EPA United States Environmental Protection Agency Region IV

Policy, Planning and
Evaluation Branch
345 Courtland Street
Atlanta, Georgia

PLANNING FOR SEA LEVEL RISE

The prognosis for sea level rise should not be a cause for alarm or complacency. Present decisions should not be based on a particular sea level rise scenario. Rather, those charged with planning or design responsibilities in the coastal zone should be aware of and sensitized to the probabilities of and quantitative uncertainties related to future sea level rise. Options should be kept open to enable the most appropriate response to future changes in the rate of sea level rise. Long-term planning and policy development should explicitly consider the high probability of future increased rates of sea level rise.

Responding to Changes in Sea Level, National Research Council, 1987

Planning For Sea Level Rise

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A. Introduction

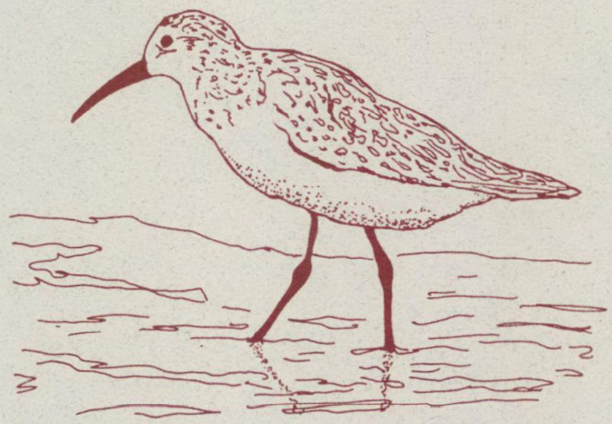
In the last few years, much attention has been given to the issue of global warming and its potential impact on the rate of Sea Level Rise (SLR). The implications of SLR are fairly well known and include increased flooding, coastal erosion, and salt water intrusion. The timing and rate of these impacts upon coastal areas are uncertain, and thus difficult to prepare for.

The current forecasts for global SLR by the year 2100 range from: 50 cm - 200 cm (17 - 68") (Titus and Greene, 1989). However, general estimates of SLR for the Atlantic and Gulf Coasts of the U.S. are 15-20 cm (6-8") higher than the global estimates in the next century.

As a coastal planner, you are concerned with the protection of your community's natural and developed resources. We are continuing to learn more information about the importance of protecting these coastal resources, and state and federal agencies have responded by enacting ordinances or adopting policies designed to restrict or carefully guide growth and development in sensitive or vulnerable coastal areas, especially wetlands. Coastal wetlands serve a variety of critical functions including storm surge protection, filtering water pollution, and providing habitats for birds, fish and plants.

If accelerated rates of SLR occur, many coastal protection measures may need to be reexamined or strengthened. Some may require major policy initiatives, while others may require small changes to existing programs. The question of how and when to respond to the potential impacts of global warming and SLR is one being asked by many coastal officials.

The USEPA's, Office of Policy, Planning and Evaluation has been gathering data and sponsoring research in this area for over a decade. This folder contains some general guidelines to help stimulate ideas and help you understand what you can do to plan for SLR.



B. General Description of Sea Level Rise

Of interest to any particular coastal region is not the global mean sea level, but the relative sea level change. Roughly speaking, relative sea level change is the net sum of coastal uplift (or subsidence) and global sea level change. Louisiana, for instance, is experiencing a large increase in relative sea level and a loss of vast areas of land to the sea largely because of subsidence or sinking. Subsidence is especially acute in Louisiana due to the modification of water and sediment flow down the Mississippi River. (For further information see EPA 1989.) Conversely, some areas located in Oregon and Washington are experiencing a drop in mean sea level. (See, for example NRC 1987.) Predictions of relative sea level involve uncertainty about the global sea level as well as future uplift or subsidence.

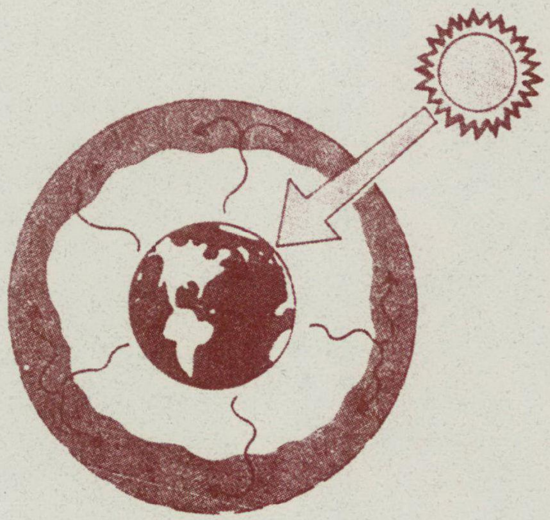
Coastal erosion rates generally increase directly in proportion to SLR. North Carolina, South Carolina, Georgia, Florida and Alabama are all currently experiencing coastal erosion. Along the Atlantic, where coasts are heavily developed, beaches have also narrowed primarily due to erosion. Barrier islands have historically overwashed, but overwash is generally inhibited now by development. The implications of a rise in sea level on coastal wetlands and drylands, as well as the cost of protecting those areas in these states, could be substantial. Coastal wetlands include back barrier marshes, estuarine marshes and tidal freshwater marshes. They perform many vital ecologic, economic, and aesthetic functions. Wetlands improve water quality, control floodwaters, provide and buffer against shore erosion, support fish and wildlife habitats, and provide nursery areas for fish and shrimp, birds, and animals. Wetlands also provide important scenic and recreational resources.

C. Causes of Sea Level Rise

The sea has risen and fallen over 100m (381') between the ice ages and interglacial periods. Sea level is traditionally perceived as constant during a human time span, but has risen over 10-25 cm (4-10") during the last century. The level of the sea is affected both by geological and climatic factors, although climate has historically had more substantial impacts on global sea level.

It appears that global warming in the last century has been partly responsible for the last century's rise in global sea level. However, the degree to which global warming will contribute to accelerated rates of SLR is still uncertain. Global warming is still of great concern; however, because the concentration of greenhouse gases is expected to double in the next century. Greenhouse gases, such as carbon dioxide, trap heat emanating from the earth's surface as depicted in the figure below. It is estimated that this effect could raise the earth's average temperature by 1.5-4.5°C (3-8°F) in the next century.

GREENHOUSE GASES TRAP HEAT

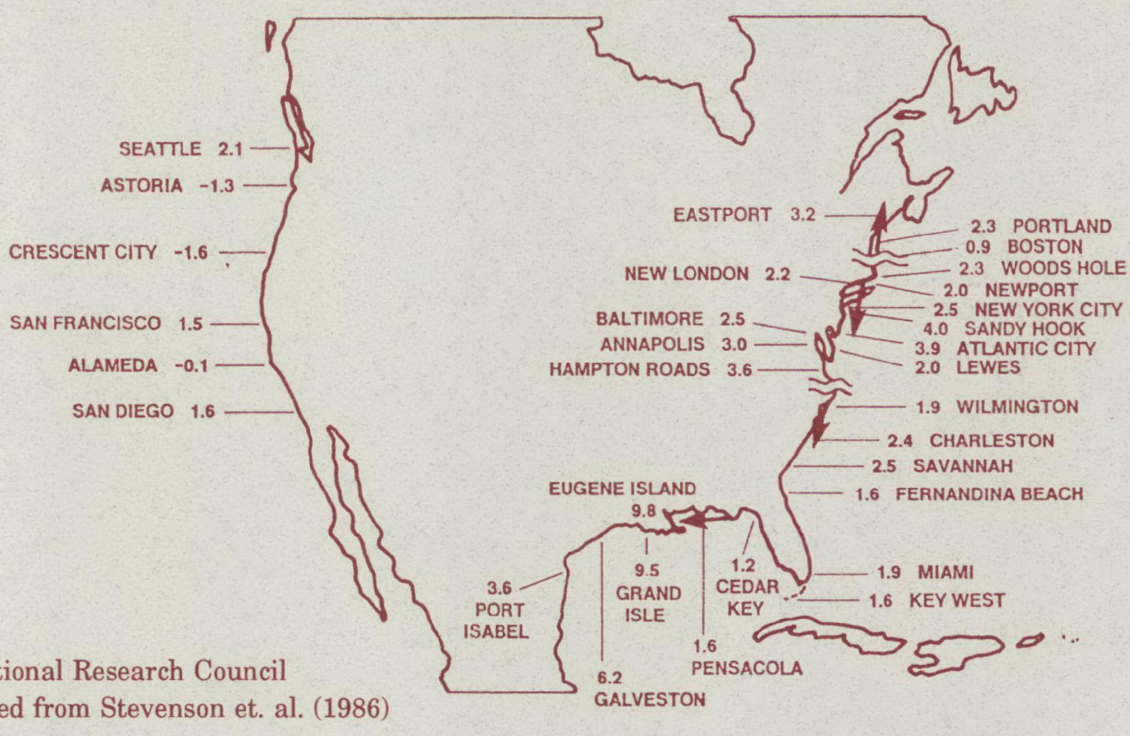


Global warming could initiate four processes that would increase sea level: thermal expansion of ocean water, melting of mountain glaciers, melting of Greenland glaciers, and the sliding into the sea of massive Antarctic glaciers. Since the magnitude of global temperature change is highly uncertain, as is our understanding of the glacial and oceanic response to any particular temperature increase, predictions of the rate of SLR are likewise highly uncertain and the subject of continuous scientific debate. The generally-accepted estimate of the rate (or range of rates) of SLR has changed from time to time as research reveals more subtle changes anticipated from global warming.

D. Historical Trends

Tide gauges have been used to determine global or eustatic sea level trends. Global sea level has risen about 10-25 cm (4-10") in the last century. This rise is caused by thermal expansion of ocean water and glacial melting. While global sea level has risen this amount, the coastal regions of the United States have experienced approximately a 30.5 cm (12") rise in sea level in the last century. This rise in sea level could be responsible for the coastal erosion problems facing many U.S. communities. The figure below documents the SLR in millimeters per year from 1940 to 1980.

ESTIMATES OF LOCAL RELATIVE SEA LEVEL CHANGES 1940-1980
in mm/year



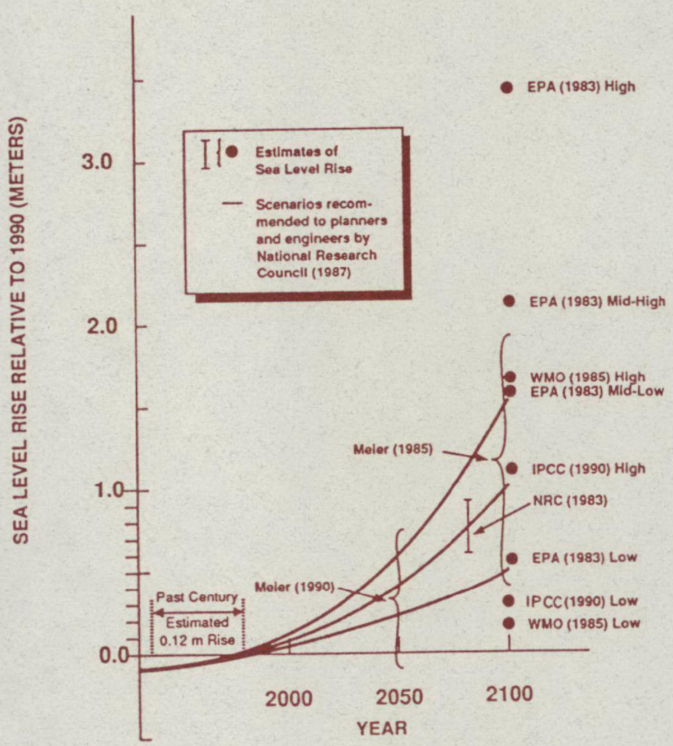
Source: National Research Council
Adapted from Stevenson et. al. (1986)

Note: One mm = .1 cm = .034"

A. General Range of Projections of Sea Level Rise

The models that forecast SLR take into account many variables. Sea level rise scenarios consider carbon dioxide emissions, concentrations of other greenhouse gases, global warming, thermal expansion of ocean water, snow and ice contribution, and other geologic factors. Many of these variables have a range of estimates, which results in ranges of SLR projections.

The graph below illustrates recent estimates of SLR by the year 2100. The lower scenarios are extrapolated from historical trends of global SLR. The other scenarios take into account global warming gases, temperature, thermal expansion of oceans, and deglaciation.



Titus and Greene, (1989) have estimated that the current "low-medium-high" scenarios for SLR by the year 2100 are 50 cm, 100 cm, and 200 cm (17", 34", 68") . However, these estimates do not take into account local geological conditions. If local subsidence is factored into the system, the relative sea level is expected to be an additional 15-20 cm (6 to 8") over the numbers indicated in the graph.

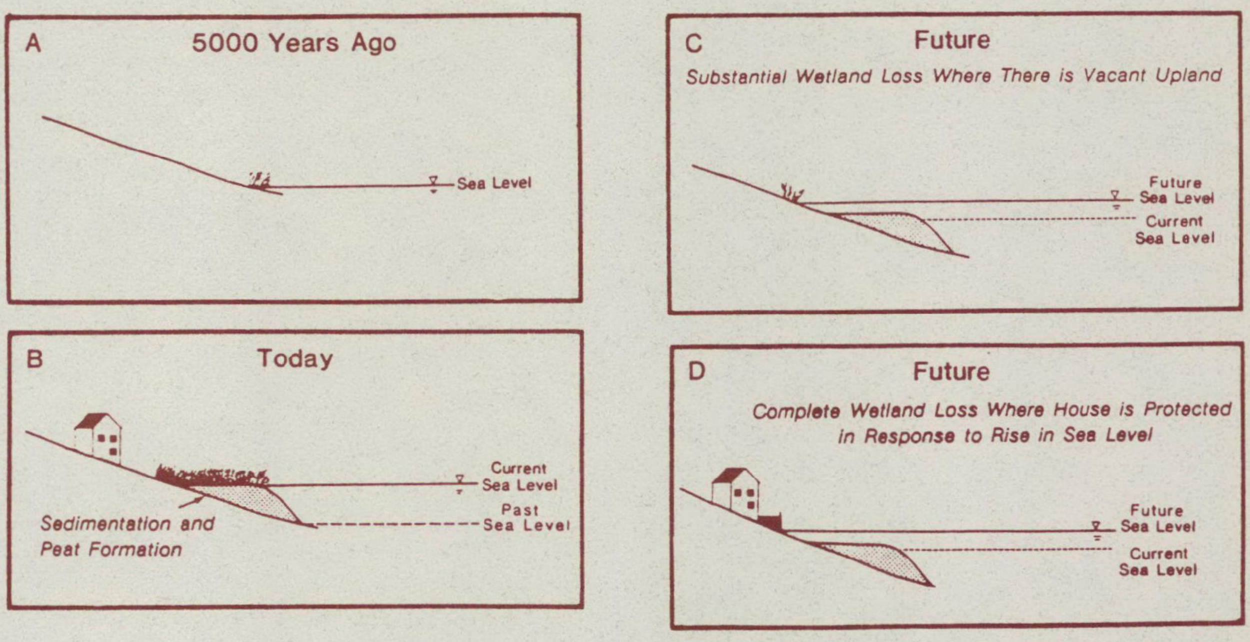
B. Southeastern United States Case Studies

Charleston, South Carolina has been the focus of extensive SLR studies. Dreyfoos et al. (1987) assessed the impacts of accelerated SLR on shoreline changes, storm surges and groundwater. The study used a range of SLR estimates, and also incorporated subsidence and river sedimentation rates. The study showed that shorelines and the 100-year flood zones would change dramatically in many of the areas around Charleston. The impact of accelerated SLR on groundwater was found to be negligible because saltwater intrusion would not become a factor until long after shallow coastal aquifers have been abandoned as a source of drinking water. (It should be noted that in other regions where groundwater is used for drinking water, changes in salinity could be important.)

Another study of Charleston (Kana, Baca, and Williams, 1988) examined the potential impacts of SLR on coastal wetlands, specifically intertidal wetlands that are generally found between the highest tide and mean sea level. These wetlands are more likely to experience the effects of changes in sea level, tidal inundation and storm surges. Intertidal wetlands include marshes, tidal flats and beaches that are vital to estuarine food chains.

The study estimated shifts in wetland areas and net loss of marsh acreage under three SLR scenarios for the year 2075. These included a current trend scenario of 24 cm (0.8 ft), a low scenario of 87 cm (2.8 ft), and a high scenario of 159 cm (5.2 ft). Each scenario assumed a sedimentation rate of 5 mm (.17") per year. The study revealed that wetlands in the Charleston area have been able to migrate landward and keep pace with the current trend in SLR. Under the current trend scenario, sedimentation and peat formation may partially offset the impact of SLR by raising the land surface. However, modeling results showed that an accelerated rate in SLR (the low and high scenarios) would result in a net loss of wetland acreage. Furthermore, wetland loss would be even greater in areas where seawalls or bulkheads are built to protect existing development. Seawalls and bulkheads, while protecting developed areas from becoming flooded, prevent wetland migration, and accelerate coastal erosion and beach loss. The following illustration demonstrates this.

EVOLUTION OF MARSH AS SEA LEVEL RISES



Source: Titus, 1986

A. Potential Sea Level Rise Impacts

The following outline identifies general examples of potential SLR impacts on natural and developed areas, and on local economies. The degree and timing of these impacts will depend on both global mean SLR and existing local conditions.

1. Natural Environment

   a. Coastal wetlands unable to keep pace with rising sea level, resulting in overall loss in wetland areas, especially in developed areas.
   b. Loss of beaches due to increased rate of erosion and inundation.
   c. Loss of significant habitat in wetlands, estuaries, coral reefs, bays, and wilderness.
   d. Saltwater intrusion into groundwater and upstream movement of the saltline in surface water.
   e. Increased estuarine salinity reduces circulation and decreases the amount of flushing, thus resulting in an increase in water pollution.

2. Infrastructure (Developed Areas)

   a. Damage or destruction of housing, resorts, and other coastal development.
   b. Flooding of transportation facilities such as bridges, railways, airports and marinas.
   c. Disruption of utilities for electricity, communication, water supply, and sewer systems.
   d. Loss of cultural or historical assets such as national parks, monuments and cemeteries.

3. Local Economy

   a. Cost of prevention and protection for natural and manmade environments.
   b. Cost of loss and damage to natural and manmade environments due to storm surge, flooding, erosion, and inundation.
   c. Loss of industry and employment in tourism, local business, factories, shipping, and commercial fisheries.

B. Techniques Used to Predict SLR Impacts

There are a variety of techniques and models used to predict impacts of SLR on specific coastal resources, such as wetlands. The table below shows data from a study that projected SLR impacts on wetlands (see Armentano, et al. 1988). The data represent changes in wetland area (in 100 hectares) from 1975 to 2100. The low and high scenarios are the same as the mid-range low (144 cm, 4 ft.) and mid-range high (217 cm, 6 ft.) projections shown in the graph in Section II. These projections also take into account local sedimentation and subsidence.

WETLAND IMPACTS FROM PROJECTED SLR*, 1975 - 2100

LOCATION	LOW SCENARIO		HIGH SCENARIO	
	Lost	Gained	Lost	Gained
Roanoke Island, NC	48	0	48	2
Albemarle, NC	41	0	48	5
N Charleston, SC	0	21	52	36
Charleston, SC	116	65	172	87
Sapelo Sound, GA	1	24	165	55
Matanzas, FL	8	14	8	37
Florida Keys, FL	1	15	236	1
10,000 Islands, FL	0	159	4	159
Cntrl. Barrier Coast, FL	1	0	1	0

Source: EPA, (Titus, 1988)

* Change in 100 hectares.
One hectare = 2.47 acres.

Other models have been developed or are being developed to assess areas most at risk from SLR. For example, scientists at the Oak Ridge National Laboratory (ORNL) have developed a coastal hazards data base to identify coastal areas most at risk from a rise in sea level. The data base provides information on coastal variables, including: 1) elevation or relief, 2) bedrock geology, 3) geomorphology or land forms, 4) vertical movements (relative sea level change), 5) horizontal shoreline movement including erosion and accretion, 6) tidal ranges, 7) wave heights, and 8) storm frequency. Data for these variables were compiled and incorporated into a Geographic Information System (GIS). ORNL is currently developing a risk index to identify coastal areas sensitive to SLR.

A. General Options

In order to respond to possible accelerated rates of SLR, planners can choose from two general approaches: entrenchment and/or retreat.

Entrenchment refers to the building of protective devices and coastal structures to literally "hold back the sea." This defensive approach includes construction of devices such as groins, bulkheads and sea walls, revetments, breakwaters, and storm surge barriers. (For information see National Research Council, 1987). Many coastal communities already use these devices to deter beach erosion and protect valuable beach-front property. Beach nourishment, another commonly used technique, involves dredging sand from offshore and pumping it onto the beach to replace sand washed away by storms or strong currents.

While technologies exist to construct protection devices to hold back the sea, their use may not be economically or environmentally feasible in every community. In areas where these approaches are not acceptable, either due to high cost or potential environmental damage, planners may choose to retreat or move back from the sea. Communities that decide to move landward also have a variety of options. For example, retreat may be accomplished by moving existing structures, prohibiting reconstruction of buildings damaged by storms, or prohibiting new construction near beaches. North Carolina, for example, established set back requirements for new home construction based on projected erosion rates. Other communities such as Galveston Island, Texas prohibit the reconstruction of buildings destroyed or damaged by storms.

The decision to implement either entrenchment or retreat measures is one which must be carefully addressed through public policy analysis. Careful consideration must be given to legal, economic, and environmental concerns prior to deciding on a particular local response to SLR.

B. Strategic Assessments

Strategic assessment is the process whereby the local decision-maker faces the fundamental questions of whether, when, and how to respond to global climate change. Because SLR is closely linked to global climate change, the strategic assessment process can be applied to SLR planning. Strategic assessments can be conducted through decision oriented analyses (i.e., part of a routine evaluation of ongoing projects) or through special studies specifically focused on problems or programs.

A decision oriented analysis might involve the consideration of SLR in Environmental Impact Statements or similar federal or state mandated review procedures. States such as

Vermont, Oregon, and Florida have adopted formal review procedures for projects meeting certain size and scale criteria. One such example is Florida's Development of Regional Impact or DRI program, in which projects meeting certain criteria are subject to a heightened level of review before being approved.

Program oriented analysis might be conducted by agencies such as the U.S. Army Corps of Engineers, whose activities may be widely impacted by SLR. Problem oriented analysis, on the other hand, may involve studies to evaluate issues associated or under the jurisdiction of several groups, such as the protection of barrier inlands (i.e., coastal protection agencies and barrier island communities).

The strategic assessment approach allows decision makers to objectively identify implications of SLR and possible responses. However, the selection of the best response for a specific area will probably involve subjective decisions based on a variety of criteria including: flexibility, urgency, cost, irreversibility, consistency, economic efficiency, political feasibility, legal and administrative feasibility, and equity.

C. Planning Approaches

As noted above, there are two general responses to SLR, entrenchment and/or retreat. The community's decision as to what type of response is more feasible and appropriate can be approached through a traditional planning process. This involves setting goals and objectives, evaluating alternatives, assessing impacts and selecting an implementation strategy. One of the most important responsibilities of planners is to guide local officials and community members through this process.

The following paragraphs describe how the impacts from SLR can be addressed through this traditional planning approach. This approach can be used specifically to address SLR or can be one part of a community's overall comprehensive plan.

Step 1 - Set Goals and Objectives - Identify probable impacts on the community's resources and determine the resources of critical concern through a goal setting process. Local participation should be encouraged from residents, business owners, and community leaders.

Information should be sought from regional and state agencies such as coastal commissions and state environmental agencies. At the federal level, information is available through agencies such as the EPA, Federal Emergency Management Agency, U.S. Army Corps of Engineers, and Oak Ridge National Laboratory. (Information on these and other sources is included in the reference section of this brochure.) As a result of this step, a community may establish one or more goals with respect to SLR planning. An example may be to limit negative impacts of SLR on coastal wetlands.

Step 2 - Identify High Risk Areas, Resources, or Facilities - Based on the specific needs and resources of the area, identify the highest priorities for responsive planning. This step should be performed by a qualified environmental professional using available technical information on coastal resources. One source of information is the coastal hazards data base developed at ORNL. The data package for the east coast of the United States is available on a regional scale and provides information and mapping related to a number of coastal variables such as elevation, wave heights, and storm frequency.

A possible outcome of this step might be the identification of a specific tidal marsh which is particularly vulnerable to increases in sea level.

Step 3 - Develop Alternative Strategies (Strategic Assessment) - Explore all types of alternatives to obtain a list of the range of response techniques available. For example, if wetlands are the resource most vulnerable to SLR, the range of options available for consideration may include:

- Increase wetlands' ability to keep pace with SLR,
- Protect coastal barriers,
- Create no-development buffers along the landward edge of wetlands, and
- Construct tide protection systems.

Step 4 - Evaluation of Alternatives - Alternatives should be evaluated based on selected criteria established by local decision makers. For the four options noted above, the construction of tide protection systems are extremely costly and may be more practical in major urban areas. Creating no-development buffers may only be practical in states with legislation allowing this type of property regulation.

Step 5 - Selection of Recommended Alternative - After a thorough analysis of the alternatives, a preferred strategy is recommended. Using the wetlands protection scenario, assume that the creation of buffers along the landward edge of the wetlands is recommended because it can be implemented through regulatory mechanisms, and is less expensive than constructing tide protection systems. The State of Maine proposes to assess response options by identifying creative regulatory tools that are uniquely suited to address priority problems. Their analysis will consider costs and benefits of alternative actions under different SLR scenarios.

Step 6 - Implementation Plan - Describe the steps necessary to implement the recommended strategy. Using the wetlands example, the decision to create buffer zones may require a change to existing zoning codes to restrict development in a defined area. If it is desirable to totally avoid construction in an area, an acquisition program to purchase land within the buffer zone may be necessary in order to protect it from development. The implementation plan should define administrative responsibility, estimated budget, institutional agreements, specific government action to be taken (i.e., ordinances, governing body approval, proper enabling legislation, etc.) and a schedule of activities.

Step 7 - Evaluation - A mechanism for self-evaluation and follow-up should be included as part of your plan. Opportunities to incorporate new information should be made.

D. Examples of Responses to Sea Level Rise

A wide range of programs, ordinances, and regulations have been adopted at the local, state and federal level to respond to adverse environmental impacts, including the potential impacts from SLR. The summary shown below and on the following pages illustrates some examples of SLR planning techniques implemented throughout the U.S.

ALTERNATIVE RESPONSES TO SEA LEVEL RISE

Source: Klarin & Hershman, University of Washington, 1990

Response	Example
Zoning	
Erosion-based setbacks	S. Carolina Beach Management Act: Establishes setbacks equal to 40 years of erosion. The baseline for the setback is reset every 5 to 10 years.
	N. Carolina Coastal Area Management Act: Establishes annual erosion rate setbacks equal to 30 years of erosion and 60 years of erosion for single and multiple residences.
Building codes and size restrictions	Maine Sand Dune Law: New development restricted to 2500 sq.ft. and 35 ft. height. Single and multiple residence buildings must be 1 ft. and 4 ft. above base flood elevation in low hazard zones.
Development restrictions in flood hazard areas	Maine Sand Dune Law: New development restricted to low hazard areas not to exceed 40% of undeveloped dune areas, with 20% being buildings.
	Florida Construction Control Lines: Establish areas within which new development must be permitted. No construction within 30 year erosion zone.

Economic Incentives/Disincentives	
Restrict new infrastructure and flood insurance availability	Coastal Barrier Resource Act: No federal subsidies for infrastructure or flood insurance within coastal barrier resource system.
Incentives to remove or relocate structures upland	Upton-Jones Amendment: Federal flood insurance upland program pays owners up to 110% to demolish or 40% to relocate damaged structures in a defined critical erosion zone.
Proposed tax incentives to control development	Delaware Beaches 2000 Plan: Proposes favorable tax assessments to property owners who develop property for uses compatible with preservation of beaches.
Project Planning	
Engineering standards	San Francisco Bay Conservation and Development Commission: Bay plan requires proposed development to consider SLR in project engineering plans under the review process.
Remodel or redesign infrastructure	Charleston, South Carolina: Designed new flood control and drainage system to account for SLR and subsidence over next 50 years.
Prohibit or Restrict Development	
Post storm reconstruction restrictions	South Carolina Beach Management Act: Restrictions on reconstruction of structures destroyed in excess of 66% by storms within setback zones. Replace all erosion and protection structures over 30-year period.
	Texas Open Beaches Act: Prohibits reconstruction of damaged buildings and protective devices on property seaward of the vegetation line that is open to public access.
Land acquisition and conservatory programs	California Coastal Conservancy: Uses state bond monies to acquire undeveloped coastal property. Florida: Buys property for preserving public beaches, public access, and recreation areas.
Preserve critical habitats and wetlands	Maryland Chesapeake Bay Critical Areas Act: Establishes buffer around wetlands and reduces density of adjacent development.
Proposed abandonment policy for coastal areas	New York Long Island Regional Planning Board: Proposal to end long-term leases of state coastal property and buy back of Barrier Island properties severely damaged by storm floods.

Nonstructural Engineering

Resedimentation of river deltas	Louisiana Coastal Environment Protection Trust Fund and State/Federal Joint Task Force: Local resedimentation projects.
Beach renourishment, dune and wetlands revegetation and stabilization programs	Florida: Beach management fund authorizes up to to $35 million annually toward beach erosion, preservation, restoration projects.
	Maryland: $60 million multi-year federal, state, and local plan to renourish ocean beach shoreline.
	South Carolina: Requires property owners to replenish sand at 150% of annual volume to replace destroyed structural erosion devices.

Groundwater Protection

Preserve coastal aquifers and groundwater resources	Maine: Requires review of permit applications by district water company to determine impact on groundwater recharge.

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