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

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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 assessing 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 develop 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

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—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 less than 10% of Maine's shoreline is sand or cobble beach. Areas adjacent to Maine's scarce 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 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 whatever yhose 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 setback 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 projects 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).