Chapter 8

Planning for Sea Level Rise before and after a Coastal Disaster

James G. Titus

INTRODUCTION

Ocean beach resorts in the United States have always faced erosion and storm damage. At first, these risks were accepted as inevitable. Development was generally sparse, and people often built relatively inexpensive cottages along the ocean that they could afford to lose. When the occasional severe storm destroyed these houses and eroded the beach, replacement structures were frequently built farther inland to maintain the original distance from the shore.[1]

After World War II, beaches became more popular and were developed more densely than before. The resulting increases in real estate values enabled greater numbers of communities to justify expensive engineering solutions to maintain their shorelines. Frequently subsidized by the federal government, the practice of stabilizing shorelines replaced the previous custom of accepting erosion as inevitable.

The projected rise in sea level poses a fundamental question: how long should these communities hold back the sea? In the decades ahead, the costs of shoreline protection will rise dramatically and the relative efficiencies of various measures will change. But without such efforts, a 1 ft rise would erode most shorelines over 100 ft, threatening recreational use of both beaches and adjacent houses. Even under the low scenario, this could happen by 2025.

Although sea level is not expected to rise rapidly until after 2000, resort communities may have to consider its consequences much sooner. After the next major storm, in particular, homeowners whose properties are destroyed will decide whether and how to rebuild; and local governments will decide whether or not to let all of them rebuild, and which options are appropriate to address the storm-induced erosion. How well a community ultimately adapts to sea level rise will depend largely on the direction it takes when it reaches this crossroads.

This chapter examines the impact of sea level rise on the decisions that must be made before and after a coastal disaster. We first sketch the impact of sea level rise on coastal resorts, as well as the implications of recent federal policy changes. Using Sullivans Island, South Carolina (part of the Charleston study area) as an example, we discuss the impact of sea level rise on property owners' decisions on whether to rebuild if a storm happens to destroy their oceanfront houses in 1990. We then discuss the community's interest in this individual decision, as well as other decisions facing local governments. We conclude by discussing several policy changes that would enable coastal communities to better prepare for a rising sea.

THE CHANGING ENVIRONMENT OF COASTAL ACTIVITIES

A premise underlying most development in coastal areas has been that risks from storms and beach erosion as well as government responses to them will, on average, stay the same. However, federal policy changes and the prospect of sea level rise are destroying the validity of that assumption. If sea level rise is not adequately addressed, erosion may rob resorts of their recreational beaches and make oceanfront houses more vulnerable to damage from storm waves. In fact, there is some evidence that this is already happening (Pilkey et al., 1981; New Jersey, 1981; Massachusetts, 1981; U.S. Department of the Interior, 1983).

Many communities along the Atlantic and Gulf coasts are concerned about erosion[2] that is primarily driven by the current sea level rise of 1 ft per century (Pilkey et al., 1981; Bird, 1976).[3] Furthermore, some geologists note that since the last major storm along the Atlantic Coast (the 1963 northeaster), the underwater portion of many beaches has eroded much more quickly than the visible portion.[4] They argue that this phenomenon -known as "profile steepening"-implies that beaches would erode more quickly during a storm today than when their profiles were flatter and thus may no longer provide as much protection from storms as in the past. For example, Trident (1979) reported that at Ocean City, Maryland, the visible part of the beach is eroding 2 ft per year, but the underwater part is eroding 7 ft per year. As a result, Humphries et al. (1983) concluded that the beach would now protect structures for only one tidal cycle (12 hours) during a major storm and that even a 10-year storm could inflict considerable damage.

Sea level rise can change the effectiveness of engineering solutions to halt beach erosion. For example, the most common method has been constructing groins, which may curtail erosion caused by alongshore currents. However, they do not prevent sand from being carried offshore, which is the type of erosion caused by sea level rise (see Sorensen et al., Chapter 6). Thus groins have failed to stop erosion in many communities.

An ongoing realignment of the responsibilities of private property owners, and federal, state, and local governments is also changing coastal development decisions. In the past, subsidized flood insurance has sometimes encouraged people to develop “high hazard” zones, transferring the economic risks to federal taxpayers. However, the federal Flood Insurance Administration intends to end these subsidies by 1988.[5] In the future, property owners will bear most of the costs from building in risky areas.

Furthermore, communities that benefit from projects that make areas less hazardous will probably have to pay more of the costs of these projects than in the past. After the 1900 hurricane killed 6,000 people in Galveston, the Army Corps of Engineers built a large seawall; and after the 1962 northeaster, the Corps supplied emergency sand to restore beaches. But the federal government is now less inclined to subsidize large-scale engineering projects. Budget-minded congressmen are less likely to vote for such projects, and when they do, they require substantial state and local contributions. States are also less likely to subsidize these projects than in the past.

THE INDIVIDUAL’S DECISION ON WHETHER TO REBUILD AFTER A STORM: SULLIVANS ISLAND

If a storm devastated a resort community today, the oceanfront houses that were destroyed would probably be rebuilt. To some people, the recreational value of being close to the beach justifies the risk of having their houses destroyed or, more recently, the cost of flood insurance premiums. If homeowners can continue to rely on the government to stabilize the shoreline, sea level rise may not substantially change this view. But if people expect their properties to be lost to erosion or the costs of maintaining them to increase (due to storm damage or higher insurance premiums), then rebuilding may be less attractive.

The case of Sullivans Island provides a conservative numerical illustration. This barrier island is typical of many family-oriented, noncommercial resort communities (see Kana et al., Chapter 4, for a description). However, the island's shoreline is currently advancing seaward, unlike most shorelines.[6] Kana

et al. estimate that under current trends,, the shore will advance 25-455 ft by 2025. Although the low scenario will cause parts of the shore to erode 45-70 f t, other parts will advance over 200 ft. Under the high scenario, the shore will erode 50-200 ft.

Gibbs (Chapter 7) divided the part of Sullivans Island within the case study area into 11 geographical zones. Table 8-1 shows his estimates of land values and structural values, as well as his estimates of the damages that would be sustained if a 100-year storm were to strike in 1990. It also shows the present value of the post-1990 damages caused by the low and high sea level rise scenarios.

Because much of the shoreline would still be advancing, the losses from sea level rise in the low scenario would be small (except in Zones 1 and 6). However, in the high scenario, the losses would be very significant in one-half of the zones. A 100-year storm in 1990 would destroy two-thirds of the value of the structures in Zones 1, 2, 6, and 7. Repairs would cost $27 million for the entire study area.

Given the immediate repair costs and future damages from sea level rise, property owners may want to reconsider whether the advantages of having an oceanfront house still justify the expense. Using data from Table 8-1, we calculated whether rebuilding makes economic sense for particular zones. (Data limitations forced us to conduct our analysis on entire zones and consider only the case where the homeowner rebuilds the original house.) We assumed that a rational property owner will rebuild only if the benefits of doing so exceed the costs. This will be the case only if the remaining value of a property is greater than the damage expected from sea level rise.

Table 8-1. Estimates of Property Values and Expected Damages from Storms and Sea Level Rise (in millions of 1980 dollars)

Table 8-1. Estimates of Property Values and Expected Damages from Storms and Sea Level Rise (in millions of 1980 dollars)

Zone	(1) Value of Land	(2) Value of Structure	(3) Damage from a 100-Year Storm in 1990[a] (percent)	(1)+(2)−(3) Remaining Property Value after 100-Year Storm	Present Value of Estimated[b] Loss from Sea Level Rise	
					Low Scenario	High Scenario
1	1.27	4.23	2.78 (66)	2.72	1.11	2.99
2	0.99	3.32	2.13 (65)	2.17	0.42	1.67
3	1.23	4.11	2.38 (58)	2.96	0.43	1.45
4	1.26	4.22	2.06 (49)	3.42	0.34	0.83
5	0.32	1.06	0.42 (40)	0.96	0.07	0.13
6	2.27	7.60	5.00 (66)	4.86	1.69	5.13
7	1.33	4.45	2.86 (65)	2.91	0.56	2.22
8	1.76	5.89	3.47 (58)	4.24	0.61	2.01
9	2.79	9.33	4.56 (49)	7.56	0.76	1.75
10	0.83	2.78	1.10 (40)	2.51	0.20	0.34
11	0.27	1.92	0.26 (29)	1.93	0.06	0.09
Total	14.32	48.91	27.02 (55)	36.24	6.25	18.61

Source: Data from Chapter 7 (unreported result).
[a]Based on repair costs.
[b]Present-value based on a 5 percent real after-tax discount rate.

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[a]Based on repair costs.
[b]Present-value based on a 5 percent real after-tax discount rate.

However, in the low scenario, property owners would lose $1.61 million more by abandoning their property than by rebuilding.

If property owners in Zone 1 could find someone to buy their land at its 1980 value, they would be less likely to rebuild. Table 8-2 shows that not rebuilding in the low scenario would yield a net loss of $0.33 million, and in the high scenario, a net gain of $1.55 million. The increased risks from sea level rise would discourage other families from buying the land to build a beach house. But someone with an alternative use in mind might be more interested in the property. For example, local governments might want to purchase land close to the shore in order to preserve a recreational beach.

To summarize these results: if property owners expect the high scenario, those in Zones 1, 2, 6, and 7 would be better off selling their property at the 1980 land value than rebuilding. Owners in Zones 1 and 6 would save money by not rebuilding their houses, even if they could not find a buyer and had to abandon their properties. Under the low scenario, rebuilding after a 100-year storm would be justified for all zones. However, if the houses in Zones 1 and 6 were entirely destroyed by a storm, property owners would save money by selling their land.[7]

We calculated the remaining value of a property as the value of the land and structures (before sea level rise) minus the damage from the storm. Table 8-1 shows that in the case of Zone 1, this value is $2.72 million. Next, we compared this value with the damages from sea level rise. Table 8-2 shows that under the high scenario, the expected damage would be $2.99 million, and property owners would thus save $0.27 million by abandoning their properties instead of rebuilding.

The Risks of Over-and Underestimating Sea Level Rise

Given the uncertainty about future sea level rise, property owners would have to weigh the costs of both overestimating and underestimating sea level rise. Table 8-3 illustrates the costs of being wrong for the six zones most affected by sea level rise.[8] (In this case we assume they have the option of selling out at the 1980 land value.)

If owners in Zone 1 assume that the high scenario is true, they will sell out (as shown in Table 8-2). But if the low scenario actually occurs, selling out will have cost them $0.34 million. On the other hand, if the property owners expect the low scenario when the high scenario is true, they will rebuild and forego the $1.54 million savings from selling out. Thus, unless they believe that the low scenario is five times more likely than the high scenario, property owners can reduce their expected losses by not rebuilding.

This type of analysis illustrates the benefits to property owners of securing better information. For several zones, the decision on whether to rebuild depends on which scenario is expected. Millions of dollars will be lost if property owners incorrectly project future damages from sea level rise. More certainty about whether the government will provide shore protection, as well as better forecasts of sea level rise, could enable property owners to avoid these losses.

Table 8-2. Analysis of Decision to Rebuild or Sell (in millions of 1980 Dollars)

Zone	(1) Remaining Property Value After 1990 Storm	(2) Projected Damage From SLR	(3) = (2)−(1) Net Savings From Abandonment	(4) Decision to Abandon or Rebuild	(5) 1980 Land Value	(6) = (3)+(5) Net Savings From Selling Out	(7) Decision to Sell or Rebuild
			If High Scenario Is True				
1	2.72	2.99	0.27	Abandon	1.27	1.54	Sell
2	2.17	1.67	−0.50	Rebuild	0.99	0.49	Sell
3	2.96	1.45	−1.51	Rebuild	1.23	−0.28	Rebuild
6	4.86	5.13	0.27	Abandon	2.27	2.54	Sell
7	2.91	2.22	−0.69	Rebuild	1.33	0.64	Sell
8	4.24	2.09	−2.15	Rebuild	1.76	−0.39	Rebuild
			If Low Scenario Is True				
1	2.72	1.11	−1.61	Rebuild	1.27	−0.34	Rebuild
2	2.17	0.42	−1.75	Rebuild	0.99	−0.76	Rebuild
3	2.96	0.43	−2.53	Rebuild	1.23	−1.30	Rebuild
6	4.86	1.69	−3.17	Rebuild	2.27	−0.90	Rebuild
7	2.91	0.56	−2.35	Rebuild	1.33	−1.02	Rebuild
8	4.24	0.66	−3.58	Rebuild	1.76	−1.82	Rebuild

Table 8-2. Analysis of Decision to Rebuild or Sell (in Millions on 1980 Dollars)

Table 8-3. Costs of Incorrectly Anticipating Sea Level Rise When Rebuilding or Selling Out Are the Available Options (in millions of 1980 dollars)

Table 8-3. Costs of Incorrectly Anticipating Sea Level Rise When Rebuilding or Selling Out Are the Available Options (in millions of 1980 dollars)

Scenario Expected *Actual Scenario*	*Low* *High*	*High* *Low*
Zone		
1	1.54	0.34
2	0.49	0.76
3[a]	0	0
6	2.54	0.90
7	0.64	1.02
8[a]	0	0
Total	5.22	3.07

[a]Property owner would choose to rebuild regardless of the scenario and thus would not lose money by expecting the wrong scenario.

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Limitations of This Analysis

Three weaknesses limit the relevance of this numerical illustration. First, the only options considered were rebuilding the original house or not rebuilding at all. Other options might be preferable. For example, where abandonment is preferable to rebuilding the original house, building a cheaper structure might be even better. By ignoring potentially superior responses, our calculations may understate the benefits of planning for sea level rise.

Second, using zonal averages obscures impacts on individual properties and probably understates the impact of the low scenario on post-disaster decisions. For example, although the expected damage is a small portion of the entire value of Zone 1, Kana et al. (Chapter 4) project that in the low scenario, erosion would destroy some of the houses along the ocean by 2025. These houses would also be more vulnerable to a 100-year storm than the average house in their zone. Thus, some houses would probably not be rebuilt even if people expect the low scenario.

Finally, Sullivans Island is far less vulnerable to sea level rise than most coastal barriers. The starboard jetty at the entrance to Charleston harbor has modified ocean waves in a manner that causes the beach to advance along most of the Island. Thus, the impact of the high scenario on Sullivans Island would be comparable to the impact of the low scenario on most other barriers.

DECISIONS FACING THE COMMUNITY

The most important issue for resort communities to resolve will be whether to hold back the sea or retreat landward. The previous section assumed that the major impact of sea level rise on a homeowner's post-disaster decisions will be property losses from increased storm damage and erosion. However, public officials must also consider the impact of rebuilding oceanfront houses on the recreational use of the beach. The fact that a property owner might choose to rebuild his house in spite of projected erosion does not

necessarily imply that the community's interest would be served by allowing the owner to do so.

Whether or not a community decides that a retreat is inevitable, the post-disaster period will be a critical time for implementing its response to sea level rise. If the community intends to defend its shoreline, it must do so soon after the storm, or redevelopment activities will be vulnerable to even a moderately severe storm. If it does not intend to fight erosion, deciding not to redevelop oceanfront lots can save the expense of later removing or protecting these properties. Finally, a major storm would increase the public's awareness of the consequences of sea level rise and thereby create a political climate more favorable to the difficult decisions that must be made.

Most measures by which resort communities can respond to sea level rise have been implemented or proposed in existing coastal hazard mitigation programs. These measures include building seawalls and other structures, pumping sand, restricting development or redevelopment, purchasing land, and modifying building codes and zoning.

Defending the Shoreline

The most commonly used measures to curtail erosion have been groins and beach nourishment. By groins, we mean long thin structures perpendicular to the shore that collect sand moving downshore, including jetties on the updrift side of inlets. By beach nourishment, we mean dredging sand from a channel or offshore and pumping it onto the beach (see Chapter 6).

Groins cannot prevent erosion caused by sea level rise, but they can move the problem downshore. A jetty at the south end of Ocean City, Maryland (acting as a long groin) has collected enough sediment to allow the shore to advance hundreds of feet, while to the south, Assateague Island National Seashore is eroding rapidly. As sea level rises, communities may use increasingly sophisticated methods to trap sand as it moves along the shore, in spite of the problems these measures may cause their neighbors.[9] In contrast, beach nourishment does not adversely affect neighboring areas, although it may be more expensive than groins.[10]

As Chapter 1 describes, beaches follow characteristic profiles. A 1 ft rise in sea level would eventually require raising the entire beach profile 1 ft. A profile that extended out to sea 0.5 mi would ultimately require 500,000 yd^3 of sand for every mile of beach. Estimates from Chapter 6 suggest that this would cost $2-5 million. In many resorts, the value of the property that would be protected could justify this level of expenditure.

However, sand pumping costs could vary considerably. Profiles extend to sea by very different amounts. For example, the profile of San Francisco may extend out several times farther than most profiles (U.S. Army Corps of Engineers, 1979), implying that protection costs would be several times greater. The availability of sand also varies considerably. Finally, the costs of beach nourishment may escalate as inexpensive supplies are exhausted. In spite of these uncertainties, such extremely valuable real estate as Miami Beach and Atlantic City could probably justify the costs in any event.

Communities that could not afford to raise their entire beach profiles might still use beach nourishment as a temporary measure until depreciation of oceanfront development or a storm makes retreat economical. As Leatherman points out in Chapter 5, much of the erosion from se, level rise does not take place until a major storm arrives. Until then, small portion of the sand ultimately required to raise the profile may be sufficient to expand the recreational beach and provide useful protection from moderate storms. Even the erosion caused by a 100-year storm involves only a fraction of the sand required to raise an entire beach profile by 1 ft. For example, the Army Corps of Engineers'(1980) plan to protect Ocean City, Maryland from a 100-year storm would require only 150,000 yd^3 of sand per mile of beach, at a cost of less than $1 million/mi.

Planning a Retreat

Communities that decide to migrate landward could combine engineering and planning measures. One possible engineering response for barrier islands would be to preserve their total acreage by pumping sand to their bayside, imitating the natural overwash process.[11] This option might require bayfront property owners to be compensated for their loss of access to the water. Furthermore, care would have to be taken to ensure that marine life was not irreparably damaged. But because less sand would be necessary, such a program would be less expensive than pumping sand to the Oceanside. In the long run, it would probably be less environmentally disruptive than any of the alternatives, particularly if mainland marshes are also allowed to migrate landward.

Planning measures will be important. North Carolina already requires most new home construction to be set back from the shore a distance equal to 30 years of erosion.[12] For existing construction, communities could implement strong post-disaster plans. Humphries et al. (1983) recommend that Ocean City, Maryland impose a temporary building moratorium after a major storm to give authorities time to decide which redevelopment is appropriate. However, the need to repair damages quickly may inhibit the careful debate necessary to adequately consider sea level rise.

Although many post-disaster development decisions cannot be made until local officials assess the damages, the general principles of redevelopment should probably be decided in advance of a storm. An assemblyman once introduced a bill to the New Jersey legislature that would have forbidden people to rebuild oceanfront houses that were more than 50 percent destroyed by a storm (Assembly Bill 1825). That bill was extremely unpopular, in part because it made no provision to compensate property owners. Our analysis of individual decisions suggests that if sea level rise is anticipated, many property owners who are offered some compensation will be willing to sell their land and write off their partly damaged houses; some might even do so without compensation.

In some instances, public officials might have to resort to eminent domain to purchase oceanfront property. Partly because of flood mitigation programs that require houses to be built on pilings sunk far into the ground, erosion from sea level rise will not always destroy the oceanfront houses now being built. Instead, some houses will continue to stand on the beach and perhaps even in the water. Although the owners of these houses might not want to move, the obstruction of the beach might be intolerable to the community and hence necessitate purchases under eminent domain.

Reaching a Decision

Public officials can use the same type of analysis as individual property owners to select the best policy, but they must also convince the public that they have reached the correct decision. Until the general public is convinced of the validity of the sea level rise projections, officials on coastal barriers may have trouble adopting the necessary responses.

Nevertheless, these officials should not defer all action until a scientific consensus emerges. As shown in the previous section, property owners in a community could save millions of dollars if they could be certain about the government's intentions. For example, property owners might conclude that sea level rise will make their property too hazardous to rebuild. If the government would stabilize the shoreline in the face of sea level rise, then announcing this policy in advance would enable these people to enjoy their properties rather than mistakenly assume that sea level rise threatens them.

Deciding on the best response to sea level rise could take communities many years. By the time this process is complete, better forecasts of sea level rise may be available. Because we cannot know when a major storm will occur, the time saved by initiating the planning process sooner rather than later may be the critical difference between being ready to act and being unprepared.

RECOMMENDATIONS

In the next few decades, sea level rise will force resort communities to either retreat several hundred feet or defend their shorelines by pumping sand. Where sand is inexpensive or real estate extremely valuable, it may be desirable to raise an entire barrier island and associated marshes in place. But if the shore retreats during a storm that destroys oceanfront structures, reclaiming the land lost would accomplish much less at a higher cost and thus be more difficult to justify.

Recent experience with post-disaster development suggests a strong inclination for homeowners to rebuild. However, subsidized beach nourishment and insurance have insulated people from the consequences of building in hazardous areas, and increasing risks from sea level rise have not been expected. As these conditions change, the relative merits of defending the shore versus migrating landward will change as well.

The political climate is rarely receptive to policies that impose costs now to protect against unknown risks in the future. But that climate will never be more favorable than when people are in the midst of recovering from a disaster that could have been avoided. Outlays for land purchases or beach nourishment would necessitate large increases in property taxes. But the drop in property values that might ultimately occur otherwise could be even greater.

On the basis of the information in this book, government officials should consider the following recommendations:[13]

1.Post-disaster plans should determine which policies are appropriate if sea level rise is expected. Because successful crisis management requires planning in advance of the crisis, many states are developing post-disaster plans for coastal communities. These plans would make excellent vehicles for preparing for sea level rise.

2.Local governments should inform the public of the risks from sea level rise and begin to formulate responses. This policy could enable property owners to avoid losses from uncertainty. Our analysis of Sullivans Island indicates that if sea level rise is expected, many property owners would base their decision to rebuild on whether the government was going to stabilize the shoreline. If the willingness of a community to pump sand is limited, a retreat of the shore is inevitable. Waiting until oceanfront lots are redeveloped to confront this issue would substantially increase private losses as well as the costs to communities of purchasing oceanfront property and otherwise adapting to sea level rise.

3.State and local governments should determine research needs and inform policy makers and *research institutions of these needs.* Coastal communities represent one of many constituencies with particular research needs. Only if they make their needs known is the necessary research likely to take place.

4.All beach nourishment efforts should consider the sand required in the long run as well as the measures that are necessary to maintain the visible portion of the beach. The steepening beach profiles that already worry many coastal geologists could be exacerbated by short-sighted policies to stabilize shorelines, particularly if sea level rise is not recognized to be causing the erosion.

5.Policies that prohibit bayside filling should be modified to permit landward migration of developed barrier islands in step with Oceanside erosion and the migration of undeveloped barriers. Policies that prevent local interests from creating new acreage by filling the baysides of barrier islands have been necessary to preserve important marine ecosystems. But as the sea rises, an inflexible adherence to this principle could harm the very environments these policies seek to protect.

In the last several thousand years, marine life adapted to the landward migration of barrier island ecosystems as the sea rose. If developed barriers are prevented from migrating, while undeveloped barriers migrate, there is no guarantee that these species would do as well: inlets would widen, changing the tides and increasing the salinity of the bays considerably; estuaries would deepen and perhaps deprive marshes of necessary sediment. Furthermore, the engineering alternatives to landward migration would disrupt Oceanside environments. The impacts of preventing migration could easily be more disruptive than filling 100 feet of an estuary every few decades, provided that the estuary and bayside marshes also migrate landward.

The potential savings in sand pumping costs will not always outweigh the institutional problems of

entire communities migrating landward. But where they do, environmental policies should not prohibit sincere efforts by engineers to decrease human interference with natural processes.

6.Interpretations of riparian rights should recognize the scarcity of sand and should treat interference with the natural transport of sediment the way they treat interference with the natural flow of water. Only time will tell whether beach nourishment or groins develop sufficiently to become the least-cost supply of sand. But if groins prove to be the cheaper, then more controls on their use will be necessary. Otherwise, coastal communities may waste considerable resources fighting over limited quantities of sand, and undeveloped barrier beaches will be effectively "mined" of their sustenance.

This possibility is especially likely for communities next to inlets where navigation requires jetties, such as Sullivans Island and Ocean City. A jetty will collect sand up to a point, after which the excess sand washes downdrift again. In the face of a rising sea, even the most enlightened local leadership will be hard pressed to explain why this excess should not be pumped onto the rest of the community's beaches but must instead be allowed to wash away.

When sea level was assumed to be stable and erosion was thought to result mainly from alongshore currents, riparian rights correctly did not interfere with communities' attempts to build groins and "keep their own sand." However, as sea level is recognized to cause the erosion, attempts to halt it by capturing sediment moving alongshore can only be interpreted as attempts to divert sand from its natural destination, the beaches downshore. These diversions will sometimes be justified, as dams for irrigation are sometimes justified. But justice will be best served if riparian rights come to recognize the increasing scarcity of sand, as they have with water.

7.*The Federal Emergency Management Agency should develop policies* that encourage communities to address shoreline retreat. The National Flood Insurance Program was designed to ensure that future development did not create the conditions that make coastal disasters likely. Building codes now require most new construction to be elevated above flood levels. Furthermore, the expected end of insurance subsidies will ensure that the only people to build in hazardous areas will be those who can afford to pay for the expected damages. However, the program has not been given a mandate to prevent disasters caused by shoreline retreat. Other than raising insurance premiums on properties that erosion makes more vulnerable to storms, the program does not address erosion.

By creating the Flood Insurance Program, Congress determined that the importance of preventing future coastal storm disasters transcended the laissez-faire notion that the marketplace adequately acknowledges risks from storms. This reasoning applies equally to coastal disasters caused by erosion and sea level rise. Communities devastated by storms will receive federal disaster assistance. In providing this assistance, the Federal Emergency Management Agency should encourage these communities to prepare for a rising sea. The improvements in technical and institutional capabilities that result from their early experiences could repay society many times over in the years to come.

8.Coastal barrier communities should consider impacts on marshes, estuaries, and mainland activities when planning for sea level rise. This chapter has discussed whether coastal barrier communities should defend their shores or migrate landward, from the narrow perspective of barrier residents and economic interests. However, the actual decision process will also involve representatives concerned with marshes, estuaries, and the mainland. We believe that in most cases, either the barrier and the mainland shore will both retreat landward, or they will both be stabilized. (Otherwise, the environmental and navigational impacts on estuaries and marshes would be severe, and perhaps intolerable.) Therefore, coastal barrier communities must take an interest in the fate of the adjacent mainland.

The impacts of sea level rise will confront coastal barriers sooner than the mainland. Nevertheless, planning the mainland's future will require more lead time because the decisions involved will be more controversial. While barrier communities may decide to migrate landward on purely economic grounds, a major reason for mainland development to retreat will be the environmental impact of not allowing marine ecosystems to adapt to sea level rise. Landward migration will require coastal barriers only to yield storm-damaged structures to an ocean that would have been difficult to hold off anyway. In contrast, a retreat will

require the mainland to yield both land and useful structures that could be inexpensively protected from encroaching marshes and estuaries.

Some people argue that it is too soon to prepare for sea level rise because the phenomenon is so far in the future and has not yet been proven. Paradoxically, this situation may make some types of farsighted decisions easier to implement. For example, zoning could require that particular properties be abandoned in the next century if sea level rises a certain number of feet. Such a measure would appeal to environmentalists who want to ensure that coastal barriers and marine ecosystems will be allowed to adapt naturally to sea level rise. Property owners who do not care about the next century or do not believe that the sea will rise should not object to such measures.

If local governments implement this type of planning measure, the necessary abandonment of low-lying areas can be conducted in an orderly fashion. In this way, our generation can save future generations from costly clashes between competing economic and environmental interests. But even if objections are raised, at least we will learn that the public already understands the prospect of sea level rise and cares about the next century more than we realized, and that would be a start.

NOTES

1. A walk along the beach at Ocean City, Maryland, for example, reveals evidence of past shoreline retreat. For the most part, the front row of houses is behind the vegetation line, but an occasional house can be found standing closer to the water, a survivor from a previous generation of development. These houses generally stand on what is now public land and cannot be rebuilt if they are destroyed by a storm.
2. See Taylor, Ronald A., "America's Losing Battle to Save Its Beaches," *U.S. News and World Report,* July 11, 1983, pp.51-52.
3. The Bruun Rule would predict that the shore should be eroding several feet per year. See Chapter 1 for an explanation of how sea level rise causes erosion.
4. Conversations with Orrin Pilkey, Geology Department, Duke University; Stephen Leatherman, University of Maryland, and Stanley Humphries, IEP, Wayland, Massachusetts.
5. Federal Emergency Management Agency. *Justification of Program Estimates for FY '84,* February 1. 1983.
6. The island has a substantial supply of sediment and a jetty offshore that cause waves to retain much of it.
7. Given our simplifying assumptions, this conclusion automatically applies to all zones. The only remaining investment is in the land, and we assumed that property owner's will receive the pre-sea level rise price, even though it would be worth less once people expect sea level rise. However, for Zones 1 and 6, the drop in property values from sea level rise probably overshadows any Possible errors from our simplifying assumptions. For example, in Zone 1, sea level rise would lower the value of the land to homeowners from $1.27 million to $0.16 Million. An offer of the original price, or even somewhat less, would be difficult to refuse.
8. The cost of expecting the high scenario when the low scenario is true was calculated as the remaining value of the property, minus the damage from level rise under the low scenario, minus the land value (which is recovered from the sale). The cost of expecting the low scenario I and rebuilding) when the high scenario is true was calculated as the remaining value of the property, minus the losses from sea level rise (high scenario), plus the cost of rebuilding, minus the value of the land (which again is recovered from selling the land).
9. For example, the jetty at Ocean City allowed the southern mile of beach to advance considerably but now is "filled up" and allows sand to pass downshore. At the same time, the northern 8 mi of Ocean City are eroding. Residents at the northern end advocate pumping the excess sand near the jetty onto the rest of the beach. Such a plan might enable Ocean City to hold back the sea indefinitely.
10. In fact, one reason that this solution to erosion is not used more extensively is the public's perception that the sand will wash away and benefit neighboring communities as much as themselves. In contrast, groins are viewed as more permanent. Earl Bradley and Chris Zabawa, Coastal Resources Division, Maryland Department of Natural Resources, personal communication, July 1983.
11. See Chapter 1 for a discussion of overwash processes.
12. *North Carolina Administrative* Code, Chapter 7H, 1983. Raleigh, North Carolina Office of Coastal

Management.

13. Policies appropriate for Louisiana would require a reconsideration of the costs and benefits of alternative levee, dredging, and water diversion Policies. Such assessments are probably even more urgent than the issues discussed here, See the comments of Sherwood Gagliano, Chapter 10, pp. 296-300.

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