Preparing for the Storm:

Recommendations for Management of Risk from Coastal Hazards in Massachusetts

May 2007

DEDICATION

The Coastal Hazards Commission (CHC) dedicates this report to its Chair, Susan Snow-Cotter, who died of inflammatory breast cancer on December 13, 2006. Susan worked for the Massachusetts Office of Coastal Zone Management (CZM) for 12 years. She started as the Ocean Policy Coordinator and most recently served as the Director. Her commitment to coastal communities, proactive management style, and ability to synthesize many diverse disciplines helped the CHC address the challenges of coastal hazards in Massachusetts. Early in the decision-making process, Susan led numerous forums, giving the public the opportunity to express their ideas and concerns to the CHC. Under her pragmatic leadership, the CHC addressed these concerns and developed comprehensive draft recommendations by August — only six months after the CHC was convened. Following her diagnosis in September, Susan continued to advance the goals of the CHC. To the very end, Susan remained dedicated to improving management of the Commonwealth's coast.

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ACRONYMS AND ABBREVIATIONS

A-zone	Special Flood Hazard Area
CHC	Coastal Hazards Commission
CPA	Community Preservation Act
CRS	Community Rating System
CZM	Massachusetts Office of Coastal Zone Management
DCR	Massachusetts Department of Conservation and Recreation
DFG	Massachusetts Department of Fish and Game
DOI	Massachusetts Division of Insurance
EOEEA	Massachusetts Executive Office of Energy and Environmental Affairs
EOT	Massachusetts Executive Office of Transportation
FAIR	Fair Access to Insurance Requirements
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
Guaranty Fund	Massachusetts Insurers Insolvency Fund
IPCC	Intergovernmental Panel on Climate Change
LIDAR	Light Detection and Ranging
LSCSF	Land Subject to Coastal Storm Flowage
MassDEP	Massachusetts Department of Environmental Protection
MassGIS	Massachusetts Office of Geographic and Environmental Information
MEMA	Massachusetts Emergency Management Agency
MPIUA	Massachusetts Property Insurance Underwriting Association
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
RVAM	Risk and Vulnerability Assessment Map
Storm Team	Massachusetts Rapid Response Coastal Storm Damage Assessment Team
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
V-zone	Coastal High Hazard Area
WHOI	Woods Hole Oceanographic Institution

CHAPTER 1 - INTRODUCTION

Massachusetts and its 78 coastal communities are vulnerable to the damaging impacts of major storms, such as northeasters and hurricanes, along more than 1,500 miles of varied coastline. As coastal development increases, less-intense storms that occur more regularly and sea-level rise will also lead to costly storm damage. The Commonwealth has consistently sought to prevent or mitigate storm damage through planning and regulations that seek to protect lives and existing property, and guide new development away from vulnerable coastal areas.

Over the past two decades, a significant amount of progress has been made in our understanding of coastal processes, risk assessment, policy, planning, regulations, and engineering. There remains, however, a clear need for an evaluation of the factors that contribute to storm damage, a review of the policies and regulations that guide the management of coastal hazards, and a comprehensive assessment of publicly owned shore protection infrastructure in the Commonwealth. The purpose of the Coastal Hazards Commission (CHC) is to review existing coastal hazards practices and policies, identify data and information gaps, and make recommendations for administrative, regulatory, and statutory changes, when necessary.

Coastal Hazards in the Commonwealth

The natural forces of wind and waves continuously shape the shorelines of Massachusetts, seeking to achieve a dynamic equilibrium between land and sea. As a result of this natural process, coastal areas cannot be studied or developed as stable environments. These dynamic environments shift and change in response to relative shoreline shape and position, the availability of sediment (sand, gravel, and cobble), periodic increases in energy (wind and waves), and continuously rising sea levels. The illusion of a stable shoreline results from nature's continuing reassessment of the balance between these factors, in which a change in the nature or amount of one triggers corresponding changes to the others until a temporary equilibrium is once again established. This tendency for shorelines to seek equilibrium is central to the problems associated with coastal development.

In the absence of development, shoreline migration — either rapid during high energy coastal storms, or gradual in response to sea-level rise — constitutes a natural phenomenon that, while dramatic, presents few long-term problems to natural systems and resources. When static systems such as coastal development are confronted with these dynamic forces, however, the migration or loss of coastal landforms is frequently accompanied by significant adverse impacts. The impacts to development associated with natural coastal processes constitute significant management challenges when they threaten the health, safety, welfare, or economics of individuals and communities.

Erosion and flooding are the primary coastal hazards that lead to the loss of lives or damage to property and infrastructure in developed coastal areas. Storms including northeasters and hurricanes, decreased sediment supplies, and sea-level rise contribute to these coastal hazards. The risk to coastal communities from these hazards continues to present major challenges to coastal developers, managers, and emergency responders at all levels of government. Policymakers are also challenged to balance development and natural resource protection in coastal areas.

Northeasters

Northeasters occur frequently in New England and are a primary concern for residents and managers alike. These low pressure systems, named for the direction from which their winds originate, are typically accompanied by considerable precipitation, high winds, and waves that cause erosion, particularly along easterly facing shores. In addition, these slow-moving weather systems, with storm surges often in excess of two feet above normal high water levels, can pound the coast over several tidal cycles piling up additional water along the shoreline, resulting in major and extended flooding of coastal and inland properties. With rising sea levels, the flooding and erosion associated with less intense northeasters can now influence coastal development on a more frequent basis.

One or two northeasters per year usually strike the coast of Massachusetts between October and April causing shoreline erosion, flooding, and property damage (MEMA and DCR, 2004). The New England Blizzard of 1978 and the No-Name or Halloween Storm of 1991 are examples of moderate to severe northeasters that influenced the coast of Massachusetts. The New England Blizzard brought record-breaking snowfall and hurricane-force winds that caused beach erosion, flooding, and property damage. The Halloween Storm also resulted in erosion and considerable property damage due to heavy surf and lunar-enhanced storm surges along the coast. Damages that occurred during these and other storm events illustrate the need for improved coastal management approaches.

Hurricanes

Hurricanes are another type of storm that causes damage along the coast. These storms form over warm tropical waters from June to November and are typically accompanied by higher wind velocities and precipitation amounts. Hurricanes that reach New England tend to be relatively fast moving, rarely impacting the coast over multiple tidal cycles. Although they are relatively infrequent visitors to Massachusetts (seven since 1938), when landfall is made, these concentrated, strong low-pressure systems usually pound south facing shores with high winds, precipitation, and storm surge. Fortunately, the shorelines of Massachusetts have not experienced a hurricane since Bob made landfall as a Category 2 in August of 1991. Five other hurricanes hit between Bob and the Great New England Hurricane of 1938, which was also a Category 2 when it tracked across Massachusetts (NOAA, 2005). While Massachusetts has never experienced a Category 4 or 5 hurricane and the frequency of hurricanes has been relatively low in New England over the last 50 years, warming of the Atlantic Ocean may drive more high-intensity storms up to Massachusetts in the future. As Hurricane Bob demonstrated, with greater levels and density of development along the coast, even a Category 2 storm will cause millions of dollars in damage.

Decreased Sediment Supplies

Coastal landforms such as coastal banks are essential to maintaining a supply of sediment to beaches and dunes. Where engineering structures are used to stabilize shorelines, the natural process of erosion is interrupted, decreasing the amount of sediment available and causing erosion to adjacent areas. Under conditions of reduced sediment, the ability of coastal resource areas such as dunes and beaches to provide storm damage prevention and flood control benefits is continually reduced. A major challenge is to ensure that regional sediment supplies are managed effectively and in ways that allow the beneficial storm damage prevention and flood control functions of natural

coastal processes to continue — both for future projects and, where possible, existing coastal development.

Sea-Level Rise

Climate change and sea-level rise are persistent contributors to coastal land loss in the Northeast. Increased volumes of water in the oceans due to thermal expansion of water as it warms and the addition of fresh water from melting ice sheets and glaciers result in the rise of sea surface levels. Records of tide gauges around Boston, Woods Hole, and Nantucket indicate that our relative sea level (the combination of a rising water surface with land subsidence) has risen approximately 10 inches over the past 100 years. The Intergovernmental Panel on Climate Change (IPCC) predicts that sea-level rise and its risk to coastal resources will accelerate over the next 100 years (IPCC, 2007). Conservative projections of sea-level rise by the end of the century range from 4 to 21 inches, while projections given a higher emissions scenario range from 8 to 33 inches (Union of Concerned Scientists, 2006). With an accelerated rate of sea-level rise, low-lying coastal areas will be particularly vulnerable to increased erosion, flooding, and inundation. In addition, these impacts will extend further inland, resulting in greater loss of land and damage to development along the coast of Massachusetts. The combination of rising sea levels, more frequent and intense storms, and increased coastal development will result in greater erosion and flooding impacts over time.

Approaches to Address Coastal Hazards

Managers generally employ many different measures to reduce the risks posed by coastal hazards along developed coasts. Policies and regulatory tools, such as setbacks and building codes, can be developed to prevent or limit new development in hazardous locations, relocate buildings at risk of severe damage, and prohibit reconstruction of destroyed buildings. Regulations are also implemented to limit the use of new shoreline-stabilization structures and to ensure that adverse impacts of project are minimized. These measures can result in a wide range of environmental and economic costs varying with the physical, economic, human, social, and natural character of coastal communities.

Non-structural measures such as beach nourishment (i.e., the active addition of sediment to a beach system) are also being considered as viable alternatives to protect development with the added benefit of maintaining recreational beaches. Massachusetts successfully completed a beach nourishment project on Revere Beach State Reservation in 1992 using an upland source of approximately 768,000 cubic yards of sediment, financed by the state and federal governments. Smaller nourishment projects were also completed on Dead Neck Beach in Osterville (1998) and Long Beach in Plymouth (1999) using sediment from offshore sources and private and local funds respectively. Two major beach nourishment projects using offshore sources of sediment have been proposed for Winthrop Beach and Siasconset Beach using state and private funds respectively. Nourished beaches can be quite successful in restoring the vitality of communities, energizing local economies, and minimizing property and infrastructure damages. Maintaining an artificial beach width, however, does require continued placement of sediment.

Work of the Coastal Hazards Commission

To address current and future coastal hazards issues in the Commonwealth, the Romney Administration and the Legislature launched the CHC in February of 2006. Governor Mitt Romney and Environmental Affairs Secretary Stephen Pritchard asked the CHC to review existing coastal hazards practices and policies, identify data and information gaps, and prepare a report with recommendations to the Legislature. The six statements below represent the charge of the CHC.

1. Characterize Massachusetts' general vulnerability to coastal hazards such as erosion, flooding, and sea-level rise.

2. Evaluate the adequacy of coastal hazards data and tools, regulations, and best management practices for development in coastal flood- or erosion-prone areas.

3. Evaluate management approaches to coastal hazards including (1) existing seawall repair, removal, or replacement with alternatives; (2) beach nourishment along with an evaluation of offshore sand mining for such purpose; (3) coastal retreat ranging from infrastructure relocation to private property acquisition; (4) market-based incentives and disincentives such as insurance; and (5) hazard mitigation planning.

4. Conduct an initial detailed assessment of the South Shore coastal region that determines coastal hazards practices; inventories public storm damage protection infrastructure; assesses the condition of this infrastructure as good, adequate, or failing; and identifies and generally characterizes significant areas of both public and private infrastructure. Additionally, the assessment will identify substandard infrastructure (e.g., seawalls and revetments) and provide estimated costs for capital and maintenance improvements. The overall objective is to develop a 20-year Coastal Infrastructure and Protection Plan.

5. Initiate similar 20-year Coastal Infrastructure and Protection Plans for the North Shore, Boston Harbor, Cape Cod and Islands, and South Coast regions.

6. Make recommendations as deemed necessary and appropriate.

At the initial monthly meetings of the CHC, the members were presented with background information on coastal hazards and management measures by experts in the field. The information included an overview of the Massachusetts coast, erosion, flooding, state and local hazard mitigation planning, publicly owned coastal structures, beach nourishment including fisheries and other habitat concerns, vulnerability to coastal storms such as hurricanes and northeasters, and potential impacts of sea-level rise on the coast. In May, five forums were held in Ipswich, Boston, Scituate, Hyannis, and Wareham to allow the public to express their concerns about erosion, flooding, storms, and sea-level rise to the CHC. The primary issues raised at the public forums include Flood Insurance Rate Maps (FIRMs), seawalls, beach nourishment, and permitting of various projects.

Five working groups of experts, primarily from state and local government agencies, academia, and the private sector, were also formed in May and met over the summer and fall to assist the CHC with drafting recommendations. The working groups focused on:

1. Coastal hazards information including data and tools,
2. Policies,
3. Planning and regulations,
4. Structural and nonstructural measures to protect coastal development, and
5. Public coastal infrastructure such as seawalls and revetments.

The CHC met in June and July to discuss the issues raised by the public at the May forums and the initial recommendations drafted by the working groups.

Draft recommendations were released to the public in August and comments were solicited through September. Fourteen comments were presented at the September meeting of the CHC. A total of 29 comments were discussed by the chairs of the working groups at the end of October and appropriate revisions were made to the draft recommendations. Also during the fall, the working groups drafted brief implementation plans for each of the recommendations that identified potential lead agencies, funding sources, next steps, and estimated timelines. The CHC approved 29 recommendations and implementation plans at their last meeting in February of 2007. Four priority recommendations were identified at this meeting. Staff of the Massachusetts Office of Coastal Zone Management (CZM) drafted the report and it was approved by the CHC in May of 2007.

Report Overview

Chapter 2 of this report presents the CHC's 29 recommendations, which are organized according to the four working groups that drafted them. Each section begins with one of the four priority recommendations. The recommendations are accompanied by detailed background information on the issues and include brief implementation plans. Chapter 3 describes the pilot infrastructure inventory project on the South Shore and presents some of its preliminary findings. Appendix A includes a list of the recommendations with the four priority recommendations highlighted. Appendix B contains links to coastal hazards data and tools compiled by the Hazards Information Working Group. Finally, the Protection Working Group analyzed and documented the potential benefits and impacts of a variety of alternatives to control flooding, erosion, and other coastal hazards along the coast of Massachusetts (Appendix C). This resource is intended to guide decision makers conducting site-specific analyses of protection alternatives who may not know what potential benefits and impacts may exist.

CHAPTER 2 - RECOMMENDATIONS

The Coastal Hazards Commission (CHC) approved the following 29 recommendations and implementation plans. The recommendations are organized according to the working groups that drafted them: Hazards Information, Policy, Planning and Regulations, and Protection. One recommendation from each working group was selected as a priority. The four priority recommendations are listed at the beginning of their respective sections.

Hazards Information

The Hazards Information Working Group focused primarily on data and tools that assess risk of coastal hazards and account for storm damage. Historical data, current studies, reports, presentations, real-time (event-based) data, models, projections, forecasts, maps, and planning tools were discussed and eight recommendations were drafted. The working group identified that Flood Insurance Rate Maps (FIRMs) need critical updates (Recommendation #1). This is one of the four priority recommendations of the CHC. In addition, the working group suggested that new data, such as Coastal Hazards Characterization Atlases, Risk and Vulnerability Assessment Maps (RVAMs), climate change and sea-level rise data, storm event data, and storm damage projections, should be collected (Recommendations #2-6). Finally, education and outreach of coastal hazards information should also be pursued and evaluated (Recommendations #7 and #8).

Flood Insurance Rate Maps

Successful coastal hazards assessment, planning, management, and mitigation require accurate data on flood and storm-damage risks. FIRMs are often used to represent these risks, however the average age of an effective FIRM panel in Massachusetts is now 19.9 years, and the study data used to create these panels is typically several years older. Federal Emergency Management Agency (FEMA) funding allocated to Massachusetts under their Map Modernization Program is insufficient to properly update FIRMs for the coastal zone. FEMA provided only $6 million for this effort, as compared to the $34 million the Massachusetts Map Modernization Business Plan estimated is necessary to update FIRMs for the entire state. The Commonwealth should follow the lead of other states and partner with FEMA to update coastal FIRMs. By providing financial and technical assistance, the partnership would help FEMA leverage funding to update FIRMs according to FEMA's guidelines and specifications.

Recommendation #1 (Priority)

Assist FEMA financially and technically to update and maintain FIRMs for the coastal zone of Massachusetts.

Implementation Plan

Lead Agency:	Massachusetts Department of Conservation and Recreation (DCR) Flood Hazard Management Program
Funding Requirement:	yes
Potential Funding Source:	state funds
Next Steps:	acquire funds
Project Duration:	5-10 years

Coastal Hazards Characterization Atlases

As part of a larger effort to provide municipal Conservation Commissions with guidance on coastal hazards, a Coastal Hazards Characterization Atlas was compiled for the South Shore of Massachusetts (Applied Coastal Research and Engineering, Inc., 2006). The purpose of the Atlas is to present information that can aid in the review of proposed projects in areas that may be vulnerable to coastal hazards. The Atlas will assist local reviewers with the identification of technical information necessary to evaluate individual projects and implement sound coastal hazard mitigation strategies. The following variables were mapped at a sub-regional scale: dominant coastal processes, storm damage susceptibility, properties with multiple National Flood Insurance Program (NFIP) claims, shoreline change rates, littoral cells, coastal engineering structures, and relative sea-level rise. The Massachusetts Office of Coastal Zone Management (CZM) should compile Coastal Hazards Characterization Atlases for the remaining four coastal regions. The estimated cost for each region is $112,500, for a total of $450,000. Based on current storm damage issues, the Atlases should be completed in the following order: North Shore, South Coast, Cape Cod and Islands, and Boston Harbor. All of the atlases should be posted online.

Recommendation #2

Compile Coastal Hazards Characterization Atlases for the North Shore, South Coast, Cape Cod and Islands, and Boston Harbor regions.

Implementation Plan

Lead Agency:	CZM
Funding Requirement:	yes
Potential Funding Source:	National Oceanic and Atmospheric Administration (NOAA) Coastal Zone Enhancement (Section 309) Grant and state funds
Next Steps:	acquire funds
Project Duration:	5 years

Risk and Vulnerability Assessment Maps

An RVAM is needed by each coastal community to determine which areas are susceptible to coastal hazards, serve as the basis for a vulnerability assessment, and provide critical information for effective and efficient hazard mitigation and emergency response planning. Many coastal communities have not developed RVAMs because they do not have the technical expertise or funding. A standardized Geographic Information System (GIS) methodology should be developed and utilized in the production of each RVAM. At a minimum, each RVAM should identify the following: critical facilities and infrastructure, erosion and flood-hazard areas, evacuation routes, and transportation infrastructure. To understand and address potential socio-economic threats to the communities, it would be beneficial to include local zoning, property boundaries, and valuation data on RVAMs.

Recommendation #3

Develop an RVAM for each coastal community using a standardized GIS methodology.

Implementation Plan

Lead Agency:	Massachusetts Emergency Management Agency (MEMA), DCR, regional planning agencies, and municipalities
Funding Requirement:	yes
Potential Funding Source:	FEMA Hazard Mitigation Grant, state funds, and municipal funds
Next Steps:	form task force of stakeholders to develop the standardized GIS methodology
Project Duration:	5 years

Climate Change and Sea-Level Rise Data

The coastal zone is being severely impacted by erosion and flooding due in part to climate change and sea-level rise. It is likely that this impact will increase in the future as sea level continues to rise at the current rate or rises at an accelerated rate. Additional shoreline change and inundation data are needed to plan for and manage current and potential future impacts of sea-level rise. The Commonwealth should support efforts by the United States Geological Survey (USGS) and others to map the current and future vulnerability of coastal areas to erosion, inundation, and storm flooding. Light Detection and Ranging (LIDAR) and other subaerial and submarine data, as well as dynamic coastal geomorphic modeling, should be utilized. These data and information will be useful to a wide range of organizations for both short-term and long-term planning.

Recommendation #4

Map and model climate change and sea-level rise data related to coastal hazards in Massachusetts.

Implementation Plan

Lead Agency:	USGS
Funding Requirement:	yes
Potential Funding Source:	federal funds and state funds
Next Steps:	acquire funds, assess status of current data, and develop plan to collect new data
Project Duration:	5 years

Storm Event Data

Coastal conditions need to be recorded immediately after major storms to capture the nature, magnitude, and spatial variability of changes. High-water marks should be flagged by the Massachusetts Rapid Response Coastal Storm Damage Assessment Team (Storm Team) during their assessment of storm damage to preserve the shoreline indicators. Licensed surveyors can map the location of these flags after the storm. The Commonwealth should also make arrangements with the United States Army Corps of Engineers (USACE), USGS, and others to collect aerial photos and LIDAR data within a week of major storms. These data will be used for disaster recovery and erosion mitigation as well as to refine predictive storm models.

Recommendation #5

Develop a process to capture coastal conditions immediately after major storm events.

Implementation Plan

Lead Agency:	CZM and MEMA
Funding Requirement:	no
Next Steps:	form task force to identify opportunities, make arrangements with appropriate agencies, and train the Storm Team
Project Duration:	6 months

Storm Damage Projections

Estimates of the potential loss along the coast due to storm events can provide important information for decision makers and the public. Historical event data can be modeled with current coastal conditions including assessed values of buildings to produce such estimates of risk. Wind data for the Great New England Hurricane of 1938 has been modeled using HAZUS, a risk assessment software program developed by FEMA. HAZUS and other models should be used to produce estimates of physical damage, economic loss, and social impacts due to winds and flooding during storm events.

Recommendation #6

Model potential storm damage based on historical event data to educate decision makers and the public to the magnitude of risk in the coastal zone.

Implementation Plan

Lead Agency:	MEMA, DCR, and CZM for wind modeling; FEMA, USACE, and NOAA for inundation modeling
Funding Requirement:	yes
Potential Funding Source:	federal funds and state funds
Next Steps:	acquire funds and run scenarios using appropriate models
Project Duration:	2-4 years

Coastal Hazards Information Portal

Many organizations produce coastal hazards information, however, the information often does not reach its intended audience because they are not informed that it exists and it is not easily accessible. In addition to printed publications, organizations should post their information online and focus on outreach to inform potential users of the availability of new data and tools. A comprehensive list of coastal hazards information is necessary to direct people to the range of data and tools available, and inform them about the purpose and timeframe of the information. This list should be compiled and posted online as a searchable portal to the information. Contact information for technical staff that can assist with coastal hazards information should also be posted on the portal. The portal also should also be publicized and updated as new information becomes available. The Hazards Information Working Group compiled a preliminary list of data and tools to serve as the foundation for the implementation of this recommendation (Appendix B).

Recommendation #7

Create and maintain an online portal to resources, websites, and data-sharing systems that distribute coastal hazards information including data and tools.

Implementation Plan

Lead Agency:	NOAA Coastal Services Center, CZM, and the Massachusetts Office of Geographic and Environmental Information (MassGIS)
Funding Requirement:	yes
Potential Funding Source:	NOAA grants
Next Steps:	acquire funds, identify resources, and create database
Project Duration:	6-12 months

Coastal Hazards Outreach Evaluation

Coastal communities need coastal hazards and emergency management information before high winds, flooding, and erosion occur. This information helps residents and visitors to understand their risk, prepare emergency supply kits, evacuate, and find shelter if needed. Typical sources of information include web pages, television, radio, newspapers, and other printed materials. Public forums, highway signs, and emergency alert systems are also used to distribute information. The Commonwealth should evaluate whether coastal communities are adequately informed about coastal hazards and emergency management information before and during storm events. Coastal communities must be kept informed with up-to-date and accurate information and actions that government officials are requesting the public to take. Evacuation information, including route changes, especially needs to reach people during power outages.

Recommendation #8

Evaluate the distribution of coastal hazards and emergency management information to coastal communities before and during major storm events.

Implementation Plan

Lead Agency:	MEMA, CZM, and municipalities
Funding Requirement:	yes
Potential Funding Source:	state funds
Next Steps:	acquire funds and develop survey to be distributed to residents and visitors of high-risk coastal areas
Project Duration:	1 year

Policy

The Policy Working Group investigated local and state government policies as well as the insurance industry. The working group developed seven recommendations, with the creation of a storm-resilient communities program identified as a priority by the CHC (Recommendation #9). In addition, the working group recommended that guidance be developed on executive orders that address coastal floodplains and barrier beaches (Recommendation #10), outreach be developed for homeowners about insurance options (Recommendation #11), incentives be provided for lower homeowners insurance premiums (Recommendations #12 and #13), and funding be sought for voluntary land acquisition (Recommendations #14 and #15).

Storm-Resilient Communities Program

Smart growth is a way for communities to address coastal hazards issues and become more resilient to storms. Coastal smart growth is much more cost effective than paying for storm damage. However, many municipalities do not have the capacity to implement the comprehensive planning that is required to adopt smart growth measures. Often a municipality can find the capacity if a successful case study is available to demonstrate that their efforts will be effective and ultimately save time and money. The state should choose coastal communities, via a competitive process, that have some capacity to plan and implement smart growth measures to serve as models for a Storm-Resilient Communities Program. These model communities should be provided with funds and guidance to become more storm-resilient, ultimately serving as case studies for other communities.

Recommendation #9 (Priority)

Establish a storm-resilient communities program to provide case studies for effective coastal smart growth planning and implementation.

Implementation Plan

Lead Agency:	Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA)
Funding Requirement:	yes
Potential Funding Source:	state funds
Next Steps:	acquire funds and define the model storm-resilient community
Project Duration:	2-4 years

Executive Orders

Several state agencies are charged with managing activities in coastal areas. While there is communication between agencies, separate agency charges often make it difficult to effectively coordinate efforts and timelines. The implementation of certain state Executive Orders, such as 149 and 181, would improve with more effective interagency coordination. Both executive orders were intended to reduce vulnerability to coastal hazards, especially damage costs. Executive Order 149 provides guidance on the general use and development of floodplains. Executive Order 181 provides guidance specifically for development and management of barrier beaches. CZM is working with the Massachusetts Department of Environmental Protection (MassDEP) to draft a guidance document that addresses portions of Executive Order 181 and Executive Order 149. The final guidance document will provide the basis for consistent implementation and a simple tool to coordinate agency action.

Recommendation #10

Finalize guidance document for state and local agencies on the implementation of Executive Orders 149 and 181 relative to publicly funded infrastructure projects, and develop guidance for the remaining sections of Executive Order 149.

Implementation Plan

Lead Agency:	CZM and MassDEP
Funding Requirement:	no
Next Steps:	update and finalize draft guidance document
Project Duration:	1 year

Homeowners and Flood Insurance Outreach

Coastal homes are vulnerable to both wind and flood damage. Homeowners, however, often do not know that while wind loss is covered by their homeowners insurance policies, only the NFIP covers flood loss due to storm surge. Many homeowners insurers require a minimum wind percentage deductible and federal flood insurance as an underwriting requirement (Bowler, 2006). However, homeowners who are not required to carry insurance sometimes choose to go without it. Without adequate coverage, homeowners can face severe financial hardship in the event of wind or flood loss.

Recommendation #11

Provide additional outreach to coastal homeowners with insurance policies to ensure that they have appropriate wind and flood coverage, and to uninsured coastal homeowners to explain the importance of homeowners and flood insurance.

Implementation Plan

Lead Agency:	Massachusetts Division of Insurance (DOI)
Funding Requirement:	no
Next Steps:	work with homeowners insurers and realtors to provide information to homeowners
Project Duration:	1 year

Homeowners Insurance Premiums and Coverage

The cost and availability of homeowners insurance through the voluntary market has become a major issue in coastal areas, largely due to national catastrophic events in the past 15 years and the revision of catastrophe models. These events and models have resulted in an overall increase in the cost of reinsurance. Private insurance companies either pass their increased costs along to policyholders, or reduce the number of policies in coastal areas. Insurance companies that remain in the voluntary market are protected to some degree by the Massachusetts Insurers Insolvency Fund (Guaranty Fund), which is a nonprofit, unincorporated legal entity that covers claims up to $300,000 when insurers become insolvent. Many companies, however, have not renewed policies, especially in the Cape and Islands region, where approximately 14,000 policies in 2004, 24,000 in 2005, and 5,300 in the first half of 2006 were not renewed (Bowler, 2006). Homeowners who cannot get insurance through the voluntary market often get policies through the Massachusetts Fair Access to Insurance Requirements (FAIR) Plan. Approximately 42% of the FAIR Plan is comprised of policies in coastal rating territories (Bowler, 2006). Insurance companies that make up the Massachusetts Property Insurance Underwriting Association (MPIUA) are concerned about this increase in FAIR Plan policies. If the FAIR Plan experiences an underwriting loss, the member companies of the MPIUA will be assessed for the claims (Bowler, 2006).

Recommendation #12

Provide incentives, such as reduced insurance premiums, for retrofitting homes in coastal areas to lessen the potential risk due to storms.

Implementation Plan

Lead Agency:	DOI
Funding Requirement:	no
Next Steps:	form task force of stakeholders including private insurance companies and realtors to develop lists of approved retrofits and economic incentives
Project Duration:	2 years

Recommendation #13

Raise the maximum coverage of the Guaranty Fund above its $300,000 limit to lessen the impact of coastal disasters.

Implementation Plan

Lead Agency:	DOI and Legislature
Funding Requirement:	no
Next Steps:	file and support legislation
Project Duration:	2 years

Voluntary Land Acquisition

Costs associated with storm damage are felt by residents, communities, and the state. Acquisition of storm-prone properties from willing sellers lessens future costs and produces benefits for the public. Public acquisition of coastal land protects habitats, provides public access, increases recreational opportunities, and may protect the quality and quantity of ground water as well. Massachusetts has several land acquisition programs at the state and local level. While all of the state programs are authorized to acquire vulnerable coastal properties, that is not necessarily their primary purpose. However, acquisition of key coastal properties can meet the needs of the programs while also mitigating coastal hazards. There are several ways for municipalities to acquire storm-prone properties. The Community Preservation Act (CPA) is funded with property taxes and can be used for acquisition and preservation of open space. The state and municipalities should acquire storm-prone properties to reduce the risk of storm damage and associated social and environmental costs.

Recommendation #14

Conserve coastal land and minimize loss through acquisition of storm-prone properties from willing sellers in fee or through conservation restrictions and easements.

Implementation Plan

Lead Agency:	Department of Fish and Game (DFG) and DCR
Funding Requirement:	yes
Potential Funding Source:	state funds
Next Steps:	acquire funds and identify storm-prone properties
Project Duration:	5-10 years

Recommendation #15

Encourage coastal communities to adopt the CPA and use the Community Preservation Fund to acquire storm-prone properties.

Implementation Plan

Lead Agency:	Community Preservation Coalition
Funding Requirement:	no
Next Steps:	inform coastal communities about the CPA
Project Duration:	2-4 years

Planning and Regulations

The Planning and Regulations Working Group explored planning and regulatory options at the local and state level. Development and implementation of hazard mitigation plans was identified as a top priority (Recommendation #16). Other recommendations from this working group include: developing controls on coastal construction (Recommendation #17), coordinating local permitting (Recommendation #18), developing performance standards for land subject to coastal storm flowage (LSCSF) (Recommendation #19), holding a coastal conference (Recommendation #20), and addressing transportation infrastructure and flooding issues (Recommendation #21).

Hazard Mitigation Plans

Hazard mitigation planning and implementation of mitigation plans help coastal communities minimize damage from future storm events. Since communities are at different stages of planning, they should coordinate with and build upon existing efforts on the local, regional, state, and federal level. Hazard mitigation plans should include smart growth measures and address the potential impacts of climate change related sea-level rise. Development and implementation of hazard mitigation plans will also help communities participating in the Community Rating System (CRS) earn points toward flood insurance premium discounts for residents with NFIP policies.

CRS is a voluntary program administered by FEMA that provides incentives for communities to do specific flood protection activities. Presently, only 15 communities in Massachusetts participate in CRS. To promote the implementation of the hazard mitigation plans, communities should participate in CRS and develop RVAMs as part of their CRS efforts. A community receives credit points for approved activities, and the total number of credit points determines the discount that residents of that community receive on their flood insurance premiums. Discounts range from 5% to 45% of the premium. Participation in CRS may make communities eligible for grants to fund projects recommended in the hazard mitigation plans.

To ensure that coastal hazard mitigation plans are developed and implemented and that communities participate in CRS, the state should fund new staff positions dedicated to this goal. These new staff positions could be located in each of the CZM regions. As an alternative, the state should consider a one-to-one match with coastal communities to assist with the cost of plan implementation. The new Coastal Hazards Characterization Atlas from CZM will be useful in defining regional problems and identifying communities that can work together to develop and implement common CRS activities. Even with the Hazards Atlas, however, identifying and implementing CRS activities can be time and resource intensive. Communities that have developed coastal hazard mitigation plans should be eligible for state funding to assist with implementation of those plans.

Recommendation #16 (Priority)

Develop, update, and implement hazard mitigation plans for coastal communities.

Implementation Plan

Lead Agency:	MEMA, DCR, CZM, and regional planning agencies
Funding Requirement:	yes
Potential Funding Source:	FEMA grants, state funds, and municipal funds
Next Steps:	acquire funds and obtain tools and staff to oversee plan development and implementation
Project Duration:	ongoing

Coastal Construction

The Board of Building Regulations and Standards is currently updating the State Building Code. The standards of the International Building Code are the starting point for consideration of potential revisions. In its update, the Board of Building Regulations and Standards should explore coastal construction options, consider mechanisms to address incremental renovations and expansions, and encourage the use of strategies to maintain the form and function of natural resources. The Board of Building Regulations and Standards, MassDEP, and CZM should encourage local building inspectors and conservation agents to work together to provide understandable advice to homeowners and commercial property owners about what can and cannot be built on coastal lots. Joint training of building inspectors and conservation agents should also be explored to integrate resource protection and building requirements on coastal properties.

Recommendation #17

Update the State Building Code requirements for coastal construction, and encourage collaboration between building inspectors and Conservation Commissions.

Implementation Plan

Lead Agency:	Board of Building Regulations and Standards, MassDEP, and municipalities
Funding Requirement:	no
Next Steps:	finalize Technical Advisory Committee on Coastal Construction and Environmental Issues report
Project Duration:	6-12 months

Local Permit Coordination

Permitting of coastal structures is typically time-consuming and confusing for prospective builders. Many towns require a person seeking to build a structure in a coastal environment to deal with all relevant regulatory bodies independent of each other. There is often little communication between the various permitting authorities on the project, allowing for certain permits to be issued for projects before other issues are addressed. This lack of coordination allows for incomplete project review and promotes the inefficient use of resources. Coastal municipalities should coordinate project reviews of their various departments either through an informal process of coordination or a process set forth in by-laws.

For example, in some municipalities the Town Manager requires coordination between departments and uses a checklist to ensure that a proposed project is reviewed by the zoning board, board of health, conservation commission, planning board, fire department, and historical commission before permits are issued. Those departments with jurisdiction over the project have the opportunity to meet in a "Development Review Team Meeting" to decide how best to proceed in terms of the different requirements of each department. Coordination can result in a more streamlined process for the applicant and facilitate resolution of the issues of the various departments involved.

One specific topic that would benefit from more guidance from MassDEP and municipal-level coordination of project review is that of repairing septic systems in vulnerable coastal areas. In addition, MassDEP, CZM, and various local permitting authorities including conservation commissions and planning boards should work together to encourage the use of Low Impact Development techniques to preserve the flood control and storm damage prevention functions of coastal resources. This coordination should promote more complete and comprehensive understanding of a project and any related permits.

Recommendation #18

Develop informal local coordination processes or modify bylaws to provide for the coordination of permitting and approval by local departments.

Implementation Plan

Lead Agency:	chief elected municipal officials
Funding Requirement:	no
Next Steps:	assemble municipal agents to discuss opportunities for coordination
Project Duration:	6-12 months

Land Subject to Coastal Storm Flowage

Coastal velocity zones (V-zone) and other high risk areas (A-zone) of LSCSF are vulnerable to hazardous flooding, wave impact, and, in some cases, significant rates of erosion as a result of storm wave impact and scour. V- and A-zones in coastal areas are generally subject to repeated storm damage, which can result in loss of life and property, increased public expenditures for storm recovery activities, taxpayer subsidies for flood insurance and disaster relief, and risks for personnel involved in emergency relief programs. Alteration of land surfaces in A-zones could change drainage characteristics that may cause increased flood damage on adjacent properties. Currently, performance standards have not been established for LSCSF in the Wetlands Protection Act regulations. MassDEP should work with a balanced group of stakeholders to evaluate the need for and feasibility of performance standards or best management practices for LSCSF. The performance standards or best management practices should address the flood control and storm damage prevention functions of LSCSF.

Recommendation #19

Evaluate the feasibility of a guidance document or revisions to the Wetland Protection Act regulations to develop best management practices or performance standards for LSCSF.

Implementation Plan

Lead Agency:	MassDEP
Funding Requirement:	no
Next Steps:	identify stakeholders and schedule meeting
Project Duration:	6 months

Coastal Conference

Municipal and state officials should stay informed of advancements in technology and coastal management strategies by interacting with colleagues at a biannual coastal conference in Massachusetts. The public should also be encouraged to attend this conference to increase awareness and support of coastal hazards issues. The proceedings from the conference should be transcribed or recorded to allow easy public access. While some of the expenses of the conference can be offset with in-kind donations, additional financial resources need to be secured to develop and execute a successful program, secure keynote speakers, and attract a broad audience. Potential partners for the conference include the Sea Grant Program, the University of Massachusetts Boston, a Massachusetts Chapter of the Floodplain Managers Association (which would need to be developed), and the Massachusetts Association of Conservation Commissions.

Recommendation #20

Create a biannual coastal conference to provide coastal managers and members of the public with a forum for the exchange of knowledge, ideas, and experiences to prevent and address coastal hazards.

Implementation Plan

Lead Agency:	Sea Grant and CZM
Funding Requirement:	yes
Potential Funding Source:	NOAA grants
Next Steps:	identify scope of conference and partners
Project Duration:	1 year

Transportation Infrastructure and Flooding

Transportation crossings of wetlands and waterways have contributed to flooding and resource impairment by altering hydrology and degrading wetland storm damage/flood protection and habitat functions. In coastal areas, existing bridges and culverts are often too small to pass normal floodwater or tidal flows, and without the critical influence of normal tides, upstream estuarine wetlands become degraded. Inland crossings may impound water, thereby exacerbating flooding and posing significant obstacles to fish and wildlife movement. Associated tide gates, which directly manage flood waters, are often not maintained or do not function as designed.

As existing crossings deteriorate and are scheduled for replacement by local municipalities and state agencies, numerous opportunities arise to correct past errors by modifying structural designs to reduce flooding and improve environmental conditions. To ensure that new transportation infrastructure does not impair the storm damage and flood protection of coastal resource areas, early stages of transportation project planning should evaluate the proximity of proposed projects to areas subject to storm damage, flooding, and tidal influence. Failure to identify these features early on can result in projects that have adverse impacts on natural buffers to hydraulic storage and flow and that compromise the storm protection provided to landward property, infrastructure, and natural resources. The resulting impacts of such projects can include loss of life and property, increased public expenditures for storm recovery activities, taxpayer

subsidies for flood insurance and disaster relief, and risks for emergency personnel. To address issues associated with tide gate management, the Commonwealth should assign and provide funding for an agency to inventory, monitor, and oversee maintenance of tide gates to protect public safety and reduce flooding risks, similar in function to DCR Office of Dam Safety.

Recommendation #21

Identify existing culverts and tide gates associated with transportation crossings of coastal wetlands that are priorities for replacement due to flood hazards or environmental resource concerns, and address flooding, wetlands hydrology, and maintenance in the early stages of the design and implementation of new or replacement transportation projects that cross coastal wetlands and waterways.

Implementation Plan

Lead Agency:	Massachusetts Executive Office of Transportation (EOT), CZM, MassDEP, and USACE
Funding Requirement:	yes
Potential Funding Source:	state funds
Next Steps:	form working group to develop strategy
Project Duration:	1 year

Protection

The Protection Working Group evaluated structural and nonstructural measures to control erosion and stabilize shorelines. The eight recommendations of the working group encompass regional sand management (Recommendations #22-26), a technical advisory committee on innovative erosion control measures (Recommendation #27), and the prioritization of public shoreline protection projects (Recommendations #28-29). Regional sand management, especially the identification and use of offshore sources of sediment for beach nourishment, is a priority of the CHC.

Regional Sand Management

Extensive armoring and alteration of the Commonwealth's shorelines has, over time, contributed to a significant reduction in the amount of source sediment available to natural sand-sharing systems, resulting in increased erosion of beaches, dunes and barrier beaches, which increases vulnerability to the natural and built environment from coastal storms and flooding. With accelerating erosion rates and sea-level rise predicted to accelerate, regional sediment management will become even more important in the future. At the present time, sediment budget data that quantifies sources and sinks of sediment along the coast of Massachusetts are completely lacking. To better manage beaches for environmental and economic benefits, sediment budgets and regional sediment management are important. Additionally, a guidance document would help facilitate the siting and review of projects that balance the need for acquisition of clean, compatible sediment for beach nourishment with other interests.

Sand dredged from tidal inlets leading into harbors on Cape Cod is routinely pumped onto nearby eroding public beaches. However, this practice of beneficial re-use of dredged sand is not routinely carried out in other regions of Massachusetts. In particular, USACE uses the policy of "the least costly, environmentally acceptable dredged disposal alternative." This usually means nearshore disposal, not beach placement. Early coordination with the USACE and a dedicated fund to supplement their least costly alternative is necessary to get dredged sand pumped onto nearby beaches.

Recommendation #22 (Priority)

Implement a program of regional sand management through policies, regulations, and activities that promote nourishment as the preferred alternative for coastal hazard protection.

Implementation Plan

* See Recommendations #23-26 below.

Recommendation #23

Develop a process using existing or newly enacted policies and/or regulations, which (1) improves coordination between the USACE, state agencies, and municipalities, (2) identifies cost-share funds, and (3) achieves permit requirements in a timely manner, so as to ensure that all dredged material suitable for beach nourishment will be placed on adjacent or nearby eroding public beaches.

Implementation Plan

Lead Agency:	CZM
Funding Requirement:	no
Next Steps:	establish communication between CZM dredge coordinator and USACE
Project Duration:	ongoing

Recommendation #24

Conduct a regional sand management study that identifies (1) critically eroding public beaches where access is open to the public, (2) areas most vulnerable to coastal hazards, and (3) potential regional nourishment methodology and costs.

Implementation Plan

Lead Agency:	CZM
Funding Requirement:	yes
Potential Funding Source:	NOAA Coastal Zone Enhancement (Section 309) Grant
Next Steps:	develop request for proposals
Project Duration:	1-2 years

Recommendation #25

Identify and map potential offshore and inland sources of suitable nourishment sediment.

Implementation Plan

Lead Agency:	USGS
Funding Requirement:	yes
Potential Funding Source:	federal funds
Next Steps:	map existing data
Project Duration:	5 years

Recommendation #26

Update and finalize existing draft document entitled Assessing Potential Environmental Impacts of Offshore Sand and Gravel Mining for the Purposes of Beach Nourishment to include contemporary state of knowledge regarding the potential short and long-term physical and biological impacts associated with offshore sediment removal.

Implementation Plan

Lead Agency:	EOEEA
Funding Requirement:	no
Next Steps:	develop consensus to update and finalize draft document
Project Duration:	1 year

Technical Advisory Committee on Innovative Erosion Control Measures

Increasingly, coastal property owners, engineers, and manufacturers are advocating for coastal protection approaches that incorporate the use of "new and innovative" protection alternatives. Lack of actual performance and impact data, coupled with difficulties fitting such proposals into the existing regulatory framework, often make permitting difficult. Other states have established processes for reviewing innovative erosion control projects and may serve as models for Massachusetts. The list of potential benefits and impacts of established protection alternatives compiled by the Protection Working Group should be a valuable resource during the implementation of this recommendation (Appendix C).

Recommendation #27

Establish a Technical Advisory Committee, consisting of a broad range of qualified professionals, to evaluate and develop construction and monitoring guidance, and recommend appropriate approval conditions for those protection approaches determined to be new and innovative.

Implementation Plan

Lead Agency:	EOEEA
Funding Requirement:	no
Next Steps:	identify members and hold first planning meeting
Project Duration:	ongoing

Prioritization of Public Shoreline Protection Projects

Often during benefit-cost analyses for shoreline protection projects, environmental resources are undervalued or not considered at all. The current decision-making framework to prioritize funding of public shoreline protection projects could significantly benefit from an improved benefit-cost analysis that includes natural resources values, and economic data on the value of beaches to the Commonwealth. The results of these studies will allow for a comparative evaluation for competitive funding of public projects.

Recommendation #28

Build upon an ongoing study by WHOI Sea Grant and the Cape Cod Cooperative Extension to quantify the inherent values of Cape Cod coastal beaches for storm damage protection, recreation, and wildlife habitat to develop similar values for all Massachusetts beaches.

Implementation Plan

Lead Agency:	Woods Hole Oceanographic Institution (WHOI) Sea Grant and Cape Cod Cooperative Extension
Funding Requirement:	yes
Potential Funding Source:	WHOI funds and Cape Cod and Islands License Plate Campaign funds
Next Steps:	acquire funds and release request for response
Project Duration:	1-2 years

Recommendation #29

Develop a standardized benefit-cost analysis model using an approach adapted from that used by the USACE to justify projects that fully compares the capital, societal, and natural resource benefits and costs of proposed shoreline protection projects and appropriate alternatives.

Implementation Plan

Lead Agency:	EOEEA and academic or research institute
Funding Requirement:	yes
Potential Funding Source:	private grants
Next Steps:	identify lead researcher and acquire funding
Project Duration:	2 years

CHAPTER 3 - INFRASTRUCTURE INVENTORY

The Infrastructure Plan Working Group of the Coastal Hazards Commission (CHC) was tasked with prioritizing coastal structure maintenance and repairs. As a result, the working group did not draft recommendations similar to those of the other four working groups.

South Shore Pilot Project

Many types of structures exist along the coast of Massachusetts to protect buildings and infrastructure constructed prior to coastal management policies and regulations. Historically, coastal land was developed out of economic necessity. Commercial development primarily included piers, wharfs, and warehouses. Residential development, roads, and other infrastructure followed due to increasing population demand and the desire to work and live near the ocean. Public and private buildings along the coast are often more valuable than their inland complements and represent an extraordinary economic investment. Today, maintenance of coastal structures built prior to 1978 to protect public and private development in dynamic coastal areas challenges the Commonwealth, municipalities, and individuals.

The Infrastructure Plan Working Group focused primarily on shoreline stabilization structures and their ability to resist major coastal storms and prevent damage due to flooding and erosion. Since ownership and maintenance are major issues for these coastal structures, a pilot project to research, inventory, survey, and assess existing coastal infrastructure was conducted along the shoreline from Hingham to Plymouth (South Shore). This coastal region was chosen since it represents the variable characteristics of the other four coastal regions in Massachusetts (Figure 1). An atlas of coastal hazards on the South Shore has also been completed and is a valuable resource for this project (Applied Coastal Research and Engineering, Inc., 2006). A methodology was developed to replicate the project along the North Shore, Boston Harbor, Cape Cod and Islands, and South Coast.

The objectives of the South Shore infrastructure inventory were to:

1. Inventory and assess the condition of coastal hazards protection infrastructure owned by the Commonwealth, maintained by the Commonwealth, and/or otherwise the responsibility of the Commonwealth using a standard methodology that can be applied to coastal infrastructure along the remainder of the Massachusetts shoreline; and

2. Develop a working database of coastal structure information, with appropriate Geographic Information System (GIS) files, which can be expanded to include future work covering the remainder of the shoreline and can be used by the Commonwealth to plan and budget for maintenance, repair, and/or reconstruction needs.

Potential municipal and state-owned coastal structures on the South Shore, identified through state and local records research, were located, recorded, and described. Coastal structures encompassed hard or man-made structures including seawalls, revetments, bulkheads, groins, jetties, breakwaters, and dikes or levees that are designed to control coastal hazards by preventing erosion

and flooding from damaging property. Soft or natural landforms including beaches, dunes, and coastal banks that are managed to provide protection and minimize potential damage to property were also considered structures for this inventory. Civil engineers performed initial condition surveys and, based on visual inspections, described and assessed the general condition of each structure. Geographically referenced digital photographs were taken of each structure to supplement the inspections. The visual inspections resulted in the rating of each structure according to its condition using a letter system (Table 1). Each structure was also assigned a priority rating based on its condition and ability to protect buildings from coastal hazards (Table 2). The capacity of the shoreline stabilization structure to protect infrastructure, such as roads and utilities, was not considered in the analysis due to time and resource constraints.

South Shore Preliminary Findings

A final draft of the South Shore Pilot Project report, including GIS data files, is currently being reviewed by members of the working group with completion of work anticipated for the end of March. Some preliminary findings from this report are presented below.

Along the South Shore, 312 publicly owned coastal structures were assessed (Bourne Consulting Engineering, 2006). The structures included bulkheads, seawalls, revetments, groins, jetties, and breakwaters (Table 3). Bulkheads and seawalls were the most abundant, with a combined total of 177 (57%). The condition of the structures ranged from excellent (A) to critical (F), but the majority of the structures were either in good (B) or fair (C) condition. Overall, 152 (49%) structures are stable and 160 (51%) need moderate to immediate repair (Figure 2). The priority ratings of the structures are currently being finalized. These findings, along with the results of the projects in the remaining coastal regions, will serve as the beginning of the development of a statewide plan for maintenance and/or repair of the Commonwealth's coastal structures.

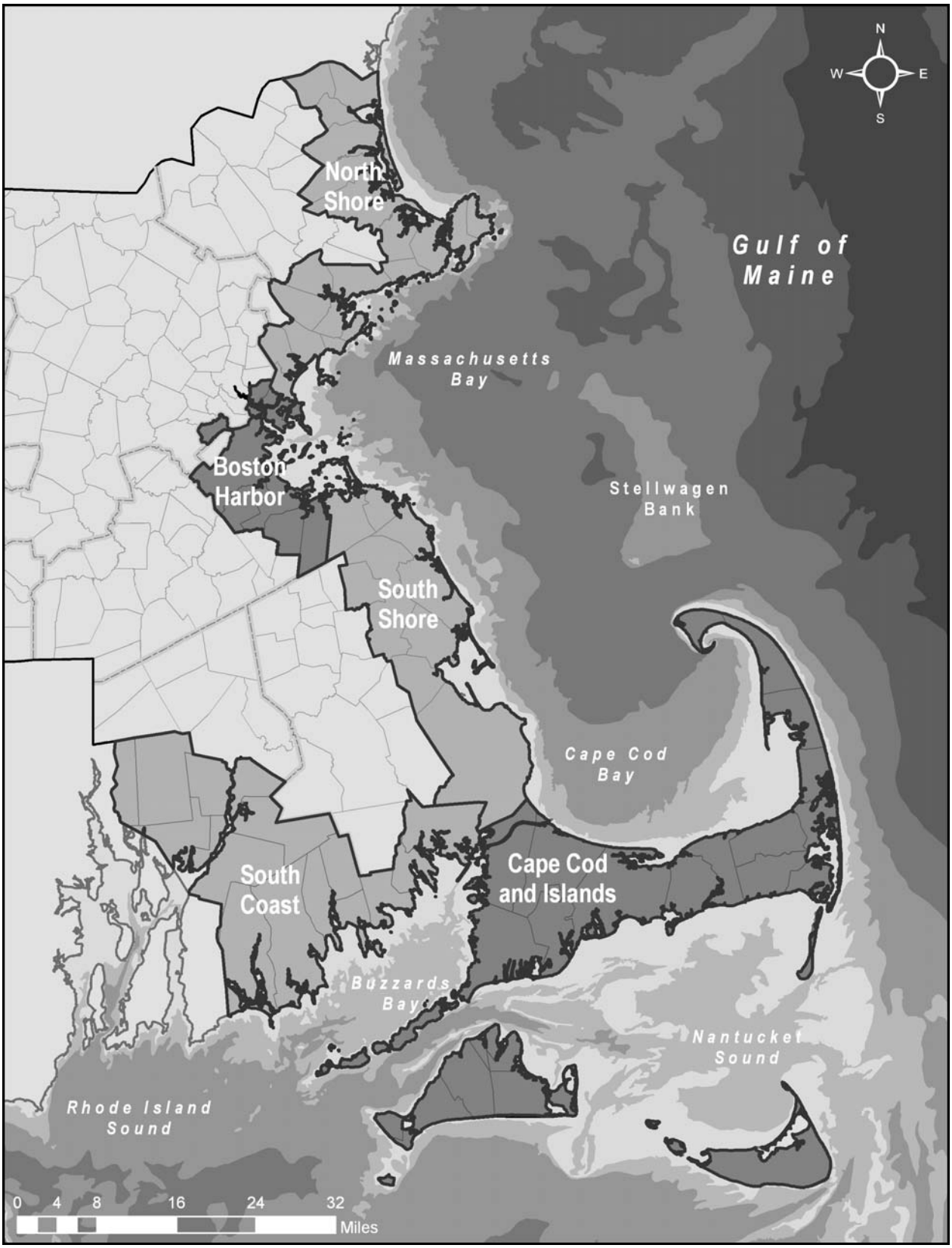

Figure 1. Five coastal regions of Massachusetts.

Table 1. Rating system for the condition of coastal structures (modified after Bourne Consulting Engineering, 2006).

Condition		Definition*	Action Required
A	Excellent	Structure is like new and expected to withstand major coastal storm without damage. Landform (beach, dune, or bank) is stable and will provide adequate protection from major coastal storm.	None
B	Good	Structure exhibits very minor problems, superficial in nature. Minor erosion to landform is present. Structure and landform are adequate to provide protection from a major coastal storm with no damage. Actions could be taken to prevent or limit future deterioration and extend life of structure.	Minor
C	Fair	Structure is sound, but may exhibit minor deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure is adequate to withstand major coastal storm with little to moderate damage. Actions should be taken to reinforce structure to provide full protection from major coastal storm and to extend life of structure. Moderate wind or wave damage to landform exists. Landform may not be sufficient to fully protect shoreline during a major coastal storm. Actions should be taken to provide additional material for full protection and extended life.	Moderate
D	Poor	Structure exhibits advanced levels of deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure should be monitored until repairs or reconstruction can be initiated. Reconstruction is required to regain full capacity of structure to resist a major coastal storm. Landform is eroded and its stability is threatened. Landform is not adequate to provide protection during major coastal storm. Actions to recreate landform to provide full protection from a major coastal storm are required.	Major
F	Critical	Structure exhibits critical levels of deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure provides little or no protection from a major coastal storm. Complete reconstruction of the structure is necessary to regain full protective capacity. Landform is eroded and integrity is lost. Landform stability is severely compromised, rate of erosion or material loss may be increasing, and landform does not provide adequate protection from a major coastal storm. Actions to recreate landform to provide full protection from a major coastal storm are required. Conditions of structure and landform may warrant emergency stabilization as failure may result in potential loss of property and/or life.	Immediate

* Based upon perceived immediacy of action and potential to cause damage if not corrected.

Table 2. Rating system for the prioritization of coastal structure repair (modified after Bourne Consulting Engineering, 2006).

Priority		Definition*	Action Required
I	None	No landward structures or residential dwelling units present.	Consider long-term planning.
II	Low Priority	Landward structures present with limited potential for significant infrastructure damage.	Consider for future project.
III	Moderate Priority	Landward structures present with potential for infrastructure damage and/or limited residential dwellings (<1 dwelling impacted/100 feet of shoreline).	Consider for active project.
IV	High Priority	High-value landward structures present with potential for infrastructure damages and/or moderate density residential dwellings (1-10 dwellings impacted/100 feet of shoreline).	Consider for next project.
V	Immediate/ Highest Priority	Critical landward structures present with potential for infrastructure damage and/or high-density residential dwellings. Conditions of structure may warrant emergency stabilization as failure may result in potential loss of property and/or life (>10 dwellings impacted/100 feet of shoreline).	Consider for immediate action due to public safety and welfare issues.

* Based upon perceived immediacy of action and presence of potential risk to inshore structures if not corrected.

Table 3. Quantity and condition of coastal structures along the South Shore.

	A	B	C	D	F	Total
Bulkhead/Seawall	8	84	68	15	2	177
Revetment	7	46	44	11	1	109
Groin/Jetty	0	7	8	6	3	24
Breakwater	0	0	2	0	0	2
Total	15	137	122	32	6	312

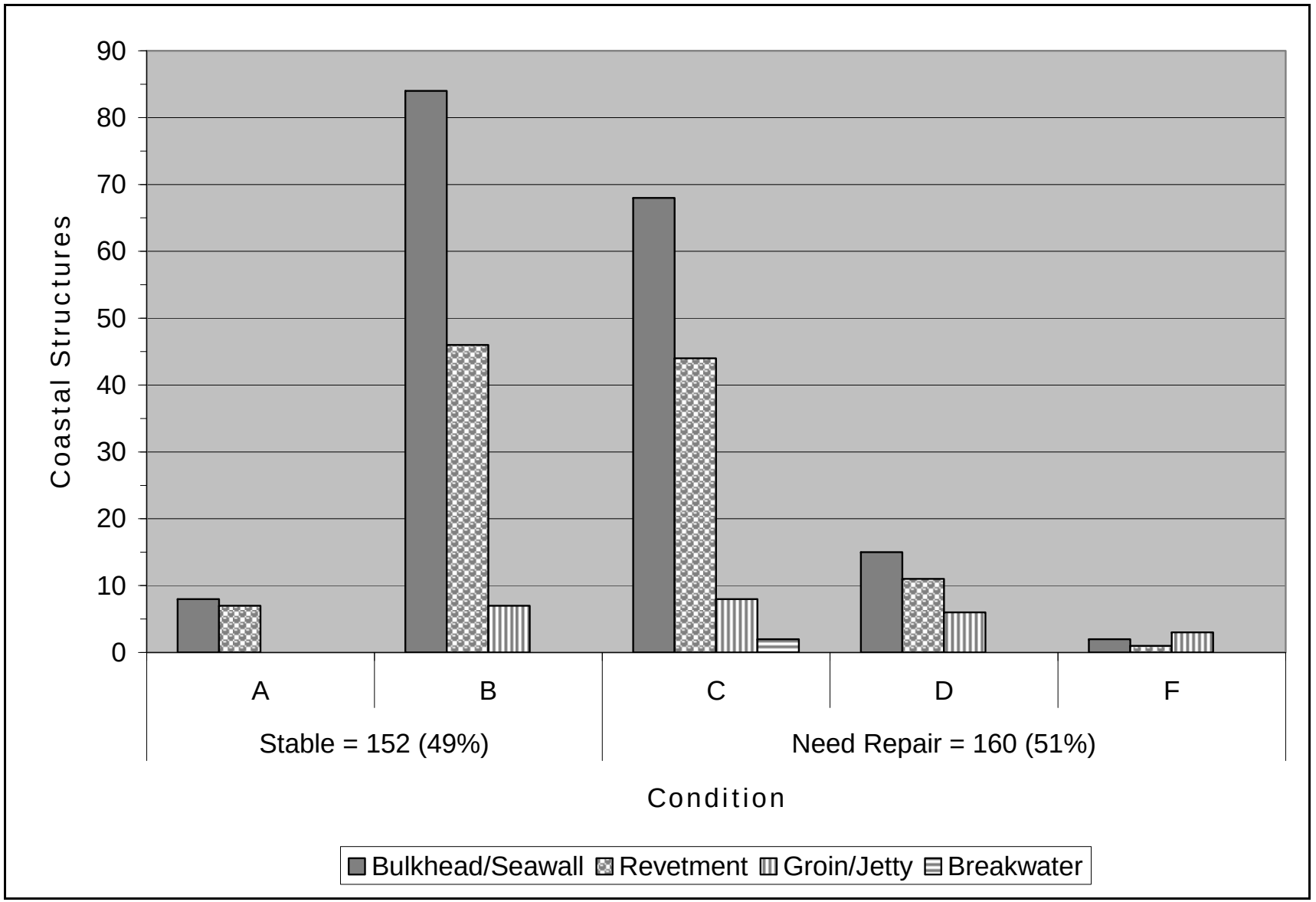

Figure 2. Condition of coastal structures on the South Shore.

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APPENDIX A - LIST OF RECOMMENDATIONS

	Recommendation	Lead Agency	Funds Required
Hazards Information			
1	**Assist FEMA financially and technically to update and maintain FIRMs for the coastal zone of Massachusetts. (Priority)**	**DCR**	**Yes**
2	Compile Coastal Hazards Characterization Atlases for the North Shore, South Coast, Cape Cod and Islands, and Boston Harbor regions.	CZM	Yes
3	Develop an RVAM for each coastal community using a standardized GIS methodology.	MEMA and DCR	Yes
4	Map and model climate change and sea-level rise data related to coastal hazards in Massachusetts.	USGS	Yes
5	Develop a process to capture coastal conditions immediately after major storm events.	CZM and MEMA	No
6	Model potential storm damage based on historical event data to educate decision makers and the public to the magnitude of risk in the coastal zone.	MEMA, DCR, CZM, FEMA, USACE, and NOAA	Yes
7	Create and maintain an online portal to resources, websites, and data-sharing systems that distribute coastal hazards information including data and tools.	NOAA, CZM, and MassGIS	Yes
8	Evaluate the distribution of coastal hazards and emergency management information to coastal communities before and during major storm events.	MEMA and CZM	Yes
Policy			
9	**Establish a storm-resilient communities program to provide case studies for effective coastal smart growth planning and implementation. (Priority)**	**EOEEA**	**Yes**
10	Finalize guidance document for state and local agencies on the implementation of Executive Orders 149 and 181 relative to publicly funded infrastructure projects, and develop guidance for the remaining sections of Executive Order 149.	CZM and MassDEP	No
11	Provide additional outreach to coastal homeowners with insurance policies to ensure that they have appropriate wind and flood coverage, and to uninsured coastal homeowners to explain the importance of homeowners and flood insurance.	DOI	No
12	Provide incentives, such as reduced insurance premiums, for retrofitting homes in coastal areas to lessen the potential risk due to storms.	DOI	No
13	Raise the maximum coverage of the Guaranty Fund above its $300,000 limit to lessen the impact of coastal disasters.	DOI and Legislature	No
14	Conserve coastal land and minimize loss through acquisition of storm-prone properties from willing sellers in fee or through conservation restrictions and easements.	DFG and DCR	Yes
15	Encourage coastal communities to adopt the CPA and use the Community Preservation Fund to acquire storm-prone properties.	Community Preservation Coalition	No
Planning and Regulations			
16	**Develop, update, and implement hazard mitigation plans for coastal communities. (Priority)**	**MEMA, DCR, and CZM**	**Yes**
17	Update the State Building Code requirements for coastal construction, and encourage collaboration between building inspectors and Conservation Commissions.	MassDEP	No

18	Develop informal local coordination processes or modify bylaws to provide for the coordination of permitting and approval by local departments.	Municipal Officials	No
19	Evaluate the feasibility of a guidance document or revisions to the Wetland Protection Act regulations to develop best management practices or performance standards for LSCSF.	MassDEP	No
20	Create a biannual coastal conference to provide coastal managers and members of the public with a forum for the exchange of knowledge, ideas, and experiences to prevent and address coastal hazards.	Sea Grant and CZM	Yes
21	Identify existing culverts and tide gates associated with transportation crossings of coastal wetlands that are priorities for replacement due to flood hazards or environmental resource concerns, and address flooding, wetlands hydrology, and maintenance in the early stages of the design and implementation of new or replacement transportation projects that cross coastal wetlands and waterways.	EOT, CZM, MassDEP, and USACE	Yes
Protection			
22	**Implement a program of regional sand management through policies, regulations, and activities that promote nourishment as the preferred alternative for coastal hazard protection. (Priority)**	**See #23-26**	
23	Develop a process using existing or newly enacted policies and/or regulations, which (1) improves coordination between the USACE, state agencies, and municipalities, (2) identifies cost-share funds, and (3) achieves permit requirements in a timely manner, so as to ensure that all dredged material suitable for beach nourishment will be placed on adjacent or nearby eroding public beaches.	CZM	No
24	Conduct a regional sand management study that identifies (1) critically eroding public beaches where access is open to the public, (2) areas most vulnerable to coastal hazards, and (3) potential regional nourishment methodology and costs.	CZM	Yes
25	Identify and map potential offshore and inland sources of suitable nourishment sediment.	USGS	Yes
26	Update and finalize existing draft document entitled *Assessing Potential Environmental Impacts of Offshore Sand and Gravel Mining for the Purposes of Beach Nourishment* to include contemporary state of knowledge regarding the potential short and long-term physical and biological impacts associated with offshore sediment removal.	EOEEA	No
27	Establish a Technical Advisory Committee, consisting of a broad range of qualified professionals, to evaluate and develop construction and monitoring guidance, and recommend appropriate approval conditions for those protection approaches determined to be new and innovative.	EOEEA	No
28	Build upon an ongoing study by WHOI Sea Grant and the Cape Cod Cooperative Extension to quantify the inherent values of Cape Cod coastal beaches for storm damage protection, recreation, and wildlife habitat to develop similar values for all Massachusetts beaches.	WHOI Sea Grant and Cape Cod Cooperative Extension	Yes
29	Develop a standardized benefit-cost analysis model using an approach adapted from that used by the USACE to justify projects that fully compares the capital, societal, and natural resource benefits and costs of proposed shoreline protection projects and appropriate alternatives.	EOEEA	Yes

APPENDIX B - COASTAL HAZARDS DATA AND TOOLS

The Hazards Information Working Group developed the following list of coastal hazards data and tools organized according to four categories: Mitigation Planning, Storm Monitoring, Response and Recovery, and Public Outreach. The working group recommends that this list serve as the foundation for the coastal hazards information portal (Recommendation #7).

Category	Organization	Title	Type	Source
Mitigation Planning	AIR Worldwide Corporation	MA Association of Insurance Agents Annual Convention Wrap-Up	Current Report	http://www.air-worldwide.com
Mitigation Planning	AIR Worldwide Corporation	Major Hurricane Strikes New York and New England: How Large Will the Losses Be?	Current Presentation	http://www.air-worldwide.com
Mitigation Planning	AIR Worldwide Corporation	The Coastline at Risk: Estimated Insured Value of Coastal Properties	Current Report	http://www.air-worldwide.com
Mitigation Planning	Cape Cod Commission	Cape Cod Atlas of Tidally Restricted Salt Marshes	Maps	http://www.capecodcommission.org/tidalatlas
Mitigation Planning	Clark University	Assessing the Vulnerability of Coastal Communities to Extreme Storms: The Case of Revere, MA, USA	Current Report	Clark, G.E., Moser, S.C., Ratick, S.J., Dow, K., Meyer, W.B., Emani, S., Jin, W., Kasperson, J.X., Kasperson, R.E., Schwarz, H.E, Mitigation and Adaptation Strategies for Global Change, 3(1): 59-82
Mitigation Planning	CZM	Art and Science of Identifying Flood Zones	Current Report	http://www.mass.gov/czm/coastlines/2002/c26.htm
Mitigation Planning	CZM	Coastal Structures Inventory	Current Data	http://www.mass.gov/czm
Mitigation Planning	CZM	Massachusetts Ocean Resource Information System	Current Data	http://www.mass.gov/czm/morisint.htm
Mitigation Planning	CZM	Shoreline Change Project	Historical Data	http://www.mass.gov/czm/hazards/shoreline_change/shorelinechange.htm
Mitigation Planning	CZM	South Shore Coastal Hazards Characterization Atlas	Maps	http://www.mass.gov/czm/hazards/ss_atlas/atlas.htm

Mitigation Planning	CZM Buzzards Bay Project National Estuary Program	Atlas of Tidally Restricted Salt Marshes in the Buzzards Bay Watershed, Massachusetts	Maps	http://www.buzzardsbay.org/smatlasmain.htm
Mitigation Planning	CZM Wetlands Restoration Program	Atlas of Tidally Restricted Marshes: North Shore of Massachusetts	Maps	http://www.mass.gov/czm/wrp/index.htm
Mitigation Planning	DCR and MEMA	MA State Hazard Mitigation Plan	Current Report	http://www.mass.gov/Eeops/docs/mema/2004_ma_approved_state_hm_plan.pdf
Mitigation Planning	FEMA	Coastal Construction Manual	Current Report	http://www.fema.gov/rebuild/mat/fema55.shtm
Mitigation Planning	FEMA	Flood Insurance Studies	Historical Reports	http://www.fema.gov/hazard/map/fis.shtm
Mitigation Planning	FEMA	Flood Map Store and Map Service Center	Maps	http://msc.fema.gov
Mitigation Planning	FEMA	HAZUS	Model	http://www.fema.gov/plan/prevent/hazus
Mitigation Planning	FEMA	Q3 Flood Data	Current Data	http://msc.fema.gov/webapp/wcs/stores/mapstore/docs/nuser_gd.pdf
Mitigation Planning	FEMA, NOAA National Weather Service, and USACE	Sea, Lake, and Overland Surge from Hurricanes Model	Model	http://www.fema.gov/plan/prevent/nhp/slosh_link.shtm
Mitigation Planning	MassGIS	Datalayers/GIS Database	Current Data	http://www.mass.gov/mgis/laylist.htm
Mitigation Planning	Metropolitan Area Planning Council	Atlas of Tidal Restrictions on the South Shore of Massachusetts	Current Report	http://www.mapc.org
Mitigation Planning	Municipalities	Local Hazard Mitigation Plans	Current Reports	various
Mitigation Planning	Municipalities	Local Risk and Vulnerability Assessment Maps	Maps	various
Mitigation Planning	Municipalities	Parcel Maps	Maps	various

Mitigation Planning	National Sea Grant	Coastal Hazards Digital Library	Current Reports	http://nsgl.gso.uri.edu/hazard.html
Mitigation Planning	National States Geographic Information Council	Ramona GIS Inventory System	Current Data	http://ma.gisinventory.net
Mitigation Planning	NOAA Coastal Services Center	Community Vulnerability Assessment Tool: New Hanover County, North Carolina Case Study	Study	http://www.csc.noaa.gov/products/nchaz/startup.htm
Mitigation Planning	NOAA National Hurricane Center	Hurricane History	Historical Data	http://www.nhc.noaa.gov/HAW2/english/history.shtml
Mitigation Planning	NOAA National Weather Service	A Centennial Review of Major Land Falling Tropical Cyclones in Southern New England	Historical Report	http://www.erh.noaa.gov/box/papers2.shtml
Mitigation Planning	NOAA National Weather Service	A Study of Moderate Coastal Flood Events Along the Eastern Massachusetts Shoreline	Historical Report	http://www.erh.noaa.gov/box/papers2.shtml
Mitigation Planning	NOAA National Weather Service	Descriptive Hurricane Information	Historical Reports	http://www.erh.noaa.gov/box/HurricaneInfo.shtml
Mitigation Planning	NOAA National Weather Service	Hurricane Research Division Reanalysis Project	Historical Data	http://www.aoml.noaa.gov/hrd/hurdat/DataByYearandStorm.htm
Mitigation Planning	NOAA National Weather Service	Storm Series: Tropical Storm Floyd, September 16, 1999	Historical Report	http://www.erh.noaa.gov/box/papers2.shtml
Mitigation Planning	NOAA National Weather Service	The Distribution of Precipitation Over the Northeast Accompanying Landfalling and Transitioning Tropical Cyclones	Historical Report	http://www.erh.noaa.gov/box/papers2.shtml
Mitigation Planning	OPeNDAP	Open-Source Project for a Network Data Access Protocol	Historical Data	http://www.opendap.org/data/datasets.cgi?xmlfilename=datasets.xml&exfunction=none

Mitigation Planning	Regional Planning Agencies	Regional Risk and Vulnerability Assessment Maps	Maps	various
Mitigation Planning	Tufts University	Climate's Long-Term Impacts on Metro Boston Project	Current Report	http://www.tufts.edu/tie/climb
Mitigation Planning	University of South Carolina Hazards Research Lab	Spatial Hazard Events and Losses Database for the United States	Historical Data	http://www.cas.sc.edu/geog/hrl/SHELDUS.html
Mitigation Planning	University of Rhode Island Coastal Resources Center	Storm Surge User Needs Report to NOAA	Current Report	http://www.crc.uri.edu/index.php?filespec=live_data.php&actid=255
Mitigation Planning	USACE	Feasibility Studies	Historical Reports	http://www.nae.usace.army.mil/library/libHP.html
Mitigation Planning	USACE	Hurricane Evacuation Study Reports	Current Reports	http://www.nae.usace.army.mil/projects/ma/hurricanemaps/hurricanestudies.htm
Mitigation Planning	USACE	Hurricane Surge Inundation Maps for New England	Maps	http://www.nae.usace.army.mil/projects/ma/hurricanemaps/hurricanestudies.htm
Mitigation Planning	USACE	Tidal Flood Profiles, New England Coastline	Historical Data	http://naelibrary.nae.usace.army.mil/dp191/ned88067.pdf
Mitigation Planning	USGS	Geologic/Sediment Character Maps of the Coast and Offshore Regions	Maps	http://marine.usgs.gov
Mitigation Planning	USGS	LIDAR Data	Current Data	http://marine.usgs.gov
Mitigation Planning	USGS	Models for Geomorphic Evolution of the Coast in Response to Sea-Level Rise	Models	http://marine.usgs.gov
Mitigation Planning	USGS	Models of Oceanographic Processes (Waves, Currents) for Mass Bay	Models	http://marine.usgs.gov
Mitigation Planning	USGS	National Assessment of Shoreline Change Project	Historical Data	http://coastal.er.usgs.gov/shoreline-change
Mitigation Planning	USGS	National Atlas of the United States	Historical Data	http://www.nationalatlas.gov/index.html

Mitigation Planning	USGS	Record of Relative Sea-Level Change for the Past 18,000 Years	Historical Data	http://marine.usgs.gov
Mitigation Planning	USGS	Reports on Geologic History of the Coast	Historical Reports	http://marine.usgs.gov
Mitigation Planning	USGS	Reports on Storm Effects, "Hot Spot" Erosion on Cape Cod	Current Reports	http://marine.usgs.gov
Mitigation Planning	USGS	Topographic DEM Data	Current Data	http://marine.usgs.gov
Mitigation Planning	WHOI Sea Grant	Volunteer Beach Profile Data	Current Data	http://www.whoi.edu/seagrant/index.html
Storm Monitoring	AWS Convergence Technologies WeatherBug	HurricaneNet	Maps	http://www.instaweather.com/hurricane
Storm Monitoring	GoMOOS	Gulf of Maine Ocean Observing System	Current Data	http://www.gomoos.org/buoy/buoy_data.shtml
Storm Monitoring	NOAA National Data Buoy Center	Buoy Data	Current Data	http://www.ndbc.noaa.gov/Maps/Northeast.shtml
Storm Monitoring	NOAA National Ocean Service	Tide Gauge Data	Current Data	http://tidesonline.nos.noaa.gov/geographic.html
Storm Monitoring	NOAA National Weather Service	Advanced Hydrologic Prediction Service	Forecasts	http://www.weather.gov/oh/ahps
Storm Monitoring	NOAA National Weather Service	FLDWAV	Model	http://www.nws.noaa.gov/oh/hrl/rvrmech/fld_avail.htm
Storm Monitoring	NOAA National Weather Service	Forecasts	Forecasts	http://www.erh.noaa.gov/er/box
Storm Monitoring	NOAA National Weather Service	National Hurricane Center Tropical Prediction Center	Forecasts	http://www.nhc.noaa.gov
Storm Monitoring	NOAA National Weather Service	Radar Image	Current Data	http://weather.noaa.gov/radar/latest/DS.p19r0/si.kbox.shtml
Storm Monitoring	USGS	Real-Time Data for Massachusetts	Current Data	http://waterdata.usgs.gov/ma/nwis/rt

Storm Monitoring	USGS	WaterWatch	Current Data	http://water.usgs.gov/cgi-bin/waterwatch?state=ma&map_type=flood&web_type=table
Response and Recovery	FEMA	Emergency Management Institute Training and Education	Training	http://www.training.fema.gov
Response and Recovery	George Washington University Institute for Crisis, Disaster and Risk Management	Publications	Current Reports	http://www.gwu.edu/~icdrm/publications/index.html
Response and Recovery	MEMA	Emergency Response Training	Training	http://www.mass.gov/Eeops/docs/mema/mema_training_calendar.pdf
Response and Recovery	MEMA	State Comprehensive Emergency Management Plan	Current Report	http://www.mass.gov/?pageID=eopsmodulechunk&&L=3&L0=Home&L1=Public+Safety+Agencies&L2=Massachusetts+Emergency+Management+Agency&sid=Eeops&b=terminalcontent&f=mema_cemp_rev3&csid=Eeops
Response and Recovery	NOAA National Weather Service	HURREVAC	Model	http://hurricanes.noaa.gov/prepare/hurrevac.htm
Public Outreach	CZM	Public Access Website	Current Reports	http://www.mass.gov/czm/beachestom.htm
Public Outreach	FEMA NFIP	Flood Smart	Current Reports	http://www.floodsmart.gov
Public Outreach	Institute for Business and Home Safety	Publications	Current Reports	http://www.ibhs.org
Public Outreach	Insurance Information Institute	Facts and Statistics: Hurricanes	Current Data	http://www.iii.org/media/facts/statsbyissue/hurricanes
Public Outreach	Northeast States Emergency Consortium	Hazards	Current Reports	http://www.nesec.org/hazards
Public Outreach	Northeast States Emergency Consortium	Power of Prevention: Taking Action Before Disaster Strikes	Current Report	http://www.nesec.org/brochure.pdf

APPENDIX C - POTENTIAL BENEFITS AND IMPACTS OF PROTECTION ALTERNATIVES

The Protection Working Group, whose members included geologists, engineers, and fisheries biologists from public and private scientific and regulatory agencies, analyzed structural and nonstructural alternatives to protect development from flooding, erosion, and other coastal hazards. This analysis lead to the development of the following list of primary potential benefits and impacts along the coast of Massachusetts. The potential benefits and impacts of protection alternatives are based on the assumption that the alternatives will be properly designed, engineered, and constructed using best available measures. The benefits and impacts will vary depending on specific site conditions including placement location. This list should be a valuable resource during the evaluation of innovative erosion control measures (Recommendation #27). The list is also intended as a general resource for decision makers who may not have knowledge of what potential benefits and impacts may exist.

	BENEFITS	IMPACTS
Societal Goals (S)	a. public safety (protection of buildings, infrastructure, etc.) b. public heath (protection of septic systems, etc.) c. public welfare (maintain property value)	a. adjacent property impacts (end scour)
Physical Resources (P)	a. maintain sediment supply b. maintain coastal landform	a. source sediment reduction/elimination b. erosion of downdrift coastal landform (beach, dune, etc.) c. erosion of fronting beach d. direct loss of landform (displacement)
Biological Resources (B)	a. maintain ecological value b. enhance ecological value (1) shellfish (2) finfish (3) crustacean (4) SAV (5) wildlife habitat	a. direct loss of resource (displacement) b. decrease ecological value (1) shellfish (2) finfish (3) crustacean (4) SAV (5) wildlife habitat (6) water quality
Recreation (R)	a. provide lateral access (along beach) b. provide perpendicular access (to beach) c. beach use d. fishing e. boating	a. impede lateral access (along beach) b. impede perpendicular access (to beach) c. decrease swimming safety
Navigation (N)	a. safe navigation	a. hazardous navigation

STRUCTURAL ALTERNATIVE*	PURPOSE	ENVIRONMENT	BENEFITS					IMPACTS				
			S	P	B	R	N	S	P	B	R	N
Seawall	upland stabilization	high energy	a, b, c					a	a, b, c, d	a, b(1), b(5)	a, b	
Revetment	upland stabilization	low and high energy	a, b, c					a	a, b, c, d	a, b(1), b(5)	a, b	
Bulkhead	upland stabilization	low energy	a, b, c			e	a	a	a, b, c, d	a, b(1), b(4)	a, b	
Groin	beach stabilization	high energy	a, b, c	b	b(2), b(3)	c, d		a	b, d	a, b(1), b(2), b(4)	a, b, c	
Jetty	inlet stabilization	high energy	a, b, c		a, b(2), b(3)	c, d, e	a	a	b, d	a, b(1), b(4)	c	
Breakwater	beach and upland stabilization	high energy	a, b, c	b	b(2), b(3)	b, d		a	b	a, b(1), b(3), b(4), b(6)	c	a
Perched Beach	beach stabilization	low energy	c	b	b(5)	a, c, d				a, b(1), b(4)		
Dike/Levee	flood prevention	low energy	a, b, c			e			d	a, b(1), b(5), b(6)		
Elevate Existing Buildings	protect buildings and beach system	low and high energy	a, b, c	a, b								

* Strategy typically involves the (re)design and construction of a man-made structure that attempts to control coastal hazards by preventing them from reaching property.

NON-STRUCTURAL ALTERNATIVE*		PURPOSE	ENVIRONMENT	BENEFITS					IMPACTS				
				S	P	B	R	N	S	P	B	R	N
Beach Nourishment	Placement	beach and upland stabilization	high energy	a, b, c	a, b	b(5)	a, b, c				a, b(1), b(2), b(4)		
	Source									d	a, b(1), b(2), b(3), b(4), b(6)		
Dune Nourishment with Vegetation/Fence		upland stabilization	high energy	a, b, c	a, b	a, b(5)					a, b(5)	b	
Coastal Bank Nourishment with Vegetation		upland stabilization	low and high energy	a, c	a, b								
Coastal Bank Vegetation		upland stabilization	low and high energy	c	b								
Salt Marsh Creation		upland stabilization	low energy	a, c	b	b(5)				a, d	a, b(1), b(5)	a, b	
Fiber Rolls (Bank Stabilization)		upland stabilization	low energy	a, c	b				a	a, b			
Relocate Buildings		protect buildings and beach system	low and high energy	a, b, c		a							
Inlet Relocation		inlet stabilization	high energy	a, b, c	a, b	a, b(1), b(2)		a		d	a, b(3), b(4), b(5)	a	

* Strategy that does not change or confront the coastal hazard directly, but complements naturally occurring processes to minimize potential damage.