2022

CLIMATE CHANGE AND NATURAL HAZARDS VULNERABLITY ASSESSMENT FOR THE CAPE FEAR REGION

NCORR

RISE
Regions Innovating for Strong Economies and Environment

NC DPS
DEPARTMENT OF PUBLIC SAFETY
PREVENT. PROTECT. PREPARE.

EDA
U.S. ECONOMIC DEVELOPMENT ADMINISTRATION

EQUAL HOUSING OPPORTUNITY

Contents

List of Figures

List of Tables

LAND ACKNOWLEDGEMENT

We wish to acknowledge and honor the Indigenous communities native to this region and recognize that this vulnerability assessment covers communities and structures that are built on Indigenous homelands and resources. We recognize the Catawba, Lumbee, and Waccamaw Siouan people as past, present, and future caretakers of this land. We also recognize the unnamed tribes that once oversaw these lands and have since relocated or been displaced.

ACRONYMS

Acronym	Definition
ACS	American Community Survey
CAMA	Coastal Area Management Act
CDBG-DR	Community Development Block Grant – Disaster Recovery
CDBG-MIT	Community Development Block Grant – Mitigation
CDC	Centers for Disease Control and Prevention
DFIRM	FEMA Digital Flood Insurance Rate Map
EMS	Emergency Medical Services
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
HUD	US Department of Housing and Urban Development
HVAC	Heating, Ventilation and Air Condition Systems
IPCC	Intergovernmental Panel on Climate Change
NCDCR	North Carolina Department of Natural and Cultural Resources
NCDEQ	North Carolina Department of Environmental Quality
NCDHHS	North Carolina Department of Health and Human Services
NCDIT	North Carolina Department of Information Technology
NCDOT	North Carolina Department of Transportation
NCDPS	North Carolina Department of Public Safety
NCEM	North Carolina Emergency Management
NCFRIS	North Carolina Flood Risk Information System
NCOBSM	North Carolina Office of State Budget & Management
NCORR	North Carolina Office of Recovery & Resiliency
NCTN	North Carolina Transportation Network
NLCD	National Land Cover Database
NOAA	National Oceanic & Atmospheric Administration
NWS	National Weather Service
RISE	Regions Innovating for Strong Economies and Environment
SFHA	Special Flood Hazard Area
SLOSH	Sea, Lakes & Overland Surges from Hurricanes
SVI	Social Vulnerability Index
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USGS	United State Geological Survey
WCT	Wind Chill Temperature
WUI	Wildland-Urban Interface

DEFINITIONS

Vulnerability assessments involve the discussion of technical information and scientific information. While technical jargon was avoided, the following terms are defined in order to aid in the reader's understanding of the information presented in this vulnerability assessment document.

Accretion: The buildup of sediment within a certain location such as that occurring naturally across a beach/dune system (opposite of erosion) (Federal Emergency Management Agency n.d.).

Base Flood: The flood having a 1 percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the "100-year flood." The base flood is the national standard used by the National Flood Insurance Program (NFIP) and all Federal agencies for the purposes of requiring the purchase of flood insurance and regulating new development. Base Flood Elevations (BFEs) are typically shown on Flood Insurance Rate Maps (FIRMs) (Federal Emergency Management Agency n.d.).

Mitigation: Capabilities necessary to reduce loss of life and property by lessening the impact of disasters. Mitigation capabilities include, but are not limited to, community-wide risk reduction projects; efforts to improve the resilience of critical infrastructure and key resource lifelines; risk reduction for specific vulnerabilities from natural hazards or acts of terrorism; and initiatives to reduce future risks after a disaster has occurred (Federal Emergency Management Agency n.d.).

Climate Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Federal Emergency Management Agency n.d.).

Compound Flooding: Flooding arising from storms causing concurrent storm surge and precipitation. This compound flooding can severely affect densely populated low-lying coastal areas (nature.com 2020).

Critical Facility: A structure or other improvement that, because of its function, size, service area, or uniqueness, has the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if it is destroyed or damaged or if its functionality is impaired. Critical facilities include health and safety facilities, utilities, government facilities and hazardous materials facilities (CRS Community Self-Assessment n.d.).

Critical Infrastructure: Critical infrastructure includes the vast network of highways, connecting bridges and tunnels, railways, utilities and buildings necessary to maintain normalcy in daily life. Transportation, commerce, clean water and electricity all rely on these vital systems (U.S. Department of Homeland Security 2022).

Ecology: The branch of biology that deals with the relations of organisms to one another and to their physical surroundings (Merriam-Webster 2022).

Erosion: The process by which tides, strong wave action, and flood waters wear down or carry away rocks, sediment (soils, sands) along a shoreline (U.S. Climate Resilience Toolkit 2022).

Exposure: The representative value of buildings (in dollars), population (in both people and population equivalence dollars), or agriculture (in dollars) potentially exposed to a natural hazard occurrence (Federal Emergency Management Agency n.d.).

Flood Insurance Rate Map (FIRM): Official map of a community on which FEMA has delineated the Special Flood Hazard Areas (SFHAs), the Base Flood Elevations (BFEs) and the risk premium zones applicable to the community (Federal Emergency Management Agency n.d.).

Floodplain: A regulatory term used by the Federal Emergency Management Agency (FEMA) also termed the "floodway," or "regulatory floodway," to describe historic-based flooding. Specifically, it is the area next to a waterbody that historically experiences flooding either via tidal water or - in a riverine system - when water comes out of the banks of the main channel. FEMA generally described a floodplain as: "any land area susceptible to being inundated by flood waters from any source," which is the broader term that can include projected, future conditions (Federal Emergency Management Agency n.d.).

Flood Zone: Flood hazard areas identified on the Flood Insurance Rate Map are identified as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded) (Federal Emergency Management Agency n.d.).

Geology: The science that deals with the earth's physical structure and substance, its history, and the processes that act on it (Merriam-Webster 2022).

Groundwater: Water that exists underground in saturated zones beneath the land surface. The upper surface of the saturated zone is called the water table (United States Geological Survey n.d.).

Hazard: A regulatory term used by FEMA to describe the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (Federal Emergency Management Agency n.d.).

Hydrography: The science of surveying and charting bodies of water, such as seas, lakes, and rivers (Merriam-Webster 2022).

Hydrology: The branch of science concerned with the properties of the earth's water, and especially its movement in relation to land (Merriam-Webster 2022).

Impact: Effects on natural and human systems. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events (Federal Emergency Management Agency n.d.).

Land Use: The human use of land. It represents the economic and cultural activities (e.g., agricultural, residential, industrial, mining, and recreational uses) that are practiced at a given place (United States Environmental Protection Agency 2021).

Land Cover: The surface components of land that are physically present and visible (United States Environmental Protection Agency 2022).

Mean High Water: The average of astronomical high tides (Federal Emergency Management Agency n.d.).

Mean Return Period: The interval between events of similar size or intensity (Federal Emergency Management Agency n.d.).

Non-Potable Water: Water that has not been examined, properly treated, nor approved by appropriate authorities as being safe for consumption (Federal Emergency Management Agency n.d.).

Potable Water: Water suitable for drinking (Federal Emergency Management Agency n.d.).

Runoff: That part of the precipitation that appears in surface streams (United States Geological Survey 2019).

Sea Level Rise: The increase currently observed in the average sea level trend, which is primarily attributed to changes in ocean volume due to two factors: ice melt and thermal expansion (NOAA 2012).

Socially Vulnerable Populations: Populations with special needs that are especially at risk because of factors like socioeconomic status, household composition, minority status, or housing type and transportation (Agency for Toxic Substance and Disease Registry 2021).

Special Flood Hazard Area (SFHA): Areas designated by FEMA as historically having "special flood, mudflow, or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or a Flood Insurance Rate Map (Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30.)" (Federal Emergency Management Agency n.d.).

Surface Water: Water sources above ground level, including streams and rivers, lakes and reservoirs, and oceans (United States Geological Survey 2019).

Topography: The arrangement of the natural and artificial physical features of an area (Merriam-Webster 2022).

Water Capacity: The ability of a water system to ensure it can provide safe and reliable drinking water now and into the future (Federal Emergency Management Agency n.d.).

Watershed: The land that water flows across or through on its way to a common stream, river, or lake (United States Environmental Protection Agency n.d.).

Water Quality: A measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics (United States Geological Survey 2018).

Wildland-Urban Interface (WUI): the zone of transition between wilderness (unoccupied land) and land developed by human activity – an area where a built environment meets or intermingles with a natural environment (Federal Emergency Management Agency n.d.).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (Federal Emergency Management Agency n.d.)

RISE PROGRAM OVERVIEW

A. North Carolina Office of Recovery and Resiliency Overview

In the wake of Hurricane Florence in 2018, the State of North Carolina established the North Carolina Office of Recovery and Resiliency (NCORR) to lead the state's efforts to rebuild smarter and stronger. At that time, eastern North Carolina communities were still recovering from Hurricane Matthew, which occurred in 2016. NCORR manages nearly $1 billion dollars in U.S. Department of Housing and Urban Development (HUD) funding in two grant types — Community Development Block Grant-Disaster Recovery (CDBG-DR) funds and Community Development Block Grant-Mitigation (CDBG-MIT) funds — aimed at making North Carolina communities safer and more resilient to future storms. Additional funding is provided through the State Disaster Recovery Acts of 2017 and 2018, the Storm Recovery Act of 2019, and the Economic Development Administration Disaster Supplemental Funds. NCORR manages programs statewide that include homeowner recovery, infrastructure, affordable housing, resiliency, and strategic buyouts. To learn more about NCORR programs, visit the ReBuild.NC.Gov[1] website. NCORR is a division of the Department of Public Safety.

B. Regions Innovating for Strong Economies and Environment Overview

Developed in partnership with North Carolina Rural Center, NCORR's Regions Innovating for Strong Economies and Environment (RISE) program supports resilience in North Carolina by:

- Facilitating the Regional Resilience Portfolio Program, which provides coaching and technical assistance to regional partners in the eastern half of the state to build multi-county vulnerability assessments, identify priority actions to reduce risk and enhance resilience in their region, and develop paths to implementation.
- Developing the North Carolina Resilient Communities Guide, a statewide resource that will provide tools, guidance, and opportunities for building community resilience.
- Hosting the Homegrown Leaders program, a NC Rural Center leadership training workshop, which operates in the eastern half of the state, which emphasizes resilience as a tool for community economic development.

RISE is funded by the U.S. Economic Development Administration and the HUD's CDBG-MIT funds, with in-kind support from NCORR and the North Carolina Rural Center. In addition, the Duke Energy Foundation committed $600,000 in grant funding to support the Regional Resilience Portfolio Program.

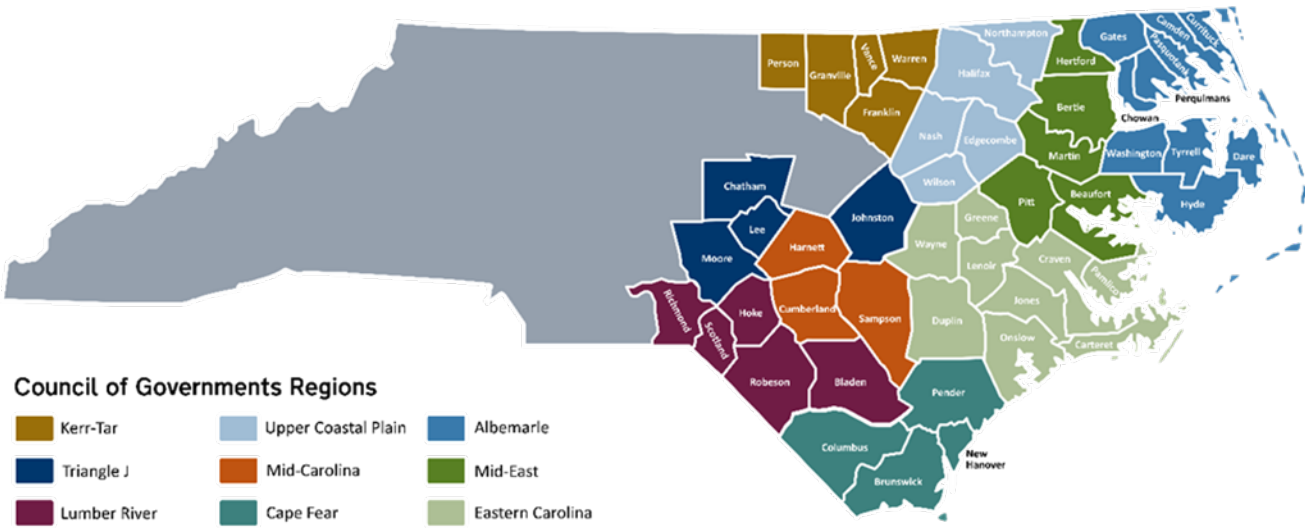
This vulnerability assessment, which covers Columbus, Brunswick, New Hanover, and Pender Counties, fulfills the first deliverable of the Regional Resilience Portfolio Program for the Cape Fear Region. The RISE Regional Resilience Portfolio Program covers nine areas, depicted in ***Figure 1***, which align with the North Carolina Council of Government Regions.

The second and final deliverable of each region's RISE Regional Resilience Portfolio Program will be a portfolio of 5–10 projects identified through community input and expert consultation. The portfolio

[1] https://www.rebuild.nc.gov/

document will outline funding opportunities and potential project partners to enable a clear path toward implementation for each project.

Figure 1. RISE Councils of Government

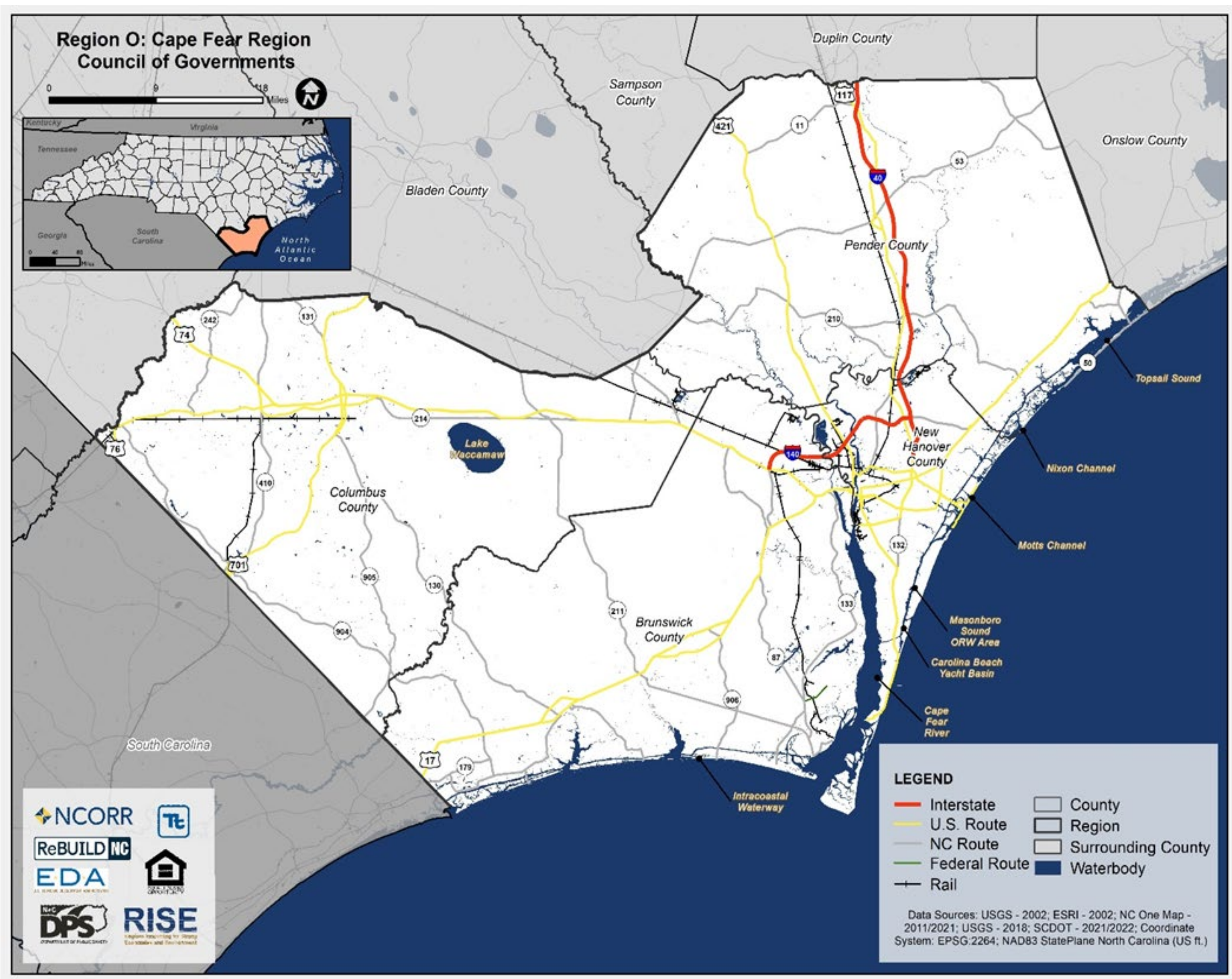


II. EXECUTIVE SUMMARY

A. The Cape Fear Region

The Regions Innovating for Strong Economies and Environment (RISE) Cape Fear Regional Resilience Portfolio Program aims to support resilience efforts throughout the Cape Fear Region by engaging local leaders and the community. This vulnerability assessment bridges science and local knowledge to identify current and future hazards impacting the region and to determine the region's strengths and challenges when faced with those hazards. The project is a partnership between the North Carolina Office of Resilience and Recovery (NCORR), the North Carolina Rural Center, and the Cape Fear Council of Governments (COG), with technical support provided by Tetra Tech. These organizations form the Project Team and lead the effort by providing guidance and support. The Cape Fear Region is composed of Columbus, Brunswick, New Hanover, and Pender Counties; refer to ***Figure 2***.

Figure 2. The Cape Fear Region



At the onset of the project, a Regional Stakeholder Partnership was formed to inform the project. The partnership is composed of local leaders from across the region who either live or work within the four counties. Leaders have backgrounds from various sectors and disciplines, including community organizations, social services, business and economic development, public health, planning and transportation, and local elected officials. Local leaders met monthly beginning in January 2022 to guide the development of the vulnerability assessment. Additionally, public input was solicited through a series of online surveys and virtual meetings to identify vulnerabilities and challenges throughout the region. The collected data informed the composition of the vulnerability assessment.

Local leaders and members of the public in the Cape Fear Region agree on the need to build resilience. When surveyed, nearly all local leaders in the Partnership agreed that natural disasters will impact the region more severely and frequently over the next 30 years. These results demonstrate the need for long-term solutions that strengthen the capacity of the region's households, communities, businesses, infrastructure, and the natural environment to prevent, withstand, respond to, and recover from natural disasters and climate hazards.

B. Summary of Findings

The vulnerability assessment provides detailed insight regarding the susceptibility of the region to climate change and its population, assets, and resources. Climate change and non-climate stressors create cascading impacts, which lead to new vulnerabilities in the region. The findings are summarized below:

Social Vulnerability and Equity, Health, and Safety

	• The region's elderly population accounts for approximately 20% of the total regional population. This is a vulnerable population that has a disproportionate risk to natural hazards in comparison to the overall population. Resilience solutions must incorporate considerations for vulnerable populations, such as including solutions that benefit those with limited mobility or financial constraints. • Lack of access to broadband (high-speed internet) in rural areas throughout Columbus and Pender Counties poses barriers to public outreach, including emergency notifications. • Inland communities have a greater presence of socially vulnerable areas, and therefore, impacts of a single hazard are exacerbated. These communities experience some of the same hazards as coastal communities, but they are impacted differently, requiring tailored solutions

Housing, Critical Infrastructure, and Community Support Systems

	• Limited safe and affordable housing options throughout the region increases recovery time post-disaster and exacerbates pre-existing disparities and social vulnerabilities. Disasters are felt more severely in communities that are already facing challenges with accessing safe and affordable housing. • Roadway infrastructure throughout the region is vulnerable to multiple hazards. Past flooding and hurricane events have resulted in extended closures and put the population at risk when evacuation routes are inaccessible. • Increased urbanization and impervious surface contribute to additional flooding and stormwater runoff. Aging infrastructure throughout the region will need to be replaced or retrofitted. Currently, the region's infrastructure does not have the capability of handing today's stormwater amounts or those amounts anticipated with climate change and increased development. Failing infrastructure impacts a community's ability to transport goods and services and can leave individuals isolated during emergencies.

Economy

- Tourism accounts for a significant sector of the regional economy. Flooding, hurricanes, erosion, and sea level rise threatens the beaches and other natural resources that are tourist attractions.

Natural and Historic Resources

- Projected population increases will increase development pressures in suburban and rural areas and therefore decrease the amount of green space available to absorb rainwater and result in increased flooding

Summary points for each of the hazards of concern are included below.

Flood

- Both coastal and inland communities are vulnerable to flooding. Coastal communities face cascading compounding hazards such as flooding, erosion, server storms, and storm surge. Inland communities are more likely to face riverine flooding or have flooding exacerbated by failing infrastructure.

Hurricane and Severe Storms

- The frequency and severity of hurricanes and severe storms are likely to increase over the course of the next 30 years. The increasing risk combined with the region's population being concentrated along the coastline will result in a larger percentage of the population being at risk to the impacts from hurricanes and severe storms.

Coastal Erosion

- Several areas of the coastline in the region have lost at least three feet of shoreline over the past several decades. This rate of erosion is anticipated to continue.
- Areas along the coastline of New Hanover and Pender Counties have experienced upwards of five feet of erosion over the past several decades.

Sea Level Rise

- Sea-level rise will have extensive impacts on the region as the majority of the population is concentrated in coastal areas, along with housing, critical infrastructure, and tourist attractions. Sea-level rise will have cascading impacts on various sectors.
- The region will need to conduct long-range plans to identify suitable areas outside of the coast for continued development to accommodate the region's projected population growth.

Extreme Temperature

- The number of high heat days is likely to increase in the region. Socially vulnerable populations face a disproportionate risk to extreme temperature. Within the region 21% of the total population is elderly; senior citizens have a higher rate of illness and death related to high heat. Fifteen percent of the population is economically disadvantaged; these households face financial burden to cool their homes adequately.

Drought

- The region has previously experienced long periods of drought, which are likely to become more frequent as temperatures rise and high heat days increase in frequency.

Tornado

- Climate change is warming the atmosphere in the region, meaning storms have potential to be more intense and occur more often.

Wildfire

- Increasing frequency and severity of wildfire will lead to increased damage to natural systems and potential damage to structures.
- Projected increases in wildfire risks and associated emissions can have harmful impacts on health.

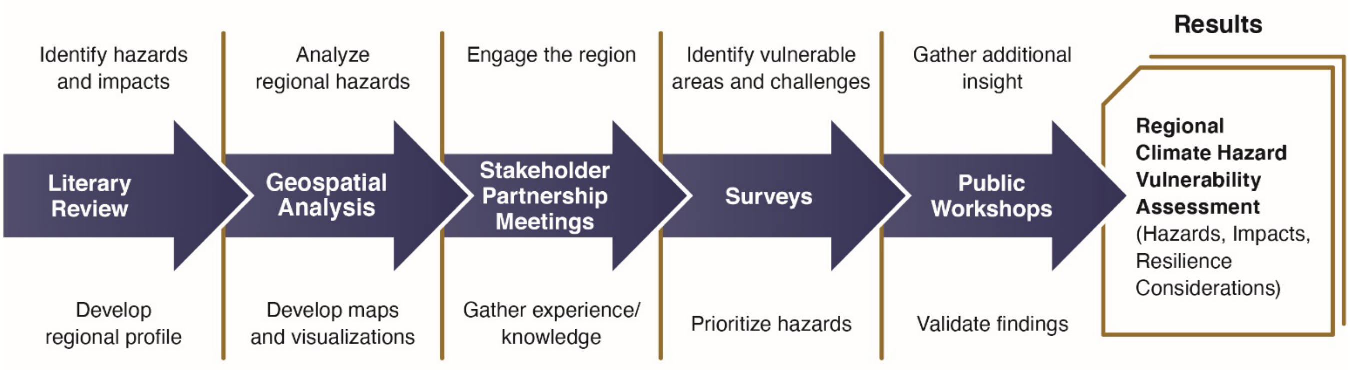
To explore individual communities and neighborhoods in the region and examine the data for yourself, please visit the webmap that accompanies this Vulnerability Assessment: Cape Fear Region - Resilience Portfolio Web Map (arcgis.com)[2] . Additional guidance and information about this webmap are available in Appendix B.

[2] https://tt-mmi.maps.arcgis.com/apps/webappviewer/index.html?id=ffa36af9b65e4960a04e74144c7ac8f2

III. METHODOLOGY

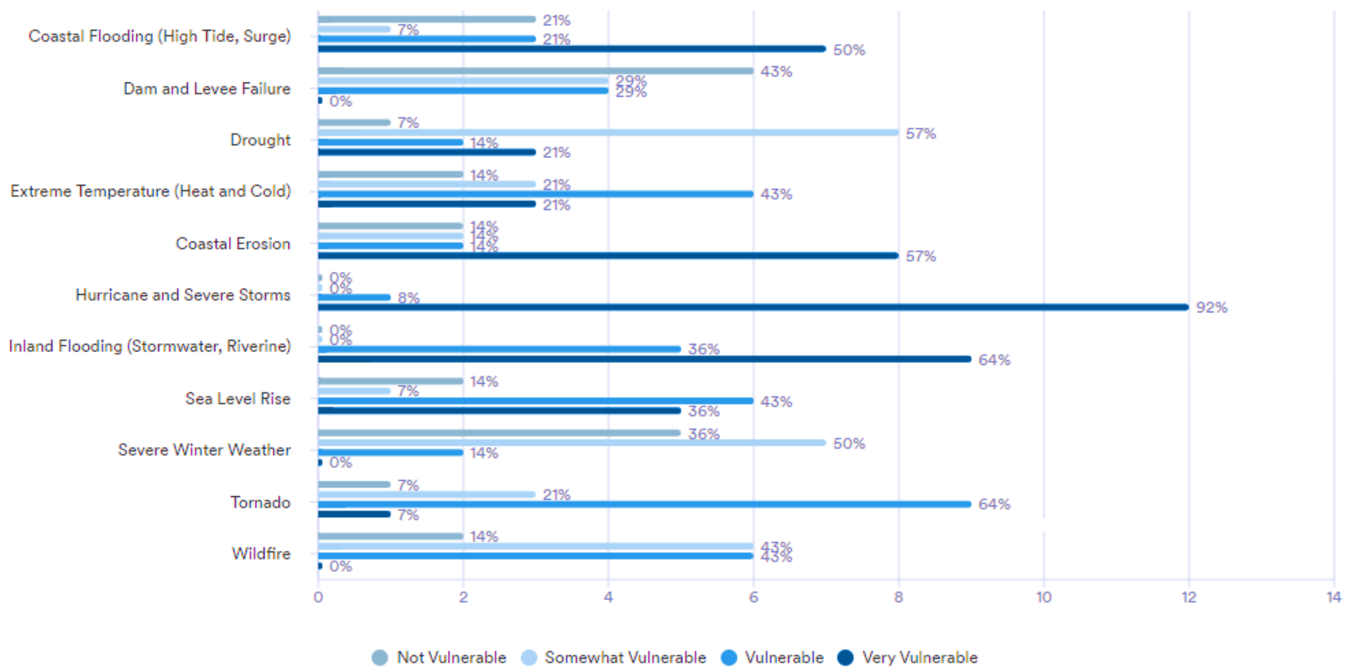
As illustrated in ***Figure 3***, the project team followed a detailed process to develop the vulnerability assessment.

Figure 3: Methodology for Developing the Vulnerability Assessment



The project team utilized data analyses, local knowledge, and existing reports to develop this vulnerability assessment. Tetra Tech performed a literature review to establish a foundation of known hazards and impacts throughout the region, followed by a quantitative geographic information system (GIS), or mapping, analysis. This data was supplemented by the lived experiences and knowledge of local leaders and community members. Local leaders were surveyed to identify the hazards that pose the greatest risk to the region. The responses from the surveys serve to establish the hazards profiled in the vulnerability assessment and the analysis of impacts on the identified sectors. Respondents ranked hurricanes and severe storms as posing the greatest risk, followed by inland flooding and erosion. To view the complete ranking of hazard risk, refer to ***Figure 4***. The figure depicts the number of responses (X-axis) received for each hazard (Y-axis).

Figure 4. Cape Fear Regional Stakeholder Partnership Hazard Ranking



A. Geographic Information System Methodology

The Climate Change and Natural Hazards Vulnerability Assessment for the Cape Fear Region was updated using best available information including the following sources:

- Hazard data published between 2014 and 2022
- 2020 Decennial Census population data
- 2015-2019 American Community Survey 5-year estimates
- NC OneMap building footprint and parcel data
- OneMap critical infrastructure inventory, supplemented with Homeland Infrastructure Foundation-Level Data (HIFLD)
- Wind hazard impacts from Hazus (v5.1)

The following summarizes the asset inventories, methodology and tools used to support the risk assessment process.

Asset Inventories

Cape Fear assets were identified to assess potential exposure and loss associated with the hazards of concern. For the vulnerability assessment the following types of assets were assessed for exposure vulnerability: population, buildings and critical facilities/infrastructure and the environment. Some assets may be more vulnerable because of their physical characteristics or socioeconomic uses. To protect individual privacy and the security of critical facilities, information on properties assessed is presented in aggregate, without details about specific individual personal or public properties.

Population

Total population statistics from the 2020 Decennial Census Bureau and 2015-2019 American Community Survey 5-year estimates were used to estimate the exposure and potential impacts to the region's population. Population counts from Census tracts in the region were totaled to estimate total population. The North Carolina State 2018 CDC/ATSDR Social Vulnerability Index (CDC/ATSDR SVI) was also used to identify Census tracts within the region with an SVI ranking of 0.5001 to 0.75 and more than 0.75001. These tracts represented areas of moderate to high social vulnerability and were referenced to assess the region's population at greatest risk to impacts. Limitations of these analyses are recognized and thus the results are used only to provide a general estimate for planning purposes.

As discussed in Section II (Region Profile), research has shown that some populations are at greater risk from hazard events because of decreased resources or physical abilities. Vulnerable populations in the Cape Fear Region included in the risk assessment are children, elderly, population below the poverty level, population with a disability, population with limited English proficiency, population without a vehicle, and population commuting to work.

Buildings

To develop the building inventory, data was compiled from NC OneMap, i.e., 2021/2022 State Parcels, and North Carolina Emergency Management (NCEM), i.e., 2010 State Building Footprints and 2020 State Building Footprints. The 2010 State Building Footprints with risk assessment attributes were referenced to assign attributes, i.e., year built, general occupancy class, and square footage, to the building footprints using the BLDG_ID field. Once building footprints were assigned attributes, the data was spatially joined to the 2021/2022 State Parcels data. The parcel data was used to fill in the gaps for building attributes. If a parcel intersected multiple building footprints, square footage was assigned based on parcel data or building footprint geometry. If the building footprint was the largest building that intersected the parcel, it was assigned the square footage from the parcel data. Otherwise, the square footage was assigned based on the area geometry of the building footprint. If a building footprint intersected multiple parcels with different occupancy classes, general occupancy classes were assigned based on the following priority: (1) residential, (2) government, (3) commercial or industrial, (4) all other general occupancy classes.

To develop the mobile home inventory, data was taken from the updated building stock inventory and the Homeland Infrastructure Foundation-Level Data (HIFLD), i.e., 2022 mobile home parks. Using the updated building stock inventory, mobile homes were extracted using general occupancy class attributes referenced from the 2010 state building footprint data with attributes, as well as the spatially joined 2021/2022 parcel data, i.e., PARUSECODE, PARUSEDESC, and PARUSEDSC2 fields.

Critical Infrastructure

Critical infrastructure was compiled from NC One Map, Homeland Infrastructure Foundation-Level Data (HIFLD), and United States Department of Transportation. Critical infrastructure was categorized into eight major sectors: education facilities; facilities with impacts to public health and environmental systems; healthcare facilities; historic and cultural resource facilities; public service facilities; transportation facilities; utilities; and vulnerable population facilities. The critical infrastructure was assigned attributes such as year built, renovated year, capacity of services, and whether backup power is available (if known).

Environment

Land use land cover data was referenced in this risk assessment to analyze changes in the environment for the Cape Fear Region. The 2021 Multi-Resolution Land Characteristics (MRLC) National Land Cover Database (NLCD) dataset was used to summarize land use exposure aggregated by agricultural land cover types. Additionally, the 2016 National Oceanic and Atmospheric Administration (NOAA) Marsh Migration dataset was used to illustrate the potential distribution of marsh and wetlands inundated under the potential future sea level rise +1 foot scenario. As sea level rises, higher elevations will become more frequently inundated, allowing for marsh migration landward. At the same time, some lower-lying areas will be so often inundated that the marshes will no longer be able to thrive, becoming lost to open water.

Analysis Methodology

To better understand potential vulnerability and losses associated with hazards of concern, the vulnerability assessment uses standardized tools, combined with local, state, and federal data and expertise to conduct the risk assessment. Three different levels of analysis were used depending upon the data available for each hazard as described below. ***Table 1*** summarizes the type of analysis conducted by hazard of concern.

- **Historic Occurrences and Qualitative Analysis** – This analysis includes an examination of historic impacts to understand potential impacts of future events of similar size. In addition, potential impacts and losses are discussed qualitatively using best available data and professional judgement.
- **Exposure Assessment** – This analysis involves overlaying available spatial hazard layers, or hazards with defined extent and locations, with assets in GIS to determine which assets are located in the impact area of the hazard. The analysis highlights which assets are located in the hazard area and may incur future impacts.
- **Loss estimation** — The FEMA Hazus modeling software was used to estimate potential losses for the hurricane wind hazard.

Table 1. Summary of Risk Assessment Analyses

Hazard	Population	General Building Stock	Critical Facilities and Lifelines
Coastal Erosion	Q	Q	Q
Flood	E	E	E
Hurricane	E, H	E, H	E, H
Sea Level Rise and 2050 1-Percent Annual Chance Flood	E	E	E
Storm Surge	E	E	E
Urban Heat Islands	Q	Q	Q

E – Exposure analysis; H – Hazus analysis; Q – Qualitative analysis

Hazard U.S. –Multi-Hazard (Hazus)

In 1997, FEMA developed a standardized model for estimating losses caused by earthquakes, known as Hazards U.S. or Hazus. Hazus was developed in response to the need for more effective national-, state, and community-level planning and the need to identify areas that face the highest risk and potential for loss. Hazus was expanded into a multi-hazard methodology, Hazus-MH, with new models for estimating potential losses from wind (hurricanes) and flood (riverine and coastal) hazards. Hazus is a geographic information system (GIS)-based software tool that applies engineering and scientific risk calculations, which have been developed by hazard and information technology experts, to provide defensible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards. The GIS framework also supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

Hazus uses GIS technology to produce detailed maps and analytical reports that estimate a community's direct physical damage to building stock, critical facilities, transportation systems and utility systems. To generate this information, Hazus uses default Hazus provided data for inventory, vulnerability, and hazards; this default data can be supplemented with local data to provide a more refined analysis. Damage reports can include induced damage (inundation, fire, threats posed by hazardous materials and debris) and direct economic and social losses (casualties, shelter requirements, and economic impact) depending on the hazard and available local data. Hazus' open data architecture can be used to manage community GIS data in a central location. The use of this software also promotes consistency of data output now and in the future and standardization of data collection and storage. More information on Hazus is available at http://www.fema.gov/hazus.

In general, probabilistic analyses were performed to develop expected/estimated distribution of losses (mean return period losses) for hurricane wind hazards. The probabilistic model generates estimated damages and losses for specified return periods (e.g., 100- and 500-year). ***Table 2*** displays the various levels of analyses that can be conducted using the Hazus software.

Table 2. Summary of Hazus Analysis Levels

Hazus Analysis Levels	
Level 1	Hazus-provided hazard and inventory data with minimal outside data collection or mapping.
Level 2	Analysis involves augmenting the Hazus-provided hazard and inventory data with more recent or detailed data for the study region, referred to as "local data".
Level 3	Analysis involves adjusting the built-in loss estimation models used for the hazard loss analyses. This Level is typically done in conjunction with the use of local data.

Erosion Rate

A qualitative assessment was conducted for erosion rates along the coastline of the Cape Fear Region. Information from the NC Division of Coastal Management was used to assess the potential impacts to the region's assets. The information used in this assessment, which was released in 2020, identifies the 2019 average annual long-term erosion rates along North Carolina's oceanfront. The erosion rates are calculated by using the earliest and most current shorelines and shore-perpendicular transects, measuring the distance between the two shorelines at each transect, and dividing the measured distance by number of years between the two shorelines. This identifies whether accretion (i.e., beaches gain sand), erosion (i.e., beaches lose sand), or no change has occurred between the earliest and most current shorelines. The resulting information is used to update North Carolina's Ocean Hazard Construction Setback Factors and the Ocean Erodible Area of Environmental Concern.

Flood

The 1- and 0.2-percent chance flood events were examined to evaluate the region's risk and vulnerability to the riverine and coastal flood hazard areas. These flood events are generally those considered by planners and evaluated under federal programs such as the NFIP.

The Cape Fear Region is composed of multiple counties. As such, the text below outlines the counties within the region and their effective dates for the FEMA Digital Flood Insurance Rate Map (DFIRM) and letter of map revision (LOMR) dates:

- Brunswick County: December 6, 2019. LOMR – January 4, 2021
- Columbus County: December 6, 2019. LOMR – December 7, 2020
- New Hanover County: December 6, 2019
- Pender County: June 19, 2020, and June 2, 2021. LOMR – October 26, 2018, and February 11, 2022

The effective FEMA Digital Flood Insurance Rate Maps (DFIRMs) were used to evaluate the region's assets risk to flood exposure.

To estimate exposure to the 1-percent and 0.2-percent annual chance flood events, the DFIRM flood boundaries were overlaid on the region's assets (building stock, critical infrastructure, and population). Building footprints and critical infrastructure that intersected the flood boundaries were totaled to estimate the total number of buildings and infrastructure located in the flood inundation areas, respectively.

To estimate the total population and vulnerable population at risk to the flood hazard, the DFIRM flood boundaries were used to extract the area of each county in the Region located in the 1-percent and 0.2-percent annual chance flood events. The population at risk to flood events was calculated by obtaining the percentage of total land area within the flood hazard for each county, multiplied against the county's total population and vulnerable population types. Additionally, the analysis summarized the total number of persons living in moderate to high socially vulnerable tracts within the region located in the 1-percent and 0.2-percent annual chance flood events. The percentage of total land area of Census tracts with CDC/ASTR SVI rankings of 0.5001 to 0.75 and more than 0.75001 located in the 1-percent and 0.2-percent annual chance flood events was multiplied against the total population and vulnerable population types within these moderate to high SVI tracts. These results were summarized for each county within the region.

Hurricane

A Hazus probabilistic analysis was performed to estimate debris generated and displacement of persons caused by the 50-year hurricane wind mean return period event. The probabilistic Hazus hurricane model activates a database of thousands of potential storms that have tracks and intensities reflecting the full spectrum of Atlantic hurricanes observed since 1886 and identifies those with tracks associated with the region. Hazus contains data on historic hurricane events and wind speeds. It also includes surface roughness and vegetation (tree coverage) maps for the area. Surface roughness and vegetation data support the modeling of wind force across various types of land surfaces. Default demographic and building inventories in Hazus were used for the analysis. Although damages are estimated at the census tract level, results were presented at the county and regionwide levels.

Sea Level Rise and 2050 1-Percent Annual Chance Flood

Sea-level rise data (in 1-foot increments) available from the NOAA Office of Coastal Management (https://coast.noaa.gov/slrdata/) published in 2017 was considered and used for this analysis to understand the assets within the region that are at risk to impacts from the projected 2050 1-percent annual chance flood event (i.e., sea level rise +1 foot and 1-percent annual chance flood event). Please note that the sea level rise data does not include additional storm surge due to a hurricane. Furthermore, the current Flood Insurance Rate Maps (FIRMs) also do not include the effects of sea-level rise.

Asset data (population, building stock, and critical infrastructure) were used to support an evaluation of assets at risk to future impacts from the projected 2050 1-percent annual chance flood hazard area. To determine the assets at risk, the region's assets were overlaid with the hazard area. Building footprints and critical infrastructure that intersected the projected 2050 1-percent annual chance flood hazard area were totaled to estimate the total number of buildings and infrastructure located in the projected flood hazard area.

To estimate the total population and vulnerable population at risk to the projected 2050 1-percent annual chance flood hazard area, the projected flood hazard area was used to extract the area of each county in the Cape Fear Region located in the 2050 flood hazard area. The population at risk to the 2050 1-percent annual chance flood was calculated by obtaining the percentage of total land area within the projected flood hazard area for each county, multiplied against the county's total population and vulnerable population types. Additionally, the analysis summarized the total number of persons living in moderate to high socially vulnerable tracts within the region located in the projected 2050 1-percent annual chance flood event. The percentage of total land area of Census tracts with CDC/ASTR SVI rankings of 0.5001 to 0.75 and more than 0.75001 located in the projected 2050 1-percent annual chance flood event was multiplied against the total population and vulnerable population types within these moderate to high SVI tracts. These results were summarized for each county within the region.

Storm Surge

An exposure analysis was conducted using the 2014 Sea – Lake Overland Surge from Hurricanes (SLOSH Model), which represents potential flooding from worst-case combinations of hurricane direction, forward speed, landfall point, and high astronomical tide were used to estimate exposure. Please note these inundation zones do not include riverine flooding caused by hurricane surge or inland freshwater flooding. The 2014 model, developed by the NOAA National Hurricane Center to forecast surges that occur from wind and pressure forces of hurricanes, considers only storm surge height and does not consider the effects of waves. The SLOSH spatial data includes boundaries for Category 1 through Category 4 storm surge events.

Asset data (population, building stock, and critical infrastructure) were used to support an evaluation of assets at risk to future impacts from storm surge. To determine the assets at risk, the region's assets were overlaid with each SLOSH Category 1 through 4 storm surge hazard area. Building footprints and critical infrastructure that intersected the SLOSH Category 1 through 4 storm surge hazard areas were totaled to estimate the total number of buildings and infrastructure located in each storm surge hazard area.

To estimate the total population and vulnerable population at risk to storm surge, the SLOSH Category 1 through 4 storm surge hazard areas were used to extract the area of each county in the Region located in storm surge hazard areas. The population at risk to storm surge was calculated by obtaining the percentage of total land area within the SLOSH Category 1 through 4 storm surge hazard areas for each county, multiplied against the county's total population and vulnerable population types. Additionally, the analysis summarized the total number of persons living in moderate to high socially vulnerable tracts within the region located in the storm surge hazard areas. The percentage of total land area of Census tracts with CDC/ASTR SVI rankings of 0.5001 to 0.75 and more than 0.75001 located in the SLOSH Category 1 through 4 storm surge hazard areas was multiplied against the total population and vulnerable population types within these moderate to high SVI tracts. These results were summarized for each county within the region.

Urban Heat Islands

A qualitative assessment was conducted for the urban heat island (UHI) hazard. Information from the Trust for Public Land, Descarte Labs, and United States Geological Survey (USGS) was used to assess the potential impacts to the region's assets. The Urban Heat Island Severity for U.S. Cities – 2019 contains the relative heat severity for every city in the United States derived from imagery from the summers of 2018 and 2019. It shows where certain areas of cities are hotter than the average temperature for that same city. Knowing where areas of high heat are located can help plan for mitigation strategies.

Considerations for Mitigation and Next Steps

The following analyses would enhance a future update of the vulnerability assessment:

- Inventory Data
    - Update risk attributes of building footprints using current tax assessor data.
    - Update critical facilities with local input and locally available data sources.
- Coastal Erosion
    - Collect data on historic costs incurred to reconstruct buildings, cultural resources and/or infrastructure due to coastal erosion impacts.
- Flood
    - Conduct a Hazus loss analysis (e.g., 100-year flood event) using building footprint risk assessment attributes and updated flood data.
- Hurricanes
    - Estimate storm surge related losses using the Hazus flood model if the data is available.
    - Conduct Hazus loss analysis using user-defined facilities and critical facilities in the latest version of Hazus.
- Sea Level Rise and Projected 2050 1-Percent Annual Chance Flood Event
    - Incorporate modeled 2050 1-percent annual chance flood event data that shows modeled extent of future flood hazard area.
- Urban Heat Islands
    - Implement locally produced data for analysis if available.

B. Data Source Summary

Table 3 summarizes the data sources used for the risk assessment for this plan.

Table 3. Risk Assessment Data Documentation

Data	Source	Date	Format
Population Data	Census Bureau; American Community Survey 5-Year Estimates	2020; 2019	Digital (GIS) Format
Social Vulnerability Index	CDC/ATSDR SVI	2018	Digital (GIS) Format
Building Footprints	NCEM	2020	Digital (GIS) Format
Parcel Boundaries	NC One Map	2021/2022	Digital (GIS) Format

Data	Source	Date	Format
Critical Facilities	NC OneMap; HIFLD	2011/2016/2018/2019; 2020/2021/2022	Digital (GIS) Format
2019 Land Cover	USGS/NLCD	2021	Digital (GIS) Format
Marsh Migration	NOAA	2016	Digital (GIS) Format
Erosion Rate	USGS; NC Division of Coastal Management	2017;2020	Digital (GIS) Format
Urban Heat Island	The Trust for Public Land	2019	Digital (GIS) Format
Digitized Effective FIRM Maps	NCFRIS; FEMA	2022; 2019/2020/2021	Digital (GIS) Format
Sea Level Rise	NOAA	2017	Digital (GIS) Format
Sea-Lake Overland Surge from Hurricanes (SLOSH) Model	NOAA	2014	Digital (GIS) Format

Limitations

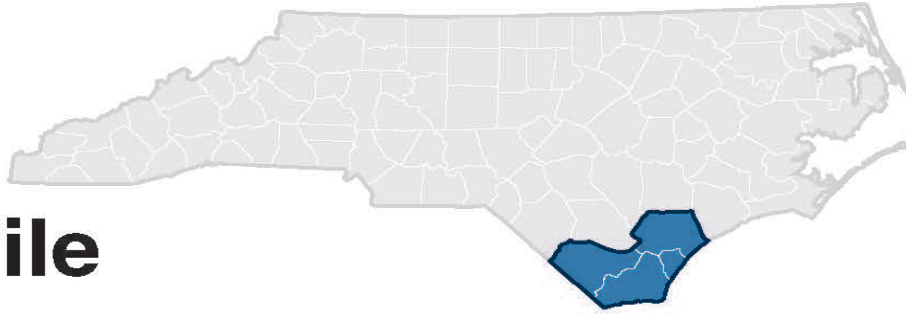
Loss estimates, exposure assessments, and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

1. Approximations and simplifications necessary to conduct such a study
2. Incomplete or dated inventory, demographic, or economic parameter data
3. The unique nature, geographic extent, and severity of each hazard
4. Mitigation measures already employed by the participating municipalities
5. The amount of advance notice residents has to prepare for a specific hazard event
6. Uncertainty of climate change projections

These factors can result in a range of uncertainty in loss estimates, possibly by a factor of two or more. Therefore, potential exposure and loss estimates are approximate. These results do not predict precise results and should be used to understand relative risk. Over the long term, the region will collect additional data to collect additional data, update and refine existing inventories, to assist in estimating potential losses.

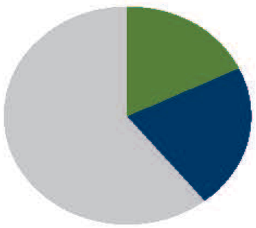
Potential economic loss is based on the present value of the general building stock utilizing best available data. The Cape Fear Region acknowledges significant impacts may occur to critical facilities and infrastructure as a result of these hazard events causing great economic loss. However, monetized damage estimates to critical facilities and infrastructure, and economic impacts were not quantified and require more detailed loss analyses. In addition, economic impacts to industry such as tourism and the real estate market were not analyzed.

Cape Fear Regional Profile



POPULATION

Total Population
473,221



84,356
Persons Under 18

101,131
Persons Over 65

Regional Median Income
$44,438

State Median Income
$56,642

Regional Population Changes

Regional population increased approximately 12% from 2010 - 2020.

Regional population is anticipated to increase 40% in the next 30 years.

HOUSING, CRITICAL INFRASTRUCTURE, AND COMMUNITY SUPPORT SERVICES

128,381
Houses Built Before Modern Flood Protection Laws

18.96%
Percentage of Residences that are Mobile Homes

847
Critical Facilities (Hospitals, Police Stations, Fire Stations, etc.)

372
Public Utility Facilities (Cellular Towers, Water Treatment Plants, & Electric Substations)

7,462
Roadway Miles

232
Rail Miles

ECONOMY

Leading industries: educational services, health care, and social assistance

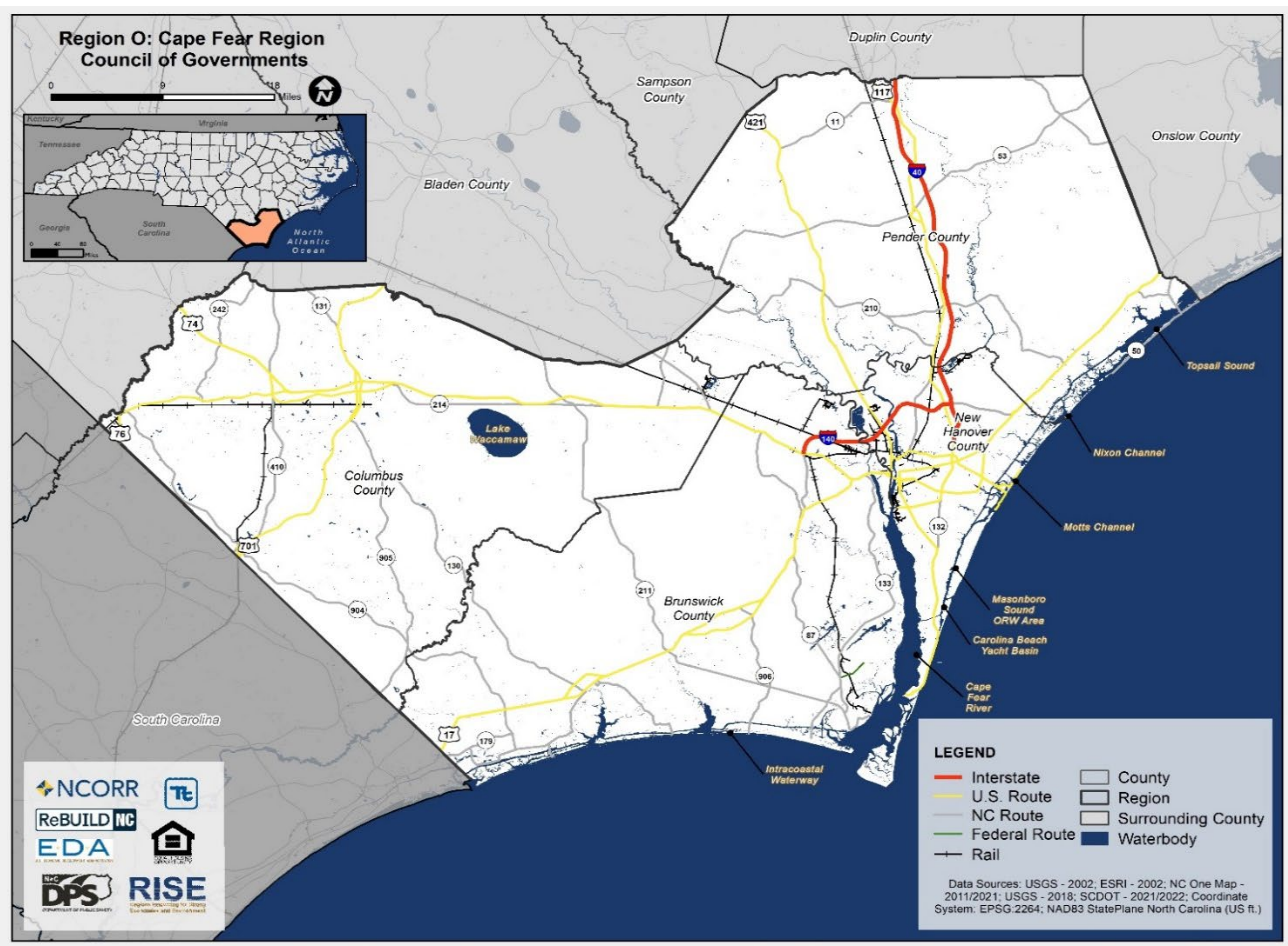
TOURISM

- **In 2020, tourism and visitor spending in the region accounted for $1.5 billion; representing 7.6% of the overall State total tourism spending.**
- **Brunswick County ranked #7 for visitor spending in the State in 2020 with $731 million spent.**
- **New Hanover County ranked #8 for visitor spending in the State in 2020 with $598 million spent.**

IV. REGIONAL PROFILE

The Cape Fear Region is composed of Columbus, Brunswick, New Hanover, and Pender Counties and totals approximately 2,889 square miles. The region is located in the southeastern corner of North Carolina. It is bordered to the north by Duplin and Onslow Counties, the east and south by the Atlantic Ocean, the southwest by South Carolina, and the west by Robeson and Bladen Counties. Refer to ***Figure 5***. Development is concentrated in Wilmington in New Hanover County and along the coastlines of Brunswick, New Hanover, and Pender Counties. Agricultural areas are concentrated in the western area of Columbus County and central Pender County. Large swaths of the region are dominated by green, open space like wetlands and forest. These natural areas provide water storage, diverse animal habitats, and more benefits to the region. Development is heavily concentrated along the coastline in Brunswick County and New Hanover County is predominately developed. These developed areas are also where the majority of the population resides within the region. With the most densely populated areas being located along the coastline, a larger percentage of the population is at risk to cascading coastal hazards such as hurricanes, storm surge, flooding, erosion, and sea-level rise. To review land uses throughout the region, refer to ***Figure 25*** in ***Appendix A***.

Figure 5. Cape Fear Region



A. Physical Setting

The Cape Fear Region has several natural features that play a role in providing protection from natural hazards but are also vulnerable themselves to impacts from hazards. Natural systems, such as wetlands, barrier islands, and estuaries, provide multiple co-benefits to the environment and people. These natural systems can improve air quality, reduce impacts from extreme heat, serve as storage for rainwater and flooding, and provide recreational and exercise opportunities for people (Kingsley 2019).

One of the largest natural resources in the region is the Green Swamp Preserve, a 15,907-acre swamp located in Brunswick and Columbus Counties. The preserve is a National Landmark and home to the Venus flytrap species and other endangered species. The preserve is susceptible to natural hazards and experience a 598-acre wildfire in 2022 as a result of a lightning strike (Brunswick County 2022). The wildfire resulted in the closure of N.C. 211 for several days.

The region has several large areas dedicated to green and open space. The North Carolina Division of Parks and Recreations identifies the following natural and recreational resources in the region (North Carolina State Parks n.d.):

- **Lake Waccamaw State Park** – 9,000 acres and 14 miles of shoreline in Columbus and Robeson Counties
- **Lumber River State Park** – 13,659 acres across Columbus and Robeson Counties
- **Fort Fisher State Recreational Area** – 287 acres of beach and marshland in New Hanover County
- **Carolina Beach State Park** – 761 acres of beach, campground, and public marina in New Hanover County

The Cape Fear Region's waterways drain into two major watersheds: The Lumber River Basin and the Cape Fear River Basin. The Waccamaw River, located in Brunswick and Columbus Counties, and the Lumber River, located in Robeson and Columbus Counties, drain into the Lumber River Basin. The Cape Fear River Basin is the largest river basin in the state, covering 9,000 square miles and more than one-third of the state's population (National Oceanic and Atmospheric Administration n.d.). The Black River, in New Hanover County, and the Northeast Cape Fear River, in Pender County, both drain into the Cape Fear River Basin. The region includes the final stretch of the Cape Fear River before it empties into the ocean.

The coastline of the Cape Fear Region is composed of beaches and barrier islands. These natural features provide protection from coastal hazards by serving as a physical barrier and absorbing wave energy prior to waves and storm surge impacting the mainland (National Oceanic and Atmospheric Administration n.d.). Barrier islands and beaches provide ecosystem benefits and recreational opportunities. The ocean side of barrier islands are typically composed of beaches and sand dunes, while the landward side often is composed of marshes and tidal flats (National Oceanic and Atmospheric Administration n.d.). Within the region, there are 14 barrier islands and beaches:

- Bird Island Reserve
- Sunset Beach
- Ocean Isle Beach
- Holden Beach
- Oak Island
- Caswell Beach
- Zeke's Island Reserve
- Carolina Beach
- Kure Beach
- Wrightsville Beach
- Masonboro Island Reserve
- Figure Eight Island

- Bald Head Island and Natural Area
- Topsail Island

The region's proximity to the Atlantic Ocean influences the climate, creating humid, subtropical conditions. The average winter temperature in the region is 48 °F, and the average summer temperature is 78 °F (National Oceanic And Atmospheric Administration n.d.). The heaviest monthly precipitation takes place during the summer months, tied to hurricanes, tropical storms, and thunderstorms. The 2020 North Carolina Climate Science Report states it is "*very likely* that average temperatures across the state will increase substantially by 2–5 degrees." (K. D. Kunkel 2020). As a result of this temperature change the number of extremely hot days will increase, and the number of extremely cold days will decrease. As the report states, "Extreme heat events will become more frequent, longer-lasting, and more intense, exacerbating demands for water." (K. D. Kunkel 2020).

B. Population

Population increase and new development can exacerbate natural hazards and climate change impacts. During the project, local leaders and members of the public raised concerns regarding the increasing population and subsequent development pressures facing the region.

Today, the region's total population is 473,221. New Hanover County has the largest population at 225,702, which is approximately four times greater than Columbus or Pender Counties. The 2020 regional population is distributed as shown in ***Table 4.*** The widespread differences in population mean that the number of people exposed to hazards and the non-climate stressors a community is vulnerable to will differ. For example, New Hanover County has a larger, concentrated population as compared to other counites in the region. This means that New Hanover County has a higher vulnerability to hazards due to more people being in harm's way. In comparison, counties with lower populations may face increased development pressures as the region's population continually increases. Local leaders identified the U.S. 17 corridor as experiencing a surge in development in recent years. Communities within this portion of Brunswick County experienced significant growth between April 2000 and July 2021; the percentage of population increase is as follows (Orona, John 2022):

- Northwest – 9.7%
- Navassa – 8.9%
- Leland – 8.6%
- Calabash – 7.6%

From 2010 to 2020, the region's total population increased by 52,081, an increase of approximately 12%. The 2020 U.S. Census indicates that most new residents in the region are moving to new areas within the same county or are moving to new counties from other counties within the state. In growing areas such as Brunswick County, 5.3% of new residents moved from other areas within the county while 4.4% of residents moved from a different county within the state (U.S. Census Bureau 2020). New Hanover County has the highest percentage of out-of-state residents relocating into the county at 3.5% (U.S. Census Bureau 2020). Over the next three decades, the region's population is projected to continue to increase, rising an estimated 40% to 664,394 by 2050. While Columbus County is projected to experience an estimated 53% decrease, all other counties are projected to experience an estimated increase of 40% or greater. Brunswick County will have the greatest population gain, with an estimated increase of 73%. Refer to ***Table 4*** for a breakdown of the region's projected population. The projected population increase will intensify the need for building the region's resilience as more people will become vulnerable to widespread hazards throughout the region. Increased stress on resources and critical facilities will result in a compounding need to effectively address current and future natural and climactic hazards.

Table 4. Cape Fear Region Population Projections

County	2010	2020	2030	2040	2050	% Change 2020–2050
Brunswick County	107,860	136,693	170,134	203,506	236,878	73.29%
Columbus County	57,855	50,623	41,283	32,433	23,584	-53.41%
New Hanover County	203,092	225,702	254,790	285,043	315,294	39.69%
Pender County	52,333	60,203	69,689	79,163	88,638	47.23%
Cape Fear (Total)	**421,140**	**473,221**	**535,896**	**600,145**	**664,394**	**40.40%**

Source: U.S. Census Bureau 2020, North Carolina Office of State Budget and Management 2022

Population Density

Population density has a strong correlation with hazard vulnerability and loss. Urban areas tend to have larger populations and a higher number of structures; therefore, these areas tend to experience greater losses during hazard events due to the concentration of people and property in one area. On the other hand, rural areas consist of the population being spread out and experience greater challenges in distributing information and resources during emergencies.

The Cape Fear Region has significant areas of both high and low population density. The land area of the region is mostly undeveloped, with a low population density. Most development lies within major cities and along the coast. New Hanover County has the highest population density in the region, which is almost six times greater than that of the state (U.S. Census Bureau 2020). Columbus and Pender Counties are both sparsely developed, with population densities less than 6 percent of New Hanover County's (U.S. Census Bureau 2020).

Race

Identifying racial makeup of a community aids in identifying frontline communities. Frontline communities often experience impacts from natural and climate hazards first and more severely. These communities are often communities of color and face additional barriers and non-climate stressors. Within the Cape Fear Region communities of color represent approximately 21% of the total regional population. Racial and ethnic distribution in the region is summarized in ***Table 5.***

Table 5. Race and Ethnicity in the Cape Fear Region

Counties	White	Black or African American	American Indian and Alaskan Native	Asian	Native Hawaiian and Other Pacific Islander	Other Race	Two or more Races
Brunswick County	115,159	12,919	830	725	3	3,084	4,746
Columbus County	34,770	16,519	1,964	246	10	972	1,076
New Hanover County	186,681	30,436	544	3,145	205	2,870	6,418
Pender County	47,895	8,791	173	321	74	2,562	1,631

Counties	White	Black or African American	American Indian and Alaskan Native	Asian	Native Hawaiian and Other Pacific Islander	Other Race	Two or more Races
Cape Fear Region (Total)	**384,505**	**68,665**	**3,511**	**4,437**	**292**	**9,488**	**13,871**

Source: American Community Survey 2019

Social Vulnerability

The ability of an individual or community to withstand and quickly recover from current and future natural hazards is critical to the resilience of the region. The same disaster can impact different populations in different ways. For example, differences in age, income, disabilities, and English proficiency affect people's ability to cope with the effects of climate change and natural hazards; communities and groups within these categories are vulnerable populations.

VULNERABLE POPULATIONS

- **Children (5 years and under)** are dependent on others to safely access resources during emergencies.
- The **elderly (65 years and over)** are more likely to lack the physical and economic resources necessary for response to hazard events.
- **Economically disadvantaged** populations are likely to lack the resources to adequately prepare for and respond to hazards.
- **People with disabilities** are faced with increased levels of difficulty, which may reduce their capacity to receive, process, and respond to emergency information and warnings.
- **Individuals with limited English proficiency** may have difficulty with understanding information being conveyed to them. Cultural differences can also add complexity to how information is being conveyed to populations with limited proficiency of English. (CDC 2020)

Within the region the highest category of vulnerable populations is the elderly, which accounts for approximately 21% of the region's total population. The elderly are more likely to lack the physical and economic resources necessary for response to hazard events and are more likely to suffer health-related consequences, making recovery slower. Those living on their own may have more difficulty evacuating their homes. The elderly population is also more likely to live in senior care and living facilities where emergency preparedness occurs at the discretion of facility operators.

Populations that are economically disadvantaged account for 15% of the region's total population, and this is reflected by the region's median income of $44,438 compared to the state's median income of $56,642 and the country's median income of $67,521. Economically disadvantaged populations are more vulnerable to hazards because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have the funds to evacuate.

The Center for Disease Control and Prevention (CDC) defines a disability as a "condition of the body or mind (impairment) that makes it more difficult for the person with the condition to do certain activities (activity limitation) and interact with the world around them (participation restrictions)" (CDC 2020). These impairments may increase the level of difficulty that individuals may face during a hazard event. Cognitive impairments may reduce an individual's capacity to receive, process, and respond to emergency information or warnings. Individuals with a physical or sensory disability may face issues of mobility, sight, hearing, or reliance on specialized medical equipment. Persons with disabilities account for approximately 15% of the region's population.

Identifying concentrations of vulnerable populations can assist communities in targeting preparedness, response, and mitigation actions. The region will need to ensure that considerations for vulnerable populations, such as mobility and financial challenges, are included in the decision-making process when identifying resilience projects and carrying out disaster management processes. ***Table 6*** provides a breakdown of vulnerable populations in the region.

Table 6. Vulnerable Populations in the Cape Fear Region

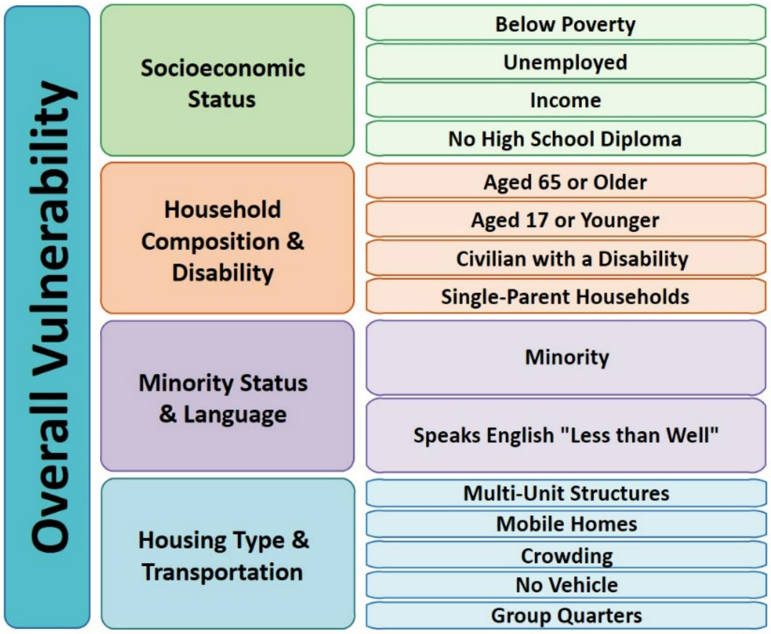
County	Total 2020 Population	Number of Persons Over 65	Number of Persons Below 5	Number of Persons Below Poverty Level	Number of Persons with a Disability	Number of Persons Limited English Speaking	Number of Persons Without Vehicle
Brunswick	136,693	40,223	5,285	15,402	21,429	538	2,113
Columbus	50,623	10,936	2,881	12,101	10,463	280	1,511
New Hanover	225,702	39,260	11,266	35,410	28,082	1,094	6,210
Pender	60,203	10,712	3,398	8,334	9,689	339	779
Cape Fear (Total)	**473,221**	**101,131**	**22,830**	**71,247**	**69,663**	**2,251**	**10,613**

Sources: American Community Survey 2019, U.S. Census Bureau 2020

Social vulnerability is the likelihood of an individual, community, or group to be negatively affected by external stressors which create barriers to the community's resilience. These external stressors may be a lack of access to transportation, socioeconomic factors (e.g., income, educational attainment, employment), or broadband access. Identifying concentrations of vulnerable populations and geographic areas with high social vulnerability can assist communities in prioritizing support and resources to build resilience across the whole community.

Information collected through the U.S. Census Bureau, American Community Survey, and other sources is used to provide data on vulnerable populations and barriers contributing to social vulnerability. To identify areas in the region experiencing a higher rate of social vulnerability, the Centers for Disease Control (CDC) Social Vulnerability Index (SVI) was utilized. The SVI is a combination of 15 different social factors that contribute to social vulnerability as shown in ***Figure 6***. By combining all these factors, a vulnerability index is established. The rankings are based on a percentile ranging from zero to one, with higher values indicating greater vulnerability.

Figure 6. CDC's Social Vulnerability Index U.S. Census Variables

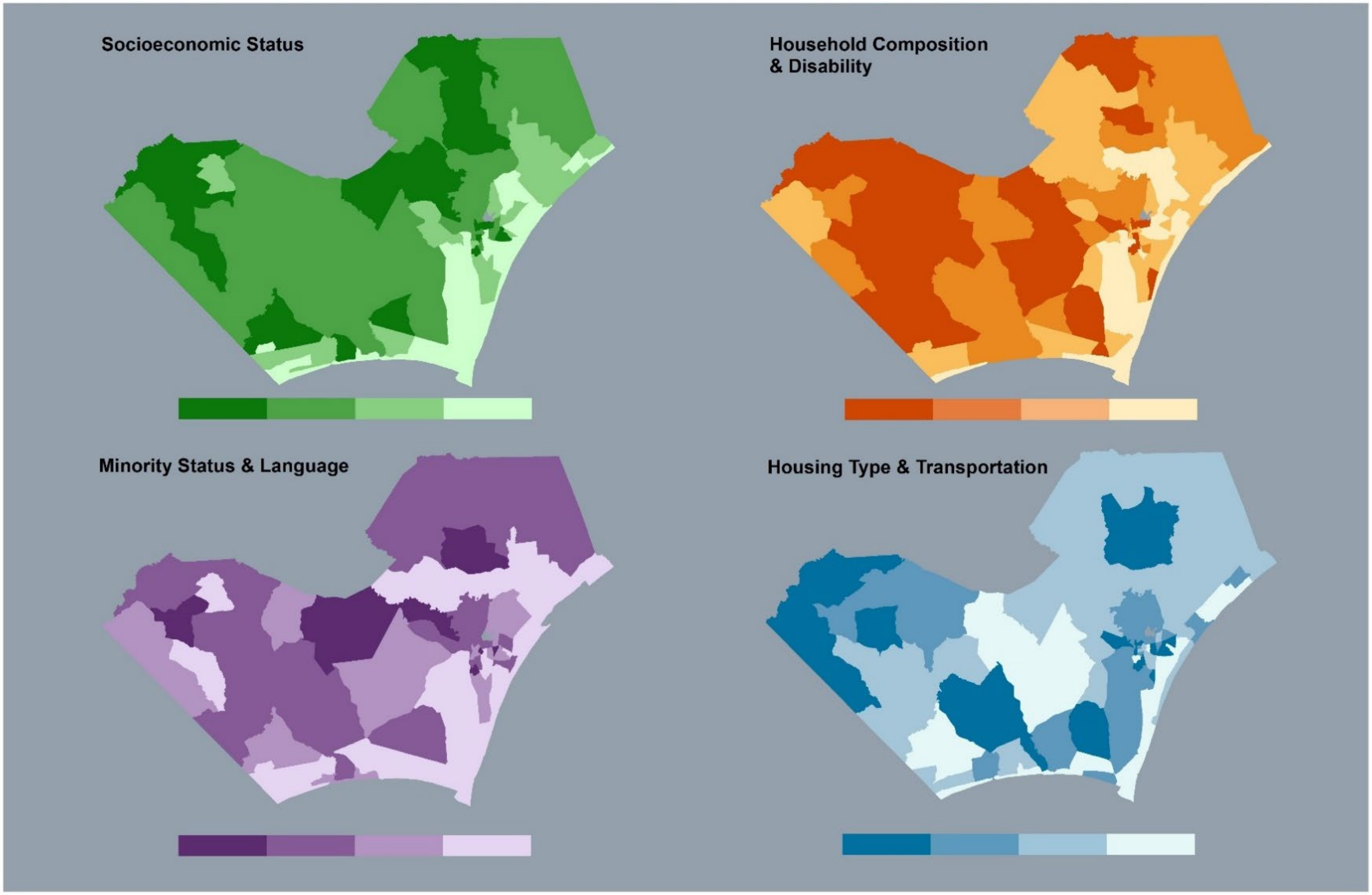


Source: Centers for Disease Control and Prevention 2022

Figure 7 depicts the each of the four themes that make up the CDC's SVI, which include socioeconomic status, household composition and disability, minority status and language, and housing types and transportation. Within the Cape Fear Region, there are widespread high social vulnerabilities with regard to socioeconomic status; almost the entirety of the region is within the moderate to high category for socioeconomic status. Areas with lower vulnerability for socioeconomic status are along the coastline and throughout New Hanover County. The same is true for household composition and disability; however, there are very high vulnerabilities in areas within Columbus and Brunswick Counties. Minority status and language is varied throughout the region, with greater vulnerability in Pender County, especially surrounding Burgaw and St. Helena. In Columbus County, increased vulnerability with regard to minority status and language is concentrated in Chadbourn, Riegelwood, and Delco. Vulnerabilities associated with the housing types and transportation theme are also varied throughout the region. Overall, areas along the coast have a lower vulnerability across all four CDC SVI themes, while Burgaw, in Pender County and areas in northern Columbus County had increased vulnerability across all four themes.

Figure 8 depicts geographical areas with an SVI of 0.75 or greater, which represents the areas with SVIs in the top 25%. Areas with a high SVI are located throughout the region. In Columbus County, areas with a high social vulnerability index are clustered in the northern area of the county around Boardman, Chadbourn, Tatums, Hallsboro, Lake Waccamaw, Sandyfield, Riegelwood, Delco, Brunswick, Sellerstown, and Tabor City. There are fewer areas in Brunswick County, and these areas are concentrated north and east of Shallotte in unincorporated portions of the county. Areas of Leland and Navassa also have a high SVI. New Hanover County's high SVI areas are located within the westside of Wilmington, and Pender County's areas are centered around Burgaw and St. Helena.

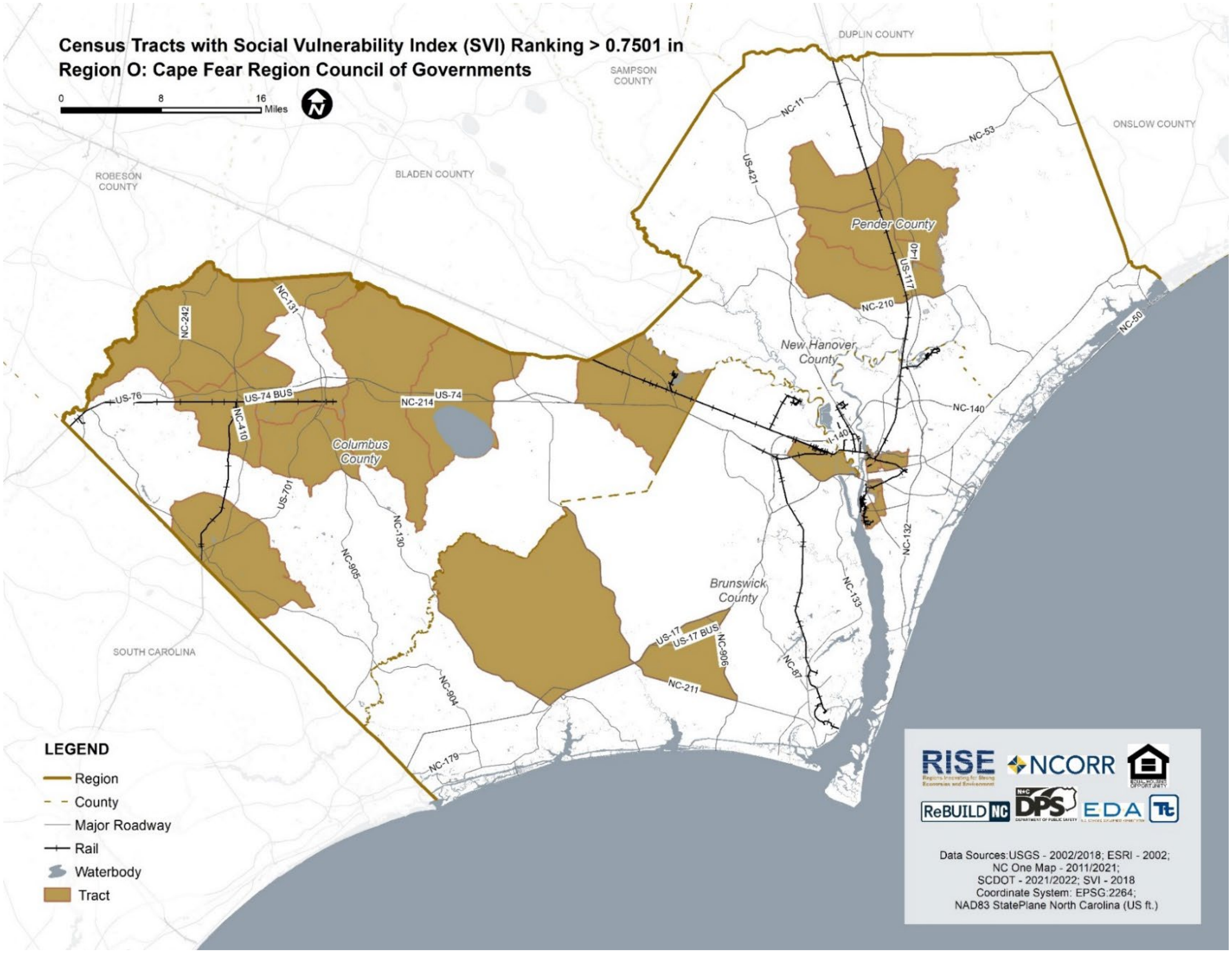
Figure 7. CDC Social Vulnerability Index Themes by Census Tracts



Highest 1 0.75 0.50 0.25 0 Lowest
VULNERABILITY

Data Sources:USGS - 2002/2018; ESRI - 2002; NC One Map - 2011/2021; SCDOT - 2021/2022; SVI - 2018
Coordinate System: EPSG:2264; NAD83 StatePlane North Carolina (US ft.)

Figure 8. Census Tracts with Social Vulnerability Index (SVI) Ranking Greater than 0.75



C. Housing, Critical Infrastructure, and Economy

During emergencies and disasters, communities require certain structures, facilities, services, and functions to remain operational and carry out life safety activities. Equally important is the need for housing that can provide safe shelter during events. The Cape Fear Region has a variety of structures with varying occupancy types that fulfill different needs for the community. Residential structures account for the largest percentage of occupancy types, with Brunswick and New Hanover County having the largest share, which is in line with these two counties also being the most populous in the region. With residential structures representing 90% of the total structures in the region, personal resilience, education, and awareness will aid in preparing individuals for no notice and short notice events, such as flash flooding, severe storms, and tornados. Additionally, building codes should prioritize resilience for residential structures. Refer to ***Table 7*** for a full breakdown of structures by occupancy types in the region. For a community to be resilient, these resources and assets must be able to withstand current and future hazards. To explore the location of critical facilities within the Cape Fear Region, visit Cape Fear Region - Resilience Portfolio Web Map (arcgis.com)[3].

Table 7. Number of Buildings by General Occupancy

County	General Occupancy							
	Residential	Commercial	Agricultural	Education	Religion	Government	Industrial	Vacant
Brunswick County	89,496	3,685	269	260	373	327	889	35
Columbus County	40,462	2,557	731	232	458	170	368	3,964
New Hanover County	89,819	4,179	307	528	355	535	1,341	271
Pender County	38,200	2,287	2,044	164	212	163	294	2
Cape Fear Region (Total)	**257,977**	**12,708**	**3,351**	**1,184**	**1,398**	**1,195**	**2,892**	**4,272**

Sources: NC One Map 2021/2022

Housing

Access to safe and affordable housing is paramount to a community's long-term resilience. Housing that withstands the range of hazards impacting the region and protects individuals leads to shortened time periods for recovery and reduces the effort required to return to normal after a disaster.

Residential structures and wood/masonry buildings are more susceptible to wind damage than commercial and industrial structures. Residential structures built prior to the adoption of floodplain ordinances and other modern-day building codes are often more vulnerable because of their construction materials and techniques. Modern-day building codes and floodplain ordinances reduce vulnerabilities by requiring structures to be built above the height of the base flood elevation or employing construction methods to withstand wave action along the coastline. Of the 257,977 residential structures in the region, 12,073 or approximately 5% were built prior to the adoption of floodplain ordinances and are located within the floodplain.

[3] https://tt-mmi.maps.arcgis.com/apps/webappviewer/index.html?id=ffa36af9b65e4960a04e74144c7ac8f2

Mobile and manufactured housing is another construction method that has a higher vulnerability as compared to traditional construction. Mitigation efforts can be made to increase the level of protection these homes provide, such as building codes requiring mobile homes are able to withstand certain windspeeds and anchoring the mobile homes. Within the Cape Fear Region, there are 48,922 mobile home buildings and 146 mobile home parks. In Pender County clusters of mobile homes are located around Burgaw and along the coastline, mobile homes are dispersed throughout Columbus County, and in New Hanover County mobile homes are generally located along the coastline. However, the highest number of mobile homes and mobile home parks is in Brunswick County (refer to ***Table 8***) with the concentrations being located in the unincorporated areas of Winnabow and along the coastline. Of the 48,922 total mobile homes in the region, 7,217 or approximately 15 percent are located within the floodplain as show in ***Figure 9***.

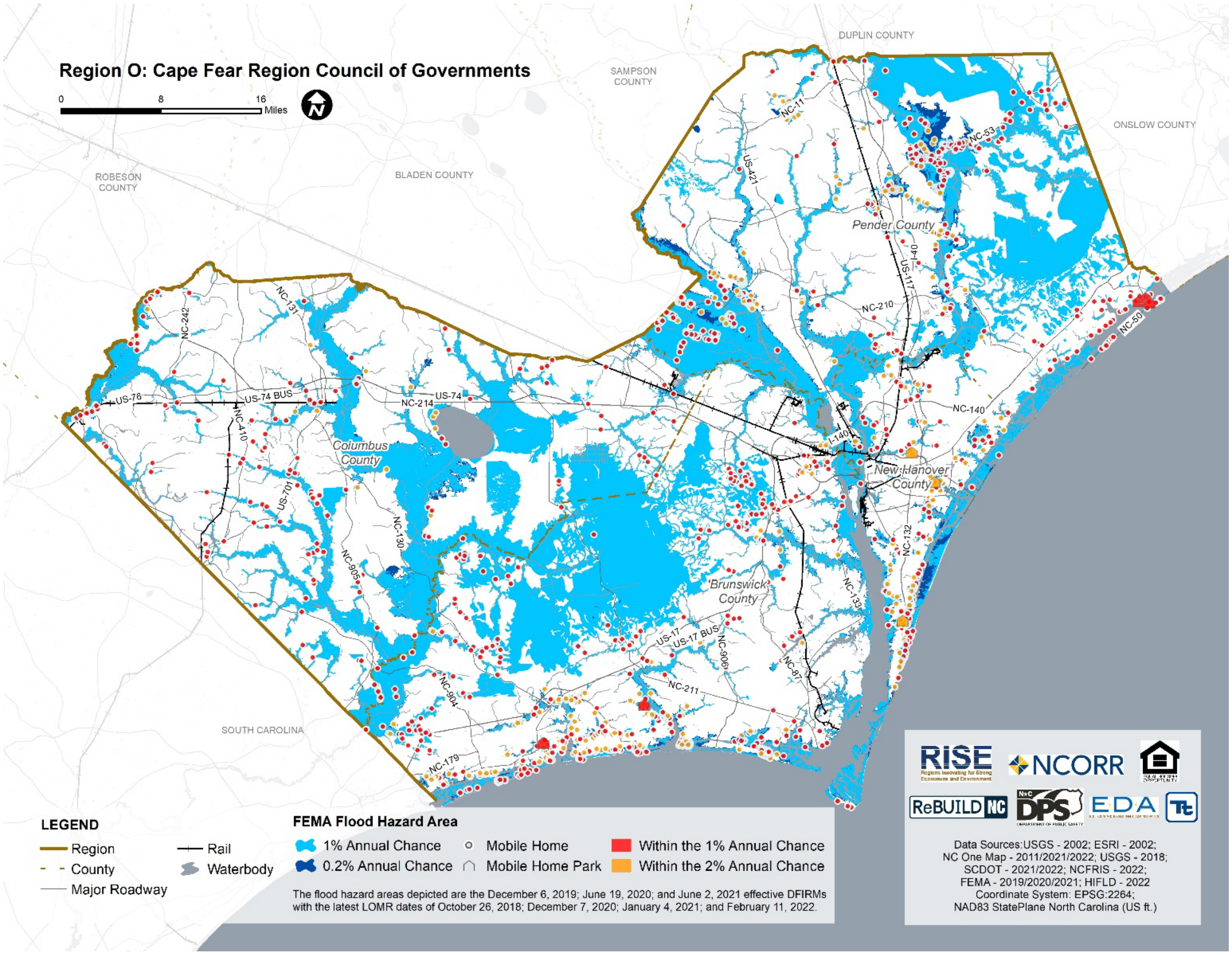
High housing costs create additional vulnerabilities, especially for economically disadvantaged populations faced with financial barriers. Often housing that is affordable to low- and moderate-income households is located in hazardous areas, such as the floodplain. Although mobile and manufactured homes present an affordable option for housing, this type of housing is more vulnerable to damage from high winds and is often more difficult to rebuild after a flood and may require replacement. Without enough affordable housing, low-income residents displaced by storm damage may not be able to secure housing. These residents may have to locate further away from employers (resulting in the added burden of commuting), face long-term displacement, relocate out of the area completely, or face homelessness.

Table 8. Total Number of Mobile Homes and Mobile Home Parks

Counties	Total Number of Mobile Home Parks	Total Number of Mobile Home Buildings	Number of Mobile Home Parks and Mobile Home Buildings Located in the 1-Percent Annual Chance Flood Hazard Area		Number of Mobile Home Parks and Mobile Home Buildings Located in the 0.2-Percent Annual Chance Flood Hazard Area	
			Number of Mobile Home Parks	Number of Mobile Home Buildings	Number of Mobile Home Parks	Number of Mobile Home Buildings
Brunswick	59	21,634	2	1,231	3	2,064
Columbus	9	11,034	-	251	-	284
New Hanover	52	6,803	-	342	3	880
Pender	26	9,451	3	951	3	1,214
Cape Fear Region (Total)	**146**	**48,922**	**5**	**2,775**	9	4,442

Sources: NCFRIS 2022; FEMA 2019/2020/2021; NC One Map 2021/2022; HIFLD 2022

Figure 9. Mobile Homes Located within the Floodplain



Critical Infrastructure

Critical facilities and infrastructure enable the continuous operation of a community during an emergency or disaster. These facilities and infrastructure provide functions and services that are essential to human health, safety, and economic security. These resources must be resilient in order to withstand current and future hazards in order to ensure a community's resilience. Critical facilities and infrastructure include essential facilities (e.g., hospitals, police stations, emergency operations centers), transportation systems, utility systems (e.g. cellular towers, water treatment plants, electric substations), high potential loss facilities (e.g. nuclear power plants, dams, military installation), and hazardous material facilities.

The roadway network of the region allows for the transport of people and goods and access to essential facilities and services during emergencies and disasters. Impacts to the roadway network can make evacuation or detours due to damages and hazard impacts slow and increase emergency response times. The region's transportation system includes roadways, bridges, airways, waterways, and ferries. Several interstates and highways cross the region, including interstate I-40 and highways U.S. 421, U.S. 74, U.S. 76, U.S. 17, and U.S. 117. Refer to ***Figure 26*** in ***Appendix A*** for a map of the transportation network. The region has approximately 7,462 miles of roadways, which are vulnerable to various natural and human-caused hazards.

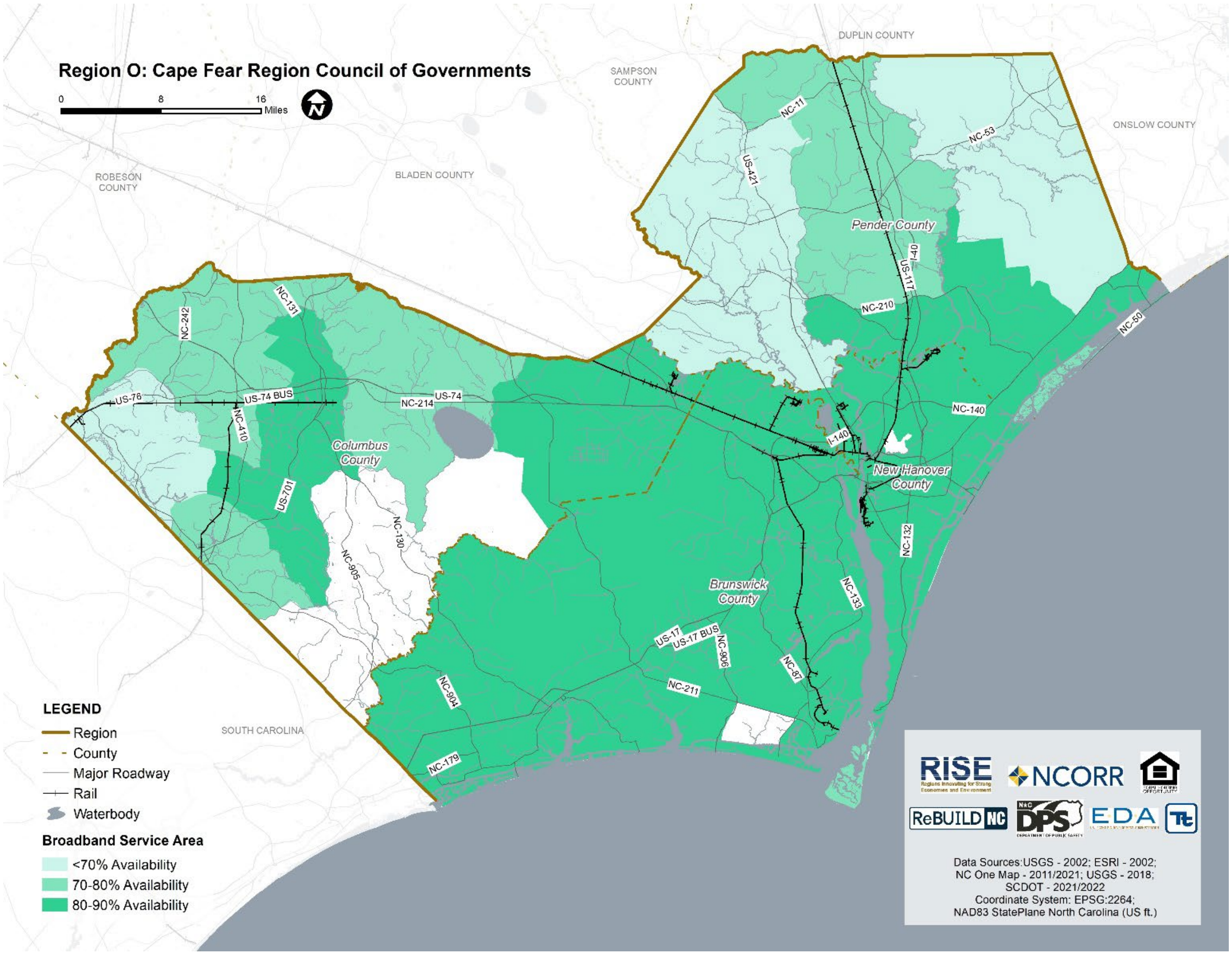
Throughout the public engagement process, several concerns were noted regarding the vulnerability of infrastructure, including roadways, bridges, stormwater management networks, and wastewater management in the region. Approximately 93 percent of local leaders strongly agreed or agreed that critical infrastructure in the region is at risk from natural or human-caused disasters. Concerns include the following:

- “I think our physical infrastructure, such as our roadways, are at severe risk. It is a balancing act because we don’t want to over-build, but at the same time, we can’t under-build, or we will experience washouts or our inability to access our region like we did during Hurricane Florence. I also think we need to build facilities with a higher wind speed to ensure there is a safe location in case of major hurricanes.”
- “High tide flooding and coastal storm surge has the ability to cut off access to goods/services as well as evacuation routes in times of storm impacts. Increased flooding frequencies impact inflow and infiltration into the wastewater system, increasing flow in less stressed systems. Traditional disposal of treated wastewater gets more and more difficult with higher water tables and more frequent rain events.”
- “The roads and bridges, including major routes such as I-40 and US HWY 421, were flooded or collapsed during Hurricane Florence.”

Throughout the vulnerability assessment, critical infrastructure will be assessed for each hazard to identify vulnerabilities.

Broadband (high-speed internet) is also considered critical infrastructure, and limited access contributes to the vulnerabilities within the region. As many warnings and other information is issued online during emergencies, communities with limited access face increased risks due to the inability to be able to receive this information. Within the region, Columbus and Pender Counties have the most limited access to broadband (high-speed internet). Combined with increased social vulnerability, these communities are at a higher risk than others in the region based on non-climate stressors. Refer to ***Figure 10*** to view broadband service areas throughout the region.

Figure 10. Broadband Service Area



Economy

After a natural hazard, economic resiliency drives recovery. It is essential to understand the major employers and economic sectors in the region whose losses or inoperability would impact the community and its ability to receive from a disaster. The major industries in the region are educational services, health care, and social assistance.

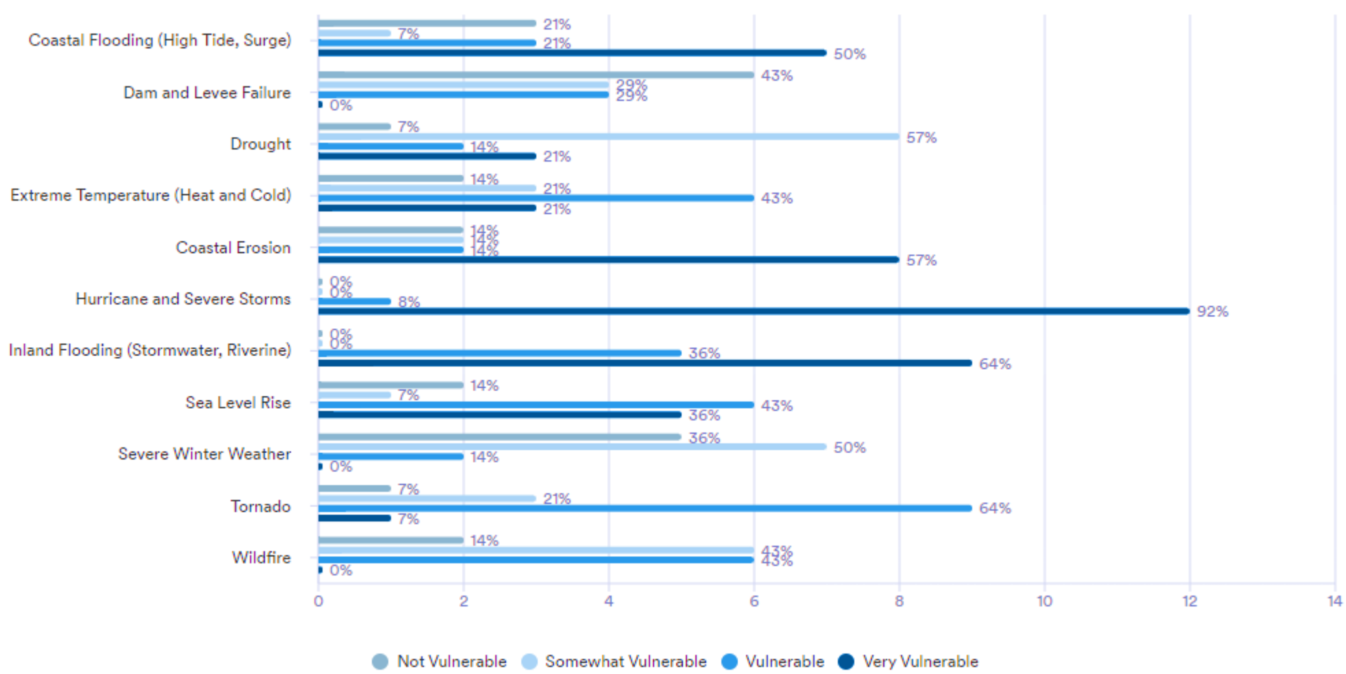
Tourism is another major driver of the region's economy. In 2020, Brunswick and New Hanover Counties both ranked within the top 10 counties statewide with the greatest visitor spending. Brunswick County ranked seventh with $731 million, and New Hanover County ranked eighth with $598 million (Visit North Carolina 2021). Impacts to beaches, coastal attractions, and recreation would impact the tourism economy locally, regionally, and statewide.

V. REGION'S STRENGTHS AND CHALLENGES RELATED TO RESILIENCE

A. Regional Climate Hazard Overview

The Cape Fear Region has previously been impacted by a variety of hazards and will face increasing climatic hazards over the next several decades. Local leaders were asked what hazards the region was most vulnerable to in order to identify the hazards for inclusion in the vulnerability assessment. Hazards include those that present immediate and long-term concerns and include episodic events (such as hurricanes) and more gradual increases (such as sea-level rise). Local leaders identified hurricanes and severe storms, inland flooding, coastal erosion, and coastal flooding as the hazards the region has the greatest vulnerabilities to as shown in ***Figure 11***.

Figure 11. Local Leader Hazard Vulnerability Survey Results



This vulnerability assessment includes an analysis of the following hazards:

- Flood
- Hurricanes and Severe Storms
- Coastal Erosion
- Sea-level Rise
- Extreme Temperatures
- Drought
- Tornado
- Wildfire

Each hazard impacts the region in specific ways, and climate change will make many hazard impacts worse for the region. See the hazard-specific sections later in this vulnerability assessment for additional details and 30-year climate projections.

B. Significant Non-Climate Stressors

Non-climate stressors are a change or trend, unrelated to climate, that can exacerbate hazards (United States Global Change Research Program n.d.). In North Carolina, the greatest non-climate stressors are population growth, aging infrastructure, socioeconomic disparity, physical attacks, cyber security, rural-urban divide, and public health threats (K. D. Kunkel 2020). Local leaders and members of the public were asked: What non-climate stressors are likely to impact your community over the next 30 years? Responses included the following:

- Increases in population
- Increases in impervious surfaces
- Changes in land use
- Loss of green space and habitats
- Aging population
- Stormwater management
- Lack of access to broadband/internet
- Loss of natural functions of floodplains
- Maintenance of public infrastructure

C. Regional Strengths and Advantages in Relation to Climate Resilience

Due to the current and projected impacts from climate change, the state and the region have efforts underway to strengthen the region's ability to respond and adapt to climate change. The following actions and initiatives contribute to increasing the region's adaptive capacity, which is the region's ability to adjust to climate change and recover from impacts.

- The 2020 North Carolina Science Report developed by the North Carolina Department of Environmental Quality provides a statewide definition of resilience, provides the likelihood of various climate change impacts to the state, identifies future actions for the state to take, and evaluates the impact of climate change on vulnerable populations. This plan equips local leaders with the information necessary to make data-informed decisions when faced with addressing the impacts of climate change.
- Each county within the region has a FEMA-approved, locally adopted hazard mitigation plan, which provides a full profile of hazards impacting the county and provides a risk assessment to determine the risk each hazard poses to the county. Each plan has a list of actions identified to reduce or eliminate the county's risk to natural hazards. The plans provide a self-assessment of each county's capability to manage and mitigate natural disasters ranging from administrative ordinances and codes, staffing capacity and capability, funding, and other programs and policies. Mitigation plans are intended to be actionable plans, which identify actions that can be implemented within the following five years of plan adoption to take quick action to reduce vulnerability in the respective county or region.
  - 2020 Bladen, Columbus, and Robeson Counties Regional Hazard Mitigation Plan
  - 2021 Southeastern North Carolina Regional Hazard Mitigation Plan (Brunswick, New Hanover, Onslow, and Pender Counties)
- The Coastal Area Management Act (CAMA) requires North Carolina's coastal counties to develop local land use plans to provide a roadmap for managing growth in coastal areas. These plans address the protection of natural resources, compatible economic development, and natural hazard risk reduction. The plans are a tool to ensure compatible uses in coastal areas.
- Housing Tax Credit (LIHTC) Program administered by the NC Housing Finance Agency (HFA) provides incentives for developers to provide low-income housing in new developments. Increasing

the availability of affordable housing in the region aids in providing safe shelter for the region, and particularly vulnerable populations.

D. Known Investments or Planning Efforts Underway

Local leaders noted the following efforts that are either completed or underway, which will strengthen the region's resilience:

- The Hurricane Matthew Redevelopment Plans (2017) prioritize projects in the region to mitigate the impacts from Hurricane Matthew. The projects identified for the region prioritize infrastructure, stream restoration, low impact development, debris management, road closure tracking and rerouting, and retrofits to roads and bridges.
- The North Carolina Department of Transportation Multimodal Vulnerability Assessment on Strategic Transportation Corridors (2022) to include the portion of U.S. 74 from I-485 in Charlotte to the Port of Wilmington. The study includes adding a 10-mile buffer around the specific portion of the roadway to identify potential vulnerabilities.
- The Resilient Coastal Communities Program aims to utilize a community-driven process for setting coastal resilience goals, assessing existing capacity and gaps, and identifying resilience projects. Communities in the region participating in the program include Sunset Beach, Leland, Navassa, Topsail Beach, and Surf City.
- The "Planning an Affordable, Resilient, and Sustainable Grid in North Carolina" (2020) project is a joint effort by the NC Department of Environmental Equality, UNC Charlotte's Energy Production Infrastructure Center, and the NC Clean Energy Technology Center. The project examines storm-related impacts and the costs and benefits of investments in electric grid resiliency.
- The City of Whiteville has partnered with the NC State University's Coastal Dynamics Design Lab to undertake a project titled "Floodprint" (2022). The project will establish flood mitigation projects in the community and identity implementation pathways, including funding.
- The North Carolina Resilient Redevelopment Planning (NCRRP) program provides a roadmap for community rebuilding and revitalization assistance for the communities damaged by Hurricane Matthew. The program empowers communities to prepare locally driven recovery plans to identify redevelopment strategies, innovative reconstruction projects, and other needed actions to allow each community not only to survive but also to thrive in an era when natural hazards are increasing in severity and frequency.
- The Back@Home program provides cost-effective, rapid rehousing for disaster survivors.
- The NC Policy Collaboratory conducted a Flood Resilience Study for Eastern North Carolina. The study includes five focal areas listed below with examples of initiatives completed throughout the study:
  - Floodplain buyouts – completed an analysis of where buyout recipients have relocated.
  - Infrastructure (water treatment and electric grid) – modeled the entire NC power grid to determine flooding impacts.
  - Financial risk – developed predictive modeling to estimate community vulnerability and expected annual uninsured loss.
  - Natural systems (wetlands and stormwater) – determined green infrastructure is most beneficial along tributaries and gray infrastructure should be prioritized along mainstem rivers.
  - Public Health – determined increased levels of pathogens and antimicrobial resistance in surface waters and last for days or weeks.

E. Recovery Processes and Challenges

The Cape Fear Region has been impacted by a variety of hazards in the past. The most recent catastrophic events resulted from Hurricanes Matthew and Florence. These events caused widespread damage, including power loss, road closures, destroyed homes, and more. These events prompted the development of post-disaster recovery and redevelopment plans. These plans discuss impacts to housing, economic development, infrastructure, agriculture, and the local environments and identify strategies for resilient redevelopment.

Challenges identified in these planning processes included:

- Age of regional infrastructure, particularly roads and stormwater systems
- Cost to repair septic and well systems
- Lack of broadband connectivity
- Local codes and policies which encourage redevelopment in hazard-prone areas
- Poor condition of regional infrastructure, particularly roads and stormwater systems
- Slow recovery process following a hazard event

In the Hurricane Matthew Redevelopment Plans the Southeastern and Sandhills Regions, the counties in the Cape Fear Region prioritized infrastructure projects for recovery efforts. These projects included a range of project types, including:

- Stream restoration
- Low impact development
- Flood sensors
- Debris management
- Retrofitting vulnerable roads and bridges
- Road closure tracking
- Real-time traffic rerouting

However, local leaders and community members expressed varying degrees of confidence in the recovery capabilities throughout the region when surveyed. Responses varied, with some respondents feeling strongly that the region possessed the appropriate skills to provide support during emergencies and disasters. Others felt strongly that additional collaboration and support was needed to adequately support communities and individuals throughout the various phases of a disaster.

Regarding the overall process to prepare for disasters, a stakeholder contributed the following thoughts:

- “[Recovery] preparation generally involves briefings from emergency officials and reminders to staff about their roles in emergency situations. It also means opening the channels of communication with our regional, state, and federal partners.”
- “Recovery involves close collaboration with our nonprofit and faith-based partners. This is a long-term process, and the strong partnerships that have been built in the community have thus far withstood the test of time.”

The State Disaster Recovery Task Force also compiled information to inform post-disaster recovery as it relates to housing and diversity, equity, and inclusion. The Housing Recovery Support Function identified the following housing-related challenges for post-disaster recovery and resilience (North Carolina State Disaster Recovery Task Force - Housing Recovery Support Function 2020):

- Shortage of affordable housing
- Shortage of housing services

- Low capacity in the public, nonprofit, and private sectors to address challenges
- Construction contractor shortages
- Heir property barriers to accessing recovery program

The Nonprofit and Volunteerism Recovery Support Function identified the following priorities to improve diversity, equity, and inclusion in post-disaster recovery and resilience activities:

- Improve communications with vulnerable populations through a clear “communication diagram” that demonstrates the flows of information between Emergency Management (state and local), nonprofit organizations, and individuals.
- Make information and resources available for residents and households in a diversity of accessible and culturally appropriate places.
- Build African American and Latino-led nonprofit capacity by sharing streamlined information about all the ways that North Carolina Emergency Management (NCEM) or other state agencies fund or pass funding to nonprofit organizations in disaster recovery.
- Broaden the community connections at NCEM and in the SERT.
- Develop a statewide Emergency Management Community Liaison Network.
- Contract with African American and Latino-led minority organizations that have strong community ties to improve equity and inclusion throughout the disaster cycle and/or compensate individuals or organizations for their expertise in this area.
- Improve diversity of emergency management personnel and elevate efforts to train employees in cultural competence and racial equity.

F. Key Gaps in Data and Understanding

To fully establish a baseline understanding of each communities’ capabilities to prepare, respond, and recover from disaster existing capabilities and gaps must be assessed. Having a complete understanding of these capabilities leads to an understanding of a community’s adaptive capabilities.

At the conclusion of the literature review conducted by Tetra Tech, it was established that many existing planning documents in the region do not focus on resilience and adaptation; the content is focused on current hazards and has limited considerations for climate change or emerging hazards. The focus appears to be primarily on addressing hazards in the near- and short-term. Climate impacts are generally limited to assessing the impacts on infrastructure from heat, ice, and winter storms. Several hazard mitigation plans are composed of actions that are emergency response and management centric. There is limited focus on hazard impacts on underserved populations, food systems, etc.

Plans that account for vulnerable populations utilize a limited scope to define vulnerable populations, which only includes the elderly and children. The plans do not capture many of the populations that would be negatively impacted by climate risks, such as migrant populations, populations with limited or no English proficiency, medically fragile populations, etc.

The literature review identified opportunities to supplement existing studies and plans to further identify resources and community structures that are in place to support disaster preparedness and community resilience. It is unclear if organizations outside of emergency management are aware of the established mutual aid agreements and how they can source resources to support their community post-disaster.

Additional data and information regarding areas targeted for growth would contribute to a comprehensive understanding of where the population may increase throughout the region. This will provide an opportunity to utilize planning and regulatory capabilities to reduce risk, to the greatest extent possible, as the population increases and more individuals are exposed to hazards.

VI. FLOOD

A. Hazard Description

In the Cape Fear Region, flooding is widespread and a serious risk. Floods are one of the most common and destructive natural hazards in the U.S. They can develop slowly over a period of days or quickly with disastrous effects that can be local (impacting a neighborhood or community) or regional (affecting entire river basins, coastlines, and multiple counties or states) (Federal Emergency Management Agency n.d.). There are a variety of types of floods that may impact region, including:

- Coastal flooding from high astronomical tides and storm surge events;
- Long-term increases in coastal flooding from sea level rise;
- Urban/stormwater flooding from rainfall overwhelming stormwater systems, often from high levels of impermeable surfaces;
- Riverine flooding from rivers, streams, and creeks overflowing their banks;
- Flash flooding from heavy rainfall leading to rapid runoff; and
- Ponding or standing water as a result of poor drainage, flat topography, or depressions in the land;

During the RISE Cape Fear Regional Portfolio Project, flooding was examined from three perspectives: coastal, inland, and urban. Each perspective presents varying causes of flooding and concerns regarding the impacts of flooding.

Members of the public noted an increase in "sunny day" flooding in the region. "Sunny day" flooding, also known as tidal flooding, nuisance flooding, and king tide flooding, is a result of temporary inundation during tidal events associated with astronomical events. The 2020 North Carolina Science Report defines this phenomenon as a water level of 1.6–2.1 feet above Mean High Water; sunny day flooding is projected to become a daily occurrence by 2100 because of sea level risk (K. D. Kunkel 2020).

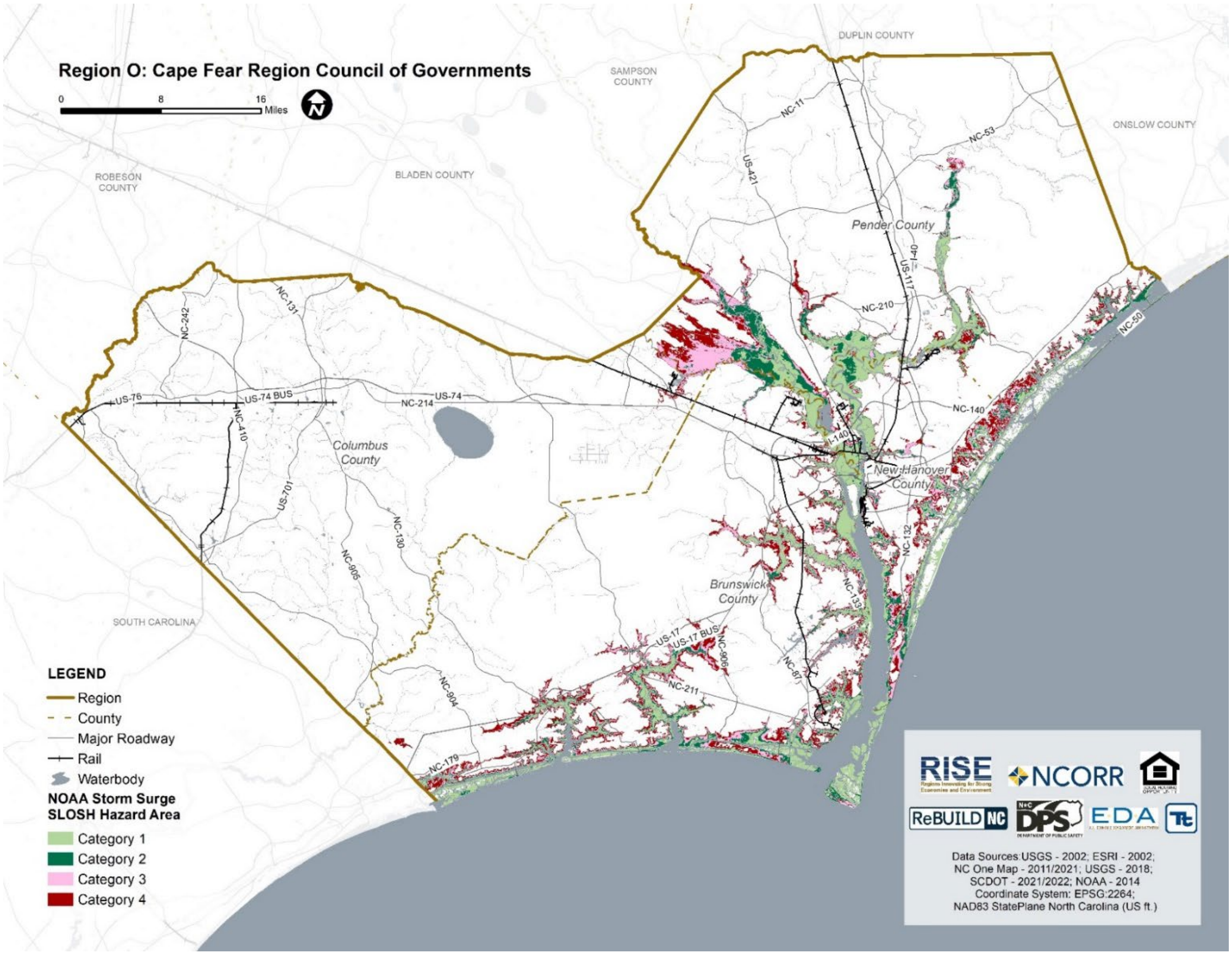
The typical low elevation of coastal areas increases the vulnerability to flooding. Flooding in coastal areas may be caused by storm events such as hurricanes. The storm surge resulting from hurricanes and storms causes additional flooding in combination with precipitation produced during storm events. Storm surge results is the abnormal rising of the water surface level due to changes in air pressure from a storm. Storm surge results in higher water levels, larger waves, and an increased likelihood of dune over wash, wave damage, and possible breaching of barrier islands. Storm surge modeling, known as Sea, Lake, and Overland Surges (SLOSH) from hurricanes, computes the maximum potential storm surges based on storm movement in different directions and strengthens in combination with topography, bathymetry, and tidal cycle. ***Figure 12*** illustrates the SLOSH map for the Cape Fear Region. In addition to coastal areas, inland areas near streams and rivers, such as Riegelwood and Northwest are vulnerable to storm surge.

Inland and urban flooding may be attributed to a location's proximity to a stream or river that is overflowing or the failure of stormwater infrastructure to handle the amount of precipitation from a storm event. Local leaders expressed concerns about the region's aging infrastructure, lack of maintenance, and general ability to handle to increased intensity of storms due to climate change. During Hurricanes Matthew and Florence, inland areas experienced extreme damages from inland and urban flooding.

Climate Change Impacts

The Cape Fear Region is projected to experience an increase in average annual temperatures and precipitation due to factors of a changing global climate. Annual precipitation amounts in the region will increase, primarily in the form of heavy rainfalls, which have the potential to increase the risk to flash flooding and riverine flooding, and flood critical transportation corridors and infrastructure. Increases in precipitation may alter and expand the floodplain boundaries and runoff patterns, resulting in the exposure of populations, buildings, and critical facilities and infrastructure that were previously outside the floodplain. This increase in exposure will result in an increased risk to life and health, an increase in structural losses, a diversion of additional resources to response and recovery efforts, and an increase in business closures affected by future flooding events due to loss of service or access.

Figure 12: Storm Surge in Cape Fear Region



B. Location and Extent

Flooding is often discussed in terms of floodplains. A floodplain is defined as the land adjoining the channel of a river, stream, ocean, lake, or other water body that becomes inundated with water during a flood or storm event. The Special Flood Hazard Area (SFHA) is an area designated by the Federal

Emergency Management Agency (FEMA) on Flood Insurance Rate Maps (FIRM). FEMA categorizes the SFHA in various zones. It is important to note that land does not need to be designated by FEMA to function as a floodplain.

The boundaries of the floodplain change due to a variety of factors. These changes may be brought on by changes in the surrounding land, such as open space being developed and creating more impervious surfaces. New roadways and structures can also restrict the flow of water and change the natural floodplain. As climate change impacts the amount and frequency of precipitation, stormwater runoff patterns will change and therefore result in changes in the floodplain. Additionally, as improvements in technology allow for better techniques to identify floodplains, the boundaries will change with these improvements.

The Cape Fear Region contains a large amount of land designated in the 1 percent annual chance flood area (A and V Zones). These areas are generally located along the coast, rivers, tributaries, and wetlands and have a high risk of flooding. There are small areas designed in the 0.2 percent annual chance flood area (B, C, and shaded and unshaded X Zones). These areas have a moderate to low risk of flooding. Refer to ***Figure 13*** to review the extent of the floodplain in the region.

Floodplain mapping is based on riverine and coastal flooding conditions. Future flooding conditions (from factors such as sea level rise and changes in rainfall) are not included in FEMA's development of floodplain mapping. As such, floodplain maps may underestimate flood risk in many areas in the region. As a result, the public may also underestimate risk. Limitations in building requirements (as many are tied to floodplain zone), flood insurance requirements (as requirements are tied to the FEMA designations), and available mitigation funding (as many federal flood mitigation funding sources are restricted to locations within the Special Flood Hazard Area [SFHA]) (Sessoms 2022).

As the sea level rises, the starting elevation of coastal flooding events will also rise. This means coastal floods are likely to reach a higher elevation and push farther inland. As a result, the floodplain will expand. ***Figure 14*** depicts the potential footprint of the 1 percent annual chance flood area with 1 foot of sea level rise, a threshold likely to be reached by 2050.

Figure 13. Floodplains in Cape Fear Region

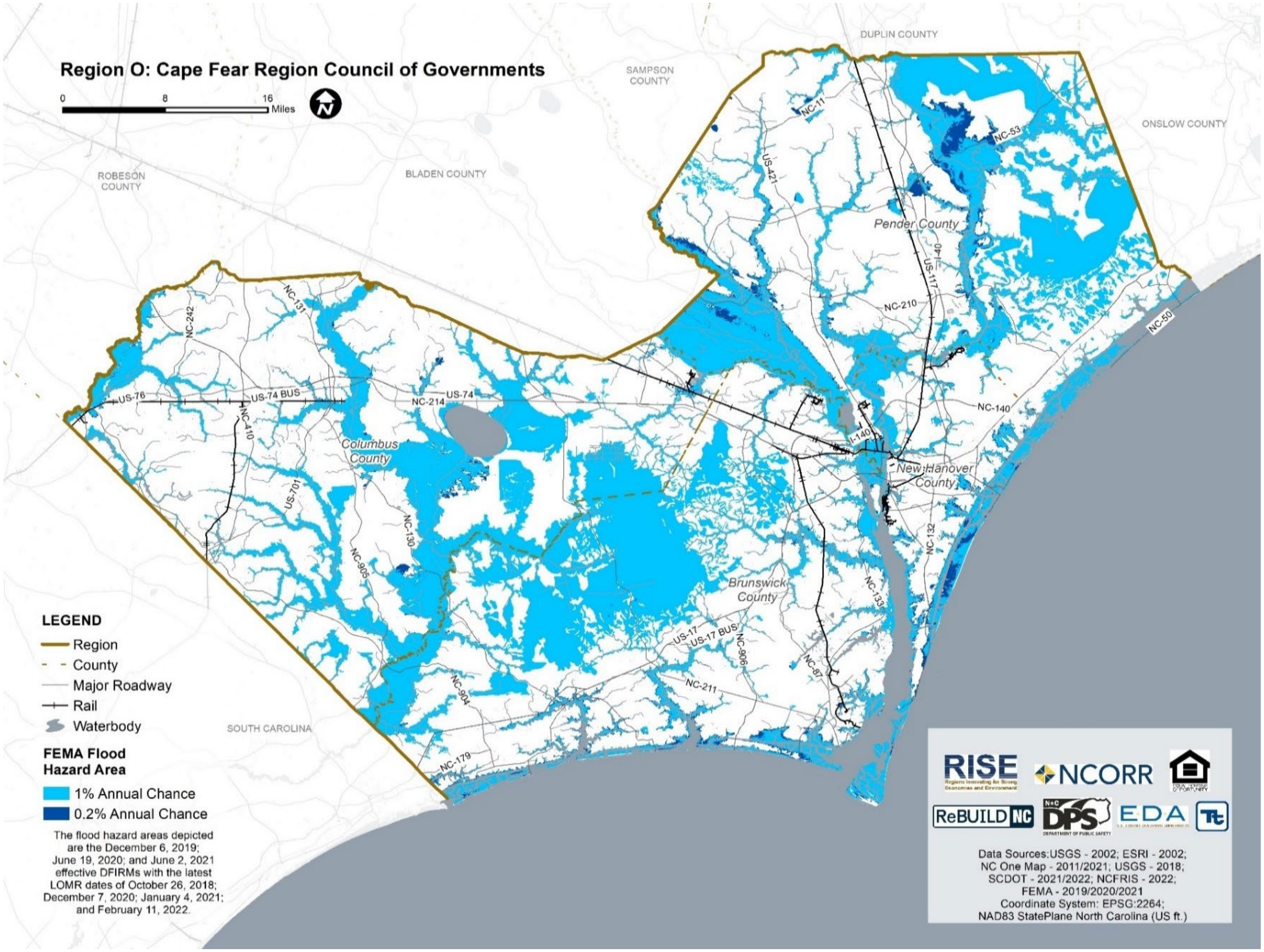
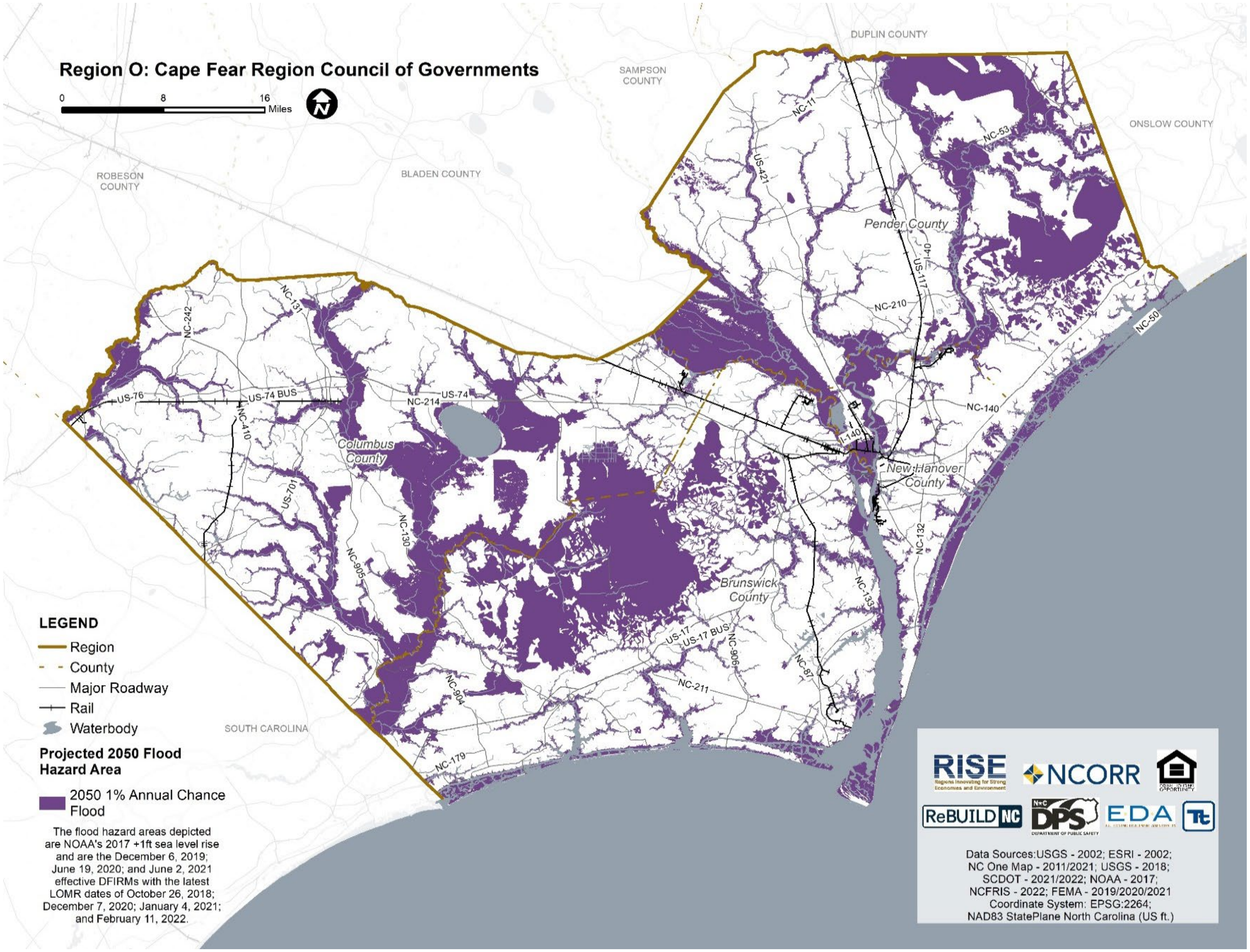


Figure 14. Projected 1 Percent Annual Chance Flood in 2050 (1 foot Sea Level Rise) in Cape Fear Region



C. Impact on Socially Vulnerable Populations and Equity

Based on the spatial analysis, the below population is vulnerable and exposed to, or living within, the flood hazard; for a detailed assessment of the regional population living in the floodplain, see ***Table 9*** and ***Table 10*** located in ***Appendix A***. However, flood risk should not be limited to only those who reside in a defined hazard area but to everyone who may be affected by the effects of a hazard event (e.g., people are at risk while traveling in flooded areas, as their access to emergency services is compromised during an event).

- Total Regional Population located within 1 percent annual chance floodplain: 154,720 (32.7 percent of total population). Of these 87,766 (18.6 percent of the total population) people are within vulnerable populations.
- Total Regional Population located within 0.2 percent annual chance floodplain: 167,439 (35.4 percent of total population). Of these 94,557 (20.0 percent of total population) people are within vulnerable populations.

Socially vulnerable populations may experience exacerbated impacts and prolonged recovery if or when impacted. This is due to many factors, including their physical and financial ability to react or respond during a hazard. Special consideration should be given to these vulnerable groups when planning for disaster preparation, response, and recovery.

D. Impact on Public Health and Safety

The impact of flooding on life, health, and safety is dependent on the severity of the event, the percentage of the population exposed to the hazard, and the provision of adequate warning time to residents. To estimate population exposed to the 1 percent and 0.2 percent annual chance flood, the FEMA Digital Flood Insurance Rate Map (DFIRM) flood boundaries were used.

In instances of flash flooding, very little time is available to warn and evacuate the community and thereby increases the risk to public safety. During public workshops, participants raised concerns about the ability of community members to access evacuation routes during emergencies and disasters as several major roadways are susceptible to flooding and therefore compromise evacuation routes. This may lead to individuals becoming injured as a direct result of floodwaters, isolated, or displaced from their homes, creating dangerous situations.

Flooding from hurricanes and storm surge provide additional time to warn and evacuate communities. However, challenges still exist due to the percentage of the population that must be evacuated, disseminating information in a timely and accessible manner, and the resources required to evacuate. Approximately 9.1 percent of the region’s population would be required to evacuate for storm surge associated with a Category 1 hurricane, and 22.9 percent of the population would be required to evacuate for storm surge associated with a Category 4 hurricane. For additional information on impacts associated with hurricanes, refer to ***Section V***.

Flooding directly contributes to public health concerns as floodwaters may carry hazardous materials and waterborne illnesses through a community. If floodwaters are slow to recede, vector-borne diseases may increase as mosquitoes and other insects breed near stagnant waters. Additionally, water entering homes produces mold, which poses a threat to the health and safety of residents.

E. Impact on Housing and Critical Infrastructure

It is important to determine the critical facilities and infrastructure that may be at risk of flooding and who may be impacted should damage occur. Critical services during and after a flood event may not be available if critical facilities are directly damaged or transportation routes to access these critical facilities are impacted. Roads that are blocked or damaged can isolate residents and can prevent access throughout the area to many service providers needing to reach vulnerable populations or to make repairs. There are 176 miles of roadway designated as evacuation routes in the Cape Fear Region that are within the floodplain; these routes are critical to providing a way for individuals to evacuate and leave hazard-prone areas. Ensuring that these evacuation routes are protected and resilient will be critical to ensuring community members have access to travel out of hazard-prone areas.

Throughout the public engagement process, concerns were noted regarding the impacts that frequent large storm events and smaller events (sunny day flooding) have on stormwater management networks and roadways. During large flooding events, infrastructure has experienced washouts and other major damage. Smaller, frequent events may lead to additional stress and degradation of these networks. In addition to the direct impacts flooding has on infrastructure, there is additional public concern regarding the ongoing maintenance of drainage ditches, water canals, and stormwater management networks to ensure they function as intended during flooding events. Failure to properly maintain infrastructure may lead to increased flooding or unintended flooding impacting additional communities.

In the Cape Fear Region, most critical facilities and lifelines are located along the coastline, within the floodplain, or concentrated in cities and towns. To see the location of these resources in the floodplain, refer to ***Appendix A***. In total, there are 551 (29.7 percent of total critical facilities) critical facilities, 256 miles of roadway, and 46 miles of rail located in the 1 percent and 0.2 percent annual chance floodplains. For a detailed assessment of critical facilities located in the floodplain, please see ***Table 12*** and ***Table 13*** a located in ***Appendix A***. Additionally, a detailed assessment of critical infrastructure located in the floodplain is available in ***Table 14*** and ***Table 15*** in ***Appendix A***.

In addition to critical facilities located in the floodplain, there are 76,897 (27.0 percent of total) other structures in the floodplain. These structures include residential, commercial, agricultural, educational, religious, governmental, industrial, and vacant buildings. The building quality of the structure and requirements of building codes and ordinances may either contribute to the vulnerability or provide mitigation against hazards.

The State of North Carolina regulates the floodplain to protect people and property, ensure federal flood insurance and disaster assistance are available, save tax dollars, and reduce future flood losses to NC communities (North Carolina Division of Emergency Management 2017). In addition, local governments adopt and enforce local floodplain regulations and ordinances. Structures built prior to modern building codes, particularly those built prior to adoption of floodplain regulations (commonly referred to as Pre-FIRM), are more vulnerable to impacts from flooding. Local leaders and members of the public raised concerns about the perceived leniency of building code restrictions and enforcement in the region. Refer to ***Table 16***, ***Table 17, Table 18,*** and ***Table 19*** in ***Appendix A*** for a detailed assessment of structures in the floodplain.

Mobile and manufactured homes are disproportionately more vulnerable than other types of housing. Within the Cape Fear Region, there are 7,217 mobile homes within the 1 percent and 0.2 percent annual chance flood areas. For a detailed assessment of the number of mobile homes and mobile home parks located in the 1 percent and 0.2 percent annual chance floodplains, refer to ***Table 18*** and ***Table 19*** in ***Appendix A***. These structures are mainly concentrated near Burgaw and Currie in Pender County, in the southern coastal tip of New Hanover County, and along the coastline in Brunswick County. Refer to ***Figure 27, Figure 28*** and ***Figure 29*** in ***Appendix A*** to review the location of mobile homes relative to the floodplain, storm surge, and the floodplain with 1 foot of sea level rise, respectively.

F. Impact on Economy

Flood events can significantly impact the local and regional economies. This includes but is not limited to general building stock damages and associated tax loss, impacts to utilities and infrastructure, business interruption, impacts on tourism, and impacts on the tax base. In areas that are directly flooded, renovations of commercial and industrial buildings may be necessary, disrupting associated services. Other economic components such as loss of facility use, functional downtime, and socioeconomic factors are less measurable with a high degree of certainty.

Flooding can cause extensive damage to public utilities and disruptions to the delivery of services. Loss of power and communications may occur and drinking water and wastewater treatment facilities may be temporarily out of operation. Debris management may also be a large expense after a flood event.

Economic assets that are dependent upon their proximity to waterways, such as ports and marinas, have a higher likelihood of flooding; however, due to the function of these assets they are also more likely to be adaptive to climate change.

G. Impact on Natural and Cultural Resources

Natural and Cultural resources may be resources that are nationally or locally recognized on a historical registry or resources that are self-identified by the community. The Cape Fear Regional Stakeholder Partnership stated the beaches within the region are cultural resources that are valuable to residents. Flood would directly impact beaches and potentially become detrimental and completely degraded beaches.

Flooding has direct impacts on habitats and natural resources throughout the region. Flooding may destroy natural habitats completely or cause disruptions to species living in these habitats. The region’s proximity to the Atlantic Ocean also brings the possibility of saltwater intruding natural landscapes during flood events. Saltwater can be detrimental to ecosystems that are not adapted for it, leading to ghost forests, as discussed in ***Section VI***. In addition to impacts on habitats, flooding may cause downed trees that leave behind debris; debris carried by high winds can lead to injury or loss of life.

Flooding may be exacerbated by sea level rise, which can result in the loss of low-lying coastal ecosystems like wetlands and the conversion of uplands to wetlands. In addition, sea level rise can result in saltwater intrusion, which can damage or kill salt intolerant plant life. For more information on sea level rise, refer to ***Section VI***.

H. Cascading Impacts from Other Hazards and Non-Climate Stressors

Flood events can exacerbate the impacts of disease outbreaks and soil movements, such as landslides, sinkholes, and subsidence. After a flooding event, runoff can pick up and transport pollutants from wildlife, soils, and hazardous materials. Such organisms and hazardous materials can then appear in drinking water and cause harm residents (Centers for Disease Control and Prevention 2021). Flooding can also put additional strain on dams, which may lead to dam failure and cause catastrophic no notice flooding.

According to National Oceanic and Atmospheric Administration (NOAA), sea level rise can amplify factors that currently contribute to coastal flooding, such as high tides, storm surge, high waves, and high runoff from rivers and creeks. All these factors change during extreme weather and climate events (NOAA 2012). The potential increase in flooding due to increased precipitation from climate change will lead to agricultural and economic losses (K. D. Kunkel 2020); this will be heightened in the Cape Fear Region due to the projected population increase and subsequent development needs to accommodate the population increase.

I. Future Changes that May Impact Regional Vulnerability to Hazard

An increase in development, particularly in low-lying and coastal areas, will worsen flooding. Paved surfaces, such as roads and parking lots, contribute significantly to urban and stormwater flooding. When this urban flooding occurs in areas where the water table is high, water has nowhere to go but up, creating localized flooding across the region. To address stormwater management related to new development while also mitigating the impacts of flooding and sea level rise, communities can consider nature-based and environmentally sound solutions such as rain gardens, bioswales, and permeable paving.

As the population increases, so may the number of people exposed to flood risk. To limit the number of residents impacted by flooding in the future, communities can consider planning and zoning solutions such as expanded regulatory floodplains, increased freeboard requirements, buyouts of vulnerable residential areas, and identification of growth areas outside of hazard-prone areas, and establishment of stormwater utilities.

VII. HURRICANES AND SEVERE STORMS

A. Hazard Description

Severe storms are a common occurrence in the Cape Fear Region. A variety of severe storm types, such as thunderstorms, lightning, hail, high winds, and hurricanes/tropical storms, have damaged property and infrastructure, downed trees and power lines, and caused injuries and fatalities. The region has sustained the greatest impacts from tropical storms and hurricanes. Tropical storms produce strong winds of 39 to 73 mph and are accompanied by heavy rain. Hurricanes winds exceed 74 mph and can cause significant storm surge, inland flooding, tornadoes, and rip currents. The hurricane season in the United States is June through November, but hurricanes are most likely to impact the Cape Fear Region from late July to early October. As climate change extends the period with ideal conditions for tropical storms and hurricanes, the region could see hurricane season lengthened.

Climate Change Impacts

The 2020 North Carolina Climate Risk Assessment and Resilience Plan states the following regarding the impacts of climate change on storm events, "Intensity of the strongest hurricanes is likely to increase with warming of the oceans and atmosphere, leading to greater damage to people, communities, our economy and natural resources from more intense hurricanes and accompanying flooding and precipitation." (K. D. Kunkel 2020). The National Hurricane Center is currently considering expanding the official hurricane season to begin in May, rather than June, as a result of the frequency of pre-season events (Cappucci 2021). A longer hurricane season compounded by an increase in event frequency will result in a decrease in the length of time for recovery between storm events; this will cause greater stress on people, resources, and services.

In low-lying coastal areas, the impacts from hurricanes will increase as seal level rise increases the base flood elevation resulting in the storm surge increasing. An increase in the frequency and intensity of storm events will exacerbate existing flooding issues as precipitation amounts increase and become more frequent.

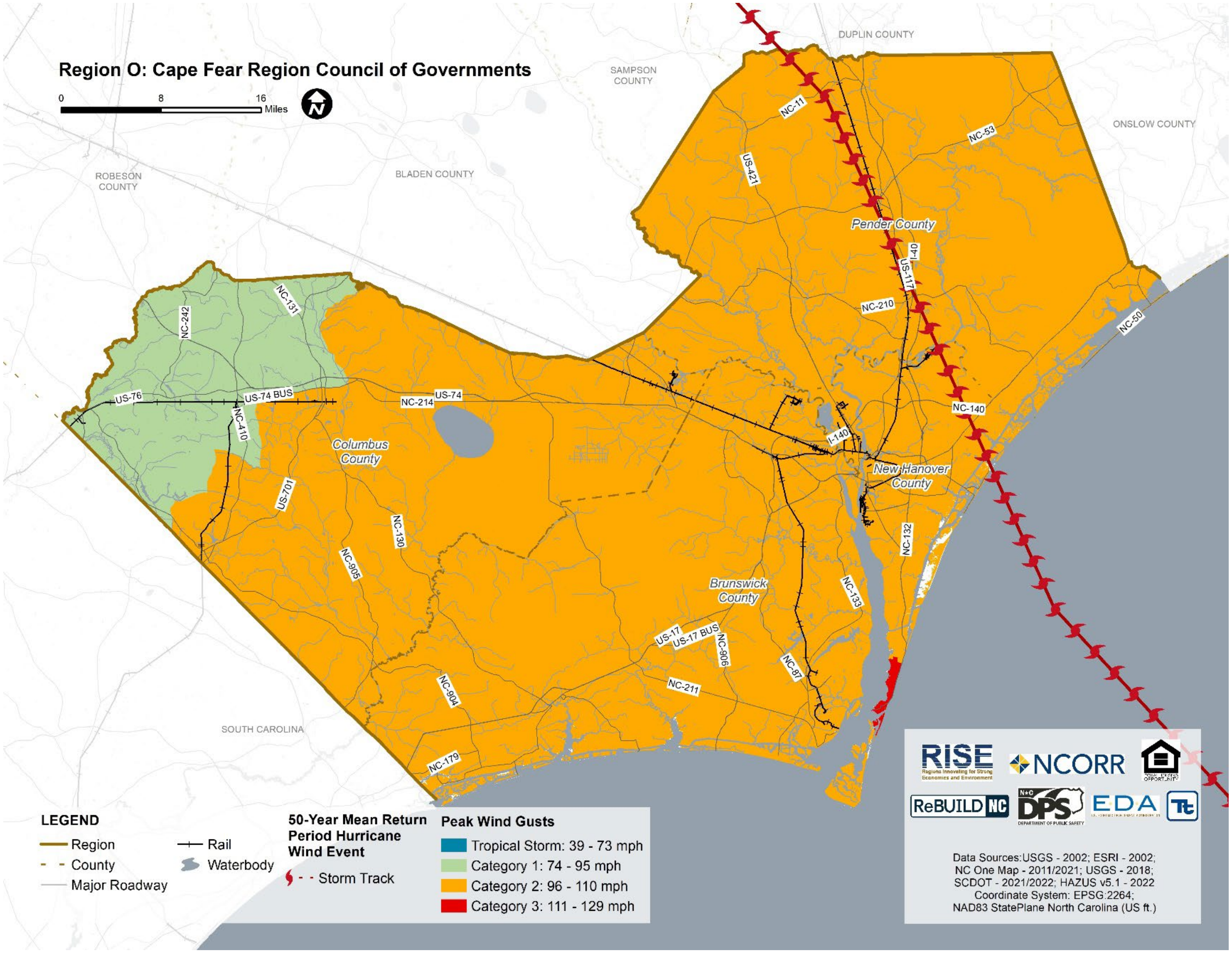
B. Location and Extent

All of the Cape Fear Region is exposed hurricanes, tropical storms, and severe storms. Severe storms may take place in any location and at any time when conditions are favorable. Thunderstorms are common occurrences during North Carolina's summer afternoons and evenings. During the warmer months of the year, weather is driven by more local-scale convective processes as the jet stream retreats north. The pop-up showers experienced during this time of year are generally small (one to a few miles across) and produce very intense, very local rainfall. During the spring and summer, thunderstorms are often associated with the passage of warm and cold fronts as storms developing along the frontal line and can impact all parts of the state. Thunderstorms in North Carolina bring strong winds and intense rain that can lead to localized flash flooding. Sometimes these storms also produce hail and tornadoes or damaging straight-line winds (North Carolina State University n.d.).

The Cape Fear Region is exposed to very high wind risk. In terms of hurricanes and tropical storms, the Cape Fear Region is in FEMA's Wind Zone III. In this zone, wind speeds can reach up to 200 mph (NIST 2011). Additionally, the region is located within a "Hurricane Susceptible Region", meaning the region is susceptible to hurricanes and other tropical cyclone events. The region often receives remnants of storms that have made landfalls in other parts of the country.

Figure 15 provides wind speeds for the 50-year return period hurricane wind event. The storm track represents the average tack of a 50-year level event. Most of the region is projected to experience Category 2 wind speeds of 96–110 mph, while the western area of Columbus County is projected to experience Category 1 wind speeds of 74–95 mph. It should be noted that the two most recent hurricanes to impact the region, Florence and Matthew, were both Category 1 hurricanes that resulted in catastrophic damages.

Figure 15. Wind Speeds for the 50-Year Mean Return Period Hurricane Wind Event



C. Impact on Socially Vulnerable Populations and Equity

Vulnerable populations may experience exacerbated impacts and prolonged recovery if or when impacted by a hurricane or severe storm. This is due to many factors, including their physical and financial ability to react or respond and their location and construction quality of their housing. The elderly are considered vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention, which may not be available due to isolation during a storm. Emergency personnel, such as police, fire, and EMS, may not be able to effectively respond and maintain the safety of its residents. Residents who have limited English proficiency may be difficult to reach with typical emergency messaging. Residents who lack transportation may have difficulty evacuating ahead of severe storms. Vulnerable populations may be more vulnerable if power loss results in heating and cooling service interruption, stagnated hospital operations, and potable water supply shortages. Special consideration should be given to these vulnerable groups when planning for disaster preparation, response, and recovery.

D. Impact on Public Health and Safety

The impact of a hurricanes, tropical storms, and severe storm events is dependent upon several factors, including the severity of the event and whether adequate warning time was provided to the community. All individuals of the Cape Fear Region are at risk to the impacts caused by hurricanes, tropical storms, and severe storms; coastal communities have a higher risk to impacts due to the potential for these events to be compounded by flooding and storm surge. Additionally, people located outdoors (i.e., recreational activities and farming) are considered vulnerable to hailstorms, thunderstorms, lightning, and tornadoes. This is due to little to no warning and the potential for shelters to not be available. Seeking out a lower-risk location will decrease a person's vulnerability.

During these events, individuals may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations have a disproportionately higher vulnerability due to the limited warning time for certain thunderstorms, hailstorms, and lightning events. Although tropical storms and hurricanes provide additional time for warning and evacuation, socially vulnerable populations may require additional time or support to prepare or evacuate.

E. Impact on Housing and Critical Infrastructure

Hurricanes, tropical storms, and serve storms pose a significant threat to structures and lifelines as a result of the many forms these events may take and the additional hazards that may accompany the storm event, such as lighting and high wind. Some structures have a higher risk due the structure's building materials and construction not being able to withstand high speed winds or the potential for the building construction material, such as wood, to catch on fire if struck by lightning. Structures with the greatest vulnerability include mobile and manufactured homes and structures built prior to modern building codes. Refer to ***Figure 29*** in ***Appendix A*** to review the location of structures built prior to modern building codes in relation to the 50-year mean storm track for hurricanes.

High wind events can result in falling tree limbs and flying debris which can damage critical infrastructure, mainly power lines, resulting in loss of power. Power loss can greatly impact households, business operations, public utilities, and emergency personnel. Power loss has a direct impact on those who depend on powered life safety systems and critical equipment; power loss in this instance could be fatal.

F. Impact on Economy

Severe storm events can have short- and long-lasting impacts on the economy. The disruption of services and business can last a few hours or several days during catastrophic events. This results in a loss of economic activity, which can have compounding impacts throughout the region. Damage from serve storms can disrupt tourism, the transportation of goods, or have direct physical impacts to economic assets, such as the facilities of major employers. The local community will also incur unanticipated costs for debris management for the removal of vegetation and construction materials from storm damages.

During storm events which have catastrophic impacts, the impact to the economy can be long-lasting as individuals may be forced to relocate out of the region due to damage to their homes or places of employment. Permanent relocation of residents reduces the tax base and economy overall.

G. Impact on Natural and Cultural Resources

Hurricanes and storm surges can be destructive to structures, including those of historical and cultural significance. The Cape Fear Region has 145 historical and cultural resource facilities located in the SLOSH Storm Surge Hazard Areas, with 23 located in the Category 1 area. Past Category 1 hurricanes, such as Hurricanes Matthew and Florence, have resulted in catastrophic damages.

Any severe weather that creates longer periods of rainfall and high winds can erode natural banks along waterways and degrade soil stability for terrestrial species. Hurricane winds can tear apart habitats causing fragmentation across ecosystems. Overall, as the physical environment becomes more altered, species will begin to contract or migrate in response, which may cause additional stressors to the ecosystems within the Cape Fear Region. The associated flooding and erosion from hurricanes, tropical storms, and severe storms can have a variety of negative impacts on the environment. Refer to ***Section VI*** and ***Section IV*** for additional impacts from erosion and flooding, respectively

H. Cascading Impacts on Other Hazards

Hurricanes, tropical storms, and severe storms often are accompanied by heavy precipitation that can cause flooding and/or erosion. High speed winds can lead to additional erosion (strong winds may move sediment along the coastline) and an increased storm surge (when strong winds blow water landward). Power outages reduce ability to control the indoor environment, often leading to heat stress after major storms.

Lightning can ignite wildfires, and strong winds can contribute to the rapid spread of a wildfire once ignited. Coastal storms can impact various natural land resources that can be easily uprooted by major wind events and storm surge, increasing potential for erosion (USGS n.d.).

I. Future Changes that May Impact Regional Vulnerability to Hazard

An increase in development will increase the potential impacts from hurricanes, tropical storms, and severe storms. Increased paved surfaces, such as roads and parking lots, to accommodate population increases and development demands will contribute significantly to urban and stormwater flooding during storm events.

As the population increases, so may the number of people exposed to storm events. To limit the number of residents impacted by flooding in the future, communities can consider planning and zoning solutions, such as expanded regulatory floodplains, increased freeboard requirements, buyouts of vulnerable residential areas, identification of growth areas outside of hazard-prone areas, and establishment of stormwater utilities.

VIII. COASTAL EROSION

A. Hazard Description

Coastal erosion is one of the primary coastal hazards leading to loss of lives, property and environmental damage, and damage to infrastructure. Erosion is the transfer of sediment like sand or silt from one location to another. The addition of sediment in a location is referred to as accretion. Accretion can be beneficial if it strengthens a shoreline, leading to wider beaches and more material for dune building. However, accretion can also narrow channels and inlets and create shoals. This can ultimately lead to a potential increase in coastal flooding risk or a lack of safe water access for recreation, emergencies, or economic activities.

In addition to coastal erosion, erosion can also occur inland along waterways and wetlands. Wetlands are areas where water covers the soil for at least part of the year and include a variety of natural systems, such as marshes, swamps, bottomland hardwoods, pocosins, and wet flats. Wetlands provide a variety of important benefits, including serving as a diverse habitat for fish and wildlife and providing flood and erosion protection. Wetlands can experience episodic erosion when strong storms create enough wave energy on inland waterways to result in scouring of the edge of the wetlands. A long-term concern for erosion in the region is the gradual retreat or loss of wetlands due to marsh migration resulting from sea level rise. Additional information regarding sea level rise impacts on wetlands can be found in ***Section VI***.

Climate Change Impacts

Erosion may be impacted by climate change in different ways. These areas are sensitive to sea level rise, changes in the frequency and intensity of storms, increase in precipitation, and warmer ocean temperatures (U.S. Environmental Protection Agency 2017). Impacts of climate change can lead to shoreline erosion and coastal flooding. The 2020 North Carolina Climate Science Report states it is *virtually certain* that sea levels along the state's coast will continue to rise, leading to an increase in coastal flooding and daily high tide flooding (K. D. Kunkel 2020).

Temperatures are projected to increase by 2–6 °F under a lower emissions scenario and by 6-10 °F under a higher emissions scenario across the state by 2100, which will lead to an increase in the intensity and frequency of severe storm events (K. D. Kunkel 2020). This will increase shoreline erosion rates due to the increased frequency and severity of precipitation, storm surges, and high wind events. The most vulnerable coastal landscapes anticipated to experience exacerbated impacts of erosion due to climate change include coastal wetlands and barrier islands.

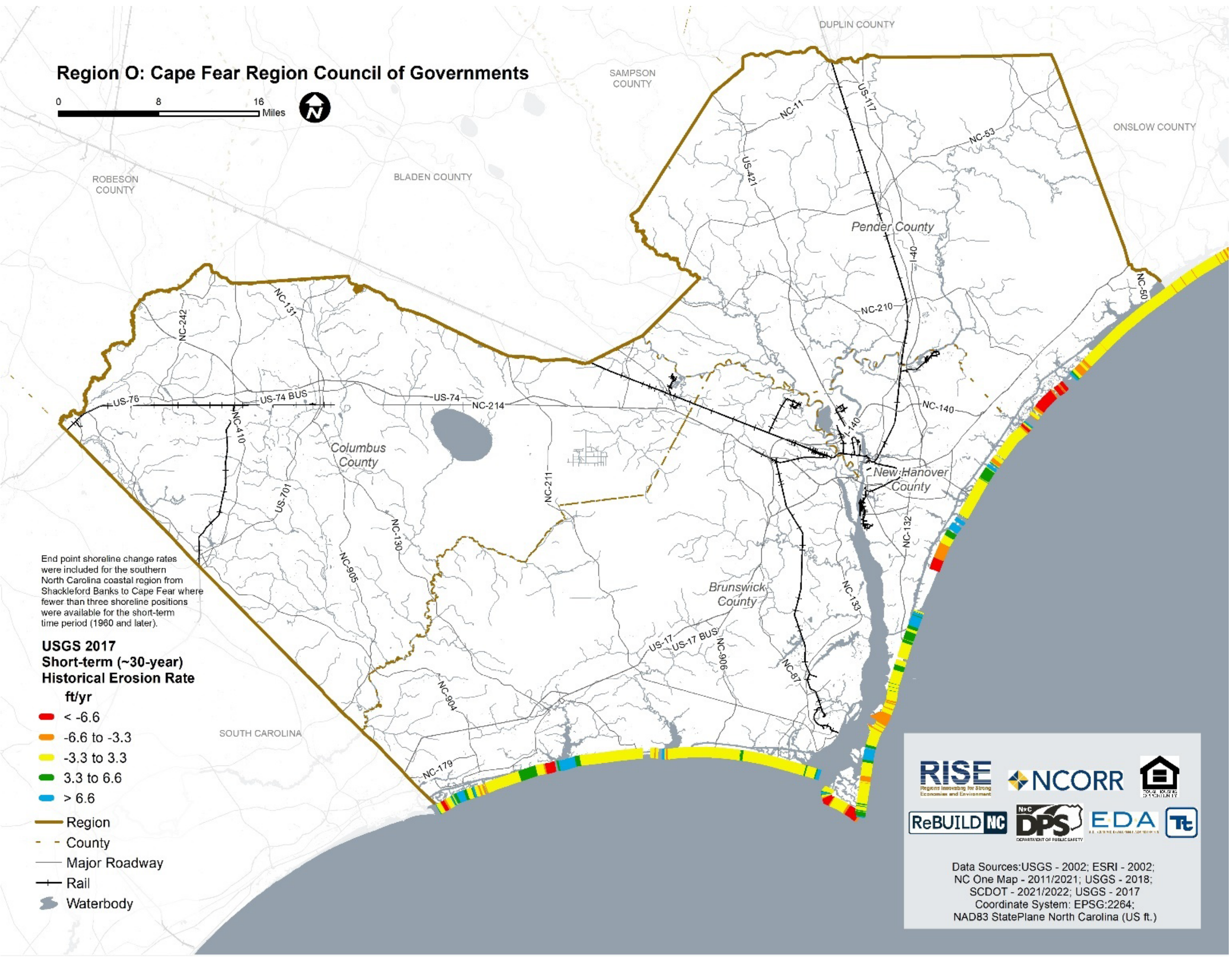
B. Location and Extent

Long-term erosion rates throughout the Cape Fear Region vary significantly because of geology and the physical nature of different locations along the shoreline. Barrier islands provide relief from erosion to the coast but are highly susceptible to erosion themselves. Although it is possible to reduce the impact or frequency of erosion, all shorelines in the region are vulnerable to erosion and some mitigation measures may exacerbate erosion and accretion. The properties most at risk of erosion will be those located within 200 feet of the erodible shoreline and beaches.

Figure 16 is a depiction of average shoreline change over the course of the next 30 years, as identified by the United States Geological Survey (USGS) Coastal Change Hazards Portal. Much of the shoreline is not anticipated to experience a change greater than 3 feet in either direction, while small areas are anticipated to gain or lose more than 6 feet.

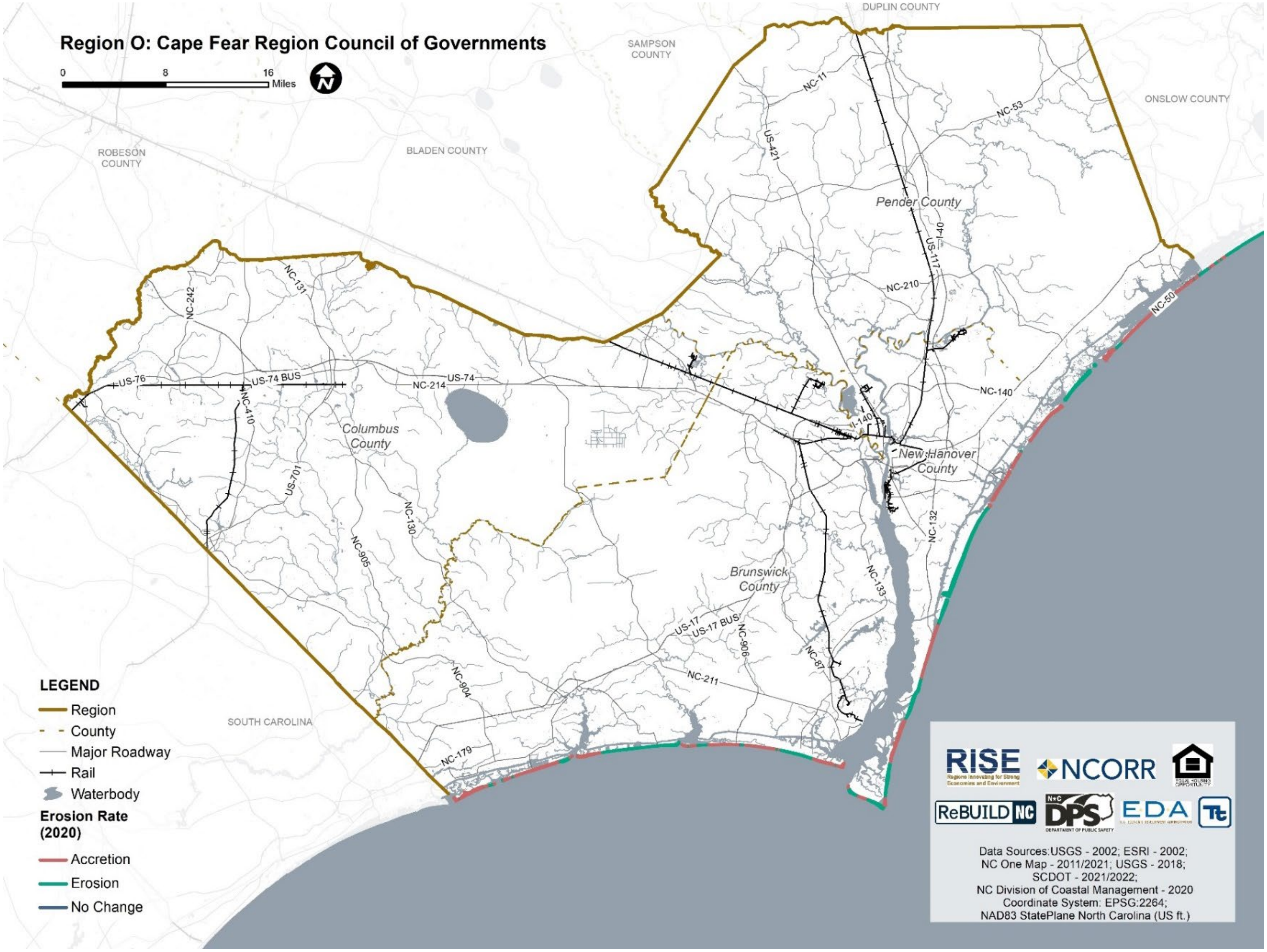
Locations that have historically experienced erosion and accretion in the region are shown in ***Figure 17***. Overall, erosion and accretion processes are alternating along the coastline. Over the next several decades, the natural process of erosion and accretion will continue and, in the process, reshape the coastline while losing land in some areas and gaining land in other areas. Coastal shorelines change constantly in response to wind, waves, tides, sea level fluctuation, seasonal and climatic variations, human alteration, and other factors that influence the movement of sand and material within a shoreline system.

Figure 16. Short-Term Shoreline Change Rates for Cape Fear Region



Source: U.S. Geological Survey n.d.

Figure 17. Erosion and Accretion in Cape Fear Region



C. Impact on Socially Vulnerable Populations and Equity

Socially vulnerable populations in the region will experience a disproportionate risk to erosion if they live in coastal areas. The cost to implement mitigation measures to increase the level of protection of a structure may create barriers for those who are economically disadvantaged. Additionally, the cost to relocate from areas prone to erosion and the lack of affordable housing options are cost-prohibitive and present additional barriers for socially vulnerable populations.

D. Impacts on Public Health and Safety

Erosion is unlikely to have a direct impact on life safety. However, the loss of natural systems, such as wetlands and barrier islands, which provide protection from natural hazards, increases the likelihood of direct impacts from flooding. For additional information on the impacts from flooding, refer to ***Section IV***.

Additional time and support required during evacuations also increases risk for vulnerable populations. Populations with mobility issues experience short-term difficulties in the event evacuation is required due to sudden flooding, sinkholes, or other emergencies arising from erosion. These barriers must be taken into consideration during long-term adaptation efforts to ensure the needs of socially vulnerable populations are recognized and met. The general population is also at risk to sudden emergencies arising from erosion.

E. Impact on Housing and Critical Infrastructure

Any buildings or critical facilities located near shorelines could be impacted by erosion. Erosion can result in the scouring of foundations and eventual collapse if corrective measures or additional protections are not put in place. Those assets located near the oceanfront shoreline have a greater risk of sudden damage and loss from coastal erosion during severe coastal storms accompanied by large waves and storm surge. Assets located behind wetlands or shorelines, away from the ocean, are more likely to experience erosion on an incremental basis, potentially providing more time for mitigation measures to be employed.

To provide a level of protection to structures, the North Carolina Division of Coastal Management uses erosion rate maps and setback factors to regulate development. Oceanfront construction setbacks are measured landward from the first line of stable natural vegetation or a static vegetation line when applicable. Setback distance is determined by two variables: (1) the size of the structure, and (2) a setback factor based on shoreline position change rates (North Carolina Environmenal Quality 2019).

Erosion can degrade infrastructure and utility lines in vulnerable areas. Critical services may be interrupted due to direct damage or impacts to the transportation network that connects these services to the community. Roads that are damaged, particularly evacuation routes, may even isolate residents and can prevent access throughout the region to many service providers needing to reach vulnerable populations. Bridges, ferries, and terminals, which may be considered major corridors for essential services and economic activity in the region, are also vulnerable to coastal erosion due to being located along shorelines.

F. Impact on Economy

Erosion can result in significant economic loss through the destruction of buildings, roads, infrastructure, natural resources, and wildlife habitats. These financial risks include but are not limited to general building stock damages and associated tax loss, impacts to utilities and infrastructure, business interruption, and impacts on tourism. In areas directly experiencing erosion, renovations of commercial and industrial buildings may be necessary, disrupting associated services.

A more permanent solution to the threat of erosion is to relocate buildings and infrastructure further away from the eroding shoreline. Where this solution is not possible, these assets may need to be abandoned. If businesses and residents relocate away from waterfront property, the low availability of developable land and high cost of housing in coastal areas may present a challenge. However, if residents with waterfront property remain, they may be required to make structural changes or construct bulkheads or riprap. The cost of these interventions may financially stress lower- or middle-income residents and can unintentionally exacerbate erosion and accretion.

The destruction caused by erosion in parks, beaches, and coastal communities that rely on tourism may experience negative economic consequences should the hazard breach these sites. Changes in the beach will impact tourism. In 2020, tourism and visitor spending in the region accounted for $1,507,960,000.00 (7.6 percent of the state total) (Visit North Carolina 2021). Coastal erosion and loss of beaches would impact the tourism economy locally, regionally, and statewide.

Areas experiencing accretion may result in waterways becoming unnavigable. In terms of impacts on the economy, accretion could impact recreation and commercial ports and marinas throughout the region. The greatest impact from a disruption in navigable waterways may be experienced by the Port of Wilmington, which produces $436 million in business revenue annually (Port of Wilmington n.d.).

G. Impact on Natural and Cultural Resources

Natural and Cultural resources may be resources that are nationally or locally recognized on a historical registry or resources that are self-identified by the community. The Cape Fear Regional Stakeholder Partnership stated the beaches within the region are cultural resources that are valuable to residents. Erosion would directly impact beaches and potentially become detrimental and completely degraded beaches.

The loss of natural resources is difficult to quantify; however, their loss would deeply cost the region’s counties and communities. The loss of beaches, dunes, wetlands, and other shoreline features would greatly reduce important ecosystems. Wetland areas and coastal habitats are important ecosystems for many species and provide other environmental benefits such as flood mitigation. Many of the cultural and natural resources in Cape Fear are located along the coastline or consists of wetlands and therefore vulnerable to erosion. The public views the region’s beaches as cultural and recreational resources that are at risk and require additional preservation and conservation measures.

H. Cascading Impacts on Other Hazards

Erosion triggers higher risk for multiple other hazards. Receding shorelines make coastal properties more susceptible to flooding. Changes in the shoreline could cause changes in land elevation and increase the impacts of sea level rise. Estimated flood extents may change based on the level of erosion that has occurred. For more information on flooding, refer to ***Section IV***.

Erosion can impact the vulnerability of communities further inland, as well, through the process of wetland migration. Erosion can lead to the loss of wetlands and cause wetlands to migrate inland. Loss of wetlands increases the likelihood of water quality issues without the natural filtration provided by wetland plants. While wetland migration inland can help to preserve wetland acreage, it comes at the expense of the habitats that wetlands will replace. Over several decades, saltwater intrusion, caused by erosion, sea level rise, and human activity, has formed “ghost forests” throughout the region. Ghost forests are forests that have been inundated with salt water, killing the trees and leaving bare trunks and stumps. In a 2021 article published in the Smithsonian Magazine, it is stated that “the loss of forests will reduce carbon storage, further fueling climate change, and the agriculture industry, timber interests will suffer as saltwater moves inland.” (Morrison 2021) This phenomenon has impacted the region to the extent that the Cape Fear Museum has dedicated an exhibit to exploring ghost forests in the region. Additionally, ghost forests increase the risk of wildfire. For more wildfire information, refer to ***Section XI***.

I. Future Changes that May Impact Regional Vulnerability to Hazard

Population growth will continue to drive new development in the region. Due to the location of the region, many new residents will want to settle along the beach and oceanfront. As the population along the coast increases, more individuals will be prone to impacts from erosion. This will be compounded by impacts from sea level rise and flooding will reduce and limit the amount of available developable land (K. D. Kunkel 2020).

Local leaders raised concerns regarding current residents resisting relocating from coastal areas and the desire of new residents to settle into these hazard-prone areas. This will result in a demand for new construction of residential structures to accommodate the increased population and new construction of commercial and industrial structures for services required to support the increase in population.

Development in wetlands in North Carolina requires a permit from either the U.S. Army Corps of Engineers or N.C. Division of Coastal Management. This reduces the likelihood of wetland benefits being lost due to development (North Carolina Department of Environmental Quality n.d.). However, a development that borders wetlands areas reduces available land for wetlands retreat and increases the likelihood of wetlands loss as the sea level rises and erosion persists.

IX. SEA-LEVEL RISE

A. Hazard Description

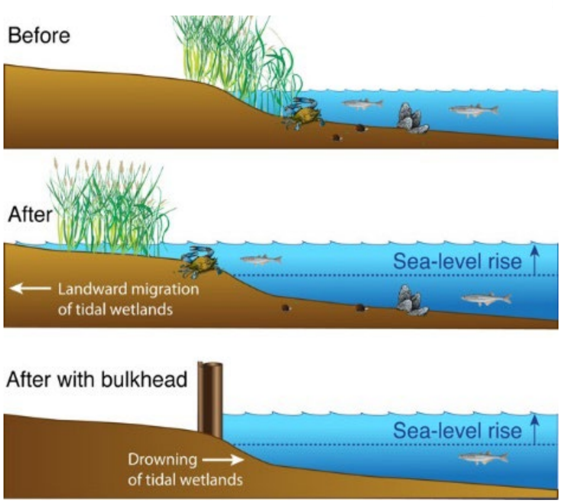
Sea level changes are tracked over time to determine absolute and relative change. Absolute sea level change is the height of the ocean surface regardless of land movement (rising or subsiding). Relative sea level rise accounts for the change in the height of the ocean surface, but factors in the elevation change of the land as well. Between 1880 and 2013, the global absolute sea level increased at a rate of 0.06 inches per year. An increased rate was noted in 1993, with sea level averaging an increase of 0.12 to 0.14 inches per year. (U.S. Environmental Protection Agency 2021). Sea-level rise is projected to increase 15.18 inches by 2050 for the region (SeaLevelRise.org n.d.).

A secondary effect of sea level rise is saltwater intrusion. When rising seas enter coastal aquifers (underground drinking water supplies), the water in the aquifer becomes contaminated with salt and undrinkable. Not only does saltwater intrusion threaten the availability of drinking water, but it can also make soils too salty for native plants to grow, creating problems for coastal forests and agriculture. Saltwater intrusion may also occur above ground and impact wetlands. Saltwater intrusion generally impacts wetlands in the following manners:

- Marsh plants adapted to low salinities may not be able to survive and are replaced by saltmarsh plants;
- Low salinity marsh plants are outcompeted by an invasive species like common reed (Phragmites australis);
- Low salinity marsh plants die off and the marsh and wetlands become open water, eliminating the protection to natural hazards that the marshes provides; and
- “Ghost forests” develop as a result of saltwater killing trees and leaving bare trunks and stumps.

B. Location and Extent

Figure 18. Wetlands Retreat and the Impact of Shoreline Protection



Source: NOAA 2022

As sea level rises, the starting elevation of coastal flooding events will also rise. This means that coastal floods are likely to reach a higher elevation and push farther inland. As a result, it is likely that the floodplain will expand. ***Figure 18*** illustrates how rising water impacts wetlands.

Figure 14 in ***Section IV*** depicts the potential footprint of the current 1 percent annual chance floodplain with 1 foot of sea level rise, a threshold likely to be reached by 2050.

When the sea pushes further inland, wetlands will migrate further inland or die if there is not adequate space for migration. This loss of wetlands may be offset by the migration of wetlands into upland areas as sea levels rise, provided that upland areas are allowed to naturally transition and no barriers to the gradual retreat of the wetlands/uplands line exists, such as bulkheads, roadways, or other forms of development.

As sea level rises, wetlands are more prone to erosion along their edges but may also experience marsh migration, where low-lying marsh converts to open water and marshes slowly take over upland areas to account for changes in water elevation. Marsh erosion and marsh migration have been identified as concerns within the region. ***Figure 19*** depicts the current location of marsh in the region; the potential marsh migration from 1 foot of sea level rise is depicted in ***Figure 20***. There are areas throughout the region that will lose wetlands are areas will become upper shoreland, changing the function of the area, reducing flood protection benefits, and disrupting habitat.

Figure 19. Present Day Marsh in Cape Fear Region

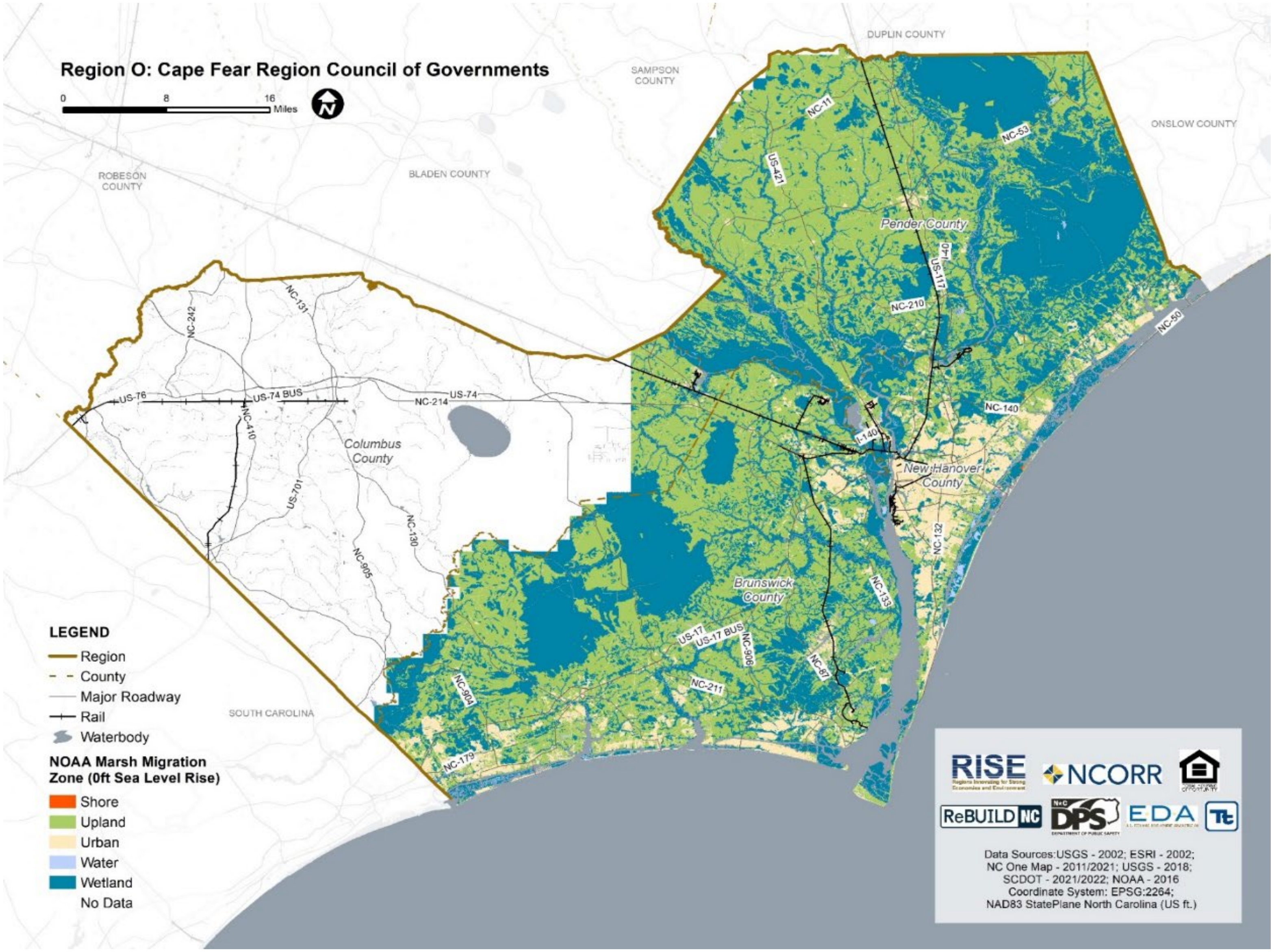
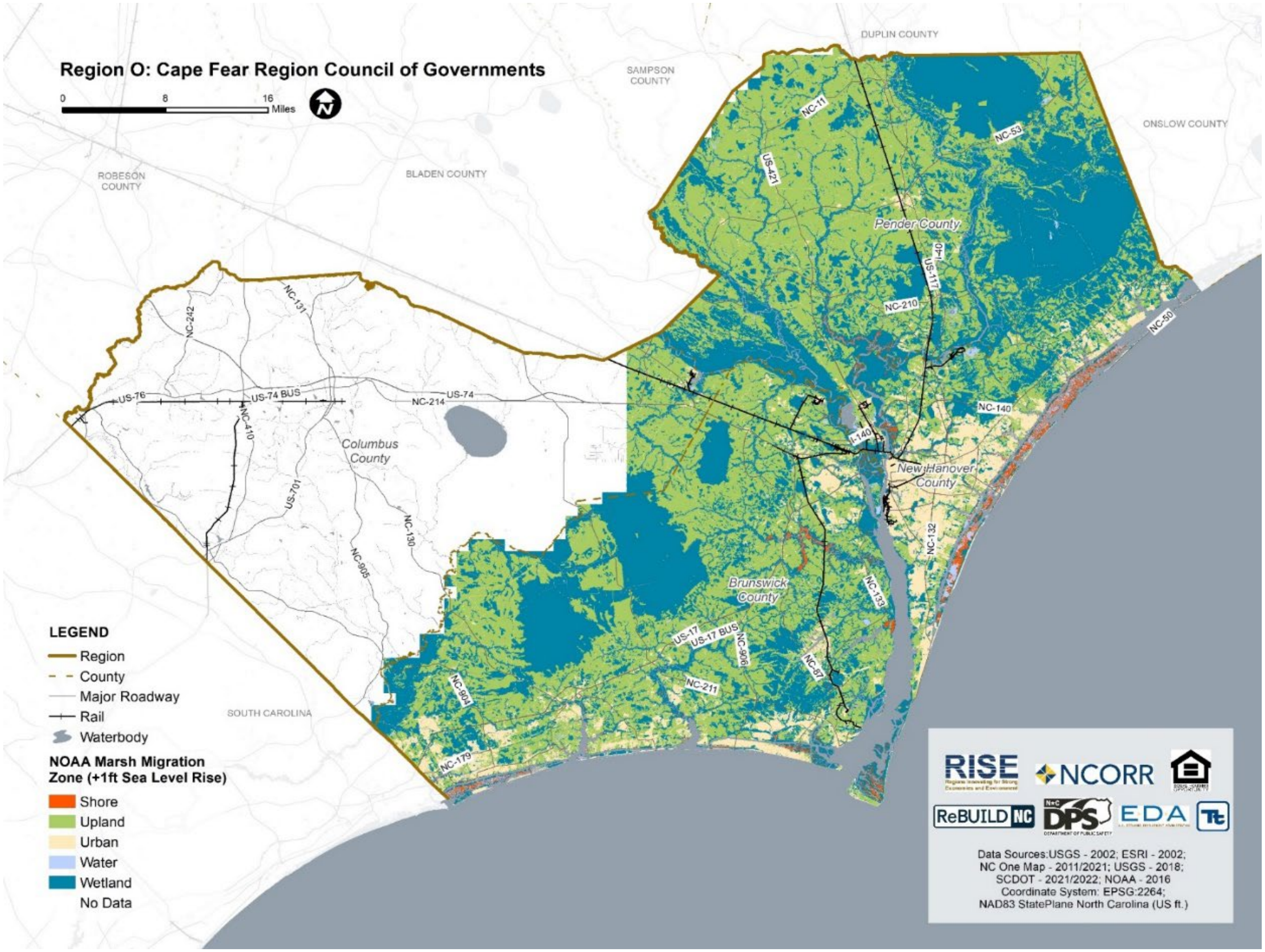


Figure 20. Marsh Migration with 1 foot Sea Level Rise



C. Impact on Socially Vulnerable Populations and Equity

Socially vulnerable populations face a disproportionate risk to flooding as described in ***Section IV.*** When compounded by sea level rise, this risk will increase. Based on the projected 2050 floodplain accounting for 1 foot of sea level rise the below socially vulnerable persons are at risk. Please note that these population totals are based on current 2020 populations and are likely to increase as the region's population is projected to increase by 40.40 percent.

- 7,226 children
- 32,899 elderly
- 21,608 economically disadvantaged
- 22,240 persons with disabilities
- 700 persons with limited English proficiency
- 3,113 persons without access to a vehicle

D. Impacts on Health and Safety

In addition to potential impacts from flooding caused by sea level rise, saltwater intrusion caused by sea level rise may lead to the elimination of safe drinking water if the aquifers accessed by potable wells are rendered too salty to drink. This is usually addressed by using a different aquifer, installing desalinization plants, or shipping water in from outside sources. However, these measures are often costly and can cause significant financial stress on the community.

E. Impact on Housing on Critical Infrastructure

Sea level rise will continue to damage the region's buildings and critical infrastructure. Saltwater can have damaging effects to building materials and cause rapid weatherization and corrosion; structures and facilities located in coastal areas susceptible to sea level rise and saltwater intrusion have a higher risk; refer to ***Section V*** for a complete analysis of the impacts flooding may have on structures and critical facilities. The potential damage and destruction of these structures and facilities may result in essential services ceasing until these services are able to be reestablished in another area not prone to hazards.

The impacts of saltwater intrusion on drinking acquirers can lead to the failure of services provided by potable water wells and aquifers or result in the need to build costly desalinization plants. Impacts from erosion resulting in sea level rise are discussed in ***Section VI***.

F. Impact on Economy

As sea level rise may be compounded by flooding, erosion, and severe storms, the same impacts are possible. Sea level rise can have lasting effects on the economy, including losses to building stock, the tax base, utilities and infrastructure, business interruption, and tourism. Sea level rise may have direct impacts on the existing building stock and reduce the availability of desirable, although hazard-prone, land for development. In areas that will be directly subjected to sea level rise renovations to commercial, industrial, and residential structures may be necessary to retrofit structures with building materials that are resistant to saltwater and constant inundation. Other economic components such as loss of facility use, functional downtime, and socioeconomic factors are less measurable with a high degree of certainty.

Assets currently within the 1 percent and 0.2 percent annual chance flood hazard areas will be at a greater risk of sea level rise, due to them being susceptible to flooding impacts in present day. The base flood elevation in areas may rise, and assets may lose space and functionality. For a detailed assessment of critical facilities located in the floodplain, refer to ***Section VI***.

Economic assets that require proximity to waterways, such as ports and marinas, have a disproportionate risk to sea level rise. Due to the nature of these businesses and activities, relocation is not an alternative. These businesses will have to implement mitigation measures in order to remain functional and adapt to sea level rise. However, sea level rise could be to a level where the function of these port and marina facilities is lost.

G. Impacts on Natural and Cultural Resources

Sea level rise will also have detrimental impacts and increase the rate that habitats are disrupted and destroyed. Flooding, saltwater intrusion, and erosion caused by sea level rise has direct impacts on the natural resources throughout the region. There is the potential for natural resources, such as wetlands, fish and wildlife habitats, and barrier islands, to be destroyed or altered in a manner that is disruptive to the regional environment. The region's natural resources have numerous benefits, including providing protection from natural hazards, such as floods, storm surge, heavy precipitation, extreme heat, wildfire, and high winds. When these natural environments are destroyed or converted, these benefits are lost, and people and property face greater vulnerabilities.

H. Cascading Impacts on Other Hazards

Sea level rise will directly exacerbate flooding, storm surge, erosion, and wetland migration. Tidal flooding levels will increase, and the floodplain will also expand. This results in a larger percentage of the population becoming vulnerable to these hazards. Public health concerns will grow as saltwater intrusion increases, putting potable water sources at risk. Refer to ***Sections IV, VI, and XI*** to learn more about the potential impacts from hazards exacerbated by sea level rise.

I. Future Changes that May Impact Regional Vulnerability to Hazard

Increases in development and population will result in a larger percentage of the population being exposed to sea level rise and subsequent flooding. An increase in development, particularly in low-lying and coastal areas, will worsen already-existing flooding issues. Paved surfaces, such as roads and parking lots, contribute significantly to urban and stormwater flooding. When this urban flooding occurs in areas where the water table is high, water has nowhere to go but up, creating numerous incidents of localized flooding across the region. To address stormwater management related to new development while also mitigating the impacts of flooding and sea level rise, communities can consider nature-based and environmentally sound solutions such as rain gardens, bioswales, and permeable paving.

By 2050, an estimated 154,759 (32.7 percent of the 2020 total population) people will live in the 1 percent annual chance flood area. With the region's population projected to increase by 40.40 percent, by 2050 this number could drastically increase as new residents locate into coastal areas. To limit the number of residents impacted by flooding in the future, communities can consider planning and zoning solutions such as expanded regulatory floodplains, increased freeboard requirements, buyouts of vulnerable residential areas, and identification of growth areas outside of hazard-prone areas, and establishment of stormwater utilities.

X. EXTREME TEMPERATURES

A. Hazard Description

Extreme temperature includes both heat and cold events, which can have a significant impact to human health, commercial/agricultural businesses, and primary and secondary effects on infrastructure (e.g., burst pipes and power failure). What constitutes *extreme cold* or *extreme heat* can vary across different areas of the country, based upon what the population is accustomed to. The potential impacts of extreme temperatures include:

- Drought and limited drinking water supply for residents;
- Adverse health impacts in vulnerable populations, such as the elderly and persons experiencing homelessness; and
- Damages to aging infrastructure and buildings as highways and roads are damaged by excessive heat as the asphalt softens, and roadways can be damaged from extreme cold temperatures during the freeze and thaw cycles.

The hottest temperatures on record in the region are 104° recorded on June 27,1952 in Wilmington and 103° recorded on August 22,1983 in Longwood.

The coldest temperatures on record in the region are 0° in Wilmington and -4° in Longwood, both recorded on December 25,1989.

Source: (North Carolina State Climate Office n.d.)

The average winter temperature in the region is 48 °F, and the average summer temperature is 78 °F (National Oceanic And Atmospheric Administration n.d.). In the Cape Fear Region, extreme cold is considered temperatures that near the freezing point. The extent of extreme cold temperatures generally is measured through the Wind Chill Temperature (WCT) Index. The WCT Index uses advances in science, technology, and computer modeling to provide an accurate, understandable, and useful formula for calculating the dangers from wind chill. Extreme heat is defined as temperatures which hover 10 degrees or more above the average high temperature for a region and that last for several weeks (Centers for Disease Control and Prevention n.d.). For the Cape Fear region, the NC Climate Science Report categories days with temperatures above 95 °F and nights with temperatures above 75 °F as extreme heat (K. D. Kunkel 2020). The extent of extreme heat temperatures is measured through the Heat Index. The Heat Index was created by the NWS to measure apparent temperature of the air as it increases with the relative humidity. There have been several days where the Heat Index in the region has exceeded 110 °F; the National Centers for Environmental Information's database reported Heat Indices above 110 °F during August 21–24, 2011; June 29–20, 2012; July 26–27, 2012; and June 14–26, 2015 (National Centers for Environmental Information n.d.). One reported fatality has been recorded because of extreme heat. On June 30, 2012, a heat wave required several residents in Columbus County to require medical treatment; a farm worker was reported to have died from heatstroke after hospitalization (National Centers for Environmental Information n.d.). There were no extreme cold events reported in the database.

Climate Change Impacts

The 2020 North Carolina Climate Risk Assessment and Resilience Plan states it is "very likely that North Carolina temperatures will also increase substantially in all seasons. Annual average temperature increase relative to the recent climate (1996 – 2015) for North Carolina are projected to be on the order of 2-5 °F under the current emissions scenario and 2-4 °F under a lower emissions scenario by the middle of this century". (K. D. Kunkel 2020). This increase in temperature will impact extreme temperatures, increasing the number of extremely hot days and decreasing extremely cold days. Additionally, the 2020 Climate Risk Assessment and Resilience Plan states, "Extreme heat events will become more frequent, longer-lasting, and more intense, exacerbating demands for water." (K. D. Kunkel 2020)

B. Location and Extent

Extreme heat can occur anywhere within the region. ***Figure 21*** shows the number of observed very hot days (temperatures equal to or greater than 95 °F) within North Carolina (K. D. Kunkel 2020). Excessive heat incidents are widespread, even if there are localized cooler areas. Areas of dense urban development are especially vulnerable to the urban heat island (UHI) effect that can further raise temperatures. Urban heat islands occur when cities replace natural land cover with impervious surfaces (buildings, pavement, etc.) that absorb and retain heat. This effect increases energy costs, air pollution levels, and heat-related mortality and illness (EPA 2022). Urban heat island effect can also occur in non-urban areas that have high levels of paved surfaces and buildings with little to no vegetation.

Figure 21 Observed Annual Number of Very Hot Days (1990 - 2018)

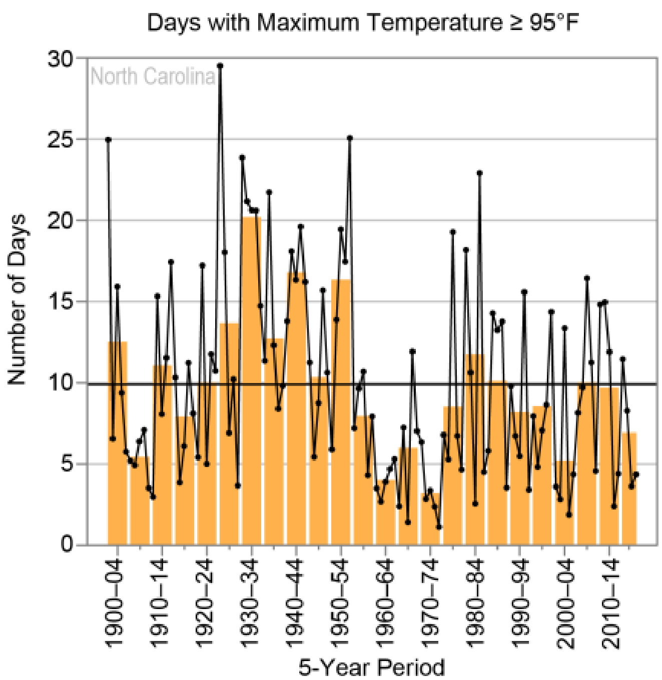
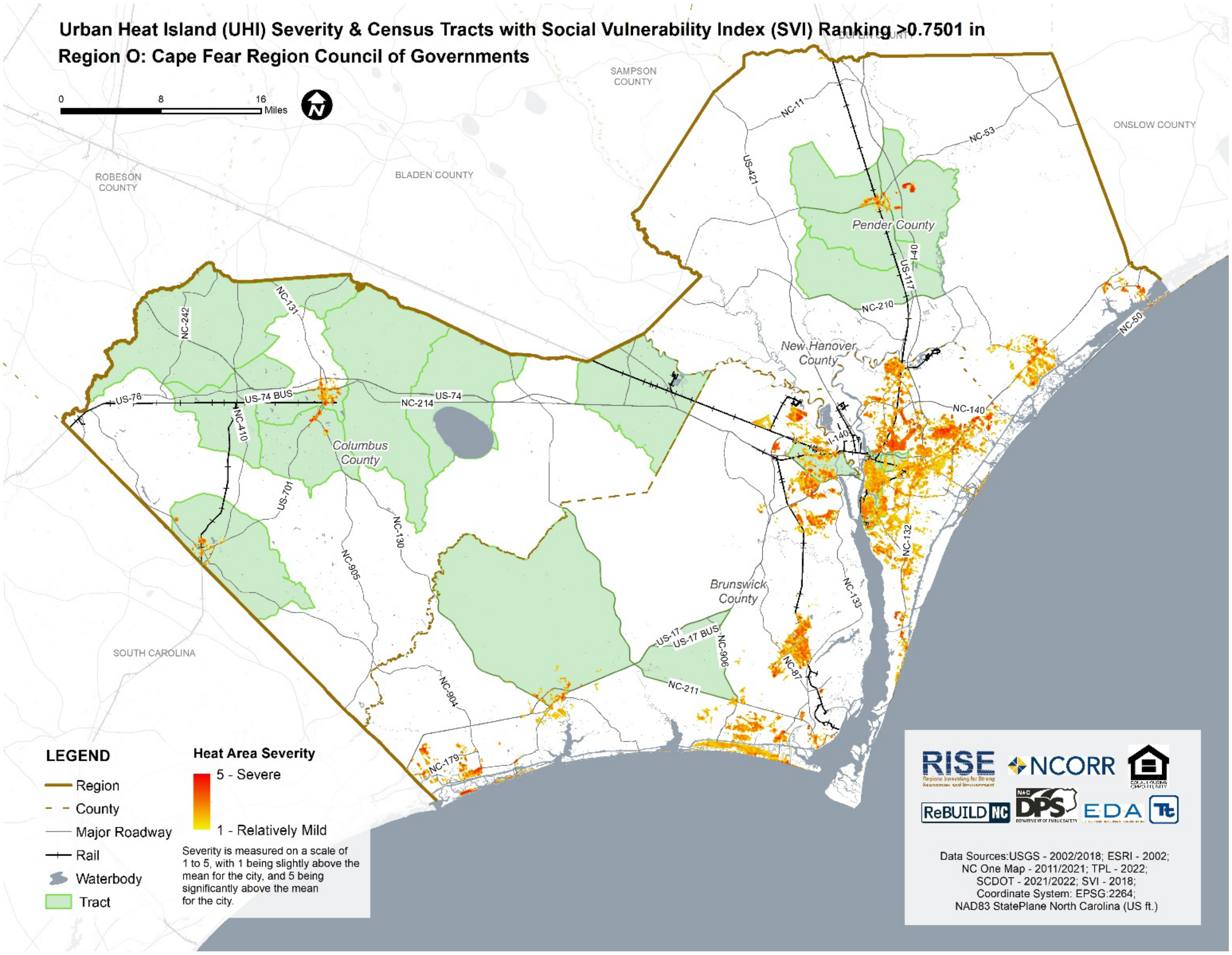


Figure 22 shows the intersection of areas of high social vulnerability and a high UHI severity. Areas where the UHI is severely higher than the mean temperature for the area are shown in red, while areas where the UHI is only slightly higher than the mean average for the area are shown in yellow. Most areas in the region with a high UHI effect are located in population centers that include:

- Whiteville and Tabor City in Columbus County
- Carolina Shores, Sunset Beach, Shallotte, Oak Island, St. James, Leland, and Navassa in Brunswick County
- Wilmington in New Hanover County
- Hampstead and Burgaw in Pender County

The UHI impacts intersect socially vulnerable areas in Whiteville, Tabor City, Leland, Wilmington, and Burgaw. The most widespread impacts are in Wilmington. Due to the negative impacts associated with UHI, areas with pre-existing barriers will be most impacted by extreme heat. Economically disadvantaged populations who cannot afford cooling and those with medical conditions will face an increased risk. Local leaders can use this information to identify areas to provide additional resources, such as cooling centers or tree plantings, to help reduce the impacts of extreme heat.

Figure 22. Urban Heat Island Severity and Social Vulnerability Index



C. Impact on Socially Vulnerable Populations and Equity

According to the Centers for Disease Control and Prevention (CDC), populations most at risk to extreme cold and heat events include the elderly; infants and children up to four years of age; individuals with chronic medical conditions (e.g., heart disease, high blood pressure); low-income persons who cannot afford proper heating and cooling; and the general public who may overexert during work or exercise during extreme heat events or experience hypothermia during extreme cold events (CDC 2021). These impacts are more pronounced in the region due to the high population of elderly (21% of regional population) and economically disadvantaged (15% of regional population).

D. Impacts on Public Health and Safety

The entire population of the Cape Fear Region is exposed to extreme temperature events. People who are outdoors should be mindful of the signs of heat-related illness and hypothermia. The North Carolina Climate-Health Scorecard scores heat-related deaths and illness as a very high vulnerability, specifically for young adults, athletes, and farm workers. Air quality and respiratory diseases are scored very high for children and older adults (North Carolina Department of Health and Human Services n.d.).

E. Impact on Housing and Critical Infrastructure

Extreme heat generally does not impact buildings; however, elevated summer temperatures increase the energy demand for cooling. Losses can be associated with the overheating of heating, ventilation, and air conditioning (HVAC) systems. Extreme cold temperature events can cause damage through freezing/bursting pipes and freeze/thaw cycles, as well as increasing vulnerability to home fires. Additionally, mobile and manufactured homes and antiquated or poorly constructed facilities can have inadequate capabilities to withstand extreme temperatures.

All critical facilities are exposed to the extreme temperature hazard. It is essential that critical facilities remain operational during natural hazard emergencies and disasters. Extreme heat events can sometimes cause short periods of utility failures, commonly referred to as brownouts, due to increased usage from air conditioners and other energy-intensive appliances. Similarly, heavy snowfall and ice storms, associated with extreme cold temperature events, can cause power interruption. Backup power is recommended for critical facilities and infrastructure.

F. Impact on Economy

Extreme temperature events also impact the economy, including loss of business function and damage to and/or loss of business inventory. Business-owners can be faced with increased financial burdens due to unexpected repairs required for the structure (e.g., pipes bursting), higher than normal utility bills, or business interruption due to power failure (i.e., loss of electricity or telecommunications). Disruptions in public transportation service will also impact the economy for both commuters and customers alike.

G. Impact on Natural and Cultural Resources

Freezing and warming weather patterns create changes in natural processes. An excess amount of snowfall and earlier warming periods may affect natural processes such as flow within water resources (USGS 2019). Likewise, rain-on-snow events also exacerbate runoff rates with warming winter weather. Extreme heat events can have particularly negative impacts on aquatic systems, contributing to fish kills, aquatic plant die-offs, and increased likelihood of harmful algal blooms.

H. Cascading Impacts on Other Hazards

Extreme temperature events can exacerbate the drought hazard, increase the potential risk of wildfires, and escalate severe storm and severe winter weather events. For example, extreme heat events may accelerate evaporation rates, drying out the air and soils. Extreme heat can also dry out terrestrial species. Extreme variation in temperatures could create ideal atmospheric conditions for severe storms or worsen the outcome of severe winter weather during freezing and thawing periods.

Extreme heat, exacerbated by drought, can increase the withdrawal of fresh water and increase the likelihood of saltwater intrusion in coastal aquifers. Saltwater intrusion is a natural process, but it becomes an environmental problem when excessive pumping of fresh water from an aquifer changes the water pressure and intensifies the effect, drawing saltwater into new areas. When freshwater levels drop, the intrusion can proceed further inland until reaching a pumped well.

I. Future Changes that May Impact Regional Vulnerability to Hazard

Increasing development will create more impervious surfaces, exacerbating the UHI effect in communities. More development will also require greater power needs, straining systems in the event of extreme temperatures. An increase in the population throughout the Cape Fear Region may also create greater strain on water resources.

XI. DROUGHT

A. Hazard Description

Drought is a normal phase in the climactic cycle of most geographical regions. According to the National Drought Mitigation Center, drought "originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector." Drought is the result of a significant decrease in water supply relative to what is "normal" in a given location.

If the weather pattern lasts a short time (a few weeks or a couple of months), the drought is considered short-term. If the weather pattern becomes entrenched and the precipitation deficits last for several months or years, the drought is considered to be long-term.

> The region experienced one of the most extreme droughts from August 2007 through February 2008. Many areas experienced precipitation levels less than 50% of their normal average. The Governor encouraged State agencies and residents to reduce water consumption by 20%. This drought was categorized in the second highest category "as extreme". No damages or injuries were reported.
>
> *Source: (National Integrated Drought Information System n.d.)*

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the duration of the drought and the larger the area impacted, the more severe the potential impacts (National Oceanic and Atmospheric Adminstration 2021).

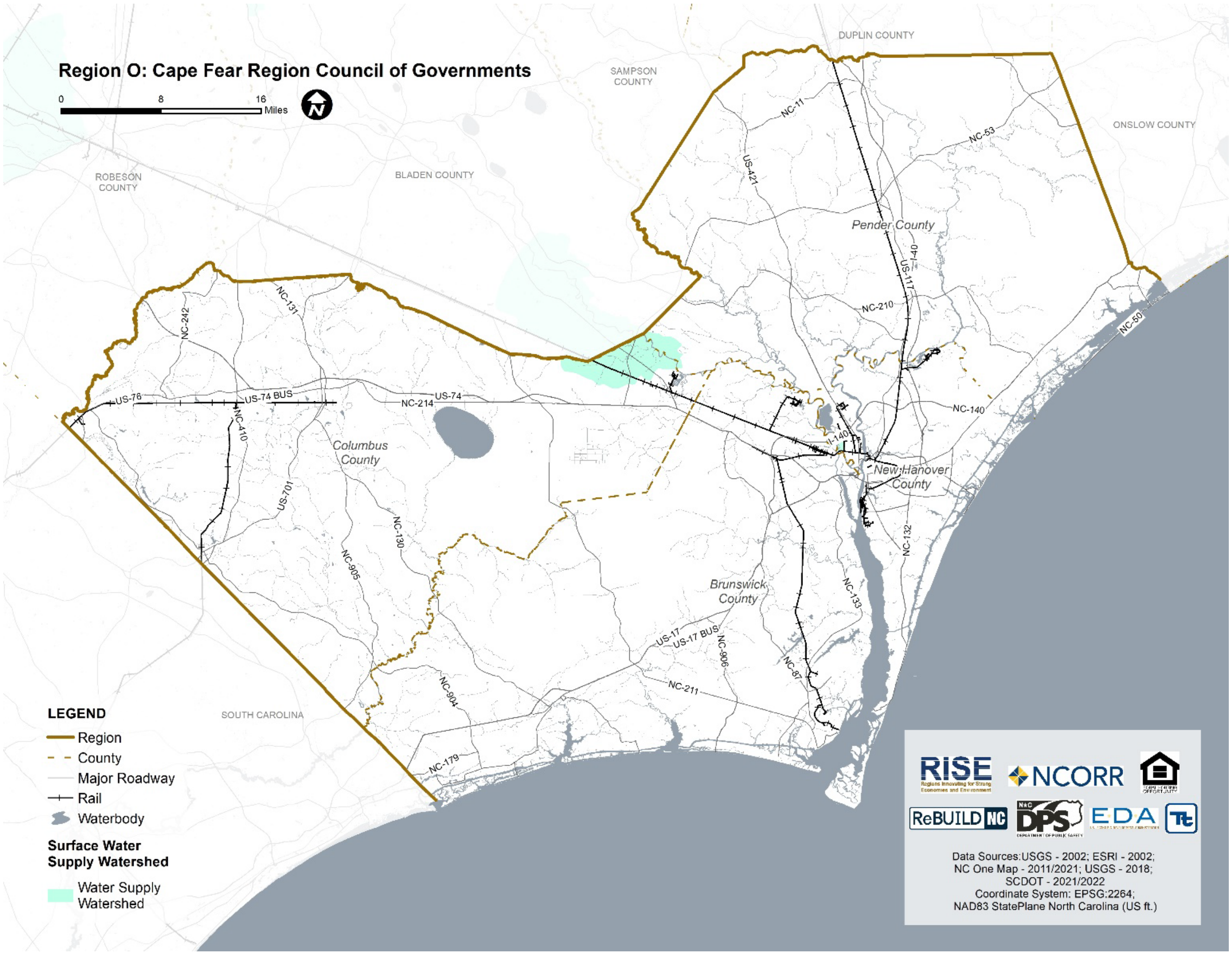
Climate Change Impacts

Future droughts in the region are likely to be more intense and frequent due to projected higher temperatures caused by climate change (K. D. Kunkel 2020). Droughts can cause deficits in surface and groundwater used for drinking water. If the region experiences an increased draw on freshwater aquifers due to drought conditions and limited supply of surface water, saltwater infusion may become exacerbated, further contaminating groundwater supplies. Warmer temperatures and longer frequent lapses in precipitation will exacerbate the impacts of drought (U.S. Forest Service n.d.).

B. Location and Extent

Droughts are a natural part of the North Carolina climate. Droughts can impact portions or the entirety of the region based upon precipitation patterns. Locations that rely on surface water supply are at higher risk to the impacts of drought than those areas that rely primarily on groundwater supply. In the Cape Fear Region, the locations reliant on surface water are limited to the area surrounding Sandyfield in Columbus County, as shown in ***Figure 23***.

Figure 23. Surface Water Supply Watersheds



C. Impact on Socially Vulnerable Populations and Equity

Vulnerable populations could be particularly susceptible to the drought hazard and cascading impacts due to age, health conditions, and limited ability to mobilize to shelter, cooling and medical resources. Considering the region's higher percentage of elderly and economically disadvantaged populations, the region’s people may experience health challenges leading to an increased need for medical services or residents may experience challenges to effectively heating and cooling their homes.

D. Impact on Public Health and Safety

Drought conditions can cause a shortage of potable water for human consumption, both in quantity and quality. A decrease in available water may also impact power generation and availability to residents.

Public health impacts may include an increase in heat-related illnesses, waterborne illnesses, recreational risks, limited food availability, and reduced living conditions. Other possible impacts to health due to drought include effects on air quality, sanitation, and hygiene. Agricultural workers are most likely to be negatively impacted financially by drought, increasing social vulnerability.

Due to the region's outdoor recreational and tourism industries, there is a higher potential for residents and visitors to experience heat-related illnesses due to the time spent outdoors.

E. Impact on Housing and Critical Infrastructure

While associated drought events are not likely to cause impacts on buildings or critical infrastructure, limited water supply can put stress on critical services such as drinking water supply and water supply for firefighting. Potable water supplies can be reduced during droughts leading to public health risks and additional strains on the region's water supply resources.

Increased demand on the power grid for cooling can impact the power grid and lead to power failure.

F. Impact on Economy

One impact of drought is its impact on water supply. When drought conditions persist with little to no relief, water restrictions may be put into place by local or state governments. These restrictions may include placing limitations on when or how frequent lawns can be watered, car washing services, or any other recreational/commercial outdoor use of water supplies. In exceptional drought conditions, watering of lawns and crops may not be an option. If crops are not able to receive water, farmland will dry out, and crops will die. This can lead to crop shortages, which, in turn, increases the price of food (North Carolina State University 2013).

Increased demand for water and electricity can also result in shortages and higher costs for these resources. Industries that rely on water for business could be impacted the most (e.g., landscaping businesses). Although most businesses will still be operational, they may still be impacted by drought. Impacts within the recreation and tourism industry would have rippling effects throughout the state, given the region's contribution to overall tourism in North Carolina. Moreover, droughts within another area could impact the food supply and price of food for residents within the region.

Direct impacts of drought include reduced crop yield, increased fire hazard, reduced water levels, and damage to wildlife and fish habitat. When a drought occurs, the agricultural industry is most at risk in terms of economic impact and damage. For example, crops may not mature, leading to a lessened crop yield, wildlife and livestock may become undernourished, land values could decrease, and ultimately there could be a financial loss for the farmer (Intergovernmental Panel on Climate Change 2016). The Cape Fear Region has over 247,118 acres (13.4% of total regional land area) of agricultural land, which may be at risk in the event of a drought.

G. Impact on Natural and Cultural Resources

Droughts can trigger wildfires, increase insect infestations, and exacerbate the spread of disease (Intergovernmental Panel on Climate Change 2016). Droughts will also impact water resources that are relied upon by aquatic and terrestrial species. Ecologically sensitive areas, such as wetlands, can be particularly vulnerable to drought periods because they are dependent on steady water levels and soil moisture availability to sustain growth.

Droughts also have the potential to lead to water pollution. Rainwater typically dilutes pollutants in water sources, but in a drought, those pollutants become concentrated due to the lack of rainwater to dilute any pollutants in water sources. Contaminated water supplies may be harmful to plants and animals. If water is not getting into the soils, the ground will dry up and become unstable. Unstable soils increase the risk of erosion and loss of topsoil (North Carolina State University 2013).

H. Cascading Impacts on Other Hazards

Droughts can have cascading impacts on water shortages and wildfires. During droughts, restrictions on water usage may be implemented as water becomes scarce and potable water supplies need to be reserved. Drought conditions increase conditions, such as dead and dying trees, grasses, and crops, that may lead to wildfires. Additionally, droughts can lead to the following:

- Long-term damage to crop quality and crop losses;
- Insect infestation leading to crop losses and reduced tree canopy; and
- Reduction in the ability to perform outdoor activities, which could result in loss of tourism and recreation opportunities.

I. Future Changes that May Impact Regional Vulnerability to Hazard

As development and population increase in the region, the vulnerability to drought will increase. An increase in paved surfaces, such as roadways and parking lots, will increase the UHI effect, therefore increasing temperatures. Population increases will increase the percentage of the population exposed to drought and wildfires resulting from drought. Population increases will require additional water supplies as the demand will increase during droughts.

XII. TORNADO

A. Hazard Description

A tornado is a violently rotating column of air that extends from a thunderstorm to the ground with an average forward speed of 30 miles per hour (mph). Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. Tornadoes can occur at any time of the year, with peak seasons at different times for different states (National Oceanic and Atmospheric Administration n.d.).

> Since 1950, there have been 143 tornado events in the region resulting in $17.6 million in damages and 14 deaths. The deadliest tornado occurred on November 16, 2006, in Columbus and Pender County. The F3 tornado claimed eight lives and caused $500,000 in damages. The initial touchdown occurred in a mobile home park, resulting in great damages.
>
> *Source: (National Centers for Environmental Information n.d.)*

Climate Change Impacts

Providing projections of future climate change for a specific region is challenging. Shorter-term projections are more closely tied to existing trends, making longer-term projections even more challenging. The further out a prediction reaches, the more subject to changing dynamics it becomes. A warmer atmosphere means storms have the potential to be more intense and occur more often.

B. Location and Extent

The entirety of the Cape Fear Region is exposed to tornadoes. The Cape Fear Region is in FEMA's Wind Zone III. In this zone, wind speeds can reach up to 200 mph (NIST 2011). Thunderstorms are common occurrences during North Carolina's summer afternoons and evenings. During the warmer months of the year, weather is driven by more local-scale convective processes as the jet stream retreats north. The popup showers experienced during this time of year are generally small (one to a few miles across) and produce very intense, very local rainfall. During the spring and summer, thunderstorms are often associated with the passage of warm and cold fronts as storms developing along the frontal line and can impact all parts of the state. Thunderstorms in North Carolina bring strong winds and intense rain that can lead to localized flash flooding. Sometimes these storms also produce hail and tornadoes or damaging straight-line winds (NCSU n.d.).

The magnitude or severity of a tornado is categorized using the Enhanced Fujita Tornado Intensity Scale (EF Scale). This is the scale now used exclusively for determining tornado ratings by comparing wind speed and actual damage.

Tornado watches and warnings are issued by the local NWS office. A tornado watch is released when tornadoes are possible in an area. A tornado warning means a tornado has been sighted or indicated by weather radar. Occasionally, tornadoes develop so rapidly that little, if any, advance warning is possible. The NWS issues advisories and warnings for winds that are typically site-specific. The NWS issues high wind advisories, watches, and warnings when wind speeds can pose a hazard or are life-threatening. The criterion for each of these varies from state to state.

C. Impact on Socially Vulnerable Populations and Equity

Residents living in mobile homes are at a higher risk to tornadoes than those living in traditionally constructed homes.

D. Impact on Public Health and Safety

The entire population of the Cape Fear Region is exposed to tornado and high wind events. Examples of impacts may include:

- Residents may be displaced or require temporary to long-term sheltering due to severe weather events.
- In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life.
- People located outdoors (i.e., recreational activities and farming) are especially vulnerable to tornadoes and high wind events due to lack of shelter.
- Power loss can greatly impact households, business operations, public utilities, and emergency personnel.
- The elderly population may be more vulnerable if power loss results in interruption of heating and cooling services, stagnated hospital operations, and potable water supplies.
- Emergency personnel such as police, fire, and EMS may not be able to effectively respond and maintain the safety of its residents.

E. Impact on Housing and Critical Infrastructure

Tornadoes and high wind events can impact buildings and critical infrastructure. Likely damages include:

- Mobile homes, other residential structures, and wood/masonry buildings are more susceptible to wind damage than commercial and industrial structures.
- Structures built prior to 1953, the time of adoption for modern building codes, may experience more wind damage due to inadequate construction techniques. The Cape Fear Region has 32,847 buildings built pre-1953.
- Critical facilities may experience structural damage directly from high winds or falling tree limbs/flying debris, which can also result in the loss of power.
- Transportation lifelines are vulnerable to cascading effects of tornadoes such as flooding, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs.

F. Impact on Economy

Tornado and high wind events can have short- and long-lasting impacts on the economy. When a business is closed during storm recovery, there is lost economic activity in the form of day-to-day business and wages to employees. Overall, economic impacts include:

- Loss of business function (e.g., tourism, recreation)
- Damage to inventory (utility outages)
- Relocation costs, wage loss, and rental loss due to building damage

- Impacts to transportation that affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting and goods transport) needs
- Damage to utility infrastructure (power lines, gas lines, electrical systems) resulting in loss of power or heat, potentially impacting business operations and heating or cooling provision to the population
- Costly debris management operations for downed vegetation and removal of damaged construction materials

G. Impact on Natural and Cultural Resources

Tornadoes and high wind events can be destructive to the natural and local environment. Tornadoes can tear apart habitats, causing fragmentation across ecosystems. Overall, as the physical environment becomes more altered, species will begin to contract or migrate in response, which may cause additional stressors to the ecosystems within the Cape Fear Region.

H. Cascading Impacts on Other Hazards

Tornadoes can be accompanied by excessive precipitation, hail, and/or lightning. This precipitation often results in secondary hazards such as flooding or structural damage. Lightning can start wildfires. Strong winds can contribute to the rapid spread of a wildfire once ignited. Tornadoes and cyclones can impact various natural land resources that can be easily uprooted by major wind events and storm surge, increasing potential for erosion (USGS n.d.).

I. Future Changes that May Impact Regional Vulnerability to Hazard

It is anticipated that any new development and new residents will be exposed to tornadoes and high wind hazards. However, due to increased standards and codes, new development might be less vulnerable to wind-related hazards compared to older building stock.

Increased population trends in the region will increase the region's overall risk to tornadoes and high wind events.

XIII. WILDFIRE

A. Hazard Description

Wildfires are anticipated to increase in the Cape Fear Region due to increasing average temperatures and more severe drought caused by Climate Change; an increase in wildfires will pose multiple risks to human health and safety, including injuries, fatalities, poor air quality, and financial losses (K. D. Kunkel 2020). Wildfires can be highly destructive and difficult to control. They occur in forested, semi-forested, or less developed areas. Wildfires can result in the destruction of forests, brush, field crops, grasslands, real estate, and personal property, and have secondary impacts on other hazards such as flooding by removing vegetation and destroying watersheds. Wildfire events can range in size and intensity. A wildfire's intensity depends significantly on meteorological conditions and human activity. Three distinct types of wildland fires have been defined and include:

> One of the most widespread wildfires to occur in the region happened on April 19, 2016, in Brunswick County. The wildfire covered 1,578 acres and resulted in $2.3 million in crop damages. The fire was started by a resident burning debris.
>
> *Source: (National Centers for Environmental Information n.d.)*

- Naturally Occurring Wildfire
- Human-Caused Wildfire
- Prescribed (i.e., controlled) Wildfire

Climate Change Impacts

Higher temperatures are expected to increase the amount of moisture that evaporates from land and water. These changes have the potential to lead to more frequent and severe droughts, which, in turn, increases the likelihood of wildfires (Environmental Protection Agency n.d.). Longer periods of high temperatures and dry conditions and multi-year droughts could create triggers for wildfires. Increased temperature and change in precipitation will also affect fuel moisture during wildfire season and the length of time wildfires can burn during a given year (Vose, Peterson and Patel-Weynand 2012).

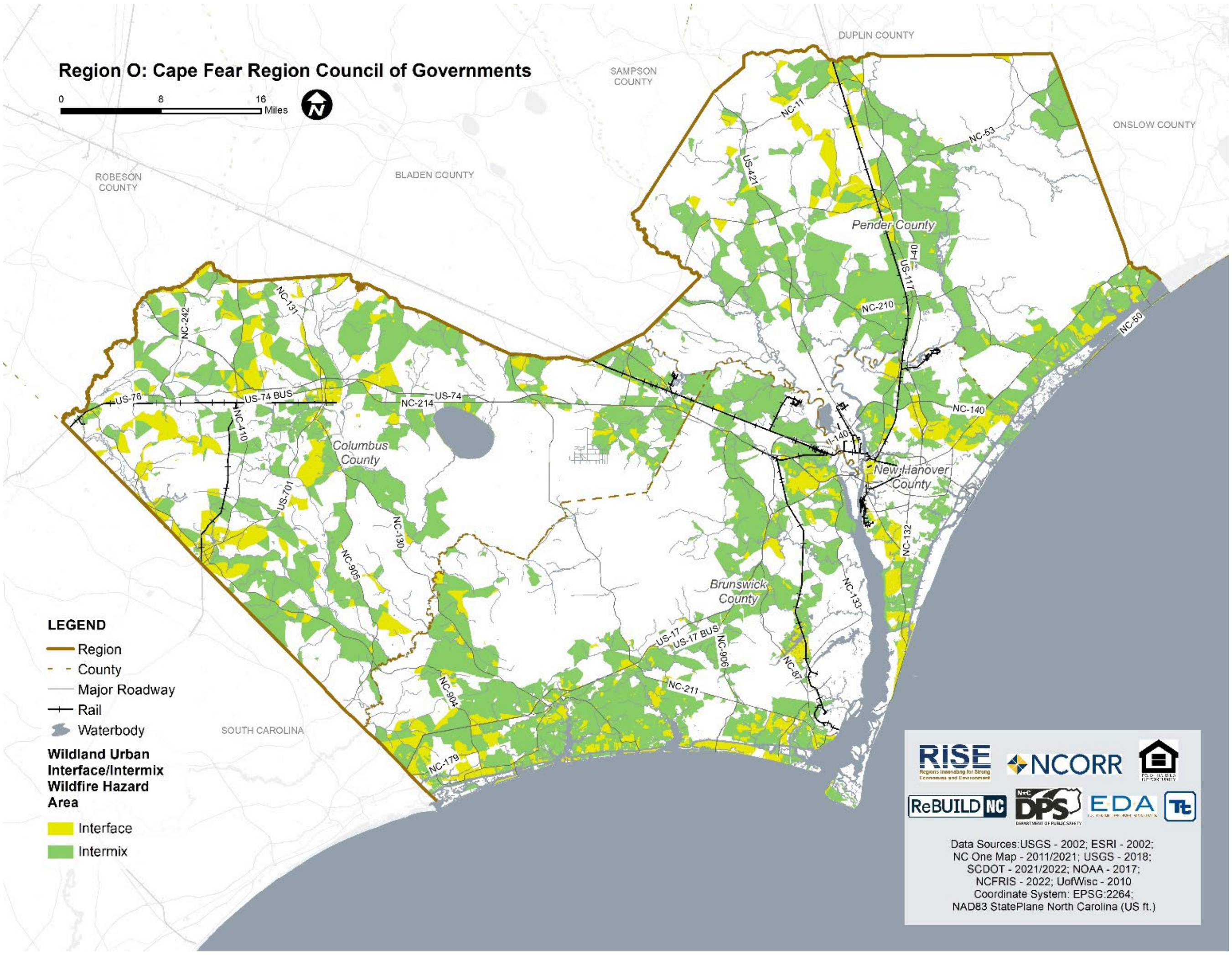
Climate change may also increase the frequency of lightning strikes. A warmer atmosphere holds more moisture, which is one of the key factors for triggering a lightning strike. Lightning strikes cause approximately half the wildfires in the United States. If the frequency of lightning strikes increases, the potential for wildfires from these strikes also increases.

B. Location and Extent

Wildfire events can occur in natural areas such as wetlands and forests and in development adjacent these areas. Areas where vegetation and trees have died due to drought or saltwater intrusion (ghost forests) have an increased risk for wildfire. However, according to the North Carolina Forest Service, careless debris burning is the leading cause of wildfires in North Carolina (North Carolina Forest Service n.d.).

In locations where people and property are near wildland areas, there is a higher risk due to the increased potential for injuries and property damages. ***Figure 24*** depicts areas in the region where vegetation and property are contiguous. These areas, known as the Wildland-Urban Interface and Intermix, signify areas with an increased risk of wildfire. North Carolina has the most acreage of Wildland-Urban Interface in the country (North Carolina Forest Service n.d.). Wildland-Urban Interface areas are transition zones, where unoccupied land transitions to developed land; these areas are shown in yellow. In Wildland-Urban Intermix areas, vegetation and development are combined; these areas are shown in green. Wildland-Urban Interface and Intermix areas are present throughout the entire region. There are large concentrations surrounding Leland and the coastal area of Brunswick County, the western region of Columbus County, the southern tip of New Hanover, and along the western, central, and coastal areas in Pender County.

Figure 24. Wildland-Urban Interface and Intermix



C. Impact on Public Health and Safety

Wildfires have the potential to impact human health and life of residents and responders, structures, infrastructure, and natural resources. Wildfires post a risk of death. The most vulnerable populations include emergency responders and those within a short distance of the interface between the built environment and the wildland environment. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

D. Impact on Housing and Critical Infrastructure

Buildings and critical facilities located in or adjacent to wooded areas are exposed and considered vulnerable to wildfires. Buildings constructed of wood or vinyl siding are generally more likely to be impacted by the fire hazard than buildings constructed of brick or concrete.

E. Impact on Economy

Wildfire can have major economic impacts on a community from the initial loss of structures and the subsequent loss of revenue from destroyed business. These events may cost thousands of taxpayer dollars to suppress and control and may involve hundreds of operating hours on fire apparatus and thousands of volunteer man hours from the volunteer firefighters. There are also many direct and indirect costs to local businesses that excuse volunteers from working in order to fight these fires.

F. Impact on Natural and Cultural Resources

According to the USGS, post-fire runoff polluted with debris and contaminants can be extremely harmful to the ecosystem and aquatic life. Studies show that urban fires in particular are more harmful to the environment compared to forest fires. (U.S. Geological Survey 2018)

G. Cascading Impacts on Other Hazards

Wildfires can increase the probability of other natural disasters, specifically floods and mudflows. Wildfires, particular large-scale fires, can dramatically alter the terrain and ground conditions, making land already devastated by fire susceptible to floods. Lands impacted by wildfire increase the risk of flooding and mudflow in those areas impacted by wildfire. Normally, vegetation absorbs rainfall, reducing runoff. However, wildfires leave the ground charred, barren, and unable to absorb water; thus, creating conditions perfect for flash flooding and mudflows. Flood risk in these impacted areas remains significantly higher until vegetation is restored, which can take up to five years after a wildfire (Federal Emergency Management Agency 2021).

Wildfires can often make flooding more severe, as debris and ash left from the fire can form mudflows. During and after a rain event, as water moves across charred and denuded ground, it can also pick up soil and sediment and carry it in a stream of floodwaters. These mudflows have the potential to cause significant damage to impacted areas. Areas directly affected by fires and those located below or downstream of burn areas are most at risk for flooding (Federal Emergency Management Agency 2016).

H. Future Changes that May Impact Regional Vulnerability to Hazard

Development in forested areas may expose more structures to the wildfire hazard in the Cape Fear region. Improved building codes and standards, as well as forest management strategies, may allow for decreased impacts to new structures.

The Cape Fear Region's population is expected to grow rapidly, exposing more people to the wildfire hazard. However, much of the growth is projected to be in the coastal areas, which will likely not have as much exposure to wildfire.

XIV. KEY TAKE-AWAYS FOR REGIONAL CLIMATE HAZARD RESILIENCE

The Cape Fear Region is vulnerable to a variety of hazards, which will worsen in the coming decades as a result of increasing climatic hazards. The land use patterns across the region are cause for concern as most development is concentrated in hazard-prone areas and therefore increases the percentage of the population exposed to hazards.

The following areas of concern or hotspots are significant in the area:

- **Coastal areas, beaches, barrier islands, and wetlands** – These natural features provide benefits for protection of life and property and environmental quality and habitat. However, these areas also have the greatest vulnerability throughout the region due to the compounding effects of erosion, flooding, hurricanes and severe storms, and sea level rise. Within the region these areas are most pronounced along the coastline of Brunswick, New Hanover, and Pender Counties. Additionally, these are the most populous areas of the region and therefore a larger percentage of the population is exposed to hazards when these natural areas are impacted.
- **Urban centers, such as Wilmington** – Urban areas have a disproportionate vulnerability due to the concentration of the population. Additionally, stress is placed on the infrastructure in urban areas due to the larger percentage of the population dependent upon that infrastructure. As infrastructure begins to age, impacts from hazards may be exacerbated due to failing infrastructure.
- **Inland areas with higher social vulnerability** – Areas outside of the coast and urban centers may not be at high risk to hazards impacting the region. However, vulnerability is increased in these areas due to barriers impacting the community's abilities to properly prepare for, respond, and recover from hazard impacts. Within the region the areas of Burgaw in Pender County and areas in northern Columbus County have high social vulnerabilities.

A. Future Conditions and Concerns

The 2020 North Carolina Climate Science Report projects that the state will experience several impacts from climate change, including increasing temperatures and sea level rise. These changes in climatic hazards will have cascading impacts resulting in more intense and frequent hazards. Rising temperatures will increase severe and tropical storms, resulting in increased flooding and erosion. Sea level rise will contribute to increased flooding, wetland migration, and more. Due to the nature of climatic hazards causing cascading effects on other hazards, resilience solutions must have multiple benefits and address multiple hazards. Climatic hazards will gradually appear; therefore, solutions must be long-term to align with the extended nature of climatic hazards. Regional solutions will position communities to implement solutions that address widespread hazards, such as extreme heat and sea level rise, rather than site-specific solutions which tend to lean more toward episodic events.

The projected 40% increase in the region's population will exacerbate several non-climate stressors. The region is already experiencing rapid population growth and development. While the majority of this growth is currently occurring in established cities and towns, continued population growth and development pressures will reach undeveloped areas and result in loss of open green space to impervious surface to accommodate the growing needs of the region. Increased development and impervious surface will increase the current stress on the region's aging stormwater and roadway infrastructure. These future changes in the region will be worsened as a result of climate change. Temperatures in the region are expected to rise. This coupled with increased impervious surface will increase high heat days and the urban heat island effect. Increasing precipitation will also result in additional runoff from increased impervious surfaces.

B. Considerations for Resilience Portfolio Development

This effort is meant to identify and address regional resilience issues on a longer time scale to include sudden natural disaster events, such as hurricanes and floods, as well as long-term concerns, such as sea-level rise. The following considerations for resilience solutions are based on data and concerns identified throughout the development of the vulnerability assessment:

- Conduct long-range planning to identify suitable areas for relocation.
- Clearly identify socially vulnerable populations in the region and ensure resources and support are prioritized and directed to these populations.
- Conduct educational campaigns to provide public awareness and education about hazards in areas that are densely populated, such as the coastline of the region. Current and new residents must understand the potential impacts to life, property, and the environment they face by residing in hazard-prone areas.
- Considering that approximately one-third of the region's critical facilities and structures are located within the floodplain, building codes should be evaluated to ensure they adequately address potential impacts from current and future hazards.

Appendix A: Figures, Maps, and Tables

Figure 25. Land Uses in Cape Fear Region

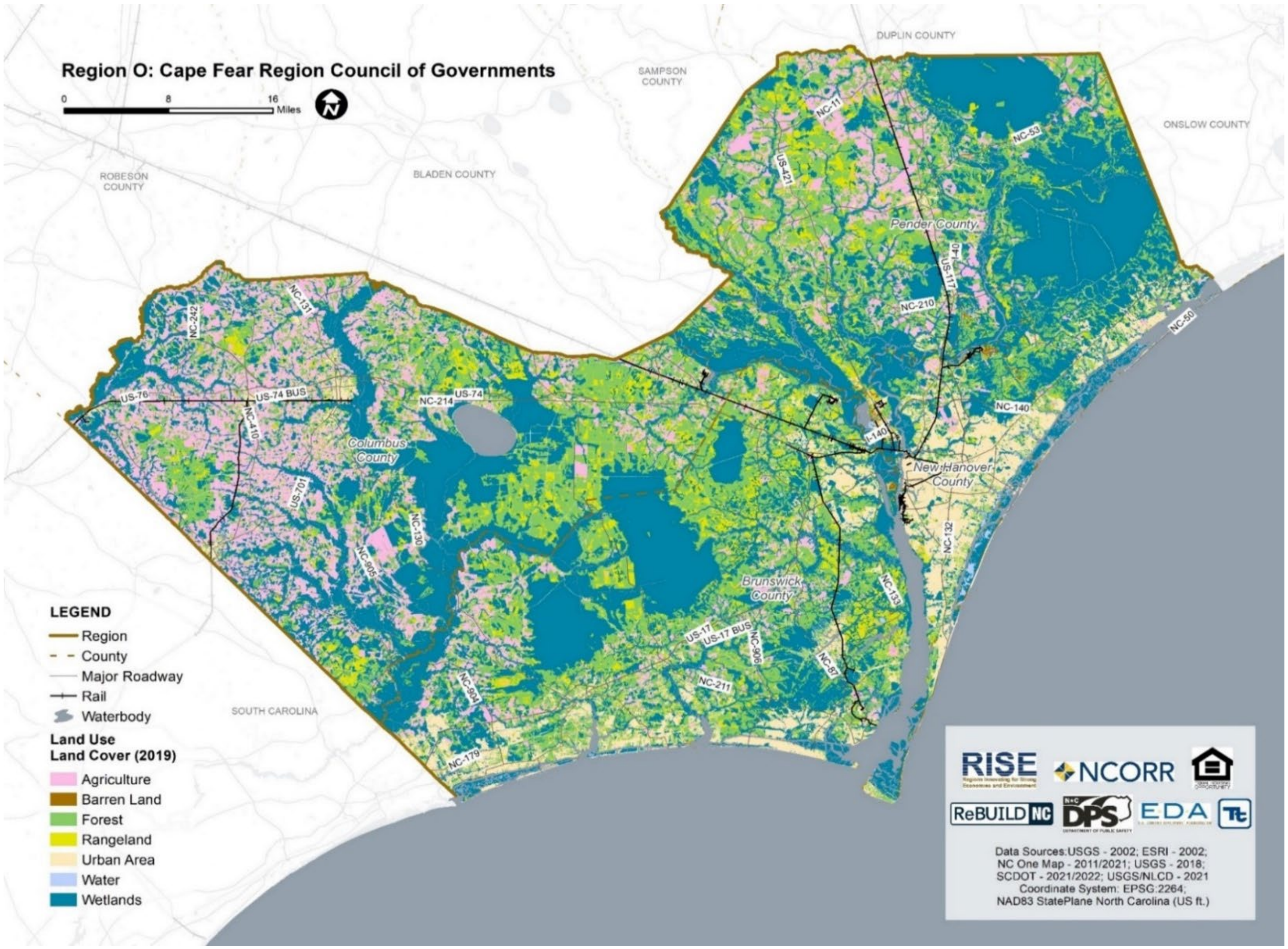


Figure 26. Transportation Network in Cape Fear Region

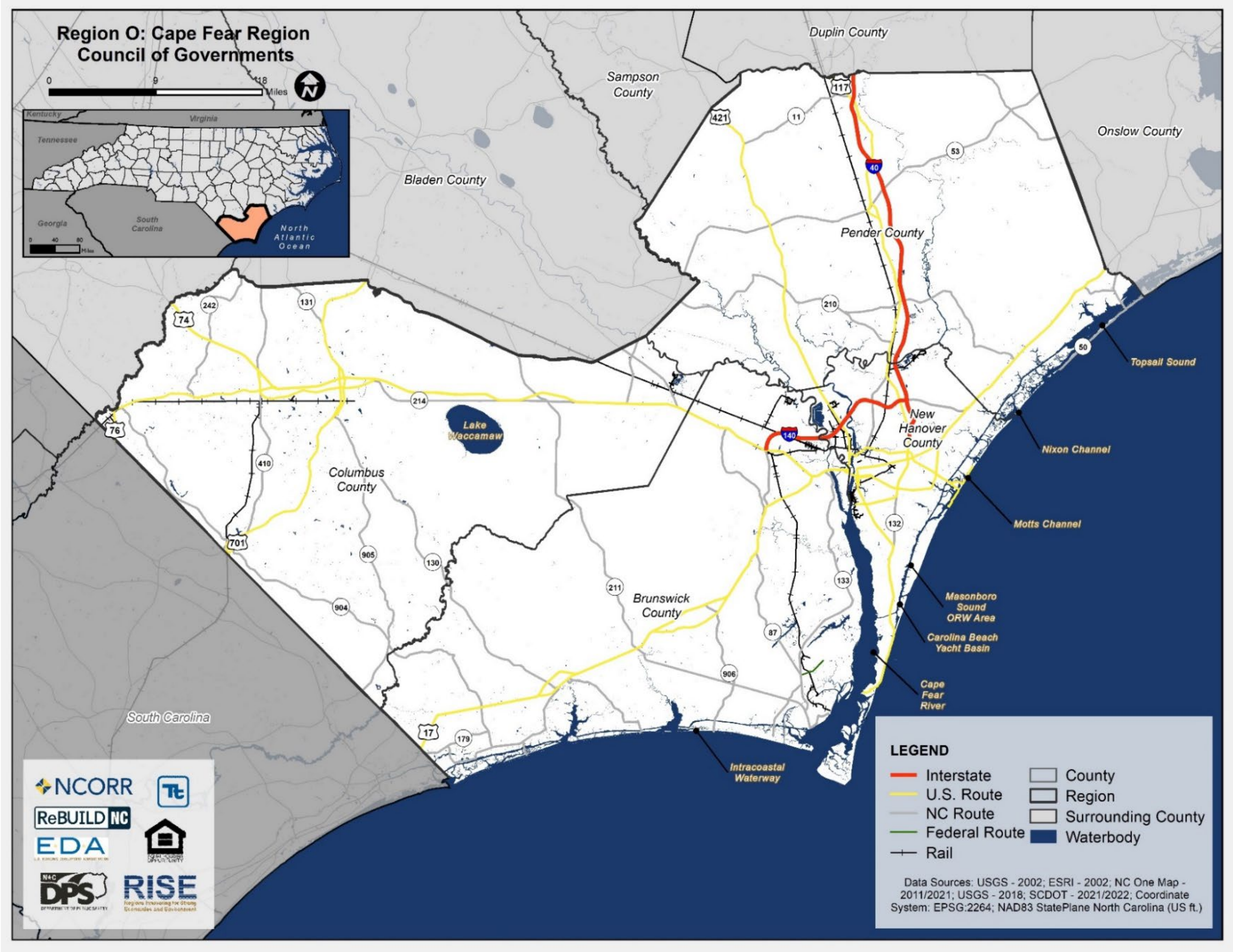


Figure 27. Mobile Homes Relative to Storm Surge

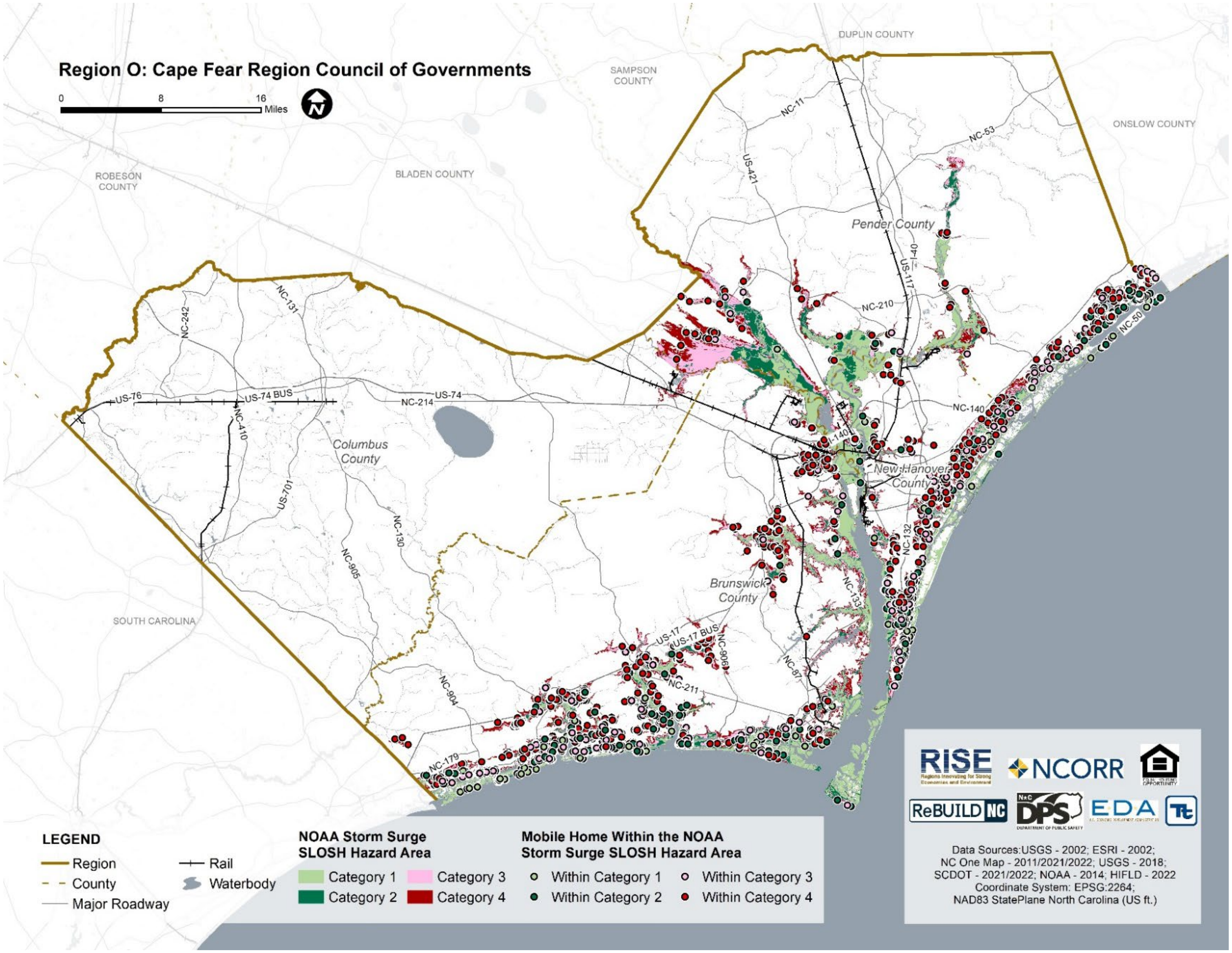


Figure 28. Mobile Homes Relative to the 2050 1 Percent Ann Chance Flood Hazard Area (1 foot Sea Level Rise)

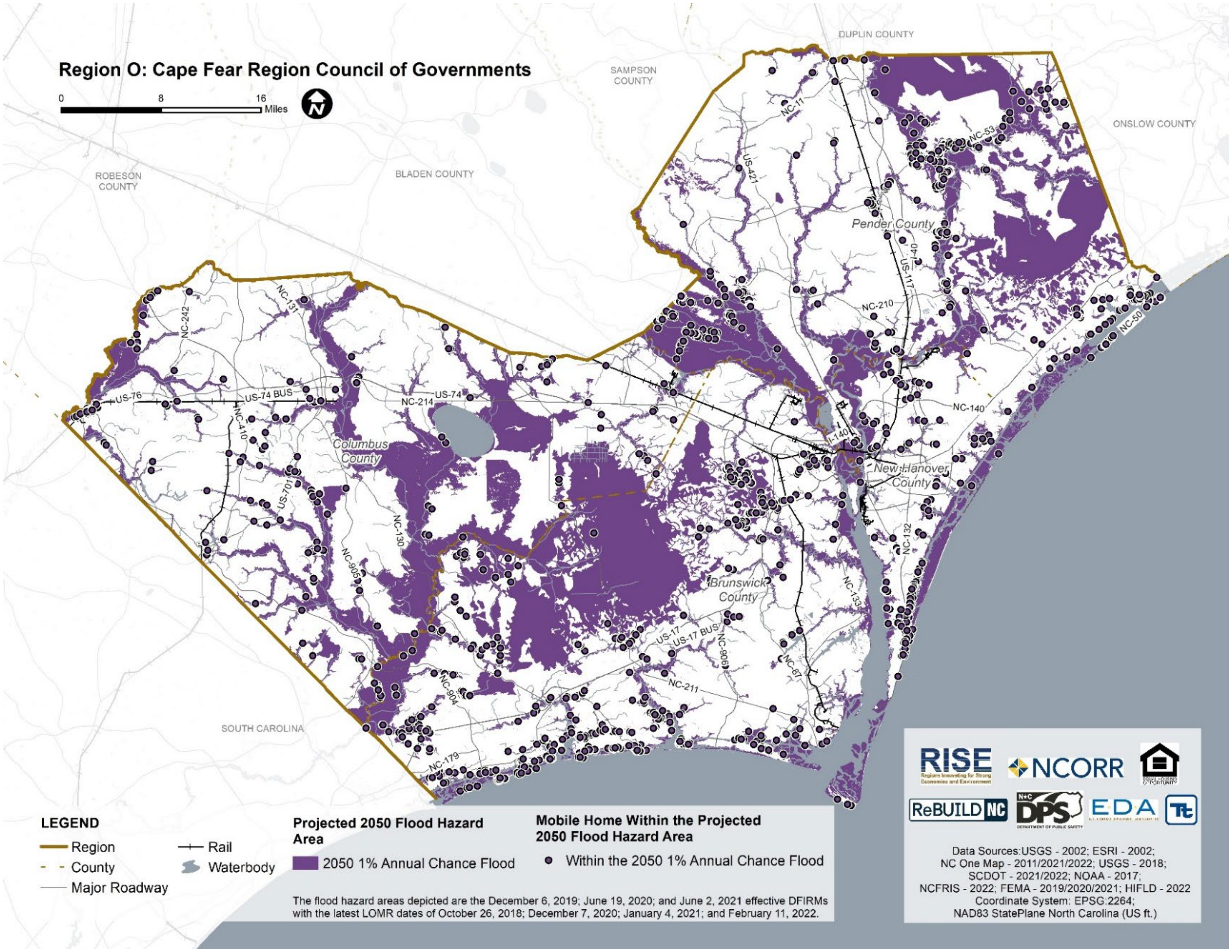


Figure 29. Building Built Prior to Modern Building Codes Relative to the 50-Year Mean Hurricane

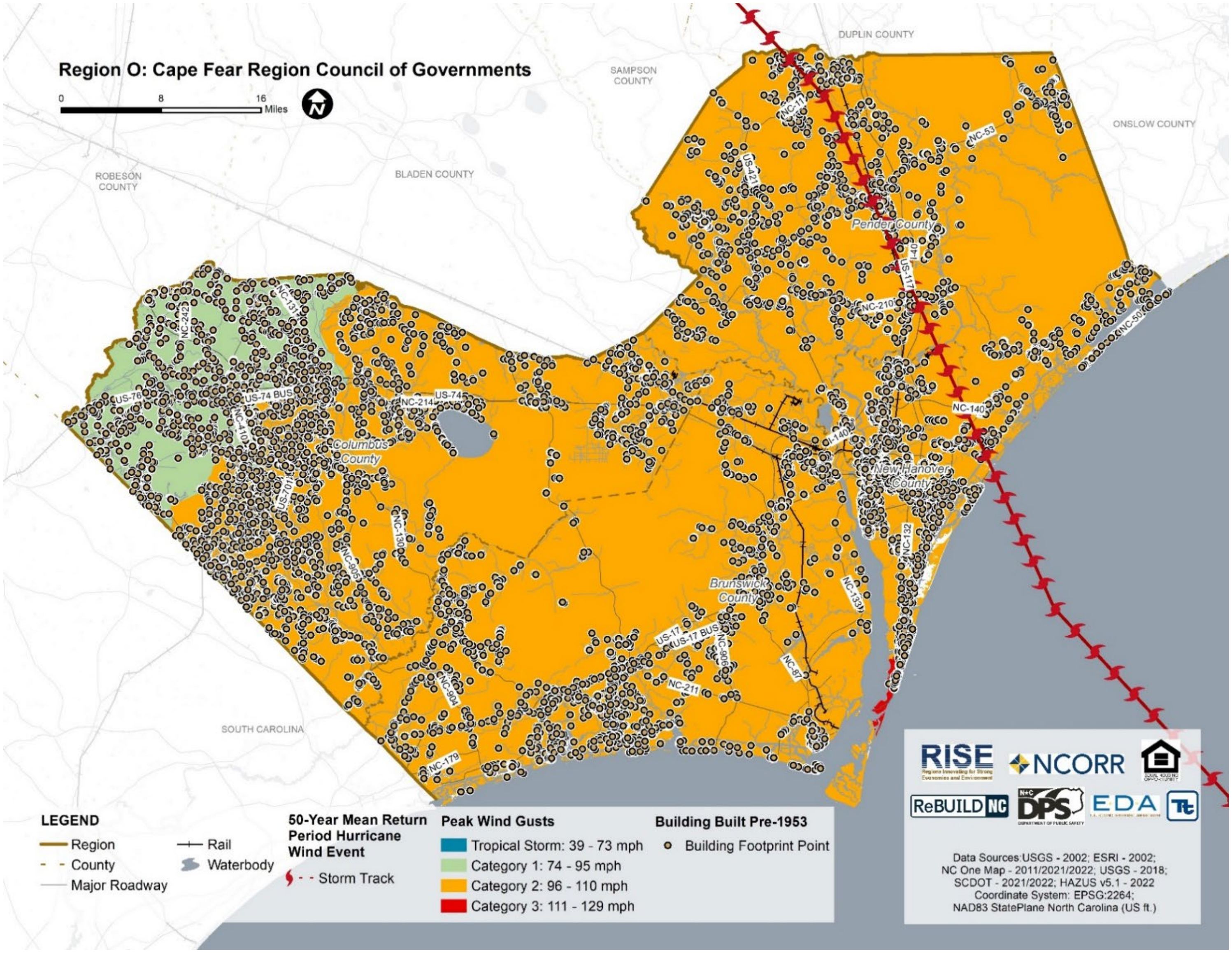


Table 9. Vulnerable Population in 1 Percent Annual Chance Flood Hazard Area

Counties	Total Population (2020 Decennial Census Population)	Total Vulnerable Population Located in the 1-Percent Annual Chance Flood Hazard Area								
		Total Population in Hazard Area	Vulnerable Population Category							
			Number of Persons Over 65	Number of Persons Below 5	Number of Persons Below Poverty Level	Number of Persons With a Disability	Number of Persons Limited English Speaking	Number of Persons without Vehicle	Number of Persons 16 and Over Commuting to Work with Public Transportation (excluding taxicab)	Number of Persons 16 and Over Commuting to Work by Walking
Brunswick County	136,693	49,932	14,693	1,931	5,626	7,828	197	772	74	174
Columbus County	50,623	14,239	3,076	810	3,404	2,943	79	425	12	54
New Hanover County	225,702	69,624	11,398	3,303	9,676	8,097	306	1,644	153	593
Pender County	60,203	20,925	3,723	1,181	2,897	3,368	118	271	41	68
Cape Fear Region (Total)	473,221	154,720	32,890	7,225	21,603	22,236	700	3,112	280	889

Sources: NCFRIS 2022; FEMA 2019/2020/2021; ACS 2019; Census 2020

Table 10. Vulnerable Population in 0.2 Percent Annual Chance Flood Hazard Area

Counties	Total Population (2020 Decennial Census Population)	Total Vulnerable Population Located in the 0.2-Percent Annual Chance Flood Hazard Area								
		Total Population in Hazard Area	Vulnerable Population Category							
			Number of Persons Over 65	Number of Persons Below 5	Number of Persons Below Poverty Level	Number of Persons With a Disability	Number of Persons Limited English Speaking	Number of Persons without Vehicle	Number of Persons 16 and Over Commuting to Work with Public Transportation (excluding taxicab)	Number of Persons 16 and Over Commuting to Work by Walking
Brunswick County	136,693	52,348	15,404	2,024	5,898	8,207	206	809	77	182
Columbus County	50,623	14,603	3,155	831	3,491	3,018	81	436	12	55
New Hanover County	225,702	77,815	12,739	3,691	10,815	9,049	342	1,838	171	662
Pender County	60,203	22,673	4,034	1,280	3,139	3,649	128	293	44	73
Cape Fear Region (Total)	473,221	167,439	35,332	7,826	23,343	23,923	757	3,376	304	972

Sources: NCFRIS 2022; FEMA 2019/2020/2021; ACS 2019; Census 2020

Table 11. Residential Pre-FIRM Buildings in 1 Percent Annual Chance Flood Hazard Area

Counties	Total Number of Buildings per County	Number of Pre-FIRM Residential Buildings in the 1-Percent Annual Chance Flood Hazard Area
Brunswick	95,334	5,515
Columbus	48,942	1,080
New Hanover	97,335	3,712
Pender	43,366	1,766
Cape Fear (Total)	284,977	12,073

Sources: NCFRIS 2022; FEMA 2019/2020/2021/2022; NC One Map 2021/2022

Table 12. Critical Facilities in the 1 Percent Annual Chance Flood Hazard Area

Total Number of Critical Facilities within the Region Located in the 1-Percent Annual Chance Flood Hazard Area											
			Facility Type								
Counties	Total Critical Facilities	Total Number of Critical Facilities in Hazard Area	Education Facilities	Healthcare Facilities	Historic and Cultural Resource Facilities	Facilities with Impacts to Public Health and Environmental Systems	Major Economic Development Asset Facilities	Public Service Facilities	Transportation Facilities	Utilities	Vulnerable Population Facilities
Brunswick County	542	72	-	6	4	1	13	8	13	23	4
Columbus County	345	23	-	5	-	-	1	5	2	9	1
New Hanover County	719	120	5	11	30	4	44	7	2	11	6
Pender County	251	27	1	3	7	-	4	6	1	2	3
Cape Fear Region (Total)	1,857	242	6	25	41	5	62	26	18	45	14

Sources: NCDCR - 2022; NC One Map - 2018/2019/2020/2021/2022; HIFLD - 2016/2018/2021/2022; FEMA 2019/2020/2021

Table 13. Critical Facilities in the 0.2 Percent Annual Chance Flood Hazard Area

Total Number of Critical Facilities within the Region Located in the 0.2-Percent Annual Chance Flood Hazard Area											
			Facility Type								
Counties	Total Critical Facilities Per County	Total Number of Critical Facilities Per County in Hazard Area	Education Facilities	Healthcare Facilities	Historic and Cultural Resource Facilities	Facilities with Impacts to Public Health and Environmental Systems	Major Economic Development Asset Facilities	Public Service Facilities	Transportation Facilities	Utilities	Vulnerable Population Facilities
Brunswick County	542	100	-	8	6	3	24	12	14	28	5
Columbus County	345	25	-	6	-	-	1	6	2	9	1
New Hanover County	719	142	5	15	31	4	48	9	2	18	10
Pender County	251	42	3	6	8	-	8	7	1	3	6
Cape Fear Region (Total)	1,857	309	8	35	45	7	81	34	19	58	22

Sources: NCDCR - 2022; NC One Map - 2018/2019/2020/2021/2022; HIFLD - 2016/2018/2021/2022; FEMA 2019/2020/2021

Table 14. Critical Infrastructure in 1 Percent Annual Chance Flood Hazard Area

Total Miles of Critical Infrastructure Located in the 1-Percent Annual Chance Flood Hazard Area				
Counties	Roadway	Rail	Evacuation (Roadway)	Evacuation (Ferry)
Brunswick County	32	1	18	-
Columbus County	21	7	10	-
New Hanover County	26	15	26	-
Pender County	35	-	25	-
Cape Fear Region (Total)	115	22	79	-

**Roadway only include transportation routes listed above in Route Class 1, 2, and 3.*
Sources: NCDOT - 2015/2020/2021; FEMA - 2019/2020/2021; NCFRIS - 2022

Table 15. Critical Infrastructure in 0.2 Percent Annual Chance Flood Hazard Area

Total Miles of Critical Infrastructure Located in the 0.2-Percent Annual Chance Flood Hazard Area				
Counties	Roadway	Rail	Evacuation (Roadway)	Evacuation (Ferry)
Brunswick County	41	1	23	-
Columbus County	23	9	12	-
New Hanover County	33	17	32	-
Pender County	44	-	30	-
Cape Fear Region (Total)	141	27	97	-

**Roadway only include transportation routes listed above in Route Class 1, 2, and 3.*
Sources: NCDOT - 2015/2020/2021; FEMA - 2019/2020/2021; NCFRIS – 2022

Table 16. Use of Buildings (or something simple like that) in 1 Percent Annual Chance Flood Hazard Area

Counties	Total Number of Buildings per County	Number of Buildings by General Occupancy Located in the 1-Percent Annual Chance Flood Hazard Area							
		General Occupancy							
		Residential	Commercial	Agricultural	Education	Religion	Government	Industrial	Vacant
Brunswick	95,334	13,558	370	45	4	25	20	72	10
Columbus	48,942	1,262	170	51	8	24	9	8	257
New Hanover	97,335	9,653	440	20	33	20	66	175	30
Pender	43,366	5,598	670	153	9	20	18	28	1
Cape Fear Region (Total)	284,977	30,071	1,650	269	54	89	113	283	298

Sources: NCFRIS 2022; FEMA 2019/2020/2021; NC One Map 2021/2022

Table 17. General Building Occupancy in 0.2 Percent Annual Chance Flood Hazard Area

Counties	Total Number of Buildings per County	Number of Buildings by General Occupancy Located in the 0.2-Percent Annual Chance Flood Hazard Area							
		General Occupancy							
		Residential	Commercial	Agricultural	Education	Religion	Government	Industrial	Vacant
Brunswick	95,334	18,175	613	51	5	44	41	106	10
Columbus	48,942	1,642	212	59	8	26	11	17	316
New Hanover	97,335	14,729	588	24	35	32	138	217	49
Pender	43,366	6,524	723	215	23	29	22	44	1
Cape Fear Region (Total)	284,977	41,070	2,136	349	71	131	212	384	376

Sources: NCFRIS 2022; FEMA 2019/2020/2021; NC One Map 2021/2022

Table 18. Mobile Homes in the 1 Percent Annual Chance Flood Hazard Area

Counties	Total Number of Mobile Home Parks per County	Total Number of Mobile Home Buildings per County	Number of Mobile Home Parks and Mobile Home Buildings Located in the 1-Percent Annual Chance Flood Hazard Area	
			Number of Mobile Home Parks	Number of Mobile Home Buildings
Brunswick	59	21,634	2	1,231
Columbus	9	11,034	-	251
New Hanover	52	6,803	-	342
Pender	26	9,451	3	951
Cape Fear Region (Total)	146	48,922	5	2,775

Sources: NCFRIS 2022; FEMA 2019/2020/2021; NC One Map 2021/2022; HIFLD 2022

Table 19. Mobile Homes in the 0.2 Percent Annual Chance Flood Hazard Area

Counties	Total Number of Mobile Home Parks per County	Total Number of Mobile Home Buildings per County	Number of Mobile Home Parks and Mobile Home Buildings Located in the 0.2-Percent Annual Chance Flood Hazard Area	
			Number of Mobile Home Parks	Number of Mobile Home Buildings
Brunswick	59	21,634	3	2,064
Columbus	9	11,034	-	284
New Hanover	52	6,803	3	880
Pender	26	9,451	3	1,214
Cape Fear Region (Total)	146	48,922	9	4,442

Sources: NCFRIS 2022; FEMA 2019/2020/2021; NC One Map 2021/2022; HIFLD 2022

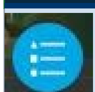
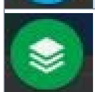
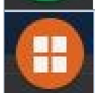
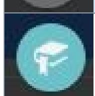
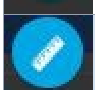
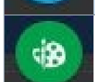
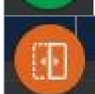
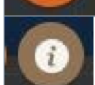
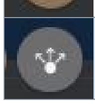
Sources: NCDCR - 2022; NC One Map - 2018/2019/2020/2021/2022; HIFLD - 2016/2018/2021/2022; FEMA 2019/2020/2021

Appendix B: Mapping Solution

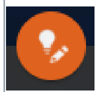
The RISE Regional Resilience Portfolio program aims to support resilience efforts throughout the region by engaging local leaders and the community. The web map in combination with the vulnerability assessment bridges science and local knowledge to identify current and future hazards impacting the region. The vulnerability assessment profiles natural hazards and climate risks, provides an analysis of the hazards' impacts on the region, and provides key takeaways for building resilience across the region. The web map is a companion tool to allow users to further explore hazard data and the exposure of critical assets throughout the region. The webmap can be accessed at: Cape Fear Region - Resilience Portfolio Web Map (arcgis.com)[4].

The table below provides an overview of the symbols available in the application:

Table 20: Map Symbology

Icon	Explanation
	Click on this tool to view the legend of layers shown in the web map.
	Click on this tool to turn layers on and off, open the attribute table, or view the layer's information to download the data.
	Click on this tool to change the basemap.
	Click on this tool to print out a static copy of the web map.
	Click on this tool to add data to the web map.
	Click on this tool to bookmark a location on the web map.
	Click on this tool to measure a length on the web map.
	Click on this tool to draw on the web map.
	Click on this tool to swipe one or more layers on the web map.
	Click on this tool for more information about the tools available in this web map.
	Click on this tool to share this web map.

[4] https://tt-mmi.maps.arcgis.com/apps/webappviewer/index.html?id=ffa36af9b65e4960a04e74144c7ac8f2

Icon	Explanation
	Click on this tool to add a note or delete a note you have added to the web map. You are encouraged to add comments about the data shown in the web map, which will be shared with other viewers of the web map.
	Click on this tool to select data shown on the web map. You may use this tool to extract and export data.

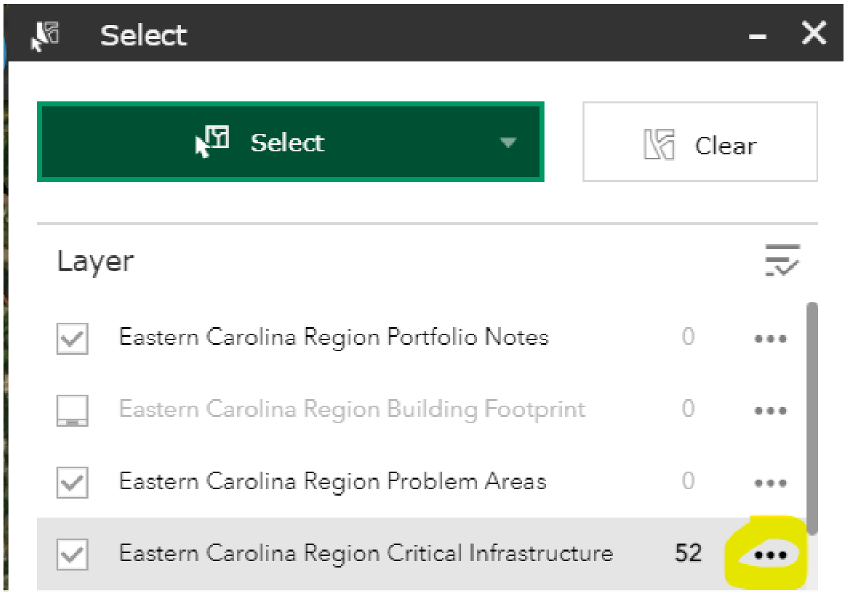
The following layers are available on the maps to visualize the identified hazards:

Table 21: Map Layers and Hazards

Layer	Hazard
Urban Heat Island	Extreme Temperature
• Wildland Urban Interface Wildfire Hazard Area • Wildland Urban Intermix Wildfire Hazard Area	Wildfire
• Storm Surge SLOSH Category 1 • Storm Surge SLOSH Category 2 • Storm Surge SLOSH Category 3 • Storm Surge SLOSH Category 4 • Projected 2050 1-Percent Annual Chance Flood Event • 1-Percent Annual Chance Flood Event • 0.2-Percent Annual Chance Flood Event	Flood
• Storm Surge SLOSH Category 1 • Storm Surge SLOSH Category 2 • Storm Surge SLOSH Category 3 • Storm Surge SLOSH Category 4	Hurricanes and Severe Storms
Short-Term (~30 Year) Historical Shoreline Change Rates Short-Term (~30 Year) Historical End Point Shoreline Change Rates Marsh Migration Zone with 1-Foot Sea Level Rise Marsh Migration Zone with 0-Foot Sea Level Rise	Erosion
Marsh Migration Zone with 1-Foot Sea Level Rise Marsh Migration Zone with 0-Foot Sea Level Rise	Sea Level Rise

Once you have selected the features using the Select Tool, click on the ellipses next to the layer you would like to extract. You can only extract layers that have a value greater than 0 next to the ellipses.

Figure 30: Layer Extraction



The following data sources were used to build the webmap application:

Table 22: Data Sources for Webmap

Data	Source	Date
Social Vulnerability Index	CDC/ATSDR SVI	2018
Building Footprints	NCEM	2020
Parcel Boundaries	NC One Map	2021/2022
Critical facilities	NC OneMap; HIFLD	2011/2016/2018/2019; 2020/2021/2022
2019 Land Cover	USGS/NLCD	2021
Marsh Migration	NOAA	2016
Erosion Rate	USGS; NC Division of Coastal Management	2017;2020
Urban Heat Island	The Trust for Public Land	2019
Digitized Effective FIRM maps	NCFRIS; FEMA	2022; 2018/2019/2020/2021
Sea Level Rise	NOAA	2017
Sea-Lake Overland Surge from Hurricanes (SLOSH) Model	NOAA	

Appendix C: References

Agency for Toxic Substance and Disease Registry. 2021. *CDC/ATSDR Social Vulnerability Index.* 08 30. Accessed 06 10, 2022. https://www.atsdr.cdc.gov/placeandhealth/svi/at-a-glance_svi.html.

American Community Survey. 2019. *2015 - 2019 American Community Survey 5-Year Estimates.*

2020. *Bladen, Columbus, Robeson Regional Hazard Mitigation Plan.* April.

Brunswick County. 2022. "Driving Creek Fire in Green Swamp Preserve of Brunswick County 100% Contained." May 17. https://www.brunswickcountync.gov/updates-on-green-swamp-wildfire-may-2022/.

Cappucci, Matthew. 2021. "NOAA Mulls Moving Start of Atlantic Hurricane Season Up to May 15." *Washington Post*, February 16.

CDC. 2020. *https://www.cdc.gov/ncbddd/disabilityandhealth/disability.html.*

Centers for Disease Control and Prevention. n.d. Accessed 2022.

—. 2021. *Use Safe Water After a Natural Disaster or Emergency.* September 20. Accessed April 26, 2022. https://www.cdc.gov/disasters/foodwater/safe-water.html.

CRS Community Self-Assessment. n.d. *What is a critical facility?* Accessed 06 10, 2022. https://crsselfassessment.us/what-is-a-critical-facility/.

Environmental Protection Agency. n.d. *Climate Change Indicators: Weather and Climate.* Accessed April 26, 2022. https://www.epa.gov/climate-indicators/weather-climate.

Federal Emergency Management Agency. 2021. *Flood Risks Increase After Fires.* March 22. Accessed April 26, 2022. https://www.fema.gov/fact-sheet/flood-risks-increase-after-fires.

—. n.d. *Floodplain Management: Principles and Current Practices.* Accessed 2018. https://training.fema.gov/hiedu/aemrc/courses/coursetreat/fm.aspx.

—. n.d. *Glossary.* Accessed 06 10, 2022. https://www.fema.gov/about/glossary.

—. 2019. *Guidance for Flood Risk Analysis and Mapping: Coastal Structures.* November. Accessed April 26, 2022. https://www.fema.gov/sites/default/files/2020-02/Coastal_Structures_Guidance_Nov_2019.pdf.

—. n.d. *National Risk Index.* Accessed 06 10, 2022. https://hazards.fema.gov/nri/exposure.

—. 2016. *Rebuilding After a Wildfire.* Accessed April 26, 2022. https://www.fema.gov/sites/default/files/2020-10/fema_rebuidling-after-a-wildfire_factsheet_2016.pdf.

Intergovernmental Panel on Climate Change. 2016. *Food Security: "Drought".* Accessed April 26, 2022. https://www.ipcc.ch/srccl/.

Kingsley, Marianne, and EcoHealth Ontario. “Commentary - Climate change, health and green space co-benefits.” “Commentaire - Changements climatiques, santé et avantages connexes des espaces verts." Health promotion and chronic disease prevention in Canada. 2019. "Kingsley, M., & EcoHealth Ontario (2019). Commentary - Climate change, health and green space co-benefits. Commentaire - Changements climatiques, santé et avantages connexes des espaces verts. Health promotion and chronic disease prevention in Canada : re." *Health Promot Chronic Dis Prev Can*, April. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6553580/.

Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. Dissen,. 2020. *2020: North Carolina Climate Science Report.* North Carolina Institute for Climate Studies.

Merriam-Webster. 2022. Accessed 06 10, 2022. https://www.merriam-webster.com/.

Morrison, Jim. 2021. *Smithsonian Magazine.*

National Centers for Environmental Information. n.d. *Storm Events Database.* Accessed June 27, 2022. https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Cold%2FWind+Chill&eventType=%28Z%29+Excessive+Heat&eventType=%28Z%29+Extreme+Cold%2FWind+Chill&eventType=%28Z%29+Heat&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=1950&endDate_mm=01&.

National Integrated Drought Information System. n.d. *Historical Data and Conditions.* Accessed May 4, 2022. https://www.drought.gov/historical-information?state=north-carolina&dataset=0&selectedDateUSDM=20070911.

National Oceanic and Atmospheric Administration. n.d. *Cape Fear.* Accessed April 26, 2022.

National Oceanic And Atmospheric Administration. n.d. *Data Tools: 1981 - 2010 Normals.* Accessed April 26, 2022. https://www.ncdc.noaa.gov/cdo-web/datatools/normals.

National Oceanic and Atmospheric Administration. n.d. "Thunderstorms, Tornadoes, Lightning... Nature's Most Violent Storms."

—. n.d. *What is a barrier island?* Accessed June 21, 2022. https://oceanservice.noaa.gov/facts/barrier-islands.html#:~:text=These%20islands%20are%20critical%20to,less%20flooding%20on%20the%20coast.

National Oceanic and Atmospheric Adminstration. 2021. *What is meant by the term drought?* March 12. Accessed April 26, 2022. https://www.weather.gov/bmx/kidscorner_drought.

nature.com. 2020. *More meteorological events that drive compound coastal flooding are projected under climate change.* 05 08. Accessed 06 10, 2022. https://www.nature.com/articles/s43247-020-00044-z#:~:text=Compound%20flooding%20arises%20from%20storms%20causing%20concurrent%20extreme,can%20severely%20affect%20densely%20populated%20low-lying%20coastal%20areas.

NCSU. n.d. *Thunderstorms.* Accessed 04 17, 2022. https://climate.ncsu.edu/learn/thunderstorms/.

NIST. 2011. *Wind Zone Map.* 09 13. Accessed 04 17, 2022. https://www.nist.gov/image/windzonemapjpg.

NOAA. 2012. *Global Sea Level Rise Scenarios for the United States National Climate Assessment.* 12 06. Accessed 04 17, 2022. http://cpo.noaa.gov/sites/cpo/Reports/2012/NOAA_SLR_r3.pdf.

NOAA SPC. n.d. *The Online Tornado FAQ.* Accessed 04 01, 2022. https://www.spc.noaa.gov/faq/tornado/.

North Carolina Department of Environmental Quality. n.d. *Wetlands.* Accessed April 26, 2022. https://deq.nc.gov/about/divisions/coastal-management/estuarine-shorelines/wetlands.

North Carolina Department of Health and Human Services. n.d. "North Carolina Climate and Health Profile." https://epi.dph.ncdhhs.gov/oee/climate/ClimateAndHealthProfile.pdf.

North Carolina Division of Emergency Management. 2017. *North Carolina Floodplain Management 2017 Quick Guide.* Accessed April 26, 2022. https://flood.nc.gov/NCFLOOD_BUCKET/FAQS/QuickGuideTopic/NCQuickGuide2017.pdf.

North Carolina Environmenal Quality. 2019. *Oceanfront Construction Setback and Erosion Rates.* Accessed April 26, 2022. https://deq.nc.gov/about/divisions/coastal-management/coastal-management-oceanfront-shorelines/oceanfront-construction-setback-erosion-rate.

North Carolina Forest Service. n.d. *The Wildland/Urban Interface.* Accessed June 27, 2022. https://www.ncforestservice.gov/fire_control/fc_wui.htm.

—. n.d. *Wildfire/Emergency Response Situation Report.* Accessed June 27, 2022. https://www.ncforestservice.gov/fire_control/sit_report.htm.

North Carolina Geologic Survey. 1985. *Geologic Map of North Carolina.* Accessed April 26, 2022. https://ncdenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a8281cbd24b84239b29cd2ca798d4a10.

North Carolina Office of State Budget and Management. 2022. *County/State Population Projections.* February 15. Accessed April 26, 2022. https://www.osbm.nc.gov/facts-figures/population-demographics/state-demographer/countystate-population-projections.

North Carolina State Climate Office. n.d. *Weather Extremes.* Accessed June 27, 2022. https://products.climate.ncsu.edu/extremes/.

North Carolina State Disaster Recovery Task Force - Housing Recovery Support Function. 2020. "Improving Housing Recovery and Resilience in North Carolina." March.

North Carolina State Parks. n.d. *Lake Waccamaw State Park Fact Sheet.*

North Carolina State University. 2013. *Temperatures Moderate and Drought Abates in April.* May 10. Accessed April 26, 2022. https://climate.ncsu.edu/blog/2013/05/climate-summary-april-2013/.

—. n.d. *Thunderstorms.* Accessed April 26, 2022. https://climate.ncsu.edu/learn/thunderstorms/.

Orona, John. 2022. "These 4 Brunswick County towns are among the fastest growing in North Carolina." *Wilmington StarNews.* June 2. https://www.starnewsonline.com/story/news/2022/06/02/brunswick-county-growth-since-pandemic-among-best-state/9966510002/.

—. 2022. "These 4 Brunswick County towns are among the fastest growing in North Carolina." *Wilmington StarNews*, June 2. https://www.starnewsonline.com/story/news/2022/06/02/brunswick-county-growth-since-pandemic-among-best-state/9966510002/?ac_cid=DM655329&ac_bid=84823224.

Port of Wilmington. n.d. *Economic Impact.* Accessed April 27, 2022. https://www.portofwilmington.com/economic-impact.html.

SeaLevelRise.org. n.d. *North Carolina's Sea Level Is Rising.* Accessed June 20, 2022. https://sealevelrise.org/states/north-carolina/.

Sessoms, Ben. 2022. "Fixing Local Flooding When Feds Deny It's In A Flood Plain." *Carolina Public Press.*

U.S. Census Bureau. 2010.

U.S. Census Bureau. 2020. *2020 Decennial Census .*

U.S. Climate Resilience Toolkit. 2022. *Sea Level Rise.* 04 19. Accessed 06 10, 2022. https://toolkit.climate.gov/topics/coastal-flood-risk/sea-level-rise.

U.S. Department of Homeland Security. 2022. *Critical Infrastructure.* 01 27. Accessed 06 10, 2022. https://www.dhs.gov/science-and-technology/critical-infrastructure.

U.S. Environmental Protection Agency. 2021. *Climate Change Indicators: Sea Level.* April. Accessed April 26, 2022. https://www.epa.gov/climate-indicators/climate-change-indicators-sea-level#:~:text=When%20averaged%20over%20all%20of,as%20the%20long%2Dterm%20trend.

—. 2017. *Climate Impacts on Coastal Areas.* 01 19. Accessed April 26, 2022. https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-coastal-areas_.html.

U.S. Forest Service. n.d. *Effects of Drought on Forests and Rangelands.* Accessed April 26, 2022. https://www.fs.usda.gov/ccrc/topics/effects-drought-forests-and-rangelands.

U.S. Geological Survey. n.d. *Coastal Change Hazards Portal.* Accessed April 26, 2022. https://marine.usgs.gov/coastalchangehazardsportal/.

—. 2018. *Water Quality After a Wildfire.* March 6. Accessed April 26, 2022. https://www.usgs.gov/mission-areas/water-resources/science/water-quality-after-wildfire.

United States Environmental Protection Agency. 2022. *Land Cover.* 05 11. Accessed 06 10, 2022. https://www.epa.gov/report-environment/land-cover.

—. 2021. *Land Use.* 09 07. Accessed 06 10, 2022. https://www.epa.gov/report-environment/land-use.

—. n.d. *Principles of Watershed Management.* Accessed 06 10, 2022. https://cfpub.epa.gov/watertrain/pdf/modules/watershed_management.pdf#:~:text=WATERSHED%20ACADEMY%20WEB%20Principles%20of%20Watershed%20Management.%20http%3A%2F%2Fwww.epa.gov%2Fwatertrain,a%20common%20stream%2C%20river%2C%20or%20lake%20%28Figure%207%29.

United States Geological Survey. 2019. *Science in Your Watershed.* 10 22. Accessed 06 10, 2022. https://water.usgs.gov/wsc/glossary.html#R.

—. 2019. *Suface-Water Use.* 3 2. Accessed 06 10, 2022. https://www.usgs.gov/mission-areas/water-resources/science/surface-water-use.

—. 2018. *Water Quality Information by Topic.* 11 13. Accessed 06 10, 2022. https://www.usgs.gov/special-topics/water-science-school/science/water-quality-information-topicv.

—. n.d. *What is groundwater?* Accessed 06 10, 2022. https://www.usgs.gov/faqs/what-groundwater.

United States Global Change Research Program. n.d. *U.S. Climate Resilience Toolkit.* Accessed June 22, 2022. https://toolkit.climate.gov/content/glossary.

Visit North Carolina. 2021. *2020 Impact of Visitor Spending by Sector.* Accessed April 26, 2022. https://partners.visitnc.com/contents/sdownload/72139/file/2020-Visitor-Spending-by-Sector.pdf.

Vose, James M., David L. Peterson, and Toral, Patel-Weynand. 2012. "Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S."