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 adaption 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 by 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 advance 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 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 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 rebuild 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 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 id 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, so not lend themselves to a cost-benefit analysis but are critical components on 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 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 States'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 ruse 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 the 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 the properties affected under 1.0 and 2.0 meter rise is not that sizeable, 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 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 influences 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 among of new development anticipated in the 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 “underutilize” 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 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 anticipatory 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 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 underdeveloped 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 underdeveloped 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 beached 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, regulating setbacks for all underdeveloped 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 of 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 buildings 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 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 the 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 costs 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 were 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 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 assumed 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 whenever 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 for new development is the 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 in using Camp Ellis as an example for other sites that may have substantial tracts of underdeveloped 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 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 nourishment will be totally independent of what happens to the underdeveloped or undeveloped lots. In fact, any development to increase the number of units within the 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 to move the position of the shoreline that will be defended slightly further 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 the compensated setback policy is that by vacating the portion of the 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 of 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 for a reactive protection strategy under both the zero and the 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 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 values 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 values 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 occurring in either the anticipated 50, 100, or 200 cm sea-level rise zones.

The economic cost of prohibiting the 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 the 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 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 estimated 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 the 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 ration 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 shoed 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 1.55. As in Option 3, the fluctuation on the ratios is also attributable to the disproportionately low number of structures and infrastructure components in the 200 cm band. Comparing Option 4 to Option 3it can be inferred that using the 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 for both developed and underdeveloped sites is the most economically efficient policy choice.

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 scenario 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 sane 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 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 in 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 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. The 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 50 cm, 100 cm, or 200 cm elevation zones, and sea-level rise does not occur or occurs to a lesser degree. The analysis shoed 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 te future removal and future site restoration costs since those would be spread over the next 100 years.

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		-	71	133	260
	Aggregate Value of Land		-	$28,175,800	$41,206,000	$46,032,900
	Economic Value of Land @ Risk		-	$14,933,174	$27,963,374	$32,790,274
	roads at risk:		-	12,778	22,440	24,922
	sewer lines at risk		-	9,617	17,767	18,951
	water lines at risk		-	12,201	19,118	21,105
	Prohibited Development		-	51	72	127
	Removal of Existing Develop.		-	210	334	364
	Site Restoration		-	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 Case Study			**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	$115,465,33	$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	$9,976,989	$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)	$9,938,674	$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
		(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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Table 4.4

COST BENEFIT ANALYSIS: ***Camp Ellis Case Study***		**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** **Undeveloped Area: Reactive Protection**					
	costs:	$7,938,674	$9,852,321	$14,500,918	$21,377,937
	benefits	$9,243,407	$9,243,407	$11,312,156	$12,030,309
	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

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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 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 being 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 the removal are the costs of purchasing relocation land, physically moving the structure, and restoring the site. However, if development is allowed, it is unrealistic to assume that not 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 the analysis if the community delays in committing to a protection strategy until after the failure of the retreatment 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, Mary 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 for Public Affairs, University of Southern Maine. Maine State Planning Office, Augusta, Maine.

7. Stephen M. Dickson, Shoreline Erosion Management Project – Phase I, Project Completion Report, Maine Geological Survey, July 1983, at 8.

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