Part III Overview: Preparing for Sea-Level Rise

Author: James G. Titus, EPA

For at least the last four centuries, people have been erecting permanent settlements in the coastal zone of the Mid-Atlantic without regard to the fact that the sea is rising. Because the sea has been rising slowly and only a small part of the coast was developed, the consequences have been relatively isolated and manageable. Part I of this report suggests, however, that a 2 mm/yr acceleration of sea-level rise *could* transform the character of the mid-Atlantic coast, with a large scale loss of tidal wetlands and possible disintegration barrier islands - and a 7 mm/yr acceleration *probably would* cause such a transformation, although shore protection may prevent some developed barrier islands from disintegrating and low-lying communities from being taken over by wetlands.

For the last quarter century, scientific assessments have concluded that regardless of possible policies to reduce emissions of greenhouse gases, people will have to adapt to changing climate and rising sea level (NAS, 1983; Hoffman *et al.*, 1983; IPCC 1990, 1996, 2001, 2007). Adaptation assessments differentiate “reactive adaptation” from “anticipatory adaptation”. (Titus, 1990; Scheraga and Grambsch, 1998; Klein *et al.*, 1999; Frankhauser et al., 1999).

Part III focuses on what might be done to prepare for sea-level rise. Chapter 9 starts by asking whether preparing for sea-level rise is even necessary. In many cases, reacting later is more justifiable than preparing now, both because the rate and timing of future sea-level rise is uncertain and the additional cost of acting now can be high when the impacts are at least several decades in the future. Nevertheless, for several types of impacts, the cost of preparing now is very small compared to the cost of reacting later. Examples where preparing appears to be rationally justified include:

- *Coastal wetland protection*. It may be possible to reserve undeveloped lands for wetland migration, but once developed, it is very difficult to make land available for wetland migration. Therefore, it is far more feasible to aid wetland migration by setting aside land before it is developed, than to require development to be removed as sea level rises.
- *Some long-lived infrastructure*. Whether it is beneficial to design coastal infrastructure to anticipate rising sea level depends on economic analysis of the incremental cost of designing for a higher sea level now, and the retrofit cost of modifying the structure at some point in the future. Most long-lived infrastructure in the threatened areas is sufficiently sensitive to rising sea level to warrant at least an assessment of the costs and benefits of preparing for rising sea level.
- *Floodplain management*. Insurance works best when premiums reflect actual risk. Even without considering the possibility of accelerated sea-level rise, the National Academy of Sciences and a FEMA-supported study by the Heinz Center recommended to Congress that insurance rates should reflect the changing risks resulting from coastal erosion. Rising sea level increases the potential disparity between rates and risk.

Chapter 10 discusses organizations that are preparing for a possible acceleration of sea-level rise. The chapter is short because few organizations responsible for managing coastal resources vulnerable to sea-level rise have modified their activities. Most of the best examples of preparing for the environmental impacts of sea-level rise are in New England, where several states have enacted policies to enable wetlands to migrate inland as sea-level rise. Ocean City (Maryland) is an example of a town considering future sea-level rise in its infrastructure planning.

Chapter 11 examines the institutional barriers that make it difficult to take the potential impacts of future sea-level rise into account for coastal planning. Although few studies (*e.g.*, U.S. Congress, 1993; Barth and Titus, 1984; Titus, 1990, 1998, 2001, 2004) have discussed the challenge of institutional barriers and biases in coastal decision making, their implications for sea-level rise are relatively straightforward:

- *Inertia and short-term thinking*. Most institutions are slow to take on new challenges, especially those that require preparing for the future rather than fixing a current problem.
- *The interdependence of decisions* reinforces institutional inertia. In many cases, preparing for sea-level rise requires a decision as to whether a given area will ultimately be given up to the sea, protected with structures and drainage systems, or elevated as the sea rises. Until communities decide which of those three pathways they will follow in a given area, it is difficult to determine which anticipatory or initial response measures should be taken.

- *Policies favoring protection of what is currently there*. In some cases, longstanding preferences for shore protection (as discussed in Chapter 5) discourage planning measures that foster retreat. Because retreat may require a greater lead time than shore protection, the presumption that an area will be protected may imply that planning in unnecessary. On the other hand, these policies may help accelerate the response to sea-level rise in areas where shore protection is needed.
- *Policies Favoring Coastal Development*. One possible response to sea-level rise is to invest less in the lands likely to be threatened. However, longstanding policies that encourage coastal development are a barrier to such a response. On the other hand, increasingly dense coastal development improves the ability to raise funds required for shore protection. Therefore, policies that encourage coastal development may be an institutional bias favoring shore protection, but they are not necessarily a barrier to responding to sea-level rise.

PART III OVERVIEW REFERENCES

Barth, M.C. and J.G. Titus (eds.), 1984: Greenhouse Effect and Sea Level Rise: A Challenge for this Generation. New York: Van Nostrand Reinhold.

Frankhauser, S., J.B. Smith, and R.S.J. Tol, 1999: Weathering climate change: Some simple rules to guide adaptation decisions. *Ecological Economics* **30**, 67-78.

Hoffman, J.S., D. Keyes, and J.G. Titus, 1983: Projecting Future Sea Level Rise; Methodology, Estimates to the Year 2100, and Research Needs. Washington D.C.: U.S. Environmental Protection Agency. 121 pp.

IPCC, 1990: Strategies for Adaptation to Sea Level Rise. Report of the Coastal Zone Management Subgroup. Available at http://yosemite.epa.gov/OAR%5Cglobalwarming.nsf/content/ResourceCenterPublicationsSLRAdaption.html. Accessed September 25, 2007.

IPCC, 1996: Climate Change 1995: The Science of Climate Change, [Houghton, J.J., L.G. Meiro Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.)]. Cambridge University Press, Cambridge and New York, 584 pp.

IPCC, 2001: Climate Change 2001: The Scientific Basis [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnston (eds.)]. Cambridge University Press, Cambridge and New York, 84 pp.

IPCC, 2007: Climate Change 2007: The Physical Science Basis [Alley, R., T. Berntsen, N.L. Bindoff, Z Chen, A. Chidthaisong, P. Friedlingstein, J. Gregory, G. Hegerl, M. Heimann, B. Hewitson, B. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, M. Manning, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, D. Qin, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, S. Solomon, R. Somerville, T.F. Stocker, R. Stott, R.J. Stouffer, P. Whetton, R.A. Wood, and D. Wratt (eds.)].

Klein, R.J.T., R.J. Nicholls. and N. Mimura, 1999: Coastal Adaptation to Climate Change: Can the IPCC Technical Guidelines be applied? *Mitigation and Adaptation Strategies for Global Change* **4**(3-4), 239-252.

Revelle, R.R. and P.E. Waggoner, 1983: Changing Climate. National Academy of Sciences, National Academy Press, Washington, D.C.

Scheraga, J.D. and A.E. Grambsch, 1998: Risks, opportunities, and adaptation to climate change. *Clim Res* **10**, 85-95.

Titus, J.G., 1990: Greenhouse effect, sea level rise, and barrier islands: case study of Long Beach Island, New Jersey. *Coastal Management* **18**, 65-90.

Titus, J.G., 1998: Rising seas, coastal erosion and the takings clause: how to save wetlands and beaches without hurting property owners. Maryland Law Review **57**(4), 1279-1299.

Titus, J.G., 2001: Does the U.S. government realize that the sea is rising? How to restructure Federal programs so that wetlands and beaches survive. *Golden Gate University Law Review*, **20**, 717-778.

Titus, J.G., 2004: Maps that depict the business-as-usual response to sea-level rise in the decentralized United States of America*.* *Global Forum on Sustainable Development: Development and Climate Change*. 11-12 November, Paris, Organisation for Economic Co-operation and Development (OECD). 22 pp.

U.S. Congress, Office of Technology Assessment, Preparing for an Uncertain Climate – Volume I, OTA-O-567 (Washington, DC: U.S. Government Printing Office, October 1993).

Chapter 9. Implications for Decisions

Author(s): James G. Titus, EPA

Contributing Author: James E. Neumann, Industrial Economics, Inc.

KEY FINDINGS

- The prospect of accelerated sea-level rise generally justifies examining the costs and benefits of taking adaptive actions. Determining whether and what specific actions are justified is difficult, due to uncertainty in the timing and magnitude of impacts, and difficulties in quantifying projected benefits and costs. Nevertheless, the literature has identified some cases where acting now is justified.
- Key opportunities for preparing for sea-level rise include coastal wetland protection, location and elevation of coastal homes, buildings and infrastructure, and examining whether and how changing risk due to sea-level rise is reflected in flood insurance rates.
- Incorporating sea-level rise into coastal wetlands programs can be justified because it is more effective to plan for the inland migration of tidal wetlands *before* people develop the dry lands onto which those wetlands would migrate, than afterwards. Possible tools include rolling easements, density restrictions, coastal setbacks, and vegetative buffers.
- Long-term shoreline planning is likely to save more than it costs; the more the sea ultimately rises, the greater the value of that planning.

Many decisions of everyday life in the coastal zone have little to do with the fact that the sea is rising. Some day-to-day decisions depend on *today's* water levels: Sailors, surfers, and fishermen all consult tide tables to decide when to go out. And the decision whether to evacuate during a storm may depend on how high the water is expected to rise above the normal level. The fact that the *normal* level of the sea is rising about 0.01 millimeters per day does not affect such short term decisions.

Sea-level rise can have an impact, however, on the outcomes of many decisions with long-term consequences. Even in some of those cases, the impacts of sea-level rise still would not warrant doing things differently today, because the impacts are far enough in the future that people will have ample time to respond in the future. For example, there is no need to anticipate sea-level rise in the construction of port facilities (NRC 1987). In other cases, the adverse impacts of sea-level rise can be substantially reduced by preparing soon.

The previous chapters discuss vulnerable private property and public resources threatened by sea-level rise including real estate, wetlands, and ecosystems, infrastructure (*e.g.*, roads, bridges, parks, playgrounds, industrial plants) and commercial buildings including hotels, casinos, and office buildings. The loss of habitats and ecosystems that support fishing and crabbing may result in the loss of those activities and the communities that depend on them. A continuing theme of previous chapters in this report is that some of these assets will be protected or preserved in their current locations, while others must move inland or be lost. This report examines some of the government policies that are, in effect, the current response to sea-level rise. This chapter discusses responses to sea-level rise that may be justified today.

This chapter describes the categories of decisions that may be sensitive, with a focus on the idea that preparing for sea-level rise is not worthwhile unless the expected present value of the benefits of preparing for sea-level rise is greater than the cost. It then examines five issues in greater detail: wetland protection, shore protection, long-lived structures, elevating homes, and floodplain management. The examples in this chapter focus on activities by governments and homeowners, rather than corporations. Most of the *available* studies have been funded by governments, with a focus either on improving government programs or providing risk communication and technical support to small property owners. Corporations engage in many of the activities discussed in this chapter; but we can not rule out the possibility that privately funded strategic assessments have identified other near-term decisions that are sensitive to sea-level rise.

Much of the discussion in this chapter reflects the basic assumption that decision makers, be they homeowners or corporations, have a well-defined objective for their interest in potentially vulnerable coastal resources. Where a well-defined objective can be stated, the principles of economics and risk management provide an appropriate and useful paradigm for thinking about decision making, and how decisions are affected by sea-level rise. Examples of such well-defined objectives might be maximizing return on an investment (for a homeowner) or maximizing overall social welfare (for a government). Certainly, non-economic factors may also be important in decision making - these could include emotions, perceptions, cultural values, or other difficult to characterize factors - but those factors are beyond what we can evaluate in this chapter. Specifically, in this chapter we use an economic framework to discuss how the prospect of rising sea level might alter certain decisions, such as nourishing a beach or erecting a protective structure, that are consistent with homeowners or governments pursuing a particular objective. See Box 9.1 for further details on the basic economic framework we adopt.

The discussion here is not directly tied to specific sea-level rise scenario, but it does consider a wide range of possible outcomes over time horizons that vary by decision from decades to centuries. As a result, the discussion implicitly acknowledges uncertainty about the future rate of sea-level rise. We also explicitly acknowledge uncertainty about the impacts of sea-level rise. The economic framework applied here, however, does not explicitly identify the extent to which decisions might be affected by sea-level rise. Instead, we reference a wide range of existing quantitative studies that are relevant to this topic.

START BOX HERE

Box 9.1 Conceptual Framework for Decision Making with Sea-Level Rise

Our conceptual framework for decision-making starts with the basic assumption that homeowners or governments with an interest in coastal resources seek to maximize the value of that resource to themselves (homeowners) or to the public as a whole (governments), over a long time horizon (on the order of 50 years or more). In each year, a coastal resource provides some value to its owner. In the case of the homeowner, a coastal property might provide rental income, or it might provide "imputed rent" that the owner derives from owning the home rather than renting a similar home. The market value of a property reflects an expectation that property will generate similar income over many years. Because income today is worth more than income in the future, however, the timing of the income stream associated with a property also matters (see explanation of "discounting" in the text).

The income a property provides over time, however, can be affected by risks to the property, including natural hazards. Even without sea-level rise, there are significant natural hazards that affect coastal resources - these include erosion, hurricane winds, and episodic flooding. All of these risks can cause damage - that damage can reduce the income the property produces, increase the costs of maintaining the property, or both. These "baseline" risks should be taken into account in estimating the value of the property today, to the extent they are known and understood by the owner and the market of potential buyers.

Sea-level rise changes the risks to coastal resources; in almost all cases, it increases existing risks. Investments can be made, however, to respond to and mitigate those changes in the risk of property damage. Decisions about those investments are the main topic of this chapter.

In an economic framework, investing in a response that mitigates coastal hazards will only be worthwhile if the cost of the investment (incurred in the short-term) is less than net expected returns (which accrue over the long-term). It follows logically that these investments are more likely to be judged worthwhile when: 1) there is a large risk of damage that will happen soon (and it can be effectively reduced); 2) there is a small cost to effectively reduce the risk; or 3) the investment shifts the risk to future years.

END BOX

9.1 DECISIONS WHERE PREPARING FOR SEA-LEVEL RISE IS WORTHWHILE

Sea-level rise justifies changing what we do today if the outcome from considering sea-level rise has an expected net benefit greater than the cost. This basic economic framework is expressed in Box 9.1: Conceptual Framework for Decision Making with Sea-Level Rise. Thus, as we consider decisions where sea-level rise justifies doing things differently, we can *exclude* from further consideration those decisions where either (a) the costs are large compared to the impacts we are considering or (b) the net benefits seem small or not necessarily positive. Few if any studies have analyzed the costs of preparing for sea-level rise. But it seems self-evident that preparing for a very small rise in sea level would not be worthwhile. Most of what we know about decisions sensitive to sea-level rise concern decisions whose consequences last decades or longer, during which time significant rise in sea level might occur. Those decisions include long-lived structures, land-use planning, and infrastructure decisions that may influence the location of development for centuries even if the structures themselves do not last a long time.

For what type of decision is there likely to be a net benefit from considering sea-level rise? Most analyses of this question have focused on cases where (1) the more sea level rises, the worse the impact; (2) the impacts are mostly in the future — and uncertain because the precise impact of sea-level rise is uncertain; and (3) if we prepare now, we will reduce the eventual adverse consequences.

The first step is to ask whether preparing now would be better than never preparing. If so, we can then investigate whether preparing now is also better than preparing during some future year. Preparing now to avoid possible effects in the future involves two key economic principles: uncertainty and discounting.

Uncertainty. Because projections of sea-level rise and its precise effects are uncertain, preparing now involves spending today for the sake of uncertain benefits. If sea level rises less than expected, then preparing now may prove — in retrospect — to have been unnecessary. And if sea level rises more than expected, whatever we do today may prove to be too little. This possibility tends to justify waiting to prepare later, if we think that a few years hence (a) we will know more and (b) the opportunity to prepare will be lost as time goes by[25]. To overcome this hurdle, either preparing now has to be fairly

[25] An extensive economic literature on decision-making and planning under uncertainty, particularly where some effects are irreversible, is applicable here. A good summary of this literature, on the topic of "quasi-option value" can be found in Freeman (2003), page 250-251. Quasi-option value arises from the value of information gained by delaying an irreversible decision (*e.g.*, to retreat). In the sea-level rise context, it applies because in the current state the costs and benefits of choosing to retreat or protect are uncertain, and we can reasonably expect that uncertainty will narrow over time, and yield a value of information, as we observe rates of sea-level rise and develop enhanced technologies for more effectively protecting or retreating. Two of the more influential works in this area include Arrow and Fisher (1974) and Fisher and Hanemann (1987); an application to climate policy decisions is Ha-Duong (1998).

inexpensive, or the preparation has to be fairly "robust" (*i.e.*, work over a wide variety of outcomes). If protecting existing development is important, beach nourishment is an example of a robust way to prepare, because the sand will do some good toward offsetting shore erosion no matter how fast or slowly the sea rises.

Discounting. Discounting is a procedure by which economists determine the "present value" of something given or received at a future date (EPA, 2000, p. 33). A dollar today is preferred over a dollar in the future, even without inflation; so a future dollar must be discounted to make costs and benefits received in different years comparable. Economists agree that the appropriate way to discount is to pick an assumed annual interest rate and compound it year-by-year, just as interest compounds, and use the result to discount future dollars. The precise rate that one should use depends on who is making the decision — and there is ongoing discussion amongst economists regarding what the discount rate should be for the U.S. Government (EPA, 2000, Chapter 6).

Most of the decisions where preparing now has a positive net benefit appear to fall into at least one of three categories: (1) the impact of sea-level rise is large in the near-term relative to value of asset; (2) preparing now costs little compared to the magnitude of the possible impact; or (3) preparing now involves options that reallocate (or clarify) risk, for example, by establishing today that the eventual costs of sea-level rise will be borne by a property owner making a decision sensitive to sea-level rise, rather than by third parties not involved in the decision. We discuss each in turn.

9.1.1 Decisions that Address Large Near-term Impacts

If the near-term impact of sea-level rise is large enough, preparing now may be worthwhile. Such decisions might include:

- Beach nourishment to protect homes that are in danger of being lost if something is not done soon.
- Enhancing vertical accretion (build-up) of wetlands that are otherwise in danger of being lost in the near term.
- Elevating homes that are clearly below the expected flood level due to historic sea-level rise (often after they have been flooded once).
- Fortifying dikes to the elevation necessary to protect from current floods.

9.1.2 Decisions Where Preparing Now Costs Little

These response options can be referred to as “low regrets” and “no regrets,” depending on whether the cost is little or nothing. In such cases, the response measure makes sense even if the sea does not rise. Examples include:

- *Setting a new home back from the sea within a given lot.* Setting a home back from the water can push the eventual damages farther into the future, lowering their expected present value. Unlike the option of not building, this approach retains almost the entire value of using the property — especially if adjacent homes are also set back so that they do not block one’s waterfront view, provided that the lot is large enough to build the same house as one would have built without the setback requirement.
- *Building a new building with a higher floor elevation.* While elevating an existing home can be costly, building it a few feet higher may add little to the cost.

- *Designing new coastal drainage systems with larger pipes to incorporate future sea-level rise*. The retrofit of rebuilding a drainage system can be substantially more expensive than including larger pipes in the initial construction (Titus *et al.*, 1987).
- *Rebuilding roads to a higher elevation during routine reconstruction.* If a road will eventually be elevated, it is easier to do so when it is being rebuilt anyway.
- *Designing bridges and other major facilities.* As sea level rises, clearance under bridges declines, impairing navigation. Building the bridge higher is inexpensive compared with rebuilding it.

9.1.3 Options That Reallocate or Clarify Risks from Sea-Level Rise

Instead of imposing a cost today to avoid problems that may or may not come later, these approaches impose a cost later — but only if and when the problem emerges. The premise for these measures is that policies and practices encourage people to behave in a fashion that increases costs more than necessary. Changing the rules and expectations can avoid those costs. Long-term shoreline planning and rolling easements are two examples.

In some cases, people will logically invest more along eroding shores if they assume that the government will provide subsidized shore protection. (Box 9.2: Erosion, Shore Protection, and Coastal Property Values). The value to to a buyer of that government subsidy is capitalized into higher land prices, which can further encourage increased construction. If the assumption of future government action is wrong (*i.e.*, government does not provide shore protection), then prices can decline; and in extreme cases, people can lose their homes unexpectedly. People's lives as well as their economic investments can be disrupted if the absence of shore protection does not become widely known until dunes or dikes fail and a community is destroyed. A policy that clearly enunciates that such an area will *not* be protected could lead people to strategically downscale the physical property[26] and avoid developing the strong emotional attachment to the sense of place at that location[27], in favor of those areas that actually will be protected. (Chapter 11 discusses this issue further.)

START BOX HERE

Box 9.2 Erosion, Shore Protection Programs, and Property Values

Do government shore protection programs increase property values and encourage coastal development? Heinz Center (2000, p. 131-134) reported that along the Atlantic Coast, a house with a remaining lifetime of 10-20 years before succumbing to erosion is worth 20 percent less than a home expected to survive 200 years. Landry *et al.* (2003) also found that property values tend to be higher with wide beaches and low erosion risk. It would therefore follow that shore protection programs that widen beaches, decrease erosion risk, and lengthen a home's expected lifetime would increase property values. Nevertheless, estimates of the impact on property values are complicated by the fact that proximity to the shore increases the risk of erosion but also improves access and views of the water (Bin *et al.*, in press).

Empirical verification that shore protection increases development is even less. Cordes and Yezer (1998) modeled the impact on new building permit activity in coastal areas of shore protection activity in 42 coastal counties, including all of the counties with developed ocean coasts in New York, New Jersey, Maryland, and Virginia. They did not find a statistically relationship between shore protection and building permits. However they did find fewer building permits in areas where both flood insurance and shore protection are unavailable. The Heinz Center (200 p. 135) estimated that federal flood insurance and other government hazards programs had increased development densities about 30 percent over what it would otherwise be.

END BOX

Rolling easements either reallocate or clarify the risks of sea-level rise, depending on the pre-existing property rights of a given jurisdiction (Titus 1998). A rolling easement is any arrangement under which property owners have no right or expectation of holding back

[26] Yohe *et al.* (1996) estimates the nationwide value of "foresight" regarding response to sea level rise at $20 billion, based largely on the strategic depreciation that foresight makes possible.

[27] Carol Farbotko (2005) argues that one can view Tuvalu as either a victim losing it's sense of place, or a potentially resilient culture that must adapt to sea level rise.

the sea if their property is threatened. In theory, such easements can be implemented either by regulation or as a special type of conservation easement[28]. In either case, they prevent property owners from holding back the sea but allow any other type of use and activity on the land. As the sea advances, the easement automatically moves or "rolls" landward. Because shoreline stabilization structures cannot be erected, sediment transport remains undisturbed and wetlands and other tidal habitat can migrate naturally. Similarly, there will always be dry or intertidal land for the public to walk along, preserving lateral public access to the shore.

Under a rolling easement, the property owner completely bears all of the risk of sea-level rise. Without a rolling easement, by contrast, along most shores property owners invest as if their real estate is sustainable, and then expend resources — or persuade governments to expend resources — to sustain the property. The overall effect of the rolling easement is that a community clearly decides to pursue retreat instead of shore protection in the future. This could also be done through a large-scale purchase of land now — but in that case there would be a large upfront cost as coastal land becomes unavailable for valuable uses.

Rolling easements, by contrast, do not prevent the land from being used for the next few decades while the land remains dry. (Even if the government purchases the rolling easement, the purchase price is a simple transfer of wealth.) The landward migration from the rolling easement should have lower eventual costs than a government buyout several

[28] Another mechanism for allowing wetlands and beaches to migrate inland are setbacks, which prohibit development near the shore. Setbacks can often result in "takings" claims if a property is deemed undevelopable due to the setback line. By contrast, rolling easements place no restrictions on development and hence are not a taking. See, *e.g.*, Titus (1998).

decades hence (Titus, 1991). Property owners can strategically depreciate their property and make other decisions consistent with the eventual abandonment of the property, efficiently responding to information on sea-level rise as it becomes available. Figure 9.1 shows how a rolling easement might work over time in an area already developed when rolling easements are obtained.

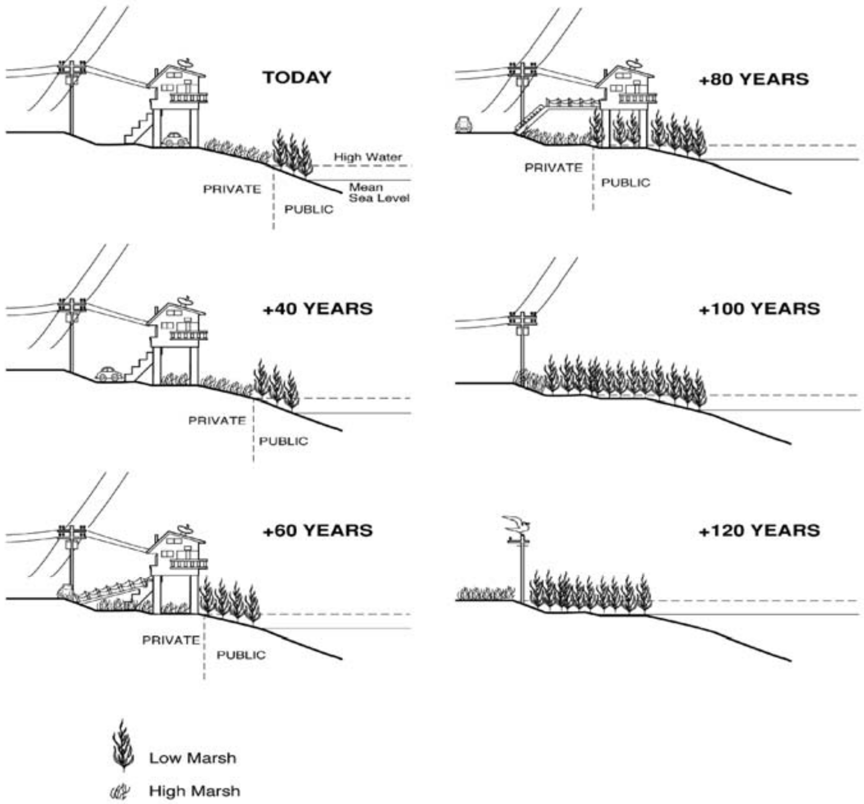

Figure 9.1 The landward migration of wetlands onto property subject to a rolling easement. A rolling easement allows construction near to the shore, but requires the property owner to recognize nature's right-of-way to advance inland as sea level rises. In this case, the high marsh reaches the footprint of the house 40 years hence. Because the house is on pilings, it can still be occupied (assuming that it is hooked to a sewerage treatment plant — a flooded septic system would probably fail). After 60 years, the marsh has advanced enough to require the owner to park the car along the street and construct a catwalk across the front yard. After 80 years, the marsh has taken over the entire yard; moreover, the footprint of the house is now seaward of mean high water and hence on public property. At this point, additional reinvestment in the property is unlikely. Twenty years later, the particular house has been removed, although other houses on the same street may still be occupied. But eventually, the entire area returns to nature (Titus, 1998).

Let us now examine some examples of long-term planning decisions and subsequent reallocation of risk.

9.2 PROTECTING COASTAL WETLANDS

The nation's wetland programs generally result in the protection of wetlands in their current locations, but they do not explicitly consider retreating shorelines. Most tidal wetlands are likely to keep pace with the current rate of sea-level rise but could become marginal with a 2 mm/yr acceleration, and could be lost if sea-level rise accelerates by 7 mm/yr (Chapter 3). The two key relationships determining future wetland area are the relationship between wetland vertical development and sea-level rise, and between the rates of seaward erosion and inland migration. If wetland vertical development keeps pace with sea-level rise, wetland area will expand if inland migration is greater than seaward erosion, remain unchanged if inland migration and seaward erosion are equal, and decline if seaward erosion is greater than inland migration. If wetland vertical development lags behind sea-level rise (*i.e.*, wetlands do not keep pace), the wetlands will eventually become submerged and deteriorate even as they migrate inland, resulting in a loss of wetland area. Thus although the dry land available for potential inland wetland migration or formation is estimated to be less than 20% of the current area of wetlands (Chapter 1), these lands could potentially become important wetland areas in the future. However, they may not be available for wetland migration and formation given current policies and land use trends (Chapter 5).

A continuation of the current practice of protecting almost all developed estuarine shores could reverse the accomplishments of important environmental programs. Until the middle of the 20th century, tidal wetlands were often converted to dredge-and-fill developments[29]. By the 1970s, the aggregate result of the combination of federal and state regulations had, for all practical purposes, halted that practice. In the Mid-Atlantic, most tidal wetlands are off-limits to development. Coastal states generally prohibit the filling of low marsh, which is publicly owned in most states under the public trust doctrine (See Chapter 7).

A landowner who wants to fill tidal wetlands on private property must obtain a permit from the Army Corps of Engineers. 33 U.S.C. §§ 403, 409, 1344(a). These permits are generally not issued unless the activity is inherently water-related, such as a marina. 40 C.F.R. § 230.10(a)(3). Even then, the owners generally must mitigate the loss of wetlands by creating or enhancing wetlands elsewhere (EPA and USACE 1990). (Activities with very small impacts on wetlands, however, often qualify for a nationwide permit.) The net effect of all these programs has been to sharply reduce the rate of coastal wetland loss (*e.g.*, Stockton and Richardson, 1987; Hardisky and Klemas, 1983) and preserve an almost continuous strip of marshes, beaches, swamps, and mudflats along the U.S. Coast. If sea-level rise accelerates, those wetlands are likely to be lost (Reed *et al*., 2008) unless either they are able to migrate inland or future generations use technology to ensure that wetland surfaces rise as rapidly as the sea (NRC, 2006).

[29] See Chapter 5 for an explanation of these developments and their vulnerability to sea level rise.

Current approaches would *not* protect wetlands for future generations if sea level rises beyond the ability of wetlands to accrete — which is likely for most of the Mid-Atlantic with a 7 mm/yr acceleration, and likely for a 2mm/yr acceleration for most of Chesapeake Bay's wetlands.

Existing federal statutes are designed to protect existing wetlands, but the totality of the Nation's wetland protection program is the end result of decisions made by many actors. Federal programs discourage destruction of most *existing* coastal wetlands, but the federal government has not moved towards allowing tidal wetlands to migrate inland (Titus, 2000). The States of North Carolina, Maryland, New Jersey, and New York own the tidal wetlands below mean high water; and Virginia, Delaware, and Pennsylvania have enough of an ownership interest under the Public Trust Doctrine to preserve them even if doing so requires landward migration (Titus, 1998). But most states give property owners a near-universal permit to protect property by preventing wetlands from migrating onto dry land. Farmers rarely erect shore protection structures, but homeowners usually do (Titus, 1998; NRC, 2006). A few coastal counties and states have decided to keep shorefront farms and forests undeveloped, (see Appendices D, E, and F) but most have not. Government agencies that hold land with conservation objectives have not decided to purchase the land or easements necessary to enable wetlands to migrate inland[30]. Thus, in effect, the United States has decided to *save* its existing wetlands. But the net effect of all the decisions made at different levels is very likely to *eliminate*

[30] But see chapter 10 for discussion of private conservancies.

wetlands by blocking their landward migration as a rising sea erodes their outer boundaries.

Not only is the long-term success of wetland protection sensitive to sea-level rise, it is also sensitive to *when* such decisions are made. The political and economic feasibility of allowing wetlands to take over a given parcel as sea level rises is much greater if appropriate policies are in place before the property is intensely developed. Many coastal lands are undeveloped today, but development continues. Deciding now that wetlands will have land available to migrate inland could protect more wetlands than delaying such a decision. In some places, such policies might discourage development in areas onto which wetlands may be able to migrate. In other areas, development could occur with the understanding that eventually land will revert to nature if sea level rises enough to submerge it. Like beach nourishment, artificial vertical build-up of tidal wetlands would not necessarily require a lead-time of several decades; but developing technologies to do so and determining whether and where they are appropriate could also take decades. To the extent that human activities[31] interfere with natural vertical accretion (build-up), restoring natural processes before the wetlands are lost is more effective than artificially re-creating them (EPA 1995; EPA and USACE 1990; Kruczynski 1990).

Even though the long-term success of the Nation's effort to protect wetlands is sensitive to sea-level rise, most of the individual decisions that ultimately determine whether wetlands can migrate inland depend on factors that are not sensitive to sea-level rise. The

[31] *E.g.*, water flow management, development that alters drainage patterns, and beach nourishment and inlet modification which thwarts barrier island overwash.

desire of bayfront homeowners to keep their homes is strong; and unlikely to abate even with a significant acceleration of sea-level rise[32]. State governments must balance the public interest in the tidal wetlands against the well-founded expectations of coastal property owners that they will not have to yield their property. Only a handful of states — none of which are in the Mid-Atlantic — have decided in favor of the wetlands (see Chapter 10). Local government decisions regarding land use reflect many interests. Objectives such as near-term tax revenues (often by seasonal residents who make relatively few demands for services) and a reluctance to undermine the economic interests of landowners and commercial establishments are not especially sensitive to rising sea level.

Today's decentralized decision making process seems to protect coastal wetlands reasonably well at the current rate of sea-level rise; but it will not enable wetlands to migrate inland as sea-level rise continues or accelerates. A large-scale landward migration of coastal wetlands is very unlikely to occur in most of the Mid-Atlantic unless a conscious decision is made for such a migration by a level of government with authority to do so.

9.3 SHORE PROTECTION

The case for anticipating sea-level rise as part of activities to prevent erosion and flooding has not been as strong as for wetland protection. The lead time required for shore protection is much less than for a planned retreat and wetland migration. Dikes,

[32] See, *e.g.*, Weggel *et al.* (1989), Titus *et al.* (1991), and NRC (2006) for an examination of costs and options for estuarine shore protection.

seawalls, bulkheads, and revetments can each be built within a few years. Beach nourishment is an incremental periodic activity; if the sea rises more than expected, one can add more sand.

The U.S. Army Corps of Engineers (Corps) has not evaluated whether sea-level rise will ultimately require fundamental changes in shore protection, but such changes do not appear to be urgent. Since the early 1990s, the Corps' guidance to project managers has urged them to attempt to identify robust strategies: "Feasibility studies should consider which designs are most appropriate for a range of possible future rates of rise. Strategies that would be appropriate for the entire range of uncertainty should receive preference over those that would be optimal for a particular rate of rise but unsuccessful for other possible outcomes." (USACE 2000a, page e-142). So far, this guidance has not significantly altered the Corps' approach to shore protection. Nevertheless, there is some question as to whether beach nourishment would be sustainable in the future if the rate of sea-level rise accelerates. It may be technically possible to double or triple the rate at which we nourish beaches and elevate the land surfaces of barrier islands 50–100 cm to offset rising sea level in the next century. But continuing such a practice indefinitely would eventually leave back barrier bays much deeper than today (see chapter 4), with unknown consequences for the environment and the barrier islands themselves. Similarly, it may be technically possible to build a low bulkhead along mainland shores as sea level rises 50–100 cm, but it could be more challenging to build a tall dike along the same shore—blocking waterfront views, requiring continual pumping, and exposing people behind the dike to the risk of flooding should that dike fail.

9.4 LONG-LIVED STRUCTURES: SHOULD WE PLAN NOW OR LATER?

The fact that eventually we will either hold back the sea or allow it to inundate a particular parcel of land does not, by itself, automatically imply that we must respond today. A community that will not need a dike until the sea rises 2 ft has little reason to build that dike today. Nevertheless, if the land where the dike would eventually be constructed happens to be vacant, the prospect of future sea-level rise might be a good reason to leave the land vacant. A homeowner whose house will be inundated in 30 to 50 years has little reason to move the house back today, but if the opportunity arises, it might be advisable to rebuild the house on a part of the lot that would provide it with a longer life.

Whether we need to be concerned about long-term sea-level rise ultimately depends on the lead time of our response options and on the costs and benefits of acting now versus later. A fundamental premise of benefit-cost analysis is that resources not deployed today can be invested profitably in another activity and yield a return on investment. Most engineering responses to sea-level rise fall into that category. For a given level of protection, dikes, seawalls, beach nourishment, jacking up structures, and elevating roadways are unlikely to cost more a few decades hence than today (USACE 2000b, 2007), and they can be implemented within the course of a few years. To the extent that this is our response to sea-level rise, we may not need to do it today. However, there are two exceptions.

The first exception might be called the "retrofit penalty" for failing to think long-term. If one is building (or rebuilding) a road or a drainage system anyway, then it may be far cheaper to design for a rise in sea level than modify it later, because in the latter case, the project needs to be built twice. For example, in a particular watershed in Charleston, South Carolina, if the sea rises one foot, the planned drainage system would fail and have to be rebuilt, but it would only cost an extra 5% to design the system today for a one-foot rise (Titus *et al.*, 1987, Table 2). The design and location of a house may be another example. If a house is designed to be moved, it can be moved; but a brick house on a slab foundation could be more problematic. Similarly, the cost of building a house 20 ft farther from the shore may be minor if the lot is large enough, whereas moving it back 20 ft could be substantial (EPA, 1989).

The second exception concerns the incidental benefits of doing something sooner. If a dike is not needed until the sea rises 2 ft because at that point a 100-year storm would flood the streets with 4 ft of water, the community is implicitly accepting the 2 ft of water that such a storm would provide today. If a dike is built now, it would stop this smaller flood as well as protect from the larger flood that will eventually occur. This reasoning was instrumental in leading the British to build the Thames River Barrier, which protects London. Some people argued that this expensive structure was too costly given the small risk of London flooding, but rising sea level meant that such a structure would eventually have to be built. Hence, the Greater London Council decided to build it during the 1970s (Gilbert and Horner, 1984).

While most engineering responses can be delayed with little penalty, the same cannot be said about land use decisions. Once an area is developed, the cost of vacating it as the sea rises is much greater than that cost would have been if the area was not developed. This is not to say that eventual inundation should automatically result in placing land off-limits to development. Even if a home has to be torn down 50 to 100 years hence, it might still be worth building. In some coastal areas where demand for beach access is great, rentals may recover the cost of home construction in less than a decade. However, once an area is developed, as a practical matter, it will not be abandoned unless either the eventual abandonment was part of the original construction plan, or the owners could not afford to hold back the sea. Therefore, the only way to preserve natural shores would be to make such a decision before an area is developed. Because the coast is being developed today, a failure to deal with this issue now is, in effect, a decision to allow the loss of wetlands and bay beaches wherever development takes place.

Among those options that have a net benefit compared to the baseline, many can be delayed because the benefits would still accrue. Delaying action can decrease the present value of the cost of acting — and increase the likelihood that the preparation is more closely tailored to what is necessary. But it can also increase the likelihood that one does not prepare until it is too late. One way to address this dilemma is to consider the lead times associated with particular types of adaptation (IPCC, 1992; O’Callahan, 1994).

9.5 DECISIONS BY COASTAL PROPERTY OWNERS ON ELEVATING HOMES

People are increasingly elevating homes to reduce the risk of flooding during severe storms, and in very low areas, people also elevate their yards. The cost of elevating even a small wood-frame cottage on a block foundation is likely to be $15,000–20,000 — and larger houses cost proportionately more. If it is necessary to drill pilings, the cost can be double because one has to move the house to the side and then move it back. If elevating the home prevents its subsequent destruction within a few decades, it will have been worthwhile. At a 5% discount rate, for example, it is worth investing 25% of the value of a structure to avoid a guaranteed loss 28 years hence. In areas where complete destruction of a home is unlikely, people sometimes elevate homes because of the lower insurance rates and to avoid the risk of water damages to walls and furniture. But the decision to elevate involves factors other than flooding as well, including better views of the water, increased storage and/or parking spaces, and greater difficulty for the elderly to enter their homes. Rising sea level can be a motivating factor to elevate a home even when one is uncertain about whether it is worth doing so, because it is likely that it will eventually be necessary (unless there is a good chance that the home will be replaced with a larger structure).

In cases where a new home is being constructed, or an existing home is elevated for reasons unrelated to sea-level rise, (such as a realization of the risk of flooding), rising sea level would justify raising the home to a higher level than would otherwise be the case. Elevating the home to (for example) 30 cm above the base flood elevation as part of the initial construction costs very little. The rising sea level increases the expected flood damages over the lifetime of a home. Thus, for very little marginal cost, future flood damages can be avoided by elevating the home more than would otherwise be the case.

9.6 FLOODPLAIN MANAGEMENT

The decisions that are potentially sensitive to rising sea level include floodplain mapping, floodplain regulations, flood insurance rates, and the various hazard mitigation activities that often take place in the aftermath of a serious storm. Although the outcomes of all these activities are clearly sensitive to sea-level rise, analysis is not available to enable assessment of whether future sea-level rise warrants changing the way things are done today.

9.6.1 Floodplain Regulations

The flood insurance program requires new (or substantially rebuilt) structures in the coastal floodplain to have the first floor above the base flood elevation (100-year flood). The program vests considerable discretion in local officials to tailor specific requirements to local conditions, or to enact regulations that are more stringent than FEMA's minimum requirements. Several communities have decided to require floor levels to be one foot (or more) above the base flood elevation. In some cases, past or future sea-level rise has been cited as one of the justifications for doing so. There is considerable variation in both the costs and benefits of designing building to accommodate future sea-level rise. If local governments believe that property owners need a nudge to optimally address sea-level rise, they can require more stringent (higher) floor elevations. A possible reason for requiring higher floor elevations is that the current structure of the program does not raise rates for existing structures even if flood risks increase over time.

9.6.2 Floodplain Mapping

Requiring flood elevations above the base flood elevation can create anomalies, unless floodplain mapping also takes sea-level rise in account. Local jurisdictions have pointed this out (see Baltimore box in Appendix F). Otherwise, building in today's floodplain would have to be higher than adjacent buildings on higher ground that is outside of the floodplain today. The ability of local officials to voluntarily prepare for rising sea level is thus somewhat constrained by the lack of floodplain mapping that takes account of sea-level rise. Creation of maps that take account of sea-level rise would thus appear to be a low-regrets activity, because it would enable local officials to modify requirements where appropriate.

9.6.3 Federal Flood Insurance Rates

A 1991 Report to Congress by FEMA concluded that there was little need to change the Flood Insurance Program because rates would be adjusted as sea level rises and flood maps are revised (FEMA, 1991). Other commentators have pointed out, however, that flood insurance rates respond to increased risk for new or rebuilt homes, but not existing homes.

Flood insurance is different than most types of insurance. Unlike automobile insurance, the flood insurance program does not adjust rates as the individual conditions of a property make it riskier. Although shoreline erosion and rising sea level increase the expected flood damages of a given home, they do not cause the rates on a given property to rise. Unless a home is substantially changed, its assumed risk is grandfathered (*e.g.*, NFIP, 2007; Heinz Center, 2000). Thus, not only do insurance rates not anticipate future sea-level rise, they do not react to the past rise. This approach, in effect, prevents property owners from feeling the "market signal" of increased risks.

New homes pay higher rates if new maps show risks to be increasing. And if the house is substantially enlarged, its rates will reflect the new risk. So whether or not a property owner feels the market signal of increased rates depends on the expected frequency of reconstruction compared with the time it will take for a significant increase in the risk. FEMA's Report to Congress assumed, in effect, that reconstruction occurs rapidly compared to the rate at which risk increases; so relatively few people will have an artificially low insurance rate due to sea-level rise (FEMA, 1991).

Other studies have reached the opposite conclusion. The National Academy of Sciences has recommended that the Flood Insurance Program create mechanisms to ensure that insurance rates reflect the increased risks caused by coastal erosion (NAS 1990, p. 9, 91). NAS pointed out that Congress has explicitly included storm-related erosion as part of the damages covered by flood insurance (42 U.S.C. §4121), and that FEMA's regulations (44 CFR Part 65.1) already defined special "erosion zones" (NAS 1990, p. 72). A FEMA-supported study by the Heinz Center (2000) and a theme issue in the *Journal of Coastal*

Research (Crowell and Leatherman, 1999) also concluded that, because of existing shore erosion, there can be a substantial disparity between actual risk and insurance rates.

Would sea-level rise justify changing the current approach? Two possible alternatives would be to: (a) shorten the period during which rates are kept fixed so that rates can respond to risk and property owners can respond; or (b) keep the current policy of fixed rates, but instead of basing rates on the risk when the house is built — which tends to systematically underestimate the risk — base the rate on an estimate of the average risk over the lifetime of the structure, using assumed rates of sea-level rise, shore erosion, and structure lifetime. The latter approach received considerable consideration in the FEMA-supported study by the Heinz Center and the theme issue in *Journal of Coastal Research*. That analysis assumed current rates of sea-level rise. FEMA has not investigated whether accelerated sea-level rise would increase the disparity between risks and insurance rates enough to revisit that decision; nor has it investigated the option of adjusting rates to reflect changing risks. Although Congress has not provided FEMA with a mandate to act on the Heinz Center recommendations, the Government Accountability Office (2007) recently recommended that FEMA analyze the potential long-term implications of climate change for the National Flood Insurance Program. FEMA has told Congress that it intends to initiate such an analysis (Buckley 2007).

9.6.4 Post Disaster Hazard Mitigation

If a coastal community is ultimately going to be abandoned to the rising sea level, a major rebuilding effort in the current location may be less useful than expending the same resources rebuilding the community on higher ground. On the other hand, if the community plans to remain in its current location despite the increasing costs of shore protection, then it is important for people to understand that commitment. Unless property owners know which path the community is following, they do not know whether to reinvest. Moreover, if the community is going to stay in its current location, owners need to know whether their land will be protected with a dike or if the street is likely to be elevated a few feet.

9.7 CONCLUSIONS

The need to prepare for rising sea level depends on the length of the period of time over which the decision will continue to have consequences, how sensitive those consequences are to how much the sea rises, how rapidly the sea is expected to rise and the magnitude of uncertainty over that expectation, the decision maker's risk tolerance, and the implications of deferring a decision to prepare. Someone making a decision with outcomes over a long period of time about an activity that is sensitive to sea level may need to consider sea-level rise — especially if whatever one might do today to prepare would not be feasible later. Decisions with outcomes over a short period of time about activities that are not sensitive to sea level probably need not consider sea-level rise — especially if whatever one might do to prepare today would be just as effective if done later.

Instances where the existing literature provides an economic rationale for preparing for accelerated sea-level rise include:

- *Coastal wetland protection*. Wetlands and the success of wetland-protection efforts are almost certainly sufficiently sensitive to sea-level rise to warrant examination of some changes in coastal wetland protection efforts, assuming that the objective is to ensure that most estuaries that have extensive wetlands today will continue to have tidal wetlands in the future. Coastal wetlands are sensitive to rising sea level, and many of the possible measures needed to ensure their survival as sea level rises have a very long lead time. Changes in management approaches would likely involve consideration of options at various levels of authority.
- *Coastal infrastructure*. Whether it is beneficial to design coastal infrastructure to anticipate rising sea level depends on the ratio of the incremental cost of designing for a higher sea level now, compared with the retrofit cost of modifying the structure later. No general statement is possible, because this ratio varies and relatively few engineering assessments of the question have been published. But because the cost of analyzing this question is very small compared with the retrofit cost, it is likely that most long-lived infrastructure in the coastal zone is sufficiently sensitive to rising sea level so as to warrant an analysis of the comparative cost of designing for higher water levels now and retrofitting later.
- *Building along the coast.* In general, the economics of coastal development alone does not currently appear to be sufficiently sensitive to sea-level rise so as to avoid construction in coastal areas. Land values are so high that development is often economic even if a home is certain to be lost within a few decades. The optimal location and elevation of new homes may be sensitive to prospects for rising sea level.

- *Shoreline planning.* A wide array of measures for adapting to rising sea level depend on whether a given area will be elevated, protected with structures, or abandoned to the rising sea. Several studies have shown that in those cases where the shores will retreat and structures will be removed, the economic cost will be much less if people plan for that retreat. The human toll of an unplanned abandonment may be much greater than if people gradually relocate when it is convenient to do so. Conversely, people may be reluctant to invest in an area without some assurance that lands will not be lost to the sea. Therefore, long-term shoreline planning is generally justified and will save more than it costs; the more the sea ultimately rises, the greater the value of that planning.
- *Rolling easements, density restrictions, and coastal setbacks.* Several studies have shown that in those cases where the shores will retreat and structures will be removed, the economic cost will be much less if people plan for that retreat. Along estuaries, a retreat is rarely forced by events and thus is likely to only occur if land remains lightly developed. It is very likely that options such as rolling easements, density restrictions, coastal setbacks, and vegetative buffers, would increase the ability of wetlands and beaches to migrate inland.
- *Floodplain management: Consideration of reflecting actual risk in flood insurance rates.* Economists and other commentators generally agree that insurance works best when the premiums reflect the actual risk. Even without considering the possibility of accelerated sea-level rise, the National Academy of Sciences (1990) and a FEMA-supported study by the Heinz Center (2000) concluded and recommended to Congress that insurance rates should reflect the

changing risks resulting from coastal erosion. Rising sea level increases the potential disparity between rates and risks of storm-related flooding.

CHAPTER 9 REFERENCES

Arrow, K.J and A.C. Fisher, 1974: Environmental preservation, uncertainty, and irreversibility. *Quarterly Journal of Economics*, **88(1)**, 312-319.

Barth, M.C. and J.G. Titus, 1984: *Greenhouse Effect and Sea Level Rise: A Challenge for This Generation.* Van Nostrand Reinhold, New York, 325 pp.

Bin, O., T. Crawford, J.B. Kruse, and C.E. Landry, Forthcoming: Viewscapes and flood hazard: coastal housing market response to amenities and risk. *Land Economics* (submitted)

Bin, O., J.B. Kruse, and C.E. Landry, forthcoming: Flood hazards, insurance rates, and amenities: evidence from the coastal housing market. *Journal of Risk and Insurance* (submitted)

Bukley, M., 2007: Testimony of Michael Buckley, U.S. Senate Committee on Homeland Security and Government Affairs, April 19, 2007

Coase, R., 1969: The problem of social cost. Reprinted in: *Economics of the Environment: Selected Readings* [Stavins, R.N. (ed.)]. W.W. Norton, New York, 4th ed. (2000), 659 pp.

Congressional Research Service, 2003: *Benefit-Cost Analysis and the Discount Rate for the Corps of Engineers Waster Resource Projects: Theory and Practice*. RL31976

Cordes, J., D. Gatzlaff, and A. Yezer, 2001: To the water's edge, and beyond: effects of shore protection projects on beach development. *Journal of Real Estate Finance and Economics*, **22(2)**, 287-302.

Cordes, J.J. and A.M.J. Yezer, 1998: In harm's way: does federal spending on beach enhancement and protection induce excessive development in coastal areas? *Land Economics*, **74(1)**, 128-145.

Crawford-Brown, D.J., 1999: *Risk-Based Environmental Decisions: Methods and Culture*. Kluwer Academic Publishers, Boston MA, 224 pp.

Crosset, K.M., T.J. Culliton, P.C. Wiley, and T.R. Goodspeed, 2004: *Population Trends along the Coastal United States: 1980–2008.* NOAA National Ocean Service, Silver Spring, MD, 47 pp. Available at http://oceanservice.noaa.gov/programs/mb/pdfs/coastal_pop_trends_complete.pdf

Crowell, M. and S.P. Leatherman (eds.), 1999: Coastal Erosion Mapping and Management. *Journal of Coastal Research*, Special Issue 28, 196 pp.

Dasgupta, P., 2006: Comments on the Stern Review's *Economics of Climate Change*. University of Cambridge, 9 pp. Available: http://www.econ.cam.ac.uk/faculty/dasgupta/Stern.pdf.

EPA, 1989: *Potential Effects of Global Climate Change on the United States: Report to Congress*. EPA Office of Policy, Planning, and Evaluation, Washington, DC.

EPA, 1995: Federal guidance for the establishment, use and operation of mitigation banks. *Federal Register*, **60(228)**, 58605-58614.

EPA, 2000: *Guidelines for Preparing Economic Analyses*. EPA 240-R-00-003, EPA Office of the Administrator, [Washington DC]. Available at http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html

Environmental Protection Agency & U.S. Army Corps Of Engineers, Mitigation Memorandum Of Agreement 4 (Feb. 6, 1990).

Farbotko, C., 2005: Tuvalu and climate change: constructions of environmental displacement in *The Sydney Morning Herald. Geografiska Annaler, Series B: Human Geography*, **87(4)**, 279-293. doi:10.1111/j.0435-3684.2005.00199

Federal Emergency Management Agency, 1991: *Projected Impact of Relative Sea Level Rise on the National Flood Insurance Program.* FEMA Flood Insurance Administration, Washington DC, 72 pp.

Fisher, A.C. and W.M. Hanemann, 1987: Quasi-option value: some misconceptions dispelled. *Journal of Environmental Economics and Management*, **14(2)**, 183-190.

Freeman, A.M., 2003: *The Measurement of Environmental and Resource Values: Theory and Methods*. Resources for the Future, Washington, DC, 2nd ed., 491 pp.

Gilbert, S. and R. Horner, 1984: *The Thames Barrier*. Thomas Telford, London, 182 pp.

Government Accountability Office, 2007: *Climate Change: Financial Risks to Federal and Private Insurers in Coming Decades are Potentially Significant*. Report to the Committee on Homeland Security and Governmental Affairs, U.S. Senate. GAO-07-285, Government Accountability Office, Washington DC, 68 pp. Available at http://www.gao.gov/cgi-bin/getrpt?GAO-07-285

Hardisky, M.A**.** and V. Klemas, 1983: Tidal wetlands natural and human-made change from 1973 to 1979 in Delaware: mapping techniques and results. *Environmental Management*, **7(4)**, 339-344.

Ha-Duong, M., 1998: Quasi-option value and climate policy choices. *Energy Economics*, **20(5/6)**, 599-620.

Heinz Center, 2000**.** *Evaluation of Erosion Hazards.* The H. John Heinz III Center for Science, Economics, and the Environment, Washington, DC, 252 pp. Available at http://www.heinzctr.org/publications.shtml#erosionhazards

Interagency Performance Evaluation Task Force, 2006: *Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System*. U.S. Army Corps of Engineers, Washington, DC. Available at https://ipet.wes.army.mil

IPCC, 1990: *Strategies for Adaption (sic) to Sea Level Rise.* Report of the Coastal Zone Management Subgroup of the Response Strategies Working Group.

IPCC CZMS (Intergovernmental Panel on Climate Change Coastal Zone Management Subgroup), 1992: *Global Climate Change and the Rising Challenge of the Sea.* IPCC Response Strategies Working Group, Rijkswaterstaat, The Hague.

Johnson, Z.P., 2000: *A Sea Level Rise Response Strategy for the State of Maryland*. Maryland Department of Natural Resources, Annapolis, MD, 49 pp.

Just, R.E., D.L. Hueth, and A. Schmitz, 2004: *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation*. Edward Elgar, Northampton, MA, 688 pp.

Kousky, C., F.E.P. Luttmer, and R.J. Zeckhauser, 2006: Private investment and government protection. *Journal of Risk and Uncertainty*, **33(1-2)**, 73–100.

Kruczynski, W.L., 1990: Options to be considered in preparation and evaluation of mitigation plans. In *Wetland Creation and Restoration: The Status of the Science* [Kusler, J.A. and M.E. Kentula (eds.)]. Island Press, Washington, DC, 594 pp.

Landry, C.E., A.G. Keeler, and W. Kriesel, 2003: An economic evaluation of beach erosion management alternatives. *Marine Resource Economics*, **18**, 105–127.

NAS, 1983: *Risk Assessment in the Federal Government: Managing the Process*. National Academy Press, Washington DC, 191 pp.

National Academy of Sciences, 1990: *Managing Coastal Erosion*. National Academy Press, Washington, DC, 182 pp.

Newell, R.G. and W.A. Pizer, 2004: Uncertain discount rates in climate policy analysis. *Energy Policy*, **32(4)**, 519-529.

NFIP (National Flood Insurance Program), 2007: *Fact Sheet: Saving on Flood Insurance Information about the NFIP's Grandfathering Rule.* FEMA, [Washington DC], 2 pp. Available at http://www.fema.gov/library/viewRecord.do?id=2497

Nordhaus, W.D., 2007a: Critical assumptions in the Stern Review on Climate Change. *Science*, **317(5835)**, 201–202.

Nordhaus, W.D. 2007b: A review of the Stern Review on *The Economics of Climate Change*. *Journal of Economic Literature*, **XLV**, 686-702.

Nossiter, A. and J. Schwartz, 2006: U.S. issues lenient guidelines for rebuilding in New Orleans. *New York Times* (Late Edition (East Coast)), April 13, A-1.

NRC, 1987: *Responding to Changes in Sea Level: Engineering Implications*. Committee on Engineering Implications of Changes in Relative Mean Sea Level, Marine Board. National Academy Press, Washington, DC, 148 pp.

NRC, 2007: *Mitigating Shore Erosion Along Sheltered Coasts*. National Academies Press, Washington, DC, 188 pp.

O'Callahan, J. (ed.), 1994: *Global Climate Change and the Rising Challenge of the Sea.* Proceedings of the third IPCC CZMS workshop, Isla de Margarita, Venezuela, 9–13 March 1992, National Oceanic and Atmospheric Administration, Silver Spring, MD, v+691 pp.

OMB (Office of Management and Budget), 1992: *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.* OMB Circular A-94, Office of Management and Budget, Washington, DC. Available: http://www.whitehouse.gov/omb/circulars/a094/a094.html.

Pilarczyk, K.W., 2007: Flood protection and management in the Netherlands. In: *Extreme Hydrological Events: New Concepts for Security*. Proceedings of the NATO advanced research workshop. [Vasiliev, O.F., P.H.A.J.M van Gelder, E.J. Plate, and M.V. Bolgov (eds.)]. Springer, Dordrecht and London, pp. 385-408.

Reed, D.J., D.A. Bishara, D.R. Cahoon, J. Donnelly, M. Kearney, A.S. Kolker, L.L. Leonard, R.A. Orson, and J.C. Stevenson, 2007: Site-Specific Scenarios for Wetlands Accretion as Sea Level Rises in the Mid-Atlantic Region. Supporting Document for CCSP 4.1, Question 3.

Samuelson, P.A. and W.D. Nordhaus, 1989: *Economics*. McGraw-Hill, New York, 13th ed., 1013 pp.

Stockton, M.B. and C.J. Richardson, 1987: Wetland development trends in coastal North Carolina, USA, from 1970 to 1984. *Environmental Management*, **11(5)**, 649-657.

Titus, J.G., 1990: Strategies for adapting to the greenhouse effect. *Journal of the American Planning Association*, **56(3)**, 311-323.

Titus, J.G., 1991: Greenhouse effect and coastal wetland policy: how Americans could abandon an area the size of Massachusetts at minimum cost. *Environmental Management*, **15(1)**, 39-58.

Titus, J.G., 1998: Rising seas, coastal erosion and the taking clause: how to save wetlands and beaches without hurting property owners. *Maryland Law Review*, **57**, 1277–1399.

Titus, J.G., 2000: Does the U.S. government realize that the sea is rising? How to restructure federal programs so that wetlands and beaches survive. *Golden Gate Law Review*, **30**, 717–786.

Titus, J.G., 2005: Does shoreline armoring violate the Clean Water Act? Rolling easements, shoreline planning, and other responses to sea level rise. In *America's Changing Coasts: Private Rights and Public Trust* [Whitelaw, D.M. and G.R. Visgilio (eds.)]. Edward Elgar, Cheltenham, UK and Northampton, MA, 248 pp.

Titus, J.G. and V. Narayanan, 1996: The risk of sea level rise. *Climatic Change*, **33(2),** 151–212.

Titus, J.G., R.A. Park, S.P. Leatherman, J.R. Weggel, and M.S. Greene, 1991: Greenhouse effect and sea level rise: the cost of holding back the sea. *Coastal Management*, **19(2)**, 171-204.

Titus, J.G., C.Y. Kuo, M.J. Gibbs, T.B. LaRoche, and M.K. Webb, 1987: Greenhouse effect, sea level rise, and coastal drainage systems. *Journal of Water Resources Planning and Management*, **113(2)**, 216-227.

USACE 2000a: *Planning Guidance Notebook* Army Corps of Engineers document # ER 1105-2-100. Washington, D.C.: Department of the Army, U. S. Army Corps of Engineers Appendix E: Civil Works Missions and Evaluation Procedures. Available at: http://www.usace.army.mil/publications/eng-regs/er1105-2-100/toc.htm (cited January 10, 2008).

U.S. Army Corps of Engineers, 2000b: 31 March 2000, EM 1110-2-1304, *Civil Works Construction Cost Index System (CWCCIS). For updated CWCCIS data tables* revised 30 September 2007, see: http://www.usace.army.mil/publications/eng-manuals/em1110-2-1304/toc.htmn

Weggel, S. Brown, J.C. Escajadillo, P. Breen, and E. Doheyn, 1989: The cost of defending developed shoreline along sheltered shores. In: U.S. Environmental Protection Agency. 1989. Report to Congress: Potential Effects of Global Climate Change on the United States. Appendix B: Sea Level Rise. Washington, DC: Office of Policy, Planning, and Evaluation.

Yohe, G., J. Neumann, P. Marshall, and H. Ameden, 1996: The economic cost of greenhouse-induced sea-level rise for developed property in the United States. *Climatic Change*, **32(4)**, 387-410.

Chapter 10. Ongoing Adaptation

Author: James G. Titus, EPA

KEY FINDINGS

- Most organizations are not yet taking specific measures to prepare for rising sea level. Recently, however, many public and private organizations have begun to assess possible response options.
- Most of the specific measures that have been taken to prepare for accelerated sea level rise have had the purpose of reducing the long-term adverse environmental impacts of sea level rise.

Preparing for the consequences of rising sea level has been the exception rather than the rule in the Mid-Atlantic. Nevertheless, many coastal decision makers are now starting to consider how to respond, and seriously thinking about changing some of the things people do to prepare for a rising sea.

This chapter examines those cases in which organizations are consciously anticipating the effects of sea-level rise. It does not catalogue the activities undertaken for other reasons that might also be justified on the basis for rising sea level, nor does it include all the cases in which an organization has authorized a study but not yet acted upon the study.

10.1 ADAPTATION FOR ENVIRONMENTAL PURPOSES

Many organizations that manage land for environmental purposes are starting to anticipate the effects of sea-level rise. Outside the Mid-Atlantic, some environmental regulators have also begun to address this issue.

10.1.1 Environmental Regulators

Organizations that regulate land use for environmental purposes generally have not implemented adaptation options to address the prospects of accelerated sea-level rise. Congress has given neither the U.S. Army Corps of Engineers (USACE) nor the Environmental Protection Agency (EPA) a mandate to modify existing wetland regulations to address rising sea level; nor have those agencies developed approaches for moving ahead without such a mandate. Outside of the Mid-Atlantic, a number of state and local governments have enacted statutes and regulations to enable wetlands to migrate inland, with the regulations in Maine, Rhode Island, and Cape Cod explicitly addressing rising sea level (Titus, 1998). But none of the eight Mid-Atlantic states have altered land use requirements to help ecosystems adjust to accelerated sea-level rise (NOAA, 2006).

Many restrictions on coastal development promulgated for unrelated reasons can also be justified as a response to sea-level rise. For example, Maryland’s coastal land use statute limits development to one home per 20 acres in most rural areas within 300 m of the shore (see Appendix F). Although the statute was enacted in the 1980s to prevent deterioration of water quality, if a similar statute were enacted today in another state, it could be justified as part of a sea-level rise adaptation strategy. The prospect of losing natural shores as sea level rises has caused Maryland to rethink wetland regulations concerning shore protection. It has a policy preference for "living shorelines", which is slowly making its way into the wetlands regulations, as the state tries to remove biases that favor hard structures over the soft approaches that enable wetlands and beaches to persist as sea level rises. In the aftermath of Hurricane Isabel, the State of Maryland attempted to move in that direction.

Federal Land Managers

The Department of Interior has a requirement that climate change impacts be taken into account in planning and decision making. The requirement is embodied in Secretarial Order 3226 signed in 2001. Testimony to Congress in 2007 by Lynn Scarlett, Deputy Secretary of Interior, detailed the many ways the Department of Interior is dealing with climate change, from land planning to management practices to scientific studies. The National Park Service has worked with the United States Geological Survey (USGS) to examine coastal vulnerability on all of its coastal parks. The U.S. Fish and Wildlife Service is incorporating studies of climate change impacts, including sea-level rise, in their Comprehensive Conservation Plans where relevant.

The National Park Service and the U.S. Fish and Wildlife Service each have large coastal landholdings that could erode or become submerged as sea level rises. Neither organization has an explicit policy concerning sea-level rise, but both are starting to consider their options. The National Park Service generally favors allowing natural processes to adjust to rising sea level, which led it to move the Hatteras Lighthouse inland some 2,900 ft at a cost of $12 million in 1999. The U.S. Fish and Wildlife Service generally allows dry land to convert to wetlands, but it is not necessarily passive as rising sea level erodes the seaward boundary of tidal wetlands. Blackwater National Wildlife Refuge, for example, has used dredge material to rebuild wetlands on a pilot basis, and has plans to spend approximately $500,000 to recreate 7,000 acres of marsh. Neither agency has made land purchases or easements to enable parks and refuges to migrate inland.

The Nature Conservancy (TNC)

TNC is the largest private holder of conservation lands in the Mid-Atlantic. It has declared as a matter of policy that it is trying to anticipate rising sea level and climate change. Its initial focus has been to preserve ecosystems on the Pamlico-Albemarle Peninsula (TNC, 2007). Options under consideration include plugging canals to prevent subsidence-inducing saltwater intrusion, planting cypress trees where pocosins have been converted to dry land, and planting brackish marsh grasses in areas likely to be inundated. As part of that project, TNC undertook the first attempt by a private conservancy to purchase rolling easements (although none were purchased). TNC owns the majority of barrier islands along the Delmarva Peninsula, but none of the mainland shore. TNC is starting to examine whether preserving the ecosystems as sea level rises would be best facilitated by purchasing land on the mainland side as well, to ensure sediment sources for the extensive mudflats so that they might keep pace with rising sea level.

State conservation managers have not yet started to prepare for rising sea level (NOAA, 2006). But at least one state (Maryland) is starting to refine a plan for conservation that would consider the impact of rising sea level.

10.2 OTHER ADAPTATION OPTIONS BEING CONSIDERED BY FEDERAL, STATE, AND LOCAL GOVERNMENTS

10.2.1 Federal Government

Federal researchers have been examining how best to adapt to sea-level rise for the last few decades, and those charged with implementing programs are also now beginning to consider implications and options. The longstanding assessment programs will enable federal agencies to respond more rapidly and reasonably if and when policy decisions are made to begin preparing for the consequences of rising sea level.

The Coastal Zone Management Act is a typical example. The Act encourages states to protect wetlands, minimize vulnerability to flood and erosion hazards, and improve public access to the coast. Since 1990, the Act has included sea-level rise in the list of hazards that states should address. This Congressional mandate has induced NOAA to fund state-specific studies of the implications of sea-level rise, and encouraged states to periodically designate specific staff to keep track of the issue. But it has not yet altered what people actually do along the coast. One commentator has suggested that for this statutory provision to be carried out, the federal government should consider providing guidance on possible responses to sea-level rise (Titus, 2000). Similarly, the Corps of

Engineers has formally included the prospect of rising sea level for at least a decade in its planning guidance for the last decade (USACE, 2000), and staff has sometimes evaluated the implications for specific decisions (e.g. Knuuti, 2002). But the Corps' overall approach to wetland permits and shore protection has not yet shifted.

10.2.2 State Government

Maryland has considered the implications of sea-level rise in some decisions over the last few decades. Rising sea level was one reason that the state gave for changing its shore protection strategy at Ocean City from groins to beach nourishment. Using NOAA funds, the state developed a preliminary strategy for dealing with sea-level rise. As part of that strategy, the state also recently obtained a complete LIDAR data set of coastal elevations.

Delaware officials have long considered how best to modify infrastructure as sea level rises along Delaware Bay, although they have not put together a comprehensive strategy[33]. Coastal Management staff of the New Jersey Department of Environmental Protection have been guided by a long-term perspective on coastal processes, including the impacts of sea-level rise. So far, neither Delaware nor New Jersey has specifically altered their activities because of projected sea-level rise. Nevertheless, New Jersey is currently undertaking an assessment that may enable it to factor rising sea level into its strategy for preserving the Delaware Estuary[34].

[33] CCSP 4.1 Stakeholder Report.

[34] CCSP SAP 4.1 Stakeholder Report (summarizing the reaction of the New Jersey Coastal Zone Management Program).

A bill in the New York General Assembly would create a sea-level rise task force (Bill AO9002 2007-2008 Regular Session). Maryland has a climate change adaptation task force that is focusing on sea-level rise.

Outside of the Mid-Atlantic, the California Legislature is considering Bill AB 1066, which would require state agencies to consider sea-level rise in their activities.

10.2.3 Local Government

A few local governments have considered the implications of rising sea level for roads, infrastructure, and floodplain management. (See text boxes in Appendices D and F.). New York City's plan for the year 2030 includes adapting to climate change. (NYC, 2008; pp. 136-40). The New York City Department of Environmental Protection is looking at ways to decrease the impacts of storm surge by building flood walls to protect critical infrastructure such as waste plants, and is also examining ways to prevent the sewer system from backing up more frequently as sea level rises (Rosenzweig et al., 2006). The city has also been investigating the possible construction of a major tidal flood gate across the Verizano Narrows to protect Manhattan. (Velasquez-Manoff, 2006).

Outside of the Mid-Atlantic, Miami-Dade County in Florida has been studying its vulnerability to sea-level rise, including developing maps to indicate which areas are at greatest risk of inundation. The county is hardening facilities to better withstand hurricanes, monitoring the salt front, examining membrane technology for desalinating seawater, and creating a climate advisory task force to advise the county commission (Yoder, 2007).

CHAPTER 10 REFERENCES

City of New York, 2008: *PlaNYC: A Greater, Greener New York*. City of New York, New York, 155 pp. Available at http://home2.nyc.gov/html/planyc2030/downloads/pdf/full_report.pdf

Knuuti, K., 2002**:** Planning for sea level rise: U.S. Army Corps of Engineers Policy. In: *Solutions to Coastal Disasters '02* [Ewing, L. and L. Wallendorf (eds.)]. American Society of Civil Engineers, Reston, VA.

NOAA, 2006: Responses to Section 309 of the Coastal Zone Management Act. Coastal Zone Enhancement Program compiled by NOAA Office of Ocean and Coastal Resource Management, Silver Spring, MD. Available at http://coastalmanagement.noaa.gov/enhanc.html. Accessed July 23, 2007.

Rosenzweig, C., D. Majors, M. Tults, and K. Demong, 2006: New York City Climate Change Task Force. In: *Adapting to Climate Change: Lessons for London.* Greater London Authority, London, pp. 150-153. Available at www.london.gov.uk/climatechangepartnership/.

TNC (The Nature Conservancy), 2007: *Save of the Week: Climate Change Action on North Carolina's Albemarle Peninsula*. The Nature Conservancy, Arlington, VA. Available at http://www.nature.org/success/art14181.html. Accessed July 23, 2007.

Titus, J.G., 1998: Rising seas, coastal erosion, and the takings clause: how to save wetlands and beaches without hurting property owners. *Maryland Law Review*, 57(4), 1376-1378.

Titus, J.G., 2000: Does the US government realize that the sea is rising? How to restructure federal programs so that wetlands and beaches survive. *Golden Gate University Law Review*, **30(4)**, 717–778.

USACE, 2000: *Planning Guidance Notebook Appendix E: Civil Works Missions and Evaluation Procedures*. Army Corps of Engineers document # ER 1105-2-100, Department of the Army, U. S. Army Corps of Engineers, Washington, DC, 310 pp. Available at: http://www.usace.army.mil/publications/eng-regs/er1105-2-100/toc.htm (cited January 10, 2008).

Velasquez-Manoff, M., 2006: How to keep New York afloat. *The Christian Science Monitor*, November 9, 2006, p. 13.

Yoder, D., 2007: Miami Dade Water and Sewer Department presentation to American Water Works Association webcast: *Global Climate Impacts*. March 14, 2006.

Chapter 11. Institutional Barriers

Lead Author: James G. Titus, EPA

KEY FINDINGS

- Most institutions were designed without considering sea-level rise.
- Many institutions were created to respond to a demand for hard shoreline structures to hold the coast in a fixed location, and have generally not shifted to retreat or soft shore protection (*e.g*., beach nourishment).
- The interdependence of decisions made by property owners and federal, state, and local governments creates an institutional inertia that currently impedes preparing for sea-level rise, as long as no decision has been made regarding whether particular locations will be protected or yielded to the rising sea.

Chapter 9 describes several categories of decisions where the risk of sea-level rise justifies doing things differently today, and Chapter 10 examined the responses people are currently making, which in most cases are very limited.

It takes time to respond to new problems. Most coastal institutions were designed before the 1980s. Land use planning, infrastructure, home building, property lines, wetland protection, and flood insurance all have been designed without considering the dynamic nature of the coast. There is also a general mindset that sea level and shores are stable — or should be. Even when a particular institution has been designed to account for shifting shores, people are reluctant to give up real estate to the sea. Although scientific information can quickly change what people expect, it takes longer to change what people want. Finally, a phenomenon known as “moral hazard” often prevails. Moral hazard refers to a situation in which insurance reduces someone’s incentive to prevent or decrease the risk of a disaster (Pauly 1974). Our political process tends to sympathize with those whose property is threatened, rather than allowing them to suffer the consequences of the risk they assumed when they bought the property. It can be hard to say “no” to someone whose home is threatened (Viscusi and Zeckhauser 2006).

This chapter explores some of the institutional barriers that discourage people and organizations from preparing for the consequences of rising sea level. This discussion has two general themes. First, examination of the institutions and decisions they make regarding sea-level rise reveals that the challenge may more appropriately be how to overcome institutional *biases* rather than *barriers*. Policies that encourage higher densities in the coastal zone, for example, may be barriers to wetland migration, but they improve the economics of shore protection. Such a policy might be viewed as creating a bias in favor of shore protection over wetland migration, but it is not really a barrier to adaptation from the perspective of a community that prefers protection anyway. A bias simply encourages one path over another; a barrier can block a particular path entirely.

Second, interrelationships between various decisions tend to reinforce institutional inertia. Omission of sea-level rise from a land-use plan may discourage infrastructure designers from preparing for it; a federal regulatory preference for hard structures may prevent state officials from encouraging soft structures. Although inertia has slowed current acts to respond to the risk of sea-level rise, it could just as easily help to sustain momentum toward a response once key decision makers decide which path the course of action should follow.

The barriers and biases examined in this chapter mostly concern governmental rather than private sector institutions. Private institutions do not always exhibit foresight—and their limitations have been an important reasons for creating government flood insurance, wetland protection, shore protection, and other government programs. But the published literature does not suggest that rising sea level would change the institutional limitations of the private sector. The duty of corporations to maximize shareholder wealth, for example, may prevent a business from altering development plans to facilitate future environmental preservation as sea level rises. But for purposes of this chapter, the duty to serve shareholders is an essential objective of the corporate institution, not a barrier that keeps corporations from fulfilling their missions. Finally, there is little literature available on private institutional barriers to preparing for sea-level rise. We do not know whether this absence implies that the private barriers are less important, or simply that private organizations keep their affairs private more than public institutions.

11.1 SOME SPECIFIC INSTITUTIONAL BARRIERS AND BIASES

Productive institutions are designed to accomplish a mission, and they design rules and procedures to help accomplish those objectives. These rules and procedures are inherently biased toward achieving the mission, and against anything that thwarts the mission. By coincidence more than design, they may facilitate or thwart the ability of others to achieve other missions.

No one has prepared an exhaustive catalogue of institutional biases in the coastal zone, but three biases have been the subject of substantial commentary: (1) shore protection versus retreat; (2) hard structures versus soft engineering solutions; and (3) coastal development versus preservation.

11.1.1 Shore Protection Versus Retreat

Federal, state, local, and private institutions all have a strong bias *favoring* shore protection over retreat in developed areas. Many institutions also have a bias *against* shore protection in undeveloped areas.

*U.S. Army Corps of Engineers (USACE) Civil Works***.** Congressional appropriations for shore protection in coastal communities generally provide funds for various engineering projects to limit erosion and flooding. The planning guidance documents for the Corps of Engineers appear to provide USACE the discretion to relocate or purchase homes if a policy of retreat is the locally preferred approach and more cost-effective than shore protection. (USACE 2000 p. 2-8). Nevertheless, the general mission of the Corps of Engineers, its history (Lockhart and Morang 2002), staff expertise, and funding preferences combine to make shore protection far more common than a retreat from the shore.

State Shore Protection. North Carolina, Virginia, Maryland, Delaware, and New Jersey all have significant state programs to support beach nourishment along the Atlantic Ocean. (See Appendices C-F). Virginia, Delaware, and New Jersey have also supported beach nourishment in residential areas along estuaries as well. Some agencies in Maryland encourage private shore protection to avoid the environmental effects of shore erosion [35] (see Appendix F) and the state provides interest-free loans for up to 75% of the cost of nonstructural erosion control projects on private property (MD DNR 2008). None of these states has a program to support a retreat in developed areas.

FEMA Programs. Some aspects of the National Flood Insurance Program (NFIP) encourage shore protection, while others encourage retreat. FEMA requires local governments to ensure that new homes along the ocean are built on pilings sunk far enough into the ground so as to remain standing even if the dunes and beach are largely washed out from under the house during a storm. 44 CFR 60.3(e)(4). Although beaches will often recover to some extent after storms, they frequently do not entirely come back. In the past, when homes were built less sturdily, strategic retreat from the shore often occurred after major storms (*i.e.*, people did not rebuild as far seaward as homes had been before the storm). Now, newer homes can withstand storms and instead of retreating the tendency is for emergency beach nourishment operations to protect oceanfront homes. The requirement for construction on pilings also encourages larger homes; after a significant expense for pilings, people rarely build an inexpensive cottage. Therefore, larger homes are better able to justify shore protection. A FEMA emergency assistance

[35] MD DNR (2006), however, favors the no-action alternative over shore protection structures.

program will often fund such nourishment in areas where the beach was nourished before the storm. (FEMA 2007 p. 86-87; 44 CFR 206.226(j)) In portions of Florida that receive frequent hurricanes, these projects are a significant portion of total beach nourishment. They have not yet been a major source of funding for beach nourishment in the Mid-Atlantic.

Several FEMA programs are neutral or promote retreat. In the wake of Hurricane Floyd, one North Carolina county used FEMA money to elevate structures, while an adjacent county used those funds to help people relocate rather than rebuild (Appendix G.) Repetitively flooded homes have been eligible for relocation assistance under a number of programs. Because of FEMA's rate map grandfathering policy, (see Chapter 9), a statutory cap on annual rate increases, and limitations of the hazard mapping used to set flood insurance rates, some properties have rates that are substantially less than the risk. As a result, these programs assist property owners and save the flood insurance program money by decreasing claims. From 1985 until 1995, the Upton-Jones Act helped fund the relocation of homes in imminent danger from erosion (Crowell *et al*. 2007 p. 22). FEMA's Severe Repetitive Loss Program is authorized to spend $80 million to purchase or elevate homes that have either made four separate claims or at least two claims totaling more than the value of the structure (FEMA 2008a). Several other FEMA programs provide grants for reducing flood damages, which states and communities can use for relocating residents out of the flood plain, erecting flood protection structures, or flood-proofing homes (FEMA 2008b, 2008c, 2008d, 2008e).

Flood insurance rates are adjusted downward to reflect the reduced risk of flood damages, if a dike or seawall decreases flood risks during a 100-year storm. Because rates are ideally based on risk, this adjustment is not necessarily a bias toward shore protection.

Wetland Protection. The combination of federal and state regulatory programs to protect wetlands in the Mid-Atlantic strongly discourages development from advancing into the sea, by prohibiting or strongly discouraging the filling or diking of tidal wetlands for most purposes (See Chapter 9). Within the Mid-Atlantic, New York promotes the landward migration of tidal wetlands in some cases (See Appendix A); Maryland favors shore protection in some cases. The Federal government has no policy on the question of retreat versus shore protection.

Existing regulations do not encourage developers to create buffers that might enable wetlands to migrate inland, nor do they encourage landward migration in developed areas (Titus, 2000). In fact, the Corps of Engineers has issued a nationwide permit for bulkheads and other erosion-control structures. [36] Titus (2000) concluded that this permit which often ensures that wetlands will not be able to migrate inland unless the property owner does not want to control the erosion. For this and other reasons, the State of New York has said that bulkheads and erosion structures otherwise authorized under the nationwide permit will not be allowed in special management areas (which cover a large percentage of the coast) without state concurrence (See Appendix A).

[36] See 61 Fed. Reg. 65,873, 65,915 (Dec. 13, 1996) (reissuing Nationwide Wetland Permit 13, Bank Stabilization activities necessary for erosion prevention). *See also* Reissuance of Nationwide Permits, 72 Fed. Reg. 11,1108-09, 11183 (March 12, 2007) (reissuing Nationwide Wetland Permit 13 and explaining that construction of erosion control structures along coastal shores is authorized).

Federal statutes appear to discourage possible efforts by regulatory programs to encourage landward migration of wetlands. Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act require a permit to dredge or fill any portion of the navigable waters of the United States).[37] Courts have long construed this jurisdiction to include lands within the "ebb and flow of the tides," (Gibbons v. Ogden; Zabel v. Tabb; 40 C.F.R. § 230.3(s)(1) (2000)), but it excludes lands that are dry today but would become wet if the sea rose a meter (Titus, 2000). The absence of a statutory requirement to enable wetlands to migrate inland can be a barrier to possible efforts by Federal wetlands programs to anticipate sea-level rise—especially measures involving preservation of lands that are currently inland of Federal jurisdiction.

In most cases, the absence of a specific policy on sea-level rise appears to have a neutral effect on whether shores are protected or retreat. An important exception concerns the stabilization of barrier islands that might otherwise migrate inland. Under natural conditions, winds and waves tend to cause beaches and marshes on the bay sides of barrier islands to slowly advance into the bay toward the mainland. Rules against filling tidal waters prevent people from artificially doing so. After a storm washes sand from the beach onto the island, local governments bulldoze the sand back onto the beach rather than putting a portion into the bay, even though that is what would happen under natural conditions. Unlike the case of wetlands migrating onto dry land, limits on Federal

[37] See The Clean Water Act of 1977, § 404, 33 U.S.C. § 1344; The Rivers and Harbors Act of 1899, § 10, 33 U.S.C. §§ 403, 409 (1994).

jurisdiction do not prevent the Federal regulatory program from encouraging the landward migration of barrier islands.

Relationship to Coastal Development. Finally, many policies encourage or discourage coastal development, as discussed below. Even policies that subsidize relocation may indirectly encourage shore protection. Such assistance reduces the risk of an uncompensated loss of one's investment, thereby encouraging coastal construction, which in turn makes shore protection more likely.

11.1.2 Shoreline Armoring Versus Living Shorelines

The combined effect of Federal and state wetland protection programs is a general preference for hard shoreline structures over soft engineering approaches to stop shoreline erosion. (Box 11.1) The Corps of Engineers has issued nationwide permits to expedite the ability of property owners to erect bulkheads and revetments. [38] There is no such permit for soft solutions such as rebuilding an eroded marsh or bay beach.[39] The bias in favor of shoreline armoring results from the fact that the statute focuses on filling navigable waterways, not the environmental impact of the shore protection. Rebuilding a beach of marsh requires more of the land below high water to be filled than building a bulkhead.

[38] Reissuance of Nationwide Permits, 72 Fed. Reg. 11,1108-09, 11183 ((March 12, 2007) (reissuing Nationwide Wetland Permit 13 and explaining that construction of erosion control structures along coastal shores is authorized)

[39] Reissuance of Nationwide Permits, 72 Fed. Reg. 11, 11183, 11185 ((March 12, 2007) (explaining that permit 13 requires fill to be minimized and that permit 27 does not allow conversion of open to water to another habitat such as beach or tidal wetlands)

Until recently, state regulatory programs shared the preference for hard structures. Maryland now favors “living shorelines” instead (Chapter 10). But Federal rules can be a barrier to these state efforts. After Hurricane Isabel destroyed many shore protection structures, and people were rebuilding them on an emergency basis, Maryland wanted to make it just as easy for someone to get a permit to replace a destroyed bulkhead with a living shoreline, as to rebuild the bulkhead. But the state was unable to obtain Federal approval (Appendix F.).

The regulatory barrier to soft solutions appears to result more from inertia than a conscious bias in factor of hard structures. The nationwide permit program is designed to avoid the unnecessary burden of issuing a large number of specific but nearly-identical permits. For decades, many people have bulkheaded their shores, so Nationwide Permit 13 was issued by the US Army Corps of Engineers in 2007 to cover bulkheads and similar structures. Because few people were rebuilding their eroding tidal wetlands, no nationwide permit for this activity has been issued. Today, as people become increasingly interested in more environmentally sensitive shore protection, they are dealing with institutions that have historically responded to requests for hard shoreline structures to hold the coast in a fixed location, and are just beginning to determine how to manage the development of soft shore protection measures.

BEGIN BOX 11.1:

The Existing Decision-Making Process for Shoreline Protection on Sheltered Coasts

- There is an incentive to install seawalls, bulkheads, and revetments on sheltered coastlines because these structures can be built landward of the Federal jurisdiction and thus avoid the need for Federal permits.

- Existing biases of many decision-makers in favor of bulkheads and revetments with limited footprints limit options that may provide more ecological benefits.

- The regulatory framework affects choices and outcomes. Regulatory factors include the length of time required for permit approval, incentives that the regulatory system creates, [and] general knowledge of the options and their consequences.

- Traditional structural erosion control techniques may appear to be the most cost-effective. However, they do not account for the cumulative impacts that result in environmental costs nor the undervaluation of the environmental benefits of the nonstructural approaches.

- There is a general lack of knowledge and experience among decision makers regarding options for shoreline erosion mitigation on sheltered coasts, especially options that retain more of the shorelines' natural features.

- The regulatory response to shoreline erosion on sheltered coasts is generally reactive rather than proactive. Most states have not developed plans for responding to erosion on sheltered shores.

Source: National Research Council, Ocean Studies Board. 2007. *Mitigating Shore Erosion Along Sheltered Coasts* p. 122-23.

END BOX

11.1.3 Coastal Development

Federal, state, local, and private institutions all have a modest bias favoring increased coastal development in developed areas. The Federal government discourages development in undeveloped areas, while state and local governments have a more neutral effect.

Coastal counties often favor coastal development because expensive homes with seasonal residents can substantially increase property taxes without much demand for government services. The property tax system often encourages coastal development. A small cottage on a lot that has appreciated to $1 million can have an annual property tax bill greater than the annual rental value of the cottage.

Congressional appropriations for shore protection encourage coastal development along shores that are protected, by reducing the risk that the sea will reclaim their land and structures. This reduced risk increases land values and property taxes, which may encourage further development. It may also encourage increased densities in areas that are not eligible for funding. The benefit-cost formulas used to determine eligibility (USACE 2000) find greater benefits in the most densely developed areas, making increased density a possible path toward federal funding for shore protection. Keeping hazardous areas lightly developed, by contrast, is not a path for federal funding. (See *e.g*. Appendix A).

Several commentators have argued that the National Flood Insurance Program (NFIP) encourages coastal development (*e.g.*, Tibbetts 2006; Platt 2007). Without insurance, some people would be reluctant to risk $250,000[40] on a home that could be destroyed in a storm.[41] People would tend to build farther away from the shore, and the homes would be scaled to the level of wealth the owner is willing to place at risk Insurance converts a large risk into a modest annual payment that people are willing to pay. FEMA has analyzed this question, however, and concluded that overall, the owners of coastal property vulnerable to waves and to flooding pay premiums more than enough to pay the flood damage claims; there is no overall subsidy (FEMA 2006a; FEMA 2006b, Hayes *et al*. 2006, Crowell *et al.* 2007). But those analyses exclude the year 2005, when Hurricanes Katrina, Rita, and Wilma required the NFIP to borrow $20 billion from the U.S Treasury (42 USC 4016 modified by PL109-208, 2006). FEMA has not decided whether to raise flood insurance rates to completely account for the risk of another storm like Katrina (Crowell *et al.*, 2007) More broadly, the combination of flood insurance and the various post-disaster and emergency programs providing relocation assistance, mitigation (*e.g.,* home elevation), and emergency beach nourishment provide coastal construction with a federal safety net that makes coastal construction a safe investment.

Flood ordinances have also played a role in the creation of three-story homes where local ordinances once limited homes to two stories. Flood regulations have induced some people to build their first floor more than 8 ft above the ground (FEMA 1984, 1994, 2000, 2007b). Local governments have continued to allow a second floor no matter the

[40] NFIP only covers the first $250,000 in flood losses. 44 CFR 61.6 For homes with a construction cost greater than $250,000, federal insurance reduces a property owner's risk, but to a lesser extent.

[41] Research quantifying the impact of flood insurance on development is sparse. See Chapter 9.

elevation of the first floor. Property owners often enclose the area below the first floor (*e.g.* FEMA 2002), creating ground-level (albeit illegal[42] and uninsurable[43]) living space.

Currently, FEMA does not adjust rates to reflect new information when flood risks increase, but rather "grandfathers" the assumed risk (NFIP, 2007). Adaptation to climate change means adjusting to the changing nature of risk. But as shore erosion and rising sea level make the property more vulnerable, rates do not rise to reflect the increased risk from erosion until the property is substantially improved (Heinz Center, 2000). Moreover, FEMA is prevented by statute from raising premiums by more than 10% per year (42 USC §4015(e)), even if premiums are substantially below the annual expected damages. Thus, the NFIP probably does provide a subsidized insurance rate for new construction along eroding shores, which would encourage people to build on such shores. Whether the NFIP will also protect policy holders from the risks of sea-level rise is less clear. Under current policy, an increase in total claims would cause an across-the-board increase in rates (Crowell *et al.* 2007). The ability of the NFIP to recover losses from Katrina through a general rate increase would be analogous to the program's ability to adjust rates in response to accelerated sea-level rise or other consequences of changing climate.

The totality of these federal programs — in conjunction with sea-level rise — creates a "moral hazard." Coastal investment is profitable but risky. If government assumes much

[42] 44 CFR §60.3(c)(2)

[43] 44 CFR §61.5(a)

of this risk, then the investment can be profitable without being risky — an ideal situation for investors (Loucks et al, 2006). The "moral hazard" concern is that when investors make risky decisions whose risk is partly borne by someone else, there is a chance that they will create a dangerous situation by taking on too much risk (Pauly, 1974). The government may then be called upon to take on even the risks that the private investors had supposedly assumed, because the risk of cascading losses could harm the larger economy (Kunreuther and Michel-Kerjant, 2007). Shore protection seems cost-effective and flood insurance rates seem to reflect the risk in most cases. But if sea-level rise accelerates, will taxpayers, coastal property owners, or inland flood insurance policyholders have to pay the increased costs?

The Coastal Barrier Resources Act (16 U.S.C. U.S.C. §3501 *et seq*.) discourages the development of designated undeveloped barrier islands and spits, by denying flood insurance, disaster assistance, federal highway funding, mortgage funding, and most other forms of federal spending to them. The increased demand for coastal property has led many of these areas to become developed anyway (GAO 1992). "Where the economic incentive for development is extremely high, the Act's funding limitations can become irrelevant." (USFWS 2002 p. 29.).

11.2 INTERDEPENDENCE: A BARRIER OR A SUPPORT NETWORK?

Uncertainty can be a hurdle to preparing for sea-level rise. Uncertainty about sea-level rise and its precise effects is one problem, but uncertainty about what others will do can also be a barrier. For environmental stresses, a single Federal agency is charged with developing and coordinating the nation's response. The response to sea-level rise requires coordination among several agencies, including EPA (protecting the environment), USACE (shore protection), Department of Interior (managing conservation lands), and FEMA (flood hazard management). State and local governments generally have comparable agencies that work with their Federal counterparts. No single agency is in charge of developing a response to sea-level rise as it affects the missions of many agencies.

The decisions that these agencies and the private sector make regarding how to respond to level rise are interdependent. From the perspective of one decision maker, the fact that others have not decided on their response is a distinct barrier to preparing their own responses. One of the barriers of this type is the uncertainty whether the response to sea-level rise in a particular area will involve shoreline armoring, elevating the land, or retreat.

11.2.1 Definition of Three Fundamental Pathways: Armor, Elevate, or Retreat

Long-term approaches for managing low coastal lands as the sea rises can be broadly divided into three pathways:

- *Protect* the dry land with seawalls, dikes, and other structures, eliminating wetlands and beaches (also known as *shoreline armoring*)
- *Elevate the land,* and perhaps the wetlands and beaches as well, enabling them to survive
- *Retreat* by allowing the wetlands and beaches to take over land that is dry today.

Combinations of these three approaches are also possible. Each approach will be appropriate in some locations and inappropriate in others. Shore protection costs, property values, the environmental importance of habitat, and the feasibility of protecting shores without harming the habitat all vary by location. Deciding how much of the coast should be protected may require people to consider social priorities not easily included in a cost-benefit analysis of shore protection.

11.2.2 Decisions That Cannot Be Made Until the Pathway Is Decided

Rising sea level has numerous implications for current activities. Nevertheless, in most cases, the appropriate response depends on whether and which of these three courses of action a particular community intends to follow. Six examples are summarized in Table 11.1, discussed below.

Table 11.1 The best way to prepare for sea-level rise depends on whether (and how) a community intends to hold back the sea.

Activity	Pathway for responding to sea-level rise: Shoreline armoring (*e.g.*, dike or seawall)	Elevate land	Retreat/wetland migration
Rebuild drainage systems	Check valves, holding tanks; room for pumps	No change needed	Install larger pipes, larger rights of way for ditches
Replace septics with public sewer	Extending sewer helps improve drainage	Mounds systems; elevate septic system; extending sewer also acceptable	Extending sewer undermines policy; mounds system acceptable
Rebuild roads	Keep roads at same elevation; owners will not have to elevate lots	Rebuild road higher; motivates property owners to elevate lots	Elevate roads to facilitate evacuation
Location of roads	Shore-parallel road needed for dike maintenance	No change needed	Shore parallel road will be lost; all must have access to shore-perpendicular road
Setbacks/subdivisions	Setback from shore to leave room for dike	No change needed	Erosion-based setbacks
Easements	Easement or option to purchase land for dike	No change needed	Rolling easements to ensure that wetlands and beaches migrate

Coastal Drainage Systems. Sea-level rise slows natural drainage and the flow of water through drain pipes that rely on gravity. If an area will not be protected from increased inundation, then larger pipes and pumping may be necessary. If an area will be protected with a dike, then larger pipes are less important than underground storage, check valves, and ensuring that the system can be retrofitted to allow for pumping (Titus *et al.*, 1987). If the land surfaces are going to be elevated, then sea-level rise will not impair drainage.

Septics and Sewer. Rising sea level can elevate the water table to the point where septic systems no longer function properly (U.S. EPA, 2002).[44] If areas will be protected with a

[44] . “Most current onsite wastewater system codes require minimum separation distances of at least 18 inches from the seasonally high water table or saturated zone irrespective of soil characteristics. Generally, 2- to 4-foot separation distances have proven to be adequate in removing most fecal coliforms in septic tank effluent.” U.S. EPA (2002).

dike, then all the land protected must eventually be artificially drained and sewer lines further extended to facilitate drainage. On the other hand, extending sewer lines would be entirely incompatible with allowing wetlands to migrate inland, because the high capital investment tends to encourage coastal protection; a mounds-based septic system is more compatible. If a community's long-term plan is to elevate the area, then either a mounds-based system or extended public sewage will be compatible.

Road Maintenance. As the sea rises, roads flood more frequently. If a community plans to elevate land with the sea, then repaving projects should elevate the roadway accordingly. If a dike is on the horizon, then repaving projects would consciously avoid elevating the street above people's yards, lest the projects prompt people to spend excess resources on elevating their yards when doing so is not necessary in the long run.

As an example, Ocean City, Maryland, currently has policies in place that would be appropriate if the long-term plan was to build a dike and pumping system — but the town intends to elevate instead. Currently, the town has an ordinance that requires property owners to maintain a 2% grade so that yards drain into the street. The town has construed this rule as imposing a reciprocal responsibility on the town itself to not elevate roadways above the level where yards can drain, even if the road is low enough to flood during minor tidal surges. Thus, the lowest lot in a given area dictates how high the street can be. As sea level rises, the town will be unable to elevate its streets, unless it changes this rule. Yet public health reasons require drainage to prevent standing water in which mosquitoes breed. Therefore, the town has an interest in ensuring that all property owners gradually elevate their yards so that the streets can be elevated as the sea rises without causing public health problems. The town has developed draft rules that would require that, during any significant construction, yards be elevated enough to drain during a 10-year storm surge for the life of the project, considering projections of future sea-level rise. The draft rules also state that Ocean City’s policy is for all lands to gradually be elevated as the sea rises (See Appendix E).

Locations of Roads. As the shore erodes, any home that is accessed only by a road seaward of the house could lose access before the home itself is threatened, and even homes seaward of the road might lose access if the road were washed out elsewhere. If the shore is expected to erode, it is important to ensure that all homes are accessible by shore-perpendicular roads, a fact that was recognized in the layout of early beach resorts along the New Jersey and other shores. But if a dike is likely, then a road along the shore would be useful for dike construction and maintenance. If all land is likely to be elevated, then sea-level rise may not have any significant impacts on the location of new roads.

Subdivision and Setbacks. If a dike is likely, then houses need to be set back enough from the shore to allow room for the dike and associated drainage systems. Setbacks and larger coastal lot sizes are also desirable in areas where a retreat policy is preferred, for two reasons. First, the setback provides open lands onto which wetlands and beaches can migrate inland without immediately threatening property. Second, larger lots mean lower density and hence fewer structures that would have to be moved — as well as less justification for investments in central water and sewer. By contrast, in areas where the plan is to elevate the land, sea-level rise does not alter the property available to the homeowner, and hence would have minor implication for setbacks and lot sizes.

Covenants and Easements Accompanying Subdivision. Although setbacks are the most common way to anticipate eventual dike construction and the landward migration of wetlands and beaches, a less expensive method would often be the purchase of (or regulatory conditions requiring) rolling easements, which allow development but prohibit hard structures that stop the landward migration of ecosystems. The primary advantage is that society makes the decision to allow wetlands to migrate inland long before the property is threatened, so people can plan around the assumption of migrating wetlands, whether that means leaving an area undeveloped or building structures that can be moved.

Local governments can also obtain easements for future dike construction. Both of these types of easements would have very low market prices in most areas, because the fair market value is equal to today’s land value discounted by the rate of interest compounded over the many decades that will pass before the easement would have any effect. As with setbacks, a large area would have to be covered if wetlands are going to migrate inland, a narrow area would be required along the shore for a dike, and no easements are needed if the land will be elevated in place.

11.2.3 Opportunities for Deciding on the Pathway

Chapters 5 briefly mentions an ongoing effort to create present maps that distinguish areas where shore protection is likely from those areas where a retreat is more likely, given current policies and land use trends (See *e.g.* Titus 2004). At the local level, one must make an assumption about which land will be protected to truly understand which lands will truly become inundated (chapter 1) and how shorelines will actually change (chapter 2), which existing wetlands will be lost (chapter 3), whether wetlands will be able to migrate inland (chapter 5), and the environmental consequences (chapter 4); the population whose homes would be threatened (chapter 6) and the implications of sea-level rise for public access (chapter 7) and floodplain management. Assumptions about future shore protection are also necessary to estimate the level of resources that would be needed to fulfill people's current expectations for shore protection.

Improving our ability to project the impacts of sea-level rise is not the only reason for mapping expectations for future shore protection. Another use of such studies has been to initiate a dialogue about what *should* be protected, so that state and local governments can decide upon a plan of what will actually be protected. Just as the lack of a plan is a barrier to preparing for sea-level rise, the adoption of a plan would remove an important barrier and signal to many decision makers that the time has come for them to plan for sea-level rise as well.

CHAPTER 11 REFERENCES

Crowell, M.H. and T.L. Hayes, 2007: *Marine Technology Society Journal*, **41(1)**, 18-27.

FEMA (Federal Emergency Management Agency), 1984: *Elevated Residential Structures*. FEMA 54, Federal Emergency Management Agency, Washington, DC, 144 pp.

FEMA (Federal Emergency Management Agency), 1994: *Mitigation of Flood and Erosion Damage to Residential Buildings in Coastal Areas*. FEMA 257, Federal Emergency Management Agency, Washington, DC, 40 pp.

FEMA (Federal Emergency Management Agency), 2000: *Above the Flood: Elevating Your Floodprone House*. FEMA 347, Federal Emergency Management Agency, Washington, DC, 69 pp.

FEMA (Federal Emergency Management Agency), 2002: *FEMA Notifies Monroe County, Florida, of Impending Flood Insurance Probation*. Region IV News Release Number: R4-02-15. Cited at http://www.fema.gov/news/newsrelease.fema?id=4528 February 5, 2008.

FEMA (Federal Emergency Management Agency), 2006a: *Costs and Consequences of Flooding and the Impact of the National Flood Insurance Program, 2006*. Cited http://www.fema.gov/library/viewRecord.do?id=2577 February 1, 2008. 89 pp.

FEMA (Federal Emergency Management Agency), 2006b: *The Role of Actuarial Soundness in the National Flood Insurance Program*. Federal Emergency Management Agency, Washington, DC, 117 pp. Cited at http://www.fema.gov/library/viewRecord.do?id=2576 February 1, 2008

FEMA (Federal Emergency Management Agency), 2007: *Public Assistance Guide*. FEMA 322. Cited at http://www.fema.gov/government/grant/pa/policy.shtm Feb 1, 2008.

FEMA (Federal Emergency Management Agency), 2007b: *Coastal Construction Manual*. Federal Emergency Management Agency, Washington, DC. Available at http://www.fema.gov/rebuild/mat/fema55.shtm

FEMA (Federal Emergency Management Agency), 2008a: *Severe Repetitive Loss Program*. [Web site] Federal Emergency Management Agency, Washington, DC. Available at http://www.fema.gov/government/grant/srl/index.shtm, cited Feb 5, 2008.

FEMA (Federal Emergency Management Agency), 2008b: *Repetitive Flood Claims Program: Program Overview*. [Web site] Federal Emergency Management Agency, Washington, DC. Available at http://www.fema.gov/government/grant/rfc/index.shtm cited Feb 5, 2008.

FEMA (Federal Emergency Management Agency), 2008c: *Hazard Mitigation Grant Program*. [Web site] Federal Emergency Management Agency, Washington, DC. Available at http://www.fema.gov/government/grant/hmgp/ cited Feb 5, 2008.

FEMA (Federal Emergency Management Agency), 2008d: *Flood Mitigation Assistance Program* [Web site] Federal Emergency Management Agency, Washington, DC. Available at http://www.fema.gov/government/grant/fma/index.shtm cited Feb 5, 2008.

FEMA (Federal Emergency Management Agency), 2008e: *Pre-Disaster Mitigation Program*. [Web site] Federal Emergency Management Agency, Washington, DC. Available at http://www.fema.gov/government/grant/pdm/index.shtm, cited Feb 5, 2008.

GAO (General Accounting Office), 1992: *Coastal Barriers: Development Occurring Despite Prohibitions Against Federal Assistance*. GAO/RCED-92-115, General Accounting Office, Washington, DC, 71 pp.

Gibbons v. Ogden, 22 U.S. 1, 217-18 (9 Wheat. 1824)

Hayes, T.L., D.R. Spafford, and J.P. Boone. 2006: *Actuarial Rate Review*. National Flood Insurance Program, Washington DC, 34 pp. Available at http://www.fema.gov/library/viewRecord.do?id=2363

The Heinz Center, 2000: *Evaluation of erosion hazards*. The H. John Heinz III Center for Science, Economics and the Environment, Washington, DC, 205 pp. Available at http://www.heinzcenter.org/publications.shtml#erosionhazards

Kunreuther, H.C. and E.O. Michel-Kerjant, 2007: Climate change, insurability of large-scale disasters, and the emerging liability challenge. *University of Pennsylvania Law Review*, **155(6)**, 1795-1842.

Lockhart, J. and A Morang, 2002: History of coastal engineering. In: *Coastal Engineering Manual, Part I*, [Morang, A. (ed.)]. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, DC. Cited at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;104 Feb 5, 2008.

Loucks, D.P., J.R. Stedinger, and E.Z. Stakhiv, 2006: Individual and societal responses to natural hazards. *Journal of Water Resources Planning & Management*, **132(5)**, 315-319.

Maryland Department of Natural Resources, 2006: *Shore Erosion Control Guidelines for Waterfront Property Owners*. Available at: http://www.dnr.state.md.us/land/sec/sec_resources.html Accessed 1.18.08

Maryland Department of Natural Resources, 2008: *Grants and Loans: Shore Erosion Control*. Cited at http://www.dnr.state.md.us/land/sec/secintro.html accessed 1.18.2008

NFIP, 2007: *Fact Sheet: Saving on Flood Insurance Information about the NFIP's Grandfathering Rule*.

Pauly, M.V., 1974: Overinsurance and public provision of insurance: the roles of moral hazard and adverse selection. *Quarterly Journal of Economics*, **88(1)**, 44-62.

Platt, R., 2007: Comments on the National Flood Insurance Program (NFIP) Evaluation Final Report. *Natural Hazards Observer,* **32(2)** Available at http://www.colorado.edu/hazards/o/archives/2007/nov07/NovObserver07.pdf.

Tibbetts, J.H., 2006: After the storm. *Coastal Heritage*, **20(4)**, 3-11. Available at http://www.scseagrant.org/Content/?cid=103

Titus, J.G., C.Y. Kuo, M.J. Gibbs, T.B. LaRoche, M.K. Webb, and J.O. Waddell, 1987: Greenhouse effect, sea level rise, and coastal drainage systems. *Journal of Water Resources Planning and Management*, **113(2)**, 216–225.

Titus, J.G., 2000: Does the U.S. government realize that the sea is rising? How to restructure federal programs so that wetlands and beaches survive. *Golden Gate University Law Review*, **30(4)**, 717-778.

Titus, J.G., 2004: Maps that depict the business-as-usual response to sea level rise in the decentralized United States of America. Presented at the Global Forum on Sustainable Development, Paris, 11-12, November 2004.

U.S. EPA, 2002: *Onsite Wastewater Treatment Systems Manual*. EPA/625/R-00/008, EPA Office of Water and Office of Research and Development, Washington, DC. Available at http://purl.access.gpo.gov/GPO/LPS21380

USACE (U.S. Army Corps of Engineers), 2000: *Planning Guidance Notebook.* Document ER 1105-2-100, U.S. Army Corps of Engineers, Washington, DC. Available at http://www.usace.army.mil/publications/eng-regs/er1105-2-100/

U.S. Fish and Wildlife Service, 2002: *The Coastal Barrier Resources Act: Harnessing the Power of Market Forces to Conserve America's Coasts and Save Taxpayers' Money*. Division of Federal Program Activities, U.S. Fish and Wildlife Service, 34 pp. Available at http://www.fws.gov/habitatconservation/TaxpayerSavingsfromCBRA.pdf

Viscusi, W.K. and R.J. Zeckhauser, 2006: National survey evidence on disasters and relief: risk beliefs, self-interest, and compassion. *Journal of Risk & Uncertainty*, **33(1/2)**, 13-36.

Zabel v. Tabb, 430 F.2d 199, 215 (5th Cir. 1970)

Part IV. Sensitivity to Sea-Level Rise at the Local Scale

Author: James G. Titus, EPA

Previous chapters have provided region-wide perspectives on different effects, social impacts, and components of society's response to sea-level rise. The issue-by-issue presentation closely matches the separate professions involved in studying the effects and developing options for adapting to sea-level rise.

Many decisions, however, concern a specific location and require local andregional perspectives and information. Fortunately, much of the information that the previous chapters presented at the regional scale is also available at the state and local scale. Moreover, some information that is not available region-wide is available for some locations: For example, previous chapters did not look at the impacts of increased salinity on drinking water, but such information is available for the Philadelphia and New York metropolitan areas, which appear to be the primary areas where sea-level rise could harm water supplies.

This report does not recommend specific policies or actions in response to sea-level rise. Instead, it summarizes information on the options that are available. Impacts of sea-level rise on any specific community or local area will depend upon many factors and need to be carefully assessed as policy options and mitigation alternatives are examined.
Part IV is an overview of Appendices A-G, which provide state and local information similar to chapters 1-5 and 7, as well as information on some aspects of the effects of sea-