

CHAPTER 5

ADAPTATION

STRATEGY



Upon completion of the vulnerability assessment, the planning team should know where it wants to direct preliminary adaptation efforts. The adaptation strategy consists of establishing goals and identifying and prioritizing actions that can help meet them. These goals and actions may change over time based on new scientific findings, improved vulnerability assessments, observed climate change impacts and consequences, and implementation successes and failures. As is discussed further in Chapter 6, goals and actions will need to be revisited and revised over time.

The basic steps involved in creating an adaptation strategy are as follows:¹

- Step 3.1: Set Goals
- Step 3.2: Identify Actions

- Step 3.3: Evaluate, Select, and Prioritize Actions
- Step 3.4: Write Action Plans

The following definitions are based on those provided in FEMA’s hazard mitigation planning guidance (FEMA 2002):

- **Goals** are general guidelines that explain what the planning team wants to accomplish. They are usually long-term (but may also be short-term), broad statements.
- **Actions** explain how measures (laws, regulations, projects, programs, plans, etc.) will be implemented to help achieve the goals.

It is recommended that all stakeholders be invited to participate in setting goals and choosing actions. This

¹ Some strategic planning processes are more involved and recommend visions, objectives, and alternative definitions. The process offered here is just a basic example of a how an adaptation strategy may be crafted.

keeps them engaged, allows for incorporation of their input, and increases the likelihood that they will be supportive of the plan and the actions chosen for implementation.

STEP 3.1: SET GOALS

There is no one set of goals that can be applied to all coastal zones. They will vary based on a number of factors, such as the type and magnitude of projected climate change impacts and the vulnerable assets as identified in the vulnerability assessment. Other important factors include the availability of financial, technical, and human resources and the state's acceptable level of impacts. Goals should be clearly written, attainable, and measurable (qualitatively or quantitatively).

After reviewing the vulnerability assessment findings, a good starting point for goal setting is to review goals established in other state plans/programs (e.g., those for coastal management, hazard mitigation², emergency operations, environmental preservation, economic development, resource management, transportation, etc.). Adaptation plans from other governments, state and local, are also useful resources. Some of these plans can be accessed online at <http://collaborate.csc.noaa.gov/climateadaptation/>.

Examples of potential goals include:

- Reduce the vulnerability of the built environment to sea level rise
- Monitor and maintain functioning and healthy coastal ecosystems
- Reduce the costs associated with disaster response and recovery
- Protect critical infrastructure from the impacts of climate change
- Minimize economic losses attributable to the impacts of climate change
- Adapt to climate change in a manner that minimizes harm to the natural environment and loss of public access



Plan goals should be clearly written, attainable, and measurable.

- Increase public awareness about climate change and how it may affect the coast
- Reduce the impact of climatic and nonclimatic stressors on natural systems
- Increase and improve technical capacity to project impacts of climate change
- Provide leadership and support to local governments for climate change adaptation planning
- Enhance the state's ability to detect climate change impacts
- Improve coordination and collaboration among relevant agencies and organizations

STEP 3.2: IDENTIFY ACTIONS

Since many of the impacts and consequences of climate change are not new, simply exacerbated or accelerated, actions to reduce them already exist and are being implemented outside the context of climate change. This chapter illustrates how familiar actions can also be used to support climate change adaptation.

However, some of these actions are likely insufficient for addressing the scale of the potential changes. It will take a combination of existing, reconfigured, and new actions to meet the challenges of climate change. Importantly, the potential impacts of climate change on the coast should be considered in all related planning, law and policy making, and investment activities.

² Note: Federal funding for hazard mitigation (which in many cases includes climate change adaptation actions) from FEMA is tied to goals set in federally approved hazard mitigation plans. To be eligible for these funds, where appropriate, state hazard mitigation and climate change adaptation goals should be aligned.

While reviewing state plans for possible goals, also look at the actions and consider the following questions in regard to actions along the coast as well as elsewhere in the watershed:

- Are there any actions that directly address climate change impacts along the coast?
- Are there any actions that indirectly address climate change impacts along the coast?
- Are there any actions that could or should be modified to help meet the goals of the adaptation plan?
- Are there any actions that are in direct conflict with the goals of the adaptation plan?

To ensure the plan is inclusive of all actions that may affect your coast and to avoid duplication, you may want to consider incorporating ongoing and already planned activities in your plan. Additionally, there may be actions that could be modified to meet multiple purposes with shared resources. If there are actions that might hinder efforts to meet adaptation goals, try to work with the entity responsible for that action to reach a mutually beneficial solution. As mentioned before, coordination and collaboration among other state agencies and stakeholders is critical, both to capitalize on each other's efforts and to avoid conflicts that could prove difficult and expensive to overcome in the future.

Think broadly and do not be afraid to think big. Do not worry about resource or technology constraints, these issues will be raised during the evaluation process, which will help the planning team narrow down the list and prioritize the agreed upon actions. Hold on to the list of actions that do not make the



Action identification is a creative and collaborative process that should involve all stakeholders.

initial cut. In the future, some of these actions may be more appropriate and/or feasible. Finally, be creative.

Actions can be built to encompass one or more measures (see examples in the table on page 51) and should be crafted so they can be clearly understood (e.g., does the action involve planning, promoting, encouraging, mandating, constructing, etc.). While not all of the measures included here can be implemented at the state level, they are examples of activities states can support and promote to local governments. A lot of climate change adaptation will take place at the local level, and financial and technical assistance from higher levels of government, as well as mandates, in some instances, will be vital to secure the necessary level of local commitment.

Not all actions included in this guide will be suitable for every situation. One action may be appropriate in one location but not in another. Suitability will depend on circumstances specific to each state and its

Learning from others...BCDC Seeks Sea Level Rise Solutions through Design Competition

The San Francisco Bay Conservation and Development Commission (BCDC) held an international design competition to identify innovative climate change adaptation strategies for coastal communities. Planning and design professionals, consultants, developers, students, and the public were invited to submit entries, which were required to solve a meaningful sea level rise problem, while being environmentally smart, simply designed, and transferable to other estuaries beyond San Francisco Bay. Six winners, from among 131 entries representing 18 countries, were awarded stipends to further refine their ideas. www.risingtidescompetition.com/risingtides/

Learning from others...Rhode Island Policy Accommodates for Sea Level Rise

In January 2008, the Rhode Island Coastal Resources Management Council (CRMC) adopted a new coastal policy to explain the science of sea level rise in the state and help manage the state's coastal resources and property and protect life and property from sea level rise. For planning and management purposes, the policy calls for an accommodation of a "base rate of expected three- to five-foot rise in sea level by 2100 in the siting, design, and implementation of public and private coastal activities." The CRMC is in the process of developing guidance that will promote the application of this policy. www.crmc.ri.gov/regulations.html

coastal zone and may require additional research, study, legal review, and legislative or regulatory change.

Planning, Law Making, and Regulating

A number of measures can be used to alleviate many of the impacts and consequences of climate change and will be critical to successful climate change adaptation efforts. Importantly, these measures include planning, law making, and regulating. Adaptation will require new, and modifications to existing, plans, laws, and regulations. Going forward, all planning and rulemaking activities should consider climate change and future conditions so outcomes support, and do not deter, adaptation efforts.

Measures listed in the table on page 51 and discussed further at the end of the chapter are more likely to be acceptable and effective if they result from a traditional planning process such as the one presented in this guide. These measures can be incorporated into the adaptation planning process or that of an existing plan (e.g., comprehensive, hazard mitigation, watershed management, capital improvement, etc.). Alternatively,

the planning team may decide a measure requires its own plan (e.g., because of scope or complexity).

One type of plan encouraged by the Coastal Zone Management Act is the Special Area Management Plan (SAMP). SAMPs are broadly defined in the act as "plans which provide for increased specificity in protecting significant natural resources, reasonable coastal dependent economic growth, improved protection of life and property in hazardous areas, including those areas likely to be affected by land subsidence, sea level rise, or fluctuating water levels of the Great Lakes, and improved predictability in governmental decision making" (CZMA 1972). SAMPs and other plans with similar intents are especially appropriate in areas where authorities overlap and coordination and cooperation is required to effectively address the multitude of needs that have arisen along the coasts.

Many local governments, and some states, have comprehensive plans to guide development. Some states require local governments to have such plans; others provide incentives that encourage them. In

Learning from others...Oregon Protects Estuaries with Estuary Management Plans

Oregon's Statewide Planning Goal 16, Estuarine Resources, establishes detailed requirements for the planning and management of the state's estuaries. The overall objective is to "recognize and protect the unique environmental, economic and social values of each estuary and associated wetlands and to protect, maintain, and, where appropriate, develop and restore the long-term environmental, economic, and social values, diversity and benefits of Oregon's estuaries." To accomplish this, Goal 16 sets broad requirements for individual estuary plans, which are prepared by affected cities and counties with input from the public and other interested units of government, and for review of individual projects. www.oregon.gov/LCD/OCMP/Est_Intro.shtml

either case, states typically specify the elements that should be included in local comprehensive plans. For the purposes of adaptation, a new adaptation element could be specified, adaptation measures could be incorporated into existing elements (e.g., land use, transportation, environment, natural hazards, etc.), as appropriate, or local adaptation plans could be incorporated by reference. In addition, to address climate change, the timeframe of comprehensive plans may need to extend further into the future. Incorporating adaptation into local comprehensive plans in some way lends them the strength of internal consistency, which is required by some states, to ensure local actions are taken based upon and consistent with the legally adopted comprehensive plan.

Research on local comprehensive plans as vehicles for reducing insured losses in natural disasters suggests that comprehensive plans that include hazard mitigation can reduce such losses: losses are lower in states that require comprehensive plans and even more so in those that require comprehensive plans to address hazards. However, research also suggests that in the absence of a state mandate to prepare a comprehensive plan and address hazards, the planning efforts of many local governments are inadequate (Burby 2005).

While mandates may result in plans, they may not have the desired effect if they do not consider existing barriers to effective planning and/or if the plans are not effectively implemented.³ When issuing or revising a state mandate, consider the role of the state in the

oversight process and how it can enforce and monitor plan implementation as well as development and content (while maintaining flexibility for local decision making).

Since plans are typically not legally binding, governments may pass laws and ordinances and issue implementing regulations to best achieve the desired outcomes identified through the planning process, especially when it comes to land use. The *Second National Assessment on Natural and Related Technological Hazards* states “No single approach to bringing sustainable hazard mitigation into existence shows more promise at this time than increased use of sound and equitable land-use management” (Mileti 1999). The same is likely to hold true for climate change adaptation as well.

Examples of actions that benefit from force of law, some of which are discussed in more detail later in this chapter, include:

- Refining permitting programs to account for climate change
- Zoning development away from sensitive and hazard-prone areas
- Creating setbacks or rolling easements
- Restricting the use of shore protection structures
- Minimizing extent of impervious surfaces
- Establishing buffers around natural features
- Instituting or strengthening building codes in flood- and erosion-prone areas

Learning from others... Washington Requires Local Shoreline Master Programs

Under the State of Washington's Shoreline Management Act, local governments must develop shoreline master programs to balance land use and preservation along shorelines. Essentially, these programs are comprehensive plans and zoning ordinances with distinct environmental orientations that are applicable to shoreline areas and customized to local circumstances. Required environmental designations dictate how much and what types of development and land use are allowed, including what type of shoreline stabilization structures (if any) are permissible. The Department of Ecology provides technical and financial assistance for plan updates. www.ecy.wa.gov/programs/sea/shorelines/

³ A number of journal articles have been published that examine the effectiveness of state planning mandates. A recent article that references other relevant research is “The Proof of the Planning is in the Platting: An Evaluation of Florida's Hurricane Exposure Mitigation Planning Mandate” published in the *Journal of the American Planning Association* (74, no. 3 (2008): 349-70).

Learning from others...Florida Coastal Communities Plan for Post-Disaster Redevelopment

The State of Florida requires all coastal counties and communities to produce post-disaster redevelopment plans. The plans are expected to cover policies, operational strategies, and roles and responsibilities for implementation to guide decisions for long-term recovery and redevelopment. They should also integrate hazard mitigation and community improvement in line with the goals of the local comprehensive plan. The Florida Coastal Management Program and Department of Community Affairs are completing a pilot planning initiative to create a best practices guide for development of local post-disaster redevelopment plans, which is scheduled to be released in 2010. www.dca.state.fl.us/fdcp/DCP/PDRP/

Regardless of your state's role in regulating or planning for local land use, the state can still make efforts to guide development to help achieve adaptation goals by providing local governments with incentives and recommendations supported by education, model ordinances, and other technical assistance. These incentives should be tied to actual plan implementation and planning outcomes assessed through an evaluation process.

Other Adaptation Measures

The Climate Change Adaptation Measures table introduces measures that can be taken to reduce the impacts and consequences of climate change on the coast. It is not a comprehensive list and is largely limited to measures that coastal managers may have a significant role in. Adaptation measures are organized into categories that describe their primary purpose. In many cases, they serve multiple purposes and could

fit into multiple categories (e.g., acquisition could fit under Growth and Development Management, Coastal and Marine Ecosystem Management, and Shoreline Management in addition to Loss Reduction). Some of them also support climate change mitigation (e.g., through carbon sequestration).

It may be useful to reorganize, add, or delete measures in this table when discussing options within the planning team and with stakeholders or when presenting options to local governments. The table also cross references the measures with the phenomena (as introduced in Chapter 2) they may be used to address and the environment (natural and built) they protect, which illustrates that a measure designed to protect one type of environment may also provide protection for the other. The individual measures are discussed, by category, in further detail at the end of the chapter prior to the Key Resources.

Recognizing the benefits of mainstreaming climate change with development, *Adapting to Coastal Climate Change: A Guidebook for Development Planners*, published by the U.S. Agency for International Development, contains an annex that organizes adaptation measures by development goals (as they pertain to climate change adaptation). The goals are:

- Functioning and healthy coastal ecosystems
- The built environment is less exposed and less vulnerable to damages from natural hazards
- Livelihood opportunities are maintained or strengthened in the face of climate change impacts
- Impacts of climate change to human health and safety are minimized
- Governance, policy, and planning capacities for planned adaptation are strengthened

Practitioner briefs describe each measure's relevance, purpose, and application to climate change; information and data requirements; design considerations; and suggestions for improving likelihood of success and provide a list of resources. www.crc.uri.edu/index.php?actid=366

Climate Change Adaptation Measures

Measure	Phenomenon								Environment	
	Increased Air Temperature	Rising Sea Levels	Declining Lake Levels	Increased Storm Intensity/Frequency	Increased Precipitation	Decreased Precipitation	Increased Water Temperature*	Ocean Acidification*	Natural Environment	Built Environment
Impact Identification and Assessment										
Research and Data Collection	x	x	x	x	x	x	x	x	x	x
Monitoring	x	x	x	x	x	x	x	x	x	x
Modeling and Mapping	x	x	x	x	x	x	x	x	x	x
Awareness and Assistance										
Outreach and Education	x	x	x	x	x	x	x	x	x	x
Real Estate Disclosure		x	x	x	x				x	x
Financial and Technical Assistance	x	x	x	x	x	x	x	x	x	x
Growth and Development Management										
Zoning		x		x	x	x			x	x
Redevelopment Restrictions		x		x	x				x	x
Conservation Easements		x	x	x	x				x	x
Compact Community Design		x		x	x				x	x
Loss Reduction										
Acquisition, Demolition, and Relocation		x		x	x				x	x
Setbacks		x		x	x				x	x
Building Codes	x	x		x	x	x			x	x
Retrofitting	x	x	x	x	x	x			x	x
Infrastructure Protection	x	x	x	x	x	x			x	x
Shore Protection Structures		x		x	x				x	x
Shoreline Management										
Regulation and Removal of Shore Protection Structures		x		x	x				x	x
Rolling Easements		x		x	x				x	x
Living Shorelines		x		x	x				x	x
Beach Nourishment		x		x	x				x	x
Dune Management		x		x	x				x	x
Sediment Management		x	x	x	x				x	x
Coastal and Marine Ecosystem Management										
Ecological Buffer Zones	x	x	x	x	x				x	x
Open Space Preservation and Conservation	x	x	x	x	x	x			x	x
Ecosystem Protection and Maintenance	x	x	x	x	x	x	x	x	x	x
Ecosystem Restoration, Creation, and Enhancement	x	x	x	x	x	x	x	x	x	x
Aquatic Invasive Species Management	x						x		x	
Water Resource Management and Protection										
Stormwater Management		x	x	x	x			x	x	x
Green Infrastructure		x	x	x	x	x		x	x	x
Water Supply Management		x	x	x	x	x			x	x

* The impacts of increased water temperature and ocean acidification are best managed by reducing the impacts of existing stressors and supporting healthy ecosystems.

STEP 3.3: EVALUATE, SELECT, AND PRIORITIZE ACTIONS

Unfortunately, there will be more things the planning team wants to do than it will be able to, for a variety of reasons. In this task, the planning team will decide which of the actions identified in the previous step are actually suitable for the state's unique set of circumstances and then prioritize them for implementation. Decisions will need to be made; difficult tradeoffs may be required. Much of this discussion is based on FEMA's *Developing the Mitigation Plan: Identifying Actions and Implementing Strategies* (2003).

One way to evaluate the proposed actions is to use a method that considers the **S**ocial, **T**echnical, **A**dministrative, **P**olitical, **L**egal, **E**conomic, and **E**nvironmental (STAPLEE) opportunities and constraints of each action. The information the planning team generates from this evaluation process will help them weigh the pros and cons of each action to determine which are best for the state. There are no right or wrong answers. The criteria are defined as follows:

- **Social**—The action should be socially acceptable.
 - Will the proposed action disproportionately affect (positively or negatively) one segment of the population?
- **Technical**—The action should be technically feasible, help to reduce losses in the long term, and have minimal cumulative and secondary impacts.
 - How effective is the action in avoiding or reducing future losses?
 - Will it create more problems than it solves?
 - Does it solve the problem or only address a symptom?
- **Administrative**—The action should be implementable by the state. Can the state meet the staffing and funding needs of the action or will it need outside assistance?
 - Does the state have the capacity (staff, technical expertise, and funding) to implement and maintain the action, or can it be realistically obtained elsewhere?
- **Political**—The action should be politically acceptable.
 - Is there political support to implement and maintain this action?
 - Is there a champion willing to help see the action to completion?
 - Is there enough public support to ensure the success of the action?
- **Legal**—The state must have the legal authority to implement/enforce the action.
 - Does the state have the authority to implement/enforce the action?
 - Are the proper laws and regulations in place to implement/enforce the action?
 - Are there any potential legal consequences?
 - Will the state be liable for the action or lack of action?
 - Is the action likely to be challenged by stakeholders who may be negatively affected?
- **Economic**—The action should be cost-effective and be likely to pass a benefit-cost analysis.
 - Are there currently sources of funds that can be used to implement the action?



Actions will need to be evaluated based on criteria established by the planning team and, once selected, prioritized for implementation.

Coastal No Adverse Impact is based on the concept of No Adverse Impact from the Association of State Floodplain Managers, which advocates that the actions of any community or property owner should not adversely impact others. It aims to help communities in the coastal zone manage development and growth to avoid activities that might increase flooding or erosion on or off site, degrade the environment, or increase the need for public services such as emergency response and stormwater management. Coastal No Adverse Impact promotes community-based decision making and responsible land use that exceeds minimum requirements established by the federal government. www.floods.org/index.asp?menuid=340&firstlevelmenuid=187&siteid=1

- What benefits (market and nonmarket) will the action provide?
- Does the cost seem reasonable for the size of the problem and likely benefits?
- What burden will be placed on the tax base or local economy to implement this action?
- Does the action contribute to or detract from other community economic goals, such as capital improvements or economic development?
- What are the economic consequences of not implementing the action?
- **Environmental**—The action should meet statutory considerations and public desire for sustainable and environmentally healthy communities.
 - How will the action affect the environment (land, water, protected species)?
 - Will the action comply with state and federal environmental laws and regulations?
 - Is the action consistent with state environmental goals?

Once the planning team has decided on the acceptable actions given review of the criteria above (or a different set of criteria), it should prioritize the actions for implementation. As part of this exercise, it may want to consider answers to the questions above as well as:

- How well the action meets the adaptation goals

The following terms (as defined by the United Nations' 2009 *Guidance on Water and Adaptation to Climate Change*) are found throughout the climate change adaptation literature and may be useful in prioritizing actions given the uncertainties of climate change:

- **Win-win options**—Cost-effective adaptation measures that minimize climate risks or exploit potential opportunities but also have other social, environmental, or economic benefits. In this context, win-win options are often associated with those measures or activities that address climate impacts but which also contribute to climate change mitigation or meet other social and environmental objectives.
- **No-regrets options**—Cost-effective adaptation measures that are worthwhile (i.e., they bring net socioeconomic benefits) whatever the extent of future climate change. These types of measures include those which are justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and are also consistent with addressing risks associated with projected climate changes.
- **Low-regrets (or limited-regrets) options**—Adaptation measures where the associated costs are relatively low and where the benefits, although mainly met under projected future climate change, may be relatively large.
- **Flexible adaptation options**—Measures which are designed with the capacity to be modified at a future date as climate changes.

Learning from others...Maine BCA Favors Retreat over Protection

In a sea level rise study conducted for the Maine State Planning Office and the U.S. Environmental Protection Agency (EPA) in 1995, benefit-cost analysis (BCA) was used to evaluate four potential options for adapting to sea level rise at a specific study site. The researchers concluded, in that particular case, that it would be more cost-effective to use rolling easements to retreat from the shoreline as sea level rises than to impose setbacks for new development or to protect development and maintain the shoreline. www.epa.gov/climatechange/effects/coastal/SLRAnticipatory.html

- How urgent the need is for implementation of the action
- How easy the action is to implement
- If the action meets multiple objectives (maximizes benefits)
- If the action also helps mitigate climate change
- How reliable the projections the action is based on are
- How flexible the action can be under a range of climate change scenarios

STEP 3.4: WRITE ACTION PLANS

Once the planning team has agreed upon the actions to move forward with, it is highly recommended that brief action plans are written for EACH individual action. Among other things, these plans will establish accountability and ease tracking and evaluating as further described in Chapter 6. Information that could be captured in these action plans includes:

- Title
- Description
- Responsible Party(s)
- Other Players
- Priority
- Cost
- Benefit-Cost Analysis
- Potential Funding Source(s)
- Schedule/Milestones
- Maintenance Needs
- Evaluation Plan
- Goals Addressed

ADAPTATION MEASURE DESCRIPTIONS

The text that follows provides brief descriptions of the adaptation measures listed in the Climate Change Adaptation Measures table on page 51. As previously stated, the measures are roughly organized into categories

that describe their primary purpose, yet not necessarily their only purpose, as some could fit into multiple categories. It is outside the scope of this document to provide all the information needed to implement each measure. Key Resources are provided at the end of the chapter.

Impact Identification and Assessment

- **Research and Data Collection**
- **Monitoring**
- **Modeling and Mapping**

It is likely that when the planning team embarked on the vulnerability assessment it did not have as much information as it would have liked. And, even if it did, circumstances will change, science and technology will evolve, and more information will become available. Adaptation is an ongoing process that will continue to rely on new and better information about climate change as well as your state's communities' needs, strengths, and weaknesses. Informed decision making supported by an ongoing vulnerability assessment program that incorporates research and data collection, monitoring, and modeling and mapping should result in coastal communities that are better prepared to adapt to a changing climate.

Research and Data Collection

There is still a lot to be learned about climate change, its impacts and consequences, and how we can reduce our vulnerability to them. The better the planning team understands what climate change means for coastal communities, the better

Learning from others...South Carolina Assesses Management of Shoreline Change

In 2007, the South Carolina Department of Health and Environmental Control established an external advisory committee made up of 23 experts from academia, government, and the private sector to examine science and policy issues related to beachfront and estuarine shoreline management in South Carolina. Specifically, the intent was to help the state address future social, economic, and natural resource impacts of shoreline changes that may result from continued (or accelerated) rise in sea level, development encroachment into the beach/dune system, shoreline alterations, and coastal storms. The committee's report, *Adapting to Shoreline Change*, reflects on over 20 years of shoreline management in South Carolina and makes suggestions for the coming decades. The goals and policy and management recommendations presented in the committee's final report are intended to provide a new foundation for continued shoreline planning, policy development, and program implementation at the federal, state, and local levels.

www.scdhec.gov/environment/ocrm/

positioned they will be to address it. A research agenda could include:

- Monitoring academic and public news media to keep informed about changes in climate change science and adaptation tools, technologies, and success stories
- Collecting physical and socioeconomic data to better understand vulnerabilities
- Documenting events and impacts associated with climate variability and change
- Projecting climate and nonclimate changes (e.g., population growth, loss/gain of open space, etc.)
- Coordinating research agendas and partnering with other state and local governments as well

as academic institutions, federal agencies, and nongovernmental organizations

While research activities can stand alone, they will also support other assessment measures (e.g., modeling and mapping) as well as the selection and design of other adaptation actions. Research will likely need to be undertaken to examine the feasibility and cost-effectiveness (benefit-cost analyses) of potential actions.

Monitoring

Monitoring plays a vital role in climate change adaptation. It can alert you to changes in the climate and associated impacts and consequences and

Learning from others...Delaware Shares Lessons Learned in Lidar Acquisition

In 2005, a coalition composed of the Delaware Department of Natural Resources and Environmental Control, U.S. Department of Agriculture, and Delaware Geological Survey contracted with the U.S. Geological Survey and the National Aeronautics and Space Administration to collect lidar for Sussex County. In 2007, the lidar for the remaining two counties, Kent and New Castle, was collected by a commercial contractor. As a result, Delaware is one of the few states with statewide lidar coverage. However, the acquisition and use of the data have posed great challenges, which the state has made great strides in overcoming. To other states seeking to obtain statewide lidar coverage, Delaware offers the following lessons learned:

- Agree on data standards
- Know the end users' technical capacity
- Use a common format for the entire state
- Ensure all data and products are contract deliverables
- Capture metadata and incorporate quality assurance and control

www.csc.noaa.gov/digitalcoast/inundation/_pdf/de_lessons.pdf



Elevation change can be monitored with surface elevation tables placed on benchmarks installed in wetlands.

track ecological and socioeconomic responses. If properly planned and implemented, a comprehensive monitoring program that incorporates multiple tools and considers a variety of systems and processes can provide input to the vulnerability assessment and adaptation strategy. Such a program can document changes and their effects, enabling timely preventive or corrective action and illustrating the effectiveness of adaptation actions. Monitoring can also be an effective way to engage community members and raise climate change awareness.

Learning from Others...Connecticut and New York Team Up to Monitor Long Island Sound

Sentinel Monitoring for Climate Change in Long Island Sound began in 2008 as a partnership between Connecticut's Department of Environmental Protection and the University of Connecticut. With the addition of the Long Island Sound Study (a bi-state partnership of federal and state agencies, user groups, concerned organizations, and individuals dedicated to restoring and protecting the sound), New York has also joined the monitoring effort. The goal of the program is to design and develop a dynamic climate change monitoring program for the ecosystems of the sound and its coastal ecoregions. The long-term monitoring program will identify resources in the sound that are most vulnerable to climate change and most critical to protect and will ultimately enable the partners to develop appropriate adaptation strategies to protect the sound's biodiversity and significant natural resources. jennifer.pagach@ct.gov

Learning from others...Oregon Monitors Beach and Shoreline Change

The Oregon Beach and Shoreline Mapping Analysis Program maintained by the Oregon Department of Geology and Mineral Industries is a monitoring program designed to document the response of Oregon's beaches to both short-term climate variability (e.g., El Niños, extreme storms) and longer-term effects associated with climate change (e.g., increasing wave heights, changes to storm tracks, and sea level rise). The broad purpose of the program is to provide high-quality scientific information about changes along the Oregon coast to coastal managers, city and county planners, the geotechnical community, and other stakeholders to support responsible land use and development, both today and into the future. www.oregongeology.com/sub/news&events/archives/press-release-2009-02-25.pdf

NOAA's National Estuarine Research Reserve Systems' System-Wide Monitoring Program (SWMP) tracks short-term variability and long-term changes in estuarine waters to understand how human activities and natural events can affect ecosystems. SWMP focuses on three related environmental measures: abiotic monitoring, including atmospheric conditions, nutrients and contaminants, and physical water quality factors (e.g., salinity, dissolved oxygen, and tidal range); biological monitoring, including biodiversity, habitat, and population characteristics; and watershed and land cover/land use classification, including changes over time in coastal and estuarine habitat and land use. Coastal managers can use these data to make informed decisions on local and regional issues, which include climate change adaptation. www.nerrs.noaa.gov/RCDefault.aspx?ID=18

A number of tools already exist for monitoring climate variability and ecological health that could be incorporated into a climate change monitoring program. Some of these tools are listed as Key Resources at the end of this chapter.

Modeling and Mapping

Modeling and mapping, which were discussed in Chapter 4, provide valuable input to climate change adaptation planning and implementation. Specifically, models and maps provide information about how climate change might affect a planning area, lending support to vulnerability assessments and communications tools. They may also be used to illustrate the potential outcomes of adaptation actions.

Models simulate reality to better understand how changes in climate may impact natural and built environments. Maps illustrate model outputs but may also be basic graphic representations of certain characteristics (e.g., social, physical, environmental) in a geographic area. Model-based maps may be risk-based, event-based, or scenario-based. Risk-based maps illustrate an event that has a specific probability of occurring over a specific time frame (e.g., Digital Flood Insurance Rate Maps). Event-based maps depict events that have already occurred and their impacts. Scenario-



Visually integrating ecosystem, infrastructure, and inundation data helps planners make more informed decisions.

based maps illustrate the outcomes of a projected event (or events). All can provide useful information for climate change adaptation planning and project implementation.

These measures, modeling in particular, can be extremely resource intensive and complex and may require engaging experts, such as academics, nongovernmental organizations, consultants, or federal partners. Alternatively, pre-existing models and maps can be used in their original form, or they could be downscaled or improved upon through

As part of its activities related to the National Flood Insurance Program, FEMA has begun the transition from Flood Map Modernization to Risk Mapping, Assessment, and Planning (Risk MAP). The vision for Risk MAP is to work collaboratively with state, local, and tribal entities to deliver quality information that increases public awareness and leads to actions that reduce threats to life and property. FEMA is updating Digital Flood Insurance Rate Maps to address gaps in required engineering and mapping, based on current conditions, for high flood risk areas impacted by coastal flooding, levees, and other flood hazards. www.fema.gov/plan/prevent/fhm/rm_main.shtm

Learning from others...BCDC Updates Sea Level Rise Maps

In 2006, the San Francisco Bay Conservation and Development Commission (BCDC) released a series of maps depicting the lands most vulnerable to sea level rise. To improve the accuracy and precision of the maps, in 2009, using funds from the California Energy Commission's Public Interest Energy Research Program, BCDC released new maps based on sea level rise data from the U.S. Geological Survey. The maps show areas vulnerable to 16 inches of sea level rise at mid-century and 55 inches at the end of the century (scenarios that are generally consistent with other state sea level rise estimates). www.bcdc.ca.gov/planning/climate_change/index_map.shtml

the addition of data (e.g., Digital Flood Insurance Rate Maps could be enhanced by adding future conditions hydrology, erosion zones, or areas that may be inundated by sea level rise). In any case, models and maps will need to be updated to reflect observed changes, new projections, improved data, and changes in exposure.

Awareness and Assistance

- **Outreach and Education**
- **Real Estate Disclosure**
- **Financial and Technical Assistance**

Effective climate change adaptation relies on an informed stakeholder base, from elected officials to the general public. In addition, since a number of the measures discussed in this guide are best implemented at the local level, providing financial and technical assistance to local governments, as well as individual home and business owners, will be critical to overall success. Increasing awareness and providing assistance enhances adaptive capacity and can better prepare your state's coast to withstand the impacts and consequences of climate change.

Outreach and Education

Outreach and education are distinct but related activities, and both are vitally important for effective climate change adaptation. In this guide, outreach is the provision of information to all stakeholders (anyone who will be affected by climate change in your state), and education involves the formal education system (typically kindergarten through grade 12).

Purposes of outreach can include engaging stakeholders in the planning effort, gaining support for planning and action implementation, informing the public about climate change and their role in adaptation, communicating the benefits of natural resources and ways to protect them, and changing attitudes and behaviors. Outreach is not a one-time activity. It should begin with the launching of the adaptation planning effort and continue throughout the process (as introduced in Chapter 3) and as



Using visuals to explain how coastal areas may be impacted by climate change can build support for adaptation.

new information becomes available, milestones are met, successes become evident, and whenever an appropriate opportunity presents itself (e.g., when the plan is released or when adaptation actions are implemented that require support, adherence, or assistance).

There are numerous challenges to communicating about climate change. The uncertainty of the science and the presence of more immediate issues are perhaps the biggest. While a few resources for helping conduct outreach and craft and deliver adaptation messages are noted at the end of the chapter, the planning team should consider enlisting communications specialists to help in this endeavor.

An outreach strategy can help guide climate change adaptation communications and, similar to the strategy for an adaptation plan, should identify goals and actions to ensure stakeholders are being reached in an effective manner. An outreach strategy involves identifying the target population, conducting a population profile (so the best way to communicate with them is understood), crafting the message, and then deciding how to disseminate it. There will likely be multiple stakeholder groups/target populations (e.g., planning team members and other participating stakeholders, the general public, state and local elected officials and other decision makers, developers, resource managers, etc.) who may require tailored messages and different delivery formats.

Learning from others...Hawaii Guide Informs Buyers about Purchasing Coastal Real Estate

Recognizing the increasing rates of rapid residential growth and development along the waterfront of the main Hawaiian Islands, the University of Hawaii Sea Grant College Program, with support from the State of Hawaii Department of Land and Natural Resources and the Coastal Zone Management Program, published the *Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawai'i—A Practical Guide of Common Questions*. The publication provides basic information on coastal hazards that waterfront property investors and developers should consider when purchasing coastal land. The guide also addresses common concerns and questions and provides options and resources to protect coastal real estate and safeguard the lives of residents. www.soest.hawaii.edu/SEAGRANT/communication/publications.php

As the strategy is drafted, the planning team should consider what is already being done to reach the target populations. Can climate change adaptation be incorporated into existing government programs for climate change mitigation, coastal management, emergency management, public health, water conservation, stormwater management, etc.? What communications vehicles are planning team members already using? Are there lessons learned that the planning team can benefit from? As appropriate, coordinate outreach efforts with federal activities, including National Flood Safety Awareness Week, Hurricane Preparedness Week, American Wetlands Month, and others. Be prepared to take advantage of windows of opportunity, which may come in the form of extreme weather events (in your state or elsewhere); the arrival of climate conditions that may affect your state (e.g., annual storm seasons, El Niño, La Niña); national media attention, etc.

“Effective communication has to achieve a match between message content, framing, and the concerns

and values with which audiences resonate” (Bostrom and Lashof 2007). When communicating with the public, consider geographic, socioeconomic, and cultural differences. Who is most vulnerable? What languages do they speak? What are their interests?

Surveys can help inform the planning team about how stakeholders feel about climate change and adaptation and what they value most and may help it better understand how to engage them on the subject. For instance, if some stakeholders have doubts about climate change, or the term itself is too politically charged, taking an approach that focuses on the impacts and consequences, many of which they may have already experienced or are familiar with, may be more effective.⁴ A demonstration of the trends can illustrate the need to take action.

Initial outreach efforts to engage and involve stakeholders (see Chapter 3) may simply include an introduction to climate change and the planning process and information about how to get involved. In crafting

A number of resources are available to help develop and conduct effective outreach. One of these resources is the NOAA Sea Grant program. Sea Grant’s network of extension agents links university resources and expertise with local communities and user groups, taking complex information and showing people how to use it to solve problems. This includes developing new information through original applied research, gathering existing information to meet user needs, and transmitting information through pamphlets, courses, workshops, lectures, and meetings. www.seagrant.noaa.gov/

⁴ While this may help adaptation’s cause, it should be noted that such an approach does not support climate change mitigation. And, since mitigation is essential to addressing climate change, this kind of approach should be used with caution.

“If individuals are to be involved in mitigating and adapting to climate and other global changes, the problems need to be meaningful and relevant; people need help to understand both causes and solutions; communicators must—despite uncertainty—create a sense of appropriate urgency (but not irrational fear); and they must enable and empower people to act in sustainable ways and support relevant public policy” (Vogel 2007).

Learning from others...Maine and Oregon Sea Grant Programs Advance Outreach through Social Science

Since 2007, Maine and Oregon Sea Grant Programs have been working together to understand how best to educate the public about climate change and motivate them to act. Specifically, the project used focus groups and surveys of coastal landowners and decision makers to better understand their concerns, knowledge, motivations, and decision-making processes and aims to, ultimately, develop a test model of public outreach about climate change that is transferable to coastal managers in other states. Videos were produced for both states based on the results. In Maine, a five-year outreach plan includes projects to address identified information gaps, including a hazard mitigation guide, an interactive web site, and a series of workshops for coastal property owners and municipal officials.

www.seagrant.umaine.edu/extension/coastal-community-resilience; <http://seagrant.oregonstate.edu/research/ClimateChange/index.html>

the message, the planning team should consider what it wants the target population to take away from the message and/or how it would like them to respond (i.e., what it would like them to do).

Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments offers the following suggestions, which should be localized and made relevant for your target population(s), for developing a general climate change adaptation message (Snover et al. 2007):

- Describe changes that have already been observed
- Describe changes that are expected
- Describe the potential impacts and consequences

- Convey the need for action but balance the challenges with optimism
- Develop a course of action
- Acknowledge that questions remain

Also, think about illustrating the message, either with images, maps, or success stories. Convey the importance of recognizing that the needs of humans and nature are complementary. Emphasize how, in some instances, adaptation will provide benefits with or without climate change. And, explain the potential costs of inaction or delayed action. As the plan evolves, so will the level and type of information that can be provided and that stakeholders will require.

A variety of traditional and nontraditional ways exist to communicate the message. These include, but are

Learning from others...Fact Sheets Support Adaptation Planning in Connecticut

The Connecticut Department of Environmental Protection has developed a series of initial climate adaptation fact sheets, “Facing Our Future,” detailing current observations and providing cursory recommendations for alternative approaches to foster adaptation at the local and regional level. These fact sheets address overlapping technical areas or categories: biodiversity and habitat, fisheries, forestry, infrastructure, natural coastal shoreline environment, outdoor recreation, water resources, and wildlife. www.ct.gov/dep/cwp/view.asp?a=2684&q=436600&depNav_GID=1619

Learning from others...Texas Brings Climate Change to the Classroom

The University of Texas Austin's Bureau of Economic Geology and the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University Corpus Christi have developed a 3-D virtual model of the Gulf of Mexico and Texas coastal environments for use in the classroom and for the general public to explore how relative sea level change may impact the coastal zone. The project, sponsored in part by the Texas State Energy Conservation Office and the Texas Coastal Coordination Council, also includes a lesson plan titled "Sea Level Changes and the Texas Coastal Environment," a PowerPoint presentation for teachers to use to introduce the lesson in their classrooms, and a short video explaining how to use the virtual model. <http://coastal.beg.utexas.edu/thscmp/vbi.htm>

not limited to, print, broadcast, online, and social media; events and meetings; internal governmental communications; billboards; and direct mail, such as newsletters, brochures, utility bills, flyers, and surveys (which can be used to inform as well as gather information). Museums, libraries, nature centers and preserves, and other informal education providers can also serve as effective venues for dissemination of information about climate change.

In addition to the education provided via the outreach program, the planning team may want to work with the state's department of education to create programs to educate teachers about climate change and to develop curricula for the classroom. The primary goals of these efforts should be to equip students with basic information about climate change and to empower them to take action and to build awareness among their family and friends. Your state research institutions can also provide input to these efforts.

Real Estate Disclosure

According to FEMA, most prospective buyers do not factor in hazards when they are considering purchasing property (CRS 2007). The disclosure of an individual property's vulnerability to coastal hazards enables potential buyers to make informed decisions reflecting the level of impacts they are willing and able to accept. States can require disclosures that include information about known flood, erosion, and subsidence hazards and may even suggest that a given property may become more vulnerable as the climate changes (e.g., rising sea levels, increasing storm intensity). States can also provide information about hazard mitigation to help new homeowners willing to accept the potential impacts and consequences. Information about rolling easements, setbacks, buffers, wetlands, redevelopment restrictions, shore protection structures (prohibition, restrictions, maintenance requirements), beach nourishment, and other coastal zone and environmental laws, regulations, and policies that may affect the property could also be disclosed.

Learning from others...South Carolina Real Estate Disclosure Protects Interests of Buyers

South Carolina's Coastal Tidelands and Wetlands Act requires contracts of sale or transfers of real property to contain disclosure statements if a beachfront property is located seaward of the setback or jurisdictional line. The statement must indicate that the property is or could be affected by the lines and must include the local erosion rate most recently made available by the South Carolina Office of Ocean and Coastal Resource Management (SC OCRM) for that zone. SC OCRM has developed an educational brochure for real estate workshops, and the state's Real Estate Commission has developed an addendum for contracts of sale that addresses the disclosure requirement and also includes information about the width of the flood zone (V-Zone). In addition, per the Residential Property Condition Disclosure Act, South Carolina's Residential Property Condition Disclosure Statement includes information about flood hazards.

www.scstatehouse.gov/code/statmast.htm; www.scdhec.gov/environment/ocrm/pubs/docs/qa_realestate.pdf;
www.llr.state.sc.us/POL/REC/index.asp?file=pub.htm

Learning from others...Louisiana Funds Resiliency Projects in Coastal Parishes

With \$10 million from the U.S. Department of Housing and Urban Development's Community Development Block Grant program, the Louisiana Recovery Authority is helping communities affected by Hurricanes Gustav and Ike create plans to increase resiliency. The competitive Comprehensive Resiliency Program will fund nonconstruction projects, such as the development of forward-thinking plans related to land use, economic development, resiliency, and water management; development of local zoning ordinances that will help prevent or dramatically minimize business, housing, and infrastructure damage from future storm events; and augmentation of local code enforcement staffs. <http://lra.louisiana.gov/index.cfm?md=newsroom&tmp=detail&articleID=608>

Information could be provided in property listings, in contracts to purchase, or at settlement and should be recorded in deeds and other appropriate legal documents; mapped hazard areas could be shown on lot surveys. Brochures that provide more detailed information about the hazards and associated regulations would also benefit potential buyers and may be part of a larger outreach strategy as described above. Best practices for hazard disclosure include providing notification as early in the process as possible, crafting clear and direct notices, educating professionals involved in the disclosure process, and establishing strong and clear enforcement provisions (Godschalk et al. 2000).

Financial and Technical Assistance

Since a lot of climate change adaptation will be taking place at the local level, it is in your state's best interest

to build the capacity of local governments to respond through both financial and technical assistance.

Financial support could be provided as competitive or formula grants or could be targeted to specific projects and pilots, which may also be accompanied by technical assistance. By supporting pilot projects, the state will be able to test out adaptation measures in a limited number of communities before applying them statewide. Financial assistance could also be provided through incentives, where special funds are only available where prerequisites established by the state have been met. An example of a related incentive program is the National Flood Insurance Program's Community Rating System, which offers discounts on flood insurance in participating communities.

Technical assistance could also take a number of forms. It could include the provision of training, data,

The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Participating communities receive flood insurance discounts that reflect reduced vulnerability to flooding. Other benefits of participation include enhanced public safety, reduction in damage to built and natural environments, avoidance of economic disruption/losses, reduction of suffering, and access to technical assistance. In addition, some activities can help a community qualify for federal assistance programs (e.g., hazard mitigation planning). There are 18 floodplain management activities credited by the CRS, organized under four series:

- Public Information
- Mapping and Regulations
- Flood Damage Reduction
- Flood Preparedness

Each CRS activity has criteria that must be met in order for communities to receive credit. Encourage local governments to review these criteria when designing and implementing adaptation measures to ensure they do so in a way that will earn them maximum credit. Additionally, consider how the activities of state agencies can support local governments in their efforts to improve their ratings, including through uniform minimum credits, which communities can earn for activities implemented by regional or state agencies. www.fema.gov/business/nfip/crs.shtm

Learning from others...Connecticut Helps Town with Climate Change Adaptation

With funding from the EPA's Climate Ready Estuaries Program, the Connecticut Department of Environmental Protection's Office of Long Island Sound Programs partnered with ICLEI—Local Governments for Sustainability through the Long Island Sound Study to host a series of coastal climate change adaptation workshops for the Town of Groton. The three-part series was designed to engage representatives from federal, state, and local governments in climate change adaptation efforts and provide them with the understanding and tools needed to effectively adapt to climate change. The results of the workshops, including an adaptation report with recommendations for future actions, will be presented to town officials and other agency leaders in fall 2010. www.icleiusa.org/action-center/planning/climate-adaptation-planning-resources/groton-connecticut-coastal-climate-adaptation-workshop-presentations; www.ctclimatechange.com/

maps, models, GIS support, planning guidebooks, model ordinances, and outreach materials. Once again, survey the planning team to see what programs already exist. Could adaptation be incorporated into them or could their focus be shifted?

Training advances outreach efforts and, as with outreach, will likely have multiple target populations and messages. Each program should address the individual needs of the target population, which could be elected officials; state and local planners, natural resource managers, or building code officials; developers; marine contractors; the general public; etc. For example, a training program to educate elected officials about their role in climate change adaptation would look very different from a program designed to teach marine contractors about living shorelines.

Many local governments already provide map information services, where they respond to inquiries regarding the location of a property in relation to special flood hazard areas as well as its base flood elevation. However, due to both financial and technical constraints, this information may be limited

to information on a Digital Flood Insurance Rate Map. Should the state expand mapping activities to better capture the location of natural resources and identify areas susceptible to other coastal hazards, this information could be passed along (e.g., as GIS overlays) to local governments to better inform their map information service as well as their planning efforts. In addition, this information could be used as input to a coast-wide web mapping application that would allow local governments and other stakeholders to view the location of hazard-prone and natural areas.

In addition to providing data, maps, and models, which will help lay the foundation for an adaptation plan, the state can further support the planning activities of local governments by providing planning guidance, such as a local version of this document customized for your state. Consistent information provided all along your coast in the form of vulnerability assessment tools and planning requirements and standards can help compare needs across communities and better assess how to allocate limited resources.

Learning from others...Ohio Coastal Atlas Supports Coastal Decision Making and More

The Ohio Coastal Atlas Project is a suite of resources developed by the Ohio Department of Natural Resources Office of Coastal Management. The atlas provides coastal decision makers, professionals, educators, interest groups, and the public with information about Lake Erie and its watershed. The atlas project consists of a 240-page printed edition, a DVD, and two online components—an interactive Lake Erie map viewer and static map library. Topics range from Lake Erie bathymetry, elevation contour lines, coastal barrier resources, wetlands, land cover, U.S. Army Corps of Engineers project locations, flood hazards, sand resources, nearshore substrates, and more. www.ohiodnr.com/AtlasGIS/tabid/19562/Default.aspx

NOAA's National Estuarine Research Reserve System's Coastal Training Program offers a number of trainings relevant to meeting the challenges of climate change. Programs focus on issues such as living shorelines, Coastal No Adverse Impact, effective science communication, wetland restoration, and more.

In 2009, the "Planning for Climate Change" workshop, geared primarily toward shoreline planners, was developed for Coastal Training Programs at National Estuarine Research Reserves (and other programs/agencies) to customize and use as part of their climate change educational efforts. It was piloted twice in Washington State and, while it lays a foundation in current climate research, it primarily addresses the fundamentals of how to prepare and adapt to the anticipated impacts of climate change. The workshop has already been modified for the San Francisco area, and a number of other reserves plan to offer similarly customized workshops in 2010. Workshop materials, evaluation results, lessons learned, PowerPoint presentations, and streaming video of the training sessions are available online. Project partners include the Padilla Bay National Estuarine Research Reserve, Washington State Department of Ecology, Washington Sea Grant, the University of Washington's Climate Impacts Group, and the King County Executive Office. <http://nerrs.noaa.gov/Training.aspx>

Growth and Development Management

- **Zoning**
- **Redevelopment Restrictions**
- **Conservation Easements**
- **Compact Community Design**

As development and redevelopment along our coasts continues, there are a number of ways growth can be managed to guide it away from hazard-prone areas and valuable or sensitive natural resources. While growth is often desirable and necessary, it must be managed in a way that addresses the needs of the population and also offers protection to natural resources and supports the services they provide.

A robust planning program is essential to effectively manage growth and development, and it is widely recognized that land use planning is an effective way to reduce risks associated with natural hazards (Burby 1998). While most growth will be managed locally, there is still a role for the state to play, including restricting growth where it affects state lands and offering assistance and disincentives (e.g., not providing funding for infrastructure or other services that will encourage growth in inappropriate areas) to local governments.

The greatest opportunity to protect land is before it is developed. It is much easier and cheaper to direct new construction away from sensitive and hazard-prone

In consultation with the Smart Growth Network, NOAA, EPA, the International City/County Management Association, and Rhode Island Sea Grant drafted coastal and waterfront smart growth elements to address the unique growth-related issues of waterfront communities. The elements augment the existing smart growth principles to reflect the specific challenges and opportunities characterizing the coast and waterfront. *Smart Growth for Coastal and Waterfront Communities* is a guidance document for planners, government officials, developers, nonprofit groups, and coastal and waterfront residents that describes the coastal and waterfront smart growth elements to help communities plan for growth while protecting their natural and economic resources, maritime heritage, and traditional sense of place. The guide includes an overview of growth-related challenges and opportunities faced by coastal and waterfront communities, a description of tools and techniques for applying smart growth elements, and case studies illustrating smart growth in action. A number of the suggestions can be applied to climate change adaptation.

<http://coastalsmartgrowth.noaa.gov/>

The Coastal Barrier Resources Act (CBRA) was passed in 1982 to “minimize the loss of human life, wasteful expenditure of federal revenues, and the damage to fish, wildlife, and other natural resources associated with the coastal barriers.” It does so through a free-market approach that restricts federal expenditures that might encourage or support development, including flood insurance, within the Coastal Barrier Resources System, which consists of undeveloped coastal barriers along the Atlantic, Gulf, and Great Lakes coasts. The law does not prohibit development; it simply assigns the burdens associated with the potential hazards directly to those who choose to accept them and away from the American taxpayers. According to the U.S. Fish and Wildlife Service, which administers the program, CBRA has saved over \$1 billion and will save millions more in the future. www.fws.gov/habitatconservation/coastal_barrier.html

areas than it is to restore disturbed and degraded land and to retrofit or move existing structures. A number of the measures discussed in this guide can be used to restrict unwise development. Vulnerability is best reduced by limiting exposure. However, even if land is allowed to be developed, measures that can help reduce the impacts of climate change (e.g., easements and building design) are more feasible before development than after.

Growth and development management also includes loss reduction and shoreline management measures. These measures are discussed in more detail later in this chapter.

Zoning

Intended to create a healthy, safe, and orderly community while balancing a diversity of interests, ideally as envisioned by a comprehensive plan, zoning is one of the most commonly used methods of regulating land use. A number of the measures discussed in this guide can be implemented through zoning.

Zoning can be used to regulate parcel use, density of development, building dimensions, setbacks, impervious surfaces, type of construction (e.g., easily movable), shore protection structures, landscaping, etc. It can also be used to regulate where development can and cannot take place, making it an invaluable tool in efforts to protect natural resources and environmentally sensitive areas and guide development away from hazard-prone areas. Permissible uses and standards vary by zoning district. Types of districts include general use districts; overlay districts, where provisions in addition to those on the underlying districts apply; and special use districts, in which all uses require permits.

Floodplain zoning is an example of a zoning application that, if thoughtfully drafted, can provide multiple benefits. In addition to protecting life and property, benefits of floodplain zoning can include resource conservation, open space preservation, public access, and water-quality protection. Floodplain regulations that just meet the minimum requirements of the National Flood Insurance Program are more focused on how to build safely in the floodplain and may not provide the additional benefits.

Learning from others...Rhode Island Restricts Development on Coastal Barriers

At the state level, Rhode Island classifies its barrier islands into three categories based on the level of development present: developed, moderately developed, and undeveloped. In the 1980s, the state banned any new residential and commercial buildings on moderately and undeveloped barrier beaches, 82 percent of the state’s barrier beaches, to prevent additional development in these high hazard areas. The state’s Coastal Resources Management Program regulations also prohibit the expansion of construction of new public infrastructure such as water, gas, and sewer lines on all the state’s barrier islands. www.crmc.ri.gov/regulations.html

Learning from others...Shoreland Zoning Ordinances Required in Wisconsin

Wisconsin requires counties to administer shoreland zoning ordinances that meet the minimum standards of Wisconsin's Shoreland Management Program. These standards are designed "to further safe and healthful conditions; prevent and control water pollution; protect spawning grounds, fish and aquatic life; control building sites, placement of structures and land uses; and reserve shore cover and natural beauty." A model ordinance and *Creating an Effective Shoreland Zoning Ordinance: A Summary of Wisconsin Shoreland Zoning Ordinances* are available online. <http://dnr.wi.gov/org/water/wm/dsfm/shore/local.htm>

As the climate changes, adjustments will need to be made. Zoning regulations will need to be adaptive. Current regulations may need to be revised to accommodate for new conditions. For example, regulations that limit building height may need to be altered in light of changing elevation requirements. Your state may want to encourage local governments to review the adequacy of their zoning, make changes and additions as appropriate, and to consider climate change in future zoning decisions. As the need for new districts arises, model language can help ease the process and advance state interests.

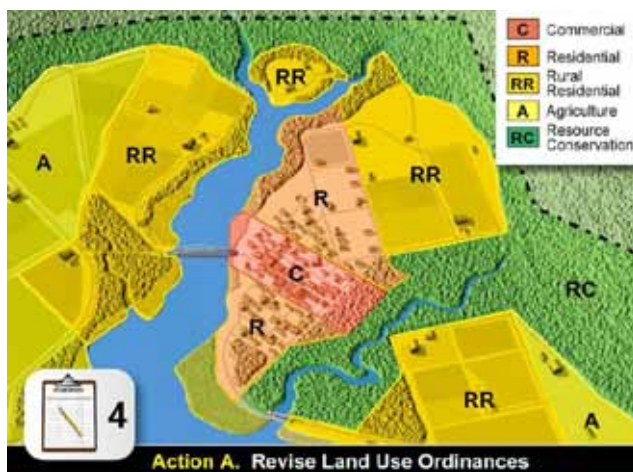
Subdivision regulations, which are typically linked to zoning regulations but often separate, are also useful tools in limiting development in hazard-prone and sensitive areas. Subdivision regulations go beyond zoning regulations, establishing requirements for lot creation and development. Regulations may limit the

subdivision of land in inappropriate areas; specify characteristics such as size, shape, orientation, and layout; set standards for infrastructure, open space, buffers, landscaping, and access/egress; and require hazard assessments and the consideration of impacts on neighboring lands.

Redevelopment Restrictions

The most likely places to be affected by the impacts of climate change are those that have been affected by related events in the past. A building lost to one storm is likely to be lost to another if built back on its prestorm footprint and without significant structural improvements. Despite the desire to return to prestorm conditions, it is important to build back right. Combining restrictions with acquisition/demolition/relocation programs provides safer options to property owners in the wake of the loss of or damage to their homes or businesses. Such restrictions will likely be more acceptable if adopted prior to a disaster rather than during recovery.

Restrictions could apply to repetitive losses or severe repetitive losses as defined by FEMA, or they could apply to any structure in a particular area (e.g., the 100- or 500-year floodplain) that is destroyed or substantially damaged. A prohibition on redevelopment of structures destroyed or substantially damaged by storms or chronic erosion would serve multiple purposes. It would protect life and property by removing them from harm's way and allow the natural and beneficial functions of the floodplain to return. However, an outright prohibition is often politically and practically difficult to implement (though less so when public



Zoning is a regulatory tool that communities can use to implement growth and development management measures.

Learning from others...Maine Restricts Reconstruction of Wave-Damaged Buildings

Maine's Coastal Sand Dune Rules set standards for reconstruction of buildings severely damaged (damage that exceeds 50 percent of a building's value) by ocean waves. Any reconstructed building must meet restrictions on building size, height, and elevation as well as setback requirements, to the extent practicable. However, projects within the coastal sand dune system may not be permitted if "the property may reasonably be expected to be eroded as a result of changes in the shoreline such that the project is likely to be severely damaged after allowing for a two-foot rise in sea level over 100 years." A building located in a V-Zone may not be reconstructed more than once. www.maine.gov/sos/cec/rules/06/chaps06.htm



Combining redevelopment restrictions with acquisition, demolition, relocation programs enables communities to "build back better" after a disaster.

health or access is at stake). Restrictions that attach provisions to reconstruction, such as siting, design, and construction requirements, are often more achievable.

At a minimum, where rebuilding is allowed, general permitting requirements for new construction should be enforced, including for those structures that were nonconforming prior to their loss. In addition, rebuilding after a loss provides an opportunity to include additional measures that will better protect the building and the land on which it resides.

Conservation Easements

A conservation easement is a legal agreement between a landowner and a land trust or government agency that can be used to restrict development in sensitive and hazard-prone areas. Unlike acquisition and open space preservation and conservation, which are also useful tools for managing where development takes place and are discussed in the Loss Reduction and Coastal and Marine Ecosystem Management categories, respectively, easements may not preclude other land uses and allow property to remain in private ownership.

Landowners can sell or donate their easement. Easements that are sold are also known as PDRs (purchase of development rights). Landowners who donate their easement may be eligible for federal or state tax breaks. Easements typically apply in perpetuity and are passed on from owner to owner. Most are placed on individual properties, but they may also be placed on subdivisions or coordinated at a regional scale (e.g., to more effectively manage a strip of shoreline or accommodate beach and wetland migration).

Conservation easements can be placed on the entire property or on select areas and can be written to prohibit all types of development or to impose restrictions and requirements in regard to size, construction, etc.⁵ Easements can also be used to ban or set standards for shore protection and restrict

⁵ Rolling easements are a type of conservation easement that may or may not be voluntary. For more information, see the Shoreline Management category.

Learning from others...Maryland Program Protects Land through Easements

Maryland's Rural Legacy Program aims to protect large, contiguous tracts of land and other strategic areas from sprawl development and to enhance natural resource, agricultural, forestry and environmental protection. It does so through the acquisition of easements and fee estates from willing landowners and the supporting activities of Rural Legacy Sponsors and local governments. Through the program, 7,200 acres of land have been protected to date in the Coastal Bays Rural Legacy Area through



the purchase of easements. www.dnr.state.md.us/land/rurallegacy/

activities that may impair natural processes. And, as appropriate, they can be used to secure public access.

Conservation easements are typically voluntary. As such, landowners have input on their restrictiveness. The voluntary and flexible nature of easements makes them more attractive to landowners but often less effective than regulatory approaches such as setbacks, zoning, etc.⁶ A conservation easement program is likely to be most effective when it has strong planning and outreach components that identify lands that would benefit from easements and inform property owners about easements and their benefits.

Compact Community Design

Compact community design⁷ allows development to occur while protecting natural resources. It is a pattern of development that aims to use land

more efficiently by grouping a mixed-use of buildings together, minimizing their collective footprint, and leaving undeveloped land in its natural state.⁸ More open space and fewer impervious surfaces means reduced runoff and flooding. It also means reduced investments in services and infrastructure design, construction, and maintenance. Compact communities are also known for their walkability, thus compact community design also helps mitigate climate change.

The high density development suggested by compact community design can allow for more opportunities to guide development away from sensitive and hazard-prone areas, but without proper planning, it can lead to increased susceptibility to hazards. Any such design must still consider the location of hazard-prone areas as well as the location and carrying capacity of evacuation routes. Compact community design is best implemented in conjunction with zoning ordinances that regulate development in hazard-prone areas and strong building codes.

⁶ An alternative to a conservation easement that still allows for development is a transfer of development rights, which is a voluntary, market-based land use mechanism that transfers development rights from sending zones, parcels designated unsafe or in need of protection, to receiving parcels, areas deemed acceptable for additional growth.

⁷ Other related concepts include compact building design, conservation design, and clustered development.

⁸ Open space preserved through compact community design should be done so in conjunction with plans for green infrastructure and wetland migration corridors, which are discussed later in this chapter.



Compact community design, when combined with protected open space, can provide a natural buffer from coastal hazards, such as storms and sea level rise.

Along heavily developed coastlines, compact community design may be difficult to implement since little undeveloped open land will be available. Nonetheless, there are times when opportunities may present themselves, including when planning economic redevelopment projects, when previous uses on large tracts of land are no longer supported (e.g., military facilities are closed down), and in the aftermath of a disaster.

Loss Reduction

- **Acquisition, Demolition, and Relocation**
- **Setbacks**
- **Building Codes**
- **Retrofitting**
- **Infrastructure Protection**
- **Shore Protection Structures**

The intent of the measures in this category is largely to reduce losses to life and property (e.g., homes, businesses, infrastructure) from the impacts of

climate change, primarily the exacerbation of existing hazards, such as storms, floods, and high winds. Some of the measures are more permanent than others, and some more controversial. Some require moving development away from hazard-prone areas, and others provide for protection where development in these areas is allowed or already in place. And, some provide benefits to the natural environment as well as the built environment, while others can negatively affect the natural resources we are also trying to bolster and preserve.

Acquisition, Demolition, and Relocation

The most effective way to reduce losses is to acquire hazard-prone properties, both land and structures, demolish or relocate structures, and restrict all future development on the land. Generally, acquisition is the best and most cost-effective hazard mitigation alternative because it permanently removes people and their homes from harm's way (FEMA 1998). In addition, it can reduce the emotional and financial costs associated with response and recovery from future storms, reduce flooding by restoring natural floodplain functions and increasing flood storage area, and support environmental and public access/recreational goals.

While acquisition serves multiple purposes, this discussion focuses on the acquisition of land and associated structures that are vulnerable to natural hazards. The open space preservation and conservation discussion later in the chapter examines the acquisition of property primarily for natural resource protection.

Acquisition programs, also known as buyout programs, typically acquire land and structures and

Learning from others...Puerto Rico Families Relocated after Hurricane Georges

Following Hurricane Georges in 1998, the Office of the Governor of Puerto Rico created the New Secure Housing Program to relocate families whose homes had been damaged or destroyed by flooding. As part of the program's Toa Baja project, and with funds provided by FEMA's Hazard Mitigation Grant Program, 223 families were relocated. Following acquisition, the City of Toa Baja demolished the remaining structures and cleaned up the site. www.fema.gov/mitigationbp/brief.do?mitsslid=748

Learning from others...Two Hundred+ Mississippi Homes Removed from Harm's Way

Following Hurricanes Georges in 1998, Gulfport, Mississippi, implemented a \$19 million acquisition project as a result of repetitive coastal flood losses in the Brickyard Bayou neighborhood. With funding from FEMA (and local match), the city acquired and demolished approximately 230 residential buildings, a number of which were repetitive loss properties.

After Hurricane Katrina, damage assessments conducted by FEMA indicated that the majority of the acquired homes would have been flooded by up to six feet of water had they not been removed. Houses just outside the project area sustained significant flood damage. FEMA concluded that the project "essentially paid for itself with losses avoided in this one event." www.fema.gov/library/viewRecord.do?id=1857

require structures to be demolished or relocated and the land to be deeded as open space in perpetuity and restored to its natural condition to allow for more appropriate uses. Factors involved in the decision to demolish or relocate may include cost-effectiveness (some structures are easier and cheaper to move than others), condition of the structures, property owner interests, availability of land for relocation, etc. Acquisition/demolition projects are typically easier to implement than acquisition/relocation projects.



A buyout program can be an effective tool for removing people and development from hazard-prone areas.

It is a good idea to plan for acquisition by identifying and prioritizing properties and structures for acquisition. Target properties may include:

- Properties that have suffered multiple losses (e.g., repetitive loss and severe repetitive loss properties)
- Properties with structures that are substantially damaged or destroyed
- Properties (with and without structures) that are in an identified hazard-prone area (e.g., floodway, sea level rise inundation area, special flood hazard area, erosion hazard area)
- Hazard-prone properties for which retrofitting (e.g., elevating) is not cost-effective
- Properties in potential wetland migration corridors

Learning from others...Alaska Village Plans for Relocation

In 1994, in response to severe erosion problems, now aggravated by climate change, the Village of Newtok, Alaska, began planning for relocation. With input and commitment from village residents, a site approximately nine miles southeast of Newtok was selected and approved by Congress as part of a land exchange with the U.S. Fish and Wildlife Service. In May 2006, the Newtok Planning Group, consisting of federal, state, village, regional, and nongovernmental partners, was formed to accelerate the process by identifying resources and establishing a relocation strategy. While significant progress has been made by the group, including characterizing the site and developing an infrastructure plan, obstacles remain. Funding, in particular, remains a major challenge. www.commerce.state.ak.us/dca/planning/Newtok_Planning_Group_Webpage.htm

Learning from others...Texas Program Offered Financial Assistance for Removal

Under the Texas Open Beaches Act, the state may petition the courts to authorize the removal of any structure on the public beach to ensure the public's access. In 2006, the Texas General Land Office offered financial assistance to homeowners for reimbursement of expenses (up to \$50,000) for relocation or demolition of structures that had become located on the public beach easement as a result of weather events or erosion. Priority was given to structures that posed a threat to public health and safety or prevented the public from accessing the beach. In Surfside, Texas, 34 properties were identified as eligible for assistance. Most of the 34 owners accepted assistance from the state or were bought out by FEMA. In September 2008, 10 of the 14 properties still engaged in litigation with the state were destroyed by Hurricane Ike. www.glo.state.tx.us/news/archive/2006/events/beachplan.html

While buyout programs are typically voluntary, where property owners are not required to sell, other tools for acquiring structures and property in hazard-prone areas include exactions and eminent domain. In all cases, a concerted planning effort, involving potential sellers where applicable, should be undertaken to help avoid piecemeal acquisition that might result in coastal blight or a checkerboard pattern of homes and vacant lots that would still require public services and may diminish property values. The actual acquisition may take place in advance of a hazard event or in the wake of one, when funding, and willingness to sell, may be easier to come by and when eminent domain may come into play.

Typically, relocation involves acquiring land and relocating structures out of harm's way rather than demolishing them. Some relocation projects, for example, where the majority of the structures are substantially damaged or destroyed, may involve demolition along with active efforts to relocate people into new homes in safer areas. Relocation may occur at different scales. It may involve moving individual structures or moving neighborhoods. In some cases, it may even involve moving entire communities.

A plan for relocation that identifies potential structures for relocation as well as sites that can accommodate them will ease the process in the context of postdisaster recovery—or in advance of sea level rise inundation. In instances where a homeowner of a habitable structure (i.e., not substantially damaged or destroyed) is interested in acquisition but not relocation, there may be other uses for the building that would justify its relocation (e.g., for

local government usage, Habitat for Humanity, domestic violence shelter, etc.).

Setbacks

While setback and buffer regulations as described in this guide are similar in effect, they differ in purpose. The discussion here focuses on the use of setbacks largely for the purpose of protecting structures from hazards by keeping the structures away from a property's most vulnerable areas. As such, they are closely tied to other regulations that manage development in hazard-prone areas, such as redevelopment, floodplain management, and shore protection structure regulations. Subdivision regulations can require lots to be deep enough to accommodate initial setbacks as well as future relocations. And, building codes can ensure structures can be moved with relative ease.

Setbacks may be regulated at the state or local level, or both, and may be based on size or use. Typically, they require structures to be sited at a distance measured inland from a specific shoreline feature, such as a high water mark, vegetation line, dune toe, or bluff crest. This distance may be a fixed number of feet (e.g., 100 feet) or may be based on the long-term annual rate of erosion (e.g., 30 times the long-term annual rate of erosion). Fixed numbers may not be adequate in highly erosive areas and may be too restrictive in others; and setbacks based on long-term average annual rates of erosion do not currently account for how erosion rates will change as sea level rises. Neither allow for catastrophic storms.

Learning from others...Setbacks Prove Effective following Hurricane Floyd

A study conducted for FEMA in North Carolina after Hurricane Floyd illustrated the benefit of setbacks. It examined the cost of flood damage to oceanfront buildings with similar structural characteristics and found flood losses to be highest for structures located directly on the open beach or setback 0–30 feet from the first line of vegetation. The average loss to these structures was twice as high as to those in the 31–100 foot setback area and more than three times the loss experienced by structures 100 feet or more from the shorefront. www.ncfloodmaps.com/pubdocs/pfloydprt.pdf

A 1990 report from the National Academies recommended minimum development standards for areas experiencing significant erosion based on local rates of erosion (NRC 1990). Specifically, it suggested that no new development should be permitted seaward of 10 times the annual rate of erosion and only readily movable structures should be permitted seaward of 60

times the annual rate of erosion (and even then, most should be landward of 30 times the annual rate of erosion).

These recommendations did not factor in sea or lake level change. New and updated setback regulations could benefit from the following:

- Consideration of a range of sea level rise scenarios and the possibility of catastrophic storms
- Establishment of policies to address the potential for future land loss
- Establishment of policies to address how setbacks and property lines may be affected by declining lake levels
- Selection of multipliers reflecting estimated physical life of structures rather than economic life (length of a 30-year mortgage)
- Examination of vertical (i.e., based on elevation) rather than horizontal setbacks



Setbacks help to protect shorefront structures by requiring them to be built outside of a property's most hazard-prone areas.

Learning from others...North Carolina Bases Erosion Setbacks on Size

In 2009, new setback rules took effect in North Carolina. The new rules, which are administered by the North Carolina Division of Coastal Management, are based solely on size and do away with an exemption in the previous rules treating single-family homes larger than 5,000 square feet differently than other similarly sized structures. The new minimum setback remains 30 times the long-term average annual erosion rate, as measured from the vegetation line, for all structures less than 5,000 square feet. The setback for ALL structures between 5,000 and 9,999 square feet is 60 times the erosion rate. For structures 10,000 square feet and larger, the setback increases incrementally with structure size, reaching a maximum setback of 90 times the erosion rate for structures 100,000 square feet and larger. <http://dcm2.ehnr.state.nc.us/News/2009%20releases/setbacks.html>; <http://dcm2.ehnr.state.nc.us/setbacks.htm>

- Disclosure of setback-related threats and what they mean for future property owners (e.g., redevelopment restrictions)
- Regularly scheduled evaluations and updates of requirements and allowance for emergency action if warranted

Building Codes

When a structure is going to be built in a hazard-prone area, it should be done so in a manner that considers the potential impacts of that hazard (e.g., flood, wind) and how best they can be avoided. Building codes that regulate design, construction, and landscaping of new structures can improve the ability of structures in hazard-prone areas to withstand hazard events and can also reduce the effects of high temperatures. They also indirectly protect neighboring structures and natural resources. Building codes that consider future conditions and the potential for climate change and are regularly reviewed and updated based on new information will provide even greater protection.

According to the Institute for Business and Home Safety (IBHS 2005):

A building code is the minimum acceptable standard used to regulate the design, construction, and maintenance of

buildings for the purpose of protecting the health, safety, and general welfare of the building's users. The purpose of building codes is to build safe buildings, thereby reducing deaths, injuries and property damage. This preserves the built environment, both residential and commercial, reduces public and private disaster aid, and maintains employment in businesses and institutions that otherwise might be forced to close following a catastrophe.

The level of protection provided by building codes depends on the provisions of the codes as adopted and enforced by state and local governments. State-imposed building codes can help ensure a minimum level of protection. They may apply statewide, with more stringent requirements in hazard-prone areas, or they may apply only in areas susceptible to hazards such as hurricanes. To provide even more protection and address specific needs, states can allow local governments to supplement the state's minimum requirements with additional provisions.

Many states and local building codes are based on model codes founded on established scientific and engineering principles. These model building codes can be modified to better address specific needs and hazards. The International Code Council maintains the most up-to-date and widely adopted model building codes, which incorporate multihazard disaster-resistant

The Institute for Business and Home Safety's (IBHS) Fortified for Safer Living single-family residential construction program is a package of "code-plus" upgrades that greatly increase a new home's resistance to hazards such as hurricanes, floods, and more. Specifically, the program's requirements strengthen a home's outer envelope (roof and wall systems, doors, glazed openings, and the foundation).

Prior to Hurricane Ike, IBHS had designated 13 homes in Gilchrest, Texas, as "Fortified." In general, the Fortified homes performed better than others in the area, most of which were destroyed. Following the storm, all but 3 of the 13 Fortified homes survived, and the 3 that



failed did so because they were struck by "un-Fortified" neighboring houses that had been washed off their foundations. <http://disastersafety.org/text.asp?id=fortified>

construction standards. These codes include the International Residential Code (single- and two-family structures) and the International Building Code (commercial and multifamily structures). Two consensus standards from the American Society of Civil Engineers (ASCE) are referenced in the International Codes and are also useful resources: ASCE 24-05 Flood Resistant Design and Construction and ASCE 7-05 Minimum Design Loads for Buildings and Other Structures.

“Post-disaster assessments have proven that, in most cases, the use and enforcement of stricter building codes produce buildings that are more resistant to disasters” (FEMA 2000). However, the enforcement of these codes is critical to their success. Local building departments are typically responsible for ensuring builders comply with the codes so structures provide the base-level of protection required by the state or local government. Enforcement activities include permit approval, design and plan review, and site visits. A successful building code program will include regular continual training of enforcement agents as well as education of the building community and property owners.

Flood

In Special Flood Hazard Areas (100-year floodplain), the minimum requirements of the National Flood Insurance Program (NFIP) include requiring permits for new and substantially improved development, elevating the lowest floor of all buildings to or above the Base Flood Elevation (BFE) (alternatively, nonresidential buildings outside of the V-Zone can be dry-floodproofed to the BFE); anchoring structures to prevent flotation, collapse, or lateral movement;



Elevating existing structures can help protect them from storm surge and other flood events.

restricting development in the regulatory floodway; using flood-resistant construction materials and methods that minimize flood damage; and treating substantially improved structures like new buildings that must meet the minimum NFIP standards. Additional rules apply to the construction of the space below the BFE and limit its use to parking, building access, and storage. Buildings constructed in the V-Zone, which is subject to coastal high hazard flooding where waves during the base flood are at least three feet, must also be elevated on pilings or columns (i.e., fill is prohibited), and the bottom of the lowest horizontal structural member must be elevated to or above the BFE.

Since the Digital Flood Insurance Rate Maps that identify where these requirements apply may be out of date, and because they do not reflect future conditions (e.g., sea level rise, growth, etc.), codes

Learning from others...Massachusetts Protects Safety and Natural Resources through Building Codes

The Massachusetts Departments of Environmental Protection and Public Safety worked together to improve public safety and protect natural resource areas through revisions to the Massachusetts Basic Building Code. The revised code establishes special administrative, design, and construction requirements for new and existing buildings and structures located in A-Zones, V-Zones, and coastal wetland resource areas with coastal dunes that provide protection from storms and floods. Changes to the code include requiring two feet of freeboard in the V-Zone and design and construction requirements in coastal dunes that eliminate conflicts between the Wetlands Protection Act regulations and the previous code. www.mass.gov/dep/water/resources/bcbro.htm

that only mimic the NFIP's minimum requirements for construction in the currently mapped flood hazard areas may not be enough to protect people and property from future or present day storms.⁹ To provide a higher level of protection and better prepare coastal communities for climate change, state and local governments are encouraged to adopt codes that consider sea level rise and include higher regulatory standards. Examples include:

- Adding freeboard (an additional height requirement above the BFE)^{10,11}
- Applying V-Zone requirements to the Coastal A-Zone (area landward of V-Zone that is still subject to storm surge and damaging waves (1.5-3 feet)) or the entire Special Flood Hazard Area
- Applying codes outside of the Special Flood Hazard Area (e.g., to a point landward of the limit of the Special Flood Hazard Area where the ground elevation is equal to that of the adjacent A-Zone's BFE plus freeboard)
- Applying codes to all structures undergoing improvements and repairs

High Winds

Buildings can also be constructed to withstand the direct and indirect impacts of high winds, which are associated with storm intensity. Where high winds are

a concern, building codes typically require structures to meet certain performance standards. Roofs, exterior walls, doors (including garage doors), windows, and skylights should be constructed/installed to maintain the integrity of the building envelope and reduce the potential for damage and collapse from wind and wind-borne debris. Increased structural wind-resistance can be achieved by adhering to special design techniques, using stronger, more wind-resistant materials and connections, such as hurricane clips and the bracing of gabled roofs; and protecting openings with impact-resistant materials or shutters.



Hurricane clips help anchor roofs to their main structure to prevent detachment during severe winds.

Learning from others...Florida Building Code Proves Successful

Following Hurricane Andrew, coastal areas of Florida began to use and enforce high wind design provisions for residential housing. When the hurricane season of 2004 struck, the Florida Building Code, which contains the wind-related provisions, had only been in force since 2002, but Charlotte County had been observing them since 1996. A study conducted by the Institute for Business and Home Safety found the frequency and severity of claims in Charlotte County were reduced (60 and 42 percent, respectively) for homes built after the adoption of the modern codes. It also found that the new requirements allowed homeowners to return to their homes more quickly, reducing the disruption to their lives. www.disastersafety.org/text.asp?id=hurricane_charley; www.dca.state.fl.us/fbc/commission/FBC_0606/Report_SurveyProject_Gurley_33006.pdf

⁹ One of the objectives of FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) initiative is to provide updated flood hazard data for 100 percent of the nation's populated coastal areas (based on current conditions).

¹⁰ The 2009 edition of the International Residential Code requires one foot of freeboard in the V-Zone and Coastal A-Zone (if delineated).

¹¹ In a 2006 report, the American Institutes for Research found that adding freeboard during construction is cost-effective and that reduced flood insurance premiums pay for the cost of freeboard in one to three years in a V-Zone house and in six years in an A-Zone house (Jones et al. 2006).

Retrofitting

Although recent improvements in construction practices and regulations have made new structures less hazard-prone, many existing structures remain vulnerable and will likely be more so as climate changes. And, as these changes are realized and codes evolve to keep up with them, even structures built to or above current codes are likely to become threatened.

Existing structures can be protected from hazards through retrofitting.¹² While retrofitting may not bring a structure “up to code” (unless required during a substantial improvement), it does help existing structures better withstand hazard events and may reduce insurance premiums. Retrofitting techniques exist for a number of hazards, including floods and high winds, and many of them are similar to those required in the construction of new structures.

Examples include:

- Elevating or floodproofing flood-prone structures
- Reinforcing and bracing roofs and garage doors
- Anchoring homes to their foundations
- Installing shutters on windows and other glass openings
- Removing impervious surfaces
- Replacing exterior building components with stronger, more hazard-resistant alternatives



Hurricane shutters can be added to existing structures to reduce the damage caused by wind and water.

Since retrofitting is typically not required, homeowners may not be aware of what they can do to protect their homes and themselves. Regular improvement and maintenance projects provide good opportunities for homeowners to strengthen their homes as well as improve the structure and increase its value. An outreach program can help inform the public about how to incorporate retrofitting into these projects, using the building codes as a guide—with the goal of retrofitting existing structures up to code.

Infrastructure Protection

As described in Chapter 4, infrastructure includes the basic facilities, services, networks, and systems needed for the functioning of a community that if lost or

Learning from others...Florida Program Funded Home Inspections and Retrofitting

In 2006, Florida state lawmakers appropriated funds to create the My Safe Florida Home program to help Floridians identify and make improvements to strengthen their homes against hurricanes through free wind inspections and grant funds. Between 2006 and 2009, when the program expired, the program provided inspections to more than 400,000 homeowners and retrofitted nearly 33,000 homes. An analysis of the program found that for every grant dollar provided, hurricane losses are expected to be reduced by as much as \$1.50. This equates to a drop of around \$140 million in total losses for the retrofitted homes. www.mysafefloridahome.com/; www.rms.com/Publications/RMS_MSFH_Report_May_2009.pdf

¹² Retrofitting programs that target mitigating climate change (e.g., energy efficiency/weatherization) can be expanded to also consider adaptation.

Learning from others...Massachusetts Considers Sea Level Rise in Infrastructure Siting

In the 1990s, the Massachusetts Water Resources Agency designed and built Boston's Deer Island wastewater treatment plant in consideration of sea level rise. Specifically, the plant was built 1.9 feet higher than required at the time to accommodate the amount of sea level rise projected to occur over the expected lifetime of the facility (~50 years). And, in a nod to climate change mitigation, the plant gets approximately one-quarter of its power needs



through on-site renewable energy sources.
www.mwra.com/03sewer/html/sewditp.htm

damaged could cause significant disruption (physically, functionally, and economically). Since infrastructure is critical to the functioning of a healthy community, it must be sited, designed, constructed, and maintained so the provision of services continues uninterrupted. Infrastructure protection entails fortification against the impacts of climate change and, in some cases, shoring up of capacity.

While many of the ideas discussed under building codes and retrofitting also apply to infrastructure, the value of infrastructure, both socially and economically, suggests the need for stricter requirements for new infrastructure construction (e.g., plan for the 500-year event, rather than the 100-year event) and a more concerted effort to retrofit existing facilities and systems. Roads, bridges, water and power utilities, stormwater systems, and other infrastructure that are already worn or overcapacity are likely to be most vulnerable to climate change.¹³ Addressing and correcting existing deficiencies needs to be a priority and should be handled concurrently with adjustments necessary to meet projected future conditions and needs. Similarly, adaptation should be considered and incorporated into regular maintenance and upgrade activities.

In general, designing for the future is less expensive than retrofitting, rebuilding, or moving infrastructure. When planning for new infrastructure, siting should be the first consideration. Facilities and system components should not be constructed in hazard-

prone (current or projected) or valuable natural resource areas, where possible, or in areas that would encourage undesirable growth. When avoiding these areas is not possible, efforts should be made to design and construct facilities and system components to the highest level of protection feasible in a manner that allows for flexibility and future modifications.

Shore Protection Structures

Shore protection structures protect existing development allowing it to stay in place. However, they often damage or destroy other valuable coastal resources (economic, ecological, recreational, and aesthetic), require substantial expenditure (initial design and construction and maintenance), and create a false sense of security. They may also encourage additional development. Shore protection structures provide an immediate fix that may not be sustainable. Nevertheless, it is understood that in some cases, for the purposes of protecting existing (not future) development, there may be no other acceptable or practical options. Alternatives to shore protection structures are discussed in the Shoreline Management category that follows.

Shore protection structures are designed to reduce flooding/inundation and erosion of land and protect structures and infrastructure. Despite the name, the intent is to protect the built environment and the land it sits on rather than the shore itself.

¹³ Onsite sewage disposal systems will also be vulnerable as sea levels rise and their separation from groundwater becomes inadequate.

Most shore protection structures are built parallel or perpendicular to the shoreline:

- **Shore parallel** (seawalls, revetments, bulkheads, breakwaters, rip rap)—These structures help hold the land back from the sea and the sea back from the land and/or dissipate wave energy.
- **Shore perpendicular** (groins, jetties)—These structures interrupt sediment transport and trap sediment to build/rebuild beaches and/or stabilize navigational channels and inlets.

While they may be successful at meeting the level of protection they are designed for, all of these structures disrupt the natural flow of sediment, which may result in the loss of the natural shoreline, coastal habitat, and the associated ecosystem services and amenities, either directly in front of the structure or in adjacent areas. With the exception of breakwaters, which are built offshore, shore parallel structures also inhibit the ability of wetlands to migrate inland as sea level rises and may interfere with public access. In most cases, protection in one area will lead to losses in another (or the demand for more shore protection structures), both to the built and the natural environment.

Large flood control systems like dikes (levees) and movable gates and barriers (e.g., Maeslantkering in the Netherlands and the Thames River Barrier in the United Kingdom) are also being considered as viable defenses against sea level rise. These structures require significant investment and come with their own set of concerns and adverse impacts.

When there are no suitable alternatives, future shore protection structures should be designed



Offshore breakwaters can keep sand onshore, reducing the rate of shoreline erosion.

and constructed to minimize adverse impacts at the site of the structure as well as to the broader coastal system, based on future climate change projections, and so they are flexible enough to allow for modifications. Existing structures will likely require upgrading, replacement, or removal. All structures will require monitoring and maintenance to ensure they continue to function as planned.

Shoreline Management

- **Regulation/Removal of Shore Protection Structures**
- **Rolling Easements**
- **Living Shorelines**
- **Beach Nourishment**
- **Dune Management**
- **Sediment Management**

Shoreline management activities aim to preserve the natural shoreline, which in turn provides protection to property, supports coastal habitat and public access, and enhances aesthetic and

Learning from others...California Ties Impact Mitigation to Shoreline Armoring Projects

The California Coastal Act allows for shore protection structures if existing development is in jeopardy of being lost to erosion and no other alternative solution is possible. The California Coastal Commission, which administers the act, requires the negative impacts (i.e., loss of public access) be mitigated when shore protection structures are allowed. While the exact mitigation requirements are site-specific, the commission commonly requires the property owner to dedicate a public access easement seaward of the approved structure to compensate for any loss of the public beach.

http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_mitigation.html

Learning from others...Maine Manages Beaches through Scoring System

The Maine Geological Survey, with support from the Maine Coastal Program, developed a beach scoring system to help manage the state's sandy shoreline along Saco Bay. The study enabled managers to identify beaches where erosion control efforts are needed, prioritize sites, and determine the appropriate action (e.g., beach renourishment, dune restoration, or a combination). Inputs to the scoring system included historical shoreline change data and other physical beach characteristics. <http://maine.gov/doc/nr/mc/mgs/explore/marine/virtual/scoring/slides.htm>

recreational amenities. The measures in this category are mutually reinforcing and could be integrated into a comprehensive shoreline management strategy that identifies needs and explores, combines, and prioritizes actions. While these measures are preferable to shore protection structures, they are not as effective at protecting buildings and infrastructure along the coast as some of the measures described in the Loss Reduction category above, since natural shorelines are more vulnerable to the forces of nature.

Regulation and Removal of Shore Protection Structures

As previously discussed, the use of shore protection structures is only supported as an action of last resort to protect valuable real estate and infrastructure. They often do more harm to the natural shoreline than good. To protect the natural shoreline and the benefits it provides, states can use regulations to limit shoreline hardening as well as to promote alternative forms of protection and to encourage development that reduces the needs for shore protection structures.

Regulations can specify allowable uses, locations, and structures, prohibit new structures, and/or

require the removal of existing structures given specified circumstances (e.g., no longer maintained, substantially damaged, need to return land to natural functions, etc.). The size, design, and placement of shoreline stabilization structures can also be regulated to minimize environmental and public access impacts. Regulations that severely restrict the use of shore protection structures or require their removal should also require disclosure of such restrictions in real estate transactions.



Removing or breaching manmade levees can be an effective way to restore natural processes.

Learning from others...North Carolina Prohibits Oceanfront Erosion Control Structures

In North Carolina, permanent erosion control structures are prohibited on the oceanfront since they "may cause significant adverse impacts on the value and enjoyment of adjacent properties or public access to and use of the ocean beach." Included in this ban are bulkheads, seawalls, revetments, jetties, groins, and breakwaters. Such structures may be permitted only under certain circumstances, such as to protect an erosion-threatened bridge that provides the only existing road access to a substantial population on a barrier island or to maintain an existing commercial navigation channel of regional significance. In such cases, the erosion-control structure must not adversely affect adjacent private properties, coastal resources, or public use of the beach. <http://dcm2.ehnr.state.nc.us/Rules/Text/t15a-07h.0300.pdf>

Learning from others...Rhode Island Prohibits Structural Shoreline Protection along Barriers and Oceanfront

To protect the sediment source of its beaches and preserve natural sand transport, the Rhode Island Coastal Resources Management Council has banned the installation of revetments, bulkheads, seawalls, groins, breakwaters, jetties, and other erosion control structures along all barriers and ocean facing coastline. Structures predating the regulations are allowed to remain, but any structure that is more than 50 percent damaged by a storm or other process must comply with current programmatic requirements and may not be rebuilt. www.crmc.ri.gov/regulations.html

Rolling Easements

Rolling easements are shoreline easements designed to promote the natural migration of shorelines. Typically, rolling easements prohibit shore protection structures, which interfere with natural shoreline processes and movement, but allow other types of development and activities. As the sea rises, the easement, which is usually delineated by a physical characteristic such as the line of vegetation, moves or “rolls” landward, sediment transport and wetland migration occur as nature intended, and public access to the shore is preserved. Since rolling easements reflect changing conditions, they are likely to be a more effective response to the impacts of climate change than traditional zoning, which is based on conditions at the time of the rule making.

Rolling easements, which may be donated, purchased, or regulated, place no restrictions on development. They allow landowners to build anywhere on their

property with the understanding that they will not be able to hold back the sea by armoring their shoreline or deny public access. Once the shoreline has eroded to a point where a privately owned structure is on public land, a threat to human health and safety, and/or threatened by flooding and erosion, that structure should be relocated. The possible need for relocation may encourage the building of smaller, more mobile structures that will likely cause less environmental disruption.

Living Shorelines

In low- to medium-energy coastal and estuarine environments and tidally influenced creeks, streams, and rivers, living shorelines can be effective alternatives to shore protection structures in efforts to restore, protect, and enhance the natural shoreline and its environment. Living shorelines use stabilization techniques that rely on vegetative plantings, other organic materials (e.g.,

Learning from others...Texas Protects Public Beach through Rolling Easements

The Texas Open Beaches Act (OBA) aims to protect access to the public beach, which is the area between the mean low tide line and the line of vegetation (including privately owned land) along the Gulf of Mexico. It does so through a rolling public beach easement. As the line of vegetation moves inland due to erosion, so does the public beach. The commissioner of the General Land Office may call for the removal of buildings that end up on the public beach if they interfere with public access or threaten public safety, health, or welfare. The OBA



also prohibits structures that would block public access, effectively disallowing shore protection structures. www.glo.state.tx.us/coastal/beachdune.html

Learning from others...Virginia Promotes Living Shorelines

The Virginia Coastal Zone Management Program is working with partners to promote living shorelines. The state's Living Shoreline Strategy, funded through Section 309 of the Coastal Zone Management Act, includes a Living Shoreline Summit (in conjunction with the Maryland Coastal Zone Management Program), revisions to the state's wetlands guidelines, research to further document the habitat value and refine the design of living shorelines, a protocol for determining the feasibility of living shorelines on a reach (shoreline segment) basis, additional shoreline situation reports and shoreline evolution studies to better inform local shoreline management decisions, a shoreline planning guidance document to help localities proactively address shoreline management issues and meet comprehensive planning requirements, a brochure and web site for landowners, and a design manual and training program for contractors.

www.deq.virginia.gov/coastal/livingshore.html

biologs, matting), and sand fill or a hybrid approach combining vegetative planting with low rock sills or footers, living breakwaters (e.g., oysters), or other shore protection structures designed to keep sediment in place or reduce wave energy. The techniques and materials used will depend on site-specific needs and characteristics. There are a number of benefits to living shorelines. Specifically, they:

- Maintain natural shoreline dynamics and sand movement
- Trap sand to rebuild eroded shorelines or maintain the current shoreline
- Provide important shoreline habitat
- Reduce wave energy and coastal erosion
- Absorb storm surge and flood waters

- Filter nutrients and pollutants from the water
- Maintain beach and intertidal areas that offer public access
- Are aesthetically pleasing
- Allow for landward migration as sea levels rise
- Absorb atmospheric carbon dioxide
- Are less costly than shore protection structures

In some states, the regulatory framework makes it more difficult to implement living shorelines projects than the traditional shore protection structures previously discussed. Regulations should be reviewed and revised to encourage the use of living shorelines where appropriate.

Beach Nourishment

Beach nourishment is the process of placing sand on an eroding beach, typically making it higher and wider, to provide a buffer against wave action and flooding and/or to improve the recreational value of the beach. In the United States, beach nourishment is preferred over shore protection structures because it preserves the aesthetic and recreational values of protected beaches by mimicking the characteristics of natural beach and dune systems. In addition to protecting the nourished shoreline and landward property and infrastructure, beach nourishment generally benefits, rather than negatively impacts, adjacent



Hybrid shoreline stabilization structures that employ marsh plantings and low rock sills (to protect the vegetation) can help stabilize eroding banks.

Learning from others...New Jersey Protects Shorefront with Beach Nourishment

In New Jersey, beach nourishment is the preferred approach to dealing with beach erosion and shorefront protection. The New Jersey Department of Environmental Protection's Bureau of Coastal Engineering, in cooperation with the U.S. Army Corps of Engineers, provides beach nourishment and renourishment projects for the purpose of restoring New Jersey's beaches. State funding comes from the Shore Protection Fund, which ensures the availability of funds needed to continue the beach nourishment program and protect New Jersey's coastal communities. www.nj.gov/dep/shoreprotection/nourishment.htm

beaches (e.g., by adding sediment to the system) and may also create, restore, and protect habitat.

Beach nourishment projects require large volumes of sediment compatible with the natural beach. These sediments may come from onshore or offshore sources and may be "beneficial use" sediments from dredging projects. Some projects may include shore protection structures to help retain/protect the added sand (e.g., groins and breakwaters).

Since nourished beaches will be susceptible to the same natural forces as the beaches before them, they will require periodic renourishment. Renourishment intervals typically range from 2 to 10 years but will vary by project, shoreline characteristics, number and intensity of storms, and sea level rise (NRC 1995).

Despite the benefits of beach nourishment, there are some drawbacks to consider. Beach nourishment projects:

- Are very expensive and require regular maintenance at additional costs
- Require large amounts of suitable sediment that may be difficult to come by
- Are difficult to evaluate in terms of benefits and costs due to the uncertainty of project lifetime
- Create a false sense of security that may encourage unwise development
- Can have serious long- and short-term environmental effects at the project and source sites and in nearby areas of the water column and the water bottom



By adding sand to an eroding beach, beach nourishment can protect shorefronts against wave action and flooding.

Dune Management

Sand dunes are important shoreline features and are an environmentally friendly form of shore protection. In addition to serving as buffers against erosion and flooding, which they do by trapping windblown sand, storing excess beach sand, and protecting inland areas against wave runup and overwash, they also provide habitat for wildlife. Dunes, however, are not permanent. So, to retain, enhance, or facilitate the provision of their valuable services, they may be restored or created in conjunction with a beach nourishment project as discussed above or may be managed as part of a separate effort. Since dunes and beaches are interdependent, dune management should be incorporated into a strategy that considers the broader coastal system.

Dune restoration is relatively inexpensive and entails the use of dune grass and other types of native

Learning from others...Connecticut Program Supports Dune Restoration

Connecticut’s Department of Environmental Protection provides technical support to towns and citizens for dune restoration and has restored a number of dune areas on state beaches. Planting American beach grass to replace vegetation that has been lost is the primary method used to restore dunes. www.ct.gov/dep/cwp/view.asp?A=2705&Q=323538



Sand dunes serve as buffers against erosion and flooding and provide habitat for wildlife. Vegetation and sand fences can help stabilize dunes.

vegetation and sand fences to capture shifting and blowing sands and stabilize dunes. The use of vegetation and sand fences to build and stabilize dunes is not a quick fix, will only be effective under certain conditions, and may not be effective as a way of encouraging the growth of new dunes where dunes did not exist in the past.

A number of other measures discussed in this guide can be used to manage and protect dunes, vegetation, and associated habitat, including laws and regulations (e.g., zoning, buffers, setbacks, etc.) that restrict development and other harmful activities (e.g., sand mining, foot and vehicular traffic). To continue to allow for public access, dune walkovers or fenced pedestrian paths could be considered in planning and project design.

Sediment Management

Sediment management is an important aspect of shoreline management and supports some of the other measures discussed in this category and the next. It requires an understanding of sedimentation processes in the management area, recognizes the importance of sand and other sediments in protecting, maintaining, and restoring the shoreline and its associated waters and ecosystems, and incorporates activities affecting the erosion, transport, deposition, and removal of sediment. These activities include dredging and placing sediment, building shore protection structures and other structures that trap or divert sediment, and mining.

Learning from others...Michigan Program Protects Unique and Fragile Dunes

Michigan’s Sand Dunes Protection and Management Program, administered by the state’s Department of Environmental Quality, aims to protect the state’s sand dunes by minimizing the impacts of development within designated critical dune areas along the shorelines of Lake Michigan and Superior. It does so through a permit program that regulates earthmoving, vegetation removal, and construction activities within legally defined critical dune areas. Among other things, the standards require new uses to be set back behind the crest of a critical dune, limit the amount of grading and vegetation removal allowed, and prohibit construction on steep slopes. www.michigan.gov/deq/0,1607,7-135-3311_4114---,00.html

Learning from others...California Regionalizes Sediment Management

The California Coastal Sediment Management Master Plan is an ongoing, collaborative effort by the Coastal Sediment Management Workgroup, a partnership of federal and state agencies, to evaluate California's coastal sediment management needs and promote regional, systemwide solutions. The intent of the plan is "the conservation, restoration, and preservation of the valuable sediment resources along the coast of California to reduce shoreline erosion and coastal storm damages, provide for environmental restoration and protection, increase natural sediment supply to the coast, restore and preserve beaches, improve water quality along coastal beaches, and optimize the beneficial use of material dredged from ports, harbors, and other opportunistic sediment sources." It is implemented through region-specific coastal regional sediment management plans, which are prepared by regional entities with oversight and assistance from the workgroup. <http://dbw.ca.gov/csmw/default.aspx>

Sediment management is best accomplished through a regional effort involving all levels of government and other stakeholders (coastal as well as inland) who share an interest in a sediment system (i.e., a system within which sediment exchange occurs naturally). Regional sediment management "includes the entire environment, from the watershed to the sea; accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, and oceans; and protects and enhances the nation's natural resources while balancing national security and economic needs" (Corps n.d.).

Any regional sediment management effort should include an emphasis on the beneficial use of dredged material. A sediment management program that recognizes sediment as a valuable resource and links needs with appropriate opportunities will be the most effective at reducing economic and environmental losses associated with climate change. Beneficial use of dredged material involves using sediment



Sediment dredged from navigation and diversion channels can be used to restore and create wetlands.

dredged from waterways for a productive purpose, such as beach nourishment, habitat restoration and development, public access facilities, and shore protection structures (e.g., levees and dikes), among other things.

Learning from others...Louisiana Regulates Beneficial Use of Dredged Material

In 2009, the Louisiana Department of Natural Resources Office of Coastal Management enacted new rules on the beneficial use of material dredged in projects requiring a coastal use permit. The new rules include four options: 1) implementing a project that makes beneficial use of the dredged material, 2) providing for the use of the dredged material on an approved coastal restoration project, 3) using dredged material at another location that creates the same amount of beneficial use, or 4) making a voluntary contribution to the Coastal Resources Trust Fund (based on the amount of material dredged). <http://dnr.louisiana.gov/crm/coastmgt/rules/2009-10.pdf>

The EPA's Climate Ready Estuaries program works with National Estuary Programs to help assess climate change vulnerabilities, engage and educate stakeholders, develop and implement adaptation strategies, and share lessons learned with other coastal managers. The Climate Ready Estuaries web site offers information on climate change impacts to different estuary regions, access to tools and resources to monitor changes, and information to help managers develop adaptation plans for estuaries and coastal communities. The program's 2009 progress report describes accomplishments to date, including activities being managed by partners, lessons learned in the adaptation planning process, challenges encountered, and next steps. www.epa.gov/cre/

Coastal and Marine Ecosystem Management

- [Ecological Buffer Zones](#)
- [Open Space Preservation and Conservation](#)
- [Ecosystem Protection and Maintenance](#)
- [Ecosystem Restoration, Creation, and Enhancement](#)
- [Aquatic Invasive Species Management](#)

Coastal and marine ecosystem management encompasses a number of measures to conserve (or preserve) and restore ecosystems. While many of the measures discussed in other categories can also play a role in ecosystem management (and vice versa), the measures featured in this category are primarily focused on managing for ecological structure and function and protection of biological diversity.¹⁴ Generally, they include activities that create and accommodate new natural areas, refocus management of existing ecosystems, and restore degraded ecosystems.

It is unlikely that ecosystems can be effectively managed to address climate change through a single measure. Traditional activities, adjusted to consider climate change, along with best management practices that reduce existing stressors and a plan that identifies, integrates, and prioritizes related activities, will be

pivotal in helping coastal and marine ecosystems adapt to the changing climate. Nevertheless, because of the remaining gaps in our knowledge about ecosystem processes and how they may react to climate change, it is important to include monitoring and remain flexible in any ecosystem management program.

Ecological Buffer Zones

Ecological buffer zones (buffers) are similar to setbacks (and may be included within setbacks), but are typically designed to protect the natural, rather than the built, environment. By protecting natural resources, buffers protect the natural and beneficial functions those resources provide. Protective services include providing habitat and connectivity; minimizing erosion and flooding by stabilizing soil, providing flood storage, and reducing flood velocities; and improving water quality through filtration of harmful sediment, pollutants, and nutrients.

Specifically, buffers are land use regulations designed to reduce the impacts of land uses (e.g., development) on natural resources by providing a transition zone between a resource and human activities. Typically, buffers are maintained in their natural vegetative state and activities such as vegetation removal, soil

Ecosystem-based management is an innovative approach to addressing the many challenges faced by coastal and marine ecosystems. It considers the whole ecosystem, regardless of political boundaries, including humans and the environment, rather than managing one issue or resource in isolation and is concerned with the sustainability of both human and ecological systems. www.ebmtools.org/

¹⁴ Among other things, healthy ecosystems such as wetlands also protect upland areas from storms and flooding, filter pollutants, and serve to mitigate climate change by enhancing carbon sequestration and reducing emissions that result from degradation.

Learning from others...Rhode Island Uses Buffers to Protect Ecological Systems

The Rhode Island Coastal Resources Management Program defines its coastal buffer zone as “a land area adjacent to a shoreline (coastal) feature that is, or will be, vegetated with native shoreline species and which acts as a natural transition zone between the coast and adjacent upland development.” State regulations generally require buffers for new residential, commercial, and industrial development. The vegetation in the buffer must be retained in a natural, undisturbed condition or managed in accordance with a buffer management plan. For residential developments, buffer widths range from 15 to 200 feet and depend on the designated water use category and lot size. Commercial and industrial development buffer requirements are determined on a case-by-case basis. Minimum vegetated buffers of 200 feet are required on all properties adjacent to designated critical habitat areas. In some more developed areas, such as the Metro Bay region, Rhode Island employs an Urban Coastal Greenway that allows for a narrower buffer in return for providing public access and more stormwater control on the site. www.crmc.ri.gov/regulations.html

disturbance, and construction are restricted or prohibited. As climate changes, buffers will also be able to support inland wetland migration as well as carbon sequestration.

The effectiveness of any buffer will depend on several factors, including size, elevation, vegetation, slope, soil, permitted activities, adjacent land uses, stormwater flow, and erosion rate. In addition, effectiveness will also be dependent on property owner compliance and the monitoring and enforcement of buffer regulations. If drafting new or revised buffer regulations, consider these characteristics as well as how buffers, and the natural resources they protect, might be affected by climate change in the next century.



Maintaining natural buffers along shorelines can help protect coastal and marine resources from polluted runoff and homes from erosion. (Note where buffer ends and mowed grass begins.)

Open Space Preservation and Conservation

There are a number of benefits to preserving open space. Open spaces can improve the environment and a community’s quality of life and contribute to economic well-being. Specifically, open spaces:

- Protect and provide habitat
- Reduce flooding and stormwater runoff
- Support water quality maintenance
- Promote groundwater recharge
- Provide opportunities for recreation
- Enhance natural and cultural resources
- Sequester carbon
- Allow for evaporative cooling

Open space preservation and conservation can be accomplished through the management of lands dedicated as open space through a number of the measures previously discussed, such as zoning, redevelopment restrictions, acquisition, easements, setbacks, and buffers. While there are costs associated with the management of open space, the public expenditures may be lower than if the land was developed and the provision of full services was required. Management costs could be defrayed by transferring the title to a nonprofit conservation organization.

Open space management plans can be developed to guide the acquisition and use of open space in a manner that fulfills multiple community objectives

Learning from others...New Jersey Land Conservation Targets Hazard-Prone and Protective Lands

New Jersey's Coastal Blue Acres Program, part of the Department of Environmental Protection's Green Acres Program, is designed to provide grants and loans to municipalities or counties to acquire important coastal lands for recreational and conservation purposes. To be eligible for acquisition through the Blue Acres Program, the land must have been severely damaged by storms, threatened by future storms, or serve as a buffer to protect other land from storm damage. The 1995 bond act that created the program appropriated funds for the purchase of undeveloped land in high-risk erosion areas or property that serves important buffering roles (75 percent grant/25 percent loan) and land severely damaged by storms (50 percent grant/50 percent loan). www.state.nj.us/dep/greenacres/



Open spaces can improve the environment and a community's quality of life and contribute to economic well-being.

(e.g., trails, athletic fields, campgrounds, community gardens, wildlife refuges, environmental education centers, etc.). Any such plan should consider the impacts and consequences of climate change, sea level rise and flooding in particular, to ensure that investments are wisely made (land purchase as

well as use and amenity placement). Open space management should also consider the key role of open space in green infrastructure and wetland migration programs (see more on these measures in the pages that follow).

Ecosystem Protection and Maintenance

Ecosystems are difficult and costly to repair and replace. It is more desirable to maintain and protect resilient systems. This largely involves reducing the impacts of nonclimate stressors and may include:

- Restricting activities (through regulations if necessary)
- Restoring natural processes, such as water flow and sedimentation (e.g., by removing shore protection structures or upstream dams)
- Encouraging stricter nutrient management
- Reducing land-based pollution
- Modifying harvest or use rates

Learning from others...Florida Considers Climate Change in Land Conservation

Florida Forever, Florida's state land acquisition and conservation program, provides a blueprint for conserving the state's natural and cultural heritage. Administered by Florida Department of Environmental Protection's Division of State Lands, program goals include environmental restoration, water resource development and supply, increased public access, public lands management and maintenance, and increased protection of land through conservation easements. Project prioritization includes consideration of climate-change lands, which are defined as lands "where acquisition or other conservation measures will address the challenges of global climate change, such as through protection, restoration, mitigation, and strengthening of Florida's land, water, and coastal resources." These lands sequester carbon, provide habitat, protect coastal lands or barrier islands, and otherwise mitigate and help adapt to the effects of sea level rise. www.dep.state.fl.us/lands/fl_forever.htm

Marine protected areas (MPAs) are valuable tools for conserving the nation's natural and cultural marine resources as part of an ecosystem approach to management. MPAs conserve natural heritage, cultural heritage, and sustainable production and are designed to maintain ecosystems' natural states and to absorb shocks, particularly in the face of large-scale and long-term changes such as climate change. The National System of MPAs provides benefits to the nation, to participating MPAs, and to ocean stakeholders, including enhanced stewardship, partnership building, and increased support for marine conservation. <http://mpa.gov/>

- Monitoring and responding to threats like invasive species (see page 92), harmful algal blooms, hypoxia, and coral bleaching
- Conducting outreach and awareness
- Acquiring sensitive lands and/or protective buffers
- Designating and/or connecting protected areas

Facilitating Wetland Migration

Wetlands that are not able to naturally keep up with increased rates of sea level rise through accretion of sediment and organic matter may be able to migrate landward, along with the functions and services they provide, given the proper soil and hydrological conditions and the lack of barriers. However, the ability to migrate and ultimate sustainability will depend on factors such as rate of change, topography, and upland land uses. Although costly and complex, if migration is constrained, wetland loss may be compensated for through the creation of new wetlands in suitable areas.

Steps that can be taken to facilitate wetland migration include:

- Prohibiting and removing shore protection structures that would impede migration
- Acquiring land suitable for migration through easements or acquisition¹⁵
- Requiring ecological buffer zones, setbacks, and/or rolling easements
- Adhering to the principles of compact community design

Adopting policies that support these activities before the suitable corridors are overly developed will likely be more cost-effective and politically palatable than once development has moved in. Wetland management programs should include analysis of how climate change may affect the coastal wetlands so strategic decisions can be made about land acquisition and other protective measures.

Managing for Ocean Acidification

With the impacts and reversibility of ocean acidification still uncertain, management responses are still being developed. The mitigation of climate change by reducing greenhouse gas emissions may be the best response as adaptation may not be feasible. Currently, recommendations to help reduce the impacts of ocean acidification, in addition to mitigation, include:

- Conserving and restoring natural landscapes
- Reducing land-based sources of pollution and nutrients that contribute to acidification
- Reducing other nonclimate stressors to enhance resilience
- Promoting marine connectivity
- Protecting high biodiversity ecosystems that are likely to be less vulnerable to the impacts of ocean acidification
- Spreading the threat by replicating ecosystems in different areas where pH may vary
- Monitoring and sharing information with researchers and other managers about observed impacts

¹⁵ Acquisition of parcels within identified corridors could be structured to allow landowners continued use or occupancy of their lands (while maintaining wetland values) during their lifetimes, after which ownership would transfer to a designated government agency.

Ecosystem Restoration, Creation, and Enhancement

Unlike the previous measures in this category, many of the activities designed to restore, create, or enhance coastal and marine ecosystems entail manipulation of the physical, chemical, or biological characteristics of a site. While there is considerable scientific confidence in support of activities that reduce nonclimate stressors, the effectiveness of the measures discussed here in helping systems adapt to climate change is not as evident, and their consideration, while still essential, requires a clear understanding of how a system functions and how it might be affected by climate change (CCSP 2008b).

These projects should be designed to withstand the impacts of climate change, incorporating native species that will be able to adapt to anticipated future conditions. The focus should be on maintaining and enhancing connectivity and preserving ecosystem functionality and services rather than re-creating a specific species composition. Representation and replication can help increase the likelihood of ecosystem or habitat survival.¹⁶ Ensuring resilient native species and habitats are well-represented and replicated decreases the possibility of catastrophic events destroying systems.

Specific activities for restoring, creating, or enhancing an ecosystem will vary by ecosystem type as well as by species. Brief descriptions of wetland, coral



Restoration projects may entail placing and shaping sediment and planting vegetation, in addition to other activities, in order to rebuild degraded wetlands.

reef, and artificial reef projects are included below. A more detailed discussion is outside the scope of this document. See the Key Resources at the end of this chapter for more information.

Wetlands

Restoration, creation, and enhancement consist of a wide-range of activities and are essential in recovering or replacing ecosystems that have been degraded or destroyed (Interagency Workgroup on Wetland Restoration 2003):

- **Restoration**—Returning a degraded wetland or former wetland to a pre-existing condition or as close to that condition as is possible.
- **Creation**—Converting a nonwetland (either dry land or unvegetated water) to a wetland.

Learning from others...Louisiana Repairs Wetlands with Mississippi River Sediment

The Louisiana Coastal Protection and Restoration Authority and EPA have embarked on a project to build and restore nearly 500 acres of marsh in Lower Jefferson and Plaquemines parishes using sediment from the Mississippi River. The Mississippi River Sediment Delivery System at Bayou Dupont will involve mining sediments from the river and transporting them by pipeline to the designated areas, which are outside the levees. After the material is transported, native vegetation will be planted on the new marsh. The sediment source was chosen because it will be replenished naturally. Pipeline infrastructure will remain in place after the project is complete so it can be used for future projects. www.lacoast.gov/projects/overview.asp?statenumber=BA%2D39

¹⁶ “Representation refers to protecting a portfolio of variant forms of a species or ecosystem so that, regardless of the climatic changes that occur, there will be areas that survive and provide a source for recovery. Replication centers on maintaining more than one example of each ecosystem or population such that if one area is affected by a disturbance, replicates in another area provide insurance against extinction and a source for recolonization of affected areas” (CCSP 2008b).

Learning from others...South Carolina Habitat Program Employs Community Volunteers

The South Carolina Department of Natural Resources operates a community-based habitat restoration and monitoring program that brings together volunteers and scientists to restore and monitor oyster habitat along the South Carolina coast. The purpose of the South Carolina Oyster Restoration and Enhancement Program is to restore and enhance oyster habitat by planting recycled oyster shells in the intertidal environment to form new, self-sustaining oyster reefs.

<http://score.dnr.sc.gov/>



Restored, created, and enhanced wetlands serve as storm buffers, improve water quality, provide habitat to fish and wildlife, enhance outdoor recreation opportunities, and more.

- **Enhancement**—Increasing one or more of the functions performed by an existing wetland beyond what currently or previously existed in the wetland. There is often an accompanying decrease in other functions.

Examples of activities associated with these types of projects include planting and seeding, which could include plant species adapted to future climate conditions; waterflow modification; sediment diversion and/or placement; filling canals; recontouring topography; dredging and removal of fill materials; prohibition and removal of shore protection structures and other barriers that impede natural processes; water quality improvements; and invasive species control.

Any project designed to restore, establish, or enhance an ecosystem will require planning, long-term management, monitoring, and, possibly,

land acquisition. In general, of the three project types, restoration is the most likely to be successful (Interagency Workgroup on Wetland Restoration 2004). The outcomes of projects that create new ecosystems or new ecosystem services are more uncertain, especially when the additional uncertainties of climate change are factored in. Wetland creation is usually difficult and typically requires a lot more planning and effort than restoration projects. Generally, it is easier to create wetlands from open water than it is to convert uplands. In either case, one type of ecosystem is likely to be destroyed in order to establish the new one. Tradeoffs will need to be made and understood.

Coral

Restoring damaged coral reef ecosystems is an important part of protecting and preserving ecosystem health. Reef restoration can help prevent further degradation and facilitate the natural recovery process. Future work on developing restoration strategies may ultimately make reefs more resilient to the impacts of climate change. To date, most restoration efforts have been focused on repairing damage caused by human impacts, such as vessel groundings and anchoring, and these efforts serve to restore natural function, structure, and diversity among injured reefs. Managers have conducted pilot projects on applying restoration techniques that may be used to respond to climatic event disturbances, such as coral bleaching, and disease mortality events.

Coral reef restoration largely entails stabilizing and repairing the damaged framework, recreating topography, and transplanting corals dislodged, propagated in nurseries, and/or relocated from other suitable sources (e.g., corals “orphaned” as a result of coastal construction projects). Restoration of natural processes may also include ecological approaches

such as reinstating herbivores, protecting herbivore populations, enhancing recruitment, and reducing the prevalence of disease. Restoration projects are difficult and expensive and may take decades to demonstrate their success. Thus, they require sound planning, long-term management, experimentation, and monitoring.

Artificial Reefs

Artificial reefs are constructed of a wide variety of man-made materials and placed underwater to restore, create, or enhance ecosystems, typically as a fisheries management tool. “Properly constructed and strategically sited artificial reefs can enhance fish habitat, provide more access to quality fishing grounds, benefit fishermen and the economies of shore communities, increase total fish biomass within a given area, and provide managers with another option for the conservation and management of fishery resources” (NOAA 2007b). Artificial reefs may also serve as breakwaters, protecting shorelines from erosion, and provide recreational opportunities.

NOAA’s 2007 *National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs* outlines the state’s role in planning for artificial reef construction and maintaining regulatory and quality control to ensure all artificial reefs in state waters:¹⁷

- Have biological justification relating to present and future fishery management needs
- Will have minimal negative effects on existing fisheries and/or conflicts with other uses
- Will have minimal negative effects on other natural resources and their future use
- Use materials that have long-term compatibility with the aquatic environment¹⁸
- Are monitored to determine whether reefs meet permit terms and conditions and are functioning as anticipated

The use of artificial reefs is a complex issue that requires planning, long-term monitoring, and evaluation to ensure the anticipated benefits are derived. There is still considerable debate on how artificial reefs impact the natural aquatic community into which they are introduced. “Improperly planned, constructed, or managed reefs may be ineffective, may cause conflict among competing user groups at the reef site, may increase the potential to overharvest targeted species, or may damage natural habitats. In such cases the benefits from the planned objectives of these structures may be negated” (NOAA 2007b). In some instances, artificial reefs may not be allowed in “Special Aquatic Sites,” which are areas possessing special ecological characteristics of productivity,

Learning from others...Mississippi Rebuilds Artificial Reefs

Mississippi’s Department of Marine Resources Artificial Reef Bureau, in partnership with Mississippi Gulf Fishing Banks, is working to rebuild fishing reefs destroyed by Hurricane Katrina. About 90 percent of Mississippi’s inshore and offshore artificial reefs were destroyed by the storm. As of early 2010, 100 percent of the inshore reefs and 65 to 70 percent of offshore reefs had been rebuilt. Cultch material is often made up of crushed limestone, concrete, or other suitable material. In addition, the state constructed an artificial reef off the undeveloped Deer Island using debris from storm-damaged bridges to help slow erosion of the island, which provides protection to the mainland, and enhance recreational fishing in the area. www.dmr.state.ms.us/Fisheries/Reefs/artificial-reefs.htm



¹⁷ While not explicitly mentioned in the plan, the mention of future needs and uses in these requirements suggests a need to consider how these needs and uses may be affected by climate change.

¹⁸ “The collective experience of the state artificial reef managers over the past several decades has revealed that a number of secondary use materials are unsuitable as artificial reef material. Among those that have been found to be persistently problematic are: wood; fiberglass; plastic; light vehicle bodies; fiberglass boats and boat molds; railroad boxcars; and light gauge metal items, such as refrigerators, washing machines, and clothes dryers” (NOAA 2007b). The plan also advises against using tires in artificial reef construction.

habitat, wildlife protection, or other important and easily disrupted ecological values (e.g., coral reefs, sanctuaries and refuges, and vegetated shallows).

Aquatic Invasive Species Management

Climate-driven changes are likely to combine with other stressors to further increase the vulnerability of natural systems to invasive species (Karl et al. 2009). Changes in climate may alter pathways; influence establishment, spread, and distribution; and affect the ability of native systems to repel invasion. Impacts are likely to vary by region as well as species. Some species, both desirable and invasive, may thrive under new conditions; others may find them unsuitable (EPA 2008). Despite the uncertainties, aquatic invasive species management plays a critical role in overall ecosystem management and should be planned and implemented in a manner that is flexible and considers and monitors for potential changes.

The Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990, amended by the National Invasive Species Act of 1996, calls for states to develop aquatic invasive species management plans. By incorporating climate change into these plans, they could serve as the basis for modifying management activities (prevention, control, eradication) to meet changing conditions. In a 2008 report, the EPA's National Center for Environmental Assessment recommended the following initial steps:

- Incorporate climate change considerations into leadership and coordination activities
- Identify new aquatic invasive species threats as a result of climate change



Aquatic invasive species like the zebra mussel can upset ecosystems, threaten native species, damage structures, and cause other serious problems.

- Identify ecosystem vulnerabilities and improve methods to increase ecosystem resilience
- Evaluate the effectiveness of control mechanisms under changing conditions
- Manage information systems to include considerations of changing conditions

An aquatic invasive species program may include “research to assess current and future invasive threats or identify pathways; detection of newly established species (e.g., monitoring, surveys, inspection); import, introduction, or release requirements for species (e.g., permits and licenses); transport and shipping requirements; quarantine; education and public awareness efforts; control (e.g., biological, chemical, and manual); emergency

Learning from others...Massachusetts Plans for Aquatic Invasive Species

With leadership from the Massachusetts Office of Coastal Zone Management, the Massachusetts Aquatic Invasive Species Working Group, composed of state and federal agencies and nonprofit organizations, works to minimize the impacts of aquatic invasive species in the state. The group published the Massachusetts Aquatic Invasive Species Management Plan in 2002 and focuses on prevention and education; early detection, monitoring, and species identification; rapid response; and control. One program component is the Marine Invader Monitoring and Information Collaborative, a network of trained community groups and citizens that uses a standardized monitoring protocol to collect aquatic invasive species data and information. www.mass.gov/czm/invasives/

response efforts; and restoration of degraded areas to increase resilience against reinvasion” (EPA 2008). Importantly, an aquatic invasive species program that considers climate change will include a comprehensive monitoring system that can detect new aquatic invasive species and changes in existing ones and how they affect the management area.

Water Resource Management and Protection

- Stormwater Management
- Green Infrastructure
- Water Supply Management

Many of the impacts of climate change will be related to water, either too much of it, or not enough. A number of the measures discussed throughout this chapter can be used to help protect



Detention basins can be designed to mimic natural ponds with gentle side slopes and native vegetation, which help prevent erosion and suspension of sediment and intercept pollutants from runoff.

coastal communities from too much water—sea level rise and other types of inundation, in particular. This category includes measures that can be taken to manage stormwater, urban shallow flooding that tends to result from heavy precipitation events rather than rising waters, and to manage water supplies in anticipation of dry periods and corresponding water shortages. These are activities that, along with floodplain management, would benefit from being managed together as part of a comprehensive integrated water resources management program.

Stormwater Management

In general, the purpose of stormwater management is to control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff. However, it also plays an important role in preventing damage to the built environment and the natural systems that protect it.

Existing drainage systems may be ill-equipped to handle the amount of stormwater runoff that will accompany the more intense rainfall events expected in the future. Those in low-lying areas will be further challenged by losses in elevation attributed to rising sea levels. To accommodate for these changes, coastal communities may need to modify and enhance the capacity of their drainage systems and should consider climate change when implementing and updating existing stormwater management plans. Modifications and enhancements may include:¹⁹

- Updating stormwater regulations
- Incorporating green infrastructure (see next page)

Learning from others...Maryland Funds Stormwater Enhancements to Address Climate Change

As part of its Coast-Smart Communities Initiative, Maryland’s Department of Natural Resources is providing financial and technical assistance to coastal communities to address the impacts of sea level rise and climate change. One of the first four projects selected under the initiative will allow for improvements to Caroline County’s floodplain and stormwater management programs. The project will include consolidation of and changes to the two ordinances to meet and exceed state requirements, public outreach, and input to a forthcoming rezoning process, which will consider natural resource protection and public safety issues. www.dnr.state.md.us/CoastSmart/

¹⁹ Since some modifications and enhancements could encourage growth in the short-term, growth controls may also be needed.

- Limiting/removing impervious surfaces
- Acquiring easements for new and wider drainage ditches
- Implementing and enforcing stream dumping regulations
- Improving carrying and storage capacity of streams, channels, and basins through ongoing maintenance
- Installing larger pipes and culverts
- Adding pumps
- Creating retention and detention basins
- Converting culverts to bridges



By capturing runoff from impervious surfaces, such as roofs, roads, and driveways, rain gardens allow water to seep slowly into the ground and help protect nearby waterbodies by reducing runoff and filtering pollutants.

Green Infrastructure

As it relates to water resource management and protection, “green infrastructure” is a comprehensive approach that promotes the use of natural and built systems to improve infiltration, evapotranspiration, capture, and reuse of stormwater at regional, community, and site scales. It uses soil and vegetation in lieu of or in addition to the “hard” or “gray” infrastructure typically used to divert, store, and treat

stormwater. Some aspects of green infrastructure will need to be managed through regulations (e.g., land use, building codes) and land acquisition programs; others will be most effective when promoted through outreach, education, and training.

Learning from others...Georgia Manual Promotes Green Infrastructure along Coast

The Coastal Stormwater Supplement to the Georgia Stormwater Management Manual provides Georgia’s coastal communities with guidance on an integrated, green infrastructure-based approach to natural resource protection, stormwater management, and site design that can be used to better protect coastal Georgia’s natural resources from the negative impacts of land development and nonpoint source pollution. The manual seeks to shift the focus of stormwater management efforts from postconstruction alleviation of impacts to preconstruction prevention. www.georgiaepd.org/Documents/CoastalStormwaterSupplement.html

Learning from others...Green Infrastructure Plays Key Role in Wisconsin Stormwater Management

Established by Wisconsin state law, the Metropolitan Milwaukee Sewerage District is a regional government agency that provides water reclamation and flood management services. To help reduce the number of combined sewer overflow events and improve the water quality in Lake Michigan, the agency has invested in a number of green infrastructure projects. Programs include “Green Seams,” a land acquisition program, and the Lake Michigan Rain Gardens Initiative. The agency also promotes downspout disconnection and has partnered with local businesses and municipalities to make rain barrels accessible to the public. <http://v3.mmsd.com/>

By helping to maintain and restore natural hydrology and removing nutrients, pathogens, and pollutants from stormwater, these approaches:

- Improve water quality and groundwater recharge
- Reduce stormwater flooding
- Protect ecosystems
- Provide habitat
- Provide recreational opportunities
- Improve aesthetics

In general, regional green infrastructure is an interconnected network of natural lands and waters that provide essential environmental functions (e.g., wetlands, floodplains, and forests) and the buffers that protect them. Examples of community and site-level

green infrastructure practices that may help coastal communities adapt to climate change include:

- Vegetated swales and media strips
- Urban forestry
- Porous pavement
- Rain gardens
- Green roofs
- Rain barrels and cisterns
- Downspout disconnection

Water Supply Management

Since climate change will likely negatively affect both water quantity and quality, and coastal populations will continue to grow, water supply managers must be prepared to respond to associated changes in supply

Learning from others...California Unites Land Use and Water Supply Planning

California state law requires cities and counties to link water supply information with certain land use decisions. Specifically, for proposed housing developments of 500 or more homes, it requires local water agencies to verify there is enough water to serve the project for at least 20 years, including long periods of drought. www.water.ca.gov/urbanwatermanagement/

Learning from others...Regional Compact Protects Valuable Water Resources in Great Lakes

In December 2005, the governors of the eight Great Lakes states endorsed the Great Lakes-St. Lawrence River Basin Water Resources Compact to protect and preserve the Great Lakes, and it has since been enacted into law in each state. The compact calls for each state to:

- Develop and maintain a water resources inventory
- Develop its own water conservation and efficiency goals and objectives consistent with basinwide goals and objectives
- Develop and implement a water conservation and efficiency program
- Prohibit new or increased diversions
- Manage and regulate new or increased withdrawals and consumptive uses in accordance with the compact



- Collectively conduct a periodic assessment of the cumulative impacts of withdrawals, diversions, and consumptive uses, which should consider climate change

www.cglg.org/projects/water/Agreement-Compact.asp

and demand. Water conservation, recovery, and reuse will be central to efforts to protect sustainable water supplies. Examples of activities to support these efforts or provide additional protection include the following:

- Encouraging changes in behavior (incentives)
- Modifying water utility operations
- Diversifying water supplies
- Integrating groundwater and surface water management
- Increasing storage capacity
- Employing new technologies
- Revising drought and water plans
- Revising/implementing regulations and building codes
- Modifying water pricing
- Reallocating water distribution
- Increasing use of water markets
- Relocating/retrofitting existing infrastructure
- Incorporating green infrastructure

Future planning should consider the multiple climate change phenomena that will affect water supplies and the supporting infrastructure. In addition, it should allow for flexibility to make adjustments as needed based on enhanced projections, seasonal forecasts, and observed changes.

KEY RESOURCES

General

- Adapting to Coastal Climate Change: A Guidebook for Development Planners, U.S. Agency for International Development. www.crc.uri.edu/index.php?actid=366
- Advanced Floodplain Management Concepts (training), Federal Emergency Management Agency. <http://training.fema.gov/EMICourses/>
- Coastal No Adverse Impact, Association of State Floodplain Managers. www.floods.org/index.asp?menuid=340&firstlevelmenuid=187&siteid=1
- Coastal Training Program, National Estuarine Research Reserve System. www.nerrs.noaa.gov/Training.aspx
- Community Rating System, FEMA. www.fema.gov/business/nfip/crs.shtm
- DisasterSafety.org, Institute of Business and Home Safety. www.disastersafety.org/
- Developing the [Hazard] Mitigation Plan: Identifying Actions and Implementing Strategies, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Guidance on Water and Adaptation to Climate Change, United Nations Economic Commission for Europe. www.unece.org/env/documents/2009/Wat/mp_wat/ECE_MP.WAT_30_E.pdf
- Integrating Historic Property and Cultural Resource Considerations into Hazard Mitigation Planning, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Introduction to Hazard Mitigation (online training), FEMA. <http://training.fema.gov/EMIWeb/IS/>
- Local Strategies for Addressing Climate Change, NOAA Coastal Services Center. www.csc.noaa.gov/publications.html
- Managing Coastal Erosion, National Research Council of the National Academies. http://books.nap.edu/catalog.php?record_id=1446
- Managing Floodplain Development through the National Flood Insurance Program (training), FEMA. <http://training.fema.gov/EMICourses/>
- Mitigating Shore Erosion along Sheltered Coasts, National Research Council of the National Academies. http://books.nap.edu/catalog.php?record_id=11764
- National Flood Insurance Plan/Community Rating System (training), FEMA. <http://training.fema.gov/EMICourses/>
- Negotiating for Coastal Resources (training), NOAA Coastal Services Center. www.csc.noaa.gov/cms/cls/negotiating_coastal.html
- Planning for Climate Change, NOAA Estuarine Reserves Division. <http://nerrs.noaa.gov/CTPIndex.aspx?ID=455>
- Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/planning/adaptation-guidebook/
- Shoreline Management: Alternatives to Hardening the Shore, NOAA Office of Ocean and Coastal Resource Management. <http://coastalmanagement.noaa.gov/shoreline.html>
- Special Area Management Plans. NOAA Office of Ocean and Coastal Resource Management. <http://coastalmanagement.noaa.gov/special.html>
- Synthesis of Adaptation Options for Coastal Areas, EPA Climate Ready Estuaries. www.epa.gov/cre/adaptationoptions.html

- U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory. <http://chl.erdc.usace.army.mil/>
- Using the Hazard Mitigation Plan to Prepare Successful Mitigation Projects, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs, U.S. Army Corps of Engineers. <http://140.194.76.129/publications/eng-circulars/>

Impact Identification and Assessment

See also Key Resources in Chapter 4.

- Climate Prediction Center, NOAA National Weather Service. www.cpc.ncep.noaa.gov/
- CoastWatch, NOAA National Environmental Satellite, Data, and Information Service. <http://coastwatch.noaa.gov/>
- Coral Reef Watch, NOAA National Environmental Satellite, Data, and Information Service. <http://coralreefwatch.noaa.gov/>
- Integrated Coral Observing Network, NOAA. <http://ecoforecast.coral.noaa.gov/>
- National Estuarine Research Reserve System Research. NOAA Estuarine Reserves Division. www.nerrs.noaa.gov/Research.aspx
- National Water Information System. U.S. Geological Survey. <http://waterdata.usgs.gov/nwis>
- NOAA Climate Service. www.climate.gov/
- NOAAWatch: NOAA's All Hazard Monitor, NOAA. www.noaaWATCH.gov/
- nowCoast, NOAA Office of Coast Survey. <http://nowcoast.noaa.gov/>
- Science-Based Monitoring Restoration Monitoring of Coastal Habitats, NOAA National Centers for Coastal Ocean Science. http://coastalscience.noaa.gov/ecosystems/estuaries/restoration_monitoring.html
- Tides and Currents, NOAA Center for Operational Oceanographic Products and Services. <http://tidesandcurrents.noaa.gov/>
- U.S. Drought Portal. National Integrated Drought Information System. www.drought.gov/
- U.S. Water Monitor. U.S. Geological Survey. <http://watermonitor.gov/>
- WaterWatch, U.S. Geological Survey. <http://water.usgs.gov/waterwatch/>

Awareness and Assistance

- Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Decisionmaking, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Building Public Support for Floodplain Management, Association of State Floodplain Managers. www.floods.org/ace-files/documentlibrary/Publications/BPS_Guidebook_2_1_10.pdf
- Climate Literacy—The Essential Principles of Climate Science: A Guide for Communities and Individuals, U.S. Climate Change Science Program. www.globalchange.gov/resources/educators/climate-literacy
- Communicating Sustainability, United Nations Environment Programme. www.unep.fr/scp/publications/details.asp?id=DTI/0679/PA
- Education and Outreach Training, U.S. Fish and Wildlife Service National Conservation Training Center. <http://nctc.fws.gov/>

- ICLEI Resource Guide: Outreach and Communications, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/engaging-your-community/
- Risk Behavior and Risk Communication: Synthesis and Expert Interviews, NOAA Coastal Services Center. www.csc.noaa.gov/publications.html
- Seven Cardinal Rules of Communication, EPA. www.epa.gov/CARE/library/7_cardinal_rules.pdf

Growth Management

- Coastal Community Planning and Development (training), NOAA Coastal Services Center. www.csc.noaa.gov/training/ccpd.html
- Hazard Mitigation: Integrating Best Practices into Planning, American Planning Association, FEMA. www.fema.gov/library/viewRecord.do?id=4267
- Smart Growth for Coastal and Waterfront Communities, NOAA, EPA, International City/County Management Association, Rhode Island Sea Grant. <http://coastalsmartgrowth.noaa.gov/>

Loss Reduction

- Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, FEMA. www.fema.gov/rebuild/mat/fema55.shtm
- Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings, FEMA. www.fema.gov/library/viewRecord.do?id=2441
- Engineering Principles and Practices of Retrofitting Floodprone Residential Structures, FEMA. www.fema.gov/library/viewRecord.do?id=1645
- FEMA Mitigation Assessment Team Reports, FEMA. www.fema.gov/rebuild/mat/mat_reprts.shtm
- Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding, FEMA. www.fema.gov/library/viewRecord.do?id=1420
- Implementing Floodplain Land Acquisition Programs in Urban Localities, University of North Carolina Center for Urban & Regional Studies. <http://people.vanderbilt.edu/~james.c.fraser/publications/Floddplain%20Project%20Report.Final.pdf>
- International Code Council (codes available for purchase). www.iccsafe.org/
- Introduction to Residential Coastal Construction (online training), FEMA. <http://training.fema.gov/EMIWeb/IS/>
- Local Officials Guide for Coastal Construction, FEMA. www.fema.gov/library/viewRecord.do?id=3647
- [Hazard] Mitigation Best Practices Portfolio, FEMA. www.fema.gov/plan/prevent/bestpractices/
- Retrofitting Flood-Prone Residential Buildings (training), FEMA. <http://training.fema.gov/EMICourses/>
- Sea Level Rise Planning Maps: Showing the Likelihood of Shore Protection. <http://plan.risingsea.net/>
- Selecting Appropriate [Hazard] Mitigation Measures for Floodprone Structures, FEMA. www.fema.gov/library/viewRecord.do?id=2737

Shoreline Management

- Beach Nourishment, U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory, <http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;192>
- Beach Nourishment and Protection, National Research Council of the National Academies. http://books.nap.edu/catalog.php?record_id=4984

- Beneficial Use of Dredged Material, U.S. Army Corps of Engineers.
<http://el.erdc.usace.army.mil/dots/budm/budm.cfm>
- Living Shorelines, NOAA Restoration Center.
<http://habitat.noaa.gov/restoration/techniques/livingshorelines.html>
- Regional Sediment Management, U.S. Army Corps of Engineers. www.wes.army.mil/rsm/
- Shore Protection Assessment: How Beach Nourishment Works, U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory.
<http://chl.erdc.usace.army.mil/pub-beachnourishment>

Coastal and Marine Ecosystem Management

- Adaptive Management: The U.S. Department of the Interior Technical Guide, U.S. Department of the Interior. www.doi.gov/initiatives/AdaptiveManagement/documents.html
- Addressing Elevation and Inundation Issues in Habitat Restoration Planning and Implementation, NOAA National Ocean Service. <http://response.restoration.noaa.gov/cpr/library/publications.html>
- Aquatic Nuisance Species Task Force. <http://anstaskforce.gov/default.php>
- Climate Ready Estuaries Coastal Toolkit. EPA Climate Ready Estuaries. www.epa.gov/cre/toolkit.html
- Ecosystem-Based Management Tools Network. www.ebmtools.org/
- Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research, EPA National Center for Environmental Assessment.
<http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=188305>
- GIS Tools for Strategic Conservation Planning (training), NOAA Coastal Services Center.
www.csc.noaa.gov/digitalcoast/training/gisforscp.html
- Habitat Priority Planner: A New Planning Tool for Coastal Communities, NOAA Coastal Services Center.
www.csc.noaa.gov/hpp/
- An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement, Interagency Workgroup on Wetland Restoration. www.lsu.edu/slegal/pdfs/WetlandsUsersGuide.pdf
- National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs, NOAA National Marine Fisheries Service.
www.nmfs.noaa.gov/sfa/PartnershipsCommunications/NARPwCover3.pdf
- National Conservation Training Center, U.S. Fish and Wildlife Service. <http://nctc.fws.gov/>
- NOAA Habitat Program. <http://habitat.noaa.gov/>
- NOAA National Marine Protected Areas Center. <http://mpa.gov/>
- NOAA Restoration Center. <http://habitat.noaa.gov/restoration/>
- Planner's Guide to Wetland Buffers for Local Governments, Environmental Law Institute.
www.elistore.org/reports_detail.asp?ID=11272
- Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- A Reef Manager's Guide to Coral Bleaching, Great Barrier Reef Marine Park Authority, NOAA, and the International Union for the Conservation of Nature.
www.coris.noaa.gov/activities/reef_managers_guide/
- Strategies for Managing the Effects of Climate Change on Wildlife and Ecosystems, The H. John Heinz III Center for Science, Economics and the Environment. www.heinzcenter.org/publications/

Water Resource Management and Protection

- EPA Stormwater Program, EPA, Office of Water.
http://cfpub.epa.gov/npdes/home.cfm?program_id=6
- Low Impact Development, EPA, Office of Wetlands, Oceans, and Watersheds. www.epa.gov/nps/lid/
- Managing Wet Weather with Green Infrastructure, EPA, Office of Wastewater Management.
http://cfpub.epa.gov/npdes/home.cfm?program_id=298
- Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scale. EPA Office of Research and Development.
www.epa.gov/smartgrowth/water_scorecard.htm
- Water Resources of the United States. U.S. Geological Survey. <http://water.usgs.gov/>

Evaluate, Select, and Prioritize Actions

- Benefit Cost Analysis, FEMA. www.fema.gov/government/grant/bca.shtm
- Benefit-Cost Analysis: Entry-Level Training, FEMA. <http://training.fema.gov/EMICourses/>
- Project Design and Evaluation (training), NOAA Coastal Services Center.
www.csc.noaa.gov/cms/cls/project_design.html
- Using Benefit-Cost Review in [Hazard] Mitigation Planning, FEMA.
www.fema.gov/plan/mitplanning/resources.shtm