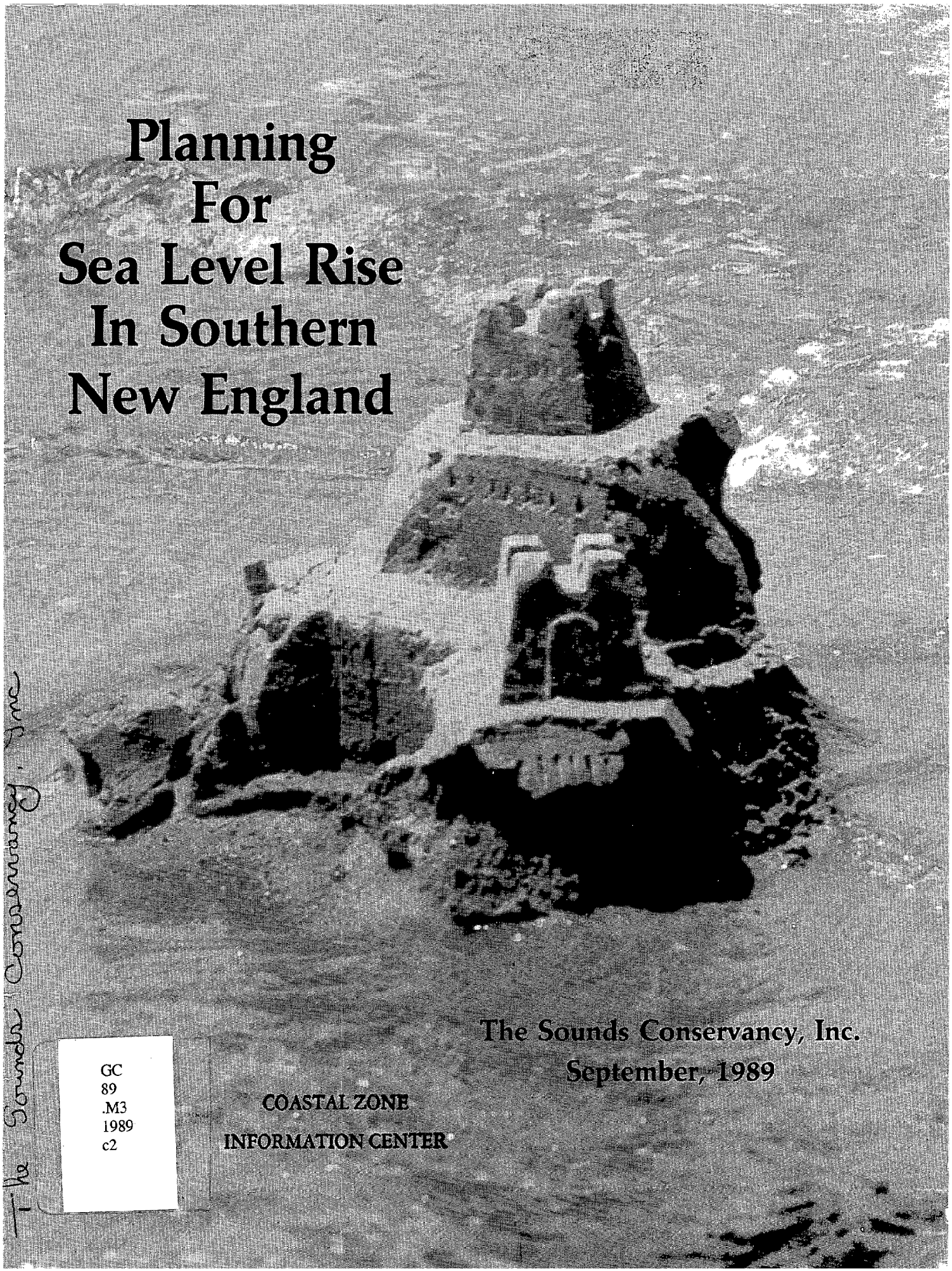
Planning For Sea Level Rise In Southern New England



The Sounds Conservancy, Inc.

September, 1989

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Planning For Sea Level Rise In Southern New England

by
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SEPTEMBER 1989

Introduction

We love the sea. We love to swim in it, sail on it, eat food fresh from it, and live as near as we can to it. This affection for the ocean has brought us close to its shores; half the U.S. population now lives within 50 miles (80 kilometers) of a coastal beach or a Great Lakes shore, and that percentage is growing.[1] Nearly one third of all human beings live within 60 kilometers (37.2 miles) of a coastline.[2]

Statistics show that, even as we rush toward the sea, it is rushing toward us; the mean level of the sea is rising today, as it has for centuries, and if the theory of the greenhouse effect is correct, the rate of rise will accelerate substantially over the next century.

That the greenhouse effect will raise world temperature is by no means unanimously accepted, among scientists or any other group. What becomes quickly evident during a review of our coasts' recent history, however, is that we are already feeling the effects of the head on collision between man and sea at the shoreline.

In Chatham, Mass., millions of dollars worth of property faces destruction from erosion, which has been accelerated by the breach torn open in 1987 in Nauset Beach, a barrier beach that protected the shore from the ocean for more than four decades. Although Chatham's case is a particularly dramatic one, it illustrates the basic problem of relying on pieces of land that are mobile by nature to support or protect development.

Storms of the ferocity of the hurricane of 1938, which killed more than 600 people on the East Coast and caused property damage of $3.2 billion (1987 dollars)[3] are not common. In historic terms, however, they occur with regularity. According to Norbert Psuty, director of the Center for Coastal and Environment Studies at Rutgers University, the past 25 years have been a "low storm phase" for the East Coast, a lull that cannot last.[4] If a storm like the hurricane of 1938 were to strike southern New England today, the loss of property and, depending on the advance warning, human life, would be great, due to the coast's dense development.

Serious erosion problems exist today, at the current rate of sea level rise. It may be by sheer luck that these problems have not been more serious. Even if sea level rise does not accelerate, the measures necessary to prepare for it make sense; present conditions justify modifying the way coastal areas are managed.

The bottom line is that the sea will rise; be it by storm or greenhouse gases, violently or gradually, for a 12-hour period or for the next century, the sea is coming up, and coastal inhabitants better prepare for it.

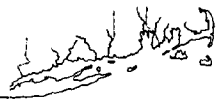
But how? The options are to stabilize the shoreline, retreat from the shoreline, or some combination of the two.[5] The best of the three is the third option, but with a strong preference for retreat in all feasible situations.

What's wrong with hard stabilizers? In and of themselves, nothing; in certain situations they are the accepted resolution to erosion problems. The Coast Alliance's "And Two if By Sea" summarizes why hard stabilizers are best avoided:

> "Hard" stabilizers such as groins, jetties ... seawalls and the like retain sand only until pounding waves or a storm eventually destroy them. In the meantime, they often starve downstream beaches by trapping sand on shore and out of the "littoral drift," which carries sand and other building material parallel to the coastline [6]

Hard stabilizers exacerbate erosion in two other ways. They reflect the force of waves into the erodible substances they rest on, a process that can eventually result in the destruction of the stabilizers themselves. They also limit the ability of natural barriers such as dunes to migrate, causing them to shrink and even disappear.[7]

Owners of coastal property will naturally want permission to protect it from erosion. This is a solution that may solve the problem of one piece of property, but at great cost to neighboring property, and to the environment. Some states have already prohibited any hard structural stabilizers on beaches, "based on the belief that providing protection for



public enjoyment is more important than protecting private property."[8]

Coastal planners face a variety of situations where the question of whether or not to stabilize is confronted. How can a whole city retreat rather than stabilize? Fortunately, there are also a variety of solutions to these dilemmas; beach nourishment, for example, can be an effective, environmentally benign means of stabilization, if planned and executed correctly.

But time is a factor in mankind's relationship with the sea. As time passes, the coast is developed and inhabited more and more densely; meanwhile, the sea continues to rise. The longer we wait, the more serious the problem will become, and the harder it will be to ask for the necessary sacrifices to make compromise solutions possible. The sea is at our doorstep; the time for action is now. We don't have time to waste.

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1. Barnard L. Collier, "Crusader on the Beach." *New York Times Magazine*, Dec. 12, 1988.

2. *The Greenhouse Gases*. United Nations Environment Program, 1987.

3. Michael D. Lemonick, et al, "Shrinking Shores." *Time*, Aug. 10, 1987.

4. Ibid.

5. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, *Responding to Changes in Sea Level, Engineering Implications* (National Academy Press, 1987.)

6. Beth Millemann, *And Two if By Sea*. (Coast Alliance, Inc. 1986).

7. Personal communication with W. Frank Bohlen, Department of Marine Sciences, University of Connecticut, July 8, 1989.

8. Op cit. Millemann, 1986.

Summary

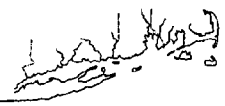
An unprecedented acceleration in the rate of sea level rise could result from the so-called "greenhouse effect," the theory that increasing concentrations of carbon dioxide and other gases in the atmosphere will cause a gradual but pronounced warming of the earth's surface and atmosphere. How fast the sea is likely to rise is not known, but estimates produced by computer models range from 36 to 212 centimeters (1 ft. 2 inches to 7 ft.) in the next century.[1] In this discussion, the more conservative estimates of an approximately 40 centimeter (1 ft. 4 in.) rise in the next century will be accepted.

The impact of such a jump in the rate of sea level rise would be tremendous, and calls for preparation on the part of those living in coastal areas, beginning immediately.

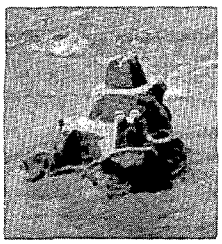
The Sounds Conservancy recommends the following actions, and asks for support in their implementation from officials at all levels of government, and from individual citizens concerned with the future of southern New England's coasts:

1. Construction of new hard stabilizers—groins, jetties, seawalls and the like—should be prohibited in the coastal zone. Special exceptions should be considered only if preserving the threatened coast is in the public interest, such as in existing urban areas.
2. All federal expenditures that support development in coastal hazard areas should be terminated.
3. A setback of 60 times the annual current rate of erosion—a figure determined by coastal geologists—should be required for all new construction.
4. Construction in the coastal zone should be minimized, and every opportunity to remove structures from the high hazard zone should be taken. Structures in the 100-year flood plain that are destroyed by act of man or God should not be replaced.
5. National Flood Insurance coverage for new construction in high hazard zones should be discontinued. FEMA's temporary amendment providing advance insurance payments to help owners of homes in "imminent danger of collapse or subsidence" to relocate should be made permanent. Continued coverage of these structures should be conditioned on a setback of 60 times the calculated annual erosion rate.
6. Coastal communities should be required to draw up "post-disaster plans" so they will know how sea level rise will affect them. Sea level rise predictions should be visible on town aerial, planning, zoning and tax assessor maps. Local governments should inform the public of the risks from long-term sea level rise and begin to formulate responses based on the above plans.
7. State and local tax incentives for relocation out of flood- and erosion-prone areas should be provided. States should make it possible for owners of coastal property to sell the development rights of that property to the state. Property owners should be allowed to sell their property to the state or to conservancy groups, then lease it back for periods of 50 or 100 years, thereby reducing public expenditures. Similar steps should be taken to facilitate the preservation of undeveloped areas adjacent to wetlands.
8. Federal and state governments should promote research projects on sea level rise. Among their principal goals should be improving understanding and projecting future sea level and rate of sea level rise; improving understanding of the impacts of sea level rise on wetlands; and researching beach management technologies that are not detrimental to coastal areas. State and local governments should determine research needs and inform policy makers and research institutions of those needs. Local governments should prepare maps illustrating the effects of sea level rise. State governments should require assessments of the potential effect of sea level rise on all projects in the coastal zone.
9. As sea level rises and new low and high tide lines are established, states should review and determine legal rights to land coming under their jurisdiction.
10. A worldwide effort to reduce production of greenhouse gases should be led by the United States.

1. John S. Hoffman, John B. Wells, and James G. Titus, "Future Global Warming and Sea Level Rise." *Iceland Coastal and River Symposium.* (Reykjavik: National Energy Authority, 1986.)



Global Warming and Sea Level Rise



Man's continual experimentation with the world ecosystem has begun to yield profound and often unwelcome global changes to our natural environment, some of them irreversible. These changes will eventually have an impact on many aspects of life for every inhabitant of the earth. Some of them may be the result of the greenhouse effect.

> Since the mid-19th century, scientists have recognized that carbon dioxide and certain other atmospheric gases allow incoming solar radiation to pass through the atmosphere but absorb and re-emit the low-energy radiation emanating from the Earth's surface, warming the lower atmosphere (the troposphere) in the process.[1]

Any attempts today to calculate the ultimate effects on the global environment of the continuing buildup of greenhouse gases in the atmosphere should be recognized as estimates, because the variables in the equation of the greenhouse effect outnumber the constants.

> The global climatic system is extremely complex. It consists of many interrelated components that, in themselves, are only partially understood. Changing one of these components—in this case, increasing the quantity of atmospheric greenhouse gases—will undoubtedly have repercussions throughout the natural systems that determine global climate.[2]

Will the world's developed nations increase or decrease their use of fossil fuels? Will the less developed, more populous nations increase or decrease theirs?

Will worldwide deforestation by man continue, decreasing the ecosystem's natural ability to absorb carbon dioxide, the principal greenhouse gas? Will temperatures rise faster than plant life can adapt, thereby accelerating deforestation? In warmer weather, dead vegetation decays faster, releasing more carbon dioxide into the atmosphere—will this be offset by faster plant growth, which will increase the demand for carbon dioxide? If global warming causes forest growth to shift its concentration toward the poles, will the reduced reflectivity of the dark forests (in comparison to highly reflective ice and snow) accelerate the warming trend?

How fast will the ocean absorb excess heat? Will higher temperatures increase evaporation and therefore cloud cover, and have a cooling effect?

Will higher temperatures increase worldwide energy consumption, thereby accelerating the production of greenhouse gases?

What are some of the unforseen side effects of a worldwide increase in temperature, and where do they fit into the equation?

The correct answers to these questions are not known. Estimates can be made for some of them, while others can only be guessed at.

Statistics indicate that average world temperature is rising. Although the cause of this phenomenon is not clear, some of the world's most respected scientists have agreed that the greenhouse effect is real. In October 1985, a conference was held in Villach, Austria, on greenhouse gases and climate change. The conference, which was sponsored by the United Nations Environment Program, the World Meteorological Association, and the International Council of Scientific Unions, included among its conclusions the following statements:

> If present trends continue, atmospheric carbon dioxide and other greenhouse gases combined would be radiatively equivalent to a doubling of carbon dioxide from pre-industrial levels possibly as early as the 2030's.
>
> The most advanced experiments with general circulation models of the climatic system show increases of the global mean equilibrium surface temperature for a doubling of the atmospheric carbon dioxide concentration, or the equivalent, of 1.5 degrees to 4.5 degrees centigrade.[3]

Moreover, it is believed that the process will continue, unless measures are taken to slow or reverse it.[4]

Among the results of this unprecedented rate of atmospheric warming could be an accelerated rate in the rise of global sea level, due to the expansion of ocean water from the increased temperature, possibly combined with the melting of temperate zone glaciers.[5]

Relative mean sea level is known to be rising, resulting in increased beach erosion, in many parts of the world. This rate is affected in various ways by local subsidence or uplift, a gradual lifting or sinking of the coast itself due to geologic activity. (Estimates of annual subsidence in Boston and Portland, Maine, for example, are 1 millimeter [0.04 inches]; Providence 0.5 mm. [0.02 in.]; New York City 1.5 [0.06 in,])[6]

In the northeastern United States, the present best estimates of sea level rise in 14 cities average 2.6 millimeters (0.104 of an inch) per year.[7] Although it has not been proven, the possibility of a more dramatic rise in sea level over the next century is based in well-understood and widely accepted scientific theory.

How fast the seas may rise is, again, difficult to forecast with certainty, but estimates range from 20 to 212 centimeters (1 ft. 2 in. to 7 ft.). The Villach Conference produced the following statement on the subject:

> It is estimated on the basis of observed changes since the beginning of this century that global warming of 1.5 degrees to 4.5 degrees centigrade would lead to a sea level rise of 20 to 140 centimeters.[8]

If reality falls somewhere between these estimates, what will that mean for the southern New England coastline in the year 2030?

The major impacts of sea level rise are permanent inundation of low-lying coastal areas, increased beach erosion, increased flooding, and increased salt water intrusion into groundwater aquifers in some areas.[9]

In the winter of 1987, storm waves from the Atlantic Ocean surged onto Nauset Beach on Cape Cod, Mass. opening a ½ mile breach into Chatham Harbor. The breach is now more than one mile wide and extensive shoaling of sand is continuing in the harbor. (TSC Photo, July 1987)

Some of the coastal areas that will first face permanent inundation from sea level rise are undeveloped wetlands. Many of these are valued recreation areas and natural habitats, and losing them permanently to the sea is undesirable to both their human visitors, who have enjoyed tham for generations as recreation sites, and to the various species of wildlife which rely on them for breeding and feeding areas. (See chapter five)

Depending on the extent of the sea's rise, however, permanent inundation may have more serious implications for human inhabitants of coastal regions than simply the loss of recreational sites. In many areas, the land that would be flooded in the event of a storm of an intensity likely to occur every 100 years on average—the 100-year flood zone—is densely developed. Given a 40-centimeter rise over the next century, some of these areas would have to be abandoned.

Many areas not permanently inundated would face an increased risk of flooding during storms and exceptionally high tides. The reach of the ocean's destructive storm surges would extend farther inshore than before; moreover, the frequency and severity of these events may be increased by global warming, because hurricanes generated in the tropics derive their energy from warm water. According to Kerry A. Emanuel, a professor of meteorology at the Massachusetts Institute of Technology, an increase in average temperature of one degree centigrade (1.8 fahrenheit) would increase the severity of hurricanes.[10]

Another consideration is the environmental effect of intrusion of salt water for the first time into regions that had previously been exclusively fresh water environments. The process may be exacerbated by a decrease in fresh water feeding these estuaries from upriver, if decreased precipitation results from the drier conditions caused by the greenhouse effect, as has been speculated. Decreased precipitation could also diminish the supply of fresh water from upriver if rivers are diverted to supply densely populated areas with water. If the sea level rises sufficiently, salt water could eventually contaminate fresh water aquifers, which are recharged by rivers, and on which many communities depend for drinking water. An assessment of how vulnerable southern New England is to this threat has not been made.[11]

Erosion of the beach areas will also result from a rise in sea level. According to Bruun (1962), higher water levels result in inland erosion.[12] Every foot (30.48 cm.) of vertical sea level rise can be expected to result in approximately 100 additional feet (30.48 meters) of shoreline erosion horizontally.[13] Although this process could be stopped in some areas by large-scale measures to either armor or renourish the erodible coasts, many miles of coastline would be lost to the scouring action of the sea.

The gravity-fed drainage and sewage systems of coastal communities could also be threatened by rising seas. For example, many of these systems are designed for a 10-year flood. But sea level rise would raise the 10-year flood level, putting them under water in the event of such a storm. The inundation of these facilities would threaten both the public health of the local communities and the marine life of surrounding coastal areas, to say nothing of the staggering cost of restoring destoyed drainage and sewage facilities and cleaning up coastal areas following such a storm.

In the event of significant worldwide reduction of fossil fuel combustion, one hopes that mankind would be rewarded with only a moderate rise in global temperature, and a correspondingly moderate rise in sea level. There may already be a considerable commitment to sea level rise, however.

> If greenhouse gas concentrations stopped increasing in the year 2030, sea level would continue to rise, probably at a similar rate for many decades. Since the warming would continue, mountain glaciers would continue to melt, and thermal expansion of the oceans would continue for many centuries.[14]

Once made, the changes in climate—including a higher sea level—will be irreversible "for any time of interest to us or our children."[15]

But even assuming that the most conservative estimates on the acceleration of sea level rise are true, it would be wise to begin planning ahead. With advance preparation for sea level

rise, residents of coastal areas and the policies, laws and infrastructures on which they depend will be able to anticipate and mitigate the effects of this process. Without this preparation, society will simply have to respond to these and other, less predictible scenarios as they unfold, possibly at much greater cost.

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1. Irving M. Mintzer, *A Matter of Degrees: The Potential for Controlling the Greenhouse Effect.* (World Resources Institute, 1987.) Per Arhennius, S., *On the influence of Carbonic acid in the air upon the temperature of the ground,"* in Phil. Mag. 1986, 41,237.

2. Ibid.

3. United Nations Environment Program/World Meteorological Organization (WMO)/International Council of Scientific Unions, "An Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts." (World Meteorological Association, Geneva Switzerland, 1985).

4. Op cit. Mintzer, 1987.

5. James G. Titus, "Greenhouse Effect, Sea Level Rise and Coastal Zone Management." *Coastal Zone Management Journal,* Volume 14, Number 3. (1986)

6. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, *Responding to Changes in Sea Level, Engineering Implications* (National Academy Press, 1987.)

7. Ibid.

8. Op cit. United Nations Environment Program et al. 1985.

9. John S. Hoffman, John B. Wells, and James G. Titus, "Future Global Warming and Sea Level Rise." *Iceland Coastal and River Symposium.* (Reykjavik: National Energy Authority, 1986.)

10. Peg Van Patten, "Life in the 21st Century: A Sea of Troubles?" *Nor'Easter.* Vol 1 No. 1 (Sea Grant, 1989)

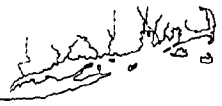
11. Ibid.

12. James G. Titus, "Greenhouse Effect and Sea Level Rise." *Coastal Zone Management Journal,* Volume 14, Numer 3, 1986. Per P. Bruun, "Sea Level Rise as a Cause of Shore Erosion, *Journal of the Waterways and Harbors Division,* 88(WW1) 1962: 117-30.

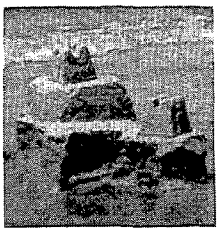
13. Michael C. Barth and James G. Titus, eds. *Greenhouse Effect and Sea Level Rise.* (Van Nostrand Reinhold Company Inc., 1984.)

14. Wigley, Tom M.L., summary based on paper submitted by W. Bach at the United Nations Environment Program joint meeting of the Task Team on Implications of Climatic Changes in the Mediterranean and the Coordinators of Task Teams for the Caribbean, Southeast Pacific, South Pacific, East Asian Seas and South Asian Seas regions, Oct. 1988, published in report of the meeting.

15. Richard A. Houghton and George M. Woodwell, "Global Climate Change." *Scientific American.* April 1989.



Stabilization Versus Retreat



The gravity of the various possibilities outlined in chapter one depends on the level to which the sea actually rises. Unfortunately, the decisions which could retard the greenhouse effect cannot be made on the local or even the state level; a global consensus on slowing or stopping the production of greenhouse gases needs to be reached. But decisions *can* be made on the state and local levels to prepare for a rise in sea level, and to mitigate its effects.

In order for preparations to be made, however, society must first decide what sacrifices it is willing to make in order to continue its coexistence with the ocean. Among the assets, owned and unowned, that are threatened by the relentless advance of the sea are land, buildings, wildlife and recreational areas. Will the residents of southern New England be willing to sacrifice some of these things to prevent others? Will owners of waterfront property? Will taxpayers be willing to pay to preserve them? If so, how much is society willing to pay to resist the advance of the sea, and for how long?

The following excerpt from the Coast Alliance's "And Two If By Sea" outlines the basic argument for not armoring coastal areas against sea level rise.

> Heavy development along the beach is...costly as it exacerbates shoreline erosion by using structural stabilizers such as seawalls, groins, jetties...revetments and the like. These "stabilizers," in turn, often promote erosion in downstream areas by "starving" other beaches and barrier islands from a free-flowing sand supply. Beaches shrunken from upstream sand impoundment face another threat from sea level rise...Rising seas and shrinking sand supplies could spell disaster for coastal barriers, the islands, beaches and spits that are the "front-line" defense for coasts and coastal communities. But a nationally orchestrated plan of "strategic retreat" from beach development could help ensure public access to the water, and significantly reduce some of these destructive pressures threatening to destroy our valuable coasts.[1]

But why is it so important to keep the coast free and flexible? What can be done to achieve this end, and how far can society be asked to go to achieve it? Before these questions can be answered, it is necessary to look at the alternatives in detail.

Should a planner, developer or property owner discover that his project, property or home is in some danger from sea level rise, what should he do? How can he decide the best path to pursue, for the benefit of his property, for his neighbors' property, and for the environment? What are the impacts, long and short-term, of stabilization and retreat?

Although resisting the advance of the sea is a costly endeavor, there are some situations in which there is no choice, such as where there is dense development close to the shore, with no unoccupied land immediately inshore to retreat to; a port city for example. If stabilization is pursued, there are numerous methods from which to choose, including groins, bulkheads, sea walls, revetments, offshore breakwaters, storm surge barriers, and beach nourishment.[2]

Whoever designs stabilization measures must do so with sea level rise in mind, since those measures will face an unusual challenge from the sea; wave height and therefore fluid power are increased in deeper water.[3] Stabilization measures have proven to be effective in slowing erosion, and can be retrofitted to keep pace with sea level rise; stabilization is therefore almost always feasible, if someone is willing to pay for it.[4]

The short-term economic advantage of stabilization is clear. If the shore is stabilized in a permanent way, much of the risk is taken out of land speculation in valuable coastal areas, and development of some of the nation's most valuable real estate can continue apace.

But measures of stabilization have also shown themselves to have harmful side effects. They hinder the natural flow of sand along the shoreline, resulting in the "starvation" of other areas, including natural coastal barriers.

> Coastal barriers—including barrier islands, dunes, spits and other coastal landforms—are particularly vulnerable to storm and flood damage, heavy erosion and sea level rise. Despite their vulnerability, coastal barriers are the critically important "front line of storm defense for a thousand miles of United States coastline." (They) migrate as the forces of erosion and accretion help to move the islands closer to land, downstream or futher out to sea. Their mobility helps them —unlike continental shores—to avoid immediate destruction by erosion.[5]

Stabilization measures also create permanent barriers between man and sea, replacing beaches, among society's most prized recreation areas; there are beaches in the United States today that have been whittled down to a thin strip of sand next to a mound of riprap. Such areas, which preclude the kind of recreational use beaches are valued for, stand as monuments to man's helplessness in controlling the coast.

These stabilizers can also dramatically alter the coastal ecosystem.

> ...studies suggest that a one and one-half meter rise in sea level could result in a 50 to 90 percent loss of coastal wetlands in the United States. The loss of wetlands would be particularly great if inland areas are developed and protected with bulkheads or levees.[6]

Although expensive, beach nourishment can be an effective means of combatting erosion, if it is done correctly. A beach nourishment plan must be agreed to by all owners of waterfront property in an area; if only one section of the beach is nourished, as often happens, the sand can be washed into an area where it is environmentally harmful.[7]

This aerial photograph of the coast of Chatham, Mass., illustrates many of the potential problems of sea level rise. Without hard stabilizers or a coordinated beach nourishment program, many of these houses would be threatened by erosion. However, most of them obviously have no room on the same lot to which they can retreat. Note that, even without further sea level rise, due to the hard stabilizers there is virtually no beach at high tide. This is the kind of situation coastal planners must avoid creating.

Many areas where it has been decided to attempt to stabilize the coast rather than retreat have become battlegrounds between man and sea. Man may be able to fight the sea to a draw, but the cost of control of the coast is excessive: a Pyrrhic victory. To paraphrase a sardonic epigram coined during the Vietnam War, it may be necessary to destroy the shoreline to save it.

The long-term effects of stabilization, though not all predictable, are also worth considering. In coastal areas, ecology and economy are inextricably intertwined. To give two obvious examples, if marinelife in an area is harmed, the income of local fishermen suffers; if water becomes too filthy to swim in, income from the tourist trade is reduced, particularly in an area like southern New England. Although nobody is predicting that these would be the long-term effects of stabilization of the shoreline, there is no doubt that a full-scale effort to resist the rise of the sea would pit man against nature, and as in all such conflicts, the environment would suffer.

The alternative to stabilization of the shoreline is retreat from it.

> The key to fighting the shoreline erosion is not to "armor" the coast, but to withdraw from it expensive and ultimately fruitless "stabilizers" and heavy development so that there will be a coastline left to enjoy.[8]

Although economically painful to some in the short term, in the long term this option would be both economically and environmentally advantageous.

> It may be preferable for some communities to move back from the shoreline in a planned and orderly fashion. Otherwise as sea level rises there is a significant likelihood that a number of communities will retreat involuntarily as a result of unpredictable disasters.[9]

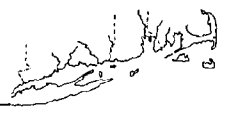
The economic cost of a planned retreat would certainly be less than the cost of a forced one, because it would avoid the expense of cleaning up and replacing structures destroyed by storms and erosion. No environmental damage could possibly result from a planned retreat.

But the task of actually instituting an organized retreat from coastal areas is a monumental one, requiring society to change its entire outlook on the shoreline from a place to conquer and occupy to a place to visit, enjoy, and protect. Society would have to concede that it has moved too close to the sea, and that it needs to back up a little bit. These changes of philosophy would allow the sea to have its way with the shoreline, to continue to mold it and shape it, as it has for thousands of years.

Although retreat from the shoreline should not be adopted as a simple, rigid rule for all situations, the time has come to adopt it as a general policy, around which other policies and regulations would be shaped. Stated simply, whenever possible, wherever possible, and as soon as possible development should be moved away from the shoreline. As Duke University Geologist Orrin Pilkey put it, with the characteristic bluntness that has helped make him the best-known proponent of retreat from coastal areas, "Retreat is the ultimate solution. Property owners must pack up and move."[10]

If the possibility of erosion were eliminated through full-scale stabilization of the shoreline, increasing the density of coastal development would no longer be limited by the sea and what it permits, but by man. Unfortunately, man's laws and common sense have brought us worldwide pollution of the ocean, the virtual extermination of a variety of marinelife, and the kind of coastal development we have today, with its resultant overcrowding and environmental problems.

After eons of nature's successful care of the seas before man set out in his first dugout canoe, the human race has taken only relative moments to do what may prove to be irreparable damage to the coast. Considering human kind's poor record, it seems wise to let nature take over managing her coastal areas again, by getting out of her way.



1. Beth Millemann, *And Two If By Sea*. Coast Alliance, Inc., Washington, D.C. 1986. Per Second Skidaway Institute of Oceanography Conference on America's Eroding Shoreline, "National Strategy for Beach Preservation." (Savannah, Ga.: Skidaway Institute. June 1985.)

2. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, *Responding to Changes in Sea Level, Engineering Implications* (National Academy Press, 1987.)

3. Ibid.

4. Ibid.

5. Op cit. Millemann, 1986.

6. James G. Titus, "Causes and Effects of Sea Level Rise." U.S. Environmental Protection Agency, 1988.

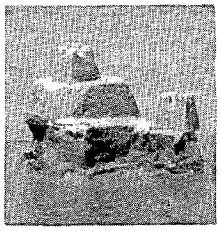
7. Personal communication with W. Frank Bohlen, Department of Marine Sciences, University of Connecticut, July 8, 1989.

8. Beth Millemann, "And Two If By Sea." Coast Alliance, Inc., Washington, D.C. 1986.

9. Op cit. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, 1987.

10. Michael D. Lemonick, et al. "Shrinking Shores." *Time*. Aug. 10, 1987.

Implementation and Enforcement



Putting a policy of retreat in place can be accomplished in different ways by different communities. Areas with low-density coastal development can rely on building codes, setbacks, zoning, and land-use plans. More developed communities will have to address the issues of existing buildings and shoreline stabilization structures. The problems are so diverse that their solutions will require many different actions by different levels of government as well as the private sector. The diversity of retreat mechanisms will be governed by the widely varying characteristics of natural shoreline systems.[1]

It is essential to make decisions soon on how to respond to sea level rise. Every bit as important as deciding on policies, however, will be finding acceptable and workable ways of putting them into effect. This will be difficult; rapid sea level rise will doubtlessly cause hardship to some, most of all owners of waterfront property.

The decision that should be made sooner rather than later is how much power should be given to government planners over how coastal areas are managed given the accelerated rise of the seas. Politicians, planners, and bureaucrats will play large roles in shaping the coasts of the future. It's important, therefore, that they have clear and fair guidelines to work with. Legislators entrusted with creating any new laws pertaining to coastal areas should seek a fair distribution of the sacrifice this crisis will demand.

New Development

The states of southern New England vary in their approach to coastal management. In both Rhode Island and New York, for example, no new construction is allowed on the coast's natural protective features such as dunes and barrier beaches. In Rhode Island, any new construction must have a setback—a minimum distance from the shore—of 50 feet, unless it is located in an area designated by the Coastal Resources Management Council as a critical erosion area. If it is, the setback must be at least 30 times the calculated annual erosion rate, or 60 times that rate for a structure of more than four dwelling units. New York also requires a minimum setback calculated on 30 years of erosion.

The notion of coupling setback regulations to rate of erosion is a good one, providing the kind of flexibility that is important when planning around a shifting coastline. But it still may not be flexible enough, since the rate of erosion will not remain constant if sea level rise accelerates. If the conservative estimate of a 40 centimeter rise in the next century is accurate, that will be almost twice as fast as today's estimated rate in the northeastern United States of about 2.6 millimeters annually.

This increased rate of sea level rise will, in some situations, result in a corresponding increase in the rate of erosion, depending on coastal features, both natural and manmade. Broad, sandy beaches and soil embankments will erode rapidly. Erosion will continue at least as far as erodible substances exist within the reach of waves, and may or may not stop when it reaches a rocky shore or sea wall, depending on design, craftsmanship and the whims of nature.

State coastal regulations should therefore be tied to increases in the rate of sea level rise and in the rate of erosion. Since an approximate doubling of the former and some increase in the latter are considered conservative estimates, a setback of 60 times the current estimated annual rate of erosion should be required for all new development. Although more stringent than current requirements in southern New England, this would not be a law of unprecedented severity; in Maine, a demonstration that new construction will not be affected by erosion for 100 years is compulsory.

Existing Development

But what about existing structures? Can a government agency be given the authority to limit what can be done to protect them, require that they be moved, or both?

These questions will surely generate debate. For one thing, the preservation of highly valuable land hangs in the balance. For another, the activities coastal management agencies would be likeliest to prohibit—and have already severely limited in some states—would be those designed to prevent erosion and storm damage, such as sea walls and bulkheads, since these structures could cause long-term environmental damage, including the destruction of wetlands and beaches. Coastal ecosystems, particularly wetlands, provide vital habitat, breeding and feeding areas for thousands of species. If vast expanses of wetlands are destroyed between the irresistible force of the rising sea and the immovable bulk of armored coasts, the effect on those environments and possibly on the global food chain could be devastating (see chapter five).

A stilt house at Misquamicut, R.I. will allow flood waters to pass underneath but in the future, with expected sea level rise, the owners may have to reach their home by boat rather than by car. (TSC Photo, 1988)

The region's coastal management laws mandate that these areas be protected. In Connecticut, for example, the Coastal Area Management (CAM) Act, passed in 1978, requires that all types of natural shorelines—bluffs and escarpments, rocky shore fronts, natural beaches, intertidal flats, tidal wetlands—be preserved, not only in form, but in their value as habitat, feeding, and breeding areas. Moreover, the act requires that, where possible, non-structural mitigation measures be employed. The act states that one of its policies is:

> ...to maintain the natural relationship between eroding and depositional coastal landforms and to minimize the adverse impacts of erosion and sedimentation on coastal land uses through the promotion of nonstructural mitigation measures. Structural solutions are permissible when necessary and unavoidable for the protection of infrastructural facilities, water-dependent uses, or existing inhabited structures, and where there is no feasible, less environmentally damaging alternative and where all reasonable mitigation measures and techniques have been provided to minimize adverse environmental impacts.[2]

Coastal management laws in Massachusetts, New York and Rhode Island also are designed to minimize structural solutions to erosion, but none of the four states prohibit it.

In Massachusetts, the impact of sea level rise is considered before permits are issued for a project in the coastal zone, although this policy is not backed by any particular law. "The general policy is to avoid building new structures in low-lying, flood-prone areas," said, Richard F. Delaney, former Director of the Massachusetts Department of Coastal Zone Management. "For existing structures, the policy is to look for opportunities to relocate. But in some areas—downtown Boston, for example—you can't relocate. You can't relocate the city, so you need to take structural steps to protect it, but we're trying to minimize that."[3]

The time has come to put this approach into law. The North Carolina Coastal Resources Commission prohibits any hard structural stabilizers on beaches, including sea walls and groins. The states of southern New England should follow this example.

Retreat

This raises the most difficult question. If a property owner believes that his property is in danger of destruction due to sea level rise, can he be prohibited from taking steps to protect it?

Although this may seem unfair to the person who bought or built his home in good faith, it is no less fair than the fate of the house decreed by accelerated sea level rise: destruction, and possibly loss of life in the process. One choice remains for owners of houses or other property in danger from erosion: relocate.

But relocation of existing structures will be an option to a minority of those who own waterfront property. The majority will be homeowners, with lots too small to allow for retreat from the coastal zone. For these people, the price of sea level rise will be very high indeed.

To pass legislation today requiring that all structures that would be affected by a 40-centimeter rise be immediately moved 200 feet back would cause chaos, if not an out-and-out revolt. A more feasible approach would be to apply constant pressure on owners of property—both public and private—to retreat from the shore, in the form of various incentives, while giving them ample time to act.

Providing a tax break to property owners who fit certain criteria within ten years is one option. For those who own more than one structure, the size of the tax break should correspond to the significance of the structure moved, giving more priority to a residence or industrial site than to a boat house.

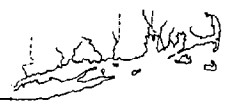
If more than 50 percent of a structure is destroyed by storm or erosion, its replacement should not be permitted. Other methods of easing development away from the shore can also be tried.

> One example would be long-term leases that expire 50 to 100 years hence or when high tide rises above a property's elevation. This approach, which has been applied on Long Island, allows the market to explicitly incorporate its assessment of sea level rise into its valuation of the leases. Although leaseholders have requested no-cost extensions on their leases when they expire, local governments generally have found enforcing the provisions of leases easier than enforcing regulations requiring people to abandon property. Moreover, this approach can be implemented by the private sector; for example a conservancy willing to lease the land back to developers for 99 years might be able to buy lowlands very cheaply.[4]

The Federal Emergency Management Authority is also in a good position to provide incentives for propery owners to move structures back from the shoreline. (See chapter four)

Owners of property that could pose a threat to public health or to the environment should they be inundated—industries using toxic chemicals, for example—would be offered the same incentives, but the move would be mandatory, with a shorter deadline.

Most coastal states have jurisdiction in coastal areas below the mean high tide line. As sea level rises and new low and high tide lines are established, states should review and determine legal rights to this newly created public trust land.



The Importance of Local Enforcement

Although federal and state agencies should develop guidelines and have oversight capabilities to enforce them, local planning and zoning commissions should have primary responsibility for coastal land use management. If a property owner must be told that, for environmental reasons, he may not protect his property, it is better that the decision be made only after careful consideration by a familiar group of elected or appointed residents of the community.

Moreover, the number of owners of waterfront property in any given state is large; in contrast to the relatively small number who now apply for permits for work in the state's coastal zone, *all* owners of coastal property would eventually be affected by rising sea levels, and most of them would seek to protect their property. It would not be possible for a state agency to consider each case individually without large increases in staffing.

The problem with leaving tough decisions to local commissions is that commission members would face tremendous pressure to be flexible, and find ways to allow property owners to protect their property. It is much easier for an anonymous state official to sign the death warrant for a valuable and much-loved piece of property than for a fellow town resident, who may also happen to be a neighbor and friend. It is therefore essential that the local commissions be given very clear and unambiguous state laws on which to base their decisions.

Public Projects

Measures of preparation for sea level rise can be divided into two categories: those that should be acted upon immediately, and those that should not be acted upon before the rise of the seas has been indisputably proven.

> In some instances the most appropriate response to sea level rise and climate change can be implemented if and when the consequences occur. In other instances—particularly urban (drainage) systems being overhauled today—the most cost-effective approach would be to prepare for these consequences before they occur and possibly before people are certain that they will occur. Only if civil engineers soon begin to consider the implications of the greenhouse effect will it be possible to take advantage of all the possible solutions.[5]

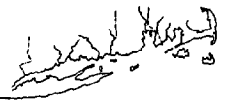
The above reference to civil engineers could logically be made to all coastal planners. No matter how determined society may some day be to retreat from the shoreline, activity in coastal areas will continue, if society is to function. Roads must continue to cross bodies of water on bridges, wastewater must be purified, access to the sea must be provided, for both commercial and recreational purposes. No one wants to see these activities stop; what should be changed is their design.

If an acceptance of accelerated sea level rise were to become a routine aspect of coastal planning, then new structures would be secure, whether the sea rises 40 centimeters in the next century, or if we simply continue to be battered with nature's routinely rough weather. Projects can be designed to withstand accelerated sea level rise without great expense. Requiring that all projects be designed to absorb a 40-centimeter rise in sea level therefore makes economic sense: if the sea rises 40 centimeters by the year 2090, they'll still be secure; if it doesn't, they'll better weather the many storms, large and small, that will surely come between now and then.

Retrofitting existing structures is a much more costly endeavor, because it requires altering the design and perhaps the location of a structure. Retrofitting should therefore only be mandatory when major maintenance work or renovation of the structure is scheduled.

The Need for Consensus

Although southern New England states do not need to have identical laws regarding coastal development, they should follow uniform guidelines that require an equivalent sacrifice from property owners. This will not only discourage residents from fleeing their state to escape its laws, but it will indicate a consensus among lawmakers that would encourage public support for the measures.



1. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, *Responding to Changes in Sea Level, Engineering Implications* (National Academy Press, 1987.)

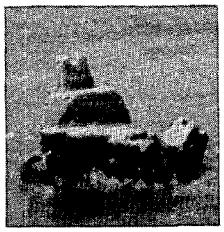
2. Connecticut General Statutes, Sec. 22a-92.

3. Personal communication with Richard F. Delaney, Urban Harbors Institute, March 27, 1989.

4. James G. Titus, "Preparing for Global Warming." In: J. Smith and D. Tirpak, *The Potential Effects of Global Climate Change on the United States*; Draft Report to Congress; U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Office of Research and Development, 1989.

5. James G. Titus, et al. *Greenhouse Effect, Sea Level Rise, and Coastal Drainage Systems.* Journal of Water Resources Planning and Management, Vol. 13, No. 2, 1987.

Paying for Damage



If a storm devastated a resort community today, the oceanfront houses that were destroyed would probably be rebuilt. To some people, the recreational value of being close to the beach justifies the risk of having their houses destroyed or, more recently, the cost of flood insurance premiums. If homeowners can continue to rely on the government to stabilize the shoreline, sea level rise may not substantially change this (view). But if people expect their properties to be lost to erosion or the costs of maintaining them to increase, (due to storm damage or higher insurance premiums), then rebuilding may be less attractive.[1]

If the sea level rises as rapidly as indicated in some scenarios, some damage to private property will inevitably occur. Most coastal property is covered by flood insurance provided by the Federal Emergency Management Agency (FEMA), meaning if private property is destroyed by flooding, it would be replaced using federal funds.

> Although Congress (has) passed laws limiting federally supported development in the floodplain, flooding and storm damage causes loss of life and costs the taxpayer billions of dollars in federal flood insurance outlays every year.[2]

As the likelihood of sea level rise becomes more and more apparent, the absurdity of this situation does, as well. The concept of insurance coverage is based on the premise that the destruction of property is statistically *not* likely to take place; the premiums paid by the many who do not make claims cover the costs of the few who do make them. A piece of property that will likely suffer some damage is therefore considered a poor risk, and will be difficult to get insured. If it is insured, it will be at a very high premium. Considering this, the notion of federally funded insurance for property that will *probably* be damaged seems an outrageous squandering of tax dollars.

Today, properties worth billions of dollars are federally insured, making this the largest potential national liability after social security.[3] Because damage lowers the value of property, it can sometimes be written off on federal taxes as a capital loss.

Moreover, FEMA's flood insurance is provided on the basis of information from scientific studies, which in turn are based on the assumption that the ocean, its storms and waves are going to behave a certain way, and cause some damage. As the level of the sea rises, however, its depth and force increase, and its destructive capacity, never entirely predictable, will become even less so.

> The Federal Emergency Management Agency (FEMA) determines base flood elevations for the coastal counties of the United States. These elevations include the still-water level flood elevations, which have a 100-year return interval. Additionally, FEMA predicts the 100-year wave heights, which are superimposed on the base flood elevations...The predicted sea level rise will be manifested in two different ways—the change in surge elevation and the change in wave heights felt at the shoreline. The present methodology used by FEMA is to determine the wave heights at the shoreline based on a breaking condition; that is, the shoreline wave height is 78 percent of the water depth at the flooded shoreline. With rising sea level the offshore water depth will be greater, and as these storm waves propagate inland they will be larger than before.[4]

In light of the probable consequences of rapid sea level rise, this program should be reviewed, not only to save public funds, but also to bring pressure to bear on private citizens to conform to public policy regarding sea level rise.

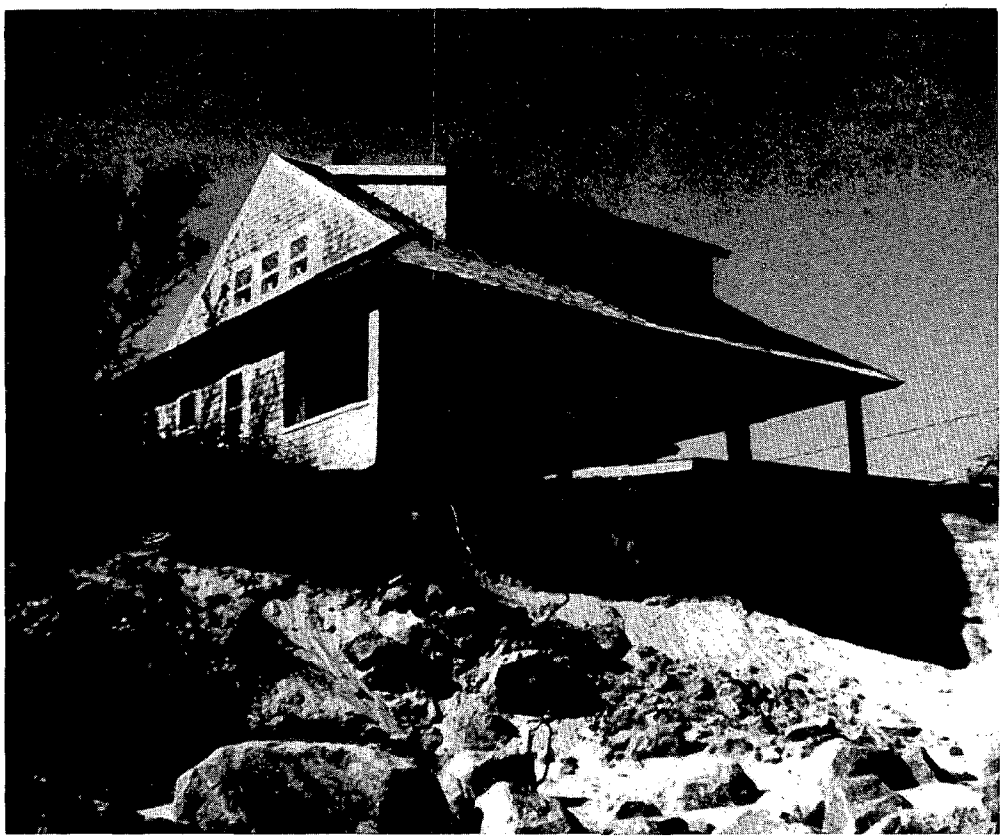
As the situation exists today, the U.S. taxpayer simply cannot afford to subsidize the reconstrucion of properties that are built too close to the shore, or on land that must even-

tually submit to the will of the sea. Moreover, it's unfair to ask him to; storms and the destruction they bring may not be predictable, but they *are* inevitable. Accelerated sea level rise would exacerbate this problem.

FEMA was created to mitigate the effects of various disasters, but is doing the opposite by providing insurance for structures built where a disaster is most likely to occur. Although FEMA regulations require that new construction follow a series of regulations designed to minimize flood damage, by providing insurance to owners of structures by the sea, FEMA is giving them a false sense of security, and encouraging them to stay in harm's way, when it should be encouraging them to retreat to a safer place.

> The National Flood Insurance Program was designed to ensure that future development did not create the conditions that make coastal disasters likely. By creating the Flood Insurance Program, Congress determined that the importance of preventing future coastal storm disasters transcended the laissez-faire notion that the marketplace adequately acknowledges risks from storms. This reasoning applies equally to coastal disasters caused by erosion and sea level rise. Communities devastated by storms will receive federal disaster assistance. In providing this assistance, the Federal Emergency Management Agency should encourage these communities to prepare for a rising sea.[5]

It should be noted that property damage by erosion, rather than flooding, is *not covered* by National Flood Insurance. This situation does a twofold disservice to the property owner; while he puts himself, his family and his property at risk by maintaining his house in a poten-



Several properties in Chatham, Mass. opposite the breach in Nauset Beach were severely eroded by ocean waves and have been removed. Massachusetts policy discourages the use of 'hard stabilizers' along the coastline. Laws passed in Maine and North Carolina ban stabilizers. (Photo for TSC by Fabio Ausenda, Cornell University, summer 1988)

tially dangerous location, thinking it will be covered should it be damaged by the sea, he may not be able to claim anything when his house falls victim not to flooding, but to erosion.[6]

The National Flood Insurance program should be reformed. But when changing this policy, it is important that property owners not be punished for the misfortune of having their property damaged or destroyed shortly after the policy is changed. In other words, the same safety net that is offered today to property owners should continue to be offered, but with different caveats. The simplest way would be not to cover any property built within a certain distance of the sea after that date the policy is changed. This way, owners of existing waterfront property would be covered, but only once; if they rebuild a destroyed house too close to the ocean, they would no longer be covered.

When former President Ronald Reagan signed the Federal Housing bill S. 825 on February 5, 1988, within the bill an amendment to the 1968 National Flood Insurance Act promoting relocation of structures out of erosion and flood-prone areas was also passed. Previously, homeowners whose houses were threatened with flood or erosion damage had to wait for their homes to be destroyed before they could receive any flood insurance money for relocation. The new law authorizes advance insurance payments to homeowners for demolition and building relocation if their homes are shown to be in "imminent danger of collapse or subsidence" from erosion or flooding. It also conditions further flood insurance coverage of these properties on reconstruction and relocation landward of a predicted 30-year erosion setback line for small buildings (1 to 4 dwelling units) and a 60-year line for all other structures. This amendment, which was enacted for only a two-year period, should be made permanent.

To further spare burdening the National Flood Insurance program with numerous claims resulting from the destruction of property built too close to the shore, FEMA should use its considerable experience in disaster planning to mitigate the impacts of sea level rise.[7] Careful planning will prevent significant loss of both life and property.

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1. Michael C. Barth and James G. Titus, eds. *Greenhouse Effect and Sea Level Rise*. (Van Nostrand Reinhold Company, 1984).

2. Beth Millemann, *And Two If By Sea*. Coast Alliance Inc., Washington, D.C. 1986.

3. Stephen P. Leatherman, *Effects of Sea Level Rise on Beaches and Coastal Wetlands*. Laboratory for Coastal Research, University of Maryland.

4. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, *Responding to Changes in Sea Level, Engineering Implications* (National Academy Press, 1987.)

5. Op cit. Barth and Titus, 1984. "Planning Before and After a Coastal Disaster."

6. Ibid.

7. Ibid.

Coastal Wetlands

The potential damage of sea level rise on southern New England's coastal wetlands cannot be exaggerated. A discussion of policies designed to protect them should not be limited to the context of whether or not to stabilize the coastline. Sea level rise, by itself, is a threat to coastal wetlands, which serve as nurseries for fish and shrimp, many birds, and other animals.[1] Because of their low elevations, coastal wetlands will be the first areas to feel the impact of an acceleration in sea level rise. The possibility of their permanent submergence by rising seas should therefore be viewed as a serious event that should be avoided, if it's not already too late.

Biologists have become aware that the ecological balance between a wetland's year round and migrating inhabitants is more delicate than previously realized. It has become evident that wetlands are not simply important to the successful migration of flocks of various kinds of birds; specific biological activity is essential at specific locations at specific times.

"Few locations among the migration pathways can provide enough food at the right time to support the needs of migratory shorebirds," said biologist J.P. Myers, a senior vice president of the National Audubon Society. "The fact that these sites must function in precise sequence both in time and in space means that functional alternatives to current staging areas are unlikely."[2] Any environmental change at all could therefore cause tremendous damage to a given species.

With a gradual rise of sea level and no man-made barriers limiting their inshore migration, wetlands are relatively adaptable to change. As coastal development continues and the rise of sea level accelerates, however, the effect of these processes on wetlands will increase:

> Wetlands have been able to keep pace with the relatively slow rates of sea level rise during the last five thousand years. As the sea level rose, new marsh formed inland...If sea level rises more rapidly than the marsh's ability to keep pace, there will be a substantial net loss. This loss could be even greater if development eliminated the vacant land necessary for new marsh to form.[3]

As with other effects of global warming, the impact of sea level rise on coastal wetlands is a complex web of interrelated and unpredictable mechanisms. Although the basic process by which wetlands would succumb to sea level rise is inundation, both shore erosion and the formation of interior marsh ponds also play a role.

> Land losses in most wetlands result from a combination of mechanisms, with shoreline erosion at the seaward edge of the marsh being the most obvious process. (But) most marshes will be long since submerged before extensive shoreline erosion occurs.
>
> A more probably catastrophic mechanism of marsh loss with a significant increase in sea levels (e.g., several feet) will be formation of extensive interior marsh ponds. These shallow-water bodies enlarge and coalesce at the expense of marsh vegetation in response to rapid coastal submergence...These marshes are being lost because sea levels outpace the ability of the marsh to maintain elevation, ultimately resulting in root death of the marsh plants.[4]

In 1967, there were an estimated 5 million acres (20,200 square kilometers, or 7,800 square miles) of wetlands in the United States.[5] This acreage has been significantly reduced by a variety of actions, including the widespread practice in the past of filling wetlands for development.[6] In 1972, however, Congress added a section to the federal Clean Water Act which put stricter requirements on filling wetlands. After that, several states passed legislation that strictly curtailed the destruction of coastal wetlands.[7] Annual permitted losses are estimated to average less than half acre per year in Connecticut,[8] and have been substantially reduced in other states as well.[9]

But available information points to increasing stress on coastal ecosystems; it is possible that half the nation's coastal wetlands could drown in the next century due to sea level rise.[10] In southern New England, where coastal development is intense, and where there are few coastal lowlands, the impact of sea level rise on wetlands would be particulary harsh.

> In New England, where there is virtually no low terrace, marshes occur in association with pocket beaches in small coves and behind small sand spits. Although the tidal range is high and thus favors maintenance of marshes, there is little lowland to be inundated and colonized by marshes. Consequently, after 2075, when sea level rise exceeds the present spring high tide level, present salt marshes will be lost with no compensating gain in new marsh area.[11]

Although southern New England does not stand to lose the vast acreage of wetlands that the flat, low-lying states on the Gulf of Mexico do, it could potentially lose a larger percentage of its wetlands.

The natural impacts of accelerated sea level rise on wetlands would by themselves be grave. They fall primarily into three categories: increased tidal flooding; wave-induced erosion; and salt intrusion.[12]

> Because tidal flooding is the essential characteristic of salt marshes, increases in the frequency and duration of floods can substantially alter these ecosystems...Sea level rise increases the frequency of tidal flooding throughout a salt marsh, causing the system to migrate upward and landward. If no inorganic sediment or peat is added to the marsh, the seaward portions become flooded so frequently that marsh grass drowns and marsh soil erodes; portions of the high marsh grass become low marsh; and upland areas immediately above the former spring tide level are flooded at spring tide and become high marsh.[13]

It should be noted that this process takes place only if the marsh encounters no upland barrier, natural or man-made, and if, as noted above, no inorganic sediment or peat is added to it.

> Sedimentation can offset the impact of sea level rise. Floods or nearby rivers can supply sediment, building the marsh upward or slowing the rate at which it retreats landward. If sea level rises slowly enough for the sedimentation and peat formation to keep pace, the marsh can maintain its position at the seaward edge and expand inland. (Peat formation seems to occur more in high latitudes such as New England than in lower latitudes such as Georgia).[14]

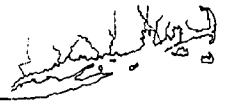
With gradual sea level rise, marshes can generally keep pace by trapping sediments in the water column and through accumulation of their own organic material.[15] But again, it should be noted that the marsh can only expand inland if it encounters no upland barrier. The extent to which the marsh can expand inland also depends on the slope of the land above the marsh; a steep slope limits it.[16]

As in most predictions of the results of the greenhouse effect on sea level rise, predicting the impacts on wetlands is difficult because there is an abundance of variables in any calculation. What, for example, will be the result of increasingly vigorous wave action caused by deeper water?

> The impacts of marsh drowning could be substantially exacerbated by additional erosion caused by larger waves striking the shore. A rise in sea level would deepen estuaries, allowing larger local waves to form and ocean waves to retain more energy before strking the marsh. Perhaps more importantly, those marshes now protected from direct wave attack by sandy barrier islands might lose their protective barriers as a result of rising seas and erode very rapidly.[17]

None of this is clear; there are more questions than answers.

What should be done? Two actions are of primary importance: minimizing physical



restrictions to wetlands, and informing the public about the situation facing these vital areas.

The fewer hard stabilizers around wetlands, the better off they'll be. Without inland barriers, wetlands have a greater possibility of shifting as they need to, and the elimination of groins and jetties will allow them to receive the sediment they must have to survive.[18] Hard stabilizers should not be permitted where they will affect wetlands. Development in areas adjacent to wetlands should also be limited.

> One anticipatory policy warranted even today would be for society to, in effect, purchase an option on the land necessary to maintain coastal ecosystems and ensure that natural shorelines are not generally replaced by armored shorelines. At least in some areas, land should revert to nature in one hundred years if sea level rises enough to subject it to tidal flooding. A rise in sea level should not negate the nation's goal of protecting wetlands, even if some areas to which the wetlands would migrate might have to become undeveloped.[19]

Other possible actions also embrace the philosophy of giving wetlands the space and sediment they need to adjust to rising sea levels. Barrier islands can be restored and marshes can be created or maintained artificially. Planners can attempt to ensure that wetlands have room to migrate landward in the future. Levees, river flow regulation, and other practices that alter sediment supply to wetlands can be modified to reduce adverse impacts.[20]

The fate of wetlands ultimately rests in the hands of the public, which pays the taxes and elects the officials that are in a position to protect them. The public, and particularly residents of coastal areas, should be made to understand the importance of wetlands, and the danger they face. Conservation of wetlands is a need recognized in many waterfront communities, although many people consider it a state or federal responsibility.[21]

> The need for increased public awareness is paramount, even where existing laws appear to protect wetland systems from future sea level rise. Laws that prohibit private property owners from constructing bulkheads would require development to retreat as sea level rises, allowing marshes to advance inland. Informed property owners can plan around the possibility that their land will eventually become marsh. But uninformed property owners may invest substantial resources in such areas, only to later learn that the law requires them to write off that investment.[22]

It is interesting to note that radiocarbon dating of marsh peat, shells and other organic remains reveal that, at least in the case of Connecticut, the configuration of the coast and today's wetlands are relatively recent and ephemeral features, and many of the changes are due to sea level rise over thousands of years.[23] These fragile ecosystems have adjusted to changes in sea level rise for millennia; what is new is man's interference with them. They'll continue to coexist with the ocean's dynamic, unpredictable behavior for many millennia into the future—if we let them.

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1. Committee on Engineering Implications of Changes in Relative Mean Sea Level; Marine Board Commission on Engineering and Technical Systems; National Research Council, *Responding to Changes in Sea Level, Engineering Implications* (National Academy Press, 1987.)

2. Peter Steinhart, "Standing Room Only." *National Wildlife*, Vol. 27, Number 3, The National Wildlife Federation, 1989.

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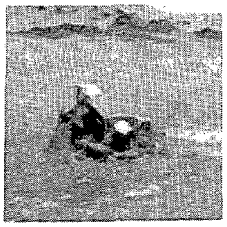
The Need For More Research



In the confusing wilderness of incomplete computer models, conflicting opinions and the unpredictable interaction of natural forces, only one thing is certain: society needs to know more about the greenhouse effect and sea level rise.

Decision makers at the federal, state and local levels need to understand the possibilities of sea level rise as they shape the laws that regulate coastal areas. Planners of projects in areas that would be affected by such an occurrence should consider the possibility while designing their projects.

Clearly, the first priority is to determine, as precisely as possible, how much and how fast the sea is going to rise. So far, this goal has remained out of reach. The unanswered questions regarding global warming and sea level rise range from the obscure to the obvious. Will global warming increase temperature and pressure of the ocean enough to trigger the release of significant quantities of methane—a greenhouse gas—trapped in the sediment of ocean shelves? If we knew exactly how much average global temperature were going to rise, could we predict with accuracy its effect on sea level?

According to James E. Hansen, head of a team of scientists studying global warming at the National Aeronautics and Space Administration's Goddard Institute for Space Studies, synchronized computer models of the effects of global warming on the atmosphere and the oceans may be two decades away.[1]

But more precise information is needed now, because development of coastal areas is continuing rapidly, using regulations that do not take sea level rise into account. If existing regulations will put drainpipes, foundations, roads and septic systems under water in fifty years, those regulations clearly need to be changed.

Funding for studies to predict the rate of sea level rise should therefore be increased. There is no possible drawback to promoting research on the greenhouse effect in general, and on sea level rise in particular. Whether it brings good news or bad, the information generated is essential, and it will make the difference between an orderly, relatively economical response to the challenges ahead and a sluggish, confused and costly one.

The responsibility for providing this funding belongs to both the federal and state governments. States should fund and organize research through state agencies and universities; additional funding should be provided by the federal government, which should also disseminate information generated by federally funded studies.

It is the responsibility of local governments, groups and individuals to make their needs and concerns in this regard known to those who can help them.

When any new waterfront project is under design, planners routinely study topographical maps of the surrounding area to assess what possible threats their project may face from the sea. If similar maps were drawn to show exactly how a rise in sea level would affect all coastal areas, planners in both the public and private sector could see what decisions need to be made.

The Federal Emergency Management Agency has prepared maps of many coastal areas showing the outline of the 100-year flood plain, which might be adaptable to show the effects of a certain level of sea level rise. Affordable computer hard- and software exists that makes creating such maps feasible on the local level.

Once adequate information is available, the burden is on planners to assess what impacts development projects will have on their surroundings, and what pressures the projects will face from sea level rise when completed. Making "strategic assessments" of whether, when and how to respond to sea level rise would be a good investment for any organization whose activities would be affected by climate or sea level change, or whose decisions have outcomes stretching over 30 years or more. If action today is warranted, the cost of the study is instantly justified to the company.[2]

The role of the state government relating to assessment of projects potentially affected by sea level rise is to pass legislation to insure that permits are not issued until these assessments are made.

A variety of assessments and impact statements are required in Connecticut, Massachusetts, New York, and Rhode Island, depending on the location and size of the project. Assessments of the effects of accelerated sea level rise are vital to increase society's preparation for them, and should be made compulsory for any project of significant size in the coastal zone.

With so many unanswered questions regarding global warming and sea level rise, it seems risky to make any absolute statements about it at all. One thing is certain, however: ignorance will not be an asset in the decades ahead. If society is to continue to enjoy its coasts, some wise decisions must be made. Knowledge is not wisdom, but wise decisions will be easier with knowledge.

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The Sounds Conservancy, Inc.

Gateways to Southern New England Rivers

43 Main Street, Box 266 Essex, Conn. 06426
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The Sounds Conservancy, Inc.

The Sounds Conservancy (TSC) is a private, not-for-profit, conservation organization whose area of concern is the six Sounds and their adjacent coastlines comprising the marine region of southern New England.

Long Island, Fishers Island, Block Island, Rhode Island, Vineyard and Nantucket Sounds create a 200-mile long seascape extending from New York's East River to Cape Cod.

Carved by glaciers, framed by glacial landforms and united by ocean waters, currents and marinelife, the SOUNDS region—with its rich and diverse resources—plays a significant role in the economy of southern New England and New York. Everyone has a stake in what happens to our SOUNDS—coastal landowners, recreationists, harvesters, researchers, and marinelife, both resident and migratory.

TSC's work and progams throughout the marine region of New York, Connecticut, Rhode Island, and Massachusetts are dedicated to: restoring, conserving and enhancing our water and coastal resources; promoting pollution abatement and the wise use of the land and water resources which nurture the SOUNDS region; supporting student research through granting research awards; encouraging careers in marine environment fields; and achieving interstate resource management.

For information about becoming a SUPPORTING ASSOCIATE of The Sounds Conservancy, please write to us at: 43 Main Street, P.O. Box 266, Essex, Conn. 06426.

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