i.e., establishing setbacks using a 100 cm rather than 50 cm or historical rate assumption) include: 1) the lack of mobility of large structures, 2) the probable continued ability to make some economic use of the site through temporary or smaller more mobile structures, 3) environmental justifications for keeping intense development back from the shoreline, and 4) the possibility of adverse shoreline effects from global climate change separate from a change in shoreline position such as storm surges and an increase in the frequency or intensity of hurricanes in Maine.[43] Conversely, it may be acceptable to use a setback based on a continuation of historical rates of rise for small structures since they are relatively mobile if the sea rises faster than expected. However, it is critical that property owners fully understand that they will be required to move if threatened by a change in shoreline position so that expectation can be built into the property's purchase price and so they have no claim that they should be able to protect their investment by engineered means.

Since the eroding shoreline is a very dynamic system and since some of the scientific uncertainty about global climate change might be reduced over the next decade, any setback regulations should be established in such a way that coastal hazard maps establish a mandatory minimum setback, but do not preclude the State from requiring a greater setback if new information justifies it. This new evidence may include evolving geologic information, evidence of recent storm damage or flooding, and information about changes in tidal inlets, as well as new information about global climate change.

So long as the requirements for removal of new, reconstructed, and replaced structures remain in place and the State retains the institutional will to enforce those requirements, the policy of retreat in the face of sea-level rise will be implemented, regardless of whether there are any mandatory setback requirements. However, incorporating mandatory setback requirements in addition to the retreat requirements will help minimize the amount of private economic loss due to unwise development decisions and will reduce the number of individuals with economic incentives to bring political pressure to bear to weaken the retreat policy.

3. Salt Marshes

a. Character of Development

The southwest coastal compartment of Maine (from the New Hampshire border to Cape Elizabeth) constitutes approximately nine percent (9%) of the State's total shoreline; approximately 65% of this shoreline is salt marsh. Similarly in the 31% of coastal shoreline in the area from Cape Elizabeth to Port Clyde, approximately 26% of the shoreline is salt marsh. Along the remaining 60% of the shoreline to the north, salt marsh shoreline is much less prevalent, constituting approximately 10% of the tidal shoreline.[44]

Historically, recreational tourism and summer home shoreline development has tended to concentrate along beaches and on scenic rocky promontories overlooking the sea. Development along marsh areas has not been as intense nor has it been as driven by seasonal or out-of-state users.

As described in Chapter Two, the mapping of selected areas using three scenarios projected that the shoreline along salt marshes would move in the magnitude of 3-35 meters (10-125 feet) landward over the next 100 years assuming a 50 cm (1.6 feet) rise in sea level; 8-50 meters (25-175 feet) landward over the next 100 years assuming a 100 cm (3.3 foot) rise in sea level; and 17-100 meters (50-325 feet) landward over the next 100 years assuming a 200 cm (6.5 foot) rise in sea level.

Structures and infrastructure are usually not the most vulnerable resources of concern in this type of setting since salt marshes are not usually the site of intensive development. The focus is instead on the values and functions of the salt marsh wetlands as critical habitat for birds, including migratory waterfowl, and endangered species; as spawning grounds and nursery areas for commercially valuable fish and shellfish; as a filter for removing pollutants and preserving water quality; as a flood water retention and flow reduction mechanism; and as a buffer protecting upland areas from erosion by absorbing and dissipating wave impacts. To continue to serve this function, it is critical that salt marshes be able to migrate inland with the change in shoreline position.

b. Natural Resources Protection Act

Unlike sand beaches, for salt marshes, there is no single law which takes precedence over all others in managing the conditions under which development on or adjacent to it will be allowed or removed. Several different State laws and local ordinances all have a role to play in placing restrictions on development.

The Natural Resources Protection Act[45] is designed to protect many of the State's resources, including coastal wetlands, from degradation. A NRPA permit is required for any regulated activity in, on, over, or adjacent to any coastal wetland. Coastal wetlands are defined to include all tidal and subtidal lands, all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water or estuarine habitat, and any marsh, swamp, bog, or other contiguous lowland subject to tidal action during the maximum spring tide level.[46] This definition allows for the regulated area to fluctuate as the shoreline changes in response to global climate change or land subsidence.

The standards of review most applicable to proposed development in salt marsh areas try to minimize loss of the critical beneficial functions generally associated with these coastal wetlands such as wildlife habitat and flood protection. Specifically they include:

- **Soil erosion.** The activity will not cause unreasonable erosion of soil or sediment nor unreasonably inhibit the natural transfer of soil from the terrestrial to the marine or freshwater environment.
- **Harm to habitats; fisheries.** The activity will not unreasonably harm any significant wildlife habitat, ... aquatic habitat, ... estuarine or marine fisheries or other aquatic life....
- **Interfere with natural water flow.** The activity will not unreasonably interfere with the natural flow of any surface or subsurface waters.
- **Flooding.** The activity will not unreasonably cause or increase the flooding of the alteration area or adjacent properties.[47]

The State has promulgated Wetlands Protection Rules to ensure that the NRPA standards are met by applicants proposing regulated activities in, on, over, or adjacent to a coastal wetland.[48] The Rules establish a wetland classification system (with coastal wetlands defined as Class I, and wetlands located within 250 feet of coastal wetlands defined as Class II) and detail standards for avoidance of loss in wetland area, functions and values. They discuss "no practicable alternatives," compensation, mitigation banking, and "no unreasonable impact" criteria. However, unlike the Sand Dune Rules, they assume a relatively fixed shoreline position. No specific provisions are included to require an applicant to demonstrate that the site will remain stable over a long period of time, nor are there any requirements for retreat or removal of any structures that might be affected by a change in shoreline position.

The DEP has promulgated regulations describing the BEP's scope of review under the Soil Erosion Standard. The only regulation that might be of use in prohibiting structures that would prevent the landward migration of wetlands is a statement that in or on "coastal banks" a proposed activity may not unreasonably affect the supply of sediment from the bank to coastal beaches or other land subject to tidal action.[49] However, this provision has not

historically been used to prevent the construction of seawalls or similar structures on or adjacent to non-sand coastal wetlands. Similarly, regulations elaborating on the scope of considerations under the harm to wildlife and fisheries and interference with natural flow of waters standards may be broad enough to embrace considerations of allowing landward migration of coastal wetlands, but do not contain express statements of that as a goal.

c. Mandatory Shoreland Zoning Act and Guidelines

The Mandatory Shoreline Zoning Act[50] requires all municipalities to adopt zoning and land use control ordinances applicable to the "shoreland area" within its boundaries which are no less restrictive than minimum guidelines adopted by the Board of Environmental Protection. The shoreland area is defined to include those areas within 250 feet of any saltwater body or within 250 feet of the upland edge of a coastal wetland [10 acres or more, as defined].[51] Among other purposes, the Shoreland Zoning Act was designed to protect against unwise development in that area; to protect buildings and lands from flooding and accelerated erosion; to control building sites, placement of structures, and land uses; to conserve shore cover; and to anticipate and respond to the impacts of development in shoreland areas.

While not specifically crafted in response to anticipated accelerated sea-level rise, the Act contains water *setback requirements* with the potential to minimize the impacts of a change in shoreline position. The Guidelines[52] prohibit the construction of any new principal or accessory structure or any substantial expansion of an existing structure within the shoreland zone unless that structure is set back 100 feet from the normal high-water line of great ponds and rivers, and 75 feet from the normal high-water line of other water bodies, tributary streams, or the upland edge of a wetland. In addition, there is essentially a 250 foot setback from the upland edge of a salt marsh or salt meadow wetland if the area is zoned Resource Protection; a Resource Protection designation is generally required in undeveloped areas if the area was rated moderate or high value by Inland Fisheries and Wildlife as of January 1, 1973.

There are, however, setback exceptions. A General Development District (or its equivalent, allowing intensive commercial, industrial, and/or recreational use) requires a 25 foot setback. There is no setback requirement in a Commercial Fisheries/Maritime Activities District (allowing functionally water-dependent uses). Thus adjacent to the upland edge of a marsh, the minimum setback requirements could range from 0 feet (for an unlikely water-dependent use in a marsh) to 25 feet for a relatively intense commercial or industrial use to 75 feet for a residential use to 250 feet in undeveloped Resource Protection Areas.

The Guidelines establish performance standards for piers, docks, wharfs, bridges, and other structures and uses extending over or beyond the normal high-water line of a water body or within a wetland. The Guidelines do not, however, establish performance standards for structures adjacent to but not currently in a wetland. This means there are no prohibitions in the mandatory minimum standards which would prevent a landowner from constructing a wall or other structure immediately outside a wetland to prevent the landward migration of a salt marsh as sea level rises.

Thus, while the Shoreland Zoning Act addresses the threat of accelerated sea-level rise to some extent by attempting to protect undeveloped land from development that would interfere with natural coastal processes, it fails to include provisions that anticipate a significant change

shoreline position, based on how far development should be removed from wetlands to minimize the negative impacts of development on wetland values and functions.

In fact, given the projected rates of change for the different scenarios, except in Resource Protection Areas, the mandatory minimum setbacks fail in two major regards: 1) since they fail to build in a margin for a change in shoreline position, they establish an inadequate buffer to protect wetland values and functions in the long term; and 2) in the more vulnerable salt marsh areas, they also fail to require structures to be set back from the upland edge of a wetland a sufficient distance to protect those structures from being overtaken by a marsh migrating inland with the change in shoreline position. For example, for the more vulnerable of the sample salt marsh sites, this study projects a landward movement of 35 meters or 115 feet over 100 years given a 50 cm rise; this exceeds the general minimum setback requirement by 40 feet, the General Development Setback by 90 feet, and the Commercial Fisheries/Maritime Activities District by 115 feet.

Continued use of inadequate setback requirements, the absence of any prohibition on construction of barriers to salt marsh migration, and the absence of any requirements for removal of structures impacted by migrating marshes sets up a situation where it is almost inevitable that landowners will try to halt the landward migration of marshes through the construction of physical barriers. If this is allowed, it will result in the loss of salt marsh wetlands as the seaward edge moves inland in response to sea-level rise and the landward edge is prevented from migrating.

d. Opportunities to Strengthen Controls on Development Along Salt Marshes

The migration of a marsh toward the upland is much less dramatic than the approach of the sea up a sand beach. The type of structure likely to be threatened in each situation is different too, with higher-intensity development more likely along sand beaches. In addition, the functions valued by the public vary. Sand beaches have significant economic, aesthetic, and recreational value; they attract high density development and anchor the Southern Maine tourism industry. Salt marsh wetlands make their contribution, but in a much less visible way; they serve as critical habitat for commercially valuable fish and shellfish, provide a different type of recreational opportunities, reduce the costs of maintaining water quality, and provide valuable flood and erosion control.

As discussed in the last section, Maine has already adopted a policy of mobility and retreat to protect sand beaches against a change in shoreline position; regulations applicable to new and replacement structures are designed to allow the beach to maintain itself by requiring removal of human impediments to allow a continuation of natural processes. However, the State has yet to explicitly evaluate extension of a policy of mobility or retreat for the salt marsh environment. The State should address the same retreat issue with regard to salt marshes. Without new parallel policies prevent bulkheads or other structures which interfere with wetland migration, a rise in sea level will result in a decrease in important salt marsh wetlands.

The State could use a couple of different approaches. One approach would be to strengthen the requirements under the Shoreland Zoning Act to expand the areas subject to the Resource Protection District prohibition on development within 250 feet of the upland edge of designated coastal wetlands. The State would need to review the sufficiency of the 1973

of designated coastal wetlands. The State would need to review the sufficiency of the 1973 Inland Fish and Wildlife maps designating moderate and high value wetlands in coastal areas and update those maps if necessary. In addition, it would need to evaluate the exemptions allowing towns to opt for non-Resource Protection designations even in mapped moderate and high value wetland areas, and the provisions allowing special exceptions in Resource Protection Districts to determine whether this approach is likely to succeed.

A second approach would be to amend the Natural Resources Protection Act to broaden the jurisdiction to require a permit for activities on land adjacent to any coastal wetland that might interfere with the projected natural migration of that wetland, assuming a specified rise in sea level. This would expand the Act so it would not only protect against wetland degradation from material or soil washing into wetlands, but would also protect against wetland loss occasioned by precluding wetlands from migrating landward in equilibrium with rising sea level.

The State would need to promulgate detailed regulations designed to prevent the hardening of the upland edge. These regulations could be modeled after the Sand Dune Rules and the amendments to those rules discussed above. They could include a prohibition on hard structures designed to limit the landward migration of salt marshes, an increase in the minimum setback from the upland edge of a salt marsh based on projected rates of change in shoreline position, a requirement that more intensive development be required to prove site stability and adequate buffering given a projected 100 cm rise in sea level over 100 years, and a requirement that all new construction and replacement structures be removed if the shoreline changes so that they are substantially interfering with natural marsh migration processes.

As part of this process, the State will need to make a conscious decision about whether all areas should be subject to the requirements that they facilitate marsh migration, or whether distinctions should be made between particular areas. For example, the State might decide that shoreline in areas already developed to a certain intensity or already developed for a particular type of use need not be maintained in an unhardened state. Or it might make distinctions based on the slope of the adjacent land in its natural state; if the slope is already relatively steep so that the wetland would probably not be able to migrate without substantial loss of area, that might argue in favor of allowing hardening of the upland edge. These options decisions would have to be studied in greater detail before State policy makers can decide what proportion of the salt marsh shoreline should be kept in an unengineered state.

4. Eroding Bluffs

a. Character of Development

Maine's shoreline includes ledge areas, which increase from approximately 3% to 24% of the shoreline as one moves northeast.[53] These ledge areas consist of both stable bedrock promontories and high bluffs of landslide-prone Ice Age mud. The bedrock promontories were generally built on first. As those prime sites have been developed, construction has spread to other areas such as eroding coastal bluffs of glacial sediment.[54] In some areas, these bluffs are eroding at a rate of one to three feet per year.[55] When the erosion is unimpeded, these coastal bluffs serve as a source of sand for beaches, particularly in areas lacking a major river to bring sediment from upstream, and a source of mud for salt marsh formation.

Unlike marsh and sand beach erosion, the erosion of most coastal bluffs is driven primarily by coastal storms rather than by any change in sea level, so projections of a change in shoreline position over the next 100 years are the same regardless of the sea-level rise scenario. And also unlike marsh and beach erosion, bluff erosion tends to be periodic, with major slumping events occurring at longer intervals rather than a small amount of erosion each year.

b. Natural Resource Protection Act

Like development in salt marsh areas, bluff development is not regulated by any single law. Development on bluffs generally falls outside the Natural Resources Protection Act (NRPA)[56] unless it is a mapped significant wildlife habitat area, or is deemed to be on land adjacent to a coastal wetland and the proposed activity would operate in such a manner that material or soil may be washed into the coastal wetland. While there are soil erosion standards which conceivably could be applicable if triggered, eroding bluffs in themselves are not a targeted natural resource.

It would be consistent with the philosophy of NRPA to amend the Act to include eroding bluffs as a protected natural resource. That Act is designed to regulate activities which might result in environmental degradation due to activities in, on or over a protected natural resource or due to material or soil being washed into protected natural resources from activities on adjacent land. Development on or adjacent to eroding bluffs increases the risk of harm to the bluff and to other protected natural resources such as sand beaches. For example activities such as lawn watering and use of septic systems may hasten the erosion and degrade the bluff and shoreline area if erosion causes system failure.

A related activity, and one that is regulated by NRPA, is that property owners who have invested in development on bluffs may try to build structures to halt the process of erosion, to the detriment of the sand beach or marsh which was to be nourished by the eroded bluff materials. The NRPA soil erosion and habitat standards would be relevant, as well as the Soil Erosion Standard for activities to affect "coastal banks," which requires that a proposed activity may not unreasonably affect the supply of sediment from the bank to coastal beaches or other land subject to tidal action.[57] As with coastal wetlands, regulations concerning harm to wildlife and fisheries and interference with natural flow of waters standards may also be applicable.

c. Mandatory Shoreland Zoning Act

Development on coastal bluffs will be controlled to a limited extent by the Mandatory Shoreland Zoning Act.[58] These bluffs are within 250 feet of the upland edge of a coastal wetland, thus would be included in the shoreland area. The minimum Guidelines require any permitted development to be set back at least 75 feet from the upland edge of that wetland. In addition, the minimum Guidelines direct the community to include lands "adjacent to tidal waters which are subject to severe erosion or mass movement, such as steep coastal bluffs" in a resource protection district. If zoned for resource protection, only non-intensive uses would be allowed; principal structures for residential, commercial, industrial, governmental, and institutional uses would be precluded. However, these areas will not always be placed in Resource Protection Districts. Under current law, even if coastal bluffs meet the criteria for resource protection designation, a municipality can opt to forego that designation if they are currently developed or meet the criteria for Limited Commercial, General Development,

or Commercial Fisheries/Maritime Activities District designation. Additionally, a municipality may opt to grant special exceptions to allow residential development on a lot in a Resource Protection District which could not accommodate development anywhere else on the lot.

d. Site Location of Development Act

A third law that might play a minor role in controlling development on eroding bluffs is the Site Location of Development Act.[59] It includes a soil standard which states that the development must be "built on soil types which are suitable to the nature of the undertaking and will not cause unreasonable erosion of soil or sediment nor inhibit the natural transfer of soil." However, this Act applies only to larger developments and there are no more detailed rules or regulations which directly relate the general standard to eroding bluffs.

e. Opportunities to Strengthen Controls on Development Along Eroding Bluffs

The type of development most likely to be located on eroding coastal bluffs is single family residences. The Site Location of Development Act will not apply to this type of development. As the laws are currently written, the major burden for preventing unwise construction falls on the Shoreland Zoning Act, as enforced by individual municipalities through their Shoreland Zoning Ordinances.

There are several problems with relying on the Shoreland Zoning Act as the primary defense against development on unstable bluffs. First, the Act has always been plagued by compliance problems. These problems may be inherent in the intergovernmental division of responsibilities incorporated in the Act. The State promulgates mandatory minimum guidelines; each individual municipality is responsible for adopting an ordinance which is consistent with the guidelines and for enforcing that ordinance. It has not been uncommon for municipal boards to view these requirements as unnecessary obstacles imposed on local landowners by the State rather than as part of a comprehensive effort to protect shoreland resources and prevent unwise development. However, local acceptance and enforcement might be growing as a result of improvements in training and certification of local code enforcement officers. If shoreland zoning is going to be relied on as the primary strategy for bluff erosion, a major public education effort on erosion and sea-level rise would be required to increase local acceptance of shoreland zoning provisions designed to mitigate those impacts.

Second, as written, a shoreland zoning ordinance will not be effective to prevent against unwise bluff development unless that area is designated for resource protection and unless the municipality does not grant special exceptions to allow single family development.[60] Municipalities are often reluctant to place land in a resource protection designation, and are frequently sympathetic to variance, special exception, or rezoning requests to allow more intensive use of this land.

Finally, if a municipality does not designate eroding bluffs as resource protection, as currently written, the remaining standards will probably be insufficient to require that development which does occur is setback a sufficient distance to protect it over its useful life. Depending on the particular bluff composition and its orientation, this study projects landward movement of the shoreline of approximately 15 to 45 meters (50 to 150 feet) over 100 years. Other studies have estimated that Maine's coastal bluffs are eroding approximately 1 to 3 feet per year, or 100 to 300 feet over the next 100 years, if the rate stays constant.[61] Thus, the

State minimum mandatory setback of 75 feet from the upland edge of a coastal wetland is unlikely to be sufficient to protect the structure over its useful life.

If development is allowed, as the bluff erodes, there will be increasing pressure to invest in public or private bluff stabilization efforts. By definition, those stabilization efforts will interfere with the transfer of sediment from the terrestrial to the marine environment. Eroding coastal bluffs are a major source of mud for the regions mud flats and salt marshes, and can be a local source for beach sand.[62] Current NRPA standards could be applied, but historically have not resulted in denial of permits for that type of bluff stabilization. However, both bluff stabilization structures and individual seawalls along sand beaches raise the same specter of interference with natural processes. This suggests that bluff stabilization structures should be regulated to the same extent as sea walls.

One approach to increase control over development on eroding bluffs is to encourage individual municipalities to amend their shoreland zoning ordinances to address the issue. Municipalities are free to adopt shoreland zoning provisions which are more stringent than the state minimum guidelines.

The Department of Economic and Community Development is in the process of drafting model performance standards for erosion prone coastal areas (beaches and eroding bluffs) designed to be incorporated into municipal shoreland zoning ordinances. These performance standards would apply throughout the shoreland zone, thus would extend protections to bluffs not already included in a resource protection district. The current draft proposes to use a formula to increase the setback beyond the normal 75 feet in areas eroding more than one foot per year; the additional setback increment would be determined by the average annual recession rate times the structure's assumed life span.

This type of formula would be a significant improvement since it would apply throughout the zone and would tie setbacks to erosion rates. It does, however, anticipate the use of erosion rate data for particular coastal areas which is not yet available from state agencies. Until funds are available for Maine Geological Survey to develop that data for the entire state, the municipality would have to work with its own geologist or Maine Geological Survey to develop that data for each application. The other limiting factor is that without amendment of the Shoreland Zoning Act, municipal adoption of these performance standards is completely voluntary.

The State should also evaluate a second approach: bringing eroding bluffs under more direct State control by amending NRPA to include eroding bluffs as a resource to be protected by the Act. This action could be taken alone or in concert with encouraging municipalities to amend their shoreland zoning ordinances as discussed above

Amending NRPA to include eroding bluffs as a protected natural resource offers the advantage of unifying direct state regulation over all of the major components of the "soft coast": sand beaches, salt marshes and eroding bluffs. By expanding the geographic reach of NRPA, it facilitates review of proposed activity based on its impact on the entire interconnected coastal system. This change should also promote consistency in underlying management policies. In addition, this approach would not have to rely on voluntary local action.

If eroding bluffs are expressly incorporated into NRPA as a protected natural resource, the State could then develop a set of rules parallel to the Sand Dune Rules to elaborate on the soil erosion standard (which mandates that the activity not inhibit the natural transfer of soil from the terrestrial to the marine environment) in the coastal bluff context. The new Rules could establish new setback requirements and a new retreat policy which would put applicants on notice that future bluff erosion would require that new and rebuilt structures be moved. These Rules would also serve to educate the public and municipalities about the fluid nature of this type of land form. Increased awareness alone might be sufficient to deter some coastal construction in this type of hazard area.

A third variation on this approach might be to allow waivers of the setback requirements for small structures with well located septic systems provided that the applicant agrees to a condition, memorialized as a recorded deed restriction putting all future owners on notice, that the structure could not be protected by engineered bank stabilization efforts and that it would have to be removed if any part of the structure was within a certain distance of the edge of the bluff.

5. Engineered Urban Shoreline

a. Character of Existing Development

A fourth distinct type of shoreline consists of engineered urban shoreline. Maine does not have much as measured in miles of shorefront. But the extensively engineered portions of harbors, such as the Portland/South Portland inner harbor, are of critical importance to the economic functioning of the region.

The engineered shoreline in this part of the harbor consists of a series of established finger piers, docks, wharfs, seawalls, bridges, and similar structures. These structures were first established, largely on filled land, more than a century ago, and have evolved over time as grandfathered structures, generally free of particular performance standards or new regulations controlling their location or environmental impact. While subject to significant variation from parcel to parcel, according to observations of the Maine Geological Survey, they are generally designed to accommodate seas which are approximately six feet higher than current mean high tide. This means that even given a projected rise in sea level of 200 cm over the next 100 years, the shoreline position will remain in its current location along this urban engineered portion of the shoreline.

However, these structures have not been engineered to accommodate higher water levels as a means of advanced planning for sea-level rise. To the contrary, the extra increment above mean high tide is required to protect uplands from most storm events. Even this added increment is occasionally insufficient in extreme storm events as evidenced by the occasional flooding of parts of Commercial Street (the closest street parallel to the waterfront) and structures located on piers south of Commercial Street. Thus, while this engineered waterfront is not vulnerable to a change in shoreline position due to a rise in sea level, if it remains as it is now, it will be vulnerable to increased storm surges. Unless the structures are raised or reinforced, the geographic extent and frequency of flooding from storm surges will increase as sea-level rises.

The inner harbor portion of the waterfront is in an intensely developed area where any sensitive natural resources have already been disturbed through construction, dredging, intense use, and other perturbations. While regulators should guard against any further environmental degradation, the economic functions rather than environmental or habitat functions are likely to take precedence in most reviews. Unlike salt marsh, sand beach, and eroding bluff areas where future regulatory strategies are driven by preserving or restoring natural functions for maximum public benefit, on engineered urban waterfronts, the maximum public benefit will probably be derived by allowing this working waterfront to continue that economic function.

Individual property owners will experience any rise in sea level as a gradual change over time. It will probably first manifest itself as slightly greater vulnerability to storm events over time. It is likely that in the course of reinforcing and rebuilding existing structures through normal maintenance and repair activities, property owners will accommodate to the increase in sea level by raising the level of decks and designing the structure to protect upland areas from slightly higher waters. This type of response would be incremental, parcel-by-parcel, and uncoordinated. If waterfront users have sufficient resources to reinvest in periodically rebuilding and modifying their infrastructure, this *de facto* response strategy may be sufficient to allow those structures to remain in place and continue their economic functioning.[63] Regulatory policies should be evaluated to determine whether they will permit periodic reconstruction of piers and wharves to allow continued economic functioning of key businesses.

b. Local Comprehensive Zoning, Flood Plain, and Shoreland Zoning Ordinances

The local comprehensive zoning ordinances for Portland and South Portland do not take the possibility of sea-level rise into consideration. Neither ordinance expressly requires the applicant to address site stability in the face of future change in sea level. To the extent that flooding is addressed in local ordinances, it is through the adoption of State-mandated minimum flood plain management regulations.[64] These regulations focus primarily on construction standards such as minimum elevation of structures and other flood-proofing requirements. The review for compliance with these flood plain management standards tends to be rather cursory, with reviewing staff and boards tending to rely on representations of the developer's architect or engineer to gauge compliance with the technical requirements of the standards.

The Shoreland Zoning Act has only minimal impact on these municipalities. Both Portland and South Portland have complied with the Act by adopting hybrid ordinances that incorporate only selected portions of the Guidelines into local ordinances. The 75 foot mandatory minimum setback requirement under the Shoreland Zoning Act is inapplicable to the engineered portion of the Portland and South Portland shorefronts since the zoning in this area is analogous to General Development (25 foot setback) or Commercial Fisheries/Maritime Activities Districts (no setback) as established in the Act.

The Shoreland Zoning Guideline's performance standards for piers, docks, wharfs, bridges, and other structures,[65] the Submerged Lands Act[66] and the current comprehensive zoning ordinance for the City of Portland generally combine to establish a land use policy favoring water-dependent uses on, over, and immediately adjacent to coastal waters. This was not the case prior to 1987 when Portland and South Portland saw high-density residential

condominiums, new office buildings, and tourist attractions such as floating restaurants approved for construction along the waterfront. The use restrictions tend to be the most stringent part of Portland's local zoning ordinances. For example, there are no setback requirements (except for 5 feet from the apron of a pier), lot coverage may be 100%, and buildings may be constructed to a height of 45 feet. Under certain conditions, a limited range of non-water dependent uses are allowed in the upper story space of waterfront buildings.

c. Opportunities to Strengthen Controls on Development Along Engineered Urban Shorelines

There appear to be two regulatory strategies to evaluate with regard to minimizing damage from sea-level rise in the engineered urban harbor context. Since natural processes are no longer at work to maintain the functioning of the shoreline system, the engineered solutions will need to be updated as necessary. One strategy is to ensure that private owners are able to improve their structures to cope with rising waters on a periodic basis as part of regular maintenance and reinvestment opportunities. Any regulations which impede this ability should be identified and evaluated to determine whether there are any unnecessary restrictions which could be eliminated.

The second opportunity to minimize future damage from increased inundation along the engineered urban shoreline is to strengthen land use controls. While not originally adopted as a response to threats posed by accelerated sea-level rise, giving a strong preference to water-dependent uses for shoreline sites can become an important component of a sea-level rise adaptive response strategy.

There are multiple policy reasons for restricting occupancy of structures over water and along the immediate shoreline to uses which must locate there in order to function. Sites which provide reasonable access to navigable waters are a scarce resource, particularly in the Portland/South Portland harbor which has a very small shoreline in comparison to other ports in urban areas of a comparable size.[67] Those sites should be reserved for those uses which cannot function without that access. Other activities which are attracted to the shore primarily for the views, ambiance, or other amenity values—such as retail shops, residential uses, and non-water dependent offices—should be required to locate further inland. They should not be allowed to preclude marine uses.[68] The only exception to this general principle should be in the case where non-water dependent uses can contribute to the economic health of water-dependent uses and key water-dependent uses would not otherwise be able to maintain the necessary piers, wharves, or similar infrastructure.

Without strong land use controls favoring water-dependent uses, during the last decade, market forces in New England's cities have combined to encourage development of high-density residential dwelling units, festival-type retail marketplaces, and high rise offices directly on the waterfront. This type of high intensity development immediately on the shore places many people, expensive structures, and complex urban infrastructure at risk from the impacts of rising seas.

In contrast, maritime uses tend to involve a lower level of investment in immobile structures or equipment, would have fewer people on site who would be exposed to the risk of storm events, and involve businesses and employees who are more cognizant of and

accustomed to dealing with the vagaries of coastal waters. Furthermore, by definition, water-dependent uses have no option but to locate along the waterfront.

Restricting new shoreline development along engineered urban waterfronts to those uses which need to be there—water-dependent-uses—should help minimize the potential damage from storm surges or coastal inundation as a result of sea-level rise. This "no regrets" strategy will hold down the value of development in areas vulnerable to increased damage from possible sea-level rise. But even if sea level doesn't rise, it is consistent with other policies supporting the preservation of shoreline sites for water-dependent uses.

Municipalities should give strict interpretation to the definition of water-dependent uses so as to disallow uses such as residential condominiums with boat slips and floating restaurants as "water-dependent uses." Similarly, as projections of sea-level change are developed with greater precision, municipalities should evaluate whether they should develop more rigorous standards for larger water-dependent use structures which would require applicants to prove that the development is designed to minimize the hazards of storm surges assuming a rise in sea level of 3 feet over the next century. This two-tiered review would be similar to the stricter scrutiny given to structures in excess of certain height and size thresholds under the Sand Dune Rules.

The State should also review its policies on water-dependent uses. The Shoreland Zoning Guidelines allow, but do not mandate, identification of areas for inclusion in Commercial Fisheries/Maritime Activities zones. While Portland has a fairly strong waterfront zoning ordinance, the State should assess whether other communities with highly engineered waterfronts are permitting non-water dependent uses to locate in areas vulnerable to sea-level rise. One way to address the dual goals of protecting and promoting water-dependent uses and of minimizing the risk of damage due to sea-level rise would be to strengthen the Shoreland Zoning Guidelines to require designation of areas meeting particular site characteristics (e.g., a combination of utility as a site for a maritime use and orientation to wind and water making it vulnerable to sea-level rise effects) as Commercial Fisheries/Maritime Activities District, thus precluding new non-water dependent uses.

C. FEDERAL LAWS AND REGULATIONS RELEVANT TO SEA-LEVEL RISE

In theory, federal laws could also supplement state laws to comprise a *de facto* substantive response to accelerated sea-level rise. In this section, relevant federal laws are reviewed in summary form to identify the extent to which they do supplement the response established by Maine's existing laws and regulations. In general this analysis concludes that while federal research efforts and funding initiatives are important in assisting states with the development of anticipatory response strategies, existing federal laws and regulations do not provide specific guidance to states or supplement state laws in a significant substantive way so as to constitute an anticipatory response strategy to accelerated sea-level rise.

1. Coastal Zone Management Program

The federal coastal zone management program, established by the Coastal Zone Management Act of 1972, as amended,[69] encourages and assists the states in preparing and implementing management programs to "preserve, protect, develop and where possible, to restore or enhance the resources of the nation's coastal zone."[70]

The Act was amended in 1990 to incorporate references to sea-level rise. A new Congressional finding states: "[b]ecause global warming may result in a substantial sea level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence."[71] Each participating state's management plan is directed to provide for management of coastal development to minimize losses caused by improper development in "flood-prone, storm surge, geological hazard, and erosion-prone areas and in areas likely to be affected by or vulnerable to sea level rise, land subsidence and saltwater intrusion, and by the destruction of natural protective features such as beaches, dunes, wetlands, and barrier islands."[72] Thus, to remain consistent with the federal law, and therefore eligible for federal financial assistance and leverage over federal actions, coastal management programs are required to incorporate sea-level rise considerations into program objectives and activities.

The 1990 amendments established section 309 Coastal Zone Enhancement Grants to assist states with specific projects to improve their management plans and implementing laws. Eight broad "enhancement objectives" qualify for the funding, including an objective on coastal hazards; anticipating and managing the effects of potential sea-level rise is one of the specific eligible topics within the hazard objective.

In summary, the Coastal Zone Management Act now requires some consideration of sea-level rise as part of the coastal management program and provides an opportunity for enhancement grant funding to facilitate planning and enhanced management. As with other coastal policy objectives, the Act does not mandate any particular sea-level rise strategy. Due to the variation among the states in regulatory framework, problems posed, and institutional allocation of responsibilities, the Act leaves it to each state to develop the response that is most appropriate for it.

2. Federal Climate Change Research

Another way the federal government is involved in planning for sea-level rise is through supported research. The U.S. Global Change Research Program is multi-year, multi-agency, federally-funded research program designed to bridge the gap between scientific research and policy initiatives. It encourages research to monitor, understand, and predict global change, and to improve the scientific basis for developing national and international policy. Greenhouse gases in the atmosphere and sea-level rise are among the global change phenomena targeted for study.

Through this program, and with other funding, the United States Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA) have taken lead roles, both within this country and in international efforts, to develop a consensus on greenhouse gas issues and response strategies. The EPA has conducted or funded a significant portion of the state climate change research on adaptive responses to accelerated sea-level rise.

It will be important for states to keep themselves informed about the results of this research so that they can review their anticipatory strategies periodically in response to developing information. However, this federal research effort does not, in itself, establish any substantive portion of a policy response strategy.

3. Federal Clean Water Act

Section 404 of the federal Clean Water Act[73] is the primary federal law controlling development in coastal wetlands, the area most vulnerable to rising seas. It requires anyone who wants to conduct dredging and filling activities in navigable waters, including wetlands, to obtain a permit from the U.S. Army Corps of Engineers (COE). Federal resource agencies, the Fish and Wildlife Service (F&W), the Environmental Protection Agency (EPA) and the National Marine Fisheries Service (NMFS), review and comment on various permit applications. Through this permitting process, the COE and the resource agencies can play a critical role in reviewing development in coastal and estuarine waters and protecting coastal wetlands.

The COE generally evaluates projects based on historical sea levels. There is no formal guidance directing the COE or the resource agencies to evaluate projects taking into consideration the risks of accelerated sea-level rise or the need to ensure that coastal wetlands have the ability to migrate. Even if accelerated sea-level rise became a routine consideration in the COE's public interest review, the COE might still have limited influence over major impediments to coastal wetland migration due to the geographic limits of its jurisdiction. Despite a lack of formal guidance or statutory directive, district offices and resource agencies may have the discretion to consider risks of accelerated sea-level rise in project review if the agencies consider them to be significant.[74]

While not within the purview of the Clean Water Act, it should be noted that the COE also plays a major role in civil works functions such as the construction of seawalls, jetties, and other hard erosion control structures, in soft erosion control efforts such as beach restoration and renourishment, and in navigation projects such as channel dredging. Historical erosion rates are typically used in project assessment. The COE is likely to play a major role in these types of engineered responses if sea-level rise accelerates.

4. Coastal Barriers Resources Act of 1982

The federal Coastal Barrier Resources Act of 1982[75] established the Coastal Barrier Resources System, consisting of undeveloped coastal barriers along the Atlantic and Gulf of Mexico coasts. The coastal barriers were designated by the Secretary of the Interior in consultation with the Governors and state coastal zone management agencies, after public comment.

The Act imposes limits on federal expenditures within the System; except for a few narrow exceptions, no new federal expenditures or new financial assistance under the authority of any federal law may be made within the System. This precludes financial assistance for most development activities. Proscribed development activities include construction or purchase of structures, construction of roads, airports, boat-landing facilities, bridges or causeways, and most erosion prevention projects.

The only exceptions to the prohibition on federal expenditures or financial assistance are for water-dependent energy resources; navigational channels, structures, and dredge material disposal; maintenance and repair of certain public roads, structures and facilities; certain military activities; Coast Guard facilities; a variety of other emergency, habitat and research activities; and "nonstructural projects for shoreline stabilization that are designed to mimic, enhance or restore a natural stabilization system."[76]

The coastal barriers identified by the federal Coastal Barrier Resources System are also identified by Maine statute as being part of the Maine Coastal Barrier System. Under Maine statute, the use of state funds and financial assistance are also prohibited (with certain exceptions) in the designated areas.[77]

The geographic extent of coverage is very limited. Only approximately 22.5 miles of Maine's 3,400 mile shoreline are included in the Coastal Barrier Resources System (CBRS).[78] Other areas which are already protected (such as through state ownership) are not included in the CBRS designations.

This Act is consistent with a retreat strategy. It prohibits erosion stabilization projects except for nonstructural shoreline stabilization projects that are designed to mimic, enhance, or restore natural stabilization systems. It limits use of public funds for development in these areas and promotes retention of natural storm protection functions. But the Act provides only limited protection; it does not restrict private development nor does it include much of the shoreline.

In light of the threat of accelerated sea-level rise, it is appropriate to evaluate whether there are other areas which meet the criteria and should be included in the system.

5. National Flood Insurance Program

The National Flood Insurance Program (NFIP),[79] first enacted in 1968, is designed to reduce the cost of Federal disaster assistance following floods. NFIP, administered by the Federal Insurance Administration under the Federal Emergency Management Agency (FEMA), made previously unavailable flood insurance protection available to property owners in flood hazard areas if the community in which they resided adopted a floodplain ordinance meeting Federal standards designed to reduce or avoid future flood losses. These ordinances were intended to ensure that any new structures constructed in a floodplain would be designed to withstand a 100-year flood with minimal damage.

Most coastal communities have opted to participate in the program by adopting building codes and zoning rules acceptable to FEMA. This voluntary local participation makes flood insurance available to owners of new and existing structures, allows owners to apply for construction loans from federally-regulated lending institutions, and makes the community eligible to receive non-emergency federal disaster relief funds (e.g., funds to repair roads, schools, sewers, etc.).

The NFIP consists of three stages: the identification stage, the emergency program stage, and the regular program stage. At the identification stage, flood-prone communities are identified, and preliminary maps are prepared to identify general outlines of floodplains,

including "A" Zones representing areas expected to be inundated during a 100-year flood. In Maine, all identification has been completed.

To enter the emergency program stage, the community must enact a preliminary ordinance which requires a permit for construction or other development in flood-prone areas and which otherwise meets FEMA standards. The ordinance must require that new construction and substantial improvements be elevated above base flood level or, in non-residential structures, be flood-proofed rather than elevated. Flood insurance is available at this emergency program stage, but there are maximum ceilings on insurance coverage of $35,000 for a single family home and $10,000 for its contents.[80] As of the end of 1993, five Maine communities which had just recently decided to join the program were still in the emergency program stage.

Once a community enters the emergency program, FEMA produces a Flood Insurance Rate Map (FIRM) for the town outlining flood-prone areas. In some communities, the FIRM is prepared based on detailed engineering studies which identify areas of special flood hazard designated Zones A, A1-30, AE, AO and AH. Each zone has corresponding requirements which must be met before a permit will be granted for construction or other development.

In communities with lower flood risks, FEMA may opt to forego detailed studies and identify only "A" Zones on the Flood Insurance Rate Map. In Maine, less than one-half of the participating towns have FIRMS based on detailed studies. The majority of towns do not have detailed studies so in these communities only "A" Zones are mapped.

A community then has six months to enter the regular program by incorporating the FIRM into its zoning ordinance or other floodplain management ordinance. Once in the regular program, full insurance coverage is generally available. A portion of that insurance may be provided at premium-subsidized rates.[81]

The National Flood Insurance Program has been subject to criticism on a variety of grounds since its inception.[82] While those general criticisms may have implications for its usefulness as a mitigation tool, for purposes of this study, the most directly relevant criticism is that the National Flood Insurance Program fails to adequately address gradual shoreline erosion.

Due to the statutory mandate of the Program, it places primary emphasis on avoiding flood damage. To this end, it relies on elevating structures and "flood-proofing" as the primary means of preventing loss of life and structures. The construction standards are primarily designed to bring structures through the intermittent effects of coastal storms without reducing the capacity of the water to runoff adjacent lands. They are not designed to minimize loss when the land underlying the structure has eroded away through a gradual process.

One study of coastal erosion, reviewing the National Flood Insurance Program and other federal responses, found that:

> recognition of erosion as a hazard in its own right, apart from coastal flooding, has only recently begun to emerge. Federal policy has typically addressed storm-generated erosion as a short-term phenomenon with little attention to longer-term or gradual erosion resulting from the effects of relative sea level rise.[83]

Other analysts have also identified this as a shortcoming of the Act, and have asserted that it fails to incorporate an adequate strategic response to shoreline erosion caused by either historical or future rates of sea-level rise.[84]

While some recent efforts have been made to amend the statute to develop greater erosion management capability based on available historical data, the statute has not been amended to incorporate any assumptions about an accelerated rate of sea-level rise as a result of global climate change.[85] Premiums do not reflect any projections of accelerated erosion due to an increase in sea level.[86] One commentator also suggests that under current law, due to a statutory cap on rate increases, even if the risk of inundation from accelerated sea-level rise becomes known and apparent, these rates will still be unable to reflect this knowledge, thus FEMA will be precluded from charging actuarially sound rates.[87]

Over the years, there have been several efforts to incorporate an erosion element into flood insurance risk assessment. A 1973 amendment added erosion as a possible flood loss,[88] and 1976 regulations further established a framework for communities to use in addressing erosion hazards.[89] But these efforts were very narrow, addressing erosion only if it related to a flood event, and ignoring gradual erosion. A national study commissioned by FEMA found that NFIP failed to take action to implement even these limited flood-related changes.[90]

The next major effort to manage erosion under NFIP took the form of the 1988 Upton-Jones Act amendments to NFIP.[91] These amendments, extended to 1995, authorize payment from the National Flood Insurance Fund to demolish or relocate insured structures that are subject to imminent collapse or subsidence as a result of erosion. The intent was to encourage removal of erosion-prone structures in advance of their collapse, minimizing hazards and reducing the total loss expenditures.

The amendments also established new setback lines by mandating that once the Act applies, no further flood insurance is permitted on that land unless the new or relocated structure is landward of the setbacks. For 1-4 family residential structures, the setback is based on a 30-year erosion standard; for any other structure, it is based on a 60-year erosion standard. These are calculated assuming a continuation of historical rates.

The Upton-Jones Amendments have been praised as an important first step in setting the stage for identifying erosion hazard zones, for adjusting premiums to reflect erosion risks as well as flood risks, and for developing new land-use standards. But there is still widespread concern over the program and multiple revisions have been recommended to improve its effectiveness.[92] For example, one national evaluation recommended that the geographic area of eligibility, the "zone of imminent collapse," be expanded to facilitate anticipatory removal of structures in advance of a major storm event.[93] Another national assessment of policy options for preparing for climate change recommended that the NFIP mapping and rate structures be revised to incorporate at least conservative estimates of sea-level rise.[94]

Even with the Upton-Jones Amendments, the NFIP still does not include any express consideration of projections of accelerated sea-level rise. Under the current Act, future erosion estimates are to be based on projections of past shoreline change as documented in existing records; sea-level rise trends will not be incorporated into the projection of future risk unless they are already "present in the existing record."[95]

In 1991 and 1992 significant amendments to the NFIP were proposed but in both years the amendments failed.[96] Both proposals expressly recognized the relative rise in sea level as threatening the flood insurance program with greater financial liability.[97] Both proposals also sought to increase compliance by imposing requirements on lenders,[98] to increase local incentives to reduce construction and the number of structures in flood-prone areas through premium rate reductions,[99] and to increase State mitigation activities such as elevation, flood-proofing, and relocation through national mitigation grants.[100] The proposals would also have established erosion management programs with mandatory (1991) or voluntary (1992) land management standards for erosion-prone areas.

Senator Kerry introduced a slightly amended "National Flood Insurance Reform Act of 1993" in August, 1993.[101] Again the bill proposes that Congress find that the relative rise in sea level exposes the NFIP to risks that should be adequately considered in risk assessment. Erosion hazard areas, to be identified based on erosion rate information and other historical data, are defined as areas where erosion is likely to result in damage to or loss of buildings and infrastructure within a 60 year period. Other than requirements that the delineations be updated periodically, there is no express recognition of the threat of an increased rate of sea-level rise as a result of global climate change.

The State should monitor the progress of the Kerry proposal and similar pending bills[102] which would amend the National Flood Insurance Program. These amendments might alter the economic incentives to develop in or retreat from vulnerable areas.

The pending amendments to NFIP do not constitute a direct response to anticipated accelerated sea-level rise as a result of global climate change, but they are designed to manage gradual coastal erosion, divorced from a flood event. They assume a continuation of historical rates of sea-level rise into the future rather than adopt a projected accelerated rate of rise. However to the extent that they would protect threatened areas from further development and would heighten the ability of natural shoreline processes to accommodate to a change in shoreline position, they could help mitigate the impact of accelerated sea-level rise.

The State may also adopt its own measures on coastal erosion to supplement the National Flood Insurance Program. For example, it could adopt provisions to establish locational restrictions for coastal structures in the 100-year floodplain keyed to 50- to 100-times the annual erosion rate and could designate erosion zones within flood hazard areas where only movable structures will be allowed.

D. CONCLUSION

The federal programs discussed above provide some limited incentives and technical assistance for states to engage in erosion mitigation planning. For example, the Coastal Zone Management Act has been amended to recognize rising seas as a critical area for anticipatory planning and now provides financial assistance for programmatic changes through Enhancement Grants. EPA's Climate Change program also provides valuable technical assistance to states. However, the federal programs are not yet internally consistent, nor are they intended to be a comprehensive response.

Given this lack of a comprehensive policy at the federal level and the general deference given to states in land use and land development matters, state governments have an opportunity to play a vital role in implementing coastal erosion mitigation strategies. States may regulate coastal development directly, as Maine has done in sand dune systems through the Natural Resources Protection Act. While the setback standards can be improved by tailoring them to individual beaches or portions of beaches, in general they have successfully established setback standards for larger structures which incorporate an assumed sea-level rise of three feet over the next century and have established an important retreat policy for all structures.

States may also approach the issue more indirectly by guiding local planning and implementing regulations. Maine has taken this approach through the Coastal Management Policies Act, the Mandatory Shoreland Zoning Act, and the Growth Management Act. Together these Acts establish overall goals and minimum standards, but leave it to individual municipalities to develop plans and regulations which are consistent with these goals.

The products of these state-mandated planning requirements have been uneven, both from town to town, and within local plans, from goal to goal. While towns generally focused a lot of energy on identifying the community's vision for itself, delineating growth and rural areas, and deciding on implementation strategies, they gave less attention to more technical issues such as preventing inappropriate development in natural hazard areas, including flood plains and areas of high erosion. While some technical assistance was available to towns concerning sea-level rise and coastal erosion, these topics did not generally receive major emphasis. At the time, this was probably a rational approach given the difficulty in obtaining municipality-specific information about historical erosion and project sea-level rise, the complexity of coastal hazard mitigation and sea-level rise issues, the existence of local floodplain ordinances, and the degree to which state agencies already regulated development in fragile environmental areas such as wetlands and sand dunes.

However, as indicated in the preceding system-by-system review of state laws and regulations, local reliance on the adequacy of state regulation may be somewhat misplaced. The State generally does a good job of regulating sand dune systems. However, there are significant gaps in state regulation of development adjacent to salt marshes and on eroding bluffs.

State legislators and resource managers will have to evaluate the most appropriate way to proceed to amend state and/or local ordinances to be prepared for the possibility of an accelerated rate of sea-level rise. The State can opt to rely on amendments to NRPA and promulgation of additional rules. Since there already seems to be an expectation that the State regulates development in coastal erosion hazard areas and since the State has the necessary technical expertise, it would make sense for the State to extend shoreline regulation to encompass the entire "soft coast" system of sand beaches, salt marshes, and eroding bluffs. This state-wide approach is also supported by considerations of:

1) interjurisdictional equity in coastal development management, since all municipalities would operate under the same restrictions;

2) availability of necessary technical and legal expertise, since the development regulations may need to be fairly complex and well-substantiated to avoid legal challenges from owners of land in vulnerable areas;

3) consistent control over state infrastructure and public investment policies; and

4) ability to consider multijurisdictional impacts of changes in coastal systems such as interference with natural processes in one town affecting the shoreline in an adjacent town.

However, the State could also opt to encourage municipalities to make necessary changes in their local land use and shoreland zoning ordinances. It is arguable that this approach would allow local municipalities to tailor the most appropriate regulations for their own conditions. However, any reliance on voluntary municipal action would have to be supplemented by extensive technical assistance from the State to provide model ordinance provisions, detailed data about local historical erosion rates, and detailed projections of changes in shoreline position given assumed sea-level rise scenarios. It would also require extensive public education about the dynamic nature of coastal systems to convince local officials and citizens of the benefit of these regulations.

A hybrid of these approaches may prove most successful since these options are not mutually exclusive. The State could strengthen the NRPA regulations to establish statewide minimum policies and regulations governing development within the "soft coast" system. And those municipalities that wish to go beyond NRPA may adopt their own more rigorous standards regulating development in erosion prone areas or wetlands as part of their shoreland zoning, land use, or wetland ordinances.

E. ENDNOTES

1. 38 MRSA §§ 1801-03.

2. COASTAL ADVISORY COMMITTEE, COASTAL MANAGEMENT POLICY GUIDELINES 9 (Augusta, ME: Maine State Planning Office, Dec. 1986).

3. *Id.*

4. For example, Maine Geological Survey, the Department of Economic and Community Development and the Department of Environmental Protection are involved in the second phase of a Section 309 Project of Special Merit to designate coastal hazard areas threatened by sea-level rise and to recommend modifications in state laws and regulations to more thoroughly address hazards created by coastal processes including sea-level rise. MAINE STATE PLANNING OFFICE, MAINE'S COASTAL PROGRAM: FUNDING APPLICATION, JULY 1993 THROUGH JUNE 1994 (III-53-56).

5. Comprehensive Planning and Land Use Regulation Act, 30-A MRSA §§ 4311-4344.

6. Mandatory Zoning and Subdivision Control Act, 38 MRSA §§ 435-449.

7. JOSEPH KELLEY, ET AL. LIVING WITH THE COAST OF MAINE 7 (Durham, NC: Duke University Press 1989).

8. 38 MRSA §§ 480-A-U.

9. Coastal Sand Dune Rules, Code Me. R., Ch. 355, §3, 06 096 355-007.

10. *Id.*

11. *Id.*

12. *Id.* §3, Preamble.

13. Development in certain back dunes was exempted from the permit requirements in 1993 (38 M.R.S.A. § 480-Q(16) exempting back dune alterations from permit requirements), but coverage has generally been reinstated by a 1994 emergency amendment which makes the exemption applicable only if the back dune site is not expected to be damaged due to shoreline change within 100 years based on historic and projected trends, and repeals the entire permit exemption for back dunes on February 15, 1995 to be replaced by permit-by-rule performance standards for activities exempt under § 16 on that date. Maine Legislative Service, 116th Legislature, Ch. 522 (March 14, 1994).

14. *Id.* § 480-B(1).

15. *Id.* § 480-D (7).

16. Coastal Sand Dune Rules, *supra* note 9, §3(A)(2).

17. Hall v. Board of Environmental Protection, 498 A.2d 260 (1985). The Court indicated that the same analysis would apply regardless of whether this was treated as new construction or rebuilding of a substantially damaged structure. *Id.* at 264.

18. Hall v. Board of Environmental Protection, 528 A.2d 453 (1987).

19. Rubin v. Board of Environmental Protection, 577 A.2d 1189 (1990).

20. Fichter v. Board of Environmental Protection, 604 A.2d 433 (1992).

21. Plaintiffs' heirs have reportedly discussed pursuing a takings claim, but as of July 1994 had not filed to do so.

22. 38 M.R.S.A. § 480-O.

23. With the exception of piers, and additions, a combined total of which cover less than 250 square feet of ground surface. *Id.* §3 (B)(1).

24. Sand Dune Rules, *supra* note 9, §3(A)(2).

25. See Appendix A, section D of this report for a more detailed discussion.

26. See Appendix A, section E of this report for a more detailed discussion.

27. See Appendix A, section F of this report for a more detailed discussion.

28. See Appendix A, section G of this report for a more detailed discussion.

29. 38 MRSA §§ 1901-1905.

30. See Appendix A, section I of this report for a more detailed discussion.

31. An applicant may contest the mapped designations through an on-site survey.

32. Coastal Sand Dune Rules, *supra* note 9, §3(A)(2).

33. RUTHERFORD H. PLATT, ET AL., COASTAL EROSION: HAS RETREAT SOUNDED? 132-135 (Program on Environment and Behavior Monograph No. 53, Institute of Behavioral Science, University of Colorado, 1992).

34. *Id.* at 191.

35. COMMITTEE ON COASTAL EROSION ZONE MANAGEMENT, MANAGING COASTAL EROSION 9 (Wash., D.C.: National Academy Press 1990).

36. Others contend if the erosion rate is more than one foot or so per year, setbacks established at 100 times the annual erosion rate are too high because they unfairly deprive property owners of the right to use coastal land, particularly if they would not even be allowed to build a small house that could be moved back if required. *See* J.G. Titus, *The Cost of Holding Back the Sea,* 19 COASTAL MANAGEMENT 171 (1991).

37. W.A. Anderson, et al., *Crustal Warping in Coastal Maine,* 12 GEOLOGY (1984).

38. T.M.L. Wigley & S.C.B. Raper, *Implications for Climate and Sea Level of Revised IPCC Emissions Scenarios* 357 NATURE 293-300.

39. STEPHEN M. DICKSON, SHORELINE EROSION MANAGEMENT PROTECT - PHASE I, PROJECT COMPLETION REPORT 2 (Maine Geological Survey, July, 16, 1993).

40. Coastal Sand Dune Rules, *supra* note 9, §3(A)(2).

41. See Coastal Sand Dune Rules, *supra* note 9, §3(B)(2)(c) which requires applicants for buildings greater than 35 feet in height or covering greater than 2500 square feet to show by clear and convincing evidence that the site will remain stable after allowing for a three-foot rise in sea level over 100 years.

42. For example, the *Fichter* situation involves applicants who purchased their vacant lot in the 1950s, well prior to the adoption of the Sand Dune Rules. The lot is surrounded by residences built on similar lots, but is too small to allow the applicants to meet current setback requirements. The applicants' taking claim was not reached in the original litigation. Fichter v. Board of Environmental Protection, 604 A.2d 433 (1992). However, a Maine Superior Court rejected a taking claim in a similar freshwater shoreline situation, holding that even though surrounded by 1920s cottages on small lots which could not meet current requirements, the applicants did not prove a regulatory taking because the landowners still had economically beneficial or productive use of their land remaining, despite the prohibition on construction of a seasonal dwelling. Drake v. Town of Sanford, York County Superior Court, Docket #CV-88-679, December 18, 1992. On appeal, the Maine Law Court held that since the Drakes had voluntarily dismissed with prejudice their state law claim for compensation, the federal just compensation claim must be dismissed as well. 643 A.2d 367, 369 (Me. 1994).

43. According to some scientists, warmer temperatures may yield a 40-50% increase in the destructive potential of hurricanes. K.A. Emanuel, *The Dependence of Hurricane Intensity on Climate, in* AIP CONFERENCE PROCEEDINGS: THE WORLD AT RISK: NATURAL HAZARDS AND CLIMATE CHANGE SYMPOSIUM 25 (Rafale Bras, ed., Cambridge, MA: MIT Center for Global Change Science and Industrial Liaison Program, 1992). If Maine experiences an increase in frequency or intensity, it could cause storm-driven beach erosion which would be in addition to coastal erosion due to an increase in sea level.

44. KELLEY, ET AL., *supra* note 7, at 4.

45. 38 MRSA § 480-A -U.

46. 38 MRSA § 480-B(2).

47. *Id.* § 480-D, (2),(3),(4) and (6).

48. Department of Environmental Protection, Bureau of Land Quality Control, Wetlands Protection Rules, [Chapter 310], Code Me. R., § [06 096 310, Page 203000.727].

49. Department of Environmental Protection, Bureau of Land Quality Control, Soil Erosion Standard of the Coastal Wetlands Law, [1A(4)(b)], Code Me. R. § [06 096 344, Page 203041].

50. Mandatory Zoning and Subdivision Control Act, 38 MRSA §§ 435-449.

51. 38 MRSA § 435.

52. State of Maine Guidelines for Municipal Shoreland Zoning Ordinances, [06-096 Department of Environmental Protection Chapter 1000, March 24, 1990].

53. KELLEY, ET AL., *supra* note 7, at 4.

54. KELLEY, ET AL., *supra* note 7, at 6.

55. KELLEY, ET AL., *supra* note 7, at 5.

56. 38 MRSA § 480-A -U.

57. Department of Environmental Protection, Soil Erosion Standard of the Coastal Wetlands Law, *supra* note 49.

58. 38 MRSA §§ 435-449.

59. 38 MRSA §§ 481-490.

60. Effective October, 1993, municipalities may now incorporate a special exception provision to allow construction of a single family residence of up to 1500 square feet in a resource protection district if there is no other location on the property where a structure may be built, if the improvements will not be on slopes of 20% or greater, if it is located out of the velocity zone (or floodway of 100-year floodplain), if it otherwise complies with the municipal floodplain ordinance and is set back at least 75 feet and to the greatest practical extent. [Public Laws, 116th Legislature, 1193 First Regular Session, Ch. 318 amending 38 MRSA § 439-A].

61: KELLEY, ET AL., *supra* note 7, at 5.

62. KELLEY, ET AL., *supra* note 7, at 30-31.

63. Further study would be required, however, to determine the vulnerability of office and residential structures on the piers (e.g., the office and condominium development on Portland Pier and Chandler's Wharf and low-lying upland areas adjacent to the piers, such as the Commercial Street office/retail area). It is possible water dependent businesses on the finger piers would be able to modify their structures and functioning to accommodate occasional higher waters, without providing the types of walls that would offer flood protection to these other uses.

64. See Appendix A, section G of this report for a more detailed discussion of the State Floodplain Management Program.

65. These performance standards require that new structures be allowed over or beyond the normal high-water line of a water body only if they require direct access to the water as an operational necessity and prohibits the conversion of existing structures extending beyond the normal high-water line to residential dwelling units. [Guidelines for Municipal Shoreland Zoning Ordinances, March 24, 1990, Section 15 (C)(5-6)].

66. 12 MRSA §§ 552, 558-A - 573. For a more detailed discussion, see Appendix A, section D of this report.

67. *See, e.g.*, MARINE LAW INSTITUTE, GUIDEBOOK TO THE ECONOMICS OF WATERFRONT PLANNING AND WATER DEPENDENT USES (prepared for the New England/New York Coastal Zone Task Force, Portland, ME: Marine Law Institute, 1988) at 233.

68. *See, e.g.*, MARINE LAW INSTITUTE, MANAGING THE SHORELINE FOR WATER DEPENDENT USES (prepared for the New England/New York Coastal Zone Task Force, Portland, ME: Marine Law Institute, 1988) and MARINE LAW INSTITUTE *supra* note 67.

69. 16 U.S.C.A. § 1451 *et seq.*

70. *Id.* § 1452.

71. 16 U.S.C.A. § 1451 (l).

72. 16 U.S.C.A. § 1452 (2)(B).

73. 33 U.S.C. § 1344.

74. The COE has factored relative sea level rise into risk assessments in Louisiana and Texas. PAUL N. KLARIN, ET AL., SEA LEVEL RISE POLICY ALTERNATIVES STUDY: VOLUME 1, ALTERNATIVE POLICY RESPONSES FOR ACCELERATED SEA LEVEL RISE AND THEIR IMPLICATIONS, 1-29 (Olympia, Washington State Department of Ecology, 1990).

75. 16 U.S.C. § 3509.

76. 16 U.S.C. § 3505(a).

77. For further discussion of Maine's Coastal Barrier Resources System, see MRSA § 1901 *et seq.* and the summary in Appendix A of this report.

78. COASTAL BARRIERS STUDY GROUP, REPORT TO CONGRESS: COASTAL BARRIER RESOURCES SYSTEM —RECOMMENDATIONS FOR ADDITIONS TO OR DELETIONS FROM THE COASTAL BARRIER RESOURCES SYSTEM, VOL 2., MAINE, (U.S. Department of the Interior, 1988).

79. 42 U.S.C. §§ 4001-4128; Federal Emergency Management Agency Regulations, 44 C.F.R. §§ 59.1 - 77.2 (1992).

80. 44 C.F.R. § 61.8(b)(1)(i).

81. At this stage, coverage price is supposed to be determined based on actuarial cost. However, for buildings in existence before the FIRM was established, a portion of the cost is subsidized by premiums. For example, for a pre-FIRM single family home the first $35,000 of coverage is at the lower, subsidized rate. An additional $150,000 of coverage can be added, but it must be paid for at the FEMA determined actuarial cost. *Id.* § 61.8(b)(1)(i) and § 61.6(a).

82. For example, in 1992, Senator John Kerry of Massachusetts, the sponsor of a set of proposed amendments to the NFIP, asserted that chronic problems with that Program included: that only 17% of those eligible for flood insurance are actually insured; that communities develop ill-advised areas, with the result that the program is now a larger financial liability; that subsidized premium rates disguise the true risk and market cost of insurance; and that coastal erosion is not factored into the actuarial process for setting rates. 138 CONG. REC. S9145-46 (daily ed. June 29, 1992) (statement of Sen. Kerry); 138 CONG. REC. S18246 (daily ed. Oct. 8, 1992).

83. PLATT, ET AL., *supra* note 33, at 36.

84. *See, e.g.*, THE POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE ON THE UNITED STATES (J.B. Smith & D.A. Tirpak, eds., Hemisphere Publishing Corporation, 1990) at 359 [hereinafter Smith & Tirpak]. A new study prepared for three Congressional committees recommends revamping the National Flood Insurance Program to provide stronger incentives to reduce potential costs associated with high-risk development in coastal areas, to address erosion along the coast, and to incorporate sea level rise into the NFIP mapping and rate structure. U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, I PREPARING FOR AN UNCERTAIN CLIMATE, (Wash., D.C.: U.S. Government Printing Office, October, 1993) at 41, 197 [hereinafter OFFICE OF TECHNOLOGY ASSESSMENT].

85. The FEMA hazard zones as currently drawn do not account for the hazards from erosion or sea-level rise. FEMA commissioned a study "to determine the impact of relative sea level rise on the flood insurance rate maps" and to "project the economic losses associated with estimated sea level rise" for the nation and by region. *See* P.L. 101-137, §5, 103 Stat. 825 (Nov. 3, 1989).

86. BENJAMIN NOBEL, SEA-LEVEL RISE AND COASTAL MANAGEMENT POLICIES IN THE UNITED STATES (Wash., DC: Resources for the Future, 1992) at 9.

87. Smith & Tirpak, *supra* note 84, at 359.

88. Flood Disaster Protection Act of 1973, 42 U.S.C. § 4121.

89. 44 CFR, Part 60.1.

90. NATIONAL RESEARCH COUNCIL, MANAGING COASTAL EROSION (Wash., DC: National Academy Press, 1990) at 73.

91. 42 U.S.C.S. § 4013(c).

92. See, e.g., the conclusions of the National Research Council in its 1990 report, MANAGING COASTAL EROSION, *supra* note 90, at 87-93 and conclusions of the OFFICE OF TECHNOLOGY ASSESSMENT, *supra* note 84, at 197.

93. NATIONAL RESEARCH COUNCIL, *supra* note 90, at 87.

94. OFFICE OF TECHNOLOGY ASSESSMENT, *supra* note 84, at 197.

95. NOBLE, *supra* note 86, at 17.

96. The companion House bill to the National Flood Insurance Mitigation Act of 1991 passed easily. But the Senate failed to pass the 1991 Act. 138 CONG. REC. S9145 (daily ed. June 29, 1992) (Statement of Sen. Kerry). The Senate did not pass the revised version of the 1991 Act, the National Flood Insurance Reform Act of 1992, either. 138 CONG. REC. S18244 (daily ed. October 8, 1992) (statement of Sen. Kerry).

97. 138 CONG. REC. S9317-9328 (daily ed. June 30, 1992) (reprint of National Flood Insurance Act of 1992) [hereinafter 1992 Act]; 137 CONG. REC. S12207-12217 (daily ed. Aug. 2, 1991) (reprint of National Flood Insurance, Mitigation and Erosion Management Act) [hereinafter 1991 Act].

98. 1992 Act §§ 21-129; 1991 Act §§ 201-209.

99. 1992 Act § 131; 1991 Act § 301.

100. 1992 Act §§ 141-148; 1991 Act §§ 401-406.

101. National Flood Insurance Act of 1993, S. 1405, 103d Cong., 1st Sess., U.S. Senate, August 6, 1993, pending.

102. *See, e.g.*, 1993 H.R. 62, National Flood Insurance Compliance, Mitigation & Erosion Management, 103rd Cong., 1st Sess., U.S. House of Representatives, Jan. 5, 1993, Pending; 1993 S. 1024, Local Innovation and Coastal Protection Act of 1993, 103rd Cong., 1st Sess., U.S. Senate, May 25, 1993, Pending.

Chapter Six

LEGAL CONSIDERATIONS FOR MAINE'S POLICY RESPONSE

Most tools that are likely to provide an effective policy response to sea-level rise are in the hands of state and local governments. As the preceding chapter indicated, federal legal authority to address rising sea level is limited to the federal flood insurance program, which has yet to incorporate assumptions of an accelerated rate of rise, and the financial and technical assistance for planning provided to states under the federal Coastal Zone Management Act. The activities of private organizations that operate on a local or regional level, such as land trusts, can be important components of a state-wide response strategy.

The response tools from which Maine can choose fall into three broad categories: regulatory, non-regulatory (i.e, market-based), and informational. The selection of appropriate tools can be based upon whether Maine decides to pursue a strategic retreat, accommodation, or resistance/protection course of action, or a combination of these approaches. In this part of the report, it is assumed that Maine will opt to pursue a retreat policy along most of the coast, based upon considerations and assumptions discussed in the preceding chapters.

This chapter examines the retreat policy tools available to Maine in terms of their legal feasibility and defensibility. The primary focus is on the potential constitutional challenges to those regulatory tools that reduce the land use choices of private landowners. While the legal authority to employ the non-regulatory, market-based tools is an important consideration, these approaches by definition present fewer bases for legal challenge, especially under the takings clause. Accordingly, their legal defensibility is discussed less extensively. The informational tools, which are very important to support both regulatory and non-regulatory approaches, are discussed only very briefly. However, it is important that Maine consider and select from the full array of tools available for a sea-level rise response; the legal feasibility is just one factor to consider in formulating the State's policies.

A. OVERVIEW OF POLICY RESPONSE OPTIONS AND TOOLS

Tools that are regulatory in nature are those within the broad range of land use controls and regulations that can be adapted for the special conditions of rising sea level. These include:

- static or dynamic construction setback lines which restrict new development next to the shoreline and are measured using either historic or accelerated shoreline erosion rates and the average useful life of structures;
- conditional land use permits for new shoreline development that require removal of structures once shoreline migration begins to occur[1] or which condition development on the conveyance of a rolling easement[2] or a covenant prohibiting the construction of a seawall or bulkhead;
- prohibitions on rebuilding of existing structures based upon projections of the future location of the tide line;
- building and engineering codes and design standards requiring new structures to be built at elevations above a future sea level; and
- buffer/no building zones around critical natural areas such as wetlands likely to migrate with rising sea level.[3]

Non-regulatory tools rely on market forces and voluntary actions rather than legal prescriptions to prevent development in areas subject to rising sea level. These include:

- public purchase of full or partial property rights such as flowage easements on land likely to be affected by rising sea level;
- incentives or subsidies for private owners to relocate development away from the shoreline;
- tax incentives to preserve undeveloped areas needed for wetland migration;
- development disincentives and exactions to pay public costs of erosion control; and
- transferable development rights to compensate landowners for development restrictions (used in conjunction with land use regulations).

Several states have already adopted many of the regulatory tools listed above in their efforts to control coastal erosion and hazards. A small number of states have expressly evaluated these tools for the purpose of anticipating a rising sea level associated with global climate change. A review of state programs with coastal hazard control and sea-level rise provisions is provided in Appendix B.

Few states have evaluated or adopted non-regulatory, market-based approaches for addressing sea-level rise. However, a number of these non-regulatory tools present advantages that should not be overlooked, especially when used in conjunction with a system of land use controls relevant for sea-level rise. The main advantage of non-regulatory tools like the voluntarily-conveyed, rolling easement is that they are useful when sea-level rise forecasts are uncertain. They do not require the same degree of scientific and technical support as regulatory restrictions. These tools, while novel today, are likely to become more feasible in the near future. This will happen when the public becomes more familiar with alternatives to land use regulation and realizes that non-regulatory alternatives are less litigation-prone and can be more cost-effective than regulation. In the discussion that follows, the feasibility of

non-regulatory alternatives particularly suited for sea-level rise policy will be considered in light of Maine law in section D.

B. REGULATORY OPTIONS FOR MAINE'S SEA-LEVEL RESPONSE

Maine, like many other states, already has in place a system of land use control laws designed to control development in environmentally-sensitive areas and to prevent growth from overtaxing public infrastructure needed to support communities.[4] As described in Chapter Five, one of these laws, the Natural Resources Protection Act, through the Sand Dune Rules, already takes account of rising sea level in sand dune systems. That Act does not, however, expressly consider rising sea level in other coastal wetland or eroding bluff areas. Given this existing body of environmental and land use control laws and their gaps in coverage, it is likely that Maine's policy makers will wish to consider adopting several additional regulatory tools that are consciously designed to anticipate the movement of the shoreline.

Several opportunities exist for strengthening Maine's regulatory controls on land use and development that would improve the legal framework for dealing with sea-level rise. The purpose of this chapter is to examine one aspect of the feasibility of these measures—their ability to withstand legal challenge by property owners. Additional considerations are also important in determining overall feasibility, including availability of technical resources to support certain regulations, legislative willingness to adopt additional land use controls measures, and public understanding and acceptance of such measures. These factors must also be considered before a final sea-level response strategy can be developed.

In Chapter Five, one measure is described that would protect Maine's valuable and limited sand beach resources by establishing construction prohibition areas, commonly referred to as "setbacks," under the Natural Resources Protection Act and the Mandatory Shoreland Zoning Act. These "no building" areas would be based upon projections of accelerated sea-level rise for some structures and on historic erosion rates for other structures in a two-tiered system of setbacks. The first tier of setback lines would apply to smaller structures and would be established using 100 times the historic annual average erosion rate for a particular beach or beach segment. A setback line calculated on this basis could also apply to favored coastal uses such as buildings that support commercial water dependent uses, e.g., shipyards and fishing support facilities.

Larger structures and developments, and certain less-favored uses, e.g., non-water dependent commercial uses like restaurants and office buildings, would be subject to a setback requirement reflecting an assumed accelerated rate of sea-level rise, for instance, 3 feet over 100 years. All new development subject to the Natural Resources Protection Act would also be conditioned on removal if changes in the shoreline result in its interference with dynamic dune processes.

Both groups of setback lines would be published on maps available to landowners and municipal officials and would be subject to periodic review and revision as new information improves predictions of shoreline change.

To protect the irreplaceable wetland resources and their ecological functions along the Maine coast, Chapter Five suggests steps to provide for the landward migration of salt marshes as the level of the sea rises. These would include the adoption of measures under the

Natural Resources Protection Act and/or local shoreland zoning ordinances to restrict new development and to phase out existing development in uplands areas adjacent to protected wetlands that are needed for inland migration. These measures could take three forms:

- an increase in the minimum setback (currently 75 feet) from the upland edge of a coastal wetland based upon projected changes in shoreline;
- a requirement that applicants for high density development located adjacent to coastal wetlands prove during site plan review that the site is stable and that the proposed structures are set back from the wetland's new upland edge that would result from a projected 100 cm rise in sea level over the next 100 years; and
- a condition on all new development and replacement structures that they be removed if changes in shoreline result in their interference with natural migration of salt marsh vegetation or tidal flows of water.

To prevent development on eroding coastal bluffs, Chapter Five suggests these natural features should be incorporated into the Natural Resources Protection Act and regulations should be adopted which would parallel the Sand Dune Rules. In addition, or in the alternative, protection under local shoreland zoning ordinances should be substantially increased. These rules would limit new development, prevent the construction of bluff stabilization devices designed to protect existing structures, and would establish a retreat policy in the event of future bluff erosion.

With respect to engineered urban shoreline, stronger land use controls than are currently in place under state and local laws would help to minimize damage from sea-level rise. The primary action suggested would restrict building occupancy to uses that require a shorefront location in order to function, uses that are sometimes referred to as "water dependent." These restrictions are within the scope of existing zoning and land use controls and would require no special legal considerations if adopted to address sea-level rise. Such controls would clearly further important state interests and leave property owners with numerous economically beneficial uses.

The following discussion will focus on the preceding recommendations that may raise more difficult questions of legal defensibility. It focuses primarily on the measures designed to protect sand dune systems, wetlands, and eroding bluffs which may face challenges by land owners under the federal and Maine constitutional provisions prohibiting governmental "taking" of property through restrictive land use and environmental regulations.

C. POTENTIAL LEGAL CHALLENGES TO THE REGULATORY TOOLS

1. Overview: Due Process and Takings Clause Challenges

As with all land use regulatory measures that restrict the options of landowners, measures anticipating climate change-induced sea-level rise may be challenged in court. Some owners may pose what is referred to as a "substantive due process" challenge to the rationale for the restrictions. They would claim, for instance, that the sea-level rise projections rely on models and possible scenarios rather than on proven rates of shoreline change on their property, and that their property use choices should not be limited by these assumptions. Some landowners

may also consider the economic impact of restrictions to be so burdensome or so inconsistent with their expectations that they will accept the risks and costs of mounting a takings clause challenge.[5] Because of its scarcity and high demand, coastal property is among the highest value property in the nation. This increases the likelihood of landowners bringing legal claims, especially for monetary damages under the takings clause.

State and local land use regulations are very likely to survive the challenge that they lack a valid public purpose or a substantial basis in fact or scientific evidence. Legislative judgments, such as the decision to include eroding bluffs under the Natural Resources Protection Act, are afforded a presumption of validity by reviewing courts. The challenger/ landowner must prove to the court that the legislation or regulations are invalid. A Maine court will uphold the regulations unless the landowner proves that the laws do not promote the general welfare, use means that are not appropriate to achieve these public goals, or are being exercised in an arbitrary or capricious manner.[6] The court will presume that the regulations are valid; the challenger must prove that the regulations fail to meet at least one of these three standards.

Courts in Maine consider protection of environmental quality and preventing harm to life and property from coastal storms a valid objective of the police (legislative) power.[7] Likewise, Maine courts have found that restricting development in environmentally sensitive areas such as wetlands is an appropriate means of achieving these legislative objectives.[8] The courts are likely to find that additional regulations of the type described above are sufficiently based in fact to be upheld against a substantive due process challenge. This will be so as long as the regulations are based on some degree of scientific evidence, including, e.g., models and projections of sea-level rise that are reasonably credible, even if there are alternative interpretations. Similarly, if the regulations are not discriminatory and treat similar property in a similar manner, the courts will not find them either arbitrary or capricious.

If a court were to conclude, however, that one of these tests is not met, it would strike down or invalidate the particular regulation. In that event, the legislature, town council or selectmen would be free to enact a modified or alternative measure that would meet these tests and achieve the same ends. The outcome would be different, however, if the landowner concedes that the regulation is a valid exercise of the police power, but claims that it deprives her of all or substantially all of her property's value. If she can convince the court that the regulation constitutes a taking without compensation, the court will not invalidate the regulation, but will require the regulatory body to compensate the landowner for the appropriate measure of economic damage she sustained.

There are several ways in which regulators can design their laws in a manner that is sensitive to the interests of landowners but which can achieve the public policy objectives. Before describing these, it is necessary to set out the basic legal standards for regulatory takings under federal and Maine law.

2. Takings Clause Principles

A landowner's challenge to Maine's sea-level rise regulations could be brought under either the federal or state constitutional provision protecting private property against governmental takings without compensation. While the tests the courts will use to analyze the

claim differ slightly, the fundamental considerations are the same: a largely factual inquiry into the purpose of the regulation and the effect it has on the particular property in question.

a. Federal Takings Law

The Fifth Amendment to the United States Constitution provides that government bodies shall not take "private property ... for public use without just compensation."[9] Although the original intent of the provision was to insure private property against physical seizure by the government, since the 1920s, the U.S. Supreme Court has held that the provision can be invoked against government regulations that effectively take private property by eliminating most of its value to the owner through restrictions on its uses. In his famous opinion in *Pennsylvania Coal Co. v. Mahon*,[10] Justice Holmes observed that while government could not function if it could not impose some constraints on private action, "if [a] regulation goes too far, it will be recognized as a taking."[11]

While the Supreme Court has consistently held that "no precise rule determines when property has been taken [by government regulation],"[12] the Court has generally recognized that a regulatory taking is effected where a land use regulation "does not substantially advance legitimate state interests, ... or denies an owner economically viable use of his land."[13] In cases where the enactment's legitimate state purpose is not seriously questioned, the Court's analysis has focused on the "economic impact of the regulation on the claimant and ... the extent to which the regulation has interfered with investment-backed expectations."[14]

The Supreme Court has developed a multi-factored balancing test, which courts are to use on a case-by-case basis, to determine when a regulatory burden is so significant that the affected property owner is entitled to compensation. The courts will look first at the character of the governmental action and will ask whether the regulation advances a legitimate state interest. Under this first test, the courts will look to see if the nature of the government action serves to cause a physical invasion of the private property, by either the imposition of a structure not owned by the property's owner or by allowing the general public to have access to the property. If a physical invasion is caused, the regulation will be considered a taking *per se*, and the courts will not look beyond that fact to consider the impact of that invasion upon the property's value.

If the regulation does not cause an invasion, and serves a legitimate state interest, the courts will then look at the extent to which the regulation affects the landowner's economic uses of the property. Under this standard, courts often look at the economic impact in two ways. They may consider the direct impact of the regulation on the market value of the property. However, regulations causing very significant reductions in market value have been sustained, so this test is not determinative of a taking, especially where the prohibited use is a public nuisance. Also, courts may consider the extent to which the restriction interferes with the owner's investment-backed expectations. This entails looking at the present uses of the property and whether the owner is enjoying some economic return on the property despite the restriction.

In essence the multi-factored test seeks to balance the public benefit of the regulation against the private costs that it imposes. To make this judgment, courts look at the specific facts of the case, including the rationale for the regulation and the circumstances of the property owner and similarly situated owners.

Courts, however, are not required to engage in this balancing process in all cases. In recent years, the Supreme Court has developed two categorical standards for finding a regulatory taking. If the regulation falls within either of these two categories, it will constitute a taking *per se* and the property owner will be entitled to compensation regardless of the degree of the economic impact or the nature of the governmental interest served. The court will not balance the harm the regulation sought to prevent against the effect on the property owner's interests to determine whether the compensation is due.

As mentioned above, the first categorical standard requires compensation in any circumstance where the effect of the regulation is to require the physical occupation of any portion of the owner's property by someone other than the owner, or by some structure or equipment not owned by the property owner, even if the economic impact of such occupation is minimal or zero.

The second categorical taking is even more recent in origin and is particularly relevant to sea-level rise related regulation because of the facts of the case in which the rule was announced. This test states that when the effect of the regulation is the total elimination of all economic value of the property, the owner is entitled to compensation for that loss regardless of the public purpose the restriction sought to achieve. Even if the purpose is to prevent a serious public harm, this will not shield such "total takings" restrictions from the compensation requirement. This second category of *per se* takings, however, has exceptions, and courts will not order compensation to the land owner when these conditions triggering the exceptions are present. Unfortunately, when these conditions will be found is unclear, as the Supreme Court has only discussed the second category of *per se* takings in one recent case, and in that case strong dissenting opinions challenged the validity of the *per se* rule and questioned the exceptions.

The "total takings" categorical rule was announced in a case challenging a state's beach erosion setback lines which were enacted as part of the state's coastal management program. In *Lucas v. South Carolina Coastal Council*,[15] the U.S. Supreme Court held that when a land use regulation prohibits all economically beneficial use of the land, the takings clause requires compensation to the owner unless the regulation merely codifies restrictions inherent in the property or in the state's common law of nuisance.

While this rule is relatively easy to state, the decision in which it was announced provides little guidance on how to determine when a land use regulation strips a property of all economic value. When Mr. Lucas first brought his challenge to South Carolina's setback law, the state trial court agreed with his claim that the property had zero remaining value. For procedural reasons the U.S. Supreme Court assumed that this factual finding of a "total taking" was correct.[16] As a consequence, the Supreme Court operated on the assumption that the beachfront setback regulation itself had reduced the property's value to zero.

The Supreme Court stated, however, that there would be no taking if the state's property or nuisance law already imposed a restriction on the use of the property that is comparable to that brought about by the challenged regulation. Unfortunately, the *Lucas* case does not tell us what principles of state property or nuisance law would constitute exceptions to the total takings rule. When the case was remanded to the state supreme court for consideration of whether this exception applied, the court merely found, without explication, that no basis

existed in South Carolina's common law to deny Mr. Lucas the right to build on his land. It then remanded the case to the trial court for a determination of the monetary damages to which Mr. Lucas was entitled.[17]

The meaning of the *Lucas* case is further complicated by the fact that the Court expressed different opinions on the new *per se* rule and on the meaning of the exceptions. In his concurring opinion, for example, Justice Kennedy stated that "[c]oastal property may present such unique concerns for a fragile land system that the State can go further in regulating its development and use than the common law of nuisance might otherwise permit."[18]

In light of the current Supreme Court's standards and views on the doctrine, the outcome of a takings claim under the federal Constitution will be hard to predict, especially where the regulation can be seen as depriving all uses of land. The implications of this uncertainty for a sea-level rise strategy will be discussed below, after the Maine law on takings is reviewed.

b. Maine Takings Law

Maine has a constitutional provision very similar to the Fifth Amendment of the U.S. Constitution. Article I, Section 6 provides that "[p]rivate property shall not be taken for public uses without just compensation; nor unless the public exigencies require it."[19] The Maine Law Court, much like the U.S. Supreme Court, has recognized that takings claims are subject to no set rule, but rather must be approached as a "factual inquiry into the substantiality of the diminution in value of the property involved."[20] Generally, a land use regulation will effect a taking under the Maine Constitution where the regulation renders the property in question "substantially useless," or where:

> it deprives an owner of one of its essential attributes, destroys its value, restricts or interrupts its common necessary, or profitable use, hampers the owners in the application of its use to the purpose of trade, or imposes conditions upon the right to hold or use it and thereby seriously impairs its value.[21]

Stated succinctly, "[t]he question is whether the right in question constitutes 'a fundamental attribute of ownership' such that its extinguishment would render the property substantially useless."[22]

At the time of this report, the Maine courts have not had an opportunity to apply the total takings rule to a land use regulation case, so it is not clear if and how the *Lucas* decision will affect Maine's takings law. In Maine's own beachfront regulation cases, however, the Maine Supreme Court has shown a willingness to define broadly the economically beneficial uses that are open to property owners and has recognized the high economic value of land along the Maine coast, even if it cannot be built upon under the law.

3. Applications of Takings Clause Principles to Potential Sea-Level Rise Regulations

Are any of the regulatory measures recommended in Chapter Five for Maine's sea level response strategy vulnerable to successful regulatory takings challenges by landowners? As the following will demonstrate, despite the uncertainty that recent Supreme Court decisions

have caused, contemporary takings law does not pose a high risk that state regulatory measures will be invalidated or found to require compensation.

a. Coastal Construction Setbacks

Construction setbacks and other development prohibitions stand a good chance of surviving legal challenges if they are carefully designed with a view toward current takings standards, including both the traditional balancing test and the categorical "total takings" rule.

Even if the construction setbacks or other development restrictions ban all new construction outright, the government will have several defenses against a takings challenge. For example, in most cases where setbacks are imposed, the restrictions will not deprive the landowner of all economically viable use of the parcel, but will only affect the shoreside portion. The government should be able to demonstrate that other valuable uses of land remain, or that the owner has already derived significant benefit from her ownership, either through subdivision and sale or through development elsewhere on the property.

Similarly, setback requirements and related prohibitions do not cause a permanent physical invasion of the property by other individuals. It is also unlikely that a court would find that similar prohibitions on holding back the sea with bulkheads or seawalls would result in a compensable physical invasion of the parcel.

Finally, the government can defeat a takings challenge if it can establish that the coastal protection regulations do not interfere with the owner's "reasonable investment-backed expectations." This may be done, for example, by emphasizing the dynamic nature of coastal property boundaries, which reflect the realities of natural cycles of accretion and erosion, and which may render the property unsuitable for the construction of a permanent residential structure. An argument may also be made that the regulations do not effect a taking because they merely serve to codify existing common law land use restrictions embodied in the principle known as the public trust doctrine. Thus, the regulations did not deprive the owner of a pre-existing, lawful use of her property.

Although the courts are likely to uphold the construction setbacks and other development prohibitions that ban new construction in identified hazard areas, it is impossible to predict this with certainty because the takings tests involve considerations of facts peculiar to the individual case.

Under Maine law, a landowner claiming a regulatory taking has the burden of proving the absence of residual beneficial uses of the regulated land before the court will find that a taking has occurred.[23] Arguably, a shorefront owner, although precluded from constructing a permanent residential structure, retains the ability to make valuable uses of her property in the face of the coastal protection regulations. She may, for instance, use her lot and the adjoining intertidal zone for sunbathing, picnicking, camping, and other nonresidential purposes. Indeed, the Maine Law Court, in *Bell v. Town of Wells*,[24] recognized the right of shorefront landowners to enjoy these uses of the adjacent intertidal zone to the exclusion of the general public.[25] As it would appear that challenging property owners would in fact retain beneficial use in their land and the adjoining intertidal zone even when the new coastal construction regulations were applied, the landowners would have a difficult time indeed establishing a regulatory taking under the "substantially useless" rule.

In fact, past Law Court decisions lend considerable weight to this argument. In *Hall v. Board of Envt'l Protection,*[26] for instance, the court reviewed a decision of the Superior Court holding that the landowners had suffered a regulatory taking of their shorefront property under the State's then-current version of the "Sand Dune Law."[27] The trial court had found that the Board of Environmental Protection's (BEP) denial of a residential construction permit constituted a taking under the Maine and United States constitutions because the denial deprived the landowners of the right to put their land to its "highest and best use," which was, the court noted, as a site "for a single-family residence on a year-round basis."[28]

The Law Court rejected the lower court's analysis, holding that, even in the face of the BEP denial, the landowners retained sufficient beneficial uses of their land to allow the State law to survive the takings challenge. Specifically, the landowners were still able to use the property during the summer months by living in a motorized camper connected to utilities, to lease it for seasonal trailer use by others, or sell it for a substantial price as had many of the landowners' neighbors.[29]

If it can be shown that landowners affected by the coastal protection setbacks would still be able to make temporary, seasonal residential use of their shorefront properties, or would be able to sell them on the open market for "substantial sums," the regulations are likely to survive a takings challenge under the rationale of *Hall*. Thus, Maine may be able to prohibit all permanent residential development on shorefronts that are subject to rising sea level and still defeat a taking challenge which alleges absence of residual beneficial uses.

Another principle of Maine property law may influence a court's determination of what constitutes a shorefront property owner's "reasonable investment-backed expectations." Since 1884, it has been clear that seaward property lines of shorefront landowners move with the water line as sand accretes and erodes at the shoreline.[30] Oceanfront owners are on constructive notice that their property could be completely consumed by one of these natural processes. Because they are presumed to know of this risk, it is at least arguable that the challenging landowners had no reason to assume they could safely construct permanent residential structures on the shorefront, or that land of such ephemeral quality is suitable for these purposes.

There is no guarantee, however, that this second argument will allow Maine successfully to avoid a regulatory takings claim in every case. Although it is undeniably true that shorefront property is held subject to the effect of natural eroding forces (or rising sea level), it seems clear that a landowner may still hold some "reasonable investment-backed expectation" to develop the land in the face of this risk, particularly where the risk of erosion has been historically minimal. It may be accurate to say that a landowner holds no "reasonable expectation" to develop shorefront property for permanent residential occupation where historical data indicates the lot in question succumbs to erosion on a frequent basis. It may be difficult or impossible, however, to sustain such an argument where the lot has historically suffered only minor shorefront erosion over the course of several decades. Whether a particular lot owner has a "reasonable expectation" to develop the land for permanent residential use will thus depend upon the individual facts and circumstances surrounding the particular parcel in question.

A landowner's expectations concerning use of her property are probably not reasonable unless they are grounded in knowledge of historic erosion rates. However, at this time, due to scientific uncertainty and lack of public education about the possible impacts of accelerated sea-level rise, it is probably unsupportable to expect landowners to have internalized global climate change-related sea-level rise projections into the "reasonable expectations" for their property. In other words, the rules of the game have not yet changed, although Maine's current Sand Dune Rules embody a consideration of the location of the shoreline in 100 years, and the public is expected to be aware of these considerations.

Partially for these reasons of public awareness and expectations, Maine may wish to adopt two different setback requirements, one based on historic erosion rates and the other upon predicted, accelerated sea-level rise. The historic rate would be applicable to low intensity and publicly favored shoreline uses. The accelerated rate would be applicable to high-intensity and disfavored shoreline uses. All would be subject to retreat requirements.

The establishment of two different setback requirements and their application to different kinds of structures based upon the expected useful life and ease of mobility should not give rise to any unfairness claims. Both bases for setbacks can be supported by technical evidence. Maps are likely to be available on which the different shoreline positions can be calculated. Moreover, the differential treatment of structures based on mobility and use preferences is not arbitrary and is clearly related to the purpose of the regulation which is to allow some land use while providing protection for the landward movement of the shoreline.

In summary, the courts in Maine have already shown a willingness to sustain coastal construction restrictions under existing laws and regulations and are likely to follow their own precedents in subsequent cases. In addition, the following points should be emphasized respecting coastal setback lines:

1) setbacks which prohibit the construction of permanent residences outright based on evidence of threats to public health and safety are defensible, but their defensibility becomes more tenuous as the threat of harm becomes more remote or the evidence of harm less certain;

2) Maine's response strategy should prohibit new construction outright where it is likely to be affected by historic erosion rates, considering the useful life of the structure;

3) in areas not expected to be affected by the continuation of historic erosion rates within 100 years, but projected to be affected by sea-level rise, Maine should regulate to allow only low-intensity, temporary uses, so as to leave owners with some economically beneficial uses; and

4) Maine can couple the partial restriction to low-intensity uses with a retreat requirement, to remove all structures in the event of rising sea level. This requirement is analyzed more fully in a later section.

b. Rebuilding Prohibitions for Existing Structures

Because much of the "soft" coast of Maine is already developed, at least that portion adjacent to sand beaches, any comprehensive retreat strategy will have to include restrictions

on the rebuilding of existing structures as they are damaged by storms and high tides. Rebuilding prohibitions are not uncommon in state beach management laws; these laws, for example, impose a ban once the structure is damaged by 50% or more. Rebuilding bans are used in conjunction with beachfront construction setback regulations.

South Carolina's Beachfront Management Act of 1988 included a rebuilding ban for existing structures located between the baseline (the crest of the primary dune) and the setback line, which the Act required to be located landward of the baseline to a distance which is forty times the average annual erosion rate.[31] The Act stated that any habitable structure "destroyed beyond repair" by natural causes or fire could not be rebuilt seaward of the baseline or between the baseline and the erosion setback line. South Carolina administrative regulations defined "destroyed beyond repair" to mean "more than two thirds (66 2/3%) of the building components making up the structure are damaged to such a degree that replacement is required in order for the structure to be habitable, functional or sound."[32] The law also restricted the construction of additions to existing structures or the installation of recreational amenities.

A number of beachfront landowners challenged these restrictions in South Carolina, claiming they amounted, on their face, to an unlawful taking of their property without compensation and a violation of due process. The federal Court of Appeals for the Fourth Circuit, however, disagreed. It held that the restriction served a legitimate state interest and bore a substantial relation to the Act's goals of protecting the state's beach/dune system. In addition, the restriction did not deprive the owners of economically viable use of their property. South Carolina's regulations allowed owners to continue the existing use of their property and dwellings in the same manner as they had prior to their enactment. The court rejected the owners' argument that the Act had diminished the market value of their property and had therefore caused a taking. It noted that even substantial market value reductions do not suffice to establish a taking. The owners were "significantly diminished only in their discretion to rebuild a structure in the speculative event of its virtually complete destruction."[33]

c. Permit Conditions Requiring Removal or Barring Future Construction of Protective Devices

Another potential measure that is contingent upon the occurence of a future event (e.g., a storm or shoreline retreat) would attach to state or local coastal land use permits special conditions requiring either removal of structures in the event of a rise in sea level or banning the construction of bulkheads. This approach offers certain advantages with respect to potential regulatory takings challenges. Removal conditions allow landowners to use or develop their property in the manner in which they desire, subject only to the contingency that a rise in sea level will necessitate the structure's removal. The regulations unquestionably afford the landowner a productive and beneficial use of the land. Because the regulation does not prohibit, for example, construction of a residential structure, its constitutional validity does not depend on a court's willingness to find, as in the *Hall* case, that other valuable uses of the property remain despite the ban on construction.

Maine's Sand Dune Rules already incorporate provisions which bar future bulkhead construction and require removal of new structures in the event of substantial damage or interference with dynamic sand dune systems. Similar regulations regulations should be extended to coastal wetlands and eroding bluffs.

Regulators should limit the objective of such permit conditions to structure removal or banning seawalls, to avoid complicating any legal challenge that may ensue. They may be tempted to modify the conditions in an effort to preserve public access and use of the shoreline and adjacent tidelands. While this is a legitimate goal, it will subject the conditions to a higher degree of legal scrutiny that increases the uncertainty that the measures will be sustained. This higher degree of constitutional scrutiny would be triggered if, for example, landowners were allowed to construct seawalls if they agree to convey an easement for public access along the wall or adjacent upland area.

In a 1987 decision, the U.S. Supreme Court identified special criteria for regulatory conditions on coastal construction where the effect of the condition is to require the permanent physical invasion of the property by the general public or government or by structures or equipment, owned by someone other than the land owner. Such conditions must be designed to alleviate very directly the burdens which that development poses on the environment or on other public interests. If the conditions seems only marginally related to the project's impacts, the condition will not appear to "substantially advance legitimate state interests" and the court will require compensation for the owner.

This close fit test is referred to as the "nexus" requirement. It stems from the U.S. Supreme Court's decision in *Nollan v. California Coastal Comm'n*,[34] where the Commission had required property owners to grant a public easement on the dry sand portion of their lot in exchange for permission to rebuild and expand the dimensions of their house. Because the public easement did not mitigate the adverse visual impacts of the house, impacts that would have justified denial of the construction permit, the Supreme Court assumed that the agency was trying to expropriate the owner's right to exclude people from their beach without having to pay for it. The Court suggested, however, that outright denial of the permit would not have been unreasonable if the grounds had been the house's adverse visual impact on public views of the ocean from the public road landward of the house.

In a 1994 decision applying the *Nollan* rule, the Supreme Court struck down municipal permit conditions designed to prevent construction in a flood-prone area. In *Dolan v. City of Tigard*, the conditions required the landowner to dedicate a part of her parcel as a public greenway for stormwater drainage, to mitigate the impact of her proposed expansion of her commercial development. Part of the dedicated greenway would be used for a pedestrian and bicycle pathway.

The Supreme Court found that the "essential nexus" existed between the permit condition and the state interests sought to be served. The constitutional problem arose because the city had not demonstrated that the dedications related specifically to the degree of impact on stormwater flooding and increased traffic that the proposed land use expansion would have. The Court stated that "[n]o precise mathematical calculation is required, but the city must make some sort of individualized determination that the required dedication is related both in nature and extent to the impact of the proposed development."[35]

It is unlikely that the *Nollan/Dolan* test would arise in a challenge to coastal permit conditions that merely require moving structures in the event of rising sea level, but if it did, such conditions would be likely to be upheld. First, a permit for development which would lie in the path of projected change in shoreline position due to changing sea level could be

denied outright and such denial, as discussed above, would likely survive a takings challenge. If, instead of denial, the structure is allowed with the condition that it be removed under certain circumstances, the requisite close fit is satisfied between the impacts that could justify denial and the condition.

Allowing the owner to undertake the development on the condition that it be removed provides flexibility in the event that sea-level rise predictions are revised downward. The condition is directly related to the adverse impact the development would have on the ability of wetland vegetation to migrate in the event of rising sea level. It does not attempt to mitigate this adverse effect by an unrelated condition.[36]

Such retreat conditions may not in fact have to meet the *Nollan/Dolan* nexus test. The *Nollan* and *Dolan* decisions hold that conditions on land use that restrict an owner's right to exclude others must satisfy a particularly demanding standard of reasonableness, beyond the "rational basis" that is normally sufficient to meet the requirements of due process and equal protection.[37] It is important to keep in mind that the *Nollan* holding involved a perceived physical invasion by the general public through the public access condition, which the Supreme Court has held is almost always a compensable taking because the right to exclude is considered a fundamental attribute of land ownership.

Regulatory conditions that restrict or eliminate other aspects of ownership would not necessarily be subject to similar scrutiny or presumption of an intent to expropriate private property rights. Courts have not yet held, for example, that the bundle of ownership rights includes a right to protect property from erosion and other natural forces, especially where to do so will harm public resources or adjoining property.[38]

Although the permit retreat conditions are very likely to be upheld if challenged in court, other considerations may counsel for extreme caution if a strategy intends to rely on permit conditions to accomplish the intended protections. Any conditional removal is likely to occur in the distant future, and there is no guarantee that future legislatures or agencies will have the political will to maintain the restriction. It would therefore be more effective if the conditions took the form of deed restrictions or covenants that would run with the land. Given that the political pressure to amend a regulatory restriction if sea-level rise occurs is almost a certainty and future legislative action is unpredictable, the benefits in durability of a deed restriction or covenant approach outweigh any slightly increased chance of judicial invalidation. Again, it is still most likely that the restriction would meet a nexus test because of the adverse effect that the proscribed bulkheads and structures would have on migrating shoreline resources.

d. The Total Takings Rule and "Background" Principles of Maine Shoreline Property Law Including the Public Trust Doctrine

In *Lucas v. South Carolina Coastal Council*,[39] the Supreme Court suggests that certain state property law principles may so limit an owner's property as to preclude any basis for a regulatory takings challenge. In order to properly evaluate the magnitude of the economic impact of a regulation on a landowner's property, the Court suggests it is necessary to consider the extent to which the state's common law operates to limit the landowner's use of her land. If the legislation achieves nothing more than codification of a pre-existing, common law land use restriction, no taking may be found. The landowner occupies the same economic

position with regard to her land both before and after the challenged legislation was enacted. The regulation has had no direct impact on the owner's reasonable investment-backed expectations.[40] If the legislation, however, reaches beyond the common law and places restrictions on land use that render the owner's property substantially useless, a regulatory taking will be found.

The question is whether the regulatory measures under consideration to anticipate rising sea level and migrating wetlands merely codify existing limitations on shoreline property use. It is difficult to state with any certainty whether existing Maine property law concepts would fall within this category. The Supreme Court's *Lucas* opinion illustrates this exception through hypothetical examples of potentially valid regulations but provides no definitive tests, relying instead on the common law concept of a nuisance. Nuisance, however, is a concept which the law defines only in general terms. Courts have to inquire into the specific facts and circumstances of a given land use, and then balance its utility against any harm caused to determine whether it is a nuisance under the law.

Given the examples the Court used in *Lucas*, however, it is possible that the regulatory measures would be considered as merely codifying concepts in Maine law concerning coastal property rights, both private and public.[41] An examination of these principles follows.

Coastal lands fall primarily into three distinct geographical areas that are defined by the action of the tides. Each of these areas has a different legal character in Maine and in all coastal states. The lands that are below the mean low tide line, and thus are continuously under sea water, are owned by the State.[42] These lands are called the submerged lands. Above the low tide line but below the mean high tide line, the area intermittently submerged by the daily tides is known as the foreshore or intertidal zone. In most American states, this area is also owned by the state and held in trust for the benefit of the public, along with the submerged lands. This rule of public ownership and use rights is referred to as the "public trust doctrine."

Above the mean high tide line, the land is subject to full private ownership, in most states. Some states have recognized public use rights or easements above the mean high tide line, sometimes to the line of vegetation above the mark of the high tide.[43] The mean high tide line, however, is not the division between public and private ownership in the State of Maine. Here, the English common law of tideland ownership, which recognized sovereign ownership of the foreshore and submerged lands, was changed by the colonists in Massachusetts. The Colonial Ordinance of 1641-48 granted to the owners of the adjacent upland private ownership rights to the foreshore, thus allowing private ownership to extend to the low tide line, subject to reserved public use rights of fishing, fowling, and navigation.[44]

With ownership rights defined on the basis of tide lines, ownership of shorefront property carries with it some inherent risks. If the ocean moves inland, as in the case of sea-level rise or land subsidence, the line of the tides moves inland as well. Under the common law in most states, the boundary between public and private property also moves with the tide line. It may happen that the shift causes the whole of what was once an owner's tract to now fall below whichever of the tide lines that defines the area of public ownership. This is known as the doctrine of erosion, and it holds that title rests with the state once the relevant tide line moves

inland.[45] Title does not return to the private owner in the event that the land reemerges from the ocean.

On the other hand, private owners can benefit from shifts in the shoreline caused by the build-up of sand or soil along the shore. The doctrine of accretion holds that new land that builds up below the tide line which had previously defined private ownership belongs to the private owner.[46] Some states have modified this rule by retaining public ownership of accretions that are the result of the property owner's actions, such as through the construction of jetties or groins. In Massachusetts, the Supreme Judicial Court has ruled that accretions belong to the littoral owner, even when the result of artificial causes, as long as they were not caused by the owner herself. If the accretions are created by government-built structures to aid navigation (e.g., by jetties), the accretions belong to the public rather than the littoral owner.[47] The Maine Law Court has not ruled on this question.

Most states recognize the public's right to use the wet sand area below the mean high tide line, either by virtue of public ownership or through public rights recognized under various common law doctrines, like the one adopted into Maine's law based upon the Massachusetts Colonial Ordinance. Several states also recognize the public's right to use dry sand areas above the high tide line. In these states, courts and legislatures have ruled that the public acquired these use rights through common law doctrines of prescription (similar to adverse possession or "squatters" rights), implied dedication to the public by the present or prior owner, or custom. In at least one state, the courts have interpreted the public trust doctrine, the principle of public ownership of lands covered by the tides, to include a public right to use the sand beach above the high tide line.[48] In states where these public rights have been acquired or recognized, the law characterizes these rights as migratory or dynamic, moving in or out as the shoreline erodes or accretes. Thus, over the years, the common law has evolved to define significant public rights in the shoreline. These rights are usually protected and supplemented by environmental and land use restrictions enacted under the police power as well as governmental programs designed to preserve the sand beaches and shorelines where the public rights apply.[49]

The common law also recognizes that owners of property bordered by navigable waters have certain property rights inherent in the land's location. Generally, these rights include the rights of ingress and egress over the submerged lands to the navigable channel. Similarly, the law recognizes the littoral owner's right to construct a pier or wharf, subject to police power regulations. Littoral property rights may also include a priority right to use the resources of the intertidal zone or the space overlying the submerged lands fronting on the littoral property to moor vessels. The littoral owner's rights do not include a right to build permanent structures that would block the public's use rights in the foreshore. Nor do they include the right to build a groin or jetty, if to do so would deprive a neighboring property of the natural movement and build-up of sand.[50] Also, state police power or public trust-based regulations can preclude uses of the public submerged lands.[51] The littoral owner does not have a property right to build protective structures in front of her property to control erosion.[52]

Moreover, the special rights or privileges that come with littoral property ownership are qualified by the recognition of a superior right of the public to use the navigational capacity of the waters.[53] This public navigational servitude on all navigable waters derives from the Commerce Clause of the U.S. Constitution.[54] Thus, a littoral owner may lose her ability to

gain access to the navigable channel from her property when the government modifies the location of the channel, builds a jetty, or makes other improvements related to public navigation. The law holds that the navigational servitude exempts such government actions from the just compensation requirement of the Fifth Amendment's takings clause. The theory is that the littoral owner's title never included a right in perpetuity to access the navigable channel.[55]

While these rules and regulations restrain property owners from making uses injurious to the public interest, it is likely that when sea-level rise becomes a reality and begins to manifest itself in increased coastal storms and erosion, pressure will be brought by homeowners to relax existing laws, regulations, or zoning restrictions, e.g., the prohibition of bulkheads. Litigation may challenge the reasonableness of development conditions that prevent shoreline armoring, requiring a determination that the restrictions substantially advance a legitimate state purpose. The restrictions could be overturned by the courts or by the legislative bodies, unless government officials prepare the public and property owners through educational efforts for the eventual retreat in the face of rising sea level.

In *Bell v. Town of Wells*,[56] the Law Court held that the public in Maine has an interest, in the nature of a "public easement," in lands lying beneath navigable tidal waters for the purposes of fishing, fowling, and navigation.[57] Although not using the term "public trust doctrine," the Law Court recognized that a set of public rights exists in the foreshore, very similar in nature to what other courts, including the U.S. Supreme Court, have described as the public trust doctrine.[58] Arguably, erosion setback lines, retreat or removal conditions, or other coastal protection measures enacted in anticipation of rising sea level would operate to prevent shorefront landowners from harming the public easement by preventing erosion and degradation of the shoreline, and hence merely reiterate the preexisting common law principle that no one may act to the detriment of the public trust. Under the *Lucas* analysis, then, no taking would be effected by the new regulations since the new rules will not cause shorefront property owners to suffer any "new" land use restrictions beyond what is imposed by existing state property and nuisance law principles.

The Maine Law Court, however, has yet to consider this question or suggest in a specific case that the public trust doctrine or public use easement can be invoked by the State to preclude land use activities occurring above the mean high tide line. Maine, like many other coastal states, has always referred to the mean high tide line as the landward boundary of the public easement.[59] Moreover, Maine's Law Court has indicated that the public trust doctrine or easement may be used only to protect the public's use of the intertidal zone for fishing, fowling, and navigation.[60] The Law Court has not shown an inclination to extend the doctrine to cover upland land use activities that do not actively interfere with one of these three public rights.[61] Thus, Maine will be able to avoid takings challenges to the coastal regulations under this legal theory only to the extent the State can demonstrate that the landowner's proposed permanent residential construction, either on the margin of a wetland, on an eroding coastal bluff, or on a sand dune area would interfere with the public's use of the intertidal zone for fishing, fowling, and navigation.

It would seem necessary, therefore, for Maine to establish in the course of permit proceedings or in conjunction with the promulgation of new coastal regulations that the

intertidal zone is likely to shift landward within a 40-50 year period and that the prohibited construction would interfere with this landward migration.[62]

Given the uneven treatment the public trust doctrine has received in the Maine courts in the last decade,[63] the question arises whether sea-level rise strategies that depend upon the public trust doctrine are feasible in Maine. Would, for example, the Law Court find that the reserved public rights move inland with rising sea level? It probably would, following its case law concerning the doctrines of accretion and erosion. But whether the migratory nature of the reserved rights would serve as a basis for restrictions on building structures on land that is now dry is an open question. The courts in Maine, however, as previously noted, have shown an inclination to uphold significant building restrictions in shoreland, wetlands, and sand dune areas under the Mandatory Shoreland Zoning Act and the Natural Resources Protection Act.[64]

The idea of a mobile public easement is illustrated in the Texas Open Beaches Act,[65] which serves to codify the common law public recreational use easement in dry sand beaches above the mean high tide line and below the line of vegetation. In a recent decision, a federal district court rejected a takings clause challenge to a provision of the Texas law which enjoins property owners from interfering with public use rights where the shoreline has migrated inland as a result of coastal erosion.[66] The court concluded, however, that the landward moving easement did not require the landowner to remove pre-existing structures that now find themselves below the line of vegetation.

A recent Massachusetts court ruling suggests that the public trust doctrine may have relevance to the takings issue and restrictions on coastal property. In 1988, several oceanfront property owners in Chatham, Massachusetts lost their homes when a winter storm broke through the barrier beach in front of their property. Regulations under the Massachusetts Wetlands Protection Act[67] had prohibited their construction of a stone revetment. Some homeowners brought suit against the Commonwealth, claiming that denial of the revetment license was an unconstitutional taking of their property. They sought several million dollars in damages.

Under the Massachusetts wetlands law, any dredging, filling, removing, or alteration of either "coastal banks" or "coastal dunes" is prohibited if it interferes with the ability of these land formations to perform their flood control and storm damage prevention functions.[68] Construction of stone revetments on dunes is prohibited unless it is determined that the dune in question is not significant to storm damage protection, flood control, or protection of wildlife habitat. Revetments may be built on coastal banks, if built to protect buildings constructed before August 10, 1978, if absolutely necessary, and if they minimize any adverse environmental impact.[69] Also, the Commissioner of the Department of Environmental Quality Engineering (now called the Department of Environmental Protection) may waive such regulatory restriction after an adjudicatory hearing, if "necessary to avoid [a restriction which] constitute[s] an unconstitutional taking without compensation" and if other conditions are met.[70]

The Massachusetts supreme court recently ruled that the Chatham homeowners were entitled to a trial on their takings claim against the Commonwealth.[71] The superior court had dismissed the claim without consideration. Before an appeal of this dismissal was heard, an

intermediate court of appeals also found that the landowners were entitled to a trial on the takings claim. In comments directed at the trial court, the court of appeals identified several factors relevant to the question of a takings, including the possible relevance of the public trust doctrine:

> ... the facts as developed at trial might establish that the coastal areas in question are impressed with a public trust (citations omitted). If so, the plaintiffs, from the outset, have had only qualified rights to their shoreland and have no reasonable investment-backed expectations under which to mount a takings challenge....[72]

This language indicates that the public trust doctrine could be a background principle of law that could preclude finding a taking even if all economic value is lost by virtue of the regulation, under the exception to the *per se* total takings rule announced by the majority opinion in the *Lucas* decision.

While the Massachusetts supreme court agreed that the landowners were entitled to a trial on the merits, it said nothing about the potential application of the public trust doctrine. It did say, however, that the *Lucas* case would not help resolve the Chatham case due to significant differences in the facts. First, the *Lucas* case did not involve any administrative proceedings. Second, the total loss was due to natural forces while the administrative proceedings were pending, and the landowners had alleged no dilatory agency conduct. In the court's view, the Chatham case was distinguishable from *Lucas* because the Massachusetts regulation by itself did not render the property valueless, and because it squarely raised the question whether government may restrict particular uses of property that may adversely affect other owners and the state.[73]

Recent U.S. Supreme Court decisions applying the takings clause to state coastal regulations have not considered directly the relevance of the public trust doctrine. In *Nollan v. California Coastal Comm'n*[74] discussed above, the Supreme Court majority did not consider any arguments based upon the California public trust doctrine. Justice Brennan's dissent, however, found the doctrine to have an important bearing on the analysis. He stated that "[t]he Court's insistence on a precise fit between the forms of burden and condition on each individual parcel along the California coast would penalize the Commission for its flexibility [in balancing private development with preserving public shoreline access], hampering the ability to fulfill its public trust mandate."[75] He went on to argue, *inter alia*, that the status of tidelands under state law is relevant to whether a property owner's investment-backed expectations are affected.[76]

As in *Nollan,* the South Carolina Supreme Court in *Lucas v. South Carolina Coastal Council* did not hear arguments based upon the public trust doctrine, nor apparently on any of the special principles of property law that help to define public and private rights in coastal lands and waters. Thus, it is very difficult to say whether principles like the mean high tide line rule, the doctrine of accretion and erosion, riparian (or littoral) rights, the navigation servitude, or the public trust doctrine have relevance to the multi-factored analysis in regulatory takings cases.

The law of nuisance in Maine does not provide direct guidance on the question whether a seawall, bulkhead, or other structure that prevents the landward migration of the shoreline constitutes a nuisance to adjacent property owners or to the public. The courts generally

employ a balancing test to determine the reasonableness of the challenged land use and whether its benefits outweigh the adverse effects it has on the public or on neighboring properties.[77] The Maine Law Court has held that:

> private property rights ... are subject to the implied condition that the property shall not be used for any purpose that injures or impairs the public health, morals, safety or welfare. If the use causes an actual and substantial injury or impairment of the public interest ... a regulating or restraining statute, or an ordinance ..., if itself reasonable and not merely arbitrary, and not violative of any constitutional limitation, is valid.[78]

Technical evidence is now available that shows the adverse effect that hard erosion control devices have on adjacent shoreline property and on the condition of the intertidal area. Thus, it is likely that a court would find that a regulatory ban on seawalls or bulkheads reflects existing principles of state nuisance law and that a landowner has no constitutionally guaranteed property right to protect her land from the sea's encroachment if to do so will damage adjacent property or public rights in the intertidal zone.

4. General Precautionary Measures to Reduce the Risks of Takings Claims

In the aftermath of the *Lucas* decision several commentators have identified ways in which state and local land use officials can structure their programs to avoid raising and potentially losing costly takings claims.[79] Some of these recommendations are reflected above, including the suggested approach of two tiers of setback lines, and allowing temporary, removable uses of land subject to sea-level rise and the landward migration of wetlands. To bolster the defensibility of these provisions, state laws, regulations and local ordinances that define these setback lines should expressly state that any construction seaward of the setback line that does not have a valid variance is a public nuisance and may be summarily removed without compensation. Florida's coastal construction setback law contains such a provision,[80] and similar language would seem appropriate in Maine, given the *Lucas* decision's emphasis on the nuisance exception.

In general, it is probably wise for Maine officials responsible for the sea-level response strategy to acknowledge that economic wipeouts may occur in certain cases due to the regulations and to be prepared to provide compensation. A portion of public funds should be encumbered for this purpose, or a fund could be created from the levying of additional real estate transfer taxes, shoreline retreat taxes, open space impact fees or other measures to raise revenues to help support the compensation and acquisition of property that must be restricted.[81]

It is also advisable to offer effective, non-litigation remedies for disputes over the burdens of land use regulations, including those necessary to anticipate rising sea level. Often, land use restrictions provide a variance procedure, for instance the one that provided under the Sand Dune Rules. In some instances, however, it may not be appropriate to allow variances, for example, where the affected land is needed for the landward migration of wetlands or eroding bluffs. Variances here could undercut the idea that these sea-level restrictions are necessary, unless they are limited to those instances when the landowner can prove by convincing evidence that their land does not meet the applicable criteria, i.e., will not be

affected by nor interfere with sea-level rise. A non-judicial forum for considering the burdens of land use restrictions could also be a method for providing non-monetary compensation to affected landowners, through, for example, density increases, transferable development rights, credit toward impact or other real estate fees, or other non-cash forms of compensation.[82]

The *Lucas* decision highlights the need for administrative processes that allow landowners to hear the rationale behind application of restrictions to their property, such as coastal protection setbacks, and to seek relief from the restrictions if they seem to be unwarranted or unreasonable in their particular circumstances or excessively harsh. This could mean a greater use of quasi-judicial, administrative proceedings than is currently practiced under Maine's land use and environmental control laws, at least at the permit appeal stage, where the owner/ applicant has an opportunity to challenge the reasonableness of the restrictions with respect to her property.[83] *Lucas* may also suggest incorporation of carefully drafted variance provisions to provide relief in circumstances in which the property can support no other beneficial use than the one denied by the restriction. Several of the state laws described in Appendix B contain such variance provisions.

The owner/applicant must bear the burden of proof, however, that no other uses are feasible, or that the environmental conditions underlying the restrictions are not applicable in her case. In states where a variance provision is available in the shoreline and wetland protection programs, the courts will require applicants to exhaust these appeal and variance provisions before the landowner can challenge the restrictions as a takings. This requirement ensures that an appropriate factual record is available for the trial court.

Any new, sea-level rise-related provisions of the Natural Resources Protection Act and municipal shoreland zoning ordinances should provide an administrative appeal process with explicit standards and burdens of proof. Such a process can elicit evidence on whether the owner has other viable uses or has already made valuable uses of her property.[84] By thus allowing agencies to establish this factual record, the process that will help the regulations survive any subsequent takings challenges.

D. POTENTIAL NON-REGULATORY OPTIONS FOR MAINE

1. Overview

The regulatory approaches described in the preceding sections may not be readily accepted by landowners and developers, particularly where they restrict current productive uses of land in exchange for future benefits if and when a rise in sea level occurs. Public education and careful implementation of land use restrictions can overcome some of this resistance and may limit the economic impact of the regulations. Nevertheless, Maine may wish to consider non-regulatory tools either as alternatives to or supplementary of regulations.

The outright purchase approach may be feasible for certain lands, for example, upland areas needed for the migration of a particularly significant salt marsh. But it clearly is not feasible for the State to purchase all the shoreland property that should be protected from development in the event of rising sea level. Private land trusts may be able to purchase additional areas, but again these entities are not likely to have the resources necessary to acquire all the needed areas.

As an alternative, one commentator suggests a "presumed mobility" approach that could be more affordable. Under this idea, the government buys the necessary property, either through eminent domain or a willing seller approach, and then leases it back to the owners for a period of time that would expire once the shoreline reaches a certain point. The principal proponent of this approach, James G. Titus of the U.S. Environmental Protection Agency, suggests it would allow current owners to develop their land on the condition that the structures will not be protected against inundation and must be removed in the event of sea-level rise.

Titus suggests that the purchase price of property interests which are realizable so far into the future would be less than 1% of the purchase price of the full fee simple title. The approach has the advantage of shifting the risk of sea-level rise from the environment (which will suffer if wetlands and other coastal resources are lost due to development) to the private property owners "by institutionalizing the presumption that development will have to make way for migrating ecosystems."[85] In the alternative, Titus suggests converting property rights to long-term leases that expire after 99 years or upon the rise of sea level enough to inundate the affected property.

A variation on this approach is suggested by Professor Joseph Sax who recommends the public purchase of a future flooding easement.[86] The easements would prohibit interference with any flooding caused by sea-level rise and would allow the easement holder to remove structures that interfere with natural sea-level rise. The flood easements would be sold through negotiated sales or required as a condition on proposed development. The purchase price would be retained by the government and compounded over time and then distributed to owners in the event that a retreat from the shoreline is necessary. Sax also suggests that each owner be required to have insurance sufficient to cover the costs of subsequent inundation. The government would pay the premiums for this insurance. The insurance policy would be treated as an annuity payable at fixed sums in the event of rising sea level.

Another idea, proposed by Lisa St. Amand of the Environmental Law Institute, suggests an application of the approach the National Park Service takes in acquiring land from private owners. The Service acquires the land through donation, purchase, or condemnation, and then allows the previous owner to occupy their former lands for their lifetime under "reservations of use and occupancy."[87] The purchase price is calculated based upon the current value of the property less 1% for each year of the term of the reservation, or the life expectancy of the reservation holder. For purchases of land needed for wetlands migration the author suggests that the purchase price would be substantially discounted by the decades-long reservation reflecting the period expected before sea-level rise becomes apparent.

St. Amand suggests another alternative that relies on providing land owners with incentives to refrain from development of their property in a manner that interferes with the natural migration of wetlands as sea-level rises. In this approach, a private land trust negotiates the creation and purchase of a "wetlands migration easement." The trust then enforces the easement in the event that a rise in sea level occurs at some distant time in the future. Again, with such a distant period for enforcement the author suggests that the easement could be purchased at a significant discount.[88]

A version of this same approach, suggested in 1990 by Judith Knapp, then a graduate student at the University of California at Berkeley,[89] advocates the use of the public trust doctrine in anticipation of actual rises in sea level. Knapp suggests that legislatures impose controls to reflect the future position of public trust resources such as the intertidal zone that will migrate landward as sea level rises.

2. Feasibility for Maine

Each of the above proposals involves changes to the legal framework that defines and regulates property rights in the State. For example, to institute the Titus proposal it would be necessary to change the nature of coastal ownership into a long-term leases. To do so would entail a program of eminent domain acquisition followed by leases back to current owners subject to the restrictions described above. This program would require legislative and administrative action, including a significant appropriation of funds for the purchases, to be refunded largely by the lease fees. It is not, however, precluded by any constitutional limitations on government action.

Similarly, the Sax proposal would require legislative action and an administrative agency that could first calculate the present discounted value of a future flood easement, according to agreed guidelines, and then decide where and when to apply them. Additionally, the Sax proposal would require a financial management entity to manage the annuities prior to the rise in sea level and their disbursement to property owners. Such a system would require careful consideration by the legislature and cooperation between various departments of the government with differing expertise.

The Knapp proposal is less likely to be feasible in Maine because of important differences in the public trust doctrines in Maine and California. As the previous discussion of the *Bell v. Town of Wells* decision indicates, the courts in Maine do not yet recognize a legislative role in defining and applying the public trust principle to coastal lands and resources. California, on the other hand, recognizes full public ownership of the intertidal zone, not merely reserved public use rights. Moreover, a broader range of public uses, including ecological preservation, has been found to be within California's public trust. It is most unlikely that the current Maine Law Court would accept the anticipatory application of any public trust-based restrictions to lands that are not now but may in the future be covered by the tides.

Given the legislative and administrative demands involved in the non-regulatory approaches, they may not be practicable in the near term. With the possible exception of the anticipatory public trust doctrine approach, however, none are infeasible on purely legal grounds.

3. Government Informational Programs for Sea-Level Rise

Other governmental programs, particularly those that educate the public about the possibility of global climate change and the associated rise in sea level, are very important in an overall response strategy. Only by early information programs, alone or in conjunction with the adoption of regulations, will the public begin to accept the idea of limitations on property use to adapt to the changing conditions of the shoreline and to preserve vital natural resources. To ensure that regulatory programs will be sustained if challenged under constitu-

tional standards, it is essential for the State to begin now to ensure that expectations about shoreline property use that would be incompatible with rising sea level do not crystallize in a manner that will defeat a prudent retreat strategy where it is appropriate.[90]

E. SUMMARY

Current standards for the protection of private property do not pose insurmountable hurdles to carefully drawn regulatory approaches to the problem of sea-level rise. The Maine Law Court has already upheld significant restrictions under the current Sand Dune Rules. This indicates a belief that such regulations do advance a legitimate state interest and do so in a manner that does not deprive land owners of their property rights in violation of the constitutional guarantee. The terseness of the *Hall* opinion, however, and the recent efforts of the federal courts to expand the protection of private property subject to government regulation may encourage other land owners to mount similar challenges to further regulation aimed at sea-level rise. In that event, the smaller the area of a parcel that is affected by the restriction, the more likely it is to be upheld.

If Maine chooses to pursue several of the regulatory options described in the preceding sections, it should develop and promulgate them as soon as possible. The earlier that the public is on notice of the likelihood of rising sea level the more likely the regulations are to withstand legal challenge. Property that is purchased after the regulations are adopted will be bought subject to the expectations that development restrictions will be applied in light of sea-level rise. The promulgation of regulations that require a wetland migration area on the upland margin or which prohibit the future construction of bulkheads that would block such migration will help to clarify the expectations of landowners. When these expectations are clarified, if it is necessary to carry out removal conditions or enforce revised coastal setbacks, the effect will be a minimal disruption of settled expectations.

F. ENDNOTES

1. Such a measure would be an example of a "presumed mobility" or adaptive approach, which could also be achieved by government or non-governmental purchase of "flowage easements." *See, e.g.*, James G. Titus, *Greenhouse Effect and Coastal Wetland Policy: How Americans Could Abandon an Area the Size of Massachusetts at Minimum Cost*, 15 ENV'L MGT. 39 (1991) and Joseph L. Sax, *The Fate of Wetlands in the Face of Rising Sea Levels: A Strategic Proposal*, 9 J. ENV'L L. 143 (1991).

2. The term "rolling easement" is used in a general sense to describe a number of different concepts, all of which include a landowner's legal obligation to remove structures from land that becomes inundated by the rise in tides. The holder of the easement, usually a government entity or land trust, can enforce the commitment as a property right. *See generally* Titus, *supra* note 1.

3. *See* Paul N. Klarin, Kristi M. Branch, Marc J. Herschman, & Thomas F. Grant, Sea Level Rise Policy Alternatives Study: Volume 2, An Analytical Review of State and Federal Coastal Management Systems and Policy Responses to Sea Level Rise, Washington Dept. of Ecology (June 1990).

4. *See generally* Alison Rieser, *Managing the Cumulative Effects of Coastal Land Development: Can Maine Law Meet the Challenge?* 39 ME. L. REV. 2 (1987).

5. The tests courts apply under these two constitutional challenges are interrelated and land use regulations are often examined under both.

6. Tisei v. Town of Ogunquit, 491 A.2d 564, 569 (Me. 1985).

7. Hall v. Board of Envt'l Protection, 498 A.2d 260 (Me. 1985).

8. Plummer v. Town of Cape Elizabeth, 612 A.2d 856 (Me.1992).

9. U.S. Const. amend. V.

10. 260 U.S. 393 (1922).

11. *Id.* at 415.

12. Agins v. Tiburon, 447 U.S. 255, 260-261 (1980).

13. Keystone Bituminous Coal Ass'n v. DeBenedictus, 480 U.S. 470, 485, (1987) (quoting Agins v. Tiburon, 447 U.S. at 260).

14. Penn Central Transp. Co. v. City of New York, 438 U.S. 104, 124 (1978).

15. 112 S. Ct. 2886 (1992).

16. The trial court relied on the property's assessed value before and after the regulations, although there was no evidence in the record that the landowner actually intended to build or had no other uses of the property. In fact, in 1990 amendments to the South Carolina law, the legislature provided for the construction of structures despite the setback in certain cases upon application of the landowner. Mr. Lucas did not apply for this variance but instead proceeded to challenge the original legislation. In an unusual move that was criticized by members of the Court, the Court accepted the case for appeal without Mr. Lucas exhausting his remedies under the 1990 amendment.

17. Lucas v. South Carolina Coastal Council, 424 S.E.2d 484, 486 (S.C. 1992).

18. Lucas v. South Carolina Coastal Council, 112 S. Ct. 2886, 2903 (Kennedy, J., concurring).

19. Me. Const. art. I, sec. 21.

20. Seven Islands Land Co. v. Maine Land Use Regulatory Comm'n, 450 A.2d 475, 482 (Me. 1982).

21. State v. Johnson, 265 A.2d 711, 715 (Me. 1970) (citation omitted).

22. *Seven Islands Land Co.*, 450 A.2d at 482; Sibley v. Inhabitants of the Town of Wells, 462 A.2d 27, 31 (Me. 1983).

23. Curtis v. Main, 482 A.2d 1253, 1258 (Me. 1984).

24. 557 A.2d 168 (Me. 1989).

25. Id. at 173, 176 (shorefront owners hold the intertidal zone in fee, subject only to an "easement" for public uses reasonably related to fishing, fowling and navigation).

26. 528 A.2d 453 (Me. 1987).

27. 38 M.R.S.A. SS 471-478 (1987) (current version at 38 M.R.S.A. SS 480A-480U (West 1989 & Supp. 1991).

28. Hall v. Board of Envt'l Protection, No. CV-83-85, slip op. at 7 (Me. Super. Ct., Dec. 4, 1986).

29. Hall v. Board of Envt'l Protection, 528 A.2d at 456. In a later ruling, the Law Court in Rubin v. Board of Envt'l Protection, 577 A.2d 1189 (Me. 1990), again upheld the sand dune rules and the Board's denial of a variance for construction on a frontal dune.

30. 76 Me. 76 (1884). *See also* Lorusso v. Acapesket Improv. Ass'n, 564 N.E. 2d 360, 367 (Mass. 1990); Mastin v. Prescott, 444 A.2d 556, 558 (N.H. 1982); Michaelson v. Silver Beach Improv. Ass'n, 173 N.E. 2d 273, 275 (Mass. 1961).

31. S.C. CODE ANN. Section 48-39-290(B) (Supp. 1989).

32. A similar definition of "destroyed beyond repair" was added in the 1990 amendments, which defined the term to mean "more than sixty-six and two-thirds percent of the replacement value of the habitable structure ... has been destroyed." S.C. CODE ANN. 48-39-270(11) (Supp. 1989). The amendments also gave the South Carolina Coastal Council the power to issue special permits allowing construction or reconstruction of habitable structures under certain conditions, even if located seaward of the baseline. S.C. CODE ANN. Section 48-39-290(D) (Supp. 1989).

33. Esposito v. South Carolina Coastal Council, 939 F.2d 165 (4th Cir. 1991), *cert. denied*, 112 S. Ct. 3027 (1992).

34. 483 U.S. 825 (1987).

35. Dolan v. City of Tigard, 662 LW 4576, 4580 (June 21, 1994).

36. *See* Surfside Colony, Ltd. v. Cal. Coastal Comm'n, 226 Cal. App. 3d 1260, 277 Cal. Rptr. 371 (1991) (Comm'n condition which seeks to mitigate cumulative impact of private erosion control structures on beach erosion through dedication of public access and recreational use easements was not supported by site-specific evidence that the revetment would cause further erosion at this particular location, thus failing to meet the nexus test of *Nollan*).

37. *Nollan* 483 U.S. at 834, n.3.

38. *See, e.g.*, Lummis v. Lilly, 429 N.E. 2d 1146 (Mass. 1982).

39. 112 S.Ct. 2886, 120 L.Ed. 2d 798 (1992).

40. *Id.* at 813, n.7. *See also* Orion Corp. v. State of Washington, 109 Wash. 2d 621, 747 P.2d 1062 (1987) (Washington's Shoreline Management Act does not deprive private tidelands owner of economically valuable uses if those uses are already denied by virtue of the state's public trust doctrine).

41. *See* Jon A. Kusler, *The Lucas Decision: Avoiding 'Takings' Problems With Wetland and Floodplain Regulations*, 4 MD. J. OF CONT. LEG. ISSUES 73 (1992-93).

42. Phillips Petroleum Co. v. Mississippi, 484 U.S. 469 (1988) (State public trust extends to all lands subject to the ebb and flow of the tides).

43. *E.g.*, Hirtz v. Texas, 773 F. Supp. 6 (S.D. Tex. 1991), *rev'd on other grounds*, 974 F.2d 663 (5th Cir. 1992); Matthews v. Bay Head Improvement Ass'n, 471 A.2d 355, 365 (N.J. 1984), *cert. denied*, 469 U.S. 821 (1984).

44. *See* Bell v. Town of Wells, 557 A.2d 168 (Me. 1989).

45. *See* Shively v. Bowlby, 152 U.S. 1, 35 (1894); HARRIET HENRY, MAINE LAWS AFFECTING MARINE RESOURCES, vol. 2, at 214-215.

46. State v. Yates, 104 Me. 360, 363, 71 A. 1018 (1908) ("It is settled law that the owner of land bordering on ... the sea, which is added to by accretion, that is the gradual and imperceptible accumulation or deposit of land by natural causes, becomes thereby the owner of also of new made land.")

47. Michaelson v. Silver Beach Improv. Ass'n, 343 Mass. 251 (1961).

48. Matthews v. Bay Head Improv. Ass'n, 471 A.2d 355 (N.J. 1984).

49. See, e.g., Florida Beach and Shore Protection Act of 1987, FLA. STAT. ch. 161 (1990) (establishing construction setback regulations) and South Carolina Beachfront Management Act, S.C. GEN. LAWS 48-39-270 to 360 (establishing setbacks and requiring local beach protection plans).

50. Lummis v. Lilly, 385 Mass. 41, 429 N.E. 2d 1146 (1982) (use of groin or jetty subject to a reasonable use rule applicable to riparian owners; relevant factors in determining reasonableness include purpose, existence of license, harm caused, practicality of avoiding harm, protection of existing values of land and water use, etc).

51. *See, e.g.*, Kreiter v. Chiles, 593 So. 2d 111 (Fla. Dist. Ct. App., Feb. 11, 1992), *cert. denied*, 61 USLW 3284, Oct. 13, 1992 (denial of permit to construct a private dock over submerged lands held in trust does not constitute a taking, absent a showing of the necessity of ingress and egress).

52. *See, e.g.*, Massachusetts v. Wilson, 413 Mass. 352, 597 N.E. 2d 43 (Mass. 1992).

53. Kaiser Aetna v. United States, 444 U.S. 164 (1979).

54. U.S. Const., art. I, sec. 8, cl. 3.

55. U.S. v. Rands, 389 U.S. 121 (1967).

56. 557 A.2d 168 (Me. 1989).

57. *Id.* at 173, 176.

58. *See* Phillips Petroleum Co. v. Mississippi, 484 U.S. 469 (1988).

59. *See* Bell v. Town of Wells, 557 A.2d at 171.

60. *Id.* at 173.

61. *Compare* Matthews v. Bay Head Improvement Ass'n, 471 A.2d 355 (N.J. 1984).

62. For a similar legal theory using California law, see Judith Knapp, "The Rising Sea Level and an Anticipatory Public Trust Doctrine in California," unpublished manuscript, U.Cal. Berkeley, Boalt Hall Law School, April 1990.

63. *Compare* Opinion of the Justices, 437 A.2d 597 (Me., 1981) with Bell v. Town of Wells, 537 A.2d 168 (M3. 1989).

64. *See* Hall v. Board of Envt'l Protection, 498 A.2d 564, 569 (Me. 1985); Drake v. Inhabitants of the Town of Sanford, Sup. Ct. No. CV-88-679 (Dec. 17. 1992) (court notes cumulative impact rationale in rejecting jury's finding that town shoreland zoning ordinance did not substantially advance legitimate state interests, but accepts jury's finding that ordinance did not deprive owner of all economically beneficial or productive uses); Plummer v. Town of Cape Elizabeth, 612 A.2d 856 (Me. Aug. 20, 1992) (local wetland ordinance does not violate substantive due process but developer is entitled to a trial on takings claim).

65. TEX. NAT. RES. CODE Sec. 61.012 (1990).

66. Hirtz v. Texas, 773 F. Supp. 6, *rev'd on other grounds*, 974 F.2d 663 (5th Cir. 1992).

67. G.L. c. 131, sec. 40 (1990).

68. 310 CODE MASS. REGS. Sec. 10.28(4) (1989).

69. *Id.* at 10.30 (3) (1989).

70. 310 CODE MASS. REGS. 10.36 (1989).

71. Wilson v. Commonwealth, 413 Mass. 352, 597 N.E.2d 43 (Mass. 1992).

72. Wilson v. Commonwealth, 31 Mass. App. Ct. 757, 768 (Jan. 9, 1992).

73. *Wilson*, 597 N.E.2d at 352, 44.

74. 483 U.S. 825 (1988).

75. *Nollan,* 483 U.S. at 847 (Brennan, J., dissenting).

76. *Id.* Justice Blackmun began his separate dissenting opinion with the following: "I do not understand the Court's opinion in this case to implicate in any way the public-trust doctrine. The Court certainly had no reason to address the issue, for the Court of Appeals of California did not rest its decision on Article X, section 4, of the California Constitution. Nor did the parties base their arguments before this Court on the doctrine." (Article X, adopted in 1879, protects the public right of way to navigable waters and the public right of free navigation, and is considered to be the constitutional basis of the public trust doctrine in California. *Id.* at 865.

77. *See, e.g.,* Lummis v. Lilly, 429 N.E. 2d 1146 (Mass. 1982).

78. Town of Windham v. LaPointe, 308 A.2d 286, 290-91 (Me. 1973).

79. *See, e.g.*, Terry D. Morgan, *Takings Law: Strategies for Dealing With* Lucas, LAND USE LAW & ZON. DIG. 3 (Jan. 1993); Eric Damian Kelly, *A Challenge to Planners: Solve the Takings Problem*, LAND USE LAW & ZON. DIG. 3 (Sept. 1993). Several of the suggestions in this section are based the recommendations of Kelly, *supra*.

80. FLA. STAT. Section 161.052(7) (1979).

81. Kelly, *supra* note 79.

82. Id.

83. *See* Rubin v. BEP, 577 A.2d 1189 (Me. 1990) (upholding Sand Dune Rules variance provision requiring applicant to prove that minimal impact on sand dune system would occur and structure would not be damaged within 100 years by shoreline changes).

84. *See* Fichter v. BEP, 604 A.2d 433 (Me. 1992) (BEP action was "quasi-legislative" in reviewing DEP's permit decision therefore applicant was not entitled to a full adjudicatory hearing on applicant's appeal of DEP finding that 100 year rise in sea level will cause the subject seawall to collapse, that seawall would interfere with the natural sand movement and redistribution and was located on a frontal dune).

85. Titus, *supra* note 1, at 45.

86. Sax, *supra* note 1.

87. *See* Lisa A. St. Amand, *Sea Level Rise and Coastal Wetlands: Opportunities for a Peaceful Migration,* 19 ENV'L AFF. 1, 18-19 (1991).

88. *Id.* at 23.

89. Knapp, *supra* note 62.

90. Regulations will still be required because the effectiveness of public education is unproven. As one commentator has noted, "development of beachfront property is not normally perceived as risky because of cognitive limitations on the perception of low-probability risks, culturally- or commercially-motivated distortions of risk level, and deliberate disregard or risk because of expected subsidization[.] Persistent publicity about risks, perhaps combined with recordation of risk information directly on deeds, could be expected to have some effect on risky land use choices eventually, but its extent would be uncertain." Marc R. Poirier, *Takings and Natural Hazards Policy: Public Choice in the Beachfront*, 46 RUTGERS L. REV. 243, 291-92 (1994).

Chapter Seven

PRELIMINARY ADAPTIVE RESPONSE STRATEGY: CONCLUSIONS AND RECOMMENDATIONS

This study evaluated whether Maine should develop an adaptive response strategy to prepare for the possibility of accelerated sea-level rise as a result of global climate change. It concludes that Maine should begin to prepare itself for the possible consequences given:

- the significant possibility of global warming,
- the magnitude of the negative impacts if global warming theories are correct, and
- the potential for anticipatory measures to reduce adverse impacts if sea-level rises as projected, without imposing substantial costs if the projections are not realized.

A. VULNERABILITY ASSESSMENT AND ANALYSIS OF EXISTING LAWS

Researchers determined that the developable portion of the study area within 100 meters of the shoreline is, for the most part, already built up. There is little usable, vacant land zoned for development. The shoreline development that has occurred over the last several years has been typified by seasonal conversion, infill development in grandfathered subdivisions or on grandfathered lots, and renovation or expansion of existing single family homes.

However, Maine has experienced a relatively depressed real estate market since approximately 1987. If development pressure increases in the future, coastal areas may face attempts to subdivide or redevelop larger estates, to consolidate and redevelop marginal seasonal homes and marginal commercial structures, and to redevelop cottage areas for multifamily residential units. Additional development pressure might also prompt individuals to attempt to develop land which is not currently zoned for development nor currently thought of as being suitable for development, specifically including eroding bluffs and land in or adjacent to coastal wetlands.

Any strategy to minimize damage from future sea-level rise should not only control the location of new development, but also consider the impacts of the strategy on existing development, and the impacts of existing development on natural coastal processes as shoreline position changes.

The mapping and vulnerability assessment for specific sites determined that the components of Maine's "soft coast" (coastal sand dune system, coastal wetlands, coastal eroding bluffs) face the prospect of significant coastal erosion and inundation even without accelerated sea-level rise, based on historic rates of change. And for beaches and coastal wetlands, that erosion and inundation will be exacerbated by an accelerated rate of sea-level rise.

1. Beaches

The most profound changes will be experienced on and adjacent to the beaches. Not only is the projected landward movement of shoreline position along beaches three to six times greater than the projected movement along salt marshes or bluffs, but a change in shoreline position along a beach is likely to affect relatively intensely developed areas immediately adjacent to the beach. At the same time, any interference with the natural migration of the sand dune system could reduce or eliminate the dry sand portion of the beach and have a very significant impact on coastal tourism, recreation, and the local economy.

However, the analysis of Maine's laws and regulations concludes that Maine already has strong laws and regulations in place to regulate development in or adjacent to sand dune systems. Maine's Natural Resources Protection Act and the accompanying Sand Dune Rules already prohibit large, new development unless the applicant can show that the site will remain stable assuming a 3 foot rise in sea level over 100 years. While smaller, new development is evaluated based on historic, rather than accelerated sea-level rise, all new development is subject to retreat requirements. There are also limits on expansion of existing development and those structures essentially cannot be rebuilt if they are destroyed by 50% or more of their value by coastal erosion or storms.

While some minor amendments would strengthen the law (e.g., adequate protection for unstable back dune sites, clarification of the standards for site stability for smaller development), the Sand Dune Rules are essentially a sound and exemplary set of far-sighted regulations. As part of the anticipatory strategy for possible sea-level rise, it is critical to ensure that NRPA and the related Sand Dune Rules are not weakened through amendments, site specific exceptions, or permissive permit-by-rule regulations for back dune sites.

2. Coastal Wetlands

To date, Maine has not been equally attentive to the potential impact of sea-level rise on coastal wetlands. Any anticipatory sea-level rise strategy should correct this omission.

It is beyond question that coastal wetlands play a critical role in maintaining landscape-level ecosystem functioning. For example, they minimize damage from coastal storms and flooding, help maintain water quality, and in serve as critical habitat for juvenile fish and waterfowl. Wetlands are important to biodiversity; even though wetlands comprise only 5% of the nation's land area, they contain a disproportionate share of federally listed rare and endangered animal species.[1] The influence of wetland loss or disruption is likely to be felt well beyond the wetland itself because of the functional links to waterways, flyways, and the fisheries.[2] Any disruption of this critical coastal ecosystem could have serious economic impacts on components of Maine's economy, particularly on the commercial fishing industry.

A rise in sea level will result in the conversion of areas that were formerly just above mean low water to open water. Some researchers have concluded that healthy coastal marshes

with an adequate supply of sediment will be able to build coastal marshland as fast as the sea rises to inundate it up to a rate almost equivalent to a 200 cm rise over 100 years.[3] This means that, given the right conditions, wetlands could migrate landward in equilibrium. But there are significant limitations: the marsh must be healthy, there must be adequate sediment, and it must not run into upland barriers, either natural (steep slopes, bedrock) or human-made (bulkhead, levee or other hardened edge).

A national vulnerability study projected that in New England, if there were no artificial interference with natural migration, a sea-level rise of .5 m to 2.0 m would result in a maximum loss of 5% in wetland area. In similar circumstances, if all shores were protected with bulkheads or similar structures, 15-17% of the remaining coastal wetlands could be lost. If only already developed areas were protected, the wetland loss could be reduced to 6-10% of remaining coastal wetlands.[4] Further study might conclude that these regional projections substantially understate the wetland loss that might occur in Maine due to its steeper slope and bedrock-dominated characteristics.

Thus, under current conditions, with a significant rise in sea level, Maine is likely to suffer a substantial reduction in wetland area for a combination of reasons. First, there are no laws designed to protect the ability of wetlands to migrate inland by precluding the artificial hardening of the upland edge. NRPA wetland regulations were formulated primarily to maintain an adequate buffer to maintain wetland habitat value, assuming a static position. They do not preclude the construction of artificial barriers to upland migration just outside the wetland.

Second, natural upland barriers will contribute to wetland loss even without human interference. The steepness of the coastal region and the fact that it is bedrock-dominated will result in a much smaller area of new marsh creation than would occur in non-rocky regions.

Finally, unless current trends are reversed, multiple stressors not directly related to sea-level rise may contribute to the death of wetland vegetation which is critical to the process of vertical accretion. For example, dredge and fill projects, nonpoint source pollution, and reductions in the supply of sediment and nutrients may tax the health of wetland vegetation.

Given that some reduction in wetland area will be inevitable due to its topography alone, Maine should focus with renewed resolve on that portion of wetland loss which is within human control. Policy-makers need to decide how much of the existing wetland shoreline should remain in a natural, unarmored condition. They could decide that all of it should be kept free from further human interference with natural inland migration. Or they could decide that in specified circumstances, existing investment justifies allowing the upland edge of a wetland to be hardened, for instance to protect already intensely developed areas. Once the decision is made, appropriate regulations patterned after the setback and retreat policy of the Sand Dune Rules should be adopted to implement this policy in coastal wetlands.

3. Eroding Bluffs

Maine's laws also fail to do a complete job of regulating the third element of the soft coast, eroding coastal bluffs. While not likely to be affected by a change in the rate of sea-level rise, it is anticipated that this erosion will continue at a significant pace into the

future, threatening individual structures. Any unified State coastal erosion/inundation policy should address bluff erosion to prevent interference with the process through hard erosion control strategies. Eroding bluffs can play an important role in the sediment budget for sand dunes and coastal wetlands. Thus, it is important to sand dunes and coastal wetlands that armoring structures not be allowed to unreasonably interfere with the transfer of soil from the terrestrial to the marine environment.

4. Urban Engineered Shorefronts

This study determined that Portland's central waterfront is already lined with engineered structures which will essentially keep shoreline position constant even given a 2 meter rise in sea level over the next century. However, it is probable that this area will experience negative impacts associated with flooding and storm surges with greater frequency, particularly in areas that already experience flooding during a 100-year storm event.

The study concluded that existing laws, particularly State enabling legislation for zoning for maritime activities and commercial fishing, the Coastal Management Policies Act and local waterfront zoning ordinances, all make an important contribution to damage mitigation by reserving this type of engineered waterfront site for water dependent uses.

5. Rocky Shores

It is not expected that Maine's rocky shoreline will be adversely affected by inundation or erosion as a result of sea-level rise associated with global climate change. There may be very minimal inland movement of the shoreline position, depending upon the adjacent slope. It was concluded that no regulatory changes are required along the hard coastline to address possible impacts of accelerated sea-level rise.

B. DEVELOPING AN ANTICIPATORY RESPONSE STRATEGY

1. Maine's Advantages

Maine has three advantages which should help it as it makes policy decisions about an anticipatory response strategy. First, even though Maine is substantially built up along its developable shoreline, it is not saddled with the intense, multi-unit recreational shoreline development characteristic of states to its south.[5] Maine is still in a position to decide *whether to allow* further intensification of shoreline development. In most other states, the decision about sea-level rise response options will be skewed by extensive investments already sunk into vulnerable but immovable structures.

Second, some analysts have characterized response strategies as a choice between *maintaining economic activities in a shorefront location* (e.g., making substantial environmental changes such as dredging sand for beach nourishment, construction of bulkheads to protect houses from migrating wetlands) or *preserving the environment* (e.g., removing structures to allow beach and wetland migration).[6] While this economy vs. the environment dichotomy may be true in other coastal states, the choices in Maine are not that stark. Maine is much more heavily dependent on its natural resources than many other coastal states. Its commercial fishing industry, other marine resource harvesting industries, coastal recreation and coastal tourism industries are of critical importance to the State's economy.

These key industries depend upon maintaining the quality and ecological functioning of Maine's coastal wetlands, marine waters and sand beaches. Thus, it is not a matter of economic activity or the environment; there are substantial economic benefits associated with maintaining the environmental quality of the coastal ecosystem.

Finally, Maine should be in a good position to develop an anticipatory sea-level response strategy because it has already successfully confronted very similar issues in regulating sand dune systems. NRPA and the associated Sand Dune Rules already establish a clear policy of retreat from advancing seas, whether at historic or accelerated rates, and impose reasonable limitations on the development expectations of owners of land within or adjacent to sand dune systems. This provides a valuable model to follow in developing policies for other areas of the soft coast.

As a means of bringing more information to bear on the complex choices to be made in developing a formal sea-level rise response strategy, researchers conducted a cost/benefit analysis of alternative response options for one site and analyzed constitutional limitations on regulatory options. The findings are summarized below.

2. Economic Cost/Benefit Analysis

The cost-benefit analysis of four options for one specific sand beach site concluded that, subject to the conditions and assumptions articulated in Chapter Four, it was more cost-effective to adopt a strategy of retreat from the shoreline as sea level rises. The benefits of a retreat strategy outweighed costs under the 50, 100 and 200 cm rise scenarios. In contrast, the analysis found that attempts to protect most of the development or to maintain the shoreline in its current position were not justified by a cost-benefit analysis. The costs of these reactive protection strategies (assuming beach nourishment, bulkheads and in one strategy a selective buy-out of threatened structures) exceeded benefits for the 50, 100 and 200 cm rise scenarios.

Specifically, that analysis concluded that for the currently eroding beach at Camp Ellis, with a sea-level rise of 50 to 200 cm by 2100, from a quantitative standpoint, the preferable option is to allow new development within the area projected to be inundated, but to require retreat of both new and existing development as the shoreline position changes (Option 4). The second most favorable response of the options evaluated was to ban all new development within the area projected to be inundated under the particular scenarios and to require existing development to retreat as it suffers major damage from coastal erosion or coastal storms (Option 3).

The major factors making the retreat strategies preferable to the reactive protection strategies were the cost of sand and the expense of ongoing beach nourishment. As noted in Chapter Four, this analysis is still very rough. The results are highly dependent upon the particular assumptions used and the analysis is very simplified. Each strategy has different costs associated with it if sea level actually rises either more or less than projected under the particular scenario; this uncertainty would need to be considered when selecting a strategy. Moreover, there are other foreseeable costs or risks, such as political feasibility, which are not addressed through this cost-benefit analysis. For example, a community might initially select Option 4 (allow construction in vulnerable areas, but with retreat requirements) but then lose the political will to enforce the retreat requirement when faced with the actual need for

abandonment. If the community then decides to protect that development, the strategy would then become one of reactive protection, with all of those associated costs.

Despite these admitted constraints, the results of this simplified cost/benefit analysis lend general support to the type of response strategy which is already embodied in the Sand Dune Rules. To implement a retreat strategy, those Rules:

1) ban all new development in a band of land which extends from the water upland to the projected shoreline 100 years hence, based on projections of a continuation of historic rate of erosion over the next 100 years;

2) allow modest continued development in the next band of land, which consists of land between the projected 100 year shoreline based on historic rates and the projected 100 year shoreline based on a 1.0 m rise in sea level.

3) allow development up to the maximum allowed by local zoning ordinances in the furthest upland band of land in the sand dune system, from the projected 100 year shoreline based on a 1.0 m rise in sea level to the upland edge of the sand dune system, subject only to the retreat requirements outlined below;

4) throughout the sand dune system, require all rebuilding or repair of existing structures to meet the requirements for new construction if the structure is damaged by 50% or more of its value; and

5) condition all new development upon the requirement that the owner remove the structure and return the site to its unaltered condition if the shoreline position changes so that the structure is on part of the active dune system for six or more months.

The existing sand dune policies are not completely reflected in either Option 3 or Option 4 of the cost-benefit analysis, but rather take a middle position between those retreat strategies. The Sand Dune Rules allow modest new development in the area described in #2, above, thus avoid the high opportunity costs otherwise incurred if all development were banned in the area threatened by accelerated sea-level rise (as in cost-benefit Option 3). There are, of course, still some opportunity costs associated with limiting the development to modest intensity rather than allowing high-intensity development, but these cost are justified by environmental, hazard mitigation, and visual access considerations which would support keeping high intensity development from locating on the shoreline even assuming no change in shoreline position.

3. Legal Considerations for Maine's Policy Response

Researchers also analyzed several legal issues to determine if they might constrain the State's ability to adopt a retreat strategy. The primary purpose of the analysis was to determine if the retreat strategies being supported in the analysis of existing laws and in the cost-benefit analysis suffered from substantial vulnerability to successful legal challenge.

The legal analysis concluded that Maine is at somewhat of a disadvantage in comparison to the majority of coastal states due to the weakness of its public trust doctrine. However, it concluded that with careful attention to drafting, U.S. constitutional law and State constitutional law give adequate room to develop, adopt and enforce regulations on coastal development to restrict new development in areas threatened by accelerated sea-level rise, to require removal of new development upon a change in shoreline position, and to prohibit the

rebuilding of existing structures which are substantially damaged by coastal storms or erosion. The analysis also concluded that existing laws give adequate opportunity to adopt some non-regulatory responses, but that other non-regulatory strategies would require statutory or constitutional amendments.

C. RECOMMENDATIONS FOR MAINE'S ANTICIPATORY RESPONSE STRATEGY

The remainder of this chapter summarizes the recommendations developed based on the analysis in the preceding chapters. It is not intended as an exhaustive list of recommendations; individual chapters should be consulted for full details.

Clearly, these recommendations are not the formal policy of any agency of the State of Maine; they are the recommendations of the members of the research team, and are presented for further consideration by appropriate state and local agencies.

These recommendations have been developed as part of a "no regrets" response based on the best available technical information at this time. Any anticipatory strategy formulated based on these recommendations will need to be reviewed periodically (e.g., every 5 to 10 years) to incorporate new information available at that time.

1. Underlying Recommendations

The key recommendation of this report, underlying all of the others, is that **the State should protect and strengthen the ability of natural systems to adjust to changes in shoreline position.** There should be a strong presumption in favor of non-interference with "soft" coastal processes including the natural inland migration of beaches and salt marshes and the natural movement of material from the terrestrial to the marine environment. The correlative recommendation is that **the State should prevent new development which is likely to interfere with the ability of natural systems to adjust to changes in shoreline position.**

2. Specific Strategies

Within these general premises, more specific strategies should be articulated. There are at least four types of responses to climate change:

1) **"No action today"/action when problem emerges,** where least-cost solutions are well-defined and can be implemented quickly at the appropriate time using existing technology and information. There is little reason to take action before the problem emerges.

2) **Anticipatory action,** where concrete measures are justified today despite uncertainties due to the minor additional cost of incorporating the measures today being outweighed by large potential gains and possible benefits even without global climate change.

3) **Planning,** where no physical changes are needed immediately, but the "rules of the game" need to be announced or changed so that people can make informed decisions based on advanced notice of how the government intends to respond to climate change and sea-level rise.

4) **Strategic assessments, research and education,** where it will take long periods of time to determine the type and timing of responses to global warming, where we need to develop a much better scientific understanding of natural processes and how to apply that knowledge to mitigate impacts, and where enlightened professionals and citizens are critical to support required changes.[7]

The following sections summarize the recommendations for each type of action.

a. Action When the Problem Emerges

This report does not identify any actions in this category to be taken now, or in the near term. Concrete problems specifically attributable to global climate change induced sea-level rise have not yet emerged to the point where it is necessary to take specific physical actions to implement solutions. Altered resource management practices (e.g., reservoir water release schedules, shifting crops) and engineered solutions specifically in response to rising sea level (e.g., raising piers and wharfs, redesigning existing coastal drainage systems, bulkheading, etc.) should be undertaken, if at all, only if there is an actual rise.

The State should continue to monitor Maine-specific sea-level rise data, global sea-level rise projections, and local conditions on a periodic basis to determine if a problem has emerged which requires specific action. It is also likely that if individuals begin to feel the effects of rising sea level, they will take certain adaptive actions on their own, without governmental incentives or mandates. For example, water-dependent uses reinforcing or maintaining their piers and wharves may build to withstand higher water level based on their own observations about reduced protection from coastal storms. Public education (discussed below) will help individuals place these actions into a larger context.

b. Anticipatory Action

Maine should encourage anticipatory tangible responses to sea-level rise if the proposed action meets the "no regrets" test. Such response options include the following:

1) Review design standards and similar specifications for every new coastal public works project to determine whether it is cost-effective to make minor alterations in the design to accommodate a changed shoreline position (e.g., slightly increasing the setback to provide a protective buffer) or to design it to accommodate a more frequent storm event (e.g., designing for a 15- to 20-year storm rather than a 100-year storm);

2) Develop a written capital investment policy to discourage an irreversible commitment of public resources for new infrastructure or structures in areas likely to be affected by accelerated sea-level rise, except to the extent necessary to support continued economic viability and efficient functioning of water-dependent uses. The policy should also provide specific guidance on avoiding coastal infrastructure investments that would encourage residential development on the shore (e.g., extension of water systems, sewer systems and roads to shoreline areas). It should also provide guidelines to help balance when shoreline capital investments might be appropriate, such as in the case of strengthening the viability of water-dependent industries or securing public waterfront access. Except for water-dependent use infrastructure, all new and substantially modified public structures and facilities should be adequately set back to protect them from erosion for 100 years assuming a rise in sea level of 100 cm by

2100. Even if shoreline position does not change, these policies are consistent with sound coastal management practices.

3) Increase the amount of upland area owned or controlled by public or quasi-public entities (e.g., State, municipality, land trust) adjacent to low-lying facilities intended to provide public waterfront access (e.g., beaches, shoreline walkways, boat ramps, waterfront parks, public docks, etc.) so that these facilities would still be available even with a change in shoreline position. Until needed for shoreline access, the additional upland could be used for beneficial purposes such as open space, parking or storage.

4) Expand coastal nature preserves, acquire key undeveloped coastal wetlands and similar conservation areas to preserve areas important to the public and to provide sufficient upland buffer areas for wetland migration in the event of a change in shoreline position. This would increase protection of threatened ecosystems now, and would enhance the prospects of wetlands being able to migrate in equilibrium with a change in sea level. In conjunction with this, review funding options and financial incentives to determine if they can be made more attractive. Mechanisms reviewed should include preferential open space tax treatment, conservation easements coupled with required property tax reassessment to reflect the decrease in value due to the encumbrance, preference for purchase of this type of land under a bond-supported public purchase program, and a real estate transfer tax surcharge on the transfer of coastal property or an income tax checkoff system to fund property acquisition. Acquisition would not have to be in fee simple. Conservation easements could protect the land in its undeveloped condition. Similarly, it may be possible to acquire a contingent "flooding" easement which would not encumber the land unless erosion or inundation changed the applicable shoreline position or upland/marsh boundary.

c. Planning and Regulatory Policy

The State should "change the rules of the game" by adopting land use restrictions which will guide the bulk of the development away from potential hazard areas and will protect the ability of coastal ecosystems to migrate. While the following policy options are generally phrased in terms of what the State of Maine should do, in some cases the State may decide it is more desirable to delegate that responsibility to local governments with retained State oversight. Summary recommendations include:

5) Halt attempts to stabilize the shoreline within or adjacent to the soft coast; maintain/restore the ability for coastal sand dune systems, coastal wetlands and eroding bluffs to migrate inland. This has already been accomplished to a great extent within the frontal dune system. Maine needs to hold the line on existing sand dune restrictions and not allow additional exceptions. Similar sorts of protections need to be extended to back dunes, coastal wetlands and eroding bluffs. For example, amend NRPA to prohibit edge-hardening structures (e.g., bulkheads, levees, etc.) adjacent to the upland edge of a coastal wetland if any part of the structure is projected to interfere with the inland migration of the wetland assuming an accelerated sea-level rise of 100 cm by 2100.

6) Along all soft coasts, establish building setbacks to protect the natural systems. Prohibit all new structures on or adjacent to sand dunes or coastal marshes if the site is projected to be affected by sea-level rise within 100 years, assuming a rise in sea level of 100 cm by 2100 (except as provided in 7, below). Similarly, for eroding bluffs, if not included within a district allowing only non-intensive use, adopt setbacks for structures and septic systems which require them to be set back from the area likely to experience erosion over the next 100 years assuming a continuation of the historic rate of erosion or, if greater, set back 75 feet plus the average annual rescission rate times the structure's assumed life span.

7) As a limited exception to 6, above, allow construction of new, small, easily-movable structures built at low densities (e.g. walkways, small single family residences on reasonably large lots, temporary/reversible structures) adjacent to sand beaches or marshes if, and only if, the site is expected to remain stable over the next 100 years assuming a continuation of the historic rate of erosion. This exception should only be allowed if the State has the political will to require removal of these structures if erosion exceeds historic rates. In cases where small, new, movable development is allowed, extend the Sand Dune Rule's "presumed mobility" policy to all areas of the soft coast (beach, marsh and bluff) by making all new building permits conditional. As a condition of approval, require the owner to agree to remove any structure permitted after adoption of the policy if the shoreline position changes so that the structure interferes with the ability of the natural systems to adjust to changes in shoreline position. Require that the condition be recorded at the appropriate registry of deeds so that all subsequent purchasers are put on notice of the risk of being in a hazard area and their obligations in the event of a change in shoreline position.

8) Notwithstanding 6, above, allow new structures for functionally water- dependent uses which meet certain performance standards designed to minimize the impact on natural systems, regardless of whether the area is likely to be affected by either historic or accelerated sea-level rise.

9) Treat existing development located within the area which is threatened by erosion or inundation from a sea-level rise of 100 cm over the next century as a non-conforming structure if it can not meet the new setback standards; prohibit expansion of the structure or intensification of use, but allow ordinary maintenance and repair so long as it is not damaged by more than 50% of its value. To the extent legally feasible without constituting a taking, extend the "presumed mobility" policy to existing structures as well to require the owner to remove any structure if the shoreline position changes so that any portion of the structure is located on public land or becomes a public nuisance (even if the structure has not sustained damage of 50% or more of its value).

10) On any site which is unlikely to be affected by accelerated sea-level rise assuming a 100 cm rise over 100 years but which is projected to be affected by a 200 cm rise over 100 years, allow new development only if it meets performance standards for cluster development designed to minimize the costs of protection should the 100 cm sea-level rise estimate be too low.

11) Supplement the State regulatory procedures by encouraging or requiring other State agencies and individual municipalities to consider a high probability of future increased rates of sea-level rise in making daily investment, development and permitting decisions. For example, consider mandating incorporation of a sea-level rise standard into shoreland zoning and subdivision review standards.

d. Strategic Assessments, Research and Education

Given scientific uncertainty and rapidly evolving scientific knowledge, coastal managers are not in a position to make decisions now about a definitive adaptive response strategy for the next century. Policy decisions will have to be made now based on the best available knowledge, with the express intent of reviewing these policies periodically as scientists refine their predictions. Continuing research will be required to revise and refine anticipatory strategies and policies as scientific knowledge increases. The State of Maine should participate in increasing the understanding of global warming and its projected impacts, particularly as applied to the State, in the following ways:

12) The State should designate one State agency as the lead agency for monitoring issues associated with global climate change and sea-level rise. This agency should keep abreast of scientific progress and policy responses of other entities. It should also work with related State agencies and with municipalities in formalizing an anticipatory response strategy and seeing that it is implemented. Because it appears that a major part of the implementation strategy will involve strengthening the core laws of the coastal management program, it would be logical to designate the State Planning Office as this lead agency. This lead agency would need to work closely with the Maine Geological Survey and other State agencies with coastal and marine responsibilities.

13) The lead State agency and cooperating State agencies should undertake additional research to document coastal erosion in Maine and to determine how global or regional projections concerning particular impacts might affect Maine. For example, the ability to regulate coastal development will be improved if Maine Geological Survey receives funding to complete its work on historic coastal erosion rates for all beach, marsh and bluff segments. In addition, the State's anticipatory plan will be strengthened if municipalities adopt complementary comprehensive plans and implementing regulations. To facilitate this, the State should increase technical assistance to municipalities to help them identify areas threatened by coastal erosion and to modify their comprehensive plans accordingly.

14) As part of a related effort, to enhance the likelihood that regulatory policies will be accepted and supported, the State should undertake a substantial educational effort aimed at local officials, code enforcement officers, other State agencies, and the general public. The focus of this effort should be to educate the target audience about the hazards of coastal erosion and inundation, including the possible impacts of an accelerated rate of sea-level rise, the fragility of the coastal ecosystem, the benefits of conserving (or restoring) it as a resilient natural

system, and the costs (both financial and environmental) of hard structures, beach nourishment and similar engineered "solutions."

15) Finally, as additional funding is available, the State should undertake supplemental studies on different aspects of sea-level rise to complement this study. The possible impacts with highest priority for further study are coastal flooding/storm surges and salinization/saltwater intrusion. These are discussed in additional detail immediately below.

D. RECOMMENDATIONS FOR ADDITIONAL RESEARCH

Additional research is recommended to complete the picture of probable impacts of accelerated sea-level rise as a result of global climate change. While flooding and storm surges are closely related to inundation and erosion, developing a flood model and conducting detailed surveys of elevations and types of structures were outside of the scope of this study.

National studies suggest that sea-level rise will bring with it additional damage from flooding and storm surges because of the loss of protective wetlands, the erosion of the shoreline, the higher base for the surge to build on, a higher water table and reduced coastal drainage. Depending upon the tides, winds and waves at the time the storm hits, there can be a substantial temporary increase in water level.[8] For example, Hurricane Hugo in 1989 caused a 6.5 meter storm surge.[9]

Low barriers can be overcome, either by overtopping or undermining, resulting in storm damage. It has been estimated that with moderate sea-level rise, today's 100-year flood could essentially become a 15-year flood (a storm with a severity averaging a 15 year recurrence interval).[10]

It is particularly important to undertake a flooding/storm surge analysis for Portland's central waterfront, particularly in the Commercial Street area. While this study concluded that there would probably be no change in shoreline position in this area due to the engineered structures (which were observed to be built approximately 2 meters above mean high water), it did not rule out damage from storm events. This area contains new residential condominiums, multi-story office buildings, retail shops, restaurants, intermodal transportation facilities, a recreational marina, the municipal fish pier and municipal fish display auction, a major ship repair facility, many other commercial fishing or other water-related enterprises, and various public or institutional uses. These structures are built on piers, wharves, and formerly filled land. Additional study is needed to assess the vulnerability of the public investments and private infrastructure along this engineered waterfront to flooding and storm surges.

Another potential impact that should have high priority for additional analysis is salinization. A rise in sea level will move the salt water/fresh water boundary landward. Saltwater intrusion may significantly impact coastal towns or residents that use a river or well as their source of drinking water.[11] Additional analysis is required to determine which coastal towns or residents may be at risk from this impact.

The problem may be particularly acute for coastal islands that rely on ground water for their drinking water. As sea level rises and decreases the island size, the fresh water lens

overlying the salt water will shrink and its ability to sustain island residents will decrease.[12] Several Maine islands have based their comprehensive plans and implementing ordinances on island carrying capacity concepts based on ground water studies. Those studies should be reviewed to determine the adequacy of any sea-level rise assumptions.

Finally, some studies suggest that a change in the fresh water/salt water boundary may impact the abundance of marine resources, particularly shellfish.[13] Additional research would be required to determine probable impacts on Maine's fisheries. While the State may not be able to take any action to prevent this change, the possible impact should be factored into decisions concerning management of the State's marine resources.

E. ENDNOTES

1. Curtis C. Bohlen, *Wetlands Politics from a Landscape Perspective*, 4 MARYLAND JOURNAL OF CONTEMPORARY LEGAL ISSUES, Fall/Winter 1992-93, at 4.

2. *Id.* at 5.

3. Robert Costanza, et al., *Modeling Coastal Landscape Dynamics*, 40 BIOSCIENCE, Feb. 1990, at 91.

4. T.V. Armentano, R.A. Park, and C.L. Cloonan, *Impacts on coastal wetlands throughout the United States*, *in* GREENHOUSE EFFECT, SEA-LEVEL RISE AND COASTAL WETLANDS 87-128 (J.G. Titus, ed., Wash., DC: EPA, 1988).

5. This may be attributable to the rocky, highly irregular coastline, the relative scarcity of sand beaches, and the temperature of the coastal water. However, in 1989, one observer of the Maine coast cautioned that "there are beach communities with the first growing pains of [this high density, highly engineered shoreside development] already apparent." JOSEPH T. KELLEY, ET AL., LIVING WITH THE COAST OF MAINE 3 (National Audubon Society and Maine Geological Survey, Duke University Press, 1989)

6. James G. Titus, *Strategies for Adapting to the Greenhouse Effect*, APA JOURNAL, Summer 1990, at 311, 313.

7. Adapted from *id.* at 315-321.

8. Fletcher, Charles H. III, *Sea-Level Trends and Physical Consequences: Applications to the U.S. Shore,* 33 EARTH SCIENCE REVIEWS, 1992, at 94.

9. *Id.*

10. THE POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE ON THE UNITED STATES 328 (J.B. Smith & D.A. Tirpak, eds., Wash., DC: Hemisphere Publishing Corporation, 1990).

11. Fletcher, *supra* note 8, at 91.

12. *Id.* at 92.

13. James G. Titus, et al., *Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea*, 19 COASTAL MANAGEMENT 179 (1991).

Appendix A

SURVEY OF MAINE'S LAWS RELEVANT TO ACCELERATED SEA-LEVEL RISE

Maine's laws contain several provisions that address the possibility of a change in shoreline position. While some of these provisions may have been adopted primarily in anticipation of continued land subsidence rather than in specific response to the threat of accelerated sea-level rise due to global climate change, they will be applicable regardless of the cause of the change. The following appendix analyzes each law according to the following format:

1. Summary of law in general;
2. Identification of portion of the law that relates to sea-level rise;
3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise;
4. Analysis of extent to which accelerated sea-level rise might affect the application of the law.

The policy implications and recommendations based on this analysis are discussed in more detail in Chapter Five of this report. Within this Appendix, the laws are reviewed in the following order:

A. Natural Resource Protection Act and Sand Dune Regulations;

B. Coastal Management Policies Act;

C. Growth Management Act;

D. Shoreland Zoning Act;

E. Site Location of Development Act;

F. Subdivision Law;

G. State Floodplain Management Program;

H. Submerged Lands Act; and

I. Coastal Barrier Resources System.

A. NATURAL RESOURCES PROTECTION ACT (38 MRSA §§ 480-A -U)

1. Summary of law in general

The Natural Resources Protection Act is designed to protect the State's rivers, streams, great ponds, fragile mountain areas, freshwater wetlands, significant wildlife habitat, coastal wetlands and coastal sand dune systems from degradation. It promotes research and management programs for these protected natural resources. The Act also establishes a permit system for all activities in, on, or over any protected natural resource, and for all activities on land adjacent to any freshwater or coastal wetland, great pond, river, stream or brook if the proposed activity would operate in such a manner that material or soil may be washed into them.

Unless otherwise specifically exempt in §480-Q of the Act, activities requiring a permit are:

- dredging, bulldozing, removing or displacing soil, sand, vegetation or other materials;
- draining or dewatering;
- filling, including adding sand or other material to a sand dune; or
- any construction, repair or alteration of any permanent structures.[1]

The Act is administered by the Department of Environmental Protection.

2. Identification of portion of the law that relates to sea-level rise

The Act defines significant wildlife habitat, coastal wetlands and coastal sand dune systems as three of the protected natural resources. Significant wildlife habitat is further defined to include specific types of areas, including habitat for officially listed endangered or threatened species; critical spawning and nursery areas for Atlantic sea run salmon; shorebird nesting, feeding and staging areas; and seabird nesting islands. However, this habitat is only protected by the Act if this significant wildlife habitat has been mapped by the Department of Inland Fisheries and Wildlife. To date, only a portion of these areas have been mapped, greatly reducing the degree of protection.

The coastal wetlands and sand dune systems protections are somewhat stronger. Coastal wetlands are defined as "all tidal and subtidal lands, including all areas below any identifiable debris line left by tidal action; all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland which is subject to tidal action during the maximum spring tide level as identified in tide tables published by the National Ocean Service."[2] The Act specifies that coastal wetlands may include portions of coastal sand dunes.

Coastal sand dune systems are defined as "sand deposits within a marine beach system, including, but not limited to, beach berms, frontal dunes, dune ridges, back dunes and other sand areas deposited by wave or wind action."[3] They may extend into coastal wetlands.

Both of these protected resources are defined in such a way that the definition of the area regulated will fluctuate as the shoreline changes in response to global climate change or land subsidence.

For those activities that do require a permit, the Act establishes statutory standards for review. The Department is directed to grant a permit upon such terms as are necessary to fulfill the purposes of the Act if the applicant can demonstrate that the proposed activity meets those standards. The application of these standards is further detailed by regulations.

The standards most applicable to shoreline activities and sea-level rise are as follows:

- **2) Soil erosion.** The activity will not cause unreasonable erosion of soil or sediment nor unreasonably inhibit the natural transfer of soil from the terrestrial to the marine or freshwater environment.
- **3) Harm to habitats; fisheries.** The activity will not unreasonably harm any significant wildlife habitat, ... aquatic habitat, ... estuarine or marine fisheries or other aquatic life....
- **4) Interfere with natural water flow.** The activity will not unreasonably interfere with the natural flow of any surface or subsurface waters.
- **6) Flooding.** The activity will not unreasonably cause or increase the flooding of the alteration area or adjacent properties.
- **7) Sand supply.** If the activity is on or adjacent to a sand dune, it will not unreasonably interfere with the natural supply or movement of sand within or to the sand dune system or unreasonably increase the erosion hazard to the sand dune system.

The Act contains a list of specified activities for which a permit is not required. The most critical exception, enacted in July 1993 as part of the general budget act,[4] amended the list of activities for which a permit is not required to add "alterations in back dunes of coastal sand dune systems" except if the site is subject to flooding during a 100-year flood event based on information from the Federal Emergency Management Agency. The applicant had to provide the DEP with a location map and notice 14 days in advance of the proposed activity prior to commencing work in the back dune area.

This 1993 exemption was criticized as being overly-broad. In many sand beach areas, the historical primary dune no longer exists; proposed development on the front tier of the beach would actually involve development of what is technically a back dune area. Yet, these back dune areas are likely to be as threatened by accelerated sea-level rise as frontal dunes. In response to these criticisms, NRPA was again amended in 1994 to limit the exemption for back dune sites to only if the site is not expected to be damaged due to shoreline change within 100 years based on historic and projected trends. The entire permit exemption for back dunes is repealed as of February 15, 1995, to be replaced by permit-by-rule performance standards.[5]

Other more general exceptions may also become important if owners try to repair and maintain structures and infrastructure in the face of rising sea level. Some of these activities which do not require a permit include maintenance and "minor repair" of structures *above the high water line* causing no additional intrusion of an existing structure into a protected resource; repair, maintenance or replacement of an existing road culvert meeting size limits; emergency repair or normal maintenance and repair of existing public works which affect any protected natural resource, so long as it does not result in additional intrusion into the protected resource; and maintenance, repair or reconstruction of existing access ways in coastal wetlands to residential dwellings as long as the access way, if in a coastal wetland, is traditionally dry at mean high tide.[6]

The NRPA regulations include Coastal Sand Dune Rules.[7] These rules are designed to guide the application of the standards requiring that development in, on, or over sand dune systems must not cause unreasonable soil erosion, must not inhibit the natural transfer of soil from the terrestrial to the marine environment, and must not unreasonably interfere with the natural flow of any surface or subsurface waters. The Rules require the Department to consider impacts which may reasonably be expected to occur during the following 100 years; projects will not be permitted if, within 100 years, the project may reasonably be expected to be damaged as a result of changes in the shoreline, including changes from sea-level rise.

The Sand Dune Rules establish a policy of mobility or retreat in the face of a migrating coastal system. If a building sustains damage to the extent of 50% or more of the building's appraised value, it may not be repaired or rebuilt without a permit; no permit will be granted for its reconstruction unless the applicant can meet all of the requirements for new construction. It is highly unlikely that the owner of a structure damaged to this extent would be able to secure a permit to repair or rebuild.

The regulations allow permits to be granted, whether for new or replacement structures, subject to the condition that the structure (and related facilities) must be removed in the event that the shoreline recedes so that parts of the structure are within the coastal wetland for 6 months or more. In that event, the site must be restored to its natural condition. The rules also prohibit the construction of new seawalls in or on any sand dune system, and limit the repair or maintenance of existing seawalls. Finally, new buildings greater than 35 feet in height or covering a ground area greater than 2,500 square feet will only be allowed if the applicant can demonstrate the site will remain stable, assuming a three foot rise in sea level over 100 years.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

NRPA, as implemented through the Coastal Sand Dune Rules, directly addresses sea-level rise. For coastal sand dune areas, it establishes a policy of restrictions on the size and intensity of development in hazardous areas, and allows development of smaller structures subject to the requirements of retreat if the shoreline position changes so that the structure would interfere with natural sand dune processes.

The mobility or retreat policy is not geared to any particular assumption about the rate of change in shoreline position; since this policy operates after-the-fact to require removal of damaged structures, it is sufficiently flexible to respond to any rate of change.

In reviewing applications for new or substantially rebuilt structures, the Rules require an assessment of whether the proposed activity may reasonably be expected to be free from damage as a result of changes in the shoreline, including changes from sea-level rise, over the next 100 years. However, the Rules give no specific guidance on what assumption reviewers should use for the rate of change in shoreline position. These assessments usually assume a continuation of historical rates of change, based on the assumption that if this rate proves to be too low, the structures are small enough to be moved pursuant to the retreat requirements. If the State wants to minimize reliance on the retreat option (e.g., prohibit development in the first place) additional guidance would be required to direct reviewers to assume an accelerated rate of shoreline change.

In contrast, the Rules governing construction of larger structures in threatened areas do assume a specific rate of shoreline change which takes into consideration an accelerated rise in sea level. An applicant to build these larger structures must prove that the site will be stable given a sea-level rise of three feet over the next century. This generally conforms to an assumed global scenario of a 100 cm rise in sea level over the next 100 years.

These Sand Dune Rules and the explicit policy of retreat apply only to a very small, but intensely developed, portion of Maine's coast. The other types of coastline are generally subject to NRPA standards and specific regulations on soil erosion and the like. These standards provide, in a much less detailed way, for consideration of non-interference with the transfer of soil from the terrestrial to the marine environment. But in non-sand dune settings, there appears to be less express consideration of a change in shoreline position and there are no rules parallel to the Sand Dune Rules which detail explicit policies of retreat or migration.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law.

The NRPA standards are sufficiently flexible to respond to accelerated sea-level rise without requiring a statutory change. The Rules require consideration of sea-level rise. If sea-level rise accelerates or if the Board is more confident about projections of a certain rate of change which exceeds historical rates, these can be used in permit reviews without any statutory amendments.

B. COASTAL MANAGEMENT POLICIES ACT (38 MRSA §§ 1801-03)

1. Summary of law in general

This 1986 law is a statement of legislative policy and intent with respect to state and local actions affecting the Maine coast. It acknowledges that there are increasing use conflicts and increasing development pressures on the coastal region. In an effort to reach a well-reasoned balance among the competing uses, it establishes nine policies and directs that state and local agencies and certain federal agencies with responsibility for regulating, planning, develop-

ing or managing coastal resources conduct their activities in a way which is consistent with the nine policies.

No procedures for implementation are adopted in the Act, nor have any regulations been promulgated. The Coastal Advisory Committee issued guidelines in December, 1986 to assist state agencies in implementing the policies. To date, implementation of the policies has been uneven among the affected agencies.

2. Identification of portion of the law that relates to sea-level rise

Eight of the nine policies articulate the need to promote ports and harbors for fishing, transportation and recreation; to manage marine resources to preserve the integrity of communities and habitats; to manage the shoreline to give preference to water-dependent uses and to promote public access; to protect critical habitat and natural areas; and to maintain the quality of fresh, marine and estuarine waters.

The remaining policy specifically addresses sea-level rise. It establishes a policy that municipalities are to discourage growth and new development in coastal areas where it would be hazardous to human health and safety as a result of natural forces including sea-level rise. Specifically, Policy Four states:

> **Hazard area development.** Discourage growth and new development in coastal areas where, because of coastal storms, flooding, landslides or sea-level rise, it is hazardous to human health and safety.

The Guidelines for Policy Four[8] present the rationale for the policy, noting that coastal floodplains, sand dunes and wetlands in their natural state provide storm protection and support a variety of important plants and wildlife. Citing the extensive damage to natural and man-made features visited by coastal storms and the direct and indirect costs to governments of repairing this damage, they establish an objective of discouraging development and redevelopment in areas that present threats to public safety or that threaten property damage which will be costly to public entities.

The implementation procedures recommend that affected agencies take the following steps:

- Government agency decisions will not support new infrastructure or related facilities in hazardous areas;
- Public funds available for improvements, renovations, or repair to existing infrastructure or other public facilities in hazard areas will give priority to their relocation out of hazardous areas.
- Government agencies will require new and modified structures/facilities to be adequately setback to protect them from erosion for 100 years.
- Government agencies will include scientific projections of sea-level rise in regulatory and management decisions affecting the shoreline.[9]

Each state agency was required by Executive Order to examine all their programs affecting the coast and, by July 1, 1987 to identify changes necessary to make them consistent with the policies. The proposed changes were to be reviewed by the Coastal Advisory Committee and were then to be incorporated into State programs before December 31, 1987.

Some agencies have made significant progress. For example, work done includes computerized hazard mapping of certain coastal areas, adoption of revised coastal sand dune regulations, and work on flood prevention. Other agencies such as the Bureau of Public Lands have incorporated the policies by reference into laws affecting coastal areas. However, implementation of Policy Four, as well as the others, has not been systematic.[10] The State has not yet adopted a Coastal Action Plan for the 1990s, one component of which would address sea-level rise and its implications for shoreline use, as recommended by the State Planning Office.[11]

By the same Executive Order, federal and local agencies were encouraged to review their

programs for compliance with these Coastal Management Policies. As applied to municipalities, this recommendation was strengthened into a requirement through the Growth Management Act and the Shoreland Zoning Act, both of which required the resulting comprehensive plans, comprehensive land use ordinances and shoreland zoning ordinances to "address" these Coastal Management Policies.[12]

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

The Coastal Management Policies are very general so they do not distinguish between hazards posed by sea-level rise caused by subsidence and sea-level rise caused by global climate change. Regardless of the specific source of the hazard, growth and new development is to be discouraged in areas threatened by these natural erosive processes.

As a general statement, Policy Four and the Guidelines, are sound as far as they go and provide an already established framework for considering the possible threats posed by accelerated sea-level rise. The Act, however, relies on essentially voluntary implementation by affected local, state and federal agencies. Some agencies, such as the Maine Geological Survey, have taken the lead in translating these general statements into concrete regulations. Others have not been aggressive in integrating these coastal management policies into their daily functioning. So despite the mandate that all agencies act in ways consistent with these policies, in the absence of any enforcement provisions or concerted executive department leadership to secure compliance, they are not proving adequate to the task of producing coordinated, multi-agency efforts to implement the policies.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

Due to the general phrasing of the Act, accelerated sea-level rise will not affect the actual application of the law. It does, however, broaden the range of variables to be considered in planning to manage hazard area development.

C. GROWTH MANAGEMENT ACT (Comprehensive Planning and Land Use Regulation Act, 30-A MRSA §§4311-4344)

1. Summary of law in general

The purpose of the Growth Management Act is to encourage municipalities to prepare comprehensive plans and to adopt implementing land use ordinances to manage growth so as to protect the integrity of the natural resource base, to control the costs of providing necessary public services, to safeguard the long-term economic viability of the State's economy, and to protect the quality of life. To provide an overall direction and consistency, the Act establishes ten State growth management goals which are to be furthered by the individual growth management efforts of each municipality. In addition, the Act requires that the comprehensive plans of coastal municipalities also address nine coastal management policies contained in the Coastal Management Policies Act. The Act is administered by the Department of Economic and Community Development in coordination with individual municipalities.

The Growth Management Act defines the elements of a comprehensive plan and implementation program and sets up a system of financial and technical assistance to towns to comply with its mandate. The Act as originally passed established a schedule for municipal plan completion ranging from January 1, 1991 through 1996. However, due to budgetary constraints, that portion of the Act was repealed in December 1991. While comprehensive plans are now voluntary, pursuant to March 1992 amendments, if a municipality (excluding those in unincorporated areas) fails to adopt a comprehensive plan consistent with the Growth Management Act by January 1, 2003 (January 1, 1998 if it has received both

planning and implementation grants) it will loose its right to enforce any land use ordinance except minimum shoreland zoning. Adoption of a comprehensive plan which is certified by the State as consistent with the Act also gives a municipality preference for receiving certain State aid, grants and assistance funds.

This Act reflects an underlying policy that "the most effective land use planning can only occur at the local level of government and comprehensive plans and land use ordinances developed and implemented at the local level are the key in planning for Maine's future."[13] The goals and policies identified in the Act are important to unify the plans so that the multiple local efforts coalesce to accomplish consistent ends.

2. Portion of the law relevant to sea-level rise

The Growth Management Act is most relevant to sea-level rise through the goals to be addressed in comprehensive plans and implementing ordinances. The ten goals statements establish some general goals including to develop an efficient system of public facilities; to protect the quality of water resources (e.g., aquifers, estuaries, rivers and coastal areas); to protect critical natural resources including wetlands, wildlife and fisheries habitat, sand dunes, shorelands and unique natural areas; to protect the marine resources industry, ports and harbors from incompatible development and to promote access to the shore for commercial fishermen and the public; and to promote access to surface waters for outdoor recreation. If towns fail to take the possibility of accelerated sea-level rise into consideration when addressing these goals, the resulting plan may be insufficient if there is a significant rise in sea level.

Similarly, the Coastal Management Policies, made applicable to municipal comprehensive planning and land use regulation efforts through the Growth Management Act, establish policies which municipalities may fail to meet if they do not consider the potential threat of accelerated sea-level rise. Under the framework established by the Growth Management Act, Policy Four (to discourage growth in areas made hazardous by sea-level rise) will be furthered primarily through voluntary municipal comprehensive planning efforts, State review for compliance as a condition of awarding implementation grants, State technical assistance, State consistency certification for preference for certain funds, and through the long-range restriction that a municipality will not be able to enforce any land use ordinance (beyond the minimum shoreland zoning requirements) if it has not adopted a comprehensive plan which is consistent with the Act (including furthering its goals) by 1998 or 2003.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

The December 1991 and March 1992 amendments to the Growth Management Act repealed the mandatory deadlines for plan completion (1991-96), and substituted the much less immediate requirement that if a municipality wants to enforce land use ordinances (including zoning), they must have adopted a plan which is consistent with the Act by January 1, 2003 (January 1, 1998 if they receive both planning and implementation assistance grants from the State). The amended Act provides more immediate incentives for compliance only in the form of preferences for certain funds and State financial and technical assistance for local growth management efforts. While the State may review the plans for compliance with the Act in certain circumstances (i.e., when the town applies for implementation assistance or when the town voluntarily requests a certificate of consistency), the State no longer has the ability to *require* towns to adopt plans and ordinances which promote the growth management and coastal policies goals. If a town opts to pursue comprehensive planning and zoning, the elements to be included in the comprehensive

plan, the local processes, and goals to be promoted remained unchanged.

Despite amendments to the law, many towns continue to voluntarily undertake comprehensive planning and to follow through by adopting implementing ordinances. The State will continue to have an important role to play in providing technical assistance to these towns.

To date, the State's technical assistance to municipalities has focused on relative sea-level rise as a result of local land subsidence, rather than on accelerated sea-level rise as a function of global climate change. The information has generally been presented within the context of meeting Policy Four of the Coastal Management Policies Act and has not been integrated into a more general discussion about potential impacts on other goals such as efficient provision of public facilities, or protection of water quality, natural resources, ports or public access.[14]

While it is important that Policy Four has been made applicable to municipalities through the Growth Management Act, additional guidance will be required from the State if it wants to encourage municipalities to plan for the possibility of an accelerated rate of shoreline change rather than just historical rates of change. If towns are expected to take the lead on coastal hazard management, they will need technical and financial assistance to evaluate the appropriateness of different strategies, to establish appropriate standards, and to translate these general recommendations into local plans and ordinances.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

If the possibility of accelerated sea-level rise is not built into the comprehensive plans and implementing ordinances developed as a result of this Act, towns will miss the opportunity to plan for this possibility now when policy adjustments are likely to be less expensive. Due to the general nature of the Act, however, accelerated sea-level rise will not affect the application of the law.

D. MANDATORY SHORELAND ZONING ACT (Mandatory Zoning and Subdivision Control Act, 38 MRSA §§ 435-449) and Guidelines

1. Summary of law in general

The Mandatory Shoreline Zoning Act requires all municipalities to adopt zoning and land use control ordinances applicable to their "shoreland area" which are no less restrictive than minimum guidelines adopted by the Board of Environmental Protection. The shoreland area is defined as "those areas within 250 feet of the normal high-water line of any great pond [10 acres or more], river or saltwater body, within 250 feet of the upland edge of a coastal or freshwater wetland [10 acres or more, as defined], or within 75 feet of the high-waterline of a stream."[15] If a municipality fails to adopt a shoreland zoning ordinance which complies with the minimum guidelines, the Board of Environmental Protection may adopt a suitable ordinance on behalf of the municipality. Shoreland zoning ordinances are enforced by the municipality; however, the State reserves the right to approve proposed amendments, to comment on proposed variances, and to bring actions against municipalities which fail to adopt, administer or enforce shoreland zoning ordinances.

2. Identification of portion of the law that relates to sea-level rise

The Shoreland Zoning Act was designed to promote public health and safety by protecting shoreland resources from degradation and by protecting against unwise development in that area. Of the multiple purposes, several relate to hazards similar to accelerated sea-level rise including: to protect buildings and lands from flooding and accelerated erosion; to control building sites, placement of structures and land uses; to conserve shore cover; and to anticipate

and respond to the impacts of development in shoreland areas.

While not specifically crafted in response to accelerated sea-level rise, the Act does contain water *setback requirements* with the potential to minimize its impacts. The Guidelines[16] established pursuant to the Act prohibit the construction of any new principal or accessory structure or any substantial expansion of an existing structure within the shoreland zone unless that structure is set back 100 feet from the normal high-water line of great ponds and rivers, and 75 feet from the normal high-water line of other water bodies, tributary streams or the upland edge of a wetland. However, in a General Development District (or its equivalent, allowing intensive commercial, industrial and/or recreational use), the setback requirement is 25 feet and there is no setback requirement in a Commercial Fisheries/Maritime Activities District (allowing functionally water-dependent uses).

These setback requirements are supplemented by a second set of provisions which require inclusion of certain land in a *resource protection district* (RP). If land is zoned RP, it is essentially subject to a 250 foot setback requirement since an RP district generally allows only non-intensive uses; no principal structures are allowed for residential, commercial, industrial, governmental or institutional uses. Municipalities are required to include in this RP district:

- All lands within the shoreland area which are also rated "moderate" or "high" value wetlands (freshwater, salt marshes, salt meadows or wetlands associated with great ponds or rivers) by the Maine Department of Inland Fisheries and Wildlife;
- The 100 year flood plains along rivers and adjacent to tidal waters as shown on FEMA Flood Insurance Rate Maps or Flood Hazard Boundary Maps;
- Land along rivers or adjacent to tidal waters which are subject to severe erosion or mass movement, such as steep coastal bluffs.

They may also include other natural areas, public access areas, wildlife habitat areas or similar sites which should be protected from development. However, even if they meet one or more of the above criteria, if they are currently developed or meet the criteria for the Limited Commercial (mixed residential and low intensity business and commercial uses), General Development (intensive commercial, industrial or recreational uses) or Commercial Fisheries/Maritime Activities District (functionally water-dependent uses), they need not be designated as resource protection.

In addition, it should be noted that the law was amended, effective October 1993, to allow municipalities to incorporate a special exception provision to allow construction of a single-family residence in a Resource Protection District if: there is no other location on the property other than in the Resource Protection District where a structure can be built, if it was a lot of record prior to adoption of the Resource Protection District, if the improvements will not be on slopes of 20% or greater, if improvements are located outside of the velocity zone in areas subject to tides and it otherwise complies with the municipal flood plain ordinance, if the structure is 1,500 square feet or less, and it is set back to the greatest practical extent and no less than 75 feet.

The Guidelines also establish *performance standards for piers, docks, wharfs, bridges and other structures and uses extending over or beyond the normal high-water line of a water body or within a wetland.* These may become increasingly important as sea level rises. Among the requirements are provisions that shore access shall be on appropriate soils and shall be constructed so as to control erosion; that the location shall not interfere with developed or natural beach areas; that the facility shall be the minimum size necessary; and that new structures will only be allowed if they require direct access to the water as an operational necessity; and that no existing structures extending beyond the normal high-water line may be converted to residential dwelling units.

Finally, by statute, as part of their shoreland zoning ordinance, coastal municipalities are required to address the *coastal management policies*, including Policy 4 requiring governments to discourage growth in coastal areas made hazardous because of sea-level rise, coastal storms, flooding or landslides. However, addressing this Policy has not been a high-profile concern on the part of municipalities or the Department of Environmental Protection. It is generally assumed that if the municipality meets the express minimum guidelines, no additional provisions are required to address the coastal management policies.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

The Shoreland Zoning Act addresses accelerated sea-level rise to some extent by attempting to protect land that is not already developed from development that would interfere with natural coastal processes. If municipalities comply with the directive that coastal lands subject to flooding and severe erosion should be designated as Resource Protection, that designation should help retain that land in its natural condition so that it can respond to changes in the shoreline. However, municipalities are frequently reluctant to designate land as RP given the limited uses allowed in that district. And the new amendment may allow new residential development in Resource Protection Districts.

Similarly, the building setbacks (100 feet from rivers and great ponds, 75 feet from coastal waters) may be of some help in mitigating possible impacts of accelerated sea-level rise. They are an improvement over no setbacks, but they will be insufficient in many areas. The performance standards for structures extending beyond the high-water line are also helpful since they are designed to minimize the intensity of that development.

However, there are several factors that restrict the Act's ability to address direct or indirect consequences of accelerated sea-level rise. First, there is an inherent tension in the Act since the minimum standards are established by the State but they are to be adopted and enforced by municipalities. A significant number of municipalities failed to pass the required amended ordinances by the July 1, 1992 deadline and face the prospect of the Board of Environmental Protection adopting an ordinance on behalf of the municipality. The portions of the Act most likely to contribute to mitigating the impacts of sea-level rise--the setback standards and the limits on development in the resource protection district--have been the subject of intergovernmental controversy; this does not bode well for local enforcement.

Second, there are many exceptions written into the Act and Guidelines which allow for more intense development than otherwise allowed. Certain mandatory minimum provisions cannot be altered by the municipality; setback requirements are in this category. However, there are ways around this limitation through the designation of a district. For example, a municipality may designate an area which includes some undeveloped land as a General Development District if there is an already discernible pattern of intensive development in the area; this would allow development of substantial intensity to continue in the shoreland zone which will only be required to set back 25 feet from the water. Similarly, while it meets the admirable objective of promoting water-dependent uses, designating an area as a Commercial Fishing/Maritime Activities district will allow intensive maritime commercial and industrial development without requiring any setback. Some local shoreland zoning ordinances allow construction of "marine related structures" without any setback requirement. While intended to accommodate water-dependent uses, there have been reports of this provision being misused to allow construction of structures which greatly exceed the functional requirements of a boat house or trap storage facility, and are suspected of being used primarily for residential purposes.

Finally, there is flexibility for municipalities to deviate from the Guidelines as long as the resulting ordinance is "equally or more effective" in achieving the purposes of the Act. This can take the form of ordinances that are completely different from the recommended districts and uses contained in the Guidelines. Municipalities may deviate from most of the non-setback standards if special local conditions justify a different set of standards.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

This Act assumes a static shoreland position. There are no provisions for adjusting the mandatory minimum setback requirement based on local historical rates of erosion or projections of accelerated rates of sea-level rise. Depending upon the shoreline configuration and type of coast, the 75 foot setback from coastal waters may be completely insufficient to protect a structure over its expected economic life. Municipalities may increase the setback requirements above the minimums to address this problem.

The Act does promote water-dependent uses by encouraging municipalities to designate Commercial Fisheries/Maritime Activities Districts. However, it makes no provision to address the dilemma created by the fact that these critical uses may be the first displaced by rising seas. Any displacement may be compounded by the Guidelines which allow municipalities to designate multiple small Commercial Fisheries/Maritime Activities Districts. This may result in the creation of districts that do not allow any room for relocation beyond the existing site.

E. SITE LOCATION OF DEVELOPMENT ACT (38 MRSA 481-490)

1. Summary of law in general

The Site Location of Development Act provides for State regulation of "development that may substantially affect the environment," including:

- development occupying land or water in excess of 20 acres;
- subdivision of a parcel of land of 20 or more acres into 5 or more lots during any 5 year period (subject to exceptions); or
- construction of a defined structure, meaning buildings, parking lots, roads, paved areas, wharves or other areas to be stripped or graded and not to be revegetated that occupy a ground area in excess of 3 acres.

Such development requires a permit from the Board of Environmental Protection. The standards for development review include: financial capacity, traffic movement, no adverse effect on the natural environment, soil types and erosion, ground water, infrastructure and flooding.

2. Identification of portion of the law that relates to sea-level rise

The standards for review of permit applications relating most directly to accelerated sea-level rise are the standards relating to the natural environment, soil and erosion, and flooding. The developer must fit the development "harmoniously into the existing natural environment" without adverse impacts on existing uses or other natural resources. Secondary and cumulative impacts of development on these resources may be considered, including the impacts on wildlife and fisheries. This standard includes the consideration that there be no unreasonable alteration of natural drainage ways.

The soil standard provides that the development "will be built on soil types which are suitable to the nature of the undertaking and will not cause unreasonable erosion of soil or sediment nor inhibit the natural transfer of soil." This standard would be considered if structures built in areas threatened by accelerated sea-level rise would inhibit the natural transfer of soil.

The standard on infrastructure requires not only that the developer make adequate provision for facilities for the proposed development, but also that the proposed development will "not have an unreasonable adverse effect on the existing or proposed" infrastructure in the municipality or area served by those services. This standard might be applicable if a proposed development, when long-range accelerated sea-level rise projections are considered, might increase local erosion and negatively impact infrastructure serving other development.

Development is only permitted if it will "not unreasonably cause or increase the flooding of the alteration area or adjacent properties nor create an unreasonable flood hazard to any structures." Until repealed effective October 1993, the Act also contained a provision that if the activity is on or adjacent to a sand dune, development will only be permitted if it "will not unreasonably interfere with the natural supply or movement of sand within or to the sand dune system."[17]

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

For those developments subject to review under the Site Location of Development Act, there are adequate standards for the Board to use to prevent development in those areas most vulnerable to accelerated sea-level rise if the Board is convinced by finding that the impacts of development in this area would be "unreasonable." The standards on the natural environment, flooding and soil erosion can be used for this purpose.

However, there are two significant limitations. First, this Act applies only to larger developments. Due to the perceived burden of going through DEP review, many developments are designed so that they only need local reviews and permits. For example, it is very common for subdivisions to consist of just under 20 acres. Very significant development could occur in areas without consideration of these standards by the state-level reviewers if each development is small enough to avoid triggering the Site Location of Development Act review.

The second limitation is that the application standards to the threat of accelerated sea-level rise is fairly subjective. The regulations are fairly detailed for certain requirements related to the standards. For example, they do require erosion and sedimentation plans and permanent erosion control measures, and 50- to 330- foot buffers to protect adjacent waterbodies. Stormwater management systems must be maintained by developers and groundwater runoff must be retained on site so that post-development runoff does not exceed pre-development runoff. There are, however, no specific parallel regulations which flesh out how the standards are to be interpreted with regard to accelerated sea-level rise. Thus if the potential impact of accelerated sea-level rise becomes an issue in a particular proposed development, the interpretation of what constitutes an unreasonable impact on the environment, erosion, or flooding as a result of changing shorelines will be left to the interpretation of the Board without any guidance from regulations.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

The definitions contained within the Act are sufficiently flexible to adjust to changing shorelines so the land area subject to review will evolve with accelerated sea-level rise. The standards are also phrased so that the Board is able to take a wide range of concerns into consideration in assessing unreasonable impact.

No specific amendments appear necessary to allow some consideration of accelerated sea-level rise within the existing standards for review.

The law could be improved to be more directly responsive to accelerated sea-level rise. In attempting to identify development that may substantially affect the environment, the Act has already identified for additional scrutiny some activities taking place in the shoreland area. For example, lots of 40 or more acres do not count as lots unless the proposed subdivision is located wholly or in part within the shoreland zone. However, 1993 amendments removed the requirement that multi-unit housing development of 10 or more units not triggering review under any other standard must receive a permit if it is located in whole or in part in the shoreland area. As the nature and magnitude of threats of accelerated sea-level rise become more concrete, the State should consider designating more activities in shoreland areas as subject to this level of state environmental review. This could be accomplished by amending the definition of development that may substantially affect the environment.

There are currently no regulations which address accelerated sea-level rise and how that should be factored into the Board's assessment of compliance with the general standards of review. The Board should consider including provisions in the regulations which are specifically designed to detail how the erosion, flooding and sand dune standards should be applied within the context of anticipatory planning for accelerated sea-level rise.

F. SUBDIVISION LAW (30-A MRSA §§ 4401-4406)

1. Summary of law in general

This law establishes the minimum criteria for municipalities to use in reviewing subdivisions (defined as the division of a parcel of land (or structure) into 3 or more lots (or dwelling units) within any five year period that begins on or after September 23, 1971. Municipalities have sole subdivision review jurisdiction for subdivisions that are below DEP Site Location of Development Act thresholds, and concurrent jurisdiction over subdivisions that also need DEP review under that Act.

Municipalities may adopt more stringent standards for subdivision review. The Department of Economic and Community Development has developed model subsivision regulations to assist municipalities with implementation of higher standards.

The substantive review criteria address water and air pollution, adequacy of water supply, impact on municipal water supply, erosion, traffic, sewage disposal, impact on municipal solid waste disposal, aesthetic, cultural and natural values, conformity with local ordinances and plans, financial and technical capacity, impact on outstanding river segments, ground water, flood areas, identification of freshwater wetlands, and storm water management.

2. Identification of portion of the law that relates to sea-level rise

The two criteria relate directly to accelerated sea-level rise: erosion and flood areas. The Act directs municipal planning boards not to approve a proposed subdivision unless it finds that:

- the proposed subdivision will not cause unreasonable soil erosion or a reduction in the land's capacity to hold water so that a dangerous or unhealthy condition results;[18] and
- if any part of the subdivision is in a "flood prone area," the proposed subdivision plan will include a condition requiring that principal structures in the subdivision will be constructed with their lowest floor, including the basement, at least one foot above the 100-year flood elevation.

This determination of the 100-year flood elevation is to be made based on Federal Emergency Management Agency (FEMA) Flood Boundary and Floodway Maps and Flood Insurance Rate Maps, and other information presented by the applicant regarding whether the proposed subdivision is in a flood-prone area.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

While neither of these standards for review specifically mention historic or accelerated sea-level rise, they address possible impacts of changing shorelines. The erosion standard is very general and is most often used to address construction practices, such as erosion controls during site preparation, construction and clean-up, and to require revegetation plans which minimize non-point source pollution. However, if accelerated sea-level rise becomes a clear threat, local boards could use this standard to address development that might cause an increase in coastal erosion due to the effects of global climate change.

The flood area standard is much less subjective and tends to be applied in a mechanical fashion. The developer and reviewers generally rely on the FEMA maps to determine whether any part of the proposed subdivision is located in a special flood hazard area. While the precise standards may vary by municipality, most municipalities have adopted floodplain ordinances so they can participate in the National Flood Insurance Program. The model floodplain management ordinance prepared by the Office of Comprehensive Planning contains standards for reviewing subdivisions within the 100 year floodplain. The 1991 model subdivision regulations, prepared by Southern Maine Regional Planning Commission with funding from Maine's Office of Comprehensive Planning, essentially restate the model floodplain management ordinance standards to augment the subdivision statute, so the review under the subdivision ordinance and floodplain management ordinance would be substantially the same. The model subdivision regulations require that:

- all public utilities and facilities be located and constructed to minimize or eliminate flood damage;
- adequate drainage be provided to reduce exposure to flood hazards; and
- the plan not only include a statement that structures in the subdivision shall be constructed with their lowest floor (including the basement) at least one foot above the 100-year flood elevation, but also that the restriction appear in any document transferring or expressing an intent to transfer any interest in real estate or structure.

Many communities have actually required that the first floor elevation be two feet above the flood elevation as part of their floodplain management ordinance, so they may impose this stricter requirement through the subdivision regulations as well.

The extent to which the subdivision regulations will address direct or indirect consequences of accelerated sea-level rise depends in large part upon the accuracy of the FEMA 100-year floodplain maps. If they are based on historic rates of sea-level rise and do not take accelerated sea-level rise into account, they may underestimate the potential problem and allow the construction of subdivisions that are not adequately setback from flood hazards.[19]

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

Accelerated sea-level rise might affect the application of the law by changing the assessment of what is an "unreasonable" burden or impact under the subdivision review standards. These standards are sufficiently flexible to allow municipal boards to focus on an evolving set of concerns as erosion and flooding problems become more evident. However, planning boards will probably not feel sufficiently secure in their knowledge or legal

standing to use these general standards to deny a project or impose conditions based on the potential impact of accelerated sea-level rise unless that threat is very well documented and almost immediate. Barring this, most planning boards will probably not factor long-range projections of accelerated sea-level rise into their review nor will they have the expertise available to them to go beyond a mechanical application of the flood area standards.

G. STATE FLOODPLAIN MANAGEMENT PROGRAM

1. Summary of program in general

Maine's Department of Economic and Community Development is the agency responsible for coordinating the National Flood Insurance Program (NFIP) in Maine. As such, it is responsible for assisting communities in qualifying for participation in the NFIP, assisting with the development and implementation of local flood plain management regulations, and establishing minimum state flood plain management regulatory standards consistent with NFIP regulations and state and federal environmental and water pollution standards.

The NFIP was created in 1968 under the National Flood Insurance Act to provide a nationwide system of federal insurance for property and structures located in designated flood hazard areas. Essentially the federal government makes relatively low-cost, guaranteed insurance available to homeowners to cover flood damage if the municipality in which they reside agrees to direct development away from designated hazardous areas and enforces a floodplain ordinance consistent with the regulations established under the Act.[20]

Maine's DECD has developed model floodplain management ordinances for adoption by municipalities. The standards within the model ordinances vary, depending upon the level of detail in the information provided by FEMA. Detailed flood insurance studies have been conducted for less than half of Maine's communities. The remaining participating communities have only "A" zone maps (designating areas of special flood hazards in which no base flood elevations are determined and an estimated base flood elevation is optional).

The model ordinances require a Flood Hazard Development Permit for any development within any special flood hazard area. The applicant must submit information including data on elevations of base flood, lowest floor of structure, and level of flood-proofing in non-residential structures as well as a certification by an engineer or architect that the floodproofing methods meet the detailed floodproofing criteria of the ordinance. These are all modeled after the federal requirements.

In addition, Maine's model ordinance contains standards for review of subdivision and development proposals requiring the Planning Board to assure that:

- All such proposals are consistent with the need to minimize flood damage;
- All public utilities and facilities are located and constructed to minimize or eliminate flood damage;
- Adequate drainage is provided so as to reduce exposure to flood hazards;
- All proposals include base flood elevation and, in a riverine floodplain, floodway data;
- Any proposed development plan will include a statement that structures on lots shall be constructed in accordance with the Development Standards, and that requirement will be included in instruments of transfer of any property interest.[21]

These are essentially the same requirements included in the 1991 Model Subdivision Regulations, discussed above.

2. Identification of portion of the program that relates to sea-level rise

Since Maine's Floodplain Management Program facilitates participation in the National

Flood Insurance Program (NFIP), it very closely parallels the federal Act. The primary focus of the national program has been to minimize damage from flooding rather than coastal erosion, but coastal erosion is gaining increasing recognition as a hazard which should be addressed by the NFIP.

The NFIP itself does not consider any projected relative rise in sea level in its risk assessment. But the program may affect development in areas which are most vulnerable to the effects of rising sea level. The Act contains a mandate to "constrict the development of land which is exposed to flood damage and minimize damage caused by flood losses" and to "guide the development of proposed future construction, where practical, away from locations which are threatened by flood hazards."[22] However, there is significant debate about the impact of the NFIP on coastal development.[23]

The FEMA hazard zones as originally drawn do not account for the hazards from erosion or sea-level rise. FEMA has commissioned a study "to determine the impact of relative sea level rise on the flood insurance rate maps" and to "project the economic losses associated with estimated sea level rise" for the nation and by region.[24] While some revisions have been proposed to address coastal erosion, no final revisions have been made to the National Flood Insurance Program nor have the maps been revised to reflect sea-level rise projections.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

Maine has taken steps to meet the guidelines of the Act by ensuring that communities incorporate provisions to guide proposed subdivisions and development away from locations which are threatened by flood hazards. However, since consideration of an accelerated rate of sea-level rise is not currently incorporated into the controlling Federal program, Maine's Floodplain Management Program is not designed to address the consequences of accelerated sea-level rise. Statutory amendments to the NFIA will be required before Maine's Floodplain Management Program can be responsive to those concerns.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

As noted above, if sea level rises and coastal erosion and sea-level rise have not been incorporated into the NFIP, claims may outstrip the funds available to pay claims, and financial resources may be allocated in a very inefficient manner to repeatedly floodproof and repair high-hazard properties. Additionally, critical natural resources such as wetlands will not be able to respond to rising sea level by migrating inland if their movement is blocked or impeded by structures or "floodproofing" measures.

H. SUBMERGED LANDS ACT (12 MRSA §§ 552, 558-A - 573)

1. Summary of law in general

This Act establishes the framework for managing State-owned submerged and intertidal lands. It recites that the State owns submerged lands (meaning those lands beneath coastal waters, from the mean low water mark (or a maximum of 1,650 feet seaward of the mean high water mark, whichever is further landward) seaward to the three-mile boundary; land below the mean low water mark of tidal rivers upstream to the farthest natural reaches of the tides; all land below the natural low water mark of great ponds; and the river bed of international boundary rivers out to the international boundary) in trust for the benefit of the public. The Act relinquishes title to, and public trust rights in, submerged and intertidal lands filled before October 5, 1975. It establishes a program for the leasing of the remaining State-owned submerged and intertidal lands. The public has a general right to make use of submerged lands for navigation, fishing and

other public trust uses, but must obtain a lease or easement for permanent structures (occupying for 7 or more months) or similar exclusive uses.

2. Identification of portion of the law that relates to sea-level rise

The portion of the law most relevant to accelerated sea-level rise is that the boundary for State ownership of submerged land is defined in relation to the mean low-water mark or 1,650 feet seaward of the mean high-water mark, whichever is further landward. This boundary will shift as the low- or high-water mark is altered as a result of sea-level rise. The statute does not create these state ownership rights, but rather recites the rights already established by federal statute and case law.

The leasing program does not give particular legal preference to the upland owner for use of submerged lands. However, the Submerged Lands Rules do create a system of littoral zones and setbacks (applicable to projects within 1,000 or less feet of the shoreline) which allows the Bureau of Public Lands to opt to require a letter of no objection from a shoreland owner into whose littoral zone the proposed project extends and establishes setback lines for structures, subject to exemptions.[25]

The Rules clarify that in coastal areas, the mean low water line (the beginning of state ownership except on mud flats) may be established through a survey conducted by a qualified land surveyor and referenced to a National Geodetic Vertical Datum as established by the National Oceanic and Atmospheric Administration.

The standards for review to be used by the Bureau in deciding whether to issue a lease or easement include an assessment of whether the use will unreasonably interfere with public access ways, navigation, fishing, marine uses, public safety. They also provide that the use should not conflict with "those aspects of the Coastal Policies or the Coastal Policy guidelines [citations omitted] which relate to the criteria considered by the Bureau as outlined in these rules."[26] It is unclear whether Coastal Policy 4 would be taken into account in submerged lands leasing decisions.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

The Act does not in itself address any direct or indirect consequences of accelerated sea-level rise since it primarily addresses submerged lands. It does establish the regulatory scheme for lands that convert from upland or intertidal lands to submerged lands as a result of accelerated sea-level rise.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

The definition of submerged lands is tied to the mean low water line, which will shift with accelerated sea-level rise. The affect of accelerated sea-level rise will be to include more land within the scope of the submerged lands scheme as state-owned lands.

I. COASTAL BARRIER RESOURCES SYSTEM (38 MRSA §§ 1901-1905)

1. Summary of law in general

The statute, a mirror of its federal counterpart (U.S. Coastal Barrier Resources Act of 1982),[27] prohibits the expenditure of state funds or state financial assistance for development activities within the coastal barrier resource system. Proscribed development activities include construction or purchase of structures, construction of roads, airports, boat-landing facilities, bridges or causeways, and erosion prevention projects. The only exceptions to the prohibition on expenditure of state funds are for:

- maintenance, replacement or repair of state roads, structures or facilities;

- protection or enhancement of fish and wildlife resources and habitats;
- recreational uses not involving an irretrievable commitment of natural resources;
- scientific research;
- nonstructural shoreline stabilization projects designed to mimic, enhance or restore natural stabilization systems; or
- emergency actions essential to save lives, protect property, public health and safety approved by the Governor.

The coastal barriers identified by the federal Coastal Barrier Resources System are also identified by Maine statute as being part of the Maine Coastal Barrier System. Maps are available through the Maine Geological Survey office and at the registry of deeds for each county.

2. Identification of portion of the law that relates to sea-level rise

This and the parallel federal law are designed to protect and conserve coastal barriers and the adjacent wetlands, marshes, estuaries, inlets and nearshore waters by discouraging development on and adjacent to those barriers. Among the reasons given for their preservation are to retain their natural storm protection function and to prevent development that would be vulnerable to hurricanes, storms and shoreline recession.

3. Analysis of extent to which it addresses any direct or indirect consequences of accelerated sea-level rise

This law provides limited protection for the included undeveloped areas in that it prohibits expenditure of state funds in support of development. It does not restrict private investment. It applies only to a small fraction of Maine's coastline; only 32 coastal barriers (e.g., coves, beaches, islands, points) are included.

4. Analysis of extent to which accelerated sea-level rise might affect the application of the law

Since the law prohibits erosion stabilization projects except for nonstructural shoreline stabilization projects that are designed to mimic, enhance, or restore natural stabilization systems, the areas designated as coastal barriers may decrease in size. In light of the threat of accelerated sea-level rise, it is appropriate to evaluate whether there are other areas which meet the criteria and should be included in the system.

J. ENDNOTES APPENDIX A

1. 38 MRSA § 480-C.
2. 38 MRSA § 480-B (2).
3. 38 MRSA § 480-B (1).
4. An Act Making Unified Appropriations and Alloocations, Ch. 410, HP 215, Legislative Document 283, Sec. G-7.
5. Maine Legislative Service, 116th Legislature, Ch. 522 (Mar. 14, 1994).
6. 38 MRSA § 480-Q.
7. Ch. 355.
8. COASTAL ADVISORY COMMITTEE, COASTAL MANAGEMENT POLICY GUIDELINES (State Planning Office, Augusta, ME, December 1986) at 9.
9. *Id.*
10. MAINE STATE PLANNING OFFICE, MAINE COASTAL PROGRAM, IMPLEMENTATION OF MAINE'S COASTAL POLICIES, 1986-1988, (submitted to the Maine State Legislature, Jan. 1, 1989) at 9-10.
11. *Id.* at 21, 23.
12. See the specific discussion of those Acts.
13. 30-A MRSA § 4312(1)(E).
14. The publication, COASTAL MANAGEMENT TECHNIQUES: A HANDBOOK FOR LOCAL OFFICIALS, prepared by Land & Water Associates and Maine Tomorrow for the Department of Economic and Community Development, October, 1988, advises that growth in hazard areas should be prevented or

discouraged to protect public health and safety, reduce public costs resulting from damage to public and private facilities, and to help maintain the health of natural systems which depend on floods and sediment to sustain them. (p. 35) It advises that sand dunes and beach systems should not be artificially "stabilized" but rather must be free to "migrate" landward with rising sea level to preserve their storm barrier function. This publication recommends that communities gather more information about natural processes occuring in their area. It recommends that towns work with Maine Geological Survey to determine their vulnerability to the effects of sea-level rise, to identify and map other hazard areas, and to determine shoreline erosion rates. It also recommends a review of FEMA maps for flood-prone areas. The publication recommends public education, vegetation maintenance, regulatory and investment responses to hazard area management. Local ordinances to restrict development in hazard areas, such as floodplain management ordinances, are identified as a first step. Additional regulatory efforts suggested may include: prohibiting structures in all floodplain areas including intermediate hazard zones, prohibiting structures and fill adjacent to and in wetlands, requiring that structures and fill be well set back from the edge of wetlands, and requiring a minimum structure elevation of 2-3 feet above flood levels to maintain a margin of safety. It also recommends that the public obtain a property interest (easement, lease or purchase) in certain hazard areas and limit use to passive recreation or other public use, that public investments be planned to avoid hazard areas, that funding priority be given to relocate public facilities out of hazard areas, and that technical and financial assistance be made available to individuals seeking to relocate out of hazardous areas (pp. 35-39).

15. 38 MRSA § 435.

16. State of Maine Guidelines for Municipal Shoreland Zoning Ordinances, 06-096 Department of Environmental Protection Chapter 1000, Mar. 24, 1990.

17. Public Laws, 116th Legislature, 1993 First Regular Session, Ch. 383, § 23 repealing 38 MRSA § 484, sub-§8..

18. 30-A MRSA § 4404(4).

19. For further discussion, see Chapter 5, National Flood Insurance Program.

20. See Chapter 5, p. 5-28 for a more complete discussion of the National Flood Insurance Program.

21. Department of Economic and Community Development, "Model Floodplain Management Ordinance," Article VIII, A-E.

22. National Flood Insurance Act, 42 USCS § 4001(e)(2).

23. For further discussion, see B. MILLEMANN & E. JONES, STORM ON THE HORIZON: THE NATIONAL FLOOD INSURANCE PROGRAM AND AMERICA'S COAST, (Wash., DC: Coast Alliance, Sept. 1989) and R.H. PLATT, ET AL., COASTAL EROSION: HAS RETREAT SOUNDED? Program on Environment and Behavior, Monograph No. 53, (Institute of Behavioral Science, University of Colorado, 1992) at 26-37.

24. P.L. 101-137, § 5, 103 Stat. 825 (Nov. 3, 1989).

25. Bureau of Public Lands, Submerged Lands Rules, 1.6 B (11).

26. *Id.*, 1.7 C (8).

27. 16 U.S.C. § 3059. *See* discussion, Chapter 5.

Appendix B

SELECTED STATE/REGIONAL POLICY RESPONSES TO ACCELERATED SEA-LEVEL RISE AND COASTAL EROSION

A. APPROACHES TO ANTICIPATED ACCELERATED SEA-LEVEL RISE AS A RESULT OF GLOBAL CLIMATE CHANGE

While some states have started to address the issue of planning for accelerated sea-level rise as a result of global climate change, even the most advanced states are only in the very preliminary stages of developing a unified response strategy. Many are still in the problem recognition stage, where they are beginning to understand the potential scope of the problem, but have yet to translate that recognition into any specific studies, statutes or programs. The following section summarizes activities in selected non-Maine jurisdictions.

1. Washington State

The State of Washington became very active in planning for accelerated sea-level rise through its Sea Level Rise Response Program, begun in 1988. Through that program, it evaluated the scientific literature on vertical land movement in the western Washington area, mapped broad patterns of vertical land movement, supported additional research on subsidence in Puget Sound, and began to study "near term, internal policy alternatives."[1]

The following policy issues were identified in Washington: siting standards and protection alternatives for coastal facilities; management of old coastal solid and hazardous waste disposal sites; shore protection alternatives; wetlands and shallow water habitat protection alternatives; and sea water intrusion responses.[2]

Washington's studies emphasize the theme that in the face of likely but uncertain levels of accelerated sea-level rise, the "first steps" toward regulation addressing this problem "can and should be done for other fiscally prudent reasons."[3] For example, if Washington accepts the theory that global warming will cause greater frequency of severe storms, a prudent response may be to require stricter design standards. The State's design standards already reflect safety measures based on "hydraulic design storms," or standards based on the projected frequency and severity of storm events (e.g., requiring that buildings be constructed in such a way or location to avoid damage from a 25-, 50- or 100-year storm). Using the "other fiscally prudent reasons" test, one response option would be to increase those design standards to require design to avoid damage from a less frequent, more severe storm event. Washington's studies suggest this type of regulation may be more politically acceptable than others based solely on anticipated sea-level rise, especially if regulations

based on sea-level rise are perceived to interfere with the use of private property. However, the State has not yet acted to incorporate the more rigorous design standards.

The State of Washington has expressed interest in conducting a formal cost-benefit analysis of specific response options if it can obtain sufficient funding. Such an analysis might be used to evaluate the different problems posed by inundation of private property in areas of high- and low-intensity development.

Douglas Canning, Sea Level Rise Project Manager of the Shorelands and Coastal Zone Management Program at the Washington State Department of Ecology, believes that such an analysis would show that highly-developed, low-lying waterfront areas, such as those in Seattle, Tacoma, and Olympia, would need to be structurally protected at some public cost because relocation would be far more costly than protection. On the other hand, he expects that private land of lower density development, such as agricultural, rural residential, and timber lands, may well cost more to protect than they are presently worth, and therefore it is unlikely that public monies should be spent to protect them.

The State of Washington's Sea Level Rise Response Program has evolved into the Coastal Erosion Management Program. The focus is on protecting natural coastal systems so they are able to respond to shoreline changes regardless of the driving force behind the change. Components of this program include working with local governments to prepare a programmatic environmental impact statement on the impacts of shoreline armoring, and developing additional information and policies on shoreline erosion control. The Sea Level Rise Response Program also facilitated use of coastal zone management funds for a sea-level rise impact study conducted by the City of Olympia.

2. California

Various agencies in California have also begun to focus on global climate change in general, and sea-level rise in particular. The April 1989 Assembly Natural Resources Committee "blueprint" for State response[4] identifies damaging shoreline erosion, decline in delta water quality, damage to structures and loss of recreational beaches, increased need for shoreline protective devices, and expensive modifications to port facilities as possible negative impacts of sea-level rise. It recommends legislation to require agencies to begin to consider global warming impacts, but does contain specific policy recommendations.

In the San Francisco Bay Area, planning for specific areas at risk from flooding is encouraged, and varying strategies are emphasized, depending on the type of coastal feature and the threat of risk from sea-level rise. In its report, the San Francisco Bay Conservation and Development Commission (BCDC)[5] recommends that planners for the area take global climate change and accelerated rates of sea-level rise into account. The report also notes that, due to local sedimentation patterns, land movement and other factors, inundation will occur at variable rates in the Bay area, and this needs to be accounted for through planning. Not surprisingly, the report finds that marshes and other tidal wetlands are at the greatest risk from flooding and notes that the economic costs of protecting them may be prohibitive.

BCDC recommendations are based on extensive research and mapping of various areas around San Francisco Bay. BCDC has also conducted detailed studies to assess expected impacts associated with tidal flooding of urban development, the creation of an inland sea in the Delta, increased salinity levels in Suisun Bay and the Delta, flooding and impeded drainage in low-lying shoreline areas, and the loss of tidal marshes and managed wetlands. These studies have resulted in the development of an engineering design review process to be used by designers and reviewing authorities to assure safety from hazards of tidal flooding.[6]

The six adopted policies[7] regarding sea-level rise are limited to the Bay Conservation and Development Commission's jurisdiction,

which covers activities in San Francisco Bay and landward to 100 feet from the shoreline. The policies are mandatory design standards rather than merely advisory criteria directing that sea-level rise be considered. While some flexibility is allowed, the Commission has set a range of rates within which engineers may work with twice the historic rate of sea-level rise established as the minimum standard assumed rate. This standard was based on data which show a doubling of the rate of sea-level rise in the Bay over the last 20 years. Engineers for all proposed projects are required to defend the specific rate of sea-level rise chosen for a particular project proposal before the Commission.

The California Coastal Commission staff has also undertaken detailed research on projected impacts on coastal wetlands, beach erosion, cliff retreat, and harbors and structures.[8] This research may eventually lead to the development of specific policy responses, but no specific implementation action has been taken since the 1989 study.[9]

3. Oregon

Oregon has begun to review possible impacts from global warming through the development of a preliminary report illustrating the range of changes that might result from global warming.[10] The report characterizes itself as speculative rather than predictive, but identifies sea-level rise concerns about shoreline retreat, flooding of coastal areas, and salt water intrusion. Following an opportunity for public comment and debate, the Oregon Department of Energy plans to develop a second report which will include recommendations for actions by State agencies.

In addition to the Department of Energy's report, James Good of Oregon State University has also conducted a recent study of the Siletz area cell on the Oregon coast to analyze the effectiveness of Oregon's laws and regulations regarding shoreline protection and beach access.[11]

Good found that State land use planning goals, regulations, and legislation have failed to adequately control the building of hard shoreline protective structures, with the result that considerable amounts of sediment are "locked up" behind such structures, and are thus unable to migrate and nourish eroding beaches.

According to this study:

> despite the fact that Oregon has one of the most far-sighted set of state land use policies in the United States ... including three land use goals that focus on natural hazards, the hazard management strategies actually employed by landowners depend more on structural mitigation than on hazard avoidance. Along the Siletz cell, the result has been the proliferation of SPSs [shoreline protective structures].[12]

The study also found that setback requirements in the research area have proven inadequate to prevent the construction of SPSs, and that a large number of lots too shallow to provide for erosion protection continue to result from subdivision.

Good asserts that the building of hard erosion control structures in the coastal zone is actually encouraged and "institutionalized" by the failure of local planning decisions to give adequate weight to State goals and regulations directing that non-structural solutions are to be "preferred".[13] He predicts that more SPSs will further exacerbate the rate of coastal erosion, which will create even more demand for permits for these structures.

To minimize coastal erosion, coastal hazards, and the use of hard erosion control structures, the study recommends concentrating on hazard avoidance as the "fundamental principle" for guiding development.[14] Where the use of these hard structures is unavoidable, Good suggests that compensation for "unavoidable adverse impacts—individual and cumulative—should be required,"[15] similar to the system Oregon uses to compensate for adverse impacts to wetland resources.

Coast-wide construction setbacks and comprehensive area management planning for the various "cells" of the Oregon coast are also suggested as useful strategies in planning for sea-level rise. In addition, Good recommends increasing State oversight of local land use decision making in flood and erosion hazard areas to help insulate local decision-makers from some of the pro-development political pressures they now feel.

More recently, in October 1993, the Oregon Coastal Natural Hazards Policy Working Group published an "Issues and Options" report which incorporates both the types of suggestions outlined above and public reaction.[16] Participants discussed many coastal management issues. Sea-level rise was not a separate issue, but rather was addressed through related issues such as coastal erosion and flooding. Policy options and suggestions considered in the report included: instituting a mandatory preference for soft erosion control strategies over hard structural solutions; prohibiting hard shoreline protective structures outright; eliminating public subsidies for development of hazardous areas; classifying sites by susceptibility to natural hazards; using public funds to buy lots made unbuildable by setback requirements; instituting more restrictive setbacks; instituting tax credits for the donation of coastal hazard properties to state or local governments; imposing stricter limitations on variances; prohibiting development in high hazard areas; imposing more restrictive lot coverage requirements; and requiring hazard disclosure to potential buyers. The report also discusses seismic issues unique to the west coast.

4. New Hampshire

New Hampshire's Office of State Planning commissioned a 1987 technical report that recommends a three-step process to approach the issue of how sea-level rise should be factored into coastal zone planning.[17] The three steps are to delineate impact areas, inventory potentially affected populations, assets and resources, and develop regulatory and legislative responses.

Based on the recommendations of this report, in 1991 the Rockingham Planning Commission published a "Preliminary Study of Coastal Submergence and Sea Level Rise in Selected Areas of New Hampshire." It describes the phenomenon of relative sea-level rise, examines the various projections for accelerated sea-level rise, and identifies potentially threatened areas by applying sea-level rise predictions to local area maps, taking account of local topography, water bodies, and patterns of development.

The report contains general suggestions for managing coastal areas in anticipation of likely but uncertain increasing rates of sea-level rise. The report stresses the importance of anticipating the phenomenon well in advance in order to minimize both costs and environmental damage:

> Some of the most cost-effective solutions to property losses that could arise take several decades to implement. Future dislocations of development can be greatly lessened by directing development away from areas that lie within the range of likely sea level rise.[18]

The report finds the risk to developed areas to be "relatively minor" in the study areas given a projected sea-level increase of 5 feet, discounting the effects of storm flooding. It finds that the structures at risk under this scenario do not account for much more than those already at risk from current storm generated flooding: "For the most part, structures within the submergence areas are already at risk from storm driven flooding."[19]

The report is less optimistic about the fate of coastal wetlands, and cites EPA estimates of wetlands losses of 26% to 82% under a one meter rise in sea-level. The report cites two basic problems for wetlands migration: 1) that sea-level will rise too rapidly for wetlands to keep pace in their upland migrations and 2) that development adjacent to wetlands will effectively prevent that migration if landowners

erect hard structures such as bulkheads to protect their properties. Noting that there is little that coastal planners can do about the first problem, but that the second problem can be mitigated by coastal land use regulation, the Rockingham County report suggests a few strategies in this regard:

> Such approaches might include: acting now to limit future development in areas where wetlands are likely to migrate to; allowing development in sensitive areas only on the condition that no attempt will be made to protect the property (via bulkheads, seawalls, etc.) from advancing wetland, and modifying the federal flood insurance program to greatly discourage or disallow reconstruction of structures damaged as a consequence of sea level rise.[20]

The report stresses federal, state, and local cooperation "to devise fair and equitable ways to abandon development that is in the path of wetland migration,"[21] but it does not suggest any concrete or particular strategies which New Hampshire should follow. However, it does stress that preventive planning is both more effective in minimizing losses of natural resources such as wetlands and is also cheaper than after-the-fact regulation.

5. Massachusetts: The Cape Cod Commission

Barnstable County's Regional Policy Plan[22] identifies the peninsula of Cape Cod, Massachusetts, as an area which is particularly vulnerable to the effects of erosion from storms and wave processes, as well as to potential problems posed by anticipated sea-level rise. By April 1990, the town of Barnstable had held two conferences on the potential effects of sea-level rise on the community as part of an effort to determine what steps community leaders could take to alleviate these effects.[23] Since that report, the County of Barnstable has incorporated specific measures to control the detrimental effects of sea-level rise on Cape Cod into its Regional Policy Plan.

The plan addresses accelerated sea-level rise in its section on coastal resources.[24] The plan notes that the present rate of erosion on the Cape results in the loss of "24 acres of upland per year, or 1080 acres by 2025." The plan compares this present rate of annual erosion with EPA's mid-range predictions, and also uses a study by Woods Hole Oceanographic Institution geologists which projects a loss of 3900 acres, based on a 1.57 foot rise in relative sea-level. The plan also notes that, at the time it was written, existing laws and regulations did not specifically address projected increases in the rate of relative sea-level rise.

The Cape Cod Regional Management Plan enumerates certain policies to deal with accelerated sea-level rise, in addition to other measures designed to control erosion or to allow for the migration of coastal features at the historic rate of sea-level rise. One goal is "[t]o limit development in high hazard areas in order to minimize the loss of life and structures and the environmental damage resulting from storms, natural disasters and sea level rise."[25] To achieve this goal, the section enumerates minimum performance standards, one of which reads:

> In order to *accommodate possible sea level rise* and increased storm intensity, ensure human health and safety, and protect the integrity of coastal landforms and natural resources, all new buildings, including replacements, within FEMA A and V flood zones shall be designed one vertical foot above existing FEMA base flood elevation and state building code construction standards.[26]

To address the problem of eroding bank and dune systems, another standard specifies that:

> [i]n areas where banks or dunes are eroding, the *setback* for all new buildings and septic systems to the top

> of the coastal bank or dune crest *shall be at least 30 times the average annual erosion rate* of the bank or dune. This rate shall be determined by averaging the erosion over the previous 30-year period at a minimum."[27]

Other standards under this goal section include a prohibition on development or redevelopment within FEMA V flood zones, although allowing an exemption for certain water-dependent uses where "no feasible alternative" exists.[28] A similar prohibition includes similar exceptions, on development and redevelopment on barrier beaches and coastal dunes.[29] There are also prohibitions on the building or expansion of public infrastructure in flood hazard zones.[30] Another performance standard prohibits the reconstruction of buildings which have been damaged at greater than 50 percent of their tax assessment valuation in flood hazard zones, on coastal banks, dunes, or barrier beaches unless they comply with specified standards for new development.[31]

6. New York: Long Island

In New York State, a hazard management plan has been proposed for the South Shore of Long Island to deal with accelerated sea-level rise and its attendant problems of increased erosion, more frequent coastal storms and resulting dislocation.[32] The South Shore Hazard Management Plan works within the framework of the New York State Coastal Erosion Hazard Areas Act.[33]

Long Island is especially vulnerable to the effects of sea-level rise in that it is characterized by extensive barrier beaches fronting on the Atlantic Ocean. At the same time, areas of its coastline are highly developed. The area also provides recreation benefits to the many residents of the metropolitan New York area. The Long Island Regional Planning Board has developed a proposed management plan for the island's south shore addressing these problems and prioritizing goals for the management of various sub-areas on Long Island's south shore.

The Long Island plan stresses the importance of planning and advanced identification of critical natural resources and undeveloped areas through extensive mapping. Responses to erosion and sea-level rise are to be tailored to specific areas. According to the plan, relatively undeveloped hazard areas are to be protected from further development; isolated structures are not to be rebuilt after destruction; building of new structures in hazard areas is discouraged; in built-up areas, some additional protective structures might be allowed if there is no significant amount of pristine shoreline.

The plan encourages "soft" management strategies, such as using sand from south shore inlet maintenance dredging to nourish downdrift beaches.[34] It discourages rebuilding in V Zone Hazard areas (determined by flood insurance rate maps) for private structures damaged over 50%. Sea-level rise is specifically mentioned, although no specific rate assumptions or timetables for retreat are given. The plan recommends that:

> a *strategic retreat* from vulnerable coastal areas is the rational approach to follow. While it is not recommended that wholesale abandonment of existing public facilities and private development located in coastal areas should occur in advance of actual sea level rise acceleration, structures should be removed from vulnerable locations over the long-term when subject to substantial damage from erosion and flooding impacts.[35]

In general, the plan designates thirteen segments of Long Island's south shore to be treated as distinct regional management units. It describes specific, detailed recommendations for shoreline management for each coastal segment. These recommendations are tailored for each segment by taking into consideration natural and anthropogenic coastal features and population densities in setting priorities for each section.

The plan is consistent with other jurisdictions in placing emphasis on the public value

of the coastline, both as public recreation and as flood and storm protection. It specifically recognizes that private coastal landowners, particularly those in high risk areas, may impinge on the rights of other members of the public through their activities in such high risk zones.

The executive summary of the plan asserts, "[p]roperty owners should not adversely impact coastal processes to the detriment of adjacent shoreline areas."[36] In the coastal high risk zone, or the Federal Flood Insurance V zone, the plan notes that the public should not be expected to pay for damage to private property: "Private interests ... should bear the burden of the loss of such structures and/or property due to erosion and flooding. Within this Coastal High Risk Zone, there is minimal public interest in making government expenditures for maintaining private development."[37] The plan also recommends that changes be made to the National Flood Insurance Program, specifically that "the elimination of federal flood insurance coverage for structures located on barrier islands and spits must be considered."[38]

The plan states a preference for retreat from high hazard areas, where feasible. It also recognizes that most often severe damage will occur as the result of storm events, and that often there are not adequate planning mechanisms in place to deal with the problems communities face in the wake of a severe coastal storm. It therefore recommends "that post-storm community re-development plans be prepared in advance to deal with those instances where a severe storm event destroys a large portion of a community and government can neither prevent re-development through regulation nor acquire properties because of a lack of financial resources."[39]

On Long Island, planners realize that preparation for the aftermath of coastal storms is an integral component of planning in areas at great risk from erosion. In very high risk areas where the preferred policy on Long Island is one of "strategic retreat," it is noted that the alternative may be chaotic and involuntary retreat at any rate:

> The policy of strategic retreat from vulnerable coastal areas in light of potential acceleration in the rate of sea level rise and subsequent flooding of low lying coastal areas is the rational approach to follow.... The alternative of gradual retreat is involuntary retreat as a result of disaster situations.[40]

Communities are to ensure that post-storm development does not exceed planned density levels, and to that end, it prohibits public expenditures for infrastructure which would have the effect of encouraging denser development on coastal barriers. In keeping with the view that the coastal barrier islands represent a significant recreational resource, communities are encouraged to consider expenditures on infrastructure for water-dependent uses facilitating public access, such as beaches, parks and fishing piers.[41] In addition, in certain high-risk coastal areas owned by the state where residents currently hold long-term leases, the plan proposes a gradual abandonment policy under which those leases are to be phased out.

The Long Island plan also recommends government purchase of certain undeveloped coastal lands for purposes of recreation and open space.[42] Again, this is in keeping with the policy that such areas provide needed recreation areas for the public at large, and that these areas are being threatened by both sea-level rise and increased coastal development.

Other priorities involve the protection of coastal wetlands and coastal bluffs, which the plan notes are threatened by accelerated rates of sea-level rise. The plan stresses the need for public awareness of the possible negative effects of bulkheads and other hard erosion control devices on wetlands, and emphasizes planning to provide for adequate buffer zones.[43]

With respect to coastal bluffs, the plan emphasizes that permit decisions regarding armoring structures should include consideration of the local sediment budget and the structure's possible negative effects on downdrift beach areas. Mitigation schemes are contemplated, such as conditioning permits for

construction of erosion control devices on a requirement to replace sand on certain downdrift beaches deprived of sediment by the artificial structure. The plan also differentiates bluffs from dunes, and points out that attempts to stabilize them may have negative impacts on local sediment budgets: "unlike the dunes, bluffs are a relic feature and cannot be expected to recover after an erosional event; the erosion of bluffs may have a more important role in the sediment budget ... than the role of dune erosion."[44]

In general, the Long Island plan is a comprehensive and flexible document, which, while it advocates a gradual retreat from the shoreline in erosion hazard areas, modifies its recommendations according to pre-existing coastal land uses and densities. It achieves this through treating the various coastal regions of Long Island separately, from the highly developed sections to the west, to the relatively pristine areas to the east.

B. SELECTED COASTAL EROSION RESPONSE STRATEGIES

Many states have adopted specific policies to minimize loss due to coastal erosion caused by coastal storms and the continuation of historic submergence. These policies have been developed in response to historical rates of change over the last century, and rarely incorporate any assumptions anticipating an increase in the rate of sea-level rise during the next century as a result of global climate change.

Since these laws are designed to mitigate erosion losses if historic rates continue into the future, as currently written, they may prove inadequate if future sea-level rise significantly exceeds historic rates of change. However, selected statutes are surveyed here for the purpose of identifying innovative land use management techniques that may be amenable to modification for application in strategies designed to respond to accelerated rates of sea-level rise.[45]

State erosion response legislation has been characterized as falling into three general groups: erosion management laws (e.g., New York, Pennsylvania, South Carolina), coastal zone management laws with an erosion element (e.g., Florida, Rhode Island, North Carolina, Michigan), and related resource management laws (e.g., New Jersey, Massachusetts and Texas).[46] This summary focuses on laws in the first two categories.

1. Rhode Island

The State of Rhode Island's Coastal Resources Management Program identifies sea-level rise as a concern, but it does not specifically mention an accelerated rate of sea-level rise as a result of global climate change. Nevertheless, the plan does address the problems caused by sea-level rise at historic rates through policies specifically tailored to protect various types of coastal environments, and varying densities of development on those features.

The Program is based on a system which classifies all waters of the state into six quality categories, based primarily on the characteristics of the adjacent shoreline. Those categories include type 1, conservation areas; type 2, low intensity use; type 3, high intensity boating; type 4, multipurpose waters (i.e. those that support or could support both commercial and recreational activities, as well as providing good fish and wildlife habitat); type 5, commercial and recreational harbors; and type 6, industrial waterfronts and commercial navigation channels.

Recommended responses to shoreline erosion and possible sea-level rise in Rhode Island vary according to the type of shoreline feature involved as well as type of waters to which they are adjacent. However, standard setbacks of a minimum of 50 feet "from the inland boundary of the coastal feature" are required, "except in areas designated by the Council as Critical Erosion Areas"[47] In critical erosion areas, setbacks of 30 and 60 times the average annual erosion rate are required, the

more stringent standard being reserved for higher density development.[48]

The section entitled "Shoreline Features" specifically mentions sea-level rise, albeit at historic rates:

> All shoreline systems are dynamic, and change their shape and character in response to storms, currents, human modifications, and *the gradual rise in sea level....* The present rate of sea-level rise is about one foot each century. A foot of vertical rise, however, accounts for an inland retreat of some 30 feet along low-profile shores."[49]

The plan asserts that most erosion to the Rhode Island Coast occurs not as a result of gradual sea-level rise, but rather from discreet storm events.

As has been noted, the plan provides for general coastal setbacks as well as more stringent ones for "Critical Erosion Areas." These critical erosion areas are mapped under 4 categories, (A-D), with annual estimated erosion rates from 2-2.5 feet for category A, to 5-6 feet for category D. Corresponding required setbacks range from 75 and 150 feet, (for four or fewer dwelling units, and for more than four dwelling units, respectively) in category (A), to 180 and 360 feet, respectively, in category (D).

Categories of Critical Erosion Areas are determined by the Rhode Island Coastal Resources Management Council independent from decisions regarding adjacent water quality. They are shown on detailed coastal planning maps included in the Rhode Island Coastal Resources Management Program document, and appear to cover only the areas of the coast most exposed and prone to erosion.

There is a variance mechanism for applicants who cannot meet such standards, but the granting of a variance "does not remove the applicant's responsibility to comply with all other Program requirements."[50] Applicants must also show that proposed alterations are "the minimum necessary to remove an undue hardship"[51] and will not cause "significant adverse environmental impacts or use conflicts,"[52] among other requirements. Another section contemplates Special Exceptions for projects which do not comply with the program's goals for projects serving "a compelling public purpose" which are water-dependent, or for which no alternative sites exist.[53]

The Plan also provides for post-hurricane emergency procedures. These procedures provide for a *temporary moratorium* on reconstruction of structures "to remain in effect for a maximum of 30 days from the disaster declaration." The moratorium should provide local officials time to assess damage, to consult with state officials, to act on possible ameliorative response actions in high damage areas such as the purchase of open space, and to "make a policy decision about re-permitting according to best available options for hurricane mitigation."[54]

The plan also emphasizes protection of coastal features, including coastal beaches and dunes, barrier beaches, coastal wetlands, coastal cliffs, bluffs and banks, rocky shores, and man-made shores.[55] It notes that "beaches are dynamic, flexible features," and that hard erosion control structures may interfere with the natural processes of dynamic coastal features.[56]

The plan states that this dynamism is particularly true for barrier beaches, which it describes as being "particularly ill-suited to human occupation."[57] It categorizes beaches as undeveloped, moderately developed, and developed, and its restrictions on development vary according to the level of development, from no new construction on undeveloped barrier beaches to requiring construction lines on three specific barrier beaches classified as developed.[58]

Regarding coastal wetlands, the Rhode Island plan notes that, "[b]ulkheading and filling along the inland perimeter of a marsh prevents inland migration of wetland vegetation as sea level rises." The plan therefore forbids use of "structural shoreline protection" except

when "the primary purpose is to enhance the site as a conservation area and/or a natural buffer against storms" in Type 1 waters, and allows such structures only pending permit approval in Type 2 waters.[59]

The discussion regarding coastal bluffs and cliffs notes that their erosion may actually provide needed sediments to down-drift beaches, and therefore instructs the Council to "encourage the use of non-structural methods to correct erosion problems associated with coastal cliffs, banks, and bluffs adjacent to Type 1 and Type 2 waters."[60] Although hard erosion control strategies are to be discouraged in these areas, they may be permitted under certain exceptional circumstances. However, the Council is instructed to:

> weigh the impact of the proposed structure on the supply of sediments to nearby beaches. Where the Council finds that a substantial reduction or elimination of sediment is likely to result, and that natural erosional processes affecting the nearby beach will thereby be accelerated, it shall deny its Assent [for the permit]."[61]

The plan also deals with rocky shores and with man-made shorelines,[62] but it points out that "[t]he presence of isolated seawalls, bulkheads, and similar structures does not constitute a manmade shoreline, as the term is used in this Program."[63]

In Rhode Island, the Coastal Resources Management Council "may order restoration or removal [of isolated structures] where it finds that the structure poses a hazard to navigation, interferes with the public's right of access to and along the shore, causes flooding or wave damage to abutting properties, or degrades the scenic qualities of the area."[64]

2. South Carolina

South Carolina's Coastal Tidelands and Wetlands Law[65] implements an aggressive and detailed beach preservation policy. The legislative findings section[66] of this statute notes that previously existing state legislation (prior to 1988) "did not provide adequate jurisdiction to the South Carolina Coastal Council to enable it to effectively protect the integrity of the beach/dune system."[67] It cites the importance of the beach/dune ecosystem to the State as a protective storm barrier, as a basis for tourism, as habitat for wildlife, and as providing recreational opportunities for South Carolinians.[68] In addition, this section notes that the system is threatened by development too close to the shore and specifically points to hard erosion control devices as exacerbating the problem of shoreline erosion:

> These armoring devices have given a false sense of security to beachfront property owners. In reality, these hard structures, in many instances, have increased the vulnerability of beachfront property to damage from wind and wave while contributing to the deterioration and loss of the dry sand beach which is so important to the tourism industry.[69]

In addition to this finding, the section points out that erosion is a natural process, which causes problems for humans "only when structures are erected in close proximity to the natural system." The section specifically notes that it is important to afford the dynamic beach/dune system space to erode and reform without hindrance by hard erosion control devices and other structures. It also states a preference for retreat from exposed beaches:

> It is in both the public and private interests to afford the beach/dune system space to accrete and erode in its natural cycle. This space can be provided only by discouraging new construction in close proximity to the beach/dune system and encouraging those who have erected structures too close to the system to retreat from it.[70]

It is the stated policy of the law to "protect, preserve, restore and enhance the beach/dune system"[71] To achieve this general goal, "local comprehensive beach management plans" are required within the context of "a comprehen-

sive, long-range beach management plan," and the plans are "to include a gradual retreat from the system over a forty-year period."[72] Other ancillary policies aim to "severely restrict the use of hard erosion control devices ... and to encourage the replacement of hard erosion control devices with soft technologies," encourage erosion control techniques with low environmental impacts, promote beach nourishment, preserve and promote public beach access, involve local governments in the coastal planning process, and to "establish procedures and guidelines for the emergency management of the beach/dune system following a significant storm event."[73]

The forty-year gradual retreat policy for areas of the South Carolina coast is based on a setback of forty times the annual erosion rate.[74] The policy requires the Council to establish a baseline paralleling the shoreline along the "crest of the primary oceanfront sand dune."[75] In addition, a setback line:

> must be established landward of the baseline a distance which is forty times the average annual erosion rate or not less than twenty feet from the baseline for each erosion zone based upon the best historical and scientific data adopted by the council as part of the State Comprehensive Beach Management Plan.[76]

The law also requires mandatory periodic revision of the baseline,[77] and "monumented and controlled survey points" in each Atlantic coastal county are required.[78] Exempted structures not subject to the setback include: wooden walkways, small wooden decks, fishing piers providing public access, golf courses, "normal landscaping," pools, and specially permitted structures.[79]

An aggrieved landowner provision is also included, whereby a landowner who feels that the setback line is in error "must be granted a review of the setback line, baseline, or erosion rate, or a review of all three."[80] These requests for review are to be forwarded to the "appropriate committee of the council and handled in accordance with the council's regulations on appeals."

The Act only allows structures other than erosion control devices to be rebuilt seaward of the baseline by special permit if:

> the structure is not constructed or reconstructed on a primary oceanfront sand dune or on the active beach and, if the beach erodes to the extent the permitted structure becomes situated on the active beach, the permittee agrees to remove the structure from the active beach if the council orders the removal ... [and] the use of the property authorized under this provision, in the determination of the council, must not be detrimental to the public health, safety, or welfare.[81]

Parties aggrieved by a decision by the Council to grant or deny such a permit have the opportunity to appeal to the full Council.[82]

The Act also provides for the gradual phasing out of erosion control structures and devices seaward of the setback line by applying an incremental system under which they may not be rebuilt in the event of damage, with the threshold of percent damage decreasing with time. Thus, erosion control structures destroyed more than eighty percent may be rebuilt until 1995 and more than two-thirds until 2010. After June 30, 2010, an erosion control structure may only be rebuilt if it is less than fifty percent destroyed.

In addition, the Act limits construction of habitable structures seaward of the setback line by providing that structures are limited to less than five thousand square feet of heated space, no part is seaward of the baseline (dune line), and that no erosion control devices are incorporated into the structure. Repairs and maintenance are allowed on if the total result is not greater than five thousand square feet of heated space. Repair or renovation is allowed for structures not damaged beyond repair. Replacement of structures destroyed by natural causes is take place, where possible, landward of the setback line; enlargement of the structure

is prohibited; and the replacement may be no farther seaward than the original.[83]

Dispute resolution regarding damage assessments of damage to protective structures is to be carried out "by a registered professional engineer acting on behalf of the council,"[84] but a property owner may challenge this assessment by obtaining "an assessment by a registered professional engineer." The section also provides for an assessment by a third registered professional engineer, should the two assessments differ. The third engineer is to be selected by the first two engineers, or, failing that, by "the clerk of the court of the county where the structure or device lies ... [and] [t]he determination of percentage of damage by the third engineer is conclusive."[85]

3. Delaware

Delaware's Beach Preservation Act specifically mentions sea-level rise as a phenomenon to be considered in regulating beach use:

> Beach erosion and shoreline migration occur due to the influence of waves, currents, tides, storms and *rising sea level*.... Development and habitation of beaches must be done with due consideration given to the natural forces impacting upon them and the dynamic nature of those natural features....[86]

Delaware's legislation puts sea-level rise in the context of on-going coastal erosion problems by defining "beach preservation," "beach erosion control" and "erosion control" as including but "not limited to, erosion control, hurricane protection, coastal flood control, shoreline and offshore rehabilitation."[87]

The legislation defines a building line parallel to the coast, "seaward of which construction of any kind shall be prohibited without a permit or letter of approval from the Department (Delaware Department of Natural Resources and Environmental Control)."[88] In addition, construction "landward of the building line on any beach ... shall be permitted only under a letter of approval from the Department."[89] Furthermore, construction carried out in violation of the Beach Preservation Law is declared to be a public nuisance.[90] The law also sets up a Beach Preservation Fund[91] to be used to fulfill the law's general goals.

Also of interest in Delaware are recommendations for strategic retreat through "planned obsolescence," developing "post-storm plan[s]," and advocating land uses which are compatible with the goals of beach preservation, "such as fishing camps and recreational uses, or for donating conservation easements."[92]

Such incentive strategies, along with improved public education and awareness about coastal processes and the consequences of sea-level rise and coastal erosion may prove an important addition to coastal hazard management programs. They may help to decrease friction between government and private property owners over an issue which is likely to increase in importance for coastal managers, residents, and user groups.

4. Florida

Florida's Beach and Shore Preservation Law provides for the establishment of construction control lines[93] which are to be periodically reviewed and updated "after consideration of hydrographic and topographic data which indicates shoreline changes that render established coastal construction control lines to be ineffective for the purposes of this act."[94] Construction control lines are to be established taking into consideration "historical storm and hurricane tides, predicted maximum wave uprush, beach and offshore ground contours, the vegetation line, erosion trends, the dune or bluff line ... and existing upland development."[95] Public hearings are required for the establishment of these lines, and allowance is made for administrative review of construction control lines for aggrieved riparian upland owners.[96] The mutable aspect and periodic review of the construction control lines allow Florida the flexibility to use the Beach and Shore Preservation Law to respond to changes in the rate of sea-level rise. The statute also envisions a state/local partnership in the

preservation of beaches.[97] The section provides for state funding of beach renourishment and restoration projects from the Beach Management Trust Fund of up to 75%, while local municipalities are required to pay the remainder.

5. Pennsylvania

While Pennsylvania's legislation does not specifically mention the issue of sea-level rise, it does contemplate the problem of coastal erosion in its Bluff Recession and Setback Act,[98] and it encourages state and municipal cooperation to regulate land uses in erosion hazard areas. The legislation deals specifically with bluffs on Lake Erie, but provides an interesting example of state-local cooperation which has applicability to the regulation of coastal bluffs.

The law provides for Pennsylvania's Environmental Quality Board to establish regulations for minimum bluff setback requirements in bluff recession hazard areas. These areas are defined as "area[s] or zone[s] where the rate of progressive bluff recession creates a substantial threat to the safety or stability of nearby or future structures or utility facilities."[99] However, six months after a given municipality has been designated as including such bluff recession hazard areas, the municipality must implement an ordinance which requires setbacks in those areas and which complies with the minimum State standards set by the Environmental Quality Board.[100] Municipal ordinances may be more restrictive than the State's minimum setback requirements.[101] The State may bring an enforcement action against municipalities which fail to adopt or implement setback ordinances.

6. Maryland: The Chesapeake Bay

Planners in Chesapeake Bay have identified the need for development of alternative site-specific strategies to protect wetlands from inundation.[102]

In the Chesapeake Bay area, private landowners have often invested heavily in waterfront properties, and are unlikely to choose to simply abandon these properties without trying to protect them. Analyses by Chesapeake Bay area coastal managers contend that the building of seawalls and dikes to protect private upland property from sea-level rise will likely have significant negative impacts on wetlands. If development is situated immediately upland of a coastal wetland, there will be nowhere for that wetland to migrate should it become inundated as the result of accelerated sea-level rise.

This is particularly significant for Chesapeake Bay, where historical wetlands and whole islands, mapped in the eighteenth century, have already disappeared.[103] Due to the nature of coastal wetlands as low-lying, very gently-sloping areas, coastal wetlands will be the first areas to be inundated, and an increase in the rate of sea-level rise will accentuate this trend.

If owners of private upland property construct sea walls and dikes, the wetlands cannot migrate to the adjacent uplands, but will rather be more quickly inundated. A possible wide-spread loss of wetlands, in addition to the ongoing anthropogenic direct destruction of wetlands through dredging and filling operations could have devastating effects on already threatened coastal ecosystems. If wetlands do not have a chance to migrate, the biological productivity of coastal ecosystems will be seriously impaired.

Maryland's wetlands protection legislation covers all areas within 1000 feet of the Chesapeake Bay that are less than 50% developed. It requires local governments to develop protection plans for wetlands by requiring buffer zones.[104] Because the legislation covers such vast areas in the Chesapeake Bay area and requires buffer zones, it may be adaptable to ameliorating the effects of accelerated sea-level rise on wetlands. Maryland also requires private landowners to pay for the costs of erosion control projects which benefit their properties, although the levy is to be calculated to cover only the cost of the project itself, and apparently does not include calculations of

costs resulting from the loss of natural shoreline features resulting from the project.[105]

C. CONCLUSION

Several recurrent themes appear in the methods these jurisdictions have adopted or are contemplating using to address the issues of sea-level rise and coastal erosion. These are summarized below.

1. Respect Dynamic Nature of Coastal Systems

One important theme is an increasing realization among legislators and planners that coastal systems are dynamic and that attempts to stabilize them may have detrimental effects on the coastal ecosystem. As the understanding of coastal processes increases, the expectation that coastal areas are immutable and permanent has come to be considered unrealistic and environmentally unsound. This is true not only in states evaluating the possible impacts of accelerated sea-level rise (e.g., Washington, Oregon, and New Hampshire) but also in states with laws designed to protect against a continuation of historical rates of shoreline change (e.g., Rhode Island, South Carolina, Florida).

2. Preserve/Enhance Resiliency of Natural System

Similarly, there is growing rejection of hard structural solutions and increased focus on maintaining (and in cases, improving) the resiliency of natural systems as the best way to minimize coastal hazards (e.g., Washington, Rhode Island, South Carolina). This approach entails: 1) preserving buffers to allow room for natural systems to migrate (Rhode Island, Washington, Maryland); 2) hazard avoidance by directing new development away from potentially high-risk areas (New Hampshire, Oregon, Florida); and 3) gradual retreat of existing development from hazard areas, at least through restrictions on rebuilding after a specified level of destruction (Cape Cod, Long Island).

3. Revisit Issues of Public Nuisance, Public Subsidy

As a related theme, the developing public policies suggest that private development in high hazard areas is increasingly being seen as a public nuisance which diminishes the quality of a public resource, often at the monetary expense of the public. There appears to be a decreasing tolerance for such hidden subsidies, and an increasing awareness that anticipated accelerated sea-level rise will exacerbate these problems. For example, it has been suggested that property owners who erect hard erosion control structures be required to pay for beach nourishment for beaches which have been starved of sand due to the erection of the structure (Long Island, Oregon).

4. Build on Existing Policies

Several factors make it difficult to implement anticipatory accelerated sea-level rise strategies at this time, including: scientific uncertainty about the timing, magnitude, and impacts of global climate change; lack of public education about and public acceptance of the probability of accelerated sea-level rise; and a failure to appreciate the possible severity of impacts caused by relatively small changes in temperature or sea-level. Furthermore, coastal resource managers and coastal landowners are just beginning to understand the importance of adjusting to accommodate the dynamic shoreline system within the parameters of non-accelerating rates of shoreline change. It is difficult enough to win acceptance of regulations designed to minimize damage from coastal erosion projected to continue at historical rates. The case has to be made even more convincing to cause coastal residents to adopt regulations to protect against unquestionably serious but remote-in-time, uncertain projections of accelerated rates of change.

Despite a leading state-level research program, the State of Washington has opted not

to develop a new, stand-alone, accelerated sea-level rise response strategy. Instead it is focusing its current efforts on more mainstream coastal erosion issues. A study conducted for that State suggests that amendments to existing laws are much more palatable and are more likely to produce the type of "no regrets" (e.g., it makes sense even if sea level doesn't rise) strategy which the State is seeking. Similarly, other states have not developed specific new legislation to address sea-level rise projections, but appear to be working within a framework of amendments to existing laws to make them more effective if accelerated sea-level rise becomes a reality. Thus prudent planners appear to be basing planning and regulations on the evidence of what coastal storms and erosion are already expected to do, but build into those regulations an extra precautionary increment for an accelerated rise, or build in a structured retreat as conditions require it.

5. Retain State/Regional Oversight of Local Decisions

Another common issue relates to the allocation of responsibilities between state, regional, and local authorities. In several jurisdictions, states and progressive regional authorities have established mandatory minimum standards for local governments; the local governments are free to establish more stringent standards if they so choose (e.g., Pennsylvania bluff erosion). An Oregon study also suggested this retained state oversight may be the optimal arrangement for this type of coastal management problem because it allows for integrated management of a public resource and helps insulate the decision-making process from some of the pro-development political pressures.

6. Develop an Integrated Strategy: Beaches, Eroding Bluffs, Migrating Wetlands

The most developed state/regional strategies are grounded in a comprehensive philosophy that applies not only to beaches, but also to the other "soft" components of the coastal system—eroding bluffs (e.g., Rhode Island, Washington, Long Island) and coastal wetlands (California, Long Island, Maryland, Rhode Island). For example, they require that permit reviews for bluff stabilization projects evaluate the importance of the eroding coastal bluffs as part of the beach sediment supply system (Oregon, Rhode Island). Several states have policies, some implemented through regulations, to protect wetlands by preserving the opportunity for inland migration by discouraging or prohibiting the hardening of the inland perimeter of coastal marshes (Rhode Island, Maryland).

7. Recognize the Complexity of Planning Process: Topography, Intensity, and Land Use

Despite a comprehensive philosophy toward the soft coast, another recurrent theme is the complexity of planning for coastal land loss due to the fact that it will affect different coastal features in different ways, at different rates. In addition, due the response costs, some strategies will only be feasible in intensely developed areas. A meaningful plan must be sufficiently sensitive to take into account the variations in coastal features and land uses.

For example, special area management planning has been advocated for the littoral cells of Oregon in planning for sea-level rise. The Long Island South Shore plan also uses a special area management planning approach to deal with its varied coast. The State of Rhode Island regulates coastal areas not by geographic region, but by shore type, population density, and the uses of adjacent waters, effectively creating a kind of special area management planning. These plans typically distinguish between strategies for undeveloped and developed areas, with general recognition that the more costly methods (e.g., hard protective structures and beach nourishment)—both in terms of financial expenditures and environmental degradation—can only be justified, if at all, in the more heavily developed areas.

8. Utilize Coastal Setback Requirements

Most surveyed jurisdictions use setback requirements to minimize erosion hazards, including Cape Cod (30 times average historical erosion rate), South Carolina (40 times average annual erosion rate), and Rhode Island (in critical erosion control areas, 30 times annual erosion rate for up to 4 units and 60 times that rate for 4 or more units). These requirements are typically based on an increment of the historical average annual rates rather than on projections of accelerated rates of sea-level rise, but there is no reason future trends could not be used to establish the setback if justified by particular circumstances. Taking a slightly different approach, San Francisco Bay Conservation and Development Commission requires applicants to design for a minimum of twice the historic annual rate of sea-level rise.

9. Evaluate a Variety of Additional Strategies

Setbacks for new construction are merely one component. Other strategies adopted or being considered include restrictions on rebuilding structures or seawalls if damaged by more than a certain percent of pre-damage value (Cape Cod, South Carolina), provisions for recalculation of coastal setback lines in response to sea-level rise or other changes (Florida), heightened design standards which take sea-level rise into account (San Francisco), stricter building codes which require an additional increment above current floodproofing requirements (Washington, Cape Cod), limits on building or expanding public infrastructure in flood hazard areas (Cape Cod), tax incentives for less intense uses along the shoreline (Delaware), purchase of undeveloped coastal lands (Long Island) and advanced post-storm redevelopment planning and/or provisions for temporary post-storm building moratoria (Long Island, Delaware, Rhode Island, South Carolina).

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40. *Id.* ch. 3.7.

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51. *Id.* § 120.A.1.

52. *Id.* § 120.A.2.

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55. *Id.* §§ 210.1-210.6.

56. *Id.* § 210.1.B.1.

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58. *Id.* § 210.1.

59. *Id.* § 210.3.C.

60. *Id.* § 210.4.C.4.

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63. *Id.* § 210.6.A.

64. *Id.* § 210.6.C.3.

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68. *Id.* § 250(1).

69. *Id.* § 250(5).

70. *Id.* § 250(6).

71. *Id.* § 260(1).

72. *Id.* § 260(2).

73. *Id.* § 260(3).-(8).

74. *Id.* § 48-39-280(B).

75. *Id.* § 280(A)(1).

76. *Id.* § 280(B).

77. *Id.* § 280(C).

78. *Id.* § 280(D).

79. *Id.* § 290.

80. *Id.* § 280(E).

81. *Id.* § 290(D)(1).

82. *Id.* § 290(D)(4).

83. *Id.* § 290(B)(1)(a)-(b).

84. *Id.* § 290(2)(b)(iv).

85. *Id.* § 290(2)(b)(iv).

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88. *Id.* §§ 6802(4), 6805(a).

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90. *Id.* §§ 6807(b).

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98. PA. CONS. STAT. § 5201 (1993)..

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Appendix C

BACKGROUND INFORMATION ON THE CASCO BAY/SACO BAY REGION

The Casco Bay/Saco Bay study region includes the portion of Maine's coastline extending from the City of Saco to the Town of Brunswick, including Old Orchard Beach and Saco in York County, and Scarborough, Cape Elizabeth, South Portland, Portland, Falmouth, Cumberland, Yarmouth, Freeport and Brunswick in Cumberland County. (*See Figure C.1*)

A. GEOLOGIC SETTING OF STUDY

Casco and Saco Bays, Maine are adjoining estuaries along the western margin of the Gulf of Maine. Each embayment is framed by a bedrock skeleton which is partially covered by unconsolidated glacigenic deposits of Pleistocene-Holocene age. Along the shoreline these deposits have been reworked by modern processes into intertidal environments such as mud flats and sand beaches.

Casco Bay is characterized by linear chains of islands, shoals and peninsulas controlled by the orientation of bedrock (Kelley, 1987). The rocks are often directly overlain by till, a mixture of gravel, sand and mud deposited by glacial ice. This material is highly variable in thickness and often occurs in the form of elongate ridges called moraines (Thompson and Borns, 1985). Till is often overlain by glacial-marine sediment, locally called the Presumpscot Formation (Thompson and Borns, 1985). The Presumpscot Formation was deposited in early postglacial times, and is a generally muddy, and often thick deposit. It crops out widely along the Casco Bay shoreline and covers much of the seafloor of the bay as well (Kelley, et al., 1989b).

Following deposition of the Presumpscot Formation, the land in Maine was uplifted as a result of the removal of the load of glacial ice. The surface of the Presumpscot Formation, the former seafloor, became deeply gullied in places and experienced landslides as it became emergent. The large rivers which carved Casco Bay, the Kennebec and Androscoggin, were blocked by glacial deposits from entering Casco Bay as sea level fell, and when the sea reached its lowstand at -60 m, around 10,500 years ago (Kelley et al., 1992) (*Figure C.2*), only small streams like the Presumpscot and Royal Rivers entered Casco Bay.

As sea level rose during the Holocene, the glacial deposits of the bay were reworked by waves and currents. As a result, most of the seafloor of the outer bay is bare rock or gravel, and significant accumulations of modern sediment exist only in areas in the lee of islands and peninsulas (Kelley et al., 1987a). As the rate of sea-level rise slowed during the past few thousand years (*Figure C.2*), the outer, ocean-facing islands were swept clean of most glacial deposits by storms, and gravel beaches and bedrock form most intertidal environments (Kelley, 1987). In the inner bay, protected from direct wave attack by islands, substantial bluffs of glacigenic deposits continue to erode. It is the erosion of this material

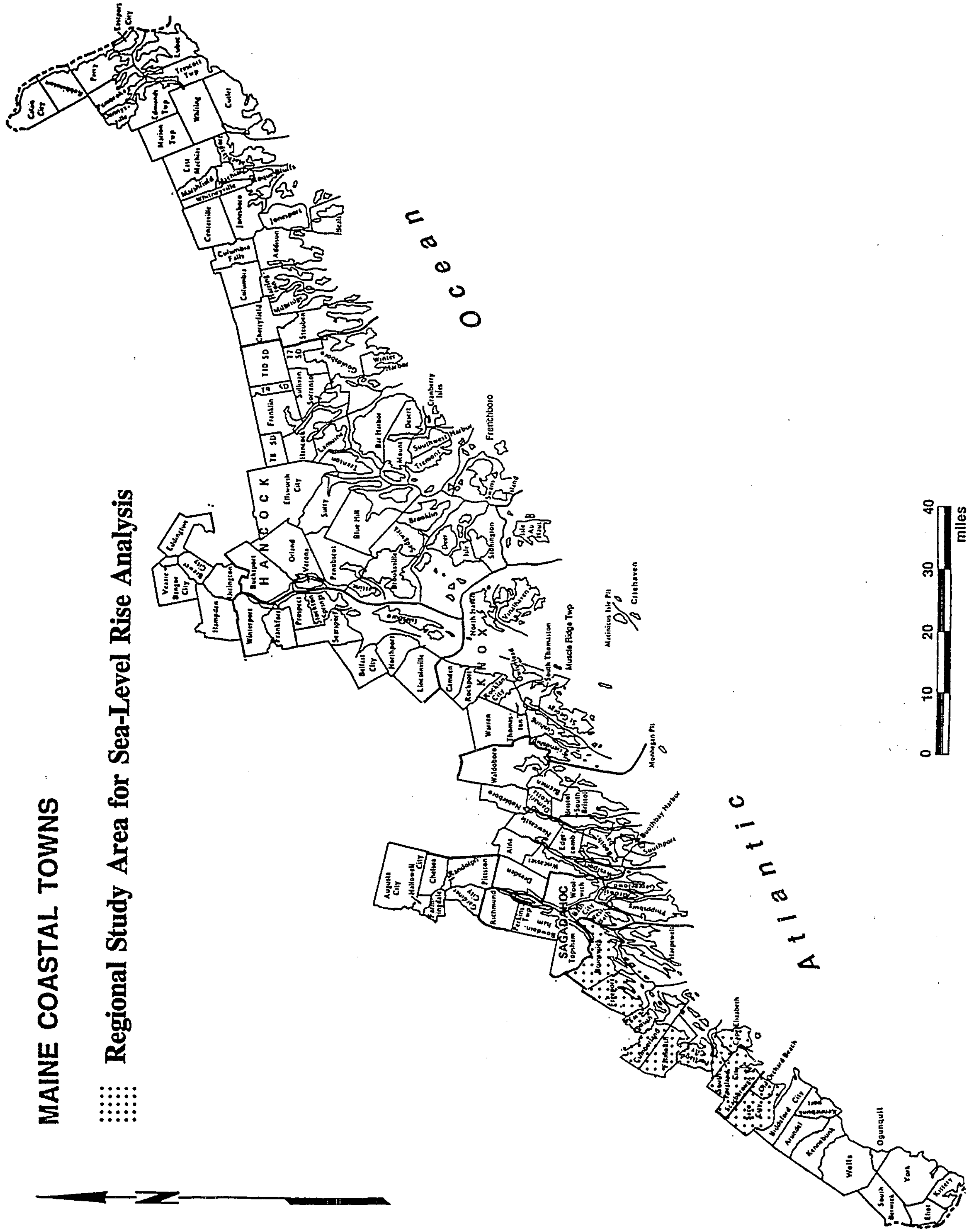

Figure C.1. Regional Study Area for Sea-Level Rise Analysis.

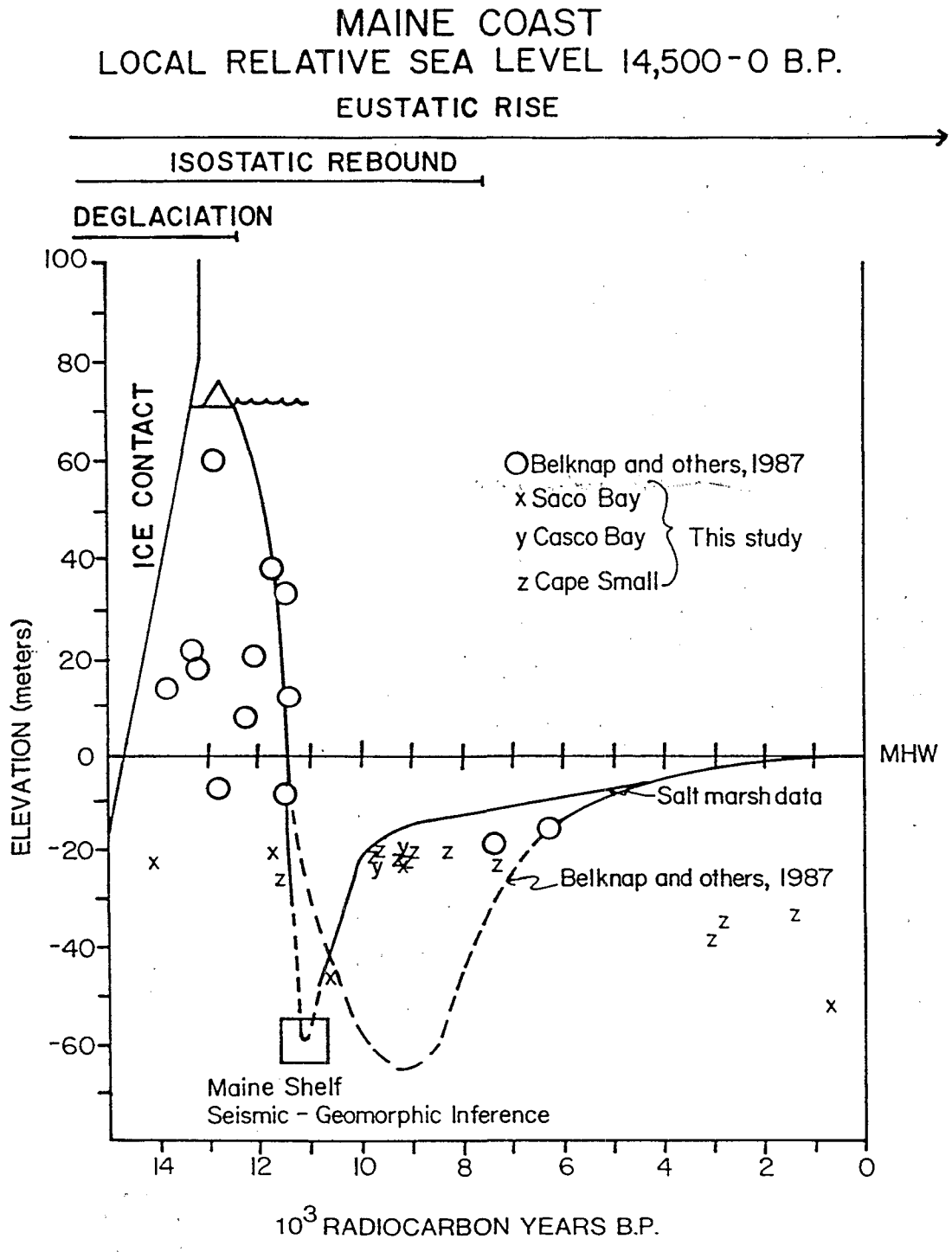

Figure C.2. Sea-level change curve for coastal Maine (from Kelley et al., 1992).

which provides sand and mud to create contemporary tidal flats and salt marshes. Owing to the abundant occurrences of the muddy Presumpscot Formation in Casco Bay, there are few natural beaches in the embayment. Those beaches that do exist are "pocket beaches" protected by rock outcrops at either end (Kelley et al., 1986; Kelley, 1987).

Saco Bay is arcuate in shape and located directly south of Casco Bay. Despite its proximity, its geological history is different from Casco Bay and this difference is manifest in most aspects of the bay's appearance (Kelley et al., 1986). Although there are till deposits on the seafloor of Saco Bay (Kelley et al., 1987b), none crop out on land. Similarly, the Presumpscot Formation is a common deposit on the bay bottom, but few exposures may be seen on land (Kelley et al., 1989c). Saco Bay experienced a similar history to Casco Bay until the time of lowering of the sea, around 10,500 years ago (Kelley et al., 1986). At that time the Saco River contributed great quantities of sand from as far away as the White Mountains of New Hampshire to the bay (Kelley et al., 1992). Sand covered the muddy Presumpscot Formation and beaches became common environments. As sea level rose during the Holocene, sand from the river maintained beaches in the bay up to the present time, although it is unclear whether sand continues to be brought down the river. Where beaches front embayments, extensive salt marshes have colonized most of the intertidal, back- barrier environments (Kelley et al., 1986, 1989c).

The effects of coastal erosion on developed and undeveloped property are not as conspicuous in Maine as they are south of New England. This may be because the rate of sea-level rise in the region is only 2.3 mm/yr, slightly more than half the rate for some mid-Atlantic states. A recent study suggests that sea level may have reached near its present elevation in Maine around 1000 years ago, however, and that many of the beaches and marshes developed during that pause of the sea (Kelley et al., in press). The current rate of sea-level rise is much greater than has occurred in several thousand years, and some contemporary erosion and land loss has been attributed to the recent increase in sea level (Wood et al., 1989; Jacobson, 1988).

B. SOCIO-ECONOMIC CHARACTERISTICS

1. Population

While the exact number of residents that stand to be affected by accelerated sea-level rise along the Casco and Saco Bay shorelines was not calculated, based on knowledge of existing shoreline development patterns, it is reasonable to estimate that of the total 1990 regional population of 180,172, roughly 3,600 to 9,000 people currently live in the immediate vicinity of the shore (2-5% of the total population). Assuming the same proportion of waterfront dwellers as compared to the total population for the region, and using population projections for the Year 2015 (the latest year for which county population projections are available) between 4,300 and 10,800 people may live in the immediate vicinity of the region's waterfront in the Year 2015.

2. Land Use and Property Values

Land use is varied along the region's shoreline. Old Orchard Beach contains Maine's only area of beachfront high-rise condominiums. The shoreline of Saco, Scarborough and Freeport includes a mix of cottage development and more substantial homes on larger lots. The wealthier suburbs of Falmouth, Yarmouth, Cumberland, are characterized by estate development along the shoreline, with small enclaves of cottage development. Industrial, commercial and institutional development predominates along the waterfronts of Portland and South Portland.

No figures were compiled for total value of properties in the region that may potentially be influenced by rising sea level. However examples of ranges of coastal property values are

given for specific mapped study area sites in Chapter Three.

3. Anticipated Land Use Change

Discussions with town officials and analysis of current development patterns throughout the region indicate that shoreline areas within 100 meters of current mean high water are already (for the most part), built out, with little usable, vacant, appropriately zoned land available for new development. During the last five years, building permits in the shoreland areas have consisted mostly of seasonal conversions, infill development in grandfathered subdivisions or on grandfathered lots, renovation or improvement of single family residences, and only very limited new single family development. However, the depressed real estate market during the last five years probably understates the potential for future demand. If development pressures reach 1980s levels, the most likely opportunities for growth in the shoreland area will be the subdivision/redevelopment of larger estates, consolidation/ redevelopment of marginal seasonal homes and marginal commercial structures, and redevelopment of seasonal cottages to multi-unit residential structures.

4. Infrastructure

Each of the municipalities in the region is served, to varying extent, by public water and sewer, and by an improved road network. There are numerous sewage treatment and stormwater outfalls along the region's shoreline.

Information provided by Maine's Department of Environmental Protection did not indicate the presence of any landfills within 100 meters of the shoreline. However, past practice in many communities was to use estuarine shorelines as dump sites. Interviews with local officials may reveal that there are, in fact, historic dumps located within this area of concern.

The only large utility of concern within the study area is Central Maine Power's Wyman power-generating facility on Cousin's Island in Yarmouth. According to plant manager David Potter, the distance from high tide to upland is about 4 ft., but during abnormal high tides, the plant has experienced some flooding. No floodproofing of the facility has taken place.

Also of concern due to the possible types of materials stored there, are sites scattered through out the study region (most on Casco Bay's islands) that were formerly used by the U.S. Defense Department. Further research would be needed to assess individual site vulnerability, and the presence of hazardous materials.

5. Cultural and Recreational Features

The shoreline parks and natural areas in the study region attract thousands of visitors each year. They include wide sandy beaches such at those at Ferry Beach State Park, Old Orchard, and Pine Point, nature trails around salt marshes such as Scarborough Marsh and Gilsland Farm, rocky promenades such as Two Lights State Park in Cape Elizabeth, forested paths like those at Wolf Neck Woods State Park in Freeport, and urban amenities such as the fitness trail around Back Cove in Portland.

The shoreline of Casco and Saco Bays is rich in history. There are more than 60 sites of known or suspected archeological resources along the shores, many of which are located on Casco Bay's islands. There are seven historic sites and two historic districts within 100 meters of the sea that may be potentially affected by rising sea level.

6. Habitat/Critical Areas

Maine's coastal waters support an extremely diverse array of marine life. High value wetlands, and marine habitats of national significance are scattered throughout the region. According to the U.S. Fish and Wildlife Service (Maine State Planning Office, 1992), some locations contain the highest diversity of marine life in all the coastal waters of the United States.

There are at least 20 registered, state critical areas within 100 meters of the shoreline. "Critical areas" are sites containing habitat for rare plants and animals, unusual geologic formations, or other important natural features.

7. Fisheries

A significant commercial fishery, both finfish and shellfish (landed value of $154 million in 1991) exists in the Gulf of Maine (MSPO, 1992). Softshell clams continue to be a valuable component of Maine's annual fish landings, and within the study area, Brunswick, Freeport, and Scarborough support sizable shellfish populations. Clusters of shellfish aquaculture leases are located in Freeport and further south in the study area.

No analysis has yet been completed which focuses on projected changes in estuarine conditions in the Gulf of Maine due to climate change. However, an analysis of the Gulf of Mexico found that those Gulf coast fisheries could be negatively affected by the loss of critical wetland habitat associated with sea-level rise. That study concluded that warmer water temperatures will be at or above tolerances for many important commercial species of finfish and shellfish and other fish could be threatened by increased salinity. The Gulf of Mexico study predicted that sea-level rise between 50 and 200 cm would reduce available food supply for marine species by 42-78%, resulting in a disproportionate loss in seafood population. A sea-level rise of 1 meter was associated with a major loss of fisheries. (Livingston, as reported in Smith & Tirpak, 1989)

It is beyond the scope of this study to attempt to quantify potential impacts to Gulf of Maine fisheries associated with global climate change. However, it is important to note that some experts project that an already threatened, multi-million dollar industry may be further affected by changes in fisheries habitat caused by sea-level rise and global warming.

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