ADAPTATION TO SEA-LEVEL RISE IN NORTH CAROLINA

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ABSTRACT

Sea-level rise (SLR) predicted for the Mid-Atlantic U.S. is expected to be greater than worldwide averages forecast by the Intergovernmental Panel on Climate Change (IPCC) in 2007. In North Carolina, sea level is expected to rise between 0.3 and 1.1 meters within the next century. SLR is anticipated to exacerbate erosion, storm surges, storm intensity, and more directly, inundate land. North Carolina’s well-established coastal zone management program is fully capable of developing a response strategy to SLR within the existing framework of the local land use plan. This study examines the various coastal laws and policies affecting the North Carolina coastal zone and takes a closer look at some of the current management challenges, many of which will be aggravated by SLR. The study presents a potential starting point for local adaptation to SLR by looking at a case study of the Town of Morehead City. The land use plan for Morehead City was used as a framework for developing a flexible SLR response toolbox. Although development of a SLR toolbox for communities at the local level will increase SLR adaptation capacity, there are still obstacles to be overcome, including the weakened role of land use plans, and the fragmented approach to SLR planning in North Carolina.

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LIST OF ACRONYMS

Acronym	Full name
North Carolina Agencies, Committees, Organizations	
AIWW	Atlantic Intracoastal Waterway
BIMP	Beach and Inlet Management Plan
CAMA	Coastal Area Management Act
CAPAG	Climate Change Action Plan Advisory Group
CELP	Coastal and Estuarine Lands Conservation Program
CHPP	Coastal Habitat Protection Plan
CRAC	Coastal Resources Advisory Council
CRC	Coastal Resources Commission
CWMTF	Clean Water Management Trust Fund
DCM	Division of Coastal Management
DEM	Division of Emergency Management
DENR	Department of Environment and Natural Resources
DMF	Division of Marine Fisheries
DWQ	Division of Water Quality
EMC	Environmental Management Commission
EWG	Estuarine Working Group
NCAC	North Carolina Administrative Code
NCCF	North Carolina Coastal Federation
NCCR	North Carolina Coastal Reserve Program
NCFMP	North Carolina Flood Mapping Program
NCIUA	North Carolina Insurance underwriting Association
OPSC	Ocean Policy Steering Committee
Federal	
CBRA	Coastal Barrier Resources Act
CCSP	U.S. Climate Change Science Program
COE	U.S. Army Corps of Engineers
CZMA	Coastal Zone Management Act
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
HMGP	Hazard Mitigation Grant Program
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OMB	Office of Management and Budget
Miscellaneous	
AEC	Area of Environmental Concern

ATM	Applied Technology and Management (Coastal Engineering Firm)
CRS	Community Rating System
DEM	Digital Elevation Model
ETJ	Extraterritorial Jurisdiction
GIS	Geographic Information System
HQW SA	High Quality Shellfishing Waters
IPCC	Intergovernmental Panel on Climate Change
ISCC	International Scientific Congress on Climate Change
LID	Low Impact Development
LIDAR	Light Detection and Ranging
LUP	Land use plan
MGD	Million Gallons per Day
PCI	Property Casualty Insurers Association of America
SLR	Sea-level rise
TNC	The Nature Conservancy

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INTRODUCTION

As adaptation and mitigation begin to share the spotlight as response strategies to climate change, it will be prudent for policymakers, local and state governments, planners, and scientists to start addressing adaptive management of sea-level rise in coastal communities. Sea-level rise (SLR) in the next 20-50 years has the potential to affect over 50% of the United States population. In addition to the threat on the built environment, SLR will affect natural systems in the critical transitional zone between marine and terrestrial environments.

A recent EPA report (2009) suggests the Mid-Atlantic region will experience some of the highest rates of SLR in the world. This and similar findings (Douglas and Peltier, 2002) present an opportunity for Mid-Atlantic States to demonstrate to the country and the world how to effectively adapt to SLR.

North Carolina in particular is poised to adopt SLR adaptation strategies (Poulter et al., 2008). Over twenty years of state coastal policy banning hardened structures along the oceanfront is currently being debated by the state legislature as the result of the growing number of threatened structures and limited success of sandbagging and beach nourishment projects. Meanwhile, estuarine shorelines face a different set of challenges related to hardened structures squeezing out critical wetland habitats and the negative effects of stormwater.

Both estuarine and beach shorelines will face challenges with SLR and expanding development. This study provides background information on current coastal policies and laws in North Carolina, as well as information on the growing challenges in the coastal zone. The Morehead City case study will reveal how a coastal community can take the first steps in managing for SLR using the framework of the local land use plan.

Chapter 1 provides an overview of coastal policy and law in both the U.S. and North Carolina. The chapter begins with an introduction to the North Carolina coastal landscape and the natural processes occurring there. It continues with a brief review of federal coastal policy, followed by a more detailed description of North Carolina coastal policy and law.

Chapter 2 addresses current coastal challenges facing North Carolina policymakers and local communities, including endangered structures, habitat loss, and SLR.

Chapter 3 examines possible responses to the challenge of sea-level rise. A case study of the Town of Morehead City, N.C. looks at potential policy responses at the local level. Using SLR inundation scenarios provided by Benjamin Poulter (Potsdam Institute for Climate Impact Research) and land use data from the Town of Morehead City, the foundation for a SLR response toolbox was created. The chapter concludes with recommendations to ensure successful implementation of the SLR toolbox into the local land use plan.

Chapter 4 summarizes the main points of the analysis and presents the conclusion.

CHAPTER 1

North Carolina Coastal Laws and Policies

Chapter 1 provides an overview of coastal policy and law in both the U.S. and North Carolina. The chapter begins with an introduction to the North Carolina coastal landscape and the natural features and processes shaping it. Following will be a detailed description of North Carolina coastal policy and law. This section describes the agencies, reports, and rules relevant to SLR and takes a closer look at the role land use planning and flood insurance plays along the North Carolina coast. The chapter concludes with some of the challenges faced in developing a SLR adaptation policy.

1.1 Coastal Landscape in North Carolina

North Carolina's coastal plain is composed of a diverse array of ecosystems; swamps, barrier islands, rivers, and estuaries occupy 325 miles of ocean shoreline and over 3,000 miles of estuarine shoreline. The geology of the coast is divisible into two provinces, with the boundary between North and South occurring at Cape Lookout (Riggs et al., 1995). Natural features in these two provinces are shaped by different natural disturbances. The Northern Province, composed of Quaternary geologic materials, is typified by gentle shore faces and long barrier islands which help protect the second largest estuarine system in the U.S., the Albemarle-Pamlico Estuary (Figure 1.1). The Southern Province is dominated by older Tertiary and Cretaceous units and is characterized by short barrier islands, numerous inlets systems (eighteen total), and a narrower sound between the estuarine shoreline and barrier islands (Riggs, et al., 2008).

Figure 1.1 Map of coastal North Carolina and the boundary between the Northern and Southern geologic units
Source: Riggs, 2008; Institute for Marine Remote Sensing of the College of Marine Science, University of South Florida.

Natural Disturbance

The two coastal zones are affected differently by disturbances. The Northern unit is hit more frequently by nor-easters while the Southern unit bears the brunt of less frequent but higher intensity hurricanes and tropical storms (Riggs et al., 2008). Since 1960, fourteen hurricanes have made direct landfall along the North Carolina coast, and eleven of those storms were category 3 or greater (NOAA, 2008). Although storms are destructive events for a developed shoreline, they are responsible for many of the unique natural features found along the North Carolina coast. Barrier islands formed approximately 3,500 years ago and have been continuously altered by the opening and closing of inlets due to storms (Riggs et al., 2008). Storm events are considered part of the barrier island life cycle and are responsible for creating new inlets, overwashing sediment, and with larger storm events, completely washing out islands.

With extensive human settlement of the coast and barrier islands over the last few decades, the natural environment's response to hurricanes and storms has changed. Hardened structures, inlet dredging, beach nourishment, beach scraping, and wetland destruction are all activities changing the effects of storms on the coast. These activities will be discussed in greater detail in Chapter 2.

One of the most dangerous effects of hurricanes and large storm events is storm surges. Storm surges occur when powerful winds push ocean water onto the shore. When storm surges combine with high tides, water levels can reach 15 feet higher than normal sea level (National Hurricane Center, 2007). In 1999, Hurricane Floyd produced a 10 ft storm surge along parts of the North Carolina coast and dropped 15-20 inches of rain. More than half of the $6 billion in damages caused by the storm is attributed to river flooding and storm surge (National Hurricane Center, 2006).

Fire is another naturally occurring disturbance along the NC coast that is aggravated by anthropogenic influences, mainly agricultural ditching. In June 2008, a peatland fire ignited by lightning burned for weeks across three northeastern counties. Ditching in the area and prolonged drought conditions aggravated the fire, and more than 40,000 acres were burned by August 2008 (Figure 1.2; National Geographic News, 2008).

Figure 1.2 Peatland fires burn along the North Carolina coast, June 2008.
Source: http://news.nationalgeographic.com/news/bigphotos/16364713.html

Natural Processes

Natural processes in the coastal zone shape the natural and built landscape differently than disturbances. These processes occur daily and the effects are visible over longer timescales. Wave action and wind strength affect erosion and accretion rates along ocean-side beaches. Alongshore transport is also responsible for accretion of sand along the oceanfront. In the estuaries, accretion requires sediment deposited from rivers or circulated through the inlets. The estuarine shoreline experiences erosion, but is less vulnerable to wave and wind action as compared with the oceanfront.

Daily tidal fluxes play a large role in inlet systems where tides act as pumps, circulating water in and out of the sound. Inlet dynamics produce much of the erosion and accretion experienced along barrier islands. As mentioned previously, tides can exacerbate storm surges and lead to serious flooding during storm events.

Natural processes, like disturbances, are also aggravated by anthropogenic influences. Water cycling in the estuaries and inlet dynamics are altered by dredging and sand mining. Dredging by the U.S. Army Corps of Engineers keeps the Atlantic Intracoastal Waterway (AIWW) navigable and ensures ports are accessible, including the port at Morehead City. Mining of sand from inlets for beach nourishment projects can alter inlet dynamics and actually increase erosion or accretion along adjacent shorelines. Hardened structures are banned along the oceanfront in North Carolina, but a few exceptions (jetties at Pea Island and Fort Macon) have created noticeable changes in the natural patterns of erosion and accretion in down shore areas. The challenges in managing natural processes to protect structures and infrastructure will be discussed further in Chapter 2.

1.2 Federal Coastal Law

Coastal Zone Management Act (1972)

Throughout the 1960s the federal government grew more aware of the mounting stress placed on the natural resources of the nation's coastal zone (Coastal Zone Management Act, 1972). The lack of coordination amongst federal, state, and local agencies made management and planning in the coastal zone ineffective. By 1966, Congress passed the Marine Resources and Engineering Development Act establishing what came to be known as the Stratton Commission. The Stratton Commission determined the growing demand on marine resources required "a plan for national action and for orderly development of the uses of the sea." The Commission believed "orderly development" would not be possible without a plan for the coastal zone. They recommended federal legislation to encourage state agency efforts in creating comprehensive coastal plans (Stratton Report, 1969). In response to the recommendation laid out by the Stratton Commission, the Coastal Zone Management Act was enacted by Congress in 1972.

The Coastal Zone Management Act (CZMA) provides federal funding for states to create and administer coastal zone programs, but the states are allowed flexibility and discretion in creating and administering their programs (Kalo et al., 2007). As amended, the CZMA addresses sea-level rise (SLR) in the first section, Section 302, Congressional Findings, where it states, "(l) Because global warming may result in a substantial sea level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence." (16 U.S.C. § 1451). Section 303 declares the national policy of

> (2)(C) the management of coastal development to minimize the loss of life and property caused by improper development in flood-prone, storm surge, geological hazard, and erosion-prone areas and *in areas likely to be affected by or vulnerable to sea level rise*, land subsidence, and saltwater intrusion, and by the destruction of natural protective features such as beaches, dunes, wetlands, and barrier islands…(emphasis added, 16 U.S.C. § 1452)

The CZMA acknowledges SLR as a coastal hazard and requires states to plan for it and to manage development to minimize loss of property due to SLR.

1.3 North Carolina Coastal Law and Policies

CAMA and the CRC

The North Carolina Coastal Area Management Act (CAMA) was passed by the N.C. General Assembly in 1974 and was federally approved in 1978 under the CZMA. The CAMA established the 15-member Coastal Resources Commission (CRC) and the 45-member Coastal Resources Advisory Council (CRAC). The CRC is responsible for creating and enforcing implementation rules for CAMA in the 20 coastal counties, while the CRAC provides technical expertise to the CRC. The Division of Coastal Management (DCM), within the Department of Environment and Natural Resources (DENR), is responsible for carrying out CRC rules and issuing permits within these 20 counties and adjacent coastal and estuarine waters.

Division of Coastal Management

As mentioned above, the DCM carries out the rules issued by the CRC under CAMA. Additionally, the DCM carries out the NC Dredge and Fill Law pertaining to permitting of dredge or fill activities in estuarine waters or State-owned lakes. The DCM administers the North Carolina Coastal Reserve Program, a program protecting 10 estuarine sites for future research and education (NCCR, 2007). The DCM is the lead state agency for the Coastal & Estuarine Land Conservation Program (CELCP). The CELCP awards federal grants to help states protect critical coastal and estuarine lands (DCM, 2009).

Currently, the DCM is involved with sandbag removal efforts along oceanfront beaches. The State of North Carolina has banned hardened structures along the ocean front for decades. The ban was codified in 1985 (15A NCAC - 07H .0308 and - 07M .0201) and incorporated into the State's General Statutes in 2003 (S.L. 2003-427, Article 7, Part 3, § 113A-115.1). Sandbags were allowed on the oceanfront to temporarily protect threatened structures from erosion for up to five years, and an extension in 2000 allowed sandbags to remain in place in conjunction with an active beach nourishment project. But due to the CRC granting variances through the years and no enforcement mechanism, some property owners have had sandbags in front of their properties for decades. The May 1, 2008 deadline for illegal sandbag removal has passed and not a single sandbag has been removed.

The Coastal Habitat Protection Plan

The Fisheries Reform Act of 1997 included a provision requiring the CRC, along with two other rulemaking commissions from the Division of Marine Fisheries and DENR, to create and approve the Coastal Habitat Protection Plan (CHPP). The CHPP was designed to identify and protect coastal habitat areas and improve the effectiveness of current programs protecting fish habitats (Street et al., 2005). It identified SLR as a potential threat to wetlands, and recommended identification of land for wetland migration:

> Buyers and owners of coastal property should be aware of sea level rise and the potential for loss of wetlands and property. Updated and accurate coast-wide estuarine erosion rates are needed for the CRC and EMC to determine adequate development guidelines and rules along the coast (DCM 2002). Priorities for coastal wetland protection should also acknowledge sea level rise, and protect gently sloping areas upland of coastal wetlands to allow for landward migration of coastal wetlands with sea level rise (Street et al., 2005).

In 2000, the Estuarine Shoreline Stabilization Subcommittee was established by the CRC to review the estuarine shoreline stabilization rule development process. Despite CRC rules stating that "[w]here possible, sloping rip-rap, gabions, or vegetation shall be used rather than vertical seawalls" (15A NCAC 07H .0208 (b)(7)(E)), "living shoreline" approaches are rarely chosen by property owners to address erosion problems. Recommendations made by the Biological and Physical Processes Work Group have only begun to be considered by the CRC, who is taking steps towards more thoroughly addressing alternatives to stabilization structures along the estuarine shore.

Beach and Inlet Management Plan

The CHPP and the Capital Improvements Appropriations Act of 2000 (N.C. H.B. 1840) mandated the creation of a comprehensive beach and inlet management plan (BIMP) to address some of the recommendations in the CHPP. The BIMP is a joint project between the Division of Water Resources and the DCM. It will look at management strategies for inlets and beaches including nourishment, dredging, storm recovery, and inlet relocation (NC DENR, 2008). The BIMP is currently undergoing a second round of public meetings hosted by DENR. Many of the public comments from the first round of meetings express concern over allowing hardened structures on the oceanfront.

Legislative Commission on Global Climate Change

The N.C. General Assembly established the Legislative Commission on Global Climate Change in 2005 to study issues related to global warming. It was mandated to study whether it was necessary for the state to begin mitigation measures by creating a global warming pollutant reduction goal (N.C. S.B. 1134). The Legislative Commission is not to be confused with the N.C.

Climate Change Action Plan Advisory Group, managed by the Division of Air Quality, within DENR. The Advisory Group is tasked with making recommendations specific to mitigating climate change (CAPAG, 2009). The Legislative Commission is addressing broader concerns, including climate change impacts in the coastal zone (N.C. S.B. 1134, §5).

Ocean Policy Steering Committee

The Ocean Policy Steering Committee was formed in 2008 to evaluate coastal policies and make recommendations for the future. The 13-member Committee reports to the CRC and released a Final Draft Report for Public Comment in February 2009. The Final Draft Report recommends developing strategies related to five emerging coastal issues: sand resource management, ocean-based alternative energy development, ocean outfalls, marine aquaculture, and comprehensive ocean management (OPSC, 2009). The report recommends incorporation of a SLR component into CAMA land use plans as well as development of a coastal vulnerability index to better assess and address emerging coastal challenges, including SLR (OPSC, 2009).

1.4 CAMA Land Use Plans

One of the CRC's main duties is certification of local land-use plans (DCM, 2007). CAMA requires the 20 coastal counties to submit Land Use Plans (LUPs) according to guidelines laid out in North Carolina Administrative Code, Title 15A, Chapter 7. By 1999, each of the 20 coastal counties had updated their plans four times, as had many municipalities. Although not required, municipalities may opt out of the county land use plan as long as their own land use plan is submitted and approved. Up to 85% of a county's planning costs can be funded through the DCM, whereas local governments are covered for up to 75% of their planning costs (DCM, 2003).

The general objective of LUPs is to "[d]evelop policies that minimize threats to life, property, and natural resources resulting from development located in or adjacent to hazard areas, such as those subject to erosion, high winds, storm surge, flooding, *or sea level rise*" (emphasis added; 15A NCAC 07B .0702). NCAC Chapter 7 addresses the establishment of Areas of Environmental Concern (AECs) and refers to the N.C. General Assembly's intentions when passing CAMA. It indicates the importance of protecting estuarine regions and their critical natural systems:

> the coastal area, and in particular the estuaries, are among the most biologically productive regions of this state and of the nation...[it] has been subjected to increasing pressures which are the result of the often conflicting needs of society expanding in industrial development, in population, and in the recreational aspirations of its citizens. Unless these pressures are controlled by coordinated management, the very features of the coast which make it economically, aesthetically, and ecologically rich will be destroyed. (15A NCAC 07H .0102)

The land use plan is a series of policies and maps that guide a community's growth and natural system conservation (DCM, 2008). While the CRC is responsible for approving the plans, the actual policies are decided on by the local community. Once the LUP is approved by the CRC, the DCM uses the plan to guide permit decisions. In practice, LUPs have not played a central role in ensuring the balance between conserving critical ecosystem functions while allowing for continued development. In 2002, revisions to 15A NCAC 7B required LUPs to include more in-depth analysis of natural systems and land suitability, as well as more extensive policy analysis for each Management Topic (DCM, 2002). The new guidelines stressed the importance of maintaining or enhancing water quality and added a new requirement for a land suitability analysis which would identify land suitable for development by considering natural system constraints (DCM, 2002).

When creating or revising a LUP, local governments or counties look to the DCM Technical Manual (2002) for guidance. Even before applying for funds from DENR to create or update a local land use plan, local governments must complete a scoping process involving government officials, DCM staff, and the local governing board. If a local government receives “CAMA funds” they must include a formal public participation plan. The citizen participation process is directly tied into the final LUP through a “Community Concerns and Aspirations” chapter where citizen comments on issues and concerns for each of the six Management Topics are listed. The six Management Topics are required to be addressed within the portion of the LUP dedicated to planning for the future. The six topics are: Public Access, Land Use Compatibility, Infrastructure Carrying Capacity, Natural Hazard Areas, Water Quality, and Areas of Local Concern (Figure 1.3; DCM, 2002).

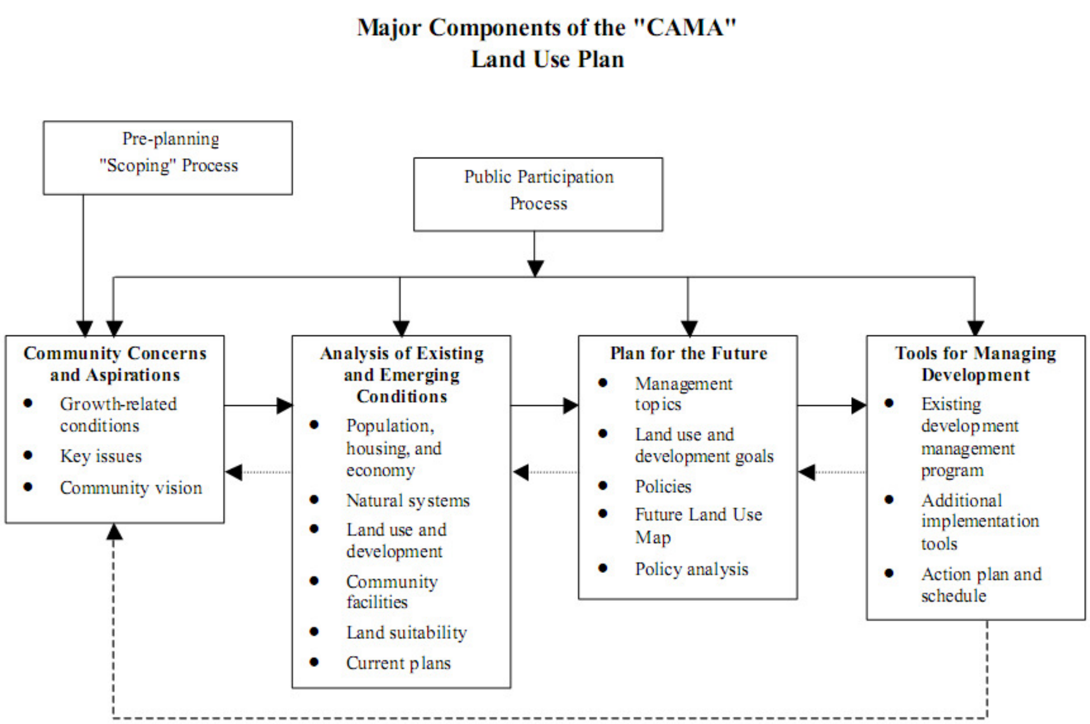


Figure 1.3 Components of local land use plans as laid out by the DCM 2002 Technical Manual for Coastal Land Use Planning

Following the “Community Concerns and Aspiration” section, a LUP must contain: an Analysis of Existing and Emerging Conditions, a Natural Systems Analysis, an Analysis of Land Use and Development, an Analysis of Community Facilities, a Land Suitability Analysis, a Review of Current CAMA Land Use Plan, and a Plan for the Future (Figure 1.3; DCM, 2002). Policies on adapting to SLR would be an appropriate topic to be covered in the Plan for the Future section. Unfortunately, LUPs rarely mention SLR as a hazard.

Although LUP guidelines have been updated to remove ambiguity and impose stricter language, a constant complaint from stakeholders is the plans do not include enforceable policies (J. Thayer, Manager of Planning, DCM; personal communication). For example, land use classes in LUPs do not have operational definitions, leaving land uses like “conservation” actually available for development. This hesitancy to solidify planning policies is reflected in the practice of fitting LUPs to comply with town ordinances rather than using LUPs as a foundation for local ordinance development. On a related side note, there is statutory language within the NCAC supporting sea-level rise as a hazard to be addressed when managing the coastal zone, but there is no reference to it in the LUP Technical Manual (DCM, 2002). Because counties and municipalities rely on the Technical Manual for LUP creation, SLR ends up not being addressed at the local level.

While revised funding guidelines are supposed to serve as an incentive for local communities to implement plans, many communities do not view the LUP as a binding document and therefore adopting a LUP does not necessarily mean the community will enforce the contents. The First Section of Morehead City’s LUP contains a disclaimer regarding the plan and its contents: “It should be noted, however, that the Land Use Plan is one of a variety of guides in making a public policy decision. The Plan should be viewed as a tool to aid in decision making and not as the final decision" (The Wooten Company, 2007). More recently LUP funding has been reduced and a NOAA program evaluation completed in 2006 found that "[w]ithout implementation funds and tools, the land use plans have reduced effectiveness in shaping the local landscape in the way envisioned by the local community, especially in communities without planning staff" (NOAA, 2006).

1.5 Flood Insurance and Hazard Planning

Improperly priced insurance along the North Carolina coast is viewed as on of the great enablers of unsustainable development. The following section is a review of federal flood hazard mitigation policies and how they apply to the North Carolina coast.

The Federal Insurance and Mitigation Administration (FIMA) administers the National Flood Insurance Program (NFIP). NFIP was created in 1968 in response to major riverine flood disasters throughout the 1920s and 1930s in the Midwest. The federal government realized the private insurance industry could not provide flood insurance to property owners due to the low occurrences of flood events but the high level of damage.

There are three components of the NFIP: (1) Flood insurance; (2) Floodplain management; and (3) Flood hazard mapping (FEMA, 2002). If communities choose to participate in NFIP, they must enforce floodplain management criteria such as establishing a Base Flood Elevation (BFE), enforcing building elevation requirements, and requiring permits for floodplain development (NC DEM, 2008). The goals of NFIP are: (1) require new buildings to be protected from flooding, (2)guide development away from flood zones, and (3) transfer the costs of flood losses onto floodplain property owners via premiums (NC DEM, 2007).

In 1994, a Community Rating System (CRS) was codified and reduced premiums for communities that implement activities to decrease the risk of flooding (preservation of open space, preparation of flood maps, maintaining drainage systems) (NC DEM, 2008). A 2000 FEMA study evaluated the performance of CRS activities in North Carolina communities post-Hurricane Floyd. The study found that preserving open space in floodplains saved several flooded communities millions of dollars. The calculated average savings to property owners who retrofitted their homes (elevation, floodproofing, etc.) was $9,900. The study then concluded that acquisition and relocation of floodprone properties was "more effective at reducing flood losses than any other approach" (The Hazard Mitigation Technical Assistance Partnership, Inc., 2000).

The Robert T. Stafford Disaster Relief and Emergency Assistance Act (the Stafford Act) was enacted in 1988 and governs the federal response to catastrophic and major disasters. The act helps state and local governments respond to emergency situations such as hurricanes and drought, and provide grants for mitigation activities. The Hazard Mitigation Grant Program (HMGP) falls under Section 404 of the Stafford Act and in North Carolina it is administered by the N.C. Department of Emergency Management (DEM). The HMGP will provide up to 75% of funding for communities implementing long-term mitigation projects (42 U.S.C. 5170c).

Mitigation activities within § 404 have been the focus of several amendments to the Stafford Act within the last decade. It was amended to expand the scope of mitigation activities to include "Property Acquisition and Relocation for Open Space" (42 U.S.C. 5170c, 1999). In addition, the Disaster Mitigation Act of 2000, another amendment to the Stafford Act, created new state mitigation plan requirements (44 C.F.R. Part 201, 2000). A state can opt to pursue an "enhanced" state plan to increase the amount of available funding.

North Carolina's State Natural Hazards Mitigation Plan was accepted by FEMA in 2004. Eleven municipalities and counties applied for HMGP funds in 1996, post-Hurricane Fran, including the coastal counties of Carteret, Craven, New Hanover, and Pender (NC DEM, 2008). Approximately 90 counties and municipalities are in the process of developing or updating natural hazard mitigation plans (NC DEM, 2007). The state is hoping to incorporate the majority of local hazard mitigation plans into the State Plan in time for the 2010 update.

In North Carolina, the Beach Plan (North Carolina Insurance Underwriting Association) was established in 1969 as an insurer of last resort for property owners who couldn't find coverage from traditional private insurers. All property and casualty insurance companies operating in North Carolina fund the Plan and share the profits or losses. In 1998, the Beach Plan expanded coverage to 18 coastal counties for wind and hail insurance and by 2003, it was authorized to cover homeowner policies (NCIUA, 2008).

Unfortunately, the program has become the first choice for coastal homeowners and it currently insures 170,000 coastal properties valued at $72 billion, up from $3.6 billion in 1995 (Property Casualty Insurers Association of America [PCI], 2009). A 2008 PCI study (Milliman, Inc., 2008) determined the Beach Plan was overstretched and would not be able to handle claims associated with a major storm. Rate and deductible hikes have recently been approved by the legislature to address the issue and will be imposed May 1, 2009. In addition, maximum coverage per property under the Beach Plan will be cut in half, from $1.5 million to $750,000. The Beach Plan will be discussed in greater detail in Chapter 2.

In 1999, coastal North Carolina suffered extensive damage during Hurricane Floyd revealing large inaccuracies in the state's flood maps. In 2000, with a $70 million investment, the state began an extensive remapping program using Lidar technology. Today, all coastal counties have been mapped and access to data has been made available online through the North Carolina Flood Mapping Program (NCFMP). The high-resolution Lidar data has allowed more accurate SLR inundation modeling and geospatial analysis.

Conclusion

Laws and policies pertaining to the coastal zone in North Carolina were established with the intentions of balancing the desire for future development with the important natural features that made and continue to make the coast a desirable place to live and visit. Overall, decision-makers and state agencies seem to be aware of SLR, given its inclusion in several codes, reports and committee recommendations, but there is no active enforcement of SLR-specific rules. An example of how a local community can take a more proactive approach to SLR will be demonstrated in Chapter 3.

1.6 Sea-Level Rise Policy Development in North Carolina

Until recently, policy-making for SLR has not been a major concern for coastal states or the federal government. Like many other natural processes affecting the coast, SLR is only a concern because coastal areas have become densely developed over the last few decades. Sea-level rise faces the challenge of being a “creeping hazard” (Glantz, 1988); a long-term, gradual process, whose affects are linked with other coastal processes such as erosion and flooding (Moser, 2005). Much of the coastal citizenry in North Carolina believes structures are falling into the water due to storm damage, rather than consistent erosion and sea-level rise.

Generally, human systems respond to extreme events before responding to gradual changes in the mean (Yohe and Tol, 2002). There are coping ranges for systems in terms of their ability to withstand change and variability due to existing resilience. For example, as will be seen in Chapter 3, Morehead City's establishment of a floodplain land use will allow them some breathing room when adapting to SLR. But as Yohe and Tol (2002) point out, it is important to understand a system's coping range as well as understand how a coping strategy can be expanded. For the Morehead City case study, this means expansion of the LUP to include SLR response strategies.

Several policy windows in North Carolina opened in the late 1980s and 1990s due to Hurricanes Hugo (1989), Bertha (1996), and Fran (1996), major coastal conferences, and program reviews (Moser, 2005). Coastal management practitioners interviewed by Moser (2005) suggested concerns over water quality, post-hurricane recovery, and property rights battles all ended up outweighing SLR concerns.

North Carolina coastal policy and planning is approaching an important crossroads (Poulter et al., 2009). Increasing concern over SLR, in particular in the Mid-Atlantic region (Titus et al., 2009), combined with a growing movement to overturn a 20-year coastal policy of no oceanfront hardening (Island Gazette, 2009), means the state will have to make some critical decisions in the next few years.

Adapting to SLR, however, is not as intimidating as state and local planners would like to believe. Adaptation will not require massive revamping of coastal management laws and policies in North Carolina since existing statutory language and newly published reports mandate planning for SLR. The management strategy for SLR will be similar to the planning strategies used to address natural processes/disturbances like erosion and flooding, with the majority of land use decisions falling onto county and municipal governments. If SLR planning is to focus on land use decisions, it makes sense to consider the local LUP as the proper vehicle for SLR planning.

CHAPTER 2

Current Coastal Challenges in North Carolina

After reviewing the policies and laws shaping coastal management practices in North Carolina, Chapter 2 follows with a snapshot of the current challenges created within this framework. North Carolina is currently facing a myriad of controversial coastal management issues, the majority of which stem from barrier island development. Estuarine communities are able to avoid some of the barrier island disputes related to hardened structures, but there is nevertheless ongoing debate over what type of shore protection is best for estuary shorelines. Additionally, development pressure is relevant to all coastal communities, estuarine and oceanfront. Sea-level rise (SLR) is an impending challenge associated with climate change predicted to exacerbate other challenges, such as erosion and flooding; issues both estuarine and oceanfront communities will have to address. The challenges associated with SLR will be looked at in greater detail at the end of this chapter.

2.1 Current Challenges in the North Carolina Coastal Zone

Structure Loss on Barrier Islands

Recent headlines from state and local news sources indicate mounting tension over barrier island management issues in North Carolina. The dynamic nature of barrier islands does not bode well for permanent structures and the dichotomy is the root problem for several issues being debated within the N.C. General Assembly, CRC meetings, local town meetings, conferences, and classrooms:

- beach nourishment/re-nourishment
- sandbags
- structure removal
- hard armoring

Beach Nourishment

Beach nourishment has occurred along the North Carolina oceanfront since the 1940s. Prior to the hurricanes of the 1990s, only 12 miles of public beach received federally funded nourishment. Today more than 122 miles of ocean beaches are nourished and the federal government has pulled out of funding any new projects (although it continues to pay 50% of re-nourishment projects) (NOAA, 2006; Riggs et al., 2008; OMB, 2007).

Beach nourishment is allowed as a shoreline protection strategy as laid forth in 15A NCAC 07M.0202(c) along with "preferred" response measures including land use planning, establishment of building setback lines, building relocation, subdivision regulations, and management of vegetation (15A NCAC 07M.0202(b)). In North Carolina, beach nourishment is an accepted strategy to preserve public beaches and protect oceanfront structures even though it is extremely costly to the public and private property owners.

Beach nourishment projects are rarely single, isolated projects. For example, Carolina Beach has completed 28 nourishment projects 1955-2006 and has placed approximately 18.55 million cubic yards of sand on the beach (Program for the Study of Developed Shorelines Database, 2006). This averages out to about 1 nourishment project every 1.75 years (Riggs et al., 2008) indicating nourishment is far from a permanent solution to erosion. The constant re-nourishment of beaches becomes extremely expensive; consider mobilization of a dredge alone costs upwards of $1 million. In 2004-2005, there were seven federal beach re-nourishment projects along the North Carolina coast and only one project totaled less than $1.5 million (Program for the Study of Developed Shorelines Database, 2006). To add to the difficulty of keeping the costly new sand on the beach, some communities mine sand from the ebb-tide delta of adjacent inlets, a process that often increases erosion along the island tip (Riggs et al., 2008).

As the Final Draft Report from the OPSC (2009) suggests, sand resources in North Carolina are in need of better management strategies due to the growing number of nourishment projects and the finite nature of the resource. The limited availability of beach-quality sand along the North Carolina coast led the OPSC to dedicate an entire section in the Report to Sand Resource Management. The Final Draft Report acknowledges the importance of developing a sand resource management plan to avoid the current "first come, first served" protocol. Alternative solutions have begun to be considered, including allowing hardened structures, relocation of threatened structures, and inlet relocation. With predicted SLR, demand for nourishment projects along the ocean front will likely increase. Depending on how seriously the recommendations of the Estuarine Shoreline Stabilization Subcommittee are implemented (see Chapter 1), beach nourishment could become a larger issue within estuarine policy as well.

Putting the resource availability and costs aside, there have been concerns raised by the scientific community about the damage to habitat that accompanies beach nourishment projects. In a groundbreaking decision, an administrative law judge in Florida issued a ruling on March 2, 2009 against a beach nourishment project because it posed a threat to the health of the offshore reef ecosystem (Recommended Order, Surfrider Foundation v. Town of Palm Beach, FL; Case No. 08-1511). The court recognized the potential negative environmental effects of the proposed nourishment project and conceded the modeling system used by many coastal engineers and the U.S. Army Corps of Engineers (COE) to predict sand distribution was flawed. While many environmental groups hail the decision as a victory, some scientists are concerned it will only push communities to rely more on sea walls and other hard structures (New York Times, 2009).

Given the current state of the economy and the tightening of the state budget, the N.C. General Assembly will have some trouble justifying million dollar requests from small coastal communities to add sand to beaches. The OMB recently removed $85 million from the U.S. Army COE budget originally set aside for beach nourishment projects (Island Gazette, 2009). As these communities look to fund projects themselves, the number of projects will certainly decrease (Topsail Voice, 2009) while the pressure to allow soft and hard stabilization structures will increase.

Sandbags

Sandbags are considered a temporary response measure to protect structures from erosion until structure relocation or beach nourishment is completed. In North Carolina, sandbags are rarely removed once installed. In 2007, the CRC issued a deadline of May 1, 2008 for illegal sandbags to be removed. Of approximately 350 sandbag structures along the coast, 150 are illegal (Wilmington Star News, 2008). The DCM is responsible for implementing the removal program; it has identified and mapped illegal sandbags, and sent 20 letters out to the worst offenders, all located in the Outer Banks. Many homeowners with illegal sandbags have dug in their heels, refusing to sign registered violation letters issued by the DCM and applying to the CRC for variances (Wilmington Star News, 2009). One condominium complex on Kure Beach, the Riggings, has had sandbags in place for 23 years and the DCM finally denied their sandbag permit after property owners declined a $2.7 million federal buyout offer (Wilmington Star News, 2009). Last month a state judge from the Office of Administrative Hearings denied extension requests from Riggings property owners who wanted to repair their illegal sandbags (Wilmington Star News, 2009).

Unlike communities implementing beach nourishment projects, many property owners using sandbags are currently breaking the law. But similar to the beach nourishment debate, the sandbag issue is reaching a boiling point. The courts will be called upon more often by both sides in the near future. Regardless of outcomes, the growing tension will inevitably intensify with SLR and increased rates of erosion.

Structure Removal

Due to the dynamic nature of barrier islands, in particular the portions adjacent to inlets, North Carolina coastal communities find themselves with condemned structures standing in public trust waters. Even with the current popularity of beach nourishment projects and sandbagging efforts of individual homeowners, structures are still being lost to natural coastal processes. Barrier island communities are constantly debating who will remove condemned structures from the oceanfront. Property owners wait to see if they can collect insurance pay-outs once the structure is destroyed by a storm, but local governments continue to push back, claiming the structures are interfering with the public's enjoyment of the beach. North Topsail Beach is one of several barrier island communities with condemned houses in public trust waters. The town recently announced an agreement had been reached with homeowners of six condemned duplex houses for $1.6 million, plus an additional $43,600 to demolish the structures (Topsail Voice, 2009; Figure 2.1).

Figure 2.1 Four years after being condemned, the town of North Topsail removes structures from the beach. *Photo Source*: Connie Pletl, http://carolinacoastonline.com/articles/2009/03/04/topsail_voice/news/doc49ae92cf94719645792078.prt)

Armoring

As mentioned in Chapter 1, hardened structures are allowed along the estuarine shoreline but not along the oceanfront in North Carolina. Many advocates for overturning North Carolina's ban on oceanfront hardened structures believe a solution to the challenges over beach nourishment, sandbags, and structure removal, is allowing hardened structures along the oceanfront. The mascot for overturning the ban in North Carolina has become the terminal groin. Over the last few years, property owners from Figure Eight Island have attempted to overturn the state ban on hardened structures in order to protect the northern tip of the private barrier island. Their lobbying efforts in 2008 resulted in introduction of Senate Bill 599, which proposed allowing a pilot study on a terminal groin; a type of hardened structure placed perpendicular to the shore. The bill died in committee before it could be voted on in the House, but a new bill (S.B. 832) was re-introduced in March 2009. The new bill contains fewer restrictions than the original in order to allow other communities to construct groins in addition to Figure Eight Island. Communities that stand to benefit from a new hardened structure policy have provided financial support for lobbying activities (The Brunswick Beacon, 2008).

The estuarine shoreline faces a different set of challenges compared with the oceanfront when considering armoring. Even though armoring is allowed along the estuarine shore it is only supposed to be used if less intrusive options are not possible (15A NCAC 07H .0208 (b)(7)(E)). The "living shoreline" approach is an erosion control strategy that substitutes planted vegetation for hardened structures. The popularity of living shorelines has grown over the last few years and there are projects throughout Maryland, Virginia, and North Carolina. Often living shoreline projects involve combining grass plantings with stone or oyster shell sills to absorb wave energy (MD DNR, 2004; NCCF, 2004).

Living shoreline proponents believe the approach reduces costs to property owners (as compared to traditional stabilization structures), and improves habitat quality, water quality, and aesthetics (Burke, 2004). The North Carolina Coastal Federation, through grant support from NOAA, Restore America's Estuaries, and N.C. Clean Water Management Trust Fund, has provided cost share funds for 19 living shoreline projects for a variety of clients, including private property owners and educational institutions (NCCF, 2004). Because living shorelines reduce erosion and stabilize shorelines, the EPA lists the approach as a "soft" adaptation option to protect estuarine shorelines from rising seas (EPA, 2009).

Beach Plan

As mentioned in Chapter 1, the Beach Plan is a state-backed insurer for 170,000 coastal properties in North Carolina. Unlike private insurance companies, The Beach Plan is not required to maintain reserves to cover damages from a 100-year storm. The Property Casualty Insurers Association of America (PCI) commissioned the Milliman Report (2008) to investigate the deficit the Beach Plan would run if a hurricane were to strike the North Carolina coast. The Report concluded the Beach plan would have the capacity to pay out $1.5 billion to cover hurricane losses, only after it has assessed $600 million from insurance companies (Milliman, Inc., 2008). The study found the Beach Plan would run a deficit from a small storm (1-in-50 year) of $1.4 billion up to $6.2 billion for a large storm (1-in-250 years).

The study raised many concerns now being addressed by the Joint Select Study Committee on the Potential Impact of Major Hurricanes on the North Carolina Insurance Industry. Many inland policy holders fear insurance companies will be forced to make up the deficit caused by undercharging coastal property owners by increasing premiums for all policy holders, essentially leaving inland property owners to subsidize coastal property owners. By increasing the assessments on the insurance companies to cover deficits, the Beach Plan could drive companies out of the state. Farmer's Insurance, the third largest writer of homeowners insurance in the country, opted to stop writing policies in North Carolina due to the potential Beach Plan assessments (Milliman, Inc, 2008). Insurance hikes recently approved by the North Carolina rate bureau would result in a statewide average increase of 4.05 percent. Along the coast in Carteret County, rates would go up as much as about 30 percent, with inland residents bearing the brunt of the hike (Carteret County News-Times, 2009).

Coastal insurance has been criticized for not passing the true cost of living at the coast onto coastal property owners. Godschalk et al. (1999) comment on how the federal role in disaster assistance has led to a sense of entitlement amongst local and state governments after a disaster has struck their community, regardless of the level of effort to mitigate risk. Perhaps with the latest rate hike, North Carolina is beginning to understand the importance of coastal property owners paying for the risk of owning a house on the water. But after decades of undervaluing risk along the coast, the state will surely be in for a fight. Several counties and municipalities have already filed suit in order to push the state to reconsider the rate increase (Island Gazette, 2009).

Dredging

As mentioned in the first chapter, the North Carolina coast is an incredibly large, dynamic system. Inlets (openings between barrier islands) allow water to flush in and out of the sound. Naturally, inlets are ever-changing; they migrate, they fill up with sand, new ones form during storms. But along the heavily engineered North Carolina coast, inlets are the only way in and out of the sound for boats and ships. Therefore certain inlets are artificially kept in place with jetties and dredged to remain navigable.

Dredging is underwater excavation performed frequently by the U.S. Army COE along the North Carolina coast. The removal of underwater sediment helps keep waterways navigable, and sometimes can provide a source of sand for beach nourishment projects. For the 2008 Fiscal Year, the Army COE dredged a total of 2.7 million cubic yards of sand in North Carolina (U.S. Army COE, 2008). The majority of this work was maintenance of channels in inlets. The Atlantic Intracoastal Waterway (AIWW) functions as an arterial waterway for businesses and recreational boaters in the sound and requires constant maintenance dredging. If dredging ceased today, the average depth of the AIWW would rise to 4 ft, as compared to the 7-12 feet maintained by dredging (Dumas et al., 2007).

While dredging has become commonplace along the North Carolina coast, there are issues of concern to a variety of stakeholders. One issue is reduced federal funding for dredging activities (OMB, 2007). Reduced funding will put pressure on the state and local governments to continue dredging of the AIWW and inlets considered critical to recreational boaters and maritime industries. Other issues include dredge spoil disposal and the ecological effects of dredging. There is concern over the effects of dredging on benthic communities when spoil is disposed offshore. In the past, dredge spoil would often be dumped in nearby marshes, a practice since abandoned in favor of creating dredge spoil islands which are capable of providing habitat for birds (NPS, 2004). If the spoil is placed on a beach, there is potential for habitat to be destroyed, especially if the sand is not compatible with existing sand. Several barrier island communities have experienced the difficulty in receiving non-compatible beach sand (NCCF, 2002). Dredging activity also removes shallow water habitats and increases water turbidity which can kill fish (Ross and Lancaster, 1996). Dredging in the AIWW has been critiqued for exacerbating erosion of estuary shorelines, including salt marshes (NPS, 2004). Sand mining in inlets is another dredging activity that is criticized for intensifying erosion of barrier islands

Dredging has become a lucrative business along the North Carolina coast. In addition to the 2.7 million cubic yards the Corps dredged in 2008, 4.5 million cubic yards was dredged by outside contractors whose six contracts totaled $28 million (U.S. Army COE, 2008). The contracted projects were mainly for harbor and AIWW maintenance. In the future, if funding continues to be slashed, dredging projects will need to be scaled back and prioritized. With SLR, dredging, like nourishment, would have to occur more frequently; a situation taxpayers may not be willing or capable of supporting. The Mason Inlet relocation was a project proposed by private property owners in Wrightsville Beach who opted to build a large condominium complex within a designated high-risk area (CBRA Zone). The funds (approximately $10 million) were fronted by New Hanover County, and later assessed to property owners (New Hanover County, 2003; ATM, 2002). Despite property owners initiating and supporting the project, their pledge to pay for it waivered once the tax assessments started. The county government has so far taken a hard line and rejected the property owner's requests for using some of the county's room occupancy tax to pay for the project (Wilmington Star News, 2007). The Mason Inlet Relocation project gives some indication that private property owners will most likely not be able to support costly dredging and nourishment projects without the aid of state and federal dollars.

Wetland Loss

Carbon sequestration, flood buffering, fish and bird habitat, and water filtration are only a few of the critical ecosystem services wetlands provide. North Carolina has lost 50% of its original 11.1 million acres of wetlands and the majority of remaining wetlands are coastal (approximately 3 million acres) (Dorney et al., 2004; Street et al., 2005). With continued development along the 3,000 miles of estuarine shoreline, combined with rising seas, the amount of wetlands lost is likely to increase. Annual salt marsh loss due to erosion has been estimated at 802 acres per year in North Carolina (Riggs and Ames, 2003).

Over 90% of North Carolina's commercial fisheries landings and 60% of recreational landings are comprised of estuarine-dependent species (Street et al., 2005). The Albemarle-Pamlico Sound is North Carolina's key resource for commercial fishing, recreational fishing, and tourism. The Sound's highly productive waters and wetlands allow it to support these activities. More than 75 species of fish and shellfish rely on the wetlands for protection and food (Stedman and Hanson, 1997).

Coastal wetlands in North Carolina are being destroyed by dredge-and-fill activities, natural disturbances, pollution, and SLR. Nutrients and other pollutants in stormwater runoff are leading to serious degradation of water quality. Wetlands in the Albemarle-Pamlico Peninsula have been extensively ditched and drained to support agricultural land development. The area has become the most productive cropland in the state (Street et al., 2005). Recent research by Poulter et al. (2008) indicates vulnerability of coastal landscapes to SLR is heightened by the existence of drainage ditches and channels. The ditches allow for increased levels of flooding and salt water intrusion.

The Nature Conservancy (TNC) is a national non-profit that has already started addressing SLR and its effects on coastal marshes. Along with the U.S. Fish and Wildlife Service, TNC has begun implementing SLR adaptation methods in the Alligator River National Wildlife Refuge, a refuge composed of formerly ditched agricultural land in Dare County, North Carolina (Charlotte Observer, 2009). In more developed parts of the North Carolina coast, marshes will be unable to migrate with rising seas due to upland development. State agencies and local communities will need to seriously consider recommendations laid out in the CHPP (2005) if they hope to preserve some of the critical services wetlands provide along the entire North Carolina coast.

Stormwater Runoff

Stormwater is the result of precipitation running off of impervious surfaces like roads, roofs, and parking lots, as well as runoff from agricultural fields and lawns. The runoff from these surfaces contains pollutants which can lead to serious water quality issues in receiving water bodies. Stormwater can also infiltrate wastewater systems leading to overflow during storm events.

In coastal North Carolina, stormwater has become a particularly large problem due to continued increases in impervious surfaces, and the dependence of local coastal economies on shellfishing. Shellfish are affected by a variety of factors including low dissolved oxygen, increased nutrients, temperature, and turbidity, pH, and water movement (Street et al., 2005). Bacteria from polluted stormwater has been cited as the cause for the majority of shellfish closures in North Carolina waters (Mallin et al. 2000, 2001; Duda and Cromartie, 1982).

When North Carolina adopted Clean Water Act "Phase II" rules in 2006, only two coastal counties were required to implement more stringent stormwater controls. In 2005, the Environmental Management Commission (EMC) began the process of revising coast-specific stormwater rules that had been in place for the 20 coastal counties since 1985 but had not successfully protected water quality.

In July 2008, new stormwater rules for the EMC were passed into law (S.B. 1967 & H.B. 2138). The new rules reduce low density development thresholds, require stormwater controls to account for larger rainfall events, prohibit inclusion of wetlands in impervious surface calculations, and extend the vegetative setback requirement. There are stricter standards if the activity or development is within ½ mile of shellfish waters (NC DWQ, 2008). Non-profits and educational institutions like the North Carolina Coastal Federation have already begun addressing coastal stormwater reduction through stormwater best management practice (BMP) projects. With support from the Clean Water Management Trust Fund, they have installed bioretention features in schools and parking lots in several coastal communities. NCCF has held instructional workshops in managing stormwater using low-impact development (LID) strategies as well as consulted with county governments on developing LID ordinances.

Conclusion

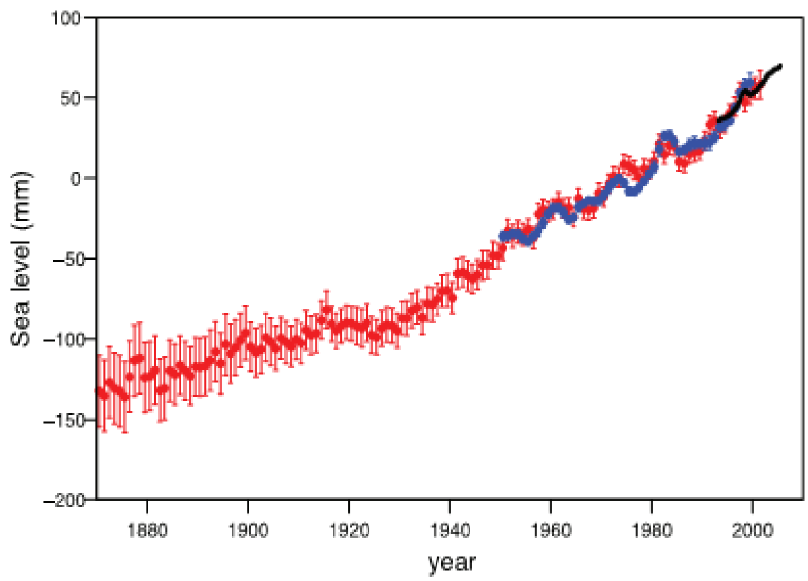
The growing mass of law suits and court decisions related to many of the challenges discussed here should be an indication of a need for statutory clarification of current practices along the North Carolina coast. The reliance of state agencies and local communities on short-term solutions without serious long-term planning is a dangerous combination. Hardened structures have been proposed as an option for shoreline stabilization due to the ineffective short-term strategies of beach nourishment and sandbagging. With rising seas, hardened structures are not necessarily the best option either, but the lack of long term, comprehensive planning along the coast currently leaves no alternatives.

Without even considering the potential threat of SLR, there are a myriad of coastal management issues related to both natural and man-made systems that will need to be addressed in the next few years. It would be unwise however, for decision-makers and coastal managers to go forward trying to solve these problems, without acknowledging future hazards. They may find that solutions to future hazards, like adapting to SLR, will help solve existing challenges as well.

2.2 Sea-Level Rise

Estimates

Sea-level rise adaptation has become the focus of many coastal management agencies within the last few years, including the DCM in North Carolina. This interest can be partly attributed to the Intergovernmental Panel on Climate Change's 2007 report. The IPCC (2007) predicted global sea-levels to rise between 0.18 and 0.59 m over the next century without considering the impacts of melting ice sheets (Figures 2.2a and 2.2b). During the March 2009 International Scientific Congress on Climate Change (ISCCC) meeting in Copenhagen, new research was presented predicting the upper range of SLR to be 1 m or more by 2100 while the lower end of the range will be at least 0.50 m due to the rates of melting ice sheets contributing more and faster than predicted (University of Copenhagen, 2009).



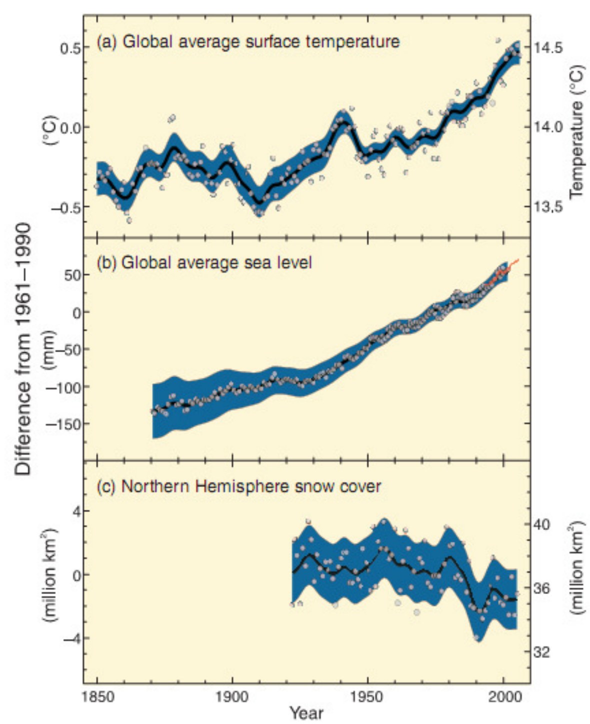


Figure 2.2a (above) and 2.2b (right). Annual averages of the global mean sea level (mm) from IPCC (2007). The red curve shows reconstructed sea level fields since 1870 (updated from Church and White, 2006); the blue curve shows coastal tide gauge measurements since 1950 (from Holgate and Woodworth, 2004) and the black curve is based on satellite altimetry (Leuliette et al., 2004). The red and blue curves are deviations from their averages for 1961 to 1990, and the black curve is the deviation from the average of the red curve for the period 1993 to 2001. Error bars show 90% confidence intervals.
Source: IPCC, 2007

As ice sheets begin to melt, the collapse of the proglacial forebulge will lead to the Mid-Atlantic coast experiencing rates of SLR twice as great as global rates (Douglas and Peltier, 2002). In North Carolina, due to land subsidence, sea level is expected to rise between 0.3 and 1.1 m within the same time span. Given the predicted rates of SLR for the Mid-Atlantic as well as the region's susceptibility to natural disturbances, North Carolina will continue to be prone to billion-dollar weather and climate-related disasters (National Climatic Data Center, 2008; Figure 2.3). Coastal managers will face tremendous obstacles in addressing SLR (as well as the predicted increases in storm intensity, erosion, and flooding) without a formal strategy.

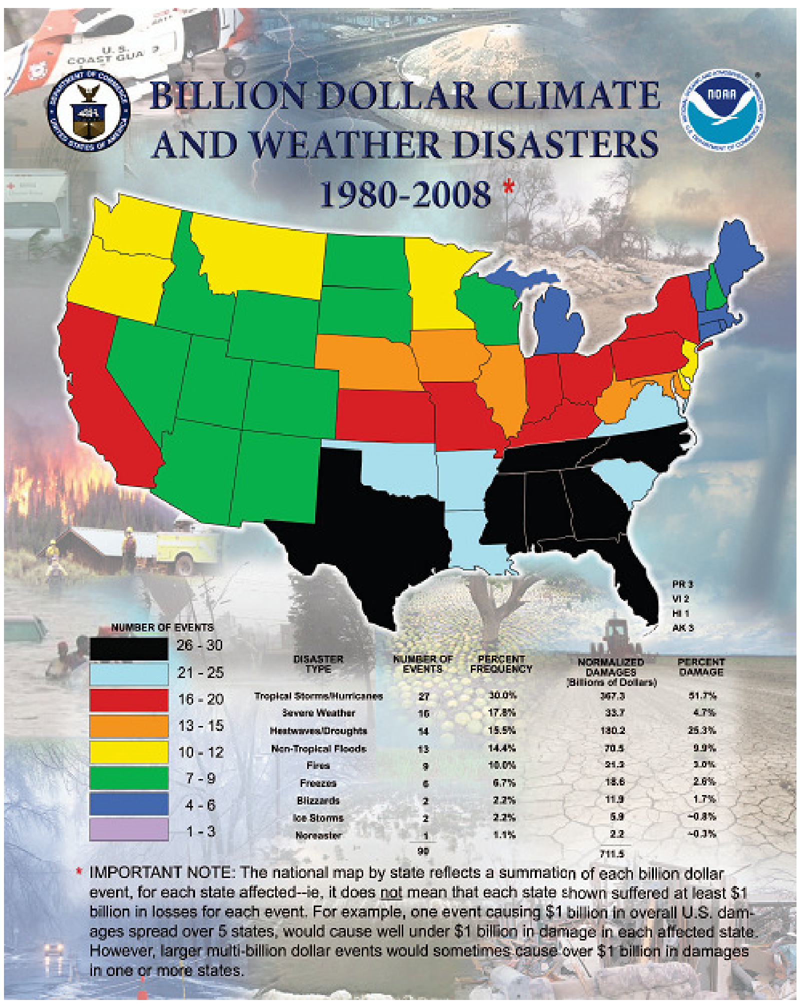


Figure 2.3. North Carolina is one of seven states that experienced 26-30 disaster events 1980-2008.
Source: National Climatic Data Center, NOAA

SLR in North Carolina

As mentioned in Chapter 1, North Carolina's coast can be divided into two geologic units. A study by Titus and Richman (2001) found North Carolina had the third largest amount of coastal land (5800 km^2) sitting below the 1.5 meter elevation contour out of all the Atlantic and Gulf states. A later study completed by Poulter and Halpin (2008) using high-resolution Lidar data found 5300 km^2 of land at or below the 1.1 m contour. The majority of this land is in the Albemarle-Pamlico Sound region, within the Northern geologic unit.

The Albemarle Region of the northern coastal plain is an area predicted to be highly susceptible to even the smallest increases in sea level. Pearsall and Poulter (2005) predict forty inches (1 m) of SLR could inundate approximately one million acres of land in the region. If present day rates do not increase, the inundation will take 200 years, but if the rate increases from 4.3 mm a year to 13 mm per year, the area will be inundated within 65 years. Some adverse effects of SLR for this area include increased erosion, saltwater intrusion, and rapid decomposition of peat-based soils (Pearsall and Poulter, 2005). The Chapter 3 case study area (Morehead City) is located along the southern fringe of the Albemarle Region (Figure 2.4).

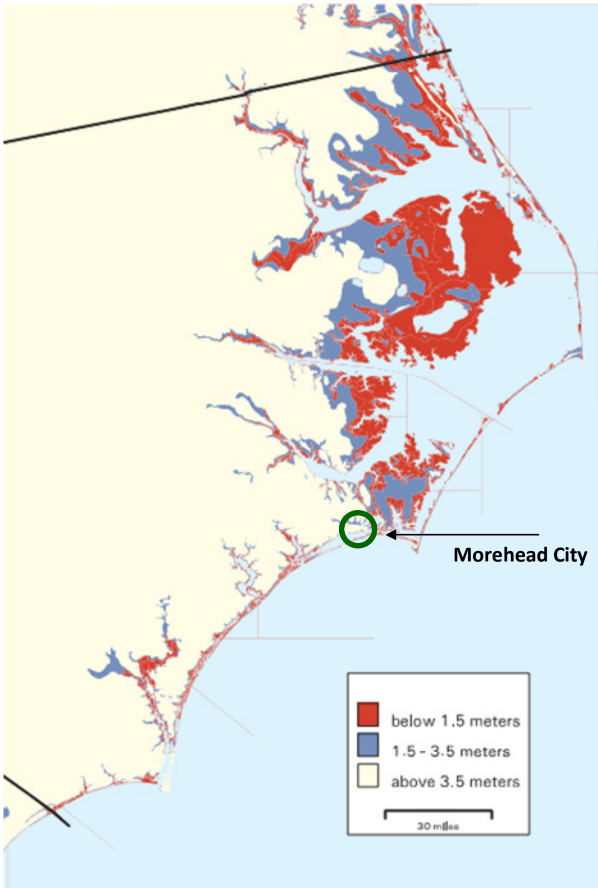


Figure 2.4 Recommended caveat from Titus and Richman (2001): *"This map is based on modeled elevations, not actual surveys or the precise data necessary to estimate elevations at specific locations. The map is a fair graphical representation of the total amount of land below the 1.5- and 3.5-meter contours; but the elevations indicated at particular locations may be wrong. Those interested in the elevations of specific locations should consult a topographic map. Although the map illustrates elevations, it does not necessarily show the location of future shorelines. Coastal protection efforts may prevent some low-lying areas from being flooded as sea level rises; and shoreline erosion and the accretion of sediment may cause the actual shoreline to differ from what one would expect based solely on the inundation of low land. This map illustrates the land within 1.5 and 3.5 meters of the National Geodetic Vertical Datum of 1929, a benchmark that was roughly mean sea level in the year 1929 but approximately 20 cm [or fill in local estimate] below today's sea level."* (Morehead City location added by author)

SLR in the Estuaries

As mentioned earlier, predicted SLR will threaten North Carolina's ocean and estuary shorelines at a rate almost double predicted global SLR. The potential for salt marsh drowning due to SLR depends on sediment supply, geomorphology, and storm frequency (Cahoon, et al., 1998). Higher sea levels can cause land above sea level to erode approximately 50-200 meters for every meter of SLR (Titus, 1998). While ocean front communities may be somewhat protected from this erosion zone by beaches, many estuarine communities have no shoreline beaches due to armoring. Data collected by Riggs and Ames (2003) indicate the majority of estuarine shores in North Carolina are eroding almost 2 m (7 ft) per year. A study of 21 shoreline sites estimated the rate of retreat is reducing wetland area in brackish marsh zones by 800 acres a year and is the result of both wave action and SLR (Riggs and Ames, 2003).

If conditions are appropriate, coastal marshes are able to build vertically at a rate equivalent to SLR. Accretion occurs in North Carolina coastal wetlands either by inorganic sediment accumulation or biogenic deposition (Moorehead and Brinson, 1995). In both instances, vegetation plays an important role in trapping mineral sediment and producing organic material (Kirwan and Murray, 2007). If the rate of SLR increases significantly, marsh vegetation will not be able to replace itself upland and low marshes in particular, will be susceptible to drowning (Donnelly and Bertness, 2001).

Human effects have been acknowledged as having a large, if not larger role in the loss of coastal wetlands: dredge-and-fill activities for land development, excessive nutrients from agriculture, altered hydrology and runoff, contaminants from runoff, prescribed fire management, subsidence from groundwater pumping, and invasive species introduction (Cahoon, 2007). Most relevant to this study is the impact of armoring the shore, which acts as a barrier to wetland migration. Upland development can also prevent wetlands from migrating in response to rising seas; up to 21% of Mid-Atlantic coastal wetlands are at risk for inundation from SLR by 2100, mostly due to this “coastal squeeze” phenomenon (IPCC, 2007).

Policy Responses

Statutory language formally acknowledges sea-level rise as a hazard in the North Carolina Administrative Code, the NC Coastal Area Management Act, and the Federal Coastal Zone Management Act. It has been listed as a concern by the NC Legislative Commission on Global Climate Change, the OPSC Final Draft Report, and the Coastal Habitat Protection Plan.

The framework exists for coastal North Carolina to begin to adapt to SLR, yet no action beyond studies and recommendations have been made. The hesitancy on the part of regulators and decision-makers may stem from the perceptions of what managing for SLR entails.

In the past, there have been three adaptation responses considered for SLR: retreat, accommodation, and protection (IPCC, 1990). Retreat has been practiced sporadically along the North Carolina coast; the most famous example was the relocation of the Cape Hatteras lighthouse (NPS, 1997). Accommodation implies people continue to use the land regardless of the risk, for example, converting coastal wetlands to aquaculture and building houses higher off the ground. This has also been partially practiced in North Carolina, as building codes have been updated to try and create homes capable of surviving large storms intact. The last scenario, protection, translates to armoring the coast to protect structures from rising water. As mentioned in Chapter 1, hard armoring has only been allowed along the estuarine shoreline in North Carolina and soft armoring (using sandbags) has been allowed as a temporary measure along the oceanfront.

Due to the uncertainty still surrounding SLR, the best management approach will be one that encompasses as many options as possible. Successful adaptation to SLR will require increasing flexibility in the three previously mentioned response strategies. For example, the "protection" response strategy can be interpreted rigidly to mean a hardened structure. The protection option has been practiced rigidly for years in states like New Jersey, often to the detriment of the beach or wetland on the other side of the seawall. But a different interpretation of the protection option has been growing in popularity in Maryland, Virginia, and North Carolina. The "living shoreline" approach has been gaining in popularity as an option that not only prevents erosion, but restores natural system functions. As mentioned earlier in the chapter, TNC is gearing up to implement the first SLR adaptation strategy in the state using a "living shorelines" approach. They are planning to plant marsh grasses and build oyster reef sills to protect the Alligator River National Refuge from rising seas (Charlotte Observer, 2009). TNC will also be installing devices to manage the flow of water into former agricultural ditches to try and restore the natural hydrology of the area.

The "living shoreline" stabilization strategy is a variation of the protection strategy and provides a way to address erosion of both wetlands and developed land along estuarine shores, an issue predicted to be exacerbated by SLR. It is a great example of a solution that is not only flexible in nature, but is capable of addressing multiple challenges at once.

The challenges facing the North Carolina coast may seem daunting, especially when considering future SLR. If the state and local communities are able to integrate resources and strategies in order to develop flexible solutions, the North Carolina coast will have a better chance of adapting to SLR as well as successfully addressing current challenges.

CHAPTER 3

Adaptation to Sea-Level Rise: A Case Study

Chapter 3 examines possible management responses to sea-level rise in North Carolina using a local case study. An analysis of geospatial data provided by the Town of Morehead City is used to create three potential land planning responses to SLR as an example of how the town can begin to develop a SLR response toolbox. The purpose of this analysis is to enhance Morehead City's Land Use Plan (LUP) and to prepare it for active management of SLR. The study shows how a flexible approach to SLR management can fit into the existing LUP framework, fully conform to the CAMA LUP guidelines, and provide options in the face of uncertainty.

While flood zones and other single-event risk predictions filter into land use planning, they are rarely seriously considered in planning decisions. SLR will have to be approached in a different, more deliberate manner. SLR inundation modeling results can be overwhelming to planners and managers who watch an entire floodplain disappear with a 1 meter rise in sea level. The good news is managers and planners can make choices today that can significantly change what their community will look like in the future. The case study on Morehead City shows how local communities can begin the journey to managing SLR with existing information and an already established framework.

Morehead City is an urbanized peninsula found just south of the dividing line between the North and South coastal plain geologic units (Riggs et al., 1995). Although Morehead City is not located along the more vulnerable ocean side, its growth is constrained by natural boundaries and it will face many of the same challenges barrier island communities will face with rising seas. It is a good representation of conditions moderately urbanized coastal towns and cities in North Carolina will encounter over the next century. Because the peninsula is not as low-lying as some areas in the Albemarle-Pamlico region, a case study of Morehead City will present a moderate example of SLR possibilities, which may be a more effective path to communicating SLR scenarios to the public (Galloway, 2008; Figure 3.1).

The case study will provide background on Morehead City's history, demographics, and natural systems. The effect of SLR on the community will be examined using several SLR inundation scenarios. The scenarios will then be used as a foundation to develop a SLR response toolbox within the local land use plan. The toolbox will be composed of three potential response options to SLR, each including a land suitability map, written component, and tables of information relevant to implementation of the option. Lastly, recommendations will be made on how to make SLR planning a reality in North Carolina.

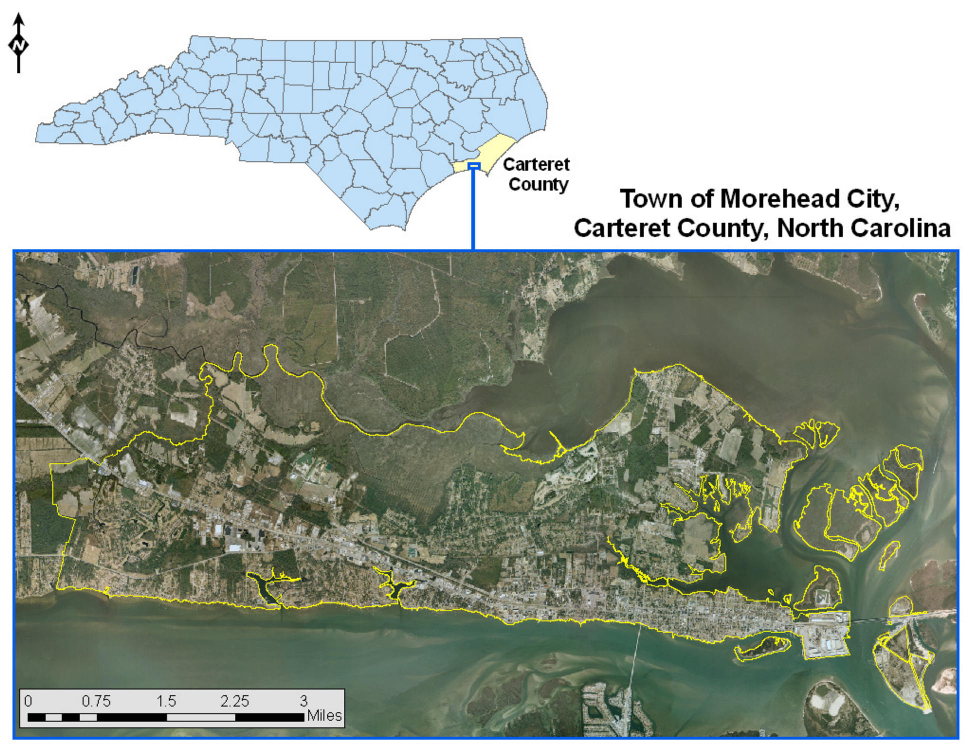


Figure 3.1 Study Area

3.1 Introduction to Morehead City, North Carolina

Historical Morehead City

John Motely Morehead and Silas Webb arrived at Shepard's Point in the early 1850's and described the future site of Morehead City as "thickly wooded and famed for its beauty of scenery." The two men, similar to Shepard's Point founder David Shepard, believed the area had potential for "a brilliant future" and immediately purchased several hundreds of acres of land from the Arendell family. John Morehead's stock in the Atlantic and North Carolina Railroads led to Morehead City becoming the terminal stop for both lines in 1857, thereby allowing establishment of the port and harbor facilities. As president of the Shepard's Point Land Company, John Morehead was poised to begin development of the area and the sale of Morehead City lots began in 1857.

The initial 100 lots created on the peninsula were sold to local people, mostly from Carteret County, and land speculators. Morehead, as "Architect and Builder of Public Works," laid out the town in squares of 16 lots with alleys bisecting each square in the form of an "H." The downtown remains in the same gridded pattern today. The railroad was built down the principal street (modern-day US-70/Arendell St.) and terminated at the eastern tip of the peninsula, where Pier 1 (precursor to the Port of Morehead City) was built. By 1858, the railroad was up and running and the town experienced a boom in growth over the next two years. Due to the tremendous success of the railroad and port, a municipal government was established in 1860, and Morehead City was incorporated in 1861. After only 15 months, the municipal government was overthrown by federal forces declaring martial during the early stages of the Civil War.

The Civil War was a crippling interruption to the burgeoning town of Morehead City. Growth was stagnant for the next three years, and municipal record keeping did not resume until 16 years after the war had ended. Shipping from Morehead City did not begin again until 1880 and was cut short by the railroad extension into Beaufort which temporarily made the neighboring town the new terminus. Infrastructure projects exploded after the turn of the century, with the introduction of electric power in 1905, followed by the construction of a roads system, waterworks, and sewer. The fishing industry became well-established during the same time (as the whaling industry declined). The construction of a cement seawall along the waterfront encouraged the founding of boat building workshops and menhaden fish houses.

Not until 1934, with the aid of a Public Works Administration loan, was the port revived and a new terminal constructed. Spurred by WW II, the North Carolina Port Authority was created in 1945 to produce adequate deep water ports through the sale of revenue bonds. The Authority officially took over supervision of the Port at Morehead City by 1949 and it has been run as a state port ever since.

Between 1960 and 1980, thousands of residents moved out of Morehead City and into newly developed “suburbs.” The migration caused one of the few periods of decreasing population in Morehead City’s history. The rise of neighborhoods outside the town boundaries led to heavy commercial and industrial development along the US-70 corridor. To take advantage of the booming growth surrounding the old town boundaries, Morehead City began an active annexation policy in 1999. Morehead City’s Extraterritorial Jurisdiction (ETJ) is currently three times the size of the original town’s limits, with plans for future expansion.

Morehead City Today

Demographics

The overall trend in population in both Morehead City and its ETJ has been upward even with the dip in population between 1960 and 1980 (Figures 3.2a and 3.2b). Although Carteret County was the 6th fastest growing coastal county in North Carolina 1970-2003, growth in Morehead City has leveled off, due to loss of jobs from the area, lack of year round housing, land availability, and transportation deficiencies (The Wooten Company, 2007). Average income has continued to rise in both Morehead City and Carteret County, although Morehead City's average in below both the state and county averages (Table 3.1). Poverty continues to decrease in Morehead City.

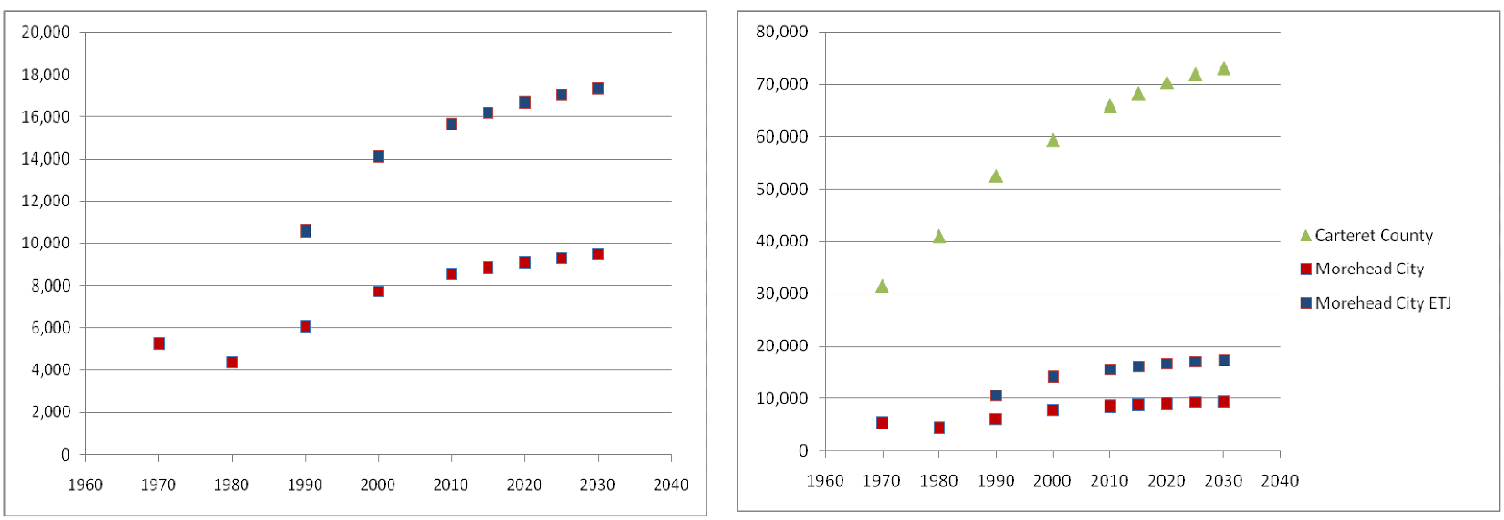


Figure 3.2a and 3.2b Population growth and predicted growth in Morehead City, ETJ, and Carteret County
Source: Morehead City Land Use Plan, 2007

Table 3.1 Average Income and poverty rates

	Year			Percent change		
	1980	**1990**	**2000**	**1980-1990**	**1990-2000**	**1980-2000**
Morehead City	$5,457.00	$11,410.00	$19,138.00	109.1%	67.7%	250.7%
Carteret County	$6,146.00	$13,227.00	$21,260.00	115.2%	60.7%	245.9%
North Carolina	$6,133.00	$12,885.00	$20,307.00	110.1%	57.6%	231.1%
Families in Poverty (MC)	17.5%	15.5%	12.3%	-11.7%	-20.4%	-29.7%

Owner-occupied housing units account for 55.5% of all housing stock in Morehead City as compared with 77% of housing units in Carteret County. The number of seasonal units has increased over 700% since 1980, a reflection of the growing tourism industry along the entire coast (The Wooten Company, 2007). The seasonal population in 2006 was 6,527, approximately 31% of the total peak population in the ETJ. Even with the large influx of seasonal residents, Morehead City continues to be a functional urban area year-round. Hospitals, universities, and commercial centers operate throughout the year, unlike other coastal and island communities. The largest employment sectors in the town are education, health, and social services; evidence of the well-established nature of institutions and businesses in the area.

The availability of amenities in the off-season is a contributing factor to the large increase in the town's population aged 50-59 over the last decade (The Wooten Company, 2007). The demographics reveal a potential for future demand in medical care, in-home services, institutional care, transportation, and housing tailored for the elderly. The population trends can also explain the decreasing average household size which at 2.06, is lower than the county and state averages.

<u>Critical Infrastructure</u>

Before Morehead City begins to plan for future development, there are pressing concerns over existing wastewater and stormwater infrastructure that need to be addressed. According to the LUP, the town's water supply system is fed by five wells capable of providing 2.55 million gallons per day (MGD). In 2002, the average daily demand was 1.18 MGD (46% of available supply), predicted to rise to 1.97 MGD (63% of available supply) by 2030 (The Wooten Company, 2007). The water supply system appears poised to accommodate the growing population. The LUP, however, does not consider the potential for saltwater intrusion associated with SLR or potential alternative sources of freshwater.

The town's wastewater and stormwater systems are not as stable as the water supply system. Morehead City established its sewer system in 1917 and expanded 75 miles of sewer lines throughout its ETJ over the last few decades (Morehead City, 2008). Due to large amounts of stormwater infiltrating into the system, several load violations occurred and the town was put under a sewer moratorium beginning in 1999 (15A NCAC 02H .0223). The moratorium prohibited the town from any additional sewer hook-ups or sewer lines expansion. In attempts to raise the moratorium, a $3 million sewer rehabilitation project upgraded the system to reduce the inflow of rainwater and other extraneous infiltration. In 2007, Morehead City received $91,000 from the Clean Water Management Trust Fund for a wastewater reuse system (NC CWMTF, 2007) and in late 2008, the town was awarded a $500,000 grant from the N.C. Rural Economic Development Center to improve two wastewater pump stations (NC Rural Center, 2008). During 2008, a new Reuse Quality Tertiary Wastewater Treatment Plant came online and increased wastewater treatment capacity to 2.5 MGD from 1.7 MGD. The old wastewater system exceeded capacity 8 out of 12 months in 2003 (The Wooten Company, 2007) and the new system did not exceed discharge limitations once during 2008 (The Wooten Company, 2008).

Morehead City has a Municipal Separate Storm Sewer System (MS4) consisting of 22.8 miles of piping. Increased development over the last two decades has led to overflow discharges into surrounding waterbodies during precipitation events (The Wooten Company, 2007). A retrofitted stormwater system in Morehead City includes ditches, pipes, catch basins and swales, but there is no guiding stormwater management document. In 2000, a 30-ft. buffer rule for new development along all navigable waterways in N.C., excluding the oceanfront, was created to address concerns over non-point source pollution. Unfortunately, there were so many applications for variances that the CRC's function was severely hindered and the rule had little impact on reducing stormwater pollution (NOAA, 2006). Hopefully, the new stormwater rules passed in July of 2008 will have a greater impact on the area.

Demographic statistics and land use patterns seem to suggest the town of Morehead City, like much of the North Carolina coast, will need to be increasingly deliberate in planning future development. Population statistics indicate population growth has slowed in the area due to a lack of year-round housing and an increase in seasonal rental units. As the average age of residents in Morehead City continues to increase, the town as a retirement community will face specific pressures associated with this demographic shift. Retirees place a high value on location amenities and recreational possibilities. The existence of conservation areas, green space, and waterfront access will all be valued by older populations.

But the demographic trends cannot be considered in isolation. Stormwater and sewer line issues continue to hamper Morehead City. The sewer moratorium has only recently been lifted but the town continues to struggle with stormwater and wastewater overflows impairing surrounding waterbodies. Water quality and other effects of the built environment on the natural systems will be discussed in greater detail in the next section.

Natural Features and Processes

<u>Geography</u>

Morehead City is an estuarine community tucked behind developed barrier island Bogue Banks and less than 15 miles northwest of Cape Lookout National Seashore. The town occupies a peninsula surrounded by the Newport River to the far north, Calico Creek and Calico Bay to the north of downtown, and Bogue Sound and the Atlantic Intracoastal Waterway to the south (Figure 3.3). The northern portion of the Morehead City ETJ contains extensive natural and drained salt/brackish marshes, the majority of which are owned by the North Carolina Coastal

Land Trust. The Trust is also responsible for conserving approximately 100 acres of marsh islands in Calico Bay called the Haystack Marshes. In total, over 600 acres of conservation land are owned by the Coastal Land Trust in Morehead City. Additionally, the North Carolina Coastal Federation and Morehead City worked together to secure funding to purchase 47-acre Sugarloaf Island, a dredge spoil island visible from the Morehead City waterfront. Over the years the island has become important habitat to shorebirds and submerged aquatic vegetation (NC CWMTF, 2002). Waters around Morehead City are considered part of the Albemarle-Pamlico Estuary, the second largest estuary in the United States (Albemarle-Pamlico NEP, 2009).

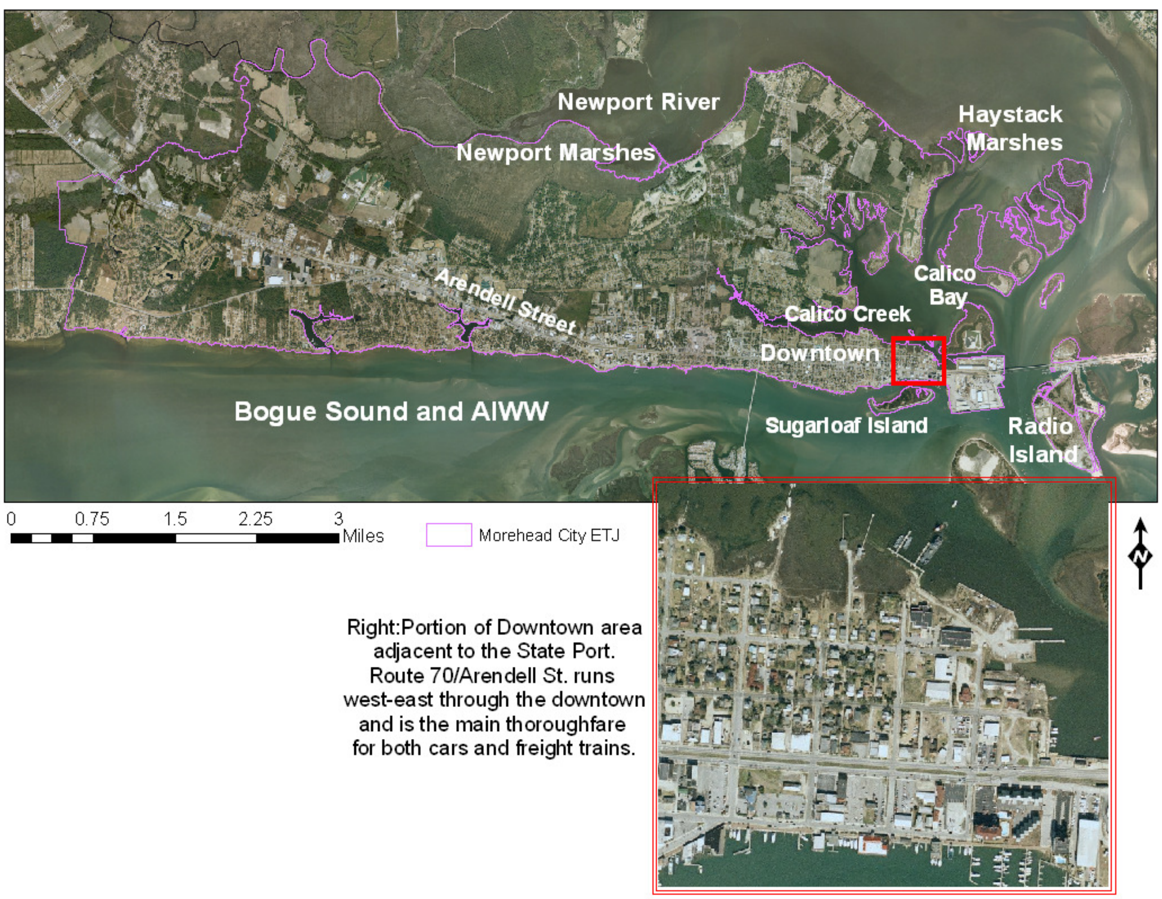


Figure 3.3 Study area

Areas of Environmental Concern (AEC)

Designated Estuarine and Ocean System Areas of Environmental Concern (AEC) are found throughout the Morehead City ETJ. The Estuarine and Ocean System AEC has four sub-classes present in Morehead City: Public Trust Areas, Estuarine Waters, Coastal Shorelines, and Coastal Wetlands. The following are abridged descriptions of the Estuarine and Ocean System AEC categories (The Wooten Company, 2007):

- *Public Trust Areas:* All water and land underneath from the normal high water mark on shore to three miles offshore. Public trust areas often overlap with Estuarine Waters.
- *Estuarine Waters:* Sounds, tidal rivers, tributaries and other bodies of water that link to the estuarine system which includes public trust areas, coastal shorelines, and coastal wetlands.
- *Coastal Shorelines:* All lands within 75 feet of the normal high water level of estuarine waters. Wetlands in this zone tend to buffer against flooding and decrease erosion.
- *Coastal Wetlands*: Any marsh in the 20 coastal counties regularly flooded by lunar or wind tides and contains one or more of the 10 designated plant species.

Areas along the Newport River, Calico Creek, and Crab Point Bay, as well as Phillips Island, Annex Island, portions of Sugarloaf Island and the Newport Marshes are areas of Coastal Wetlands (Figure 3.3; The Wooten Company, 2007).

Water Quality

Morehead City is located within a sub-basin of the White Oak River basin and the majority of waters surrounding the ETJ are designated HQW SA (Shellfishing High Quality Waters) by the Department of Water Quality, except for Calico Creek and waters surrounding the State Port. Calico Creek, Crab Point Bay and portions of the Newport River are all designated Primary Nursery Areas; shallow marsh areas with soft muddy bottoms ideal for young fish and shellfish (NCDMF, 2009). Calico Creek is also home to the Morehead City municipal wastewater treatment (WWTP) plant which discharges directly into the creek, severely impairing water quality. In 2002, approximately 25% of waters in Morehead City were closed to shellfishing (The Wooten Company, 2007). The LUP cites increasing urbanization as a cause of the impairment, but acknowledges the wastewater treatment plant (prior to 2008 upgrades) had exceeded discharge limits twice in 2000 and several times in 2002-2003.

Soils

Morehead City contains 30 different soil types and 88.5% are classified as being severely limited for septic systems (The Wooten Company, 2007). In combination with the lack of sewer lines in many portions of the ETJ, and the unlikely expansion of the sewer lines until the system completes serious upgrades, high-density development in the future will be restricted to areas already served by existing sewer lines or areas of appropriate soil quality.

Disturbance

Development pressures in Morehead City are amplified by natural disturbances. The town is vulnerable to flooding from the Newport River and sound, and will be vulnerable to SLR in the future. Erosion, especially with increasing sea level, will be a concern for the northern shore of the peninsula. The majority of the shore is lined with salt marsh wetlands designated as "floodplain." As will be seen later in the chapter, the northern marshes will bear the brunt of predicted SLR inundation.

Similar to many of the other southern-facing coastal communities in North Carolina, Morehead City experiences hurricanes and tropical storms. In 2007, Carteret County was named as the coastal county with the highest probability of hurricane force winds in 2007 by a University of Florida study (Appendix 3.1). The study considered hurricane paths over the last

155 years as well as current climate conditions. There have been 15 hurricanes passing within 50 miles of Morehead City within the last 50 years i.e. on average the area is affected by hurricanes every 3 years (Table 3.2).

Table 3.2 Hurricanes coming within 50 nautical miles of Morehead City within the last 50 years (NOAA Historical Hurricane Tracks)

Name	Year	Category
Carol	1954	2
Connie	1955	2
Ione	1955	2
Helene	1958	4
Donna	1960	2
Isbell	1964	1
Gladys	1968	1
Ginger	1971	1
Charley	1986	1
Bonnie	1998	2
Floyd	1999	2
Irene	1999	1
Isabel	2003	2
Alex	2004	2
Ophelia	2005	1

If the Town of Morehead City is to effectively address SLR going forward, it will need to focus on integrating demographic trends, infrastructure capacity, natural system capacity, and SLR predictions into its LUP. To some extent, the town will have to allow predictions of SLR and increased storm intensity to drive development and planning choices going forward. Without the consideration of natural impacts, the town will experience extensive damage to life, property, and infrastructure in the upcoming decades.

3.2 First Steps in Adapting to Sea-Level Rise

Morehead City and other coastal communities can be evaluated on their SLR adaptive capacity using the framework provided by Nicholls et al. (2007). The 2009 OPSC Final Draft Report recommends completing an exercise like this for the entire North Carolina coast**.** To determine whether there are hotspots of social vulnerability in a coastal zone, or even within a coastal community, the following criteria can be used:

Is Morehead City

- A coastal area where there are substantial barriers to adaptation (economic, institutional, environmental, technical, etc.)?
- A coastal area subject to multiple natural and human-induced stresses, such as subsidence or declining natural defenses?
- A coastal area already experiencing adverse effects of temperature rise?
- A coastal area with significant flood-plain populations that are exposed to significant storm surge hazards?
- A coastal area where freshwater resources are likely to be reduced by climate change?
- A coastal area with tourist-based economies where major adverse effects on tourism are likely?
- A coastal area containing highly sensitive coastal systems where the scope of inland migration is limited?

By examining the above-mentioned criteria, Morehead City will better understand its particular level of vulnerability to SLR.

It will be important for Morehead City to assess its level of vulnerability to SLR, but an assessment is not required in order for the town to begin to actively manage the SLR threat. So far, Morehead City has done nothing in terms of adaptation to SLR even though it has the potential to experience serious inundation in the next 80 years. In the Morehead City LUP, SLR is only addressed once, in a Hazard Mitigation Plan Matrix attached as Appendix L. It includes a brief analysis of what the town has done to address SLR and designates the effectiveness of mitigating the hazard as "Low" (The Wooten Company, 2007):

> The Town supports continued state research into the problems associated with sea level rise and will consider the development of policies to address sea level rise as more data concerning problem definition and alternative solutions are made available.

Morehead City, employing the cautionary principle, is looking to the state to take the lead in addressing SLR and will only begin to address it as a concern once data is conclusive. But local communities will place the state in a better position to act if they determine their barriers to adaptation now, rather than wait for the state to codify recommendation by the OPSC or any other Committees organized to address coastal zone management.

3.3 Methods

The level of vulnerability determined for each coastal community will guide the choices they make in adapting to SLR. Some communities may choose more reactive approaches to responding to SLR while others will actively manage for it. Given the nature of SLR (and associated effects), all communities will benefit from having flexibility in choosing the appropriate strategy. This study hopes to show how a local community can begin to develop a flexible approach to managing SLR within the existing local land use plan framework.

Data

The majority of data layers used for the analysis were provided by the Morehead City Planning Department. Land use, future land use, neighborhood, zoning, and parcel shapefiles as well as sewer and water polyline data, and an orthorectified high resolution (2 ft) photograph of Carteret County were prepared for analysis by being projected into North Carolina State Plane

Feet and removing errors, including gaps in land use data. To update the land use shapefile, the high-resolution photograph (taken in 2004) and a Google Earth image from 2006, were used for comparison of parcel and road boundaries.

Wetlands data was obtained from the National Wetlands Inventory which has been gathering wetlands information since 1994. The wetland data does not take ownership or other parcel data into account when mapping wetland types. The majority of wetlands in the Morehead City area are natural and drained salt/brackish marsh.

Flood zone data was created by the National Flood Insurance Program (NFIP), created by the Federal Emergency Management Agency (FEMA). The Town of Morehead City contains three flood zone designations within its ETJ:

1. *VE Zone*: A coastal high hazard area where wave heights are expected to be 3 feet or more.
2. *AE Zone:* Area subject to flooding by the base or 1% annual chance (100-year) flood, and waves less than 3 feet high.
3. *Shaded X Zone*: Area subject to flooding by the 0.2% annual chance (500-year) flood.

Sea-level rise inundation results were provided by Benjamin Poulter (Potsdam Institute for Climate Impact Research). The six scenarios were based on projection data from the IPCC Fourth Assessment Report (2007) for 2030 and 2080. The IPCC projections can be considered conservative because they neglect ice sheet contributions and consider only the eustatic component averaged across the entire globe (IPCC, 2007). To gather a more accurate picture of sea-level rise in North Carolina, an isostatic adjustment was added to the IPCC scenarios (Bin et al., 2007). Adjustments to ice sheet contributions were not made, although emerging research indicates a maximum scenario of 2 m of SLR by 2100 (Pfeffer, 2008). A seventh scenario created from 2001 IPCC projections for 2100 was included as a maximum inundation scenario, again without including possible ice sheet contributions (Table 3.3).

Table 3.3 Sea-level rise inundation scenarios

Year	Scenario	Projected sea level, including both eustatic and isostatic components (m)
2030	Low	0.11
	Mid	0.16
	High	0.21
2080	Low	0.26
	Mid	0.46
	High	0.81
2100	Max	1.06

A digital elevation model (DEM) was derived from Lidar data gathered by the North Carolina Floodplain Mapping Program (NCFMP, 2004). The DEM has a horizontal elevation of 15 meters (50 ft) and vertical accuracy of 25 centimeters. Poulter and Halpin (2007) identified continuing obstacles with raster modeling of sea-level rise even with higher resolution elevation data (6m and 15m). Despite higher resolution data, SLR study results still contain uncertainty due to error ranges greater than actual projected SLR amounts.

The DEM used to generate the SLR inundation results used in this study does not include portions of Calico Bay and Bogue Sound, including the Haystack Marshes, Sugarloaf Island, and a small dredge spoil island off the northern shore of the State Port. These areas were masked out for the study. It should be noted that the study area was reduced further for the creation of the SLR toolbox land suitability maps by excluding the designated State Port area because it is designated "Port Mixed Use" in the existing LUP and is under control of the state. Across the channel, Radio Island includes 150 acres already approved for marine terminal development (NC Ports, 2009). The exclusion of the port facility does not mean it will not be susceptible to future SLR or future development. This decision was made to allow the SLR toolbox to be consistent with the current LUP format. Undeniably, the Port will face issues associated with SLR similar to the rest of downtown Morehead City.

The inundation grids go beyond traditional 'bathtub' (or 'zero-side rule') model studies of SLR which simply consider elevation irrespective of surface connectivity (Moorhead and Brinson 1995; Titus and Richman, 2001; Poulter and Halpin, 2007). These models tend to create ponding in interior areas where elevations fall below the SLR level even if these areas are unconnected to coastal or estuarine waterbodies that would actually be affected by SLR (Poulter and Halpin, 2007). More recent studies have incorporated connectivity of cells to more accurately model characteristics of flooding (Poulter and Halpin, 2008; Bin et al., 2007). In this study, the results were created using an eight-sided rule in which grid cells were inundated if they were connected by way of cardinal and diagonal directions to a cell determined to be flooded based on elevation. The eight-sided rule can potentially overestimate inundation extent whereas an alternative four-sided rule (inundating cells only in cardinal directions) has the potential to underestimate inundation extent. Given the conservative nature of the SLR scenarios used for this study (due to the exclusion of ice sheet effects), the eight-sided rule creates a more moderate representation of potential SLR inundation.

There are additional factors that will influence shoreline location over the next 100 years in Morehead City. It should be noted these factors were not incorporated into the SLR model results. Wetland accretion rates, erosion rates, storm influences, dredging activity, agricultural ditching, and tidal rates are all factors with the potential to affect the location of the town's shoreline as well as the speed and extent of inundation.

Analysis

Overview

An overview of SLR effects in Morehead City will serve as an introduction to the SLR response toolbox within the LUP. The overview will contain information on how SLR is most likely to affect Morehead City. It will provide information on land uses and neighborhoods affected by SLR, as well as information on structure and parcel inundation. For the development of the SLR toolbox, three SLR scenarios were selected: the 0.16 (2030 Mid), 0.46 (2080 Mid), and 1.06 m (2100 Max) (Table 3.3).

All shapefiles were converted to grids in order to extract inundation values from the inundation grids. To get a general sense of the possible effects of SLR, all seven scenarios were overlaid with the current land use plan and areas of inundation were tabulated. In addition, areas of inundation were calculated for future land uses, which closely align with current land uses. Since the Morehead City LUP (2007) divides the ETJ into neighborhoods, inundation results were also used to calculate inundated areas by neighborhood.

Inundation of parcels was determined by using the centroid of each parcel (Bin et al., 2007; Michael, 2007). If the centroid was inundated, the parcel was designated inundated. This method yields some parcels that are almost completely inundated except the centroid designated as "not inundated." There are instances where the majority of the parcel is not inundated but the centroid is covered. For this study, these over- and under-estimates were assumed to balance each other out. In the future, higher-resolution data will eliminate some of the error.

Vacant parcels were isolated by selecting by the "structure value" attribute, assuming the parcel is vacant if the structure value equals zero. The use of the isolated vacant parcels for the three response strategies in the SLR toolbox is most likely an overestimation of future vacant land availability because it assumes within the next 20-90 years vacant parcels will remain the same. Especially given the current economic climate, it is hard to say what percent of vacant parcels will still exist in 2030, 2080 or 2100. There were some parcels removed from the vacant parcel layer because they represented boat slips, or other features where structures would not be feasible.

A basic economic analysis was performed for the 0.16 m (2030 Mid) inundation result to provide the town with a general sense of potential tax revenue losses. The study calculated the value of land lost by adding up the tax values lost and discounting at a rate of 2% (Bin et al, 2007; Michael, 2007) and 7% (Bin et al., 2007).

As noted by Yohe (1991) the tax records provided by Morehead City may not accurately reflect the market value, especially given the current instability of the housing market. Appreciation rates associated with a newly acquired shorefront status or depreciation rates from general aging and increases in risk for damage have not been included. Values of coastal wetlands are "unlikely to be captured in the assessed property values" (Bin et al., 2007) and the study did not consider the potential for increases in episodic flooding from SLR causing more damage than inundation over a much greater area (Michael, 2007).

Sea-Level Rise Management Toolbox

The SLR Toolbox will include three response plans. In the future, Morehead City would use these plans as a foundation for creating a variety of sub-options in order to populate the toolbox with as many SLR response options as possible. Each response plan will contain a land suitability map, relevant calculations to aid in implementation of the plan, and a written component. The written component contains a summary of the strategy, the implication for future development, the implications for natural systems, and an implementation strategy.

Response Plan 1: Case-by-Case/Reactive

The goal of Plan 1 is to identify areas suitable for development over the next 20 years giving minimal consideration to SLR predictions. Plan 1 is a reactive approach, meaning it would not have a formal protocol in place to address SLR damage. This is similar to the informal, unplanned way barrier island communities currently address condemned structures. To address future land development potential, a land suitability map was created using weights and categories similar to the existing land suitability map in the Morehead City LUP (The Wooten Company, 2007; Figure 3.4). The existing Morehead City land suitability map was used as the model for all three land suitability maps within the SLR toolbox.

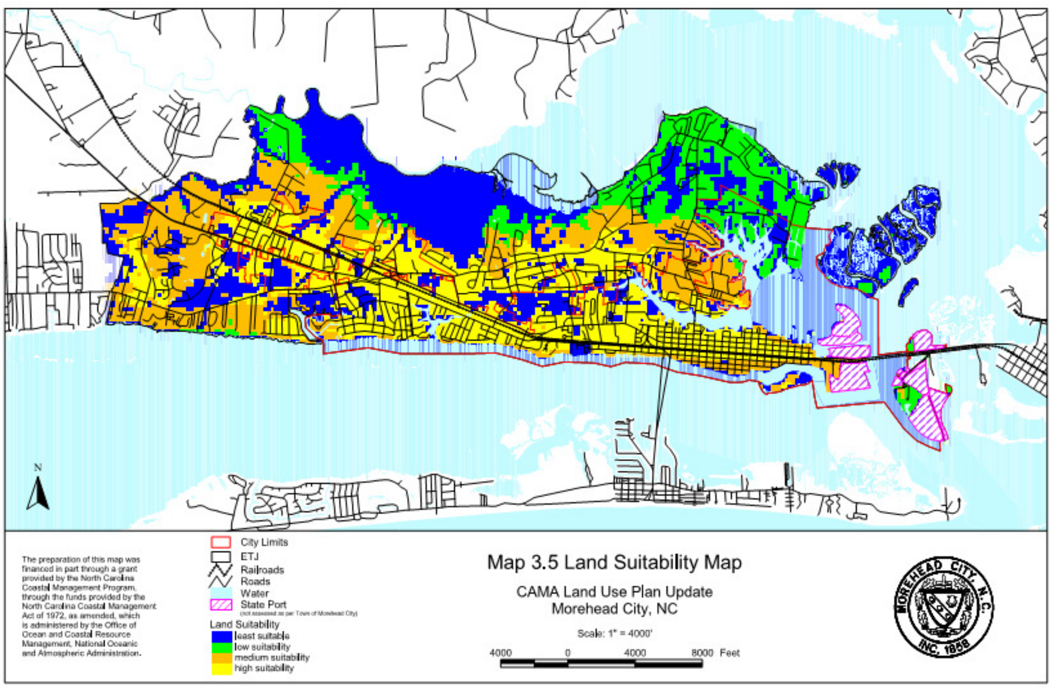


Figure 3.4 Morehead City Land Use Plan Land Suitability Map displaying land suitable for development over the next 20 years (2007)

Although areas of possible inundation from SLR were not explicitly masked from the overlay, vacant parcels that could be inundated by 2030 Mid scenario (0.16 m) were given lower weights than other inland vacant parcels. Unlike the land suitability map in the current LUP, this analysis considered vacant parcel availability but did not consider soils, Natural Heritage Areas, hazardous substance disposal sites, and other infrastructure-related factors (The Wooten Company, 2007). Similar to the LUP land suitability analysis, Plan 1 included flood zones as defined by the National Flood Insurance Program. These are areas recommended to be kept as open space (NC DEM, 2008), but can still be developed. Each grid was reclassed on a scale 0-3, 0 representing least suitable, 3 representing most suitable. Once data layers were reclassed, they were combined and thresholds were set to reclassify each suitability category. The following grids were used to create the land suitability map:

- **Wetlands:** All wetlands were classified as "least suitable".
- **Vacant parcels, reclassed to consider 2030 Mid inundation:** The vacant parcels within the "General Industrial" and "High Density Residential" future land use categories were weighted as less suitable compared to the other land use categories (Low Density Residential, Institutional, Downtown Mixed-Use, etc.). Vacant parcels predicted to be inundated by 2030 were excluded.
- **NFIP flood zones:** Coastal areas are highly susceptible to flooding but development occurs in flood zones regardless of designation, therefore the flood zones were not given weights of zero since this would affect over 5 square miles of Morehead City located within a designated flood zone.
- **Buffered sewer lines:** Due to past difficulties with sewer infrastructure in Morehead City, areas within a quarter-mile of existing sewer lines were given a "highly suitable" rating.
- **Buffered waterlines:** Same criteria as sewer lines.

Table 3.4 Data layers and attribute weights for Plan 1

Layer	Categories	Weights
	Wetland	0
Wetlands	Non-wetland	2
	Non-vacant	0
	General Industrial/High Density Residential	2
Vacant parcels	Other land uses	3
	100 & 500 yr floodplain, coastal hazard zone	1
Flood zones	Non-flood zone	2
	Greater than 0.5 miles from existing sewer line	1
	Between 0.25 and 0.5	2
Sewer lines	Within 0.25 miles	3
	Greater than 0.5 miles from existing waterline	1
	Between 0.25 and 0.5	2
Water lines	Within 0.25 miles	3

Once the land suitability map was created, the area of each suitability category was calculated. These results were compared with projected land use needs as determined in the Morehead City LUP (2007) (Table 3.5).

Table 3.5 Projected land use needs

Land Use	Additional acres needed through 2025
Residential	1,577
Commercial	433
Industrial	355
Public/Institutional	315
Total	2,680

Implementation of Plan 1 would not require much knowledge beyond what already exists in the LUP. The plan would likely use some of the overview calculations for the 0.16 m scenario, since this is the only inundation result considered in this plan.

Response Plan 2: Armored Shoreline

The goal of Plan 2 is to identify areas suitable for development over the next 20 years considering future SLR and a shoreline hardening strategy. Plan 2 assumes Morehead City opts to respond to SLR by building a seawall along the entire shore. A good portion of the shoreline along Bogue Sound is already armored to protect residential property, but there are gaps serving as public access points. The town may consider filling in these gaps to create a continuous armored shoreline, or use a combination of hardened/natural shoreline protection strategies. Plan 2 may seem extreme, but it will serve as a baseline for the development of other options related to a policy of armoring (partial hard armoring, soft armoring, hard armoring of the downtown).

To simulate a shoreline armoring policy, a 3ft-contour was created using the DEM to represent a seawall. Isolating the 3-ft contour (0.9 meters) resulted in some interior pockets of low elevation. These areas were removed, assuming they would be filled and developed if a seawall was built. Portions of the contour line were smoothed to better emulate wall construction. The resulting shapefile was then used as a clip for a new land suitability plan. The construction of a seawall would hypothetically remove the threat of flooding from adjacent waterbodies and therefore flood and wetland layers were removed (Table 3.6). This policy option did not consider the potential affects of a rising water table associated with SLR.

Table 3.6 Data layers and attribute weights for Plan 2

Layer	Categories	Weights
Vacant parcels	Non-vacant	0
	Vacant	3
Sewer lines	Greater than 0.5 miles	1
	Between 0.25 and 0.5	2
	Within 0.25 miles	3
Water lines	Greater than 0.5 miles	1
	Between 0.25 and 0.5	2
	Within 0.25 miles	3

Calculations relevant to implementation of the plan include amount and location of land suitability categories, as well as the total amount of wetlands lost (potential mitigation requirements). Once the DCM has completed mapping of hardened structures along the estuarine shore, calculations of the amount of additional seawall required can me made, as well as estimated costs.

Response Plan 3: Relocation/Migration

The goal of Plan 3 is to identify areas suitable for development over the next 20-90 years considering future SLR and a policy of structure relocation and wetland migration. In this plan, Morehead City would preempt damage from SLR by relocating threatened structures/parcels inland and allowing wetlands to migrate upland.

Salt marshes were the focus of the wetland migration portion of the plan because they are the dominant wetland type in Morehead City. The salt marsh areas were used to develop a salt marsh vacant parcel layer to add to the land suitability map. Wetland accretion and migration rates have been estimated for SLR and are dependent on slope angle, available upland, sediment availability, and erosion rates (Moorehead and Brinson, 1995). For simplicity's sake, this study did not attempt to calculate potential wetland accretion offsets of SLR because the inundation results consider connectivity of cells, not simply land elevation.

A land suitability map was created similar to the one created for Plan 1, but with some variation in weights and the addition of several new layers. Each grid was reclassed on a scale 0-3, 0 representing least suitable, 3 representing most suitable. The following grids were used to create the land suitability map:

- **Wetlands:** weighted as they were in Plan 1, with all wetland areas considered "least suitable" for development.

- **2080 Mid (0.46 m) inundation:** The inundation results for the 2080 Mid scenario (0.46 m) with areas of projected inundation weighted as "least suitable."
- **2100 (1.06 m) vacant:** Inundation results from the 2100 Max scenario (1.06 m) were not directly weighted and used in the overlay because it would have included much of the same information as the 2080 Mid layer. Instead, vacant parcels were isolated using the 1.06 m inundation scenario and weighted. The vacant parcel layer represents areas available for development and not at risk from SLR.
- **Salt Marsh migration parcels:** To try and provide some guidance as to conservation areas, vacant parcels adjacent to drained and natural salt marshes were identified (Appendix 4).
- **NFIP flood zones:** Plan 3 is intended to place greater emphasis on SLR. With increases in SLR flood zones will inevitably expand. Because there was no data available related to future flood zones given specific SLR levels, flood zones were simply re-weighted so that all flood zones were given "least suitable" ratings. This is consistent with NC Department of Emergency Management recommendations (2008).
- **Buffered sewer lines:** weighted the same as they were in Plan 1 and Plan 2.
- **Buffered water lines:** weighted the same as they were in Plan 1 and Plan 2.

Table 3.7 Data layers and attribute weights for Plan 3

Layer	Categories	Weights
Wetlands	Wetland	0
	Non-wetland	2
2080 Inundation	Inundated	0
	Not inundated	2
2100 Vacant	Non-vacant	0
	Vacant & above 1.06m	3
Salt Marsh migration parcels	Existing marsh + adjacent vacant parcels	0
	Other	2
Flood zones	100 & 500 yr floodplain	0
	Other	2
Sewer lines	Greater than 0.5 miles	1
	Between 0.25 and 0.5	2
	Within 0.25 miles	3
Water lines	Greater than 0.5 miles	1
	Between 0.25 and 0.5	2
	Within 0.25 miles	3

Calculations relevant to implementation of Plan 3 include the amount and location of land suitability categories, vacant land parcels, and average parcel size by neighborhood. Vacant parcel analysis was performed by neighborhood to allow a relocation plan to match inundated parcels with interior parcels within the same neighborhood.

3.4 Results

Overview of SLR Effects

The majority of land in the 16.6 square mile Morehead City ETJ is designated residential (58.06%) with streets and commercial land use categories a distant second and third (9.78% and 8.21%) (Table 3.8).

Table 3.8 Morehead City land use categories by area

Land Use	Acres	Sq. Miles	Percentage
Commercial	867	1.4	8.21%
Floodplain	688	1.1	6.52%
Industrial	734	1.1	6.95%
Institutional	477	0.7	4.52%
Planned Dev.	629	1.0	5.96%
Residential	6,129	9.6	58.06%
Streets	1,032	1.6	9.78%
Total	10,556	16.5	100.00%

To provide Morehead City with an overview of which areas are susceptible to SLR, land uses for all seven SLR scenarios were tabulated. Residential and floodplain land uses make up the greatest percentage of the inundated area for all seven SLR scenarios (Appendix 2). Street and planned development land uses make up the smallest percentage of inundated area for all the scenarios except the 2100 Max (1.06 m). The percent of the floodplain land use category inundated ranged from 13.5% for the lowest level of inundation to 99% for the maximum inundation scenario (Table 3.9). Considering inundation by acreage, the residential land use was the greatest area affected, ranging between 260 acres for the lowest level scenario up through 1,230 acres for the maximum inundation scenario (Table 3.9).

Table 3.9 Area inundated by land use (2100 Max, 1.06 m)

2100 Max (1.06 m)

Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	687.7	1.074	32.08%	99.92%
Residential	1230.4	1.923	57.40%	20.08%
Institutional	41.3	0.064	1.93%	8.65%
Planned Dev.	66.2	0.103	3.09%	10.51%
Street	31.1	0.049	1.45%	3.01%
Industrial	61.0	0.095	2.85%	8.32%
Commercial	25.9	0.040	1.21%	2.98%
Total	2143.6	3.349	100.00%	

The three 2030 scenarios (0.11, 0.16, and 0.21 m) inundated approximately 4-5% of the total Morehead City ETJ, the 2080 scenarios (0.26, 0.46, and 0.81 m) inundated 5-17% of the total land area, and the 2100 scenario (1.06 m) inundated one-fifth of the total area (Table 3.10).

Table 3.10 Percent of land inundated by SLR scenario

Scenario	Percent of total land inundated
2030 Low	4.00%
2030 Mid	4.38%
2030 High	4.85%
2080 Low	5.53%
2080 Mid	11.15%
2080 High	17.26%
2100 Max	20.31%

The land use calculations will assist Morehead City in determining future land use assuming some level of SLR and allow the town to better understand how much total land will be lost to inundation. The results also confirm the important role the floodplain plays in the area.

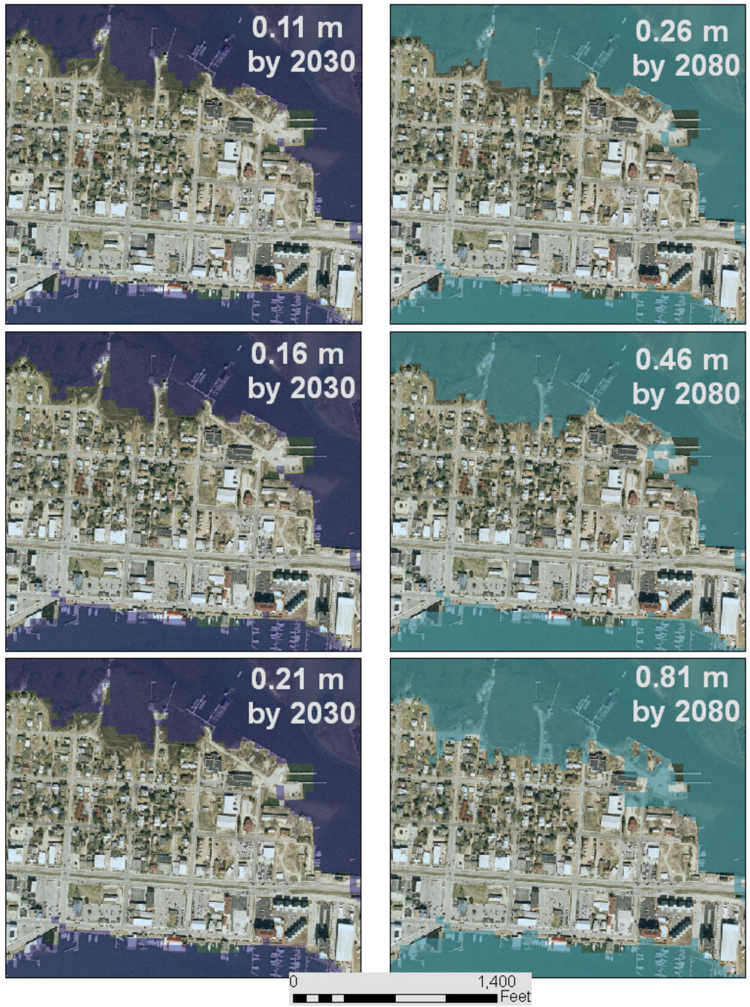


Figure 3.5 Downtown Morehead City under six inundation scenarios.

One of the central planning units utilized in the Morehead City LUP is the "neighborhood" (The Wooten Company, 2007; Appendix 3). The amount of land inundated by each SLR scenario varied greatly across neighborhoods. The majority of the floodplain consists of undeveloped wetlands in the northern portion of the Morehead City ETJ, and this was the area experiencing the most inundation under each scenario. The three neighborhoods bordering the Newport River (Neighborhoods 5, 7, and 8; Appendix 3) contained the largest amount of inundated land for all seven scenarios (Table 3.11). The neighborhoods along Bogue Sound (Neighborhoods 1-4, 6, 9, and 10) experienced far less inundation than the northern neighborhoods under all seven scenarios. The downtown area (Figure 3.5) experienced minor land loss along the northern shoreline.

Table 3.11 Area inundated by neighborhood (acres)

Sea-level rise scenario (m)	Nbhd 1	Nbhd 2	Nbhd 3	Nbhd 4	Nbhd 5	Nbhd 6	Nbhd 7	Nbhd 8	Nbhd 9	Nbhd 10	Streets
2030 Low (0.11)	21	4	15	8	120	24	69	103	30	11	8
2030 Mid (0.16)	22	4	17	8	133	24	78	115	31	11	9
2030 High (0.21)	23	4	18	8	156	25	86	128	32	11	9
2080 Low (0.26)	24	4	20	9	194	26	97	146	34	11	9
2080 Mid (0.46)	29	5	29	10	584	28	133	283	38	12	12
2080 High (0.81)	39	6	39	13	803	35	221	571	46	15	19
2100 Max (1.06)	62	8	43	15	833	46	342	668	55	20	37

The greater part of the wetlands in the Morehead City ETJ (not including the Haystack Marshes in Calico Bay), are located in Neighborhoods 5, 7, and 8. These wetlands are salt/brackish marshes and make up 71-83% of the total wetlands inundated under the 0.16, 0.46, and 1.06 m scenarios (Appendix 7).

The SLR toolbox will focus on the three inundation scenarios mentioned earlier, the 0.16, 0.46, and 1.06 m results. These results can be displayed in an introductory map for the SLR toolbox in the LUP (Figure 3.6). As part of the general overview to SLR, calculations were completed related to the number of structures inundated and the potential tax value lost (Tables 3.12 and 3.13). Wetlands data was also tallied for each of the three inundation scenarios to better understand which type of wetlands would be lost and to what extent (Appendix 7).

Table 3.12 Structures inundated

Scenario	Structures inundated	Additional structures inundated
2030 Mid (0.16 m)	23	--
2080 Mid (0.46 m)	38	15
2100 Max (1.06 m)	162	124
Total	223	

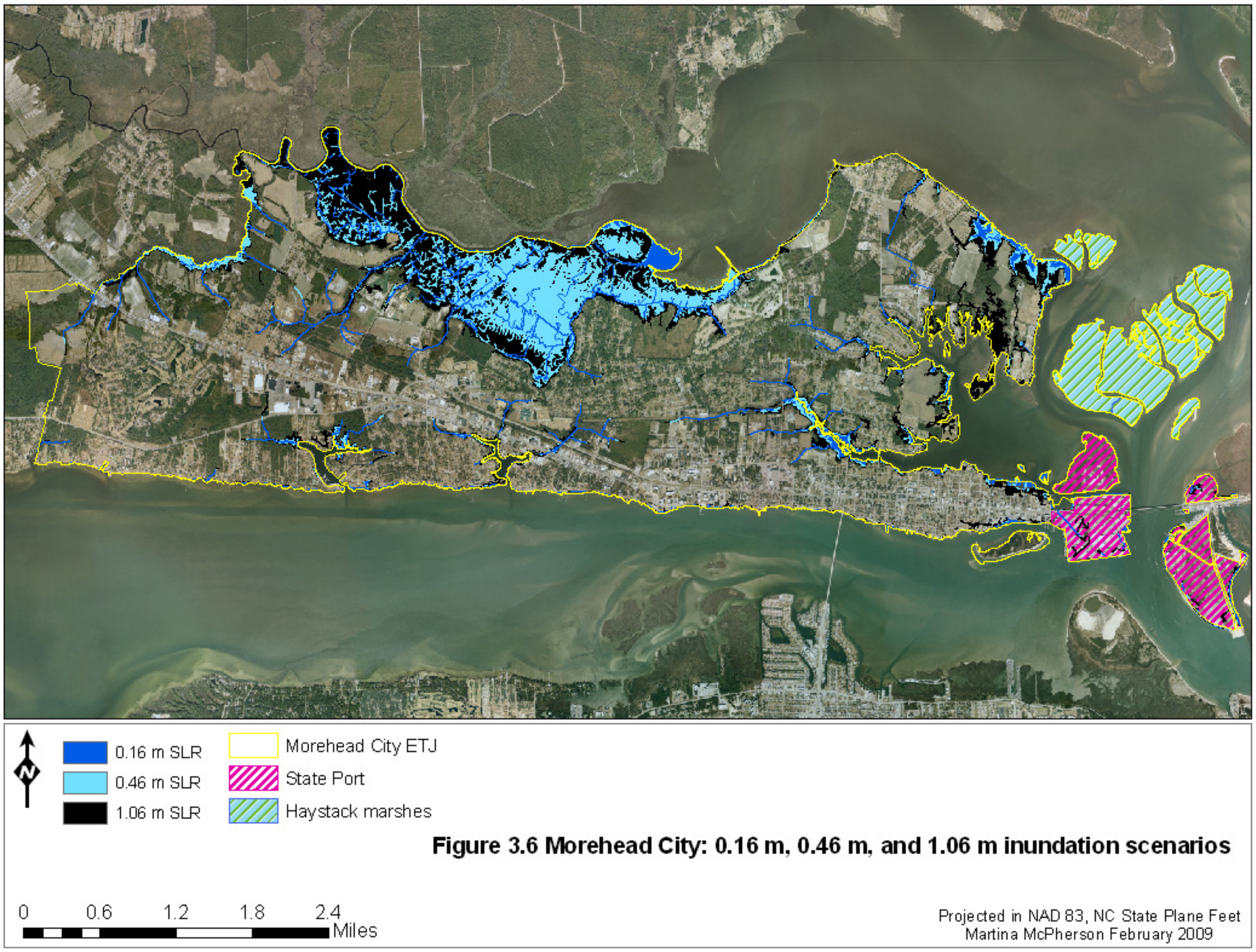


Figure 3.6 Morehead City: 0.16 m, 0.46 m, and 1.06 m inundation scenarios

The structure inundation data (Table 3.12) displays the non-linear nature of SLR effects. There are 15 additional structures inundated between the 0.16 and 0.46 m scenarios, and 124 structures inundated between the 0.46 and 1.06 m scenarios. The sea level increase between the 0.46 and 1.06 m scenario is double the increase between 0.16 and 0.46 m, but the amount of structures inundated is eight times larger.

Without considering a discount rate, the lost tax value (parcel and structure) reaches 5% of the total tax base with a 1.06 m rise in sea level (Table 3.13). Total values of lost parcels and structures for the 2030 Mid (0.16 m) scenario range between \$4.5 million (at 7% discount) and \$18.7 million (no discounting) (Table 3.14).

Table 3.13 Costs associated with inundation without considering the discount rate

Scenario	Total Value (Tax Value)	Percentage of Tax Value lost
2030 Mid (0.16 m)	$18,695,126.00	**0.55%**
2080 Mid (0.46 m)	$26,500,591.00	**0.78%**
2100 Max (1.06 m)	$180,481,846.00	**5.31%**

Table 3.14 Cost of lost structures including 2% and 7% discount rates

Scenario	Total Land Value	Total Structure Value	Other Value	Total Value (Tax Value)	Percentage of tax value lost
2030 Mid (0.16m)	$11,807,173	$5,046,596	$1,841,357	$18,695,126	
2% discounting	$7,790,087	$3,329,622	$1,214,883	$12,334,592	
7% discounting	$2,851,587	$1,218,819	$444,712	$4,515,118	**0.55%**

SLR Response Toolbox

Three response plans were created to provide a range of options to the Morehead City Planning Department. For each response strategy a land suitability map was created to determine areas best suited for development, and calculations relevant to implementation of the plan were completed.

I. Case-by-case response to SLR

If Morehead City opts to respond to SLR in an ad hoc manner, it will address the hazard once the first structure becomes threatened. Assuming the 2030 Mid scenario occurs, and residents and business owners choose not to relocate structures or armor the shore, the first structures will be threatened around Calico Creek, including the northern shore of the downtown area. By 2080 (assuming the 0.46 m scenario) structures bordering the northern salt marshes will begin to experience open-water views (Figure 3.6). The 2100 Max scenario (1.06 m) is projected to inundate 162 structures (Table 3.12).

For Plan 1, a land suitability map was generated using the previously mentioned grids (Figure 3.7). Consideration of SLR was kept to a minimum when creating the land suitability plan. A greater focus was placed on existing infrastructure, and established flood zones.

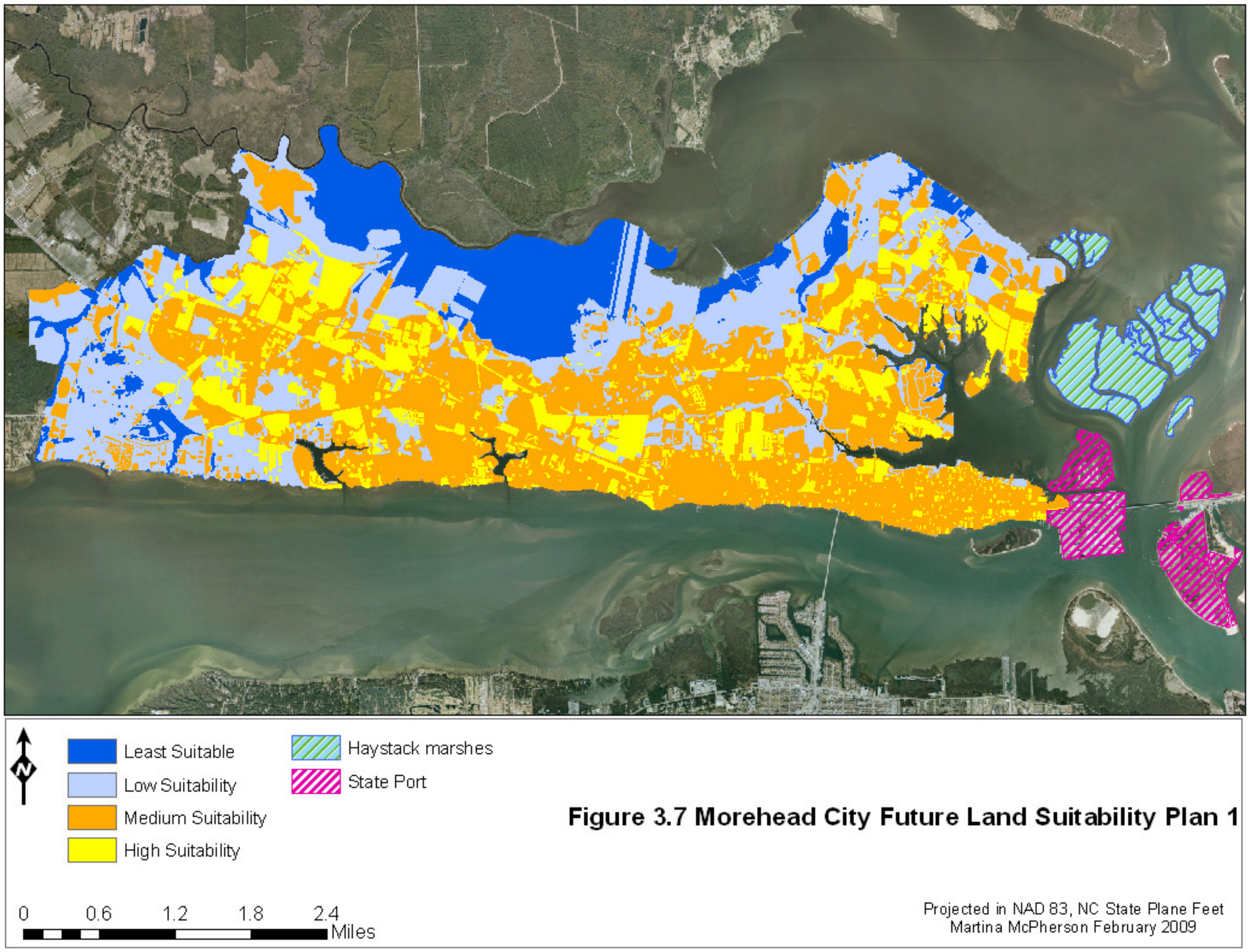


Table 3.15 Land suitability categories for Plan 1

Suitability Level	Acres	Sq. miles
Least suitable	1,500	2.3
Low suitability	2,952	4.6
Medium suitability	4,156	6.5
High suitability	1,585	2.5
Total	10,193	15.9

The land suitability map proposes the majority of land will be of medium suitability and will be located in the current downtown area and along the Route 70 corridor (Table 3.15; Figure 3.7). There would not be enough land rated as highly suitable to cover the projected 2,680 acres of development predicted for 2025 (Table 3.5). Morehead City currently allows low density development in flood zones and it can be assumed that future development will not be deterred by a designation of medium or low suitability. This could mean development continuing to encroach into the northern salt marshes; an area designated as floodplain that will serve an important role with increases in sea level (Figure 3.6).

II. Armoring response

The armoring plan will result in a different land suitability map as compared with Plan 1 because no area is considered “least suitable” (Figure 3.8). The threat of flooding is assumed to be removed and all land can be developed to a certain extent. This means the majority of projected future development (2,680 acres) will occur in land designated as highly suitable (Table 3.17). Due to poor soil quality, and potential for a rise in the water table from SLR, proximity to sewer and water lines is still considered critical for a high or medium rating. Plan 2 does not consider the consequences of storm or flooding events breaching the wall.

An armoring response is another option for Morehead City’s management of SLR. If the entire shoreline was armored at the 3 foot elevation contour, the total area of the ETJ would be reduced by approximately 2,000 acres. A little less than 1,400 of the lost 2,000 acres are salt marshes (Table 3.16). Wetlands within the wall would be filled and used for development, and wetlands on the other side of the wall would eventually be completely inundated with a 1.06 m rise in sea level.

Table 3.16 Marsh area affected by SLR

Marsh type	Current		2030 Mid (0.16 m)		2080 Mid (0.46 m)		2100 (1.06 m)	
	Acres	Sq. mi	Acres	Sq. mi.	Acres	Sq. mi.	Acres	Sq. mi.
Salt/Brackish Marsh	651	1.02	115	0.18	454	0.71	632	0.99
Drained Salt/Brackish Marsh	720	1.12	97	0.15	364	0.57	717	1.12
Total marsh	1,371	2.14	212	0.33	819	1.28	1,348	2.11

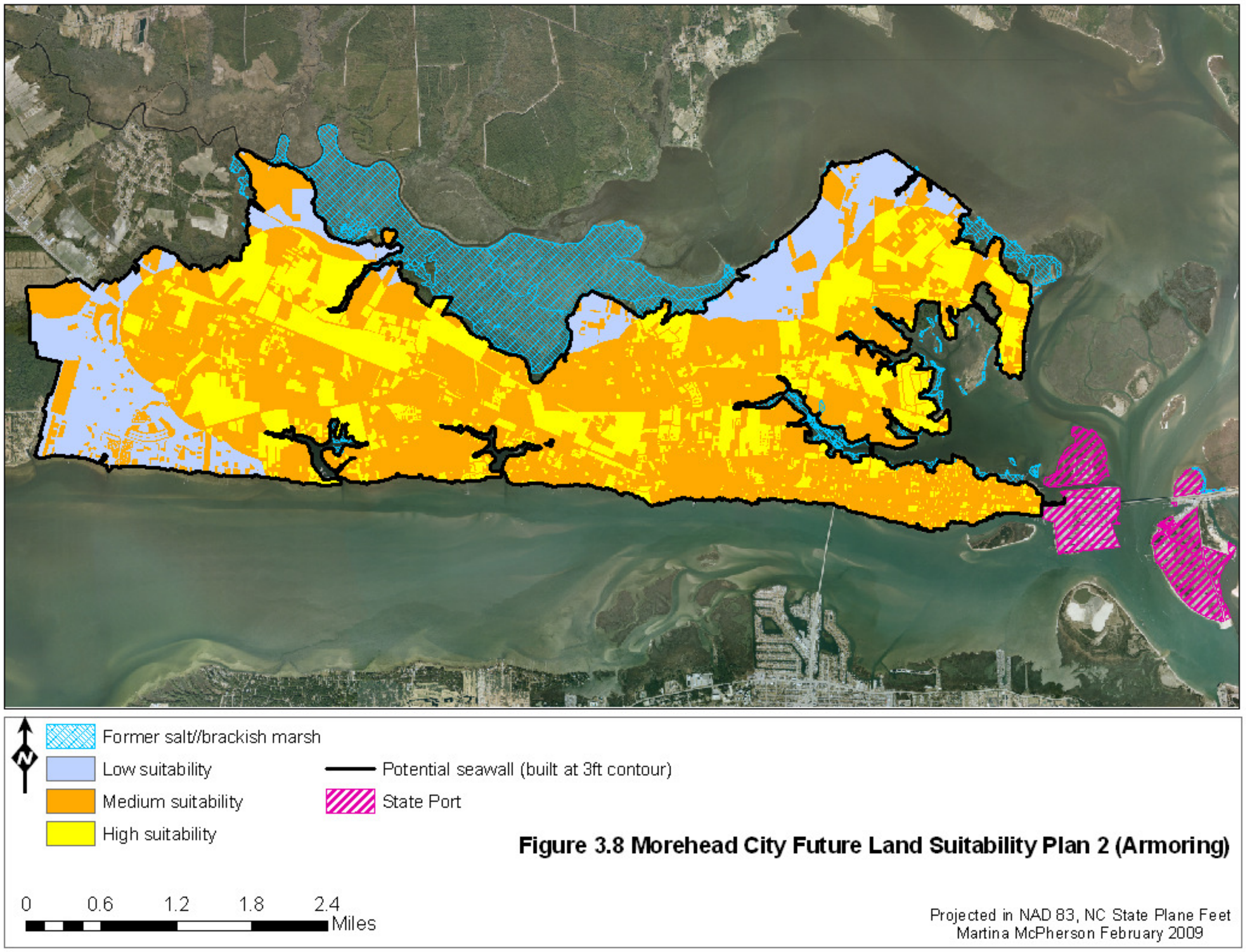


Figure 3.8 Morehead City Future Land Suitability Plan 2 (Armoring)

Table 3.17 Land suitability categories for Plan 2

Suitability Level	Acres	Sq. miles
Low suitability	1,362	2.1
Medium suitability	4,845	7.6
High suitability	2,149	3.4
Total	8,356	13.1

III. Relocation/Migration response

For the third strategy, a land suitability map was created incorporating SLR projections in several of the weighted layer components. Projected levels of inundation for 2080 were included, as were vacant parcels above the 2100 inundation level. Wetland migration was factored into the plan by removing wetland-adjacent vacant parcels from consideration for development (Appendix 4).

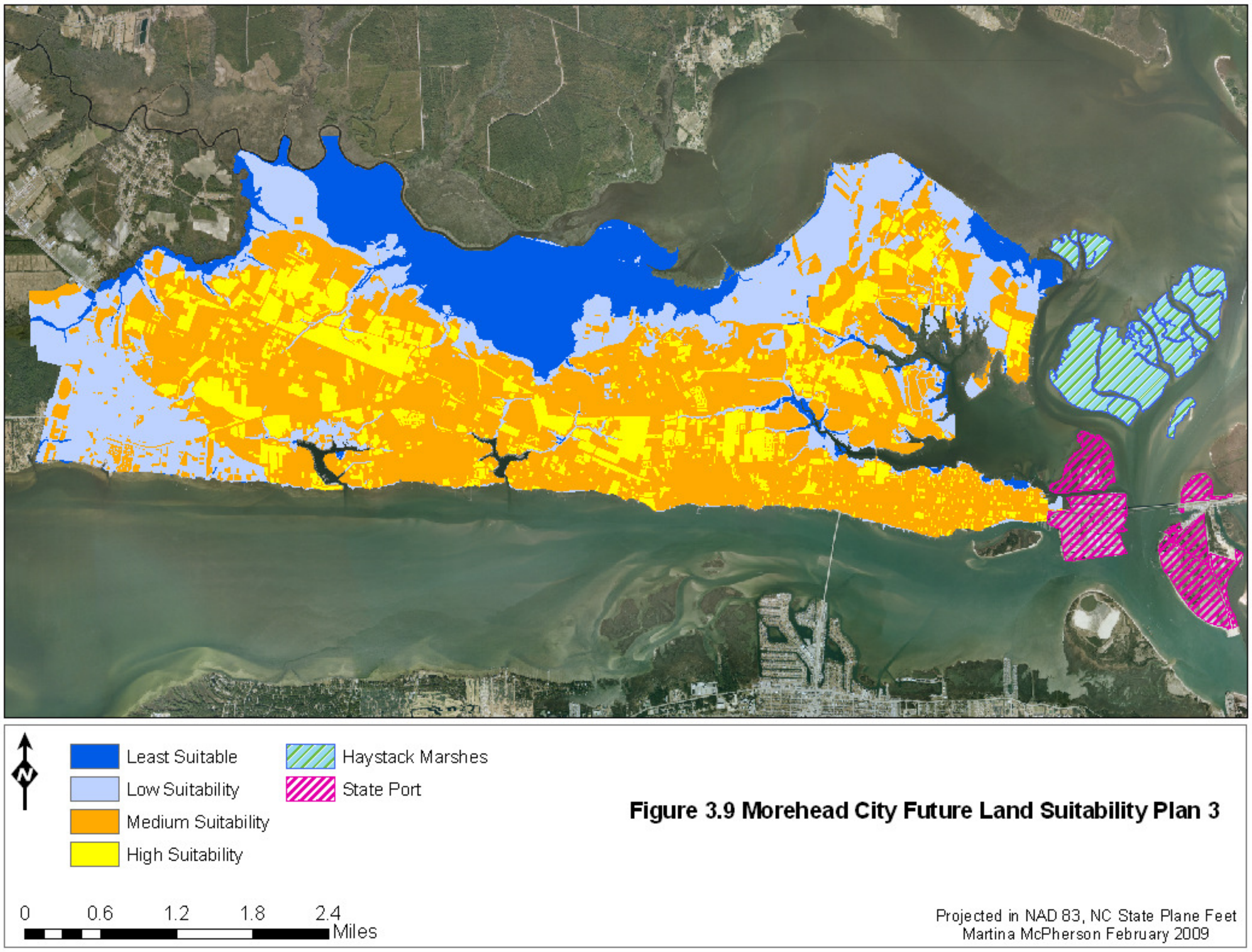


Figure 3.9 Morehead City Future Land Suitability Plan 3

Table 3.18 Land suitability categories for Plan 3

Suitability Level	Acres	Sq. miles
Least suitable	1,656	2.6
Low suitability	2,456	3.8
Medium suitability	4,616	7.2
High suitability	1,465	2.3
Total	10,193	15.9

Areas predicted least suitable for development have increased over Plan 1, while highly suitable land has been reduced by approximately 100 acres. Areas adjacent to Calico Creek are considered less suitable in this scenario as compared to Plan 1. Much of the northern shoreline has been categorized as least suitable or low suitability.

Plan 3 considers vacant parcels for potential relocation of inundated structures in addition to planning for wetland migration (Figure 3.10).

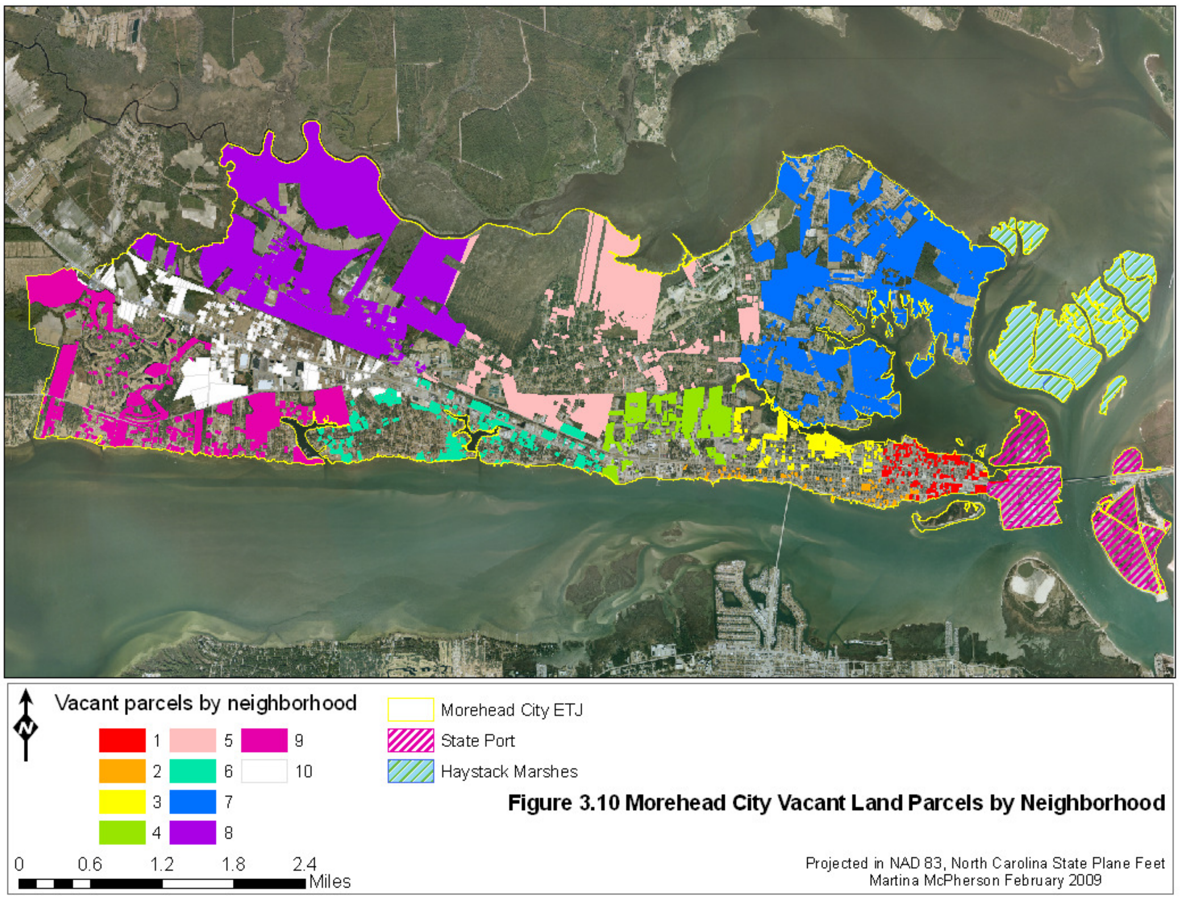


Figure 3.10 Morehead City Vacant Land Parcels by Neighborhood

If Morehead City opts to require soon-to-be-condemned structures to relocate, vacant parcels will need to be located, preferably near the original location. Generally, there are enough inland vacant parcels to accommodate all the inundated parcels for all three scenarios (Table 3.19, Appendix 5, and Appendix 6). When adding the projected need for 2,680 acres for future development by 2025, there is still sufficient vacant land to accommodate inundated parcels in 2030. Vacant land becomes scarcer by 2080 and 2100 (assuming same vacant parcel availability and future needs). The calculations do not consider the large amount of vacant land designated as wetlands or the vacant land that is salt marsh adjacent. The vacant marsh land and vacant land adjacent to the salt marshes would have the greatest effects on the vacancy levels of northern Neighborhoods 5, 7, and 8.

Neighborhoods 1, 2, 3, 5, and 8 all have vacant inland parcels available for all three scenarios, but the average size of the parcels is smaller than the average size of the inundated parcels (Table 3.19, Appendix 5, and Appendix 6). The discrepancy in average parcel size can partially be attributed to the larger, vacant, low-lying land being inundated before the smaller, inland parcels in more developed areas. For example, in Neighborhood 5 for the 0.46 m scenario, 8 of the 11 predicted-to-be-inundated parcels are actually vacant and the majority of the inland vacant parcels are in more heavily developed areas around Route 70.

Table 3.19 Vacant parcel availability and size by neighborhood for the 2080 Mid (0.46 m) scenario

	2080 Mid (0.46 m)					
Neighborhood	**# Vacant inland parcels**	**Avg. size of vacant inland parcels (s.f.)**	**Vacant inland parcels total area (acres)**	**Parcels inundated**	**Avg. size inundated parcel (s.f.)**	**Inundated parcels total area (acres)**
Neighborhood 1	168	8,470	33	32	16,471	12
Neighborhood 2	80	7,668	14	5	13,383	2
Neighborhood 3	114	28,547	75	5	40,873	5
Neighborhood 4	187	47,278	203	1	13,636	0
Neighborhood 5	277	88,273	561	28	1,011,273	650
Neighborhood 6	186	54,854	234	7	17,469	3
Neighborhood 7	495	83,892	953	13	69,931	21
Neighborhood 8	169	291,202	1,130	12	712,274	196
Neighborhood 9	317	63,714	464	6	26,299	4
Neighborhood 10	176	86,633	350	4	31,715	1
Total	2,169	--	4,017	113	--	894

3.5 Discussion

Coastal communities in North Carolina will become increasingly at risk for loss of property and ecosystem health with rising seas. Luckily, SLR will occur at a slow enough pace to allow for development of a host of adaptation responses. The flip side of the SLR planning coin is, due to the pace of inundation, town managers and planners will feel little pressure to respond (Moser, 2005). In the end, SLR could end up being planned for on an ad hoc basis, similar to how the effects of erosion and development are being addressed along the barrier islands of North Carolina. Each time a structure becomes threatened by the sea, there is a controversy surrounding what should have happened, what the response will be, who will pay for it, and what future policies should entail. As discussed in Chapter 2, this reactive approach is highly inefficient, and oftentimes neglects natural resource preservation. In planning for SLR, North Carolina has an opportunity to implement a strategy to avoid the confusion and costs associated with treating property loss on a case-by-case basis.

As can be seen from the Morehead City case study, SLR inundation results can be examined at a local level and used for land use planning purposes as simply as a flood zone or land use designation is used. When communities increase the effectiveness of shoreline management for non-climate change hazards, they will enhance their ability to respond to sea-level rise and climate change (Nicholls and Klein, 2005). But given the fact that SLR is listed in the LUP guidelines as a natural hazard, and North Carolina has been gaining increasing national attention due to the state's vulnerability to SLR (Titus et al., 2009; NOAA, 2007; House Report 110-862, 2008), it makes sense to address SLR separately in LUPs rather than assume flood zone planning will cover anticipated effects.

This study offered three possibilities for addressing SLR within the framework of the Morehead City LUP. Land suitability maps were created for the three policy approaches, and various calculations to help in implementation of the approach were also completed. Within each basic approach are numerous sub-options to be developed by Morehead City in the future (e.g. easements for wetland migration rather than vacant land purchase, partial armoring along the more threatened northern shore).

If Morehead City were to develop a SLR toolbox within the LUP, it could specify the criteria for analyzing/ranking the available options. In order to assist in the ranking would be the written component discussed earlier. The written component would contain information on where future development would occur, what would happened to natural systems, what are advantages and disadvantages to the approach, and how could the approach be implemented.

Plan 1: Case-by-case/reactive

Future development: The location of future development in this scenario can occur wherever local zoning will allow it. With minimal consideration of SLR potential, there could be an increase in development along the northern floodplain as well as along the eastern shore of Neighborhood 7. New development within the northern portions of Neighborhoods 5, 7, and 8 would have to rely on septic systems due to flooding hazards and soil characteristics. Low-impact development strategies may aid in lessening additional stormwater impacts. Increasing building elevation requirements within the town ordinances may also lessen the potential damage associated with flooding and other natural hazards. There is infill potential along the Arendell Street/US-70 corridor, including the core downtown area.

Natural environment: No additional efforts will be made to protect natural resources in this scenario even though conserving land for wetland migration will protect the town from greater storm surges, a natural hazard that Morehead City already acknowledges and includes in the LUP. The N.C. Coastal Land Trust owns hundreds of acres in the floodplain, but much of the wetland appears to be under private ownership and could therefore be developed. The primary nursery areas located in the shallow marshes will become open water with SLR. If appropriate conditions exist, wetlands may migrate onto adjacent land parcels. This will depend on sediment availability, slope, and whether property owners encourage or discourage migration. Continuing development along the northern part of the peninsula will worsen water quality conditions.

Advantages/Disadvantages: This approach will most likely be the least expensive in the short term, but could get increasingly expensive if the town is left to fund the demolition of structures in the public trust. It will also face great challenges after destructive storm events when damage is on a wider scale. Many of the advantages and disadvantages of this approach can be seen in current barrier island management efforts.

Implementation strategy: Morehead City may opt to go forward with its existing LUP (2007) and existing ordinances, only addressing SLR as it becomes a threat to property and infrastructure. Based on the experience of some barrier island communities who have in the past addressed structure loss on a case-by-case basis, it will make sense lay out standards within the town ordinances for what kind of activities will be allowed when structures and/or parcels are threatened by rising sea level. The town could require new shorefront deeds to have demolition agreements attached and may want to consider implementing height limitations for seawalls, or other armoring structures. Existing development along the shore will eventually need to be protected, relocated, or demolished and even if Morehead City chooses not to take a comprehensive approach to planning for SLR, it still should have a rough idea of what protocol should be.

Plan 2: Armoring

Future development: The armoring of the entire Morehead City shoreline would be a large undertaking and require coordination with adjacent communities. A wall like the one displayed in Plan 2 at the 3-ft contour would be 52 miles long and theoretically protect 8,300 acres of land. While the wall will protect property from surface water inundation, there is a good possibility that properties at the shore will become inundated from rising water tables. Impact fees or a tax assessment may be considered for future development in order to compensate property owners whose land ends up on the water-side of the wall. Adding the wall may be considered a taking by property owners like the N.C. Coastal Land Trust who own the majority of the wetlands on the other side of the wall along the northern shore.

Natural environment: The wall would protect all existing development from SLR inundation but leave all coastal wetlands susceptible to coastal squeeze and eventual drowning. Loss of coastal wetlands will likely decrease water quality and productivity of coastal waters which will inevitably affect the local economy. A hardened shoreline, unless combined with a beach nourishment project, will lead to loss of the already rare estuarine beaches along Bogue Sound.

Advantages/Disadvantages: Three disadvantages of armoring (Turner et al., 1990): (1) tends to encourage economic development because armored area is considered safe from natural hazards; (2) it causes ecological damage and interferes with natural processes; and (3) is inflexible and hard to remove. An advantage of armoring is it can stabilize the shoreline and prevent further erosion. In addition, there are several varieties of soft and hard armoring choices:

Figure 3.11 Marsh planting as vegetation control (left) and one year later (right) (Bendell et al., 2006).

Figure 3.12 View of a rubble mound sill (left) and a timber sheet pile sill (right) (Bendell et al., 2006).

Figure 3.13 Sloped structures constructed from rock (left) and watertight cast concrete (right) (Bendell et al., 2006).

Implementation strategy: The town will need to decide on its level of involvement. It can either take the lead, using public funds, or allow property owners to coordinate amongst themselves within parameters laid out in the town ordinances or LUP. There is potential for conflict amongst property owners regarding types of armoring strategies (soft v. hard), and the town may have to formalize its desired armoring policy through an ordinance. The town may have to develop a strategy to mitigate the wetland loss due to hard armoring.

Plan 3: Relocation/Migration

Future development: The third scenario will focus on relocating property rights and/or actual structures from the inundated shore to inland parcels. An inland parcel matching system could be required for new shoreline purchases, as well as for existing threatened parcels. A vacant parcel analysis will be useful to rank parcels based on proximity to the original parcel or proximity to water, depending on what the owner is interested in. Future development should focus on infill development along Arendell Street and in the core downtown.

Natural environment: The migration of coastal marshes will be allowed to occur naturally upland. The surrounding migration buffer will have to be studied to judge whether the marsh will be able to migrate naturally or will require man-made alterations (plantings, grading of slopes, seawall removal). With the growing amount of development around the Newport Marshes in the northern part of the peninsula, vacant land dedicated solely to conservation will be harder to acquire. The town may find it more prudent to focus on acquiring conservation easements rather than entire parcels (Wynia, 2007). Man-made ditches in marshes will be filled to prevent salt-water intrusion and slow SLR inundation.

Advantages/Disadvantages: There are several disadvantages associated with this approach: (1) higher perceived costs of relocating structures (as compared with hardening); (2) stricter town ordinances related to development may discourage future development; and (3) public resistance to idea of "retreat" (Burby and Nelson, 1991; Turner et al. 1990). Some advantages include maintaining ecosystem integrity (and the associated economic benefits) and lessening the risk of damage from natural hazards.

Implementation strategy: Stringent standards on parcel/structure relocation will have to be incorporated into the town ordinances, including clarification on when a structure or parcel must be relocated. There will also need to be a mechanism in place if a homeowner refuses to move. Data on vacant parcels will have to be consistently updated by the Planning Department. The town will have to decide what to do with existing seawalls. It may be effective to partner with local conservation groups to manage the wetland migration projects, including the filling of ditches and potential grass plantings. The town could consider encouraging a system where wetland mitigation banks can purchase vacant land for wetland migration. The LUP may be a better vehicle for an adaptive management approach but not without an ordinance strengthening the LUPs influence.

These brief written components, paired with the land suitability maps, and relevant implementation data are only the beginning of what could potentially be a robust toolbox for Morehead City's adaptation to SLR. As each response scenario is fleshed out, communities can begin to pull together aspects of each strategy that will best suit their needs.

The inclusion of a SLR toolbox within the local land use plan may be helpful to guide development, but there is no mechanism in place that demands the land suitability maps be followed. While the creation of a SLR toolbox will undoubtedly advance the town's planning capacity, it will make no difference unless the LUP's level of influence changes. As discussed in Chapter 1, Morehead City's LUP contains a disclaimer "that the Land Use Plan is one of a variety of guides in making a public policy decision. The Plan should be viewed as a tool to aid in decision making and *not as the final decision*." (emphasis added; The Wooten Company, 2007). Investing the time and money into the creation of a SLR toolbox does not make sense without a mechanism ensuring some degree of enforcement.

3.6 Recommendations

There are undoubtedly many uncertainties attached to coastal zone planning, but as discussed, the cautionary principle does not have to apply. There is inherent uncertainty with all natural events and processes threatening coastal communities on an annual and daily basis, and this has not prevented planners from considering these threats when planning development or opting to preserve land.

In order for local coastal communities in North Carolina to successfully begin planning for SLR the state needs to take on a stronger role guiding adaptation strategies, local LUPs need to become the guiding document in development decisions, and the SLR toolbox needs to provide as much flexibility as possible.

State Leadership

The state's role is addressing SLR will be important on two levels. First, it should be the leader in integrating all the committees, commission, reports, and agencies involved with SLR planning. Second, it needs to provide guidance and support to local communities.

I. Integrated Planning

The State of Maryland created a Climate Commission in 2007 that was tasked with preparing for the "likely consequences and impacts of climate change…and to establish firm benchmarks and timetables for implementing the Plan of Action" (Exec. Order 01.01.2007.07).

The Maryland Climate Commission's Final Report, released in August, 2008, acknowledged a fragmented approach to SLR will be ineffective and lists "integrated planning" as the first priority policy recommendation for the reduction of SLR impact to existing and future growth and development (MD Climate Action Plan, 2008).

The State of North Carolina needs to replace its fragmented approach to SLR with a clear, integrated system. FEMA granted $5 million to the North Carolina DEM to complete a statewide risk assessment for sea level rise (FEMA, 2009). The study will identify and evaluate short-term mitigation strategies and long-term adaptation strategies to reduce vulnerability to SLR (NC DEM, 2009). The study will present an opportunity to plan out integration of the multiple commissions and agencies beginning to address SLR. Unfortunately, the proposed membership roster for the Study's Advisory Committee is missing representatives from several critical NC agencies, such as the DCM, DWQ, and DMF. The State of North Carolina cannot effectively address SLR if it continues to allow coastal zone management agencies to study and address SLR separately from emergency and hazard management groups.

In addition to the fragmented approach to SLR management, the coastal zone is divided even further between ocean and estuarine management policies. Both the Ocean Policy Steering Committee and the Beach and Inlet Management Plan are addressing future coastal issues, but neither is taking a hard look at the estuarine shoreline. In 2004, within a NOAA review of North Carolina's Coastal Management Program, a suggestion was made to the DCM to "continue to increase its focus on estuarine planning and management" and in the next review, in 2006, NOAA found little progress in the area besides DCM's participation in NOAA's "Ecological Effects of SLR" program (NOAA, 2006).The Coastal Habitat Protection Plan (2005) may be a better vehicle to address SLR because it includes all waters flowing into coastal waters and the watersheds they drain (Street et al., 2005). Recommendations in the CHPP have led to the creation of plans or committees addressing both oceanfront and estuarine concerns.

II. Guidance and Support

While coastal communities in North Carolina have been allowed to develop and implement LUPs themselves, as Maryland's Climate Commission concluded, addressing SLR will require guidance from the state level. Local communities can begin to adapt to SLR themselves, but not every community has the resources or incentives to begin examining the issue. In Maryland, the state has initiated several studies on economics, erosion, SLR modeling, and mapping in order to provide adaptation tools for local communities (Johnson, 2008).

In addition to providing tools for local communities, the state will have to translate SLR planning strategies into regulatory programs and local communities will have to adopt town ordinances to the same effect (MD Climate Action Plan, 2008). The importance of SLR planning being codified may be better addressed locally by strengthening LUPs both in terms of its content, as well as its influence on development decisions.

Role of Local Land Use Plan

Local LUPs in North Carolina have been criticized for not being enforceable documents. While incorporating SLR into the LUP is important, it is critical for Morehead City to adopt an ordinance addressing SLR. To improve the overall effectiveness of LUPs, the state may have to revise LUP guidelines, similar to what occurred when stricter language was implemented as a result of the 2002 guideline revisions. The OPSC's Final Draft Report makes a similar recommendation (2009).

It is difficult to enforce LUP recommendations when communities are hesitant to restrict development and therefore allow local ordinances to shape the LUP rather than allowing the LUP to drive the content of the ordinances. For example, the land suitability map in the Morehead City LUP (Figure 3.4) designates the majority of the northern marshes as “least suitable” and the entire area is a NFIP flood zone (AE). The zoning map delineates the same area as a “Floodplain District.” In the Morehead City town ordinance, the floodplain district is acknowledged as land that is “environmentally sensitive,” however it can be developed once a special use permit is issued. The ordinance defines “special use” as a use not generally appropriate for the zoning designation, but when “controlled as to number, area, location, ore relation to the neighborhood, would promote the public health, safety, morals, or the general welfare” (Unified Development Ordinance, 2001). In other words, the community allows development under the special use permit in the flood zone, even though the LUP designates the land “least suitable” for development. This is one of many examples where the LUP seems to have minimal influence on the content and objective of the ordinance.

Besides the state taking regulatory action to make LUPs binding, or local communities instituting ordinance language that either addresses SLR directly, or defers to the LUP for development policy guidance, another option is a regional planning approach. Regional planning often takes the form of special overlay zones that cover several jurisdictions within a coastal zone (Davis, 2004). Regional planning organization can aid local communities in implementing relevant ordinance or bylaw language. In Cape Cod, Massachusetts, a regional planning organization provides bylaw language for local towns including language for a Floodplain Overlay District where *no development or redevelopment* is allowed in the FEMA V-zone (Cape

Cod Commission, 2009). This type of guidance is a step removed from direct state mandates, and would allow the local governments to be unified around their particular coastal interests.

Flexible Planning Options

Due to the uncertainty surrounding SLR effects and the public's hesitancy in discussing it, Morehead City should approach planning for SLR with the initial goal of examining as many policy responses as possible. Once potential policies are acknowledged, the tools needed to address these policies must be identified and developed, preferably with help from the state. Similar to what the Maryland Climate Commission suggested, the state must take on some responsibility in developing tools for local communities to use (MD Climate Action Plan, 2008). In a recent meeting regarding the development of the NC Beach and Inlet Management Plan, Director of the Division of Coastal Management, Steve Underwood, commented on coastal management methods and responding to new challenges like SLR: "People want more tools in their toolbox. Trust me - there's no silver bullet out there." (The Virginian-Pilot, 2009). In addition to coastal managers and planners, the general public will feel more comfortable knowing options are available. Poulter et al. (2009) recommend that as the newest SLR policy window begins to open in North Carolina, alternatives must be made available.

Funding

Availability of funding will greatly influence the extent to which these recommendations can be addressed. With growing interest on the part of the federal government in studying adaptation strategies for SLR, there may be increasing opportunities to gain funding directly from FEMA or NOAA budgets, similar to the $5 million in funding DEM received in the FEMA

2009 budget. Local governments will also need to locate funding to revise LUPs and incorporate SLR plans. North Carolina has several trust funds available for coastal planning projects including the Parks and Recreation Trust Fund, Natural Heritage Trust Fund, and the Clean Water Management Trust Fund which allocated $100 million in grants in 2007 (Wynia, 2007). Nonprofit or private partnerships are possible sources of funding; organizations like the Doris Duke Foundation, Pew Charitable Trust, or the Rockefeller Family Trust (Wynia, 2007). Local communities could also apply for FEMA Hazard Mitigation Grants to aid in developing Hazard Mitigation plans. Other revenue streams such as occupancy taxes, meal taxes, licenses, impact fees, and property taxes can also be considered.

The above recommendations should be considered as a starting point for effective adaptation to SLR in the State of North Carolina. Over the next few years the state can take the lead in bringing together the various stakeholders involved in coastal zone management to create an integrated SLR response framework.

CHAPTER 4

Conclusion

This study assembled several SLR response options and transformed them into land use planning tools for eventual use in a local land use plan SLR toolbox. By examining selected North Carolina laws, policies, reports, and guidelines related to coastal zone management as well as by looking at a cross-section of current and future coastal challenges, recommendations were made on how to make SLR adaptation a reality. Although the State of North Carolina is years away from providing extensive support to local communities planning for SLR, the results provided here should prove adaptation can be implemented at the local level with a great deal of flexibility using data already available through local planning departments.

The review of coastal policy and current coastal challenges in North Carolina revealed growing conflicts over management decisions along both the oceanfront and estuarine shoreline. In anticipation of potential challenges in the coastal zone, the federal government issued the Coastal Zone Management Act (1972) from which the North Carolina Coastal Area Management Act (1974) followed. Within the last decade there has been an increase in legislative and regulatory activity surrounding coastal management issues, in particular concerns over deteriorating ecological conditions due to development and shoreline stabilization strategies.

Although SLR was mentioned in early coastal zone legislation, there was no effort by the state or local governments to study or plan for it. The lack of active planning could be attributed to the general less-developed nature of the coast at the time of the CZMA and CAMA. The incredible amount of growth along the coast from the 1970s through today has forced coastal managers to try and manage the effects of natural processes that have always occurred, but are only noticed when structures are damaged. SLR has been neglected as a policy issue for decades, because damage to coastal structures was generally chalked up to large storm events, and there was less concern over protecting coastal ecosystem integrity.

In the last decade, scientific studies and private interests have begun to challenge traditional coastal policies in the State of North Carolina. State and local decision-makers are starting to weigh traditional management policies along both the estuarine and ocean shorelines against new options. As discussed in Chapter 2, there are a myriad of issues concerning coastal zone management that will need to be addressed within the next few years, mainly because it will no longer be prudent for local and state governments to stay the same course (beach nourishment, Beach Plan, armoring, etc). Many of these issues will only be exacerbated by rising seas.

In the last two years, there has been a more pro-active effort by North Carolina decision-makers and state agencies to address mounting coastal challenges. The formation of the OPSC (2008), the drafting of the BIMP (2008), and the burgeoning N.C. SLR Risk Assessment Study (2009) are indicative of this trend. In a memorandum presented to the N.C. Legislative Commission on Climate Change at the beginning on 2009, the Nicholas Institute for Environmental Policy Solutions outlined options for policy makers in planning for climate change, including planning for SLR and intense storms (Holman, 2009). The OPSC in their Final Draft Report (2008) stress the importance of addressing coastal vulnerability in order to allow for better community responses to SLR. The OPSC also encouraged adoption of a SLR component into CAMA land use plan guidelines. Given the growing momentum behind addressing SLR in North Carolina, developing a SLR management toolbox could help communities go beyond discussing the threat and towards actively taking some degree of control over it.

In order to try and develop a SLR toolbox, a North Carolina coastal community was selected for study. The Town of Morehead City case study resulted in the creation of three prototype SLR response strategies. The development of these options did not require much data beyond what is presently available at the local planning level. Even the inundation results, which were provided by an outside source, could be crudely replicated by isolating elevation contours corresponding to projected sea levels. The three response strategies developed for Morehead City are only the beginning of a possible toolbox full of variations or completely novel response strategies to SLR. This is a new approach that allows for options beyond the traditional three response scenarios (IPCC, 1990), allowing a community the ability to adaptively manage SLR.

Several lessons were gleaned from the development of the prototype response strategies and land suitability maps for Morehead City. A stronger state role, a more stringent or enforceable LUP, and management flexibility were all determined to be critical to successfully developing a SLR toolbox. Once the scaffolding for the SLR toolbox is in place, the state can begin to identify existing and desired technical tools (inundation modeling for all coastal counties, revised NFIP flood zones, wetland migration models, prioritization of lands for conservation easements).

The State of North Carolina is poised to begin adapting to SLR and local coastal communities will be important players in the SLR planning game. With the right tools, coastal communities will minimize threats and damage to property, and ensure the continued function of natural systems.

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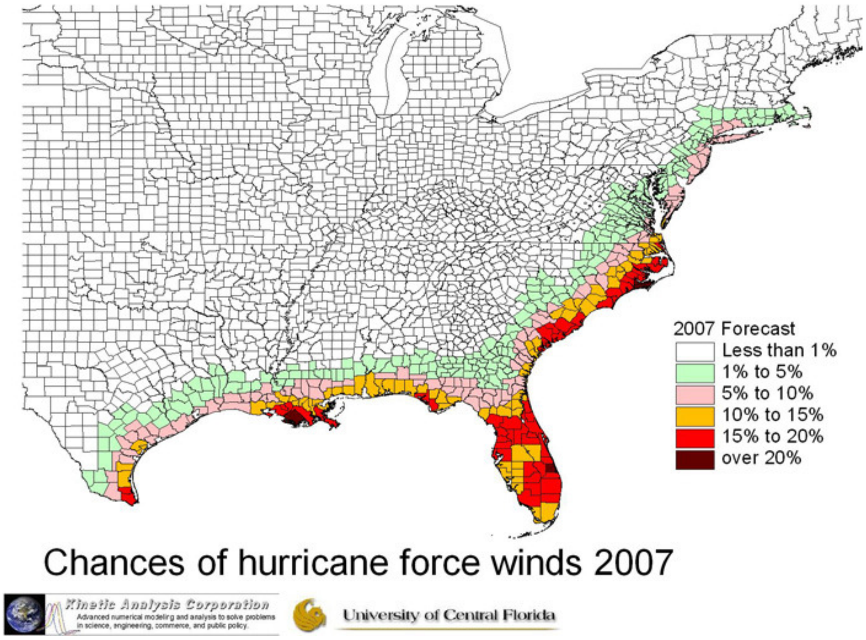
APPENDIX

Appendix 1. Probability of Carteret County experiencing hurricane force winds



Appendix 2. Tables calculating percent of land use inundated by six inundation scenarios

2030 Low (0.11 m)

Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	93.0	0.145	22.02%	13.51%
Residential	259.5	0.406	61.47%	4.23%
Institutional	13.4	0.021	3.18%	2.81%
Planned Dev.	3.0	0.005	0.72%	0.48%
Street	8.7	0.014	2.05%	0.84%
Industrial	32.5	0.051	7.69%	4.43%
Commercial	12.1	0.019	2.87%	1.40%
Total	422.2	0.660	100.00%	

2080 Low (0.26 m)

Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	160.2	0.250	27.45%	23.27%
Residential	347.8	0.543	59.59%	5.68%
Institutional	16.5	0.026	2.82%	3.45%
Planned Dev.	3.3	0.005	0.56%	0.52%
Street	9.0	0.014	1.53%	0.87%
Industrial	33.9	0.053	5.80%	4.62%
Commercial	13.1	0.020	2.24%	1.51%
Total	583.6	0.912	100.00%	

2030 Mid (0.16 m)

Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	104.3	0.163	22.57%	15.15%
Residential	286.6	0.448	62.02%	4.68%
Institutional	14.0	0.022	3.03%	2.93%
Planned Dev.	3.0	0.005	0.66%	0.48%
Street	8.8	0.014	1.90%	0.85%
Industrial	32.8	0.051	7.11%	4.48%
Commercial	12.5	0.020	2.71%	1.44%
Total	462.0	0.722	100.00%	

2080 Mid (0.46 m)

Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	500.0	0.781	42.48%	72.65%
Residential	587.5	0.918	49.91%	9.59%
Institutional	25.0	0.039	2.12%	5.23%
Planned Dev.	3.8	0.006	0.32%	0.60%
Street	9.7	0.015	0.82%	0.94%
Industrial	36.6	0.057	3.11%	4.99%
Commercial	14.6	0.023	1.24%	1.68%
Total	1177.1	1.839	100.00%	

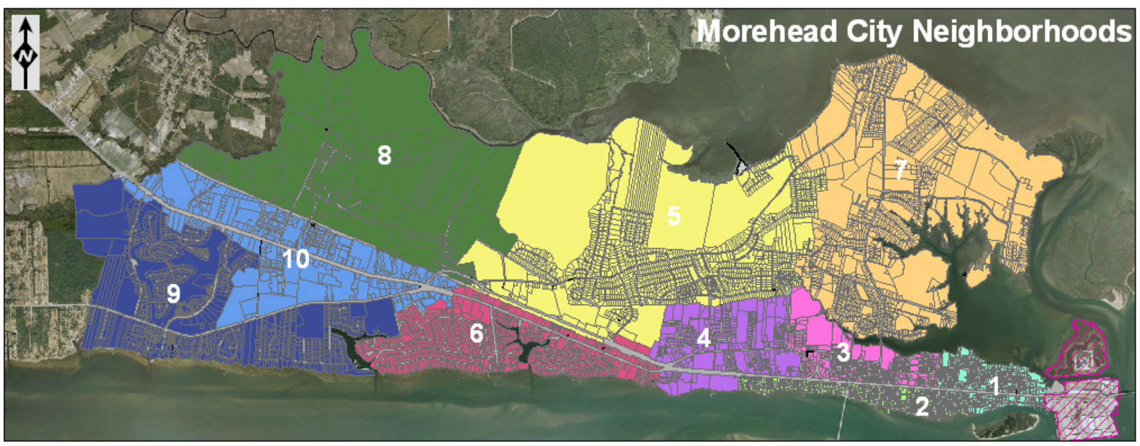
2030 High (0.21 m)

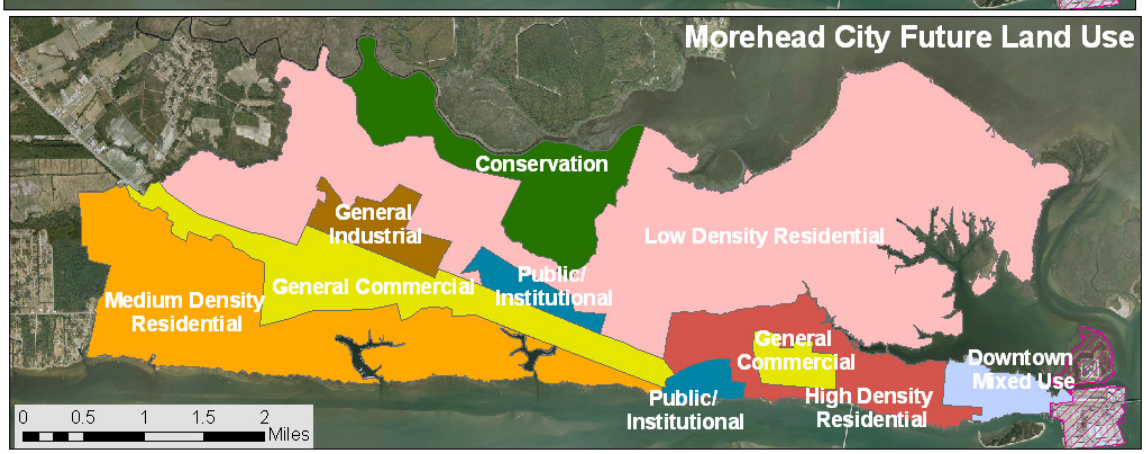
Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	125.7	0.196	24.55%	18.26%
Residential	312.6	0.488	61.06%	5.10%
Institutional	15.3	0.024	2.99%	3.21%
Planned Dev.	3.1	0.005	0.61%	0.49%
Street	8.9	0.014	1.74%	0.86%
Industrial	33.3	0.052	6.51%	4.55%
Commercial	13.0	0.020	2.53%	1.50%
Total	511.9	0.800	100.00%	

2080 High (0.81)

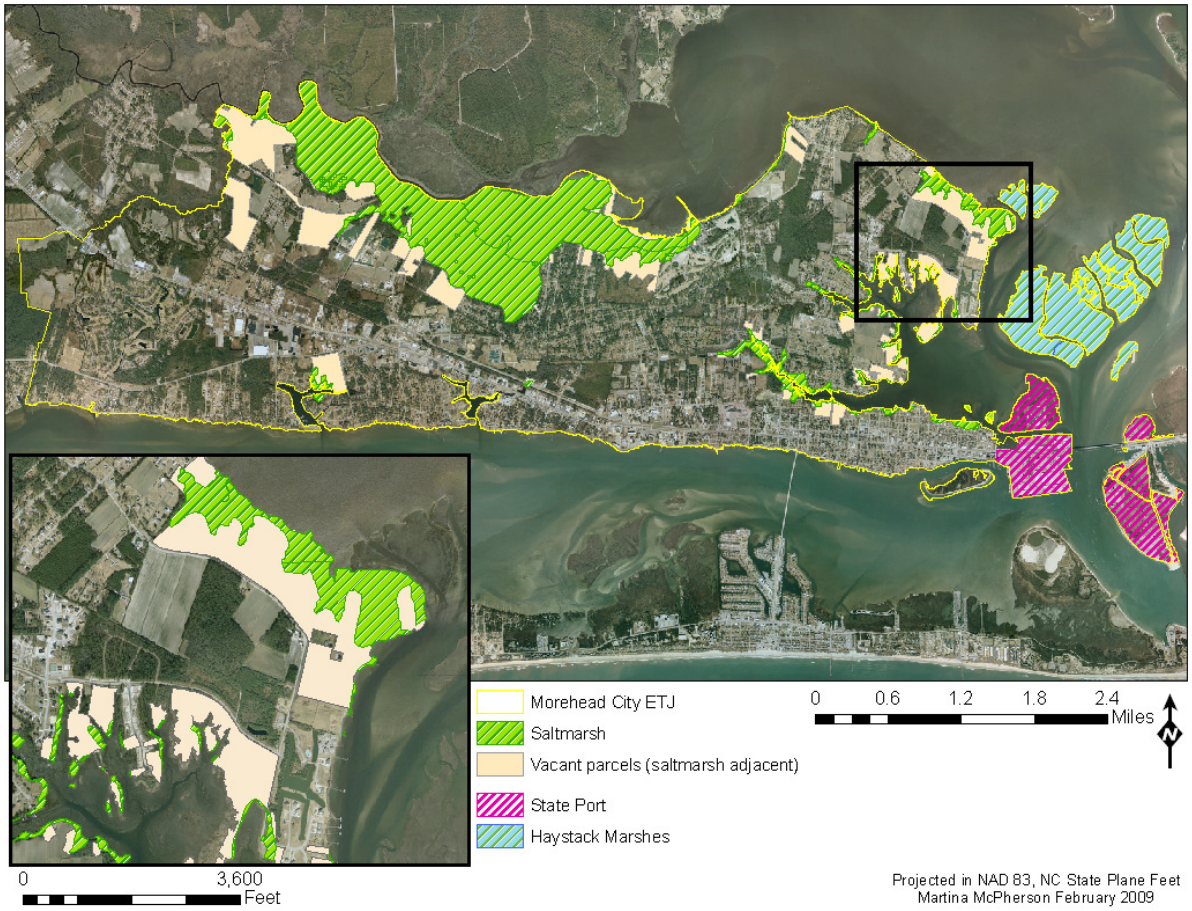
Land Use	Acres	Sq. Miles	% of inundated area	% of total land use class
Floodplain	677.5	1.059	37.20%	98.44%
Residential	1004.3	1.569	55.13%	16.39%
Institutional	35.2	0.055	1.93%	7.38%
Planned Dev.	25.3	0.040	1.39%	4.02%
Street	15.8	0.025	0.87%	1.53%
Industrial	44.7	0.070	2.45%	6.09%
Commercial	18.6	0.029	1.02%	2.14%
Total	1821.5	2.846	100.00%	

Appendix 3. Neighborhood and future land use data layers





Appendix 4. Vacant parcel adjacent to salt marsh data layer used in Plan 3



Appendix 5. Parcel information for 0.16 m inundation scenario

Neighborhood	2030 Mid (0.16 m)					
	# Vacant inland parcels	Avg. size of vacant inland parcels (s.f.)	Vacant inland parcels total area (acres)	# Parcels inundated	Avg. size inundated parcel (s.f.)	Inundated parcels total area (acres)
Neighborhood 1	175	8,988	36	21	15,076	7
Neighborhood 2	80	7,668	14	4	14,164	1
Neighborhood 3	115	28,417	75	4	47,699	4
Neighborhood 4	187	47,278	203	1	13,636	0
Neighborhood 5	286	103,020	676	11	162,182	41
Neighborhood 6	187	54,757	235	6	14,258	2
Neighborhood 7	500	84,608	971	8	16,443	3
Neighborhood 8	173	294,649	1,170	5	758,033	87
Neighborhood 9	319	63,560	465	3	14,835	1
Neighborhood 10	176	86,633	350	3	21,144	1
Total	2,198	--	4,197	66	--	149

Appendix 6. Parcel information for 1.06 m inundation scenario

Neighborhood	2100 Max (1.06 m)					
	# Vacant inland parcels	Avg. size of vacant inland parcels (s.f.)	Vacant inland parcels total area (acres)	Parcels inundated	Avg. size inundated parcel (s.f.)	Inundated parcels total area (acres)
Neighborhood 1	154	8,392	30	96	11,827	26
Neighborhood 2	80	7,668	14	11	10,172	3
Neighborhood 3	110	28,319	72	14	150,957	49
Neighborhood 4	185	47,243	201	3	38,182	3
Neighborhood 5	266	81,291	496	60	568,109	783
Neighborhood 6	179	56,095	231	29	15,707	10
Neighborhood 7	452	70,512	732	82	159,173	300
Neighborhood 8	162	206,705	769	19	1,298,278	566
Neighborhood 9	311	64,568	461	15	22,865	8
Neighborhood 10	175	86,916	349	6	16,754	2
Total	2,074		3,353	335		1,749

Appendix 7. Wetland inundation calculations

Wetland type	2030 Mid inundation (0.16)			2080 Mid inundation (0.46)			2100 inundation (1.06)		
	Acres	Sq. miles	% of total	Acres	Sq. miles	%	Acres	Sq. mi.	%
Salt/Brackish Marsh	115	0.18	38.3%	454	0.71	47.1%	632	0.99	38.7%
Drained Salt/Brackish Marsh	97	0.15	32.5%	364	0.57	37.8%	717	1.12	43.9%
Riverine Swamp Forest	31	0.05	10.5%	60	0.09	6.2%	84	0.13	5.1%
Hardwood Flat	6	0.01	1.9%	6	0.01	0.7%	9	0.01	0.6%
Managed Pineland	8	0.01	2.8%	10	0.02	1.1%	31	0.05	1.9%
Estuarine Shrub/Scrub	5	0.01	1.7%	12	0.02	1.2%	32	0.05	1.9%
Headwater Swamp	10	0.02	3.4%	23	0.04	2.4%	59	0.09	3.6%
Cutover Estuarine Shrub/Scrub	0	0.00	0.1%	1	0.00	0.1%	3	0.00	0.2%
Cutover Headwater Swamp	1	0.00	0.4%	1	0.00	0.1%	4	0.01	0.2%
Cleared Headwater Swamp	0	0.00	0.0%	0	0.00	0.0%	0	0.00	0.0%
Pine Flat	6	0.01	2.2%	12	0.02	1.2%	30	0.05	1.8%
Depressional Swamp Forest	1	0.00	0.2%	1	0.00	0.1%	1	0.00	0.1%
Cutover Hardwood Flat	0	0.00	0.1%	1	0.00	0.1%	1	0.00	0.1%
Drained Bottomland Hardwood	10	0.01	3.2%	10	0.02	1.1%	16	0.02	1.0%
Cutover Pine Flat	0	0.00	0.0%	0	0.00	0.0%	1	0.00	0.0%
Cleared Hardwood Flat	0	0.00	0.0%	0	0.00	0.0%	0	0.00	0.0%
Human Impacted	2	0.00	0.6%	2	0.00	0.2%	3	0.00	0.2%
Cutover Bottomland Hardwood	1	0.00	0.3%	1	0.00	0.1%	3	0.00	0.2%
Cleared Bottomland Hardwood	0	0.00	0.2%	1	0.00	0.1%	1	0.00	0.1%
Cleared Pine Flat	0	0.00	0.0%	0	0.00	0.0%	1	0.00	0.0%
Bottomland Hardwood	4	0.01	1.2%	4	0.01	0.4%	6	0.01	0.3%
Drained Hardwood Flat	2	0.00	0.5%	2	0.00	0.2%	2	0.00	0.1%
Total	**300**	**0.47**	**100.0%**	**964**	**1.51**	**100.0%**	**1634**	**2.55**	**100.0%**

Appendix 8. Vacant parcel information by neighborhood

Neighborhood	Area (acres)	Area (sq. mi)	Vacant parcels	Area Vacant (acres)	Avg vacant lot size (s.f.)	Avg. vacant lot size (acres)
Neighborhood 1	137	0.21	207	45	9,571	0.2
Neighborhood 2	120	0.19	82	15	7,850	0.2
Neighborhood 3	252	0.39	115	70	26,484	0.6
Neighborhood 4	427	0.67	177	149	36,710	0.8
Neighborhood 5	2,123	3.32	242	536	96,489	2.2
Neighborhood 6	534	0.83	200	124	27,066	0.6
Neighborhood 7	1,865	2.91	491	943	83,647	1.9
Neighborhood 8	1,754	2.74	158	1,182	327,889	7.5
Neighborhood 9	1,201	1.88	335	406	52,840	1.2
Neighborhood 10	774	1.21	159	264	72,368	1.7
Streets	1,008	1.58	--	--	--	--
Total	10,194	15.93	2,166	3,735	--	--