

North Carolina

Climate Risk Assessment and Resilience Plan

Impacts, Vulnerability, Risks, and Preliminary Actions

A Comprehensive Strategy for Reducing North Carolina's Vulnerability to Climate Change

June 2020



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Message from Governor Cooper

From the mountains to the coast, North Carolina is a place of hardworking, resilient people and great natural beauty. In recent years we've faced unprecedented challenges, from hurricanes and flooding to a global pandemic and economic downturn. Climate change is also testing our mettle and affecting everyday life.

We're still recovering from the damage and loss of life inflicted by two 500-year storms—Hurricane Florence and Hurricane Matthew— that hit our state within 23 months of each other. The last ten years are the warmest on record for North Carolina, and 2019 was the single hottest year. Severe storms, flooding, high temperatures, drought, and other climate stressors impact our health, safety, economy and quality of life. They contribute to crop and livestock loss, destroy endangered species and critical habitats, damage government buildings and land, disrupt business operations and economic activity and threaten our state's transportation infrastructure, cultural resources, and energy and water utilities.

As we continue to discover the many ways climate change threatens daily life for North Carolinians, we must take actions that reduce air pollution and increase resilience. Those actions can also create good paying jobs. That is why North Carolina is investing in rural and urban communities, advancing clean energy, transitioning to zero-emission vehicles, and strengthening natural infrastructure. It's also why we are supporting local governments, updating state assets, and investing in a resilient business environment. A resilient North Carolina is a strong and competitive North Carolina.

The latest climate science underscores what we already know firsthand. There will be increased temperatures, continued sea level rise, more precipitation, more intense hurricanes, more severe thunderstorms, and more storm surge flooding.

The good news is that we know the key cause of climate change—greenhouse gas emissions from human activities—and we can help control our own fate while boosting the economy. We can reduce greenhouse gas emissions and reduce our vulnerability to negative climate change impacts. In response to the Climate Crisis, I issued Executive Order No. 80 to call for a 40% drop in statewide greenhouse gas emissions by 2025, establish the North Carolina Climate Change Interagency Council, and direct state agencies to take actions that reduce emissions and strengthen our state. One of those actions is the development of this North Carolina Climate Change Risk Assessment and Resilience Plan.

This plan helps us better understand our vulnerability to climate change and how we can become more resilient to future impacts. It builds upon North Carolina's ongoing work in this area and establishes the North Carolina Resilience Strategy, which includes four elements: (1) the *North Carolina Climate Science Report*, (2) State Agency Resilience Strategies, (3) Statewide Vulnerability Assessment and Resilience Strategies, and (4) the North Carolina Enhanced Hazard Mitigation Plan.

This *Risk Assessment and Resilience Plan* is the culmination of more than a year's worth of work by state agencies and stakeholders, and I thank all who contributed to its thoughtful development. This strategic document reflects the commitment we share in creating a North Carolina where folks are healthier, better educated, and have more money in their pockets so they have opportunities to live more abundant and purposeful lives.

Governor Roy Cooper

Contents

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Executive Summary

From the world-famous Outer Banks and the majestic Blue Ridge Mountains to the 18 million acres of forest and abundant agricultural resources, North Carolina is famous for its natural beauty and diversity. We are also known for our strong communities and our resilient people. These attributes make North Carolina one of the most visited tourism destinations and one of the top five states for people looking for a new place to call home.

While we enjoy all that North Carolina has to offer, our communities, economy, environment, and natural resources are increasingly at risk from the impacts of climate change. Our state has suffered from multiple natural disasters in recent years. Storms are becoming stronger and more intense, creating an enormous toll on human life, health and our economy. Hurricane Dorian in 2019 was the third significant hurricane to impact the state following Hurricanes Matthew (2016) and Florence (2018). These storms have cost lives, along with billions of dollars in damage and inflicted psychological stress on those whose lives and livelihood have been disrupted many times over.

A resilient North Carolina is a state where our communities, economies, and ecosystems are better able to rebound, positively adapt to, and thrive amid changing conditions and challenges, including disasters and climate change; to maintain quality of life, healthy growth, and durable systems; and to conserve resources for present and future generations

To make North Carolina more resilient to both climate and non-climate related stressors, Governor Roy Cooper signed Executive Order 80 (EO80) on October 29, 2018, calling for integration of climate adaptation and resilience planning into cabinet agency policies, programs, and operations. The order directed the Department of Environmental Quality (DEQ), with support of other agencies and stakeholders, to prepare the North Carolina Climate Risk Assessment and Resilience Plan (2020 Resilience Plan) and for the Climate Change Interagency Council to submit to the Governor in March 2020. EO80 called for agencies to develop resilience strategies that support communities and sectors of the economy most vulnerable to the effects of climate change and to enhance the state government's ability to protect human life and health, property, natural and built infrastructure, cultural resources, and other public and private assets of value to North Carolinians.

In response to the order, DEQ enlisted assistance from the North Carolina Institute for Climate Studies at North Carolina State University to provide the current state of climate science and change. Representatives from many major higher education institutions in the state and other subject matter experts with national recognition contributed to the development of the North Carolina Climate Science Report (NCCSR). One key finding of the NCCSR is that, "*our scientific understanding of the climate system strongly supports the conclusion that large changes in North Carolina's climate, much larger than at any time in the state's history, are very likely (90–100% probability of outcome) by the end of this century...*". State agencies developing the 2020 Resilience Plan referenced the key findings and executive summary from the NCCSR (contained in Chapter 3) to understand the historical and projected climate trends and how they will impact state assets, programs, and services.

DEQ also enlisted the assistance of federal partners, state universities, local governments, community planners, non-governmental organizations, climate justice leaders, stakeholders interested in nature-based solutions (NBS), and other interested partners to help cabinet agencies develop the 2020 Resilience Plan.

The National Oceanic and Atmospheric Administration's (NOAA) Climate Program Office and UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) supported the agencies in applying the U.S. Climate Resilience Toolkit. Following 11 months of collaborative work, this document lays out the groundwork for focusing the state's attention on climate resilience actions both within government and together with business, academic, nonprofit, and community partners. It recognizes that climate change adaptation and the concept of resilience to improve our ability to adapt and recover from future disasters are extremely complex processes.

As detailed in the sector-based analysis, there is no single means of response. Adaptation and resilience planning needs to be highly integrated processes that occur on a continuum, across all levels of government, and involving many internal and external partners and individual actions. It also calls for collaborative work with policy makers to make informed decisions and secure financial resources to implement long-range strategies that protect people and property.

This 2020 Resilience Plan establishes the North Carolina Resilience Strategy, which is a compilation of documents organized into four elements: (1) The North Carolina Science Report, (2) State Agency Resilience Strategies, (3) Statewide Vulnerability Assessment and Resilience Strategies, and (4) the state of North Carolina Enhanced Hazard Mitigation (EHMP). This plan provides updates to elements one through three, as explained further in Chapter 7.

This plan provides the following important output: (1) our best understanding of the projected change in the climate; (2) climate justice considerations; (3) state infrastructure, assets, programs and services within 11 critical sectors that are vulnerable and at risk to climate and non-climate stressors; (4) preliminary actions currently underway or which could be taken to reduce the risk for at least three example vulnerability areas; and (5) recommendations for nature-based solutions to enhance ecosystem resiliency and sequester carbon in the state's natural and working lands (NWL). The process has led to many lessons learned, particularly the importance of increased collaboration between state agencies and statewide partners to facilitate goal setting and building internal capacity to develop long-range strategic actions.

The 2020 Resilience Plan concludes by describing next steps for implementing and updating the North Carolina Resilience Plan as well as strategic cross-cutting resilience initiatives. The Resilience Team in the North Carolina Office of Recovery and Resiliency (NCORR) will lead and coordinate state resilience planning and implementation, with support from state agencies, local governments, businesses, and community stakeholders. Elements to be addressed in future updates include: (1) incorporating new decision relevant science information, (2) state agencies expanding and implementing strategies for the 11 sectors studied, (3) developing an action plan for cross-cutting challenges, and (4) incorporating the action plan into the EHMP, which is submitted every five (5) years to the Federal Emergency Management Agency (FEMA). Supporting this ambitious path will require adequate staff, funding, expertise, time and support. Each agency will then be able to develop resilience priorities and actions that are implemented equitably and inclusively across North Carolina.

This plan is intended as a framework to guide state action, engage policy-makers and stakeholders, and facilitate collaboration among many partners to protect the state against high-impact, low frequency weather events. It serves to address underlying stressors such as the changing climate, aging infrastructure, socio-economic disparities, and competing development priorities. Strategies to advance adaptation, resiliency, and mitigation are necessary key steps.

The 2020 Resilience Plan moves North Carolina to become more resilient to the impacts of climate change, even as we work to limit the magnitude of that change by reducing greenhouse gas emissions and transitioning to clean energy. By setting clear goals, taking action, and evaluating progress on a regular basis, North Carolina can make certain that our resilient state thrives amid changing conditions and challenges.

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Chapter 1

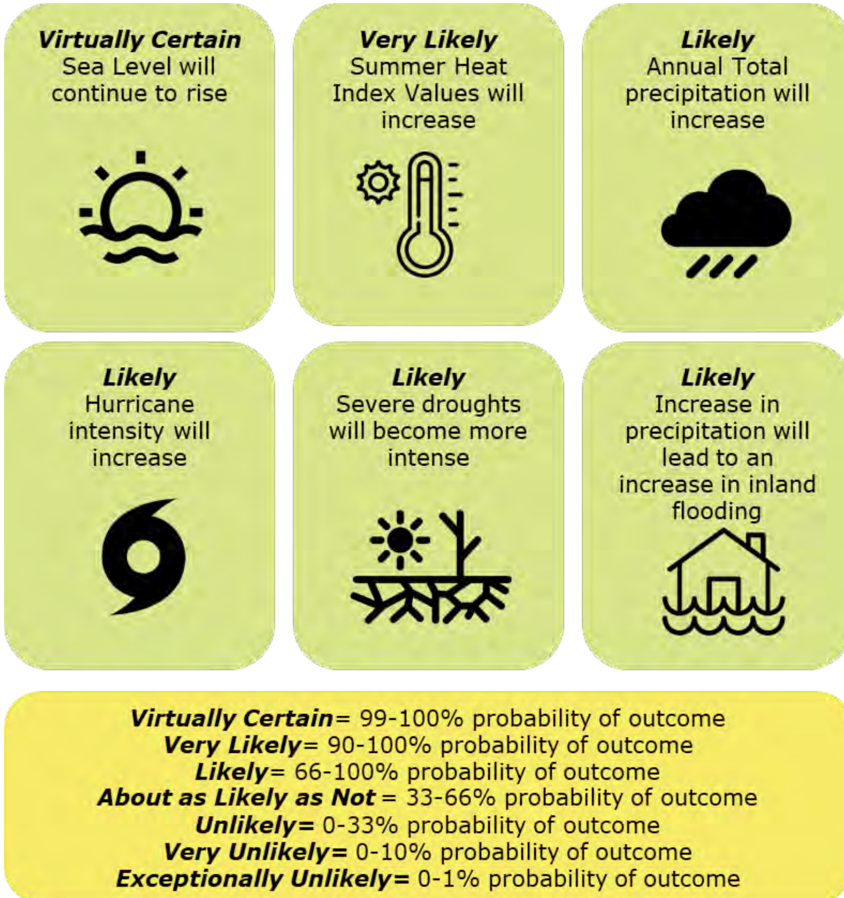
Key Findings and Recommendations

1. Key Findings and Recommendations

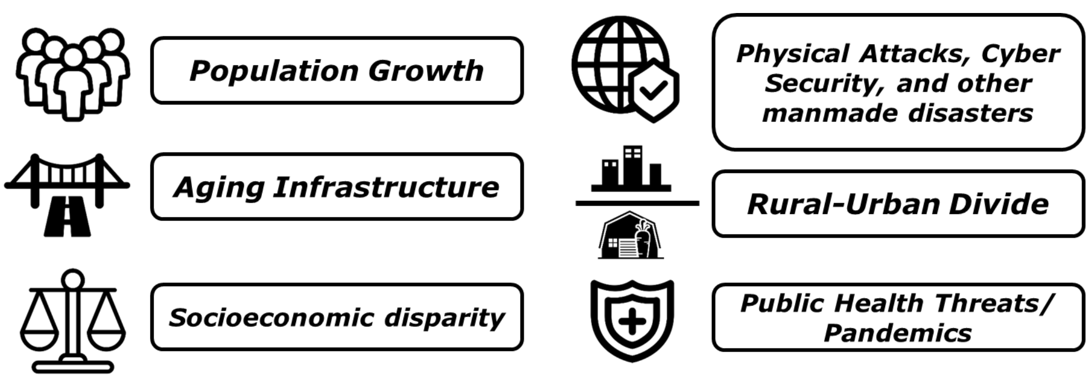
The 2020 Resilience Plan is organized as shown in Figure 1-1 below. The discussion in this chapter highlights key findings, messages, recommendations, and next steps to taking further action.

Figure 1-1: Document layout

A. Climate Change Projections in North Carolina[1]



B. Non-Climate Stressors facing North Carolina



[1] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. P. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: *North Carolina Climate Science Report*. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

C. Climate Hazards Facing North Carolina[2]

Average and Extreme Temperatures

- Although regional changes in temperature can vary from global changes, it is ***very likely*** that North Carolina temperatures will also increase substantially in all seasons. Annual average temperature increases 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.
- It is ***likely*** that the number of hot and very hot days will increase and the number of cold days (daytime maximum temperatures of 32°F or lower) will decrease.
- Warmer nights will ***very likely*** increase, reducing relief from the heat of the day and increasing heat-related stress on public health; households and people who lack access to sufficient cooling will be most vulnerable.
- Health-related problems due to heat stress such as respiratory issues will increase, young people, people of low socioeconomic status, and the elderly are especially vulnerable.
- Extreme heat events will become more frequent, longer lasting, and more intense, exacerbating demands for water.
- Plants and animals that rely on cooler temperatures may not be able to thrive in warmer temperatures and may migrate to cooler areas, and/or be out-competed for by other more heat-tolerant species.
- Warmer nights will put more stress on agricultural crops that depend on nighttime cooling.

Drought

- More intense droughts in the future due to climate change are ***likely***. This will put further stress on agriculture, forestry and municipal and agricultural water resources, causing widespread economic damage.
- Water shortages due to drought increase the risk of catastrophic wildfires, and temporarily reduce the availability of suitable habitat for wetland and aquatic animal populations.
- It is ***likely*** that future severe droughts in North Carolina will be more intense due to higher temperatures leading to more heat stress for public health, especially people who work outdoors.
- It is ***likely*** that future severe droughts in their multiple forms in North Carolina will be more **frequent** and intense due to higher temperatures leading to increased evaporation. As a result, it is ***likely*** that the frequency of climate conditions conducive to wildfires in North Carolina will increase.

Heavy Precipitation and Storms:

- Heavy precipitation accompanying hurricanes and other weather systems is ***likely*** to increase, thus increasing the potential for flooding in inland and coastal areas.
- Energy infrastructure located along inland watersheds and coastal areas will be further subject to changes in river discharge and flooding from heavy precipitation events.
- Heavy precipitation from more intense and frequent storms can cause significant damage to public and private structures such as homes, roads, utility services, etc.

[2] For a complete assessment of historical and projected climate trends in North Carolina under increased greenhouse gas concentrations, see summary of the North Carolina Climate Science Report in Chapter 3: NC Climate Science, or the full North Carolina Science Report in Appendix A.

- Vulnerable populations are most at risk of flooding and may have difficulty evacuating when necessary.

Wildfires

- Higher average temperatures and more severe droughts will lead to an increased likelihood of conditions conducive to wildfires.
- Increases in wildfires will pose a major risk for human health and emergency services, putting more lives at risk of fire related injuries, fatalities, and losses.
- Conditions more conducive to wildfires leave residents, businesses, infrastructure, forestry, and agricultural assets more at risk of related economic damages.
- Increases in population will amplify the public safety risks associated an increase in the wildfire urban interface, which increases the potential for more economic and public damage.
- More intense wildfires due to climate change will negatively impact air quality because of more fine particles in the air, exacerbating health issues such as asthma.

Coastal Flooding and Coastal Erosion

- It is ***virtually certain*** that sea level along the North Carolina coast will continue to rise due to expansion of ocean water from warming and melting of ice on land.
- It is ***virtually certain*** that rising sea level and increasing intensity of coastal storms will lead to an increase in storm surge flooding in coastal North Carolina.
- High tide flooding will a near daily occurrence at some points along the coast in the future.
- Cultural resources in fixed locations are inherently sensitive to flooding and it is difficult to reduce sites' exposures to flooding.
- Sea level rise and flooding will limit available land that is in high demand for both human (economic) and ecosystem services.
- More frequent coastal flooding will impact coastal habitats, fisheries, and the protective services that natural areas provide to local communities.
- Increased storm surges will erode shorelines and kill vegetation in maritime grasslands, tidal marshes, estuaries, lower reaches of coastal plain rivers, and low-lying wetlands near estuaries.
- Coastal erosion will reduce habitat for freshwater tidal wetlands, maritime uplands, and maritime wetlands.
- Endangered and threatened species that are vulnerable to storm surge and erosion on beaches are likely to decline.
- Coastal erosion will leave properties further at risk of flooding and storm damage, due to land or natural buffers being lost.

Hurricanes

- 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.
- More intense hurricanes will further damage wetlands and natural barriers which help to protect infrastructure and communities from storm surge, increasing the vulnerability to subsequent storms.
- Stronger hurricanes will destroy or damage public and private buildings and property.

- Vulnerable communities will be most at risk of flooding occurrences due to hurricanes; with hurricanes happening in short succession, vulnerable communities will struggle to recover between hurricanes.

Inland Flooding

- Increases in extreme precipitation is ***likely*** to increase inland flooding in North Carolina.
- Inland communities across the state are at risk from flooding due to extreme precipitation and outdated and/or undersized storm drainage infrastructure.
- Increased inland flooding caused by extreme precipitation events will further increase economic and agricultural losses after a flooding event.
- More frequent flooding will impact inland habitats, fisheries, and the protective services that natural areas provide to local communities.
- Flooding will continue to damage archaeological and historic sites on floodplains across all three physiographic regions and within every river basin in the state.
- Increased or more frequent flooding may inundate and potentially destroy more cultural resources.

Ecosystems and Habitat Loss

- Harmful algal blooms may increase due to warmer temperatures.
- Loss of organisms that rely on calcium-based shells such as oysters and clams, and organisms dependent upon them for food or habitat will be harmed by ocean acidification.
- Loss of wetlands due to sea level rise will result in habitat losses that will impact both commercial and recreational fisheries, decrease buffering capacity, adversely impacting water quality, and reducing the resilience of coastal communities.

Saltwater Intrusion

- Higher water levels due to sea level rise threaten otherwise productive land, leading to agricultural and economic losses.
- Increased saltwater intrusion due to sea level rise is expected to change the salinity of estuarine communities and to convert lower coastal floodplains from swamp forest to wetlands.
- Saltwater intrusion due to climate change will make drinking water from both groundwater and surface waters more vulnerable to contamination and/or expensive to treat and secure.
- Intrusion in freshwater sources can cause crop yields to decline and farmland to be unsuitable for growing crops due to high salinity and less available freshwater, leading to a loss of revenue in agriculture.

Public Health

- Cumulative hazards from heat and flooding are harming human health through poor air quality, flooding injuries, heat-related illness, decreased mental health, and increased infectious diseases.
- Existing inequities in environmental health exposures are exacerbated by climate change; older adults, children, low-income earners, communities of color, and veterans are disproportionately harmed.
- Changing climate can increase the areas where disease-carrying vectors such as mosquitos are present.
- Extreme weather events will put more stress on emergency management, public services, and institutions, and will require more resources to address the impacts. It will also further increase the frequency, magnitude, duration, or scale of the responses to hazards in North Carolina.

Population Growth and Other Hazards

- North Carolina's population is expected to increase, leading to more urban heat island effects and creating more heat and water related stress on people.
- Development due to population growth will lead to loss of habitat, species and natural buffers that protect communities from extreme precipitation.
- More severe climate disasters will further interrupt business activities for North Carolina's economy.
- An increase in impermeable surfaces causes more water to get funneled downstream, leading to more flooding of farmland, forested lands, and rural communities.

D. Key Observations and Recommendations: State Agency Assessment[3]

1. Agriculture and Forestry

Key Observations

- Agriculture, forestry, and endangered native plants are tied to climate due to biological, physiological, and ecological constraints. Elevated night-time temperatures will have outsized negative impacts due to disruptions in plant physiology.
- The agriculture and forestry industries must attract and retain experienced personnel as well as maintain equipment to meet a growing set of hazards.

Critical Impacts and Resilience Strategies

- Inland flooding is the greatest climate-related hazard to North Carolina Department of Agriculture and Consumer Services (NCDA&CS) assets (research stations, state forests, and nurseries) and to private farms and forests. Must focus on adaptive capacity (e.g., levees) to protect crop and pasture lands statewide.
- Research and development are needed on adaptive varieties and species for crops, livestock, and poultry to more resistant to extreme heat.
- Education of stakeholders can provide adaptive capacity for drought and wildfire. This is personnel-intensive and personnel are currently directed toward response.
- Protecting North Carolina's endemic and nearly endemic species, species that exist only in our state or a handful of places is a unique responsibility of the state.
- Regenerative practices that sequester carbon.

[3] With guidance and facilitation from National Oceanic and Atmospheric Administration's (NOAA) Climate Program Office, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) and North Carolina Institute for Climate Studies (NCICS), State agencies used the U.S. Climate Resilience Toolkit to qualitatively assess the exposure, vulnerability, and risk of agency assets, programs and services to climate-related hazards. Out of 744 impact pairs identified, agencies undertook an abbreviated assessment for a subset of potential impacts and conducted risk assessments for 48 impact pairs. The key observations and recommendations presented here explore state agency vulnerability and provides resilience strategies to take action for this subset.

2. Coastal Resources and Infrastructure

Key Observations

- Flooding from storms and extreme tides, magnified by sea level rise, is severely affecting land use, public infrastructure, and natural resources along the coast of North Carolina
- The intensity of recent storms and flooding have challenged the state's response and recovery plans. We should plan for greater extremes in the future.
- Climate hazards intensify existing social inequalities and lack of ability to adapt in economically challenged counties in the coastal region.

Critical Impacts and Resilience Strategies

- Climate change is impacting coastal habitats, fisheries, and the ecosystem services provided in coastal communities. State monitoring, research, and education can enhance understanding of impacts and potential adaptation strategies.
- Immediate focus must be on developing strategic priorities for public and natural infrastructure improvements as well as actions that integrate climate resiliency into agency operations, local disaster recovery programs, and long-term planning.
- Future climate conditions and resiliency should be integrated into current public investment decisions in local and regional water and transportation infrastructure improvements and other critical assets.
- State leadership should model adaptive behavior and incentivize local resiliency efforts that balance protection of life, property, and the environment. Inter-agency coordination can help build local capacity and action through funding and technical assistance.

3. Commerce and Business

Key Observations

- The greatest impact of recent climate hazards was business interruption. Getting people back to work and transitioning to a more resilient economy are critical.

Critical Impacts and Resilience Strategies

- Supporting rural economies with education, training and additional resources.
- Public/private partnerships help leverage risk. Government can help build resilience into infrastructure, which helps lower risks for small businesses.
- Include resilience training in North Carolina Main Street and Rural Planning programs for small towns and Main Street communities along with the businesses they support.
- The business sector needs to drive continual improvement of resource optimization.

4. Cultural Resources

Key Observations

- Cultural resources such as state and local historic sites and museums are irreplaceable, making them inherently sensitive to sea level rise and the increasing frequency and severity of heavy precipitation and flooding.
- The North Carolina Department of Natural and Cultural Resources (DNCR) is active across all 100 counties, so resources are limited. The threat of the hazard is growing.
- DNCR has regulatory authority over destruction of any public records managed on a local level.
- Much of the technical and constituent services for cultural assets are provided in a collaborative

environment with federal, state, local, and private interests all having a stake in the solutions.

Critical Impacts and Resilience Strategies

- There is no single solution to protect cultural assets from "water where it doesn't belong".
- The focus for now, and in the near-term, should be building resilience into assets owned and managed by the state, such as state museums, historic sites and parks.
- DNCR must provide greater services such as technical assistance to locally-owned cultural resources
- Develop and enhance federal, state, local, and private partnerships to build cross-boundary resiliency capacity for cultural assets.

5. Ecosystems

Key Observations

- The North Carolina Natural Heritage Program assessed ecosystem vulnerability in 2010 and updated the assessment in 2019.
- Ecosystems in all 100 counties are affected by climate change and numerous land use changes that have occurred in recent decades.
- The ecosystems with the highest risk support a high concentration of rare species and have a low tolerance of environmental variation.
- Ecosystems are shaped by climate. Human impacts reduce ecosystems' natural resilience to disturbance and change.
- Conserving and managing land for key ecosystems yields benefits to other sectors, including water resources, tourism and commerce, and public health.
- Minimizing non-climate stressors will reduce the overall stress on ecosystems and help avoid catastrophic change and loss.
- Need multi-agency understanding of the financial value of ecosystem services.

Critical Impacts and Resilience Strategies

- To improve overall landscape resilience, create nature preserves as large as possible and maintain habitat connectivity across the landscape.
- Preserve and restore wetlands and natural areas alongside rivers and streams.
- Manage land for natural processes, such as prescribed fire and restoration of natural stream flows.
- Establish natural recreation areas such as parks, trails, and greenways that will improve resilience and public health, and become valued community assets that improve quality of life.
- Increase public awareness of the importance of land conservation, planning for resilience, and the value to people of ecosystem function and services.
- Business must adopt biomimicry practices to provide holistic regenerative economic value.

6. Health and Human Services

Key Observations

- The health of the environment impacts the health of all people.
- Cumulative hazards from heat and flooding are diminishing health.
- Existing inequities in environmental health exposures are exacerbated by climate change.

Critical Impacts and Resilience Strategies

- Ongoing medical and public health services to residents are impacted.
- Increased staffing needs during hurricanes, especially for NC Emergency Operations Center, emergency shelters, coordinating emergency services, and seeking administrative waivers for benefits.

- Need additional support for North Carolina Department of Health and Human Services (DHHS) programs: Building Resilience Against Climate Effects program, Back@Home program, mold and moisture education, and infectious disease tracking.
- Strategies for creating resilience should address existing toxic exposures, such as hazardous waste and lead in water or homes, in low-income communities and communities of color.

7. Housing, Buildings, and Support Services

Key Observations

- Critical infrastructure and cross-agency assets make this sector important but difficult to prioritize.
- Need to have detailed, quantified risk assessments at a local level.

Critical Impacts and Resilience Strategies

- Flooding is the biggest hazard.
- Aging infrastructure is vulnerable, so many solutions will be costly and take time to implement.
- State-managed recovery is an immediate and growing need which shows that building resilience is important to reduce recurring impacts.
- Meet the growing demand of housing for veterans. Promote building resilience strategies for vulnerable VA hospitals.
- Waste management and its planning are important prior to and after any damage caused by environmental impacts.

8. Public Safety

Key Observations

- A permanently funded resiliency office, requiring personnel and budget, is needed.
- Public Safety is the largest state government cabinet agency with over 25,000 employees. It manages response and recovery for climate hazards and the growing number strains resources. North Carolina is viewed as a nationwide leader for these services.
- Resilience services will require greater interagency support and resources. Operational, logistical, maintenance, and resiliency challenges are synergistic in nature. All must be simultaneously addressed.
- Correctional facilities will require substantial upgrades. North Carolina is responsible for the custodial care of more than 35,000 inmates and 200 juveniles, vulnerable groups with higher exposure and low adaptive capacity.

Critical Impacts and Resilience Strategies

- Building resilience into critical infrastructure that supports response and quality of life must be an immediate priority.
- Working with local governments to build resilience is critical but will require time to build trust, institute new policies and regulations, and properly allocate resources.
- Long-term master planning is needed to determine the most cost-effective means to address, maintain, and operate resiliency plans through their life cycles.
- New and more strategically located facilities may serve well during a natural disaster.
- Training, tabletop exercises and continuity of Operation Plans for each of our divisions need to occur on an annual basis.

9. Transportation

Key Observations

- The core of North Carolina Department of Transportation (NCDOT)'s is to connect people, products and places safely and efficiently is heavily impacted by a growing number of climate-related hazards.
- NCDOT directly owns and maintains a large and diverse number of assets statewide. Storm-related damages are threatening public safety, creating economic disruptions, and causing budgetary shortfalls that require a strategic refocusing.

Critical Impacts and Resilience Strategies

- Maintaining critical connections and access must be the immediate near-term priority, whether along the coast during major storms, in the piedmont during heavy precipitation, or in the mountains due to landslides.
- All modes of transportation must be assessed for resilience to build adaptive capacity and redundancy moving forward.
- NCDOT is committed to collaborating and partnering with communities and businesses to build the resilient infrastructure they require.
- NCDOT will develop and apply resilience policies in three main areas: (1) long range transportation planning; (2) individual project planning and design; and (3) operations and maintenance.

10. Water and Land Resources

Key Observations

- Reliable, clean supplies of freshwater and land resources are essential to human and ecological health.
- Water availability affects all sectors and is vulnerable to climate change and increased demands from a growing population.
- The Water and Land Resources sector has directly managed assets and provides a number of services that require a uniquely trained and experienced workforce.
- Water infrastructure funding programs cannot meet existing demand to help communities meet their water infrastructure needs without considering additional needs due to climate change.

Critical Impacts and Resilience Strategies

- Dam and water infrastructure impacts from flooding are a big concern.
- Landslides are increasing due to extreme rainfall events.
- Water quality impacts to our drinking water and ecosystems as a result of polluted runoff are a continuing issue. Sediment is the largest pollutant by volume of our surface waters and carries excess nutrients and many other pollutants with it.
- Stormwater requirements and design specifications including rainfall intensity statistics should be assessed for future needs and revised as needed.

11. Energy

Key Observations

- Energy drives commerce, transportation, environmental controls, emergency response, agriculture, housing, and many other parts of our economy and therefore solutions must be integrated across these sectors.
- Energy resources, regulations, technology innovation, consumer demand, carbon reduction goals, and market pressures are rapidly changing the industry. This creates an opportunity to build resilience through the modernization of the energy supply and delivery infrastructure.
- North Carolina utilities, regulators, policy makers, energy planners, and emergency response planners should develop resiliency metrics to quantify human and economic costs of power

outages and apply a risk-based framework to accelerate decision making related to energy infrastructure planning and operations.

Critical Impacts and Resilience Strategies

- Disruptions to the electric power grid from increased storm intensity can be mitigated by securing a diverse source of utility scale and distributed generation assets such as microgrids equipped with renewable energy and battery storage devices, hardening the grid/transmission infrastructure, reducing demand for power, and modernizing existing grid assets with smart meters, controllers, automation, and analytics to manage a diverse source of power supply, transmission, and distribution system components.
- Stress on thermoelectric power plant cooling due to drought can be addressed with non-traditional water and energy sources, water capture and dry cooling to protect water quantity and quality, and demand side management programs.
- Fuel supply chains disruption from increased storm intensity may benefit from alternative fuel infrastructure and hardening existing pipelines, terminals, and fuel stations to facilitate evacuation routes and protect critical infrastructure.
- The North Carolina Disaster Recovery Framework, led by NC Emergency Management, should expand to focus on how to integrate resiliency planning for both storm-related outages and cyberattacks into its disaster recovery planning. The effort should evaluate how new and existing infrastructure can best be deployed to reduce recovery efforts.

E. Climate Justice Recommendations

To address the climate justice issues described in this chapter, the following recommendations are put forth by the authors of this chapter. These recommendations should be implemented with sufficient funding, staff or contracting support, as well as interagency cooperation to ensure effective action. Table 1-1 lists recommendations for cabinet agencies, Table 1-2 lists recommendations for the entire state government, and Table 1-3 lists research related recommendations.

Table 1-1: Climate Justice Recommendations for Cabinet Agencies

Entity Responsible	Recommendation
Interagency Climate Council	Develop an equitable public participation framework for all climate change mitigation and resilience efforts. For use by state agencies as well as boards and commissions.
	Design an interagency process to survey and educate staff on unified definitions of equity, vulnerability, climate risk, resilience, and other terms needed to demonstrate state's understanding and to ensure common ground within resilience work.
	Release a North Carolina Climate Justice Report as part of future North Carolina Resilience Plans with opportunities for public involvement.
North Carolina Emergency Management	Increase emphasis on communication with non-English speakers, older adults, rural communities, etc. Explore new risk communication methodologies.
	Continue to update existing state hazard mitigation, emergency preparedness, and response plans with increased emphasis on protecting, communicating with, and serving low-income populations, communities of color, older adults and people with disabilities during and after emergencies.
	Continue to support development of local hazard mitigation plans.
	Provide recommendations and guidance to local governments on maximizing the quality and effectiveness of local or regional hazard mitigation plans, especially in rural areas.
	Provide recommendations and guidance on stakeholder engagement in development and implementation of meaningful hazard mitigation plans and the inclusion of equity, diversity, and inclusion in local plans.
North Carolina Office of Recovery and Resiliency	Increase communication and interaction with all communities, including (especially) vulnerable and historically marginalized communities.
	Develop university partnerships to address gaps in research on climate resilience, especially issues that affect populations differently, and to offer capacity in the state to smaller and more rural communities to do effective and equitable resilience work.
	Develop a strategic plan for resilience-focused capacity building within socially vulnerable communities.

Entity Responsible	Recommendation
	Assist local governments in identifying additional resources to aid in advancing resilience.
	Seek funding that would be distributed to fund community-based resilience projects.
	Create a Local Government Climate Resiliency Toolkit.
	Create and strengthen working relationships among state agency advisory boards that focus on equity and inclusion, such as the DEQ Environmental Justice and Equity Advisory Board.
NC Department of Commerce	Set aside clear, numerical percentages for the number of newly established jobs/contracts/projects that should go to vulnerable communities & for which historically marginalized business receive priority bidding.
	Partner with the DOA Office of Historically Underutilized Businesses, NC Institute of Minority Economic Development, and other entities to increase outreach efforts of bidding and contracting opportunities for marginalized communities.
	Increase outreach efforts in impacted communities.
	Leverage Disaster Recovery Funds and other sources of capital to promote equitable job creation and inclusive business development in communities most vulnerable to climate change.
NC Department of Environmental Quality	Provide updated mapping when detailed climate projections come out, including overlap with socially vulnerable communities using 2020 Census and other up-to-date data.
	Continue enhanced engagement strategies for potentially underserved communities and translation and interpretation services for non-English speakers (as laid out in the DEQ's Public Participation and LEP Language Access Plans).
	Pursue continuation and expansion of Weatherization Assistance Program (WAP).
NC Department of Health and Human Services	Support the Building Resilience Against Climate Effects (BRACE) program and expand the tracking of epidemiological health impacts of climate change in North Carolina.
	Support increasing Back@Home initiative funding (post Hurricane housing initiative) to $16 million.
All Agencies Administering Disaster Recovery Funds	Increase outreach efforts in impacted communities. Implement a coordinated, strategic approach to increase communication and interaction, with an emphasis on vulnerable and historically marginalized communities.
	Offer adequate social services support to North Carolinians navigating the multitude of government processes during recovery.

Entity Responsible	Recommendation
	Increase the ability of community groups to communicate with state agencies on disaster recovery needs and the effectiveness of disaster recovery efforts
	Publish clear percentages of newly established jobs or contracts that should go to vulnerable communities and for which historically marginalized businesses receive priority bidding. Increase outreach efforts for hiring in communities where work will be completed.
	Continue to partner with the DOA Office of Historically Underutilized Businesses, NC Institute of Minority Economic Development, and other entities to increase outreach efforts of bidding and contracting opportunities for underserved communities.
	Leverage disaster recovery funds and other sources of capital to promote equitable job creation and inclusive business development in communities most vulnerable to climate change. Other sources of capital to explore include: Opportunity Funds, Donor Advised Funds, New Markets Tax Credits, Low Income Housing Tax Credits, activities of Community Development Financial Institutions, Small Business Investment Companies, Rural Business Investment Companies, and investments required by the Community Reinvestment Act.

Table 1-2: Climate Justice Recommendations for State Government

Recommendation Type	Recommendation
State Policy Changes	Adopt the targeted universalism approach for resilience, in which policies and programs begin by addressing the needs of those who are most vulnerable to climate change, and seek to improve the resilience of the entire state.
	Develop metrics to determine progress of equity and resilience initiatives.
	Adopt incentive or funding programs that encourage best practices for equitable resilience within state government and quasi-governmental organizations and among local governments, businesses, and non-profit organizations. For example, competitive funding programs within the state might include a resilience component in their scoring rubric.
	Advocate for funding from the General Assembly for climate science specific to North Carolina and for resiliency programs, policies, and interventions that support our shared efforts to prosper into the twenty-first century and beyond.
	Work with agency Human Resource offices to set goals and strategies for diversifying staff and leadership in recovery and resilience, and for hiring disaster survivors into recovery and resilience positions.
	With agency communications offices, set goals and strategies to increase interaction with communities that have historically frayed relationships with government and government officials.
	Reduce substandard housing and increase access to adequate cooling and other climate risk reduction measures.
	Advocate for funding for new or continuing weatherization programs that target low-income homeowners.
State Role in Building Local Sources of Resilience	Build capacity and leadership within communities most vulnerable to climate change impacts by promoting, supporting, and leveraging community-specific strategies, projects, and events. This recommendation could be accomplished through the North Carolina Resilient Communities program detailed in Chapter 7. These initiatives could be led by local governments or by community or faith-based organizations.
	Identify and communicate resilience resources, including educational and funding opportunities, already available to local governments and communities.
	Fund a grant program to support community or regionally-based resilience projects. This program could be sponsored by public and private funds.

Recommendation Type	Recommendation
	Engage community and faith-based organizations that work on disaster response to incorporate other elements of resilience into their programming.
	Explore opportunities to provide financial resources for climate preparation efforts to culturally specific organizations.
	Improve local resilience by ensuring that recovery programs, plans, and investments leave the community with additional capacity to cope with the next event. For example, a recovery program might include formal capacity building activities, a recovery fund might facilitate regional gatherings for grantees to share lessons learned, and planning efforts might identify clear, realistic implementation steps for after the plan is complete.
Information Needs	Improve the accessibility of hazard and climate change data to non-experts through web portals, infographics, classroom education modules, or other communication channels.
	Provide resources for community and K-12 education on climate change and resiliency.

Table 1-3: Climate Justice Research Recommendations

Research Recommendations
Examine the distribution of climate hazard exposure and impact, adaptive capacity, and benefits and burdens of resilience interventions among different groups of socially vulnerable populations.
Identify opportunities for citizen science and community observations to add value to research used by the state. For example, analyze ways for risk assessment to include qualitative methods and local knowledge.
Evaluate the effectiveness of methods for engaging different underrepresented groups in climate resilience plans, programs, and policies.
Investigate under-recognized sources of community resilience by learning more about the support systems local communities have created to 'fill in gaps' of disaster response.
Continue to map climate risks and social vulnerabilities together. Re-visit this mapping based on 2020 Census data. Use geospatial and other analyses to understand the distinction among different regions of the state and in urban, suburban, and rural areas. Extend this research to identify "hotspot" areas where climate justice issues are likely to be most severe.
Determine the best ways to measure and capture compounding vulnerabilities, or climate impacts that are experienced in the context of inequalities across health, housing, and economy.
Analyze the business and workforce development opportunities in risk and resilience fields. The results of such a study should inform programmatic decisions in the state's workforce development systems and organizations.
Analyze insurance coverage among socially vulnerable populations, especially in light of changing insurance markets and new developments with the National Flood Insurance Programs. Recommend strategies to improve insurance coverage among low-income households, including renters, in high-risk areas. Analyze insurance coverage of public assets in all communities, especially those with smaller budgets where insurance may have fallen to the wayside.

F. Key Observations and Recommendations: Nature-Based Solutions

The Natural and Working Lands (NWL) stakeholders developed 25 nature-based solutions (NBS) to build climate change resilience in communities and ecosystems and sequester carbon while also meeting other economic, ecologic and societal goals that are detailed in Appendix B: North Carolina Natural and Working Lands Action Plan.

Key Observations

- NWL stakeholders recommend that the state of North Carolina act quickly to protect, restore, and manage sufficient land area as "green-infrastructure" to provide community and ecosystem resilience.
- State agencies can build resilience using the NBS presented in the North Carolina NWL Action Plan.
- Voluntary landowner participation in carbon offset markets could be used to finance specific NBS that sequester significant amounts of atmospheric carbon and build community and ecosystem resilience.
- Important actions the state can take in building community and ecosystem resilience and sequestering carbon include:

    1. Sustainable management and financial support of the 14 million acres of privately-owned forests through new policies and economic opportunities.
    2. Protection and restoration of critical portions of the 13 million acres of floodplains and wetlands to mitigate floods as shown in the map given below.
    3. Protection, restoration and proper management of North Carolina's pocosins and coastal estuaries to build coastal resilience, sequester significant amounts of carbon, and mitigate the risk of wildfires and floods.[4]

Mapping Opportunities for Nature-Based Solutions to Build Resilience

The map presented in Figure 1-2 shows that increasing forested land area and reforesting both marginal forests and woody wetlands builds community resilience by reducing flood risks. The areas marked by the two purple colors represent land protection and reforestation opportunities to reduce flood risks. The areas marked in pink and magenta colors represent opportunities to both reduce flood risk and improve water quality. The map shows these opportunities primarily lie in the Coastal Plains, especially along major rivers. Protecting and restoring forests also sequesters carbon by removing carbon dioxide from the atmosphere and storing it in trees and soil.

[4] Peatland pocosins are saturated wetlands of Coastal Plain flats, swales, and Carolina bays, with organic matter accumulation, and with distinctive vegetation characterized by Pond Pine (Pinus serotina) and a suite of dense evergreen shrub species, which sequester and store a high volume of carbon per acre above and below ground.

Source: Nicholas Institute for Environmental Policy Solutions at Duke University

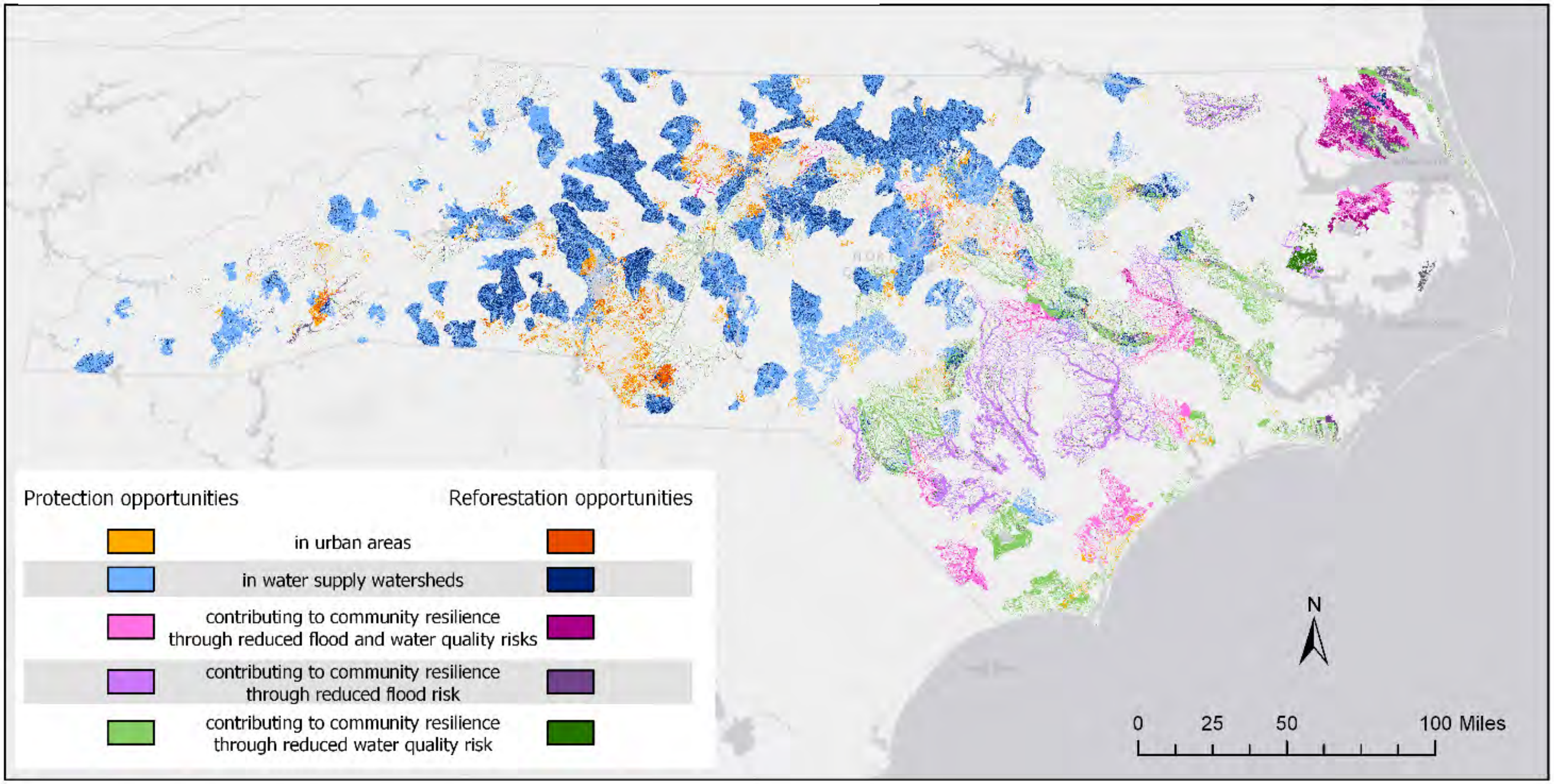


Figure 1-2: Protection and reforestation opportunities with community resilience benefit

Table 1-4 lists all the priority recommendations developed for North Carolina's Natural and Working Lands (NWL)Action Plan.

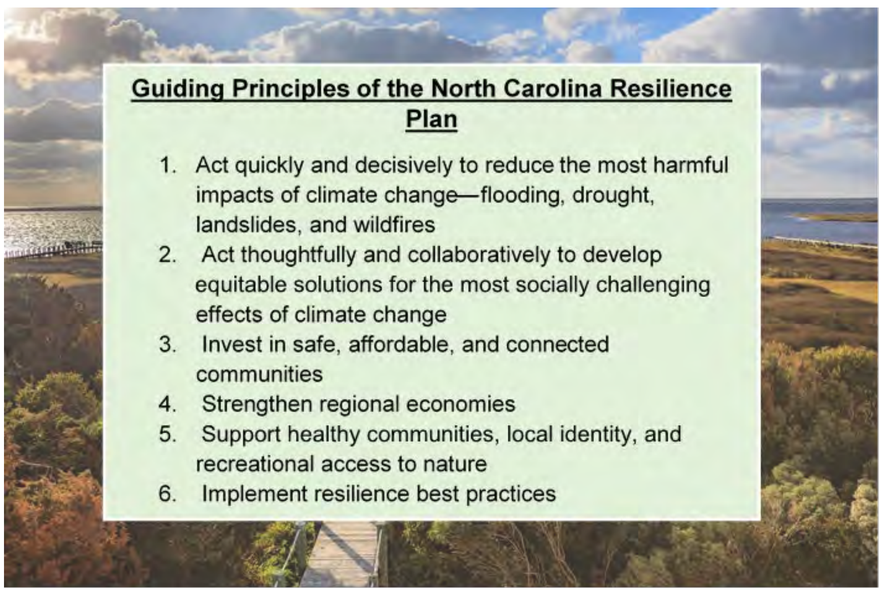
Table 1-4: Natural and Working Lands (NWL) Recommendations

Recommendation Type	Strategy
Transformative	1. Protect and restore forests and wetlands within flood prone areas.
	2. Facilitate voluntary landowner participation in carbon offset and ecosystem services markets.
	3. Build a multi-state NWL solutions toolbox.
	4. Integrate climate adaptation and resiliency strategies into local government comprehensive plans.
Protect Forest Lands	5. Conserve forest lands through easements and acquisition.
	6. Modernize forest policy and tax incentives.
Restore Forest Land	7. Expand restoration efforts on publicly owned lands.
	8. Encourage restoration and reforestation on private lands.
Enhance Forest Lands	9. Increase landowner access to forest management technical and financial assistance.
	10. Support the wood products markets.
Protect and Restore Floodplains and Wetlands	11. Coordinate the state's floodplain buyout and restoration program to increase resilience.
Restore Pocosins	12. Rewet hydrologically altered peatlands to prevent soil loss and catastrophic fire.
	13. Reforest peatlands with Atlantic White Cedar.
Enhance Pocosins	14. Enhance soil health and retention on working peatlands via best management practices and drainage management.
	15. Implement targeted interventions to protect peatlands from sea level rise and saltwater intrusion guided by scenario-based modeling.
Protect Coastal Habitats	16. Provide incentives to stakeholders for coastal habitat protection.
	17. Facilitate migration of coastal habitats through protection of migration corridors.
Restore Coastal Habitats	18. Prioritize climate change and sea level rise in coastal habitat restoration planning.
Protect and Restore Urban Lands	19. Promote urban forests through statewide programs to foster the retention of urban trees and their proper management.
	20. Protect and restore forested lands in water supply watersheds.
Enhance Urban Lands	21. Improve site preparation and soil amendment during land development.
	22. Research urban forestry climate adaptation and canopy baseline needs.
Enhance Agriculture	23. Encourage adoption of high mitigation agricultural conservation practices on croplands and pasturelands.
	24. Improve manure management on farms.
	25. Encourage food system efficiency through reduced food loss and waste.

G. Path Forward

The Path Forward is a vision for building a resilient North Carolina where our communities, economies, and ecosystems are better able to rebound, adapt, and thrive amid changing conditions and challenges, including natural hazards and climate change. Developing a shared vision of resilience will enable us to maintain and improve quality of life, nurture healthy growth, and ensure long lasting and sustainable social, economic, and environmental systems. A resilient North Carolina will also safeguard our ability to conserve resources for present and future generations.

The Path Forward first lays out guiding Principles that frame the state's action on climate resilience. It is based on the analysis and recommendations of this plan's authors and contributors, recommendations from local and community partners, and the progress that the state has made to date. The guiding principles (shown to the right) are both values and goals. The threat of climate change requires effective and decisive action, made with a clear-eyed understanding of the very real challenges we face in our state and in our world. These principles light the path.



1. Statewide Climate Vulnerability Assessment and Resilience Strategy

To guide the Path Forward, the state will maintain and update the North Carolina Resilience Plan. The North Carolina Resilience Plan is a compilation of documents organized into four elements: (1) The North Carolina Science Report; (2) State Agency Resilience Strategies; (3) Statewide Vulnerability Assessment and Resilience Strategies; and (4) the North Carolina Enhanced State Hazard Mitigation Plan (EHMP). Detailed discussion of these elements is provided in Chapter 7.

Table 1-5: North Carolina Resilience Strategy Elements

North Carolina Resilience Plan Element	Current Components	Earlier Versions	Update Cycle
1. Science Report	2020 North Carolina Climate Science Report	Chapter 2 (“Climate Trends”) of 2012 Climate Ready NC	As needed to incorporate new decision-relevant information
2. State Agency Resilience Strategies	Chapter 5 (“Climate Impacts, Risks and Vulnerabilities”) of 2020 Resilience Plan		March 2021, and annually thereafter.
3. Statewide Climate Vulnerability Assessment with Goals and Action Steps	Chapter 4 (“Climate Justice”), Chapter 6 (“Nature-Based Solutions”), Chapter 7 ("Path Forward”)	Chapter 3 (“Impacts, Risks and Vulnerabilities for North Carolina”); Appendices B through E; Chapter 4 (“Cross-Sector Strategies”), 2012 Climate Ready NC	• Priority 1: 2022 and every 4 years thereafter • Priority 2: 2024 and every 4 years thereafter
4. State Hazard Mitigation Plan	2018 North Carolina State Hazard Mitigation Plan	2013, 2010, 2007, 2004 SHMP	Current FEMA mandate: every 5 years

Table 1-6: Elements of the North Carolina Resilience Plan Going Forward

PLAN ELEMENTS	NEXT STEPS	PARTICIPATION	RESOURCE NEEDS
1. North Carolina Climate Science Report	• Update 2020 Climate Science Report as deemed necessary • Synthesize decision-relevant studies and contracted analysis from Elements 2, 3	• Universities • Federal agencies • State agencies • External contractors	• U.S. National Climate Assessment updates • Contracting funds for scientific expertise • State agency staff participation
2. State Agency Resilience Strategies	• Develop Agency strategies based on 2020 Resilience Plan Chapter 5 ("Climate Impacts, Risks, and Vulnerabilities") • Agencies seek advisory capacity on strategies from NCORR State Disaster Recovery Task Force Recovery Support Function teams (RSFs) as needed • Agencies publish Agency Resilience Strategy	• State agency resilience lead staff • NCORR resilience staff (general guidance; administration of SDRTF RSFs) • Universities • External contractors • Local governments • Stakeholders representing agency priority areas	• Funding for state agency resilience leads (1 new FTE per agency) • Each agency will have different resource needs for implementing resilience in its programs, which may include: o Contracting funds for agency-specific quantitative and qualitative risk and vulnerability assessments o Contracting funds for facilitating prioritization discussions and strategy development • NCORR guidance
3. Statewide Climate Vulnerability Assessment and Resilience Strategy	Identify, perform supporting vulnerability assessment, and develop Resilience Action Plan for Cross-Cutting Challenges: • Priority 1 Challenges: extreme events and actions potentially eligible for federal funding, such as Enhanced Hazard Mitigation Plan funding • Priority 2 Challenges: long-term issues not addressed through Priority 1.	• Statewide Strategy development process established by NCORR, with advisory input from Interagency Resilience Team and SDRTF RSFs	• Contracting funds for facilitating prioritization discussions and strategy development to gather input and prioritize actions
4. State Enhanced Hazard Mitigation Plan	• Incorporate climate science data into FEMA required Risk and Vulnerability Assessment process • Incorporate Element 3 Priority 1 Cross-Cutting Resilience Action Plan items into FEMA required Hazard Mitigation Strategy	• NCEM Hazard Mitigation, with advisory input from NCORR resilience staff (Resilience Strategy support and SDRTF administration)	• Contracting funds for quantitative and qualitative risk and vulnerability assessments • Contracting funds for facilitating prioritization discussions and strategy development to gather input and prioritize actions across levels of government

Priority Resilience Initiatives

Certain priority resilience initiatives are recommended first steps in providing opportunities for education and collaboration across stakeholder groups and sectors. Some recommended initiatives require additional dedicated funding to be successful. If this funding is not secured, these programs will not be able to move forward or will need revisions in proposed scale and scope.

The first initiative to prioritize is to **manage and coordinate statewide resilience**. The North Carolina Office of Resiliency and Recovery (NCORR) team will lead the state's resilience efforts. This involves supporting coordination among state agencies and maintaining productive relationships and partnerships between state, tribal, local, and regional governments; business and non-profit partners; and community stakeholders. Collaboration and interaction among partners inside and outside of state government helps all entities leverage expertise throughout the state to build a more resilient North Carolina.

The NCORR team provides resilience expertise to state government across the executive and legislative branches and all state agencies. The CRO also facilitates strategic planning and supports state agencies and offices as they continuously expand their capacity for and attention to resilience. Among other responsibilities, the NCORR team issue guidance to state agencies as they develop and annually update their Agency Resilience Strategies.

Additional priority resilience initiatives are discussed in full detail in Chapter 7 and listed below:

- Convene a dedicated Interagency Resilience Team
- Continue resilience efforts through the North Carolina Climate Change Interagency Council
- Establish the North Carolina Resilient Communities Program

Cross-Cutting Resilience Strategies

Various cross-cutting resilience strategies would advance resilience planning and implementation across agencies, sectors, and communities statewide. These recommended strategies include the following:

- Consider resilience criteria in making state investments
- Update plans, standards, and design values
- Increase resilience capacity in state agencies
- Identify sustainable funding sources for resilience
- Increase communication and outreach on climate change

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Chapter 2

Resilience Plan Development Process

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2. Plan Development Process

A. Introduction

Since its founding, North Carolina has grown to become a state known for its diverse population, economy, and culture. The state is divided into 100 counties with a population of over 10.4 million with a median income of $52,797 and with over 60% of residents making up its labor force.[1] North Carolina's rich history is rooted in agriculture and over the years, the population has shifted from an agricultural state with a manufacturing base in tobacco, textiles, and furniture to an advanced economy with strengths in finance, biotechnology, advanced manufacturing, and the knowledge economy more broadly.[2] The population is also experiencing a growing divide between rural and urban areas as North Carolina has metropolitan areas such as Raleigh and Charlotte, which account for over 33% of the state's population growth, as well as less dense rural cities such as Pembroke and Hickory.

North Carolina is comprised of 3 distinct physiographic provinces. The Coastal Plain, along the east coast, is well known for the profitable agriculture, fisheries, and tourism industries and diverse rural communities. The Piedmont region in the central part of the state is the heart of North Carolina's growth, encompassing the cities of Charlotte, Raleigh, Durham, and Greensboro. These cities are flourishing with expansions in the finance and research sectors, leading to an abundance of specialized job creation in areas such as the Research Triangle. The Blue Ridge Mountains along the state's western border are known for beautiful mountain peaks such as Grandfather Mountain, and lush forests, such as Pisgah National Forest. North Carolina's robust economy and rich history has provided opportunity and resources for longtime residents, tribal communities, and tourists alike.

Our geographic diversity means North Carolina has experienced devastating effects of almost every type of severe weather events and disasters. The latest science shows that these impacts will become more severe and will be endured across the state by all residents, especially those in socially vulnerable communities. These impacts have highlighted the need for action oriented state-wide resilience planning to reduce future risk.

It is important to recognize and address the threat that the changing climate poses to our state's economy, people, and culture. North Carolina is taking responsibility for the leadership and action needed to build resilience, adapt to climate hazards and risks, and reduce vulnerability to valued assets, services, and operations.

B. Executive Order 80

Governor Roy Cooper has answered the call for climate leadership by joining the U.S. Climate Alliance[3], a group of 25 bipartisan Governors whose states represent over 55 percent of the U.S. population and an economy larger than all countries except the U.S. and China. Each state has committed to implement policies that advance the goals of the 2015 Paris Agreement to reduce greenhouse gas emissions (GHGs) by at least 26-28 percent below 2005 levels by 2025 and accelerate new and existing policies to reduce carbon pollution and promote clean energy deployment at the state and federal level.

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[1] North Carolina Department of Commerce. 2019. North Carolina Annual Economic Report Retrieved from https://www.nccommerce.com/blog/2019/11/04/nc-annual-economic-report-gross-domestic-product

[2] North Carolina Department of Commerce. 2019. North Carolina Annual Economic Report. Retrieved: https://www.nccommerce.com/blog/2019/11/04/nc-annual-economic-report-gross-domestic-product

[3] http://www.usclimatealliance.org/

Through Executive Order 80 (EO80), Governor Cooper calls for North Carolina to address the impact of climate change through GHG mitigation strategies and statewide adaptation and resiliency planning. The landmark order calls for the state to strive for the following climate goals for North Carolina to achieve by the year 2025:

- Reduce statewide GHG emissions to 40% below 2005 levels.
- Increase the number of registered, zero-emission vehicles (ZEVs) to at least 80,000.
- Reduce energy consumption per square foot in state-owned buildings by at least 40% from fiscal year 2002-2003 levels.

EO80 created the **Climate Change Interagency Council** (Council), comprised of representatives of each cabinet agency and chaired by the Secretary of the Department of Environmental Quality (DEQ). EO80 directed the Council to finalize strategic plans in key action areas to mitigate the impacts of climate change by transitioning the state to clean energy and transportation sources as described below.

2019 saw the development of the **North Carolina Clean Energy Plan: Transitioning to a 21st Century Electricity System** by DEQ under EO 80.[4] The Clean Energy Plan is a stakeholder driven product that conveys a collective vision for transitioning North Carolina's electricity system to accommodate clean energy technology trends and public needs. The Plan contains recommendations and actions to achieve goals related to decarbonization of the power sector; energy affordability, price stability, and equity; and economic development opportunities for both rural and urban areas of the state.

That same year, the Department of Transportation developed the **ZEVs Plan,** also called for by EO80.[5] The plan recommends a number of strategies for increasing the number of ZEVs on North Carolina roads. These strategies are organized into four action areas: education, convenience, affordability, and policy.

To address the use of ZEVs by state government, the Department of Administration developed the **2019 Motor Fleet Zero Emission Vehicles Plan** under the EO 80 directive.[6] The plan identified 572 traditional vehicles for replacement with ZEVs, finding that doing so would save taxpayers an estimated $3.8 million and reduce emissions by over 22,000 metric tons over the lifetime of the vehicles.

Governor Cooper's EO 80 also required the Department of Commerce issue a **Clean Energy and Clean Transportation in North Carolina: A Workforce Assessment**[7], which it did in the fall of 2019. This assessment evaluates the clean energy and clean transportation sectors in North Carolina, assesses the skills and education needed in these sectors, and recommends actions for supporting such a workforce in North Carolina.

In 2019, DEQ published the **North Carolina GHG Inventory (1990-2030)**, a detailed account of GHGs emitted or stored from 1990 to 2017, as well as a projection of North Carolina's anticipated GHG emissions from 2018-2030.[8] The inventory concluded that the state is on track to meet and exceed the

[4] North Carolina Clean Energy Plan, NC Department of Environmental Quality – State Energy Office, October 2019, accessed at. https://files.nc.gov/governor/documents/files/NC_Clean_Energy_Plan_OCT_2019_.pdf
[5] North Carolina Zero Emission Vehicle Plan, NC Department of Transportation, October 2019, accessed at. https://files.nc.gov/governor/documents/files/NC_Clean_Energy_Plan_OCT_2019_.pdf
[6] North Carolina Motor Fleet Zero Emission Vehicle Plan, NC Department of Administration, October 2019, accessed at https://files.nc.gov/ncdeq/climate-change/interagency-council/EO-80-DOA-MF-ZEV-PLan--Final-.pdf
[7] North Carolina Clean Energy and Clean Transportation Workforce Assessment, NC Department of Commerce, October 2019, accessed at https://files.nc.gov/ncdeq/climate-change/interagency-council/Clean-Energy---Clean-Transportation-in-NC-A-Workforce-Assessment-2019.pdf
[8] NC Greenhouse Gas Inventory (1990-2030), NC Department of Environmental Quality - Division of Air Quality, January 2019, accessed at https://deq.nc.gov/energy-climate/climate-change/greenhousegas-inventory.

Paris emission reduction goals before 2020. The process resulted in a tracking system to monitor progress of future emission reduction activities through local and state government actions and private sector initiatives.

EO80 also directed DEQ, with the support of cabinet agencies and informed by stakeholder engagement, to prepare a **North Carolina Climate Risk Assessment and Resiliency Plan** for the Council to submit to the Governor by March 1, 2020. In preparing this 2020 Resilience Plan, agencies are required to evaluate the impacts of climate change on their programs and operations, and integrate climate change adaptation and resiliency planning into their missions and services. The directive also called for agencies to help local governments and communities vulnerable to climate change impacts develop community-level adaptation and resilience plans.

This 2020 Resilience Plan is a collective response to qualitatively analyze the vulnerability of state assets, services, and programs to climate hazards and impacts. This plan also explores examples of state agency vulnerability and provides potential resilience strategies. The purpose of this plan is to build state government capacity to understand and incorporate the impact of climate change into future decision-making. State agencies analyzed the vulnerabilities and risks associated with two to three climate stressors, such as flooding, drought, and extreme heat events. By this effort, agencies were able to better understand the climate stressors that affect them, and the impacts of those stressors, while increasing institutional understanding of climate change and interagency collaboration to address those threats. The sectors shown in Figure 2-1 are evaluated by the state agencies:

Figure 2-1: Sectors Evaluated in Chapter 5: Vulnerability, Risk, and Resilience Strategies for Addressing Climate Related Hazards

C. Historical Climate Change Adaptation and Resilience Accomplishments

In 2012, the **North Carolina Interagency Leadership Team** issued the **Climate Ready North Carolina: Building a Resilient Future**[9] report, which identified climate trends and risks associated with those trends, and recommended overarching cross-sector strategies. This 2012 Report established critical information and analysis for this 2020 Resilience Plan.

The 2012 Climate Ready North Carolina report ("2012 Report") conducted a statewide, multi-sector resilience analysis. Chapter 4 of that document ("Cross-Sector Strategies") identifies six cross-sector strategies for a resilient North Carolina, which remain applicable today. This section reiterates each strategy and summarizes the implementation status of each.

The following list is not comprehensive, but highlights some of the milestones in state government. Communities, universities, businesses, and non-profits have provided invaluable leadership and expertise during this period to increase North Carolina's resilience, and those efforts are gratefully acknowledged.

Appendices B through E of the 2012 report identify sector-specific adaptive response strategies for broad categories based upon common issues that are of concern to North Carolinians: our people, our economy, our built environment, and our natural environment. Those sector-specific impacts and strategies and progress made since 2012 are highlighted below, along with activities under way.

1. Promote comprehensive adaptation planning among state agencies

The 2012 Report recommends the following sub strategies:

- Encourage agencies to incorporate climate adaptation into existing planning programs, designs and policies, and integrate consideration of changing climate conditions into relevant decisions with long planning horizons.
- Facilitate linkages between climate adaptation, pre-disaster planning, natural hazard mitigation planning, and long-term disaster recovery planning.
- Prioritize "no-regrets" adaptation actions that yield mutual benefits with other efforts.
- Establish an ongoing process that ensures state agencies are collaboratively planning for adaptation.

North Carolina has or will implement this strategy through the following actions.

- Section 2 of EO80 required the following: "Cabinet agencies shall evaluate the impacts of climate change on their programs and operations, and integrate climate change mitigation and adaptation practices into their programs and operations."
- To provide leadership to this work, North Carolina established the North Carolina Climate Change Interagency Council and a Chief Resilience Officer.
- The General Assembly prioritized resilience in state disaster recovery through creating the North Carolina Office of Recovery and Resilience (NCORR).
- The North Carolina Climate and Health Program in DHHS is part of a national public health effort to anticipate and prepare for human health effects related to global and local climate

[9] http://www.climatechange.nc.gov/Climate_Ready_North_Carolina_Building_a_Resilient_Future.pdf

change. The program is supported by the Centers for Disease Control and Prevention's Climate and Health program.

- DHHS implemented the Building Resilience Against Climate Effects (BRACE) Framework to identify likely climate impacts, potential health effects associated with these impacts on the most vulnerable populations in the state. This funding initiative led to the development of the Climate and Health Profile Report[10], which determined the health impacts of heat-related illness and wildfire smoke as the greatest concerns in North Carolina.
- DHHS continues to track public health effects of climate change, to provide services in response to increasing extreme weather and wildfires, and to accommodate disruptions from climate-related conditions to the daily services DHHS provides.
- As described in Chapter 7 of this 2020 Resilience Plan, the state will establish an Interagency Resilience Team and each state agency will generate its own resilience strategy to be updated annually.
- North Carolina Department of Emergency Management will integrate long-term resilience practices and climate data, where appropriate, into the State Hazard Mitigation Plan starting in 2023.

2. Facilitate Communication and Education to Support Local, Regional, and State Adaptation Planning Efforts

The 2012 Report recommends the following sub strategies:

- Work to enable decision makers, stakeholders and the general public to be well informed of potential climate impacts and vulnerabilities, as well as the state's efforts to address these concerns.
- Collaborate on communication planning and outreach with partners such as universities, extension agencies, federal agencies, local governments, Councils of Governments, and nongovernmental organizations.
- Include local or state-wide concerns with specific climate adaptation options as part of outreach and education efforts.

North Carolina has or will implement this strategy through the following actions:

- The NCORR issued Natural Hazards Resilience: A Quick Start Guide for North Carolina Communities.
- The active Recovery Support Functions of the State Disaster Recovery Task Force include resilience in their mission, which is to advise on state disaster recovery efforts and build capacity to prepare for future disaster recoveries.

[10] North Carolina Department of Health and Human Services Division of Public Health, North Carolina Climate and Health Profile - Building Resilience Against Climate Effects North Carolina Climate Ready Program, March 2015. accessed https://epi.dph.ncdhhs.gov/oee/climate/ClimateAndHealthProfile.pdf

3. Collaborate with Partners to Provide Relevant Information for Decision-Making

The 2012 Report recommends the following sub strategies:

- Collaborate with partners to access climate-related information that informs decisions.
- Develop a North Carolina clearinghouse for climate adaptation with links to relevant localized and state climate information and a toolbox with adaptive response options.
- Improve understanding of various climate-related risks and systems vulnerabilities.

North Carolina has or will implement this strategy through the following actions:

- Division of Coastal Management (DCM) developed a series of webpages on Coastal Adaptation, which includes data, policy and planning tools, and success stories. It is available on the division's website.
- The North Carolina Institute for Climate Studies, in collaboration with the Office of the State Climatologist at NC State University, contributed a rigorous science assessment for the 2020 North Carolina Climate Science Report.
- The Albemarle-Pamlico National Estuary Partnership conducted a study: Climate Ready Estuaries: A Blueprint for Change with Duke University in 2010 to assess the needs of coastal communities.
- The Albemarle-Pamlico National Estuary Partnership and the NC Commission on Indian Affairs will work with tribal communities to further resiliency planning.

4. Encourage broad collaboration and partnership to leverage resources

The 2012 Report recommends the following sub strategies:

- Partner with organizations, private industry, professional associations and institutions to reduce duplication of effort and leverage resources
- Encourage partnerships at a regional level to ensure coordination

North Carolina has or will implement this strategy through the following actions:

- State and local staff continue to participate in regional partnerships that bring together resilience practitioners across the Southeast, such as the Southeast and Caribbean Climate Community of Practice and the Southeast and Caribbean Disaster Recovery Partnership.
- State and local staff continue to partner with and benefit from the expertise of numerous federally funded climate science and adaptation partnerships housed in or with significant staffing located in North Carolina, including those partially funded by the National Oceanic and Atmospheric Administration - NOAA (the National Centers for Environmental Information, North Carolina Cooperative Institute for Climate and Satellites, the Southeast Regional Climate Center, the Carolinas Integrated Sciences and Assessments Program, North Carolina Sea Grant, North Carolina National Estuarine Research Reserves), the United States Environmental Protection Agency (Albemarle-Pamlico National Estuary Partnership), the United States Geological Survey (Southeast Climate Adaptation Science Center), USDA (Southeast Regional Climate Hub), U.S. Fish and Wildlife Service (Southeast Landscape Conservation Cooperative), and the Department of Defense (Southeast Regional Partnership for Planning and Sustainability).

- State and local staff also benefit from university-based programs devoted to climate science and adaption support, including but not limited to the State Climate Office of North Carolina at NC State University and the National Environmental Modeling and Analysis Center (NEMAC) at UNC-Asheville. Researchers at public and private universities throughout the state regularly reach out to state and local governments for ideas on research that meets resilience decision needs. Since June 2019, 3 faculty teams have received notification that they will receive federal funding for proposals developed with input on resilience needs and letters of support from the NCORR and from DCM.
- State staff continue to participate in national cross-state partnerships for resilience, such as the U.S. Climate Alliance and non-profit and foundation-led efforts to bring together state-level resilience leaders.
- Six local governments in the Triangle J Council of Governments collaboratively funded the Triangle Regional Resilience Partnership, which generated a regional geospatial analysis of stressors, assets and threats and prioritized recommendations for the geographic area. The results of this effort can be accessed at: https://www.tjcog.org.

5. Partner with Communities to facilitate local climate adaptation efforts

The 2012 Report recommends the following sub strategies:

- Provide technical assistance and information for interested communities to ensure their success in working toward climate adaptation goals.
- Build local capacity to develop solutions that manage risk from extreme weather and other climate change impacts in order to reduce losses.

North Carolina has or will implement this strategy through the following actions:

- In 2016-2018, the DEQ DCM conducted the Resilience Evaluation and Needs Assessment pilot program in five communities to better understand local experiences with coastal hazards and to identify areas where state and local staff can focus resources to mitigate future impacts from flooding, winds, and other damaging events.
- To inform the pilot program, the DCM conducted a coast-wide coastal hazards needs assessment survey in February 2017.
- The Albemarle-Pamlico National Estuary Partnership conducted a Climate Resilience Evaluation and Awareness Tool exercise with the towns of Manteo and Columbia to assess vulnerabilities in water infrastructure in 2013.
- DHHS has implemented community pilot projects for adapting to increases in temperature and air quality impacts of wildfire.
- EO80 calls for the Council to "support communities that are interested in assessing risks and vulnerabilities to natural and built infrastructure and in developing community-level adaptation and resiliency plans"
- As described in Chapter 7 of this 2020 Resilience Plan, the state will establish the North Carolina Resilient Communities Program to provide resources so local governments can stand up their own resilience efforts

6. Refine Adaptation Strategies as Information Becomes Available and Tools Improve

The 2012 Report recommends the following sub strategies:

- Use the best available science to inform flexible strategies, which will evolve over time.
- Monitor, evaluate, and adjust to support adaptive management of resources.
- Ensure that expert advice and stakeholder input are a continued part of the long-term ongoing process of climate adaptation.

North Carolina has or will implement this strategy through the following actions:

- The NC Climate Science Report includes state-of-the-art climate science, provided by the North Carolina Institute for Climate Studies.
- DCM and the Coastal Resources Commission's Science Advisory Panel remain committed to updating the state of the knowledge on sea level rise every 5 years, as required by Session Law 2012-202.
- Prioritize natural infrastructure and land use strategies.
- Fund investments in resilience of existing infrastructure and housing that has a reasonable outlook for survival under climate change and non-climate stressors.

D. 2020 Resilience Plan Development Process

1. Scope of the 2020 Resilience Plan

The 2020 Resilience Plan is developed in partnership with all cabinet agencies, the Department of Agriculture and Forestry, North Carolina Institute for Climate Studies (NCICS), NOAA Climate Program Office, NEMAC, Natural and Working Lands Stakeholder Group, the NC Climate Office, and many others. It is a collective response to qualitatively analyze the vulnerability of state assets, services, and programs to climate hazards and impacts. This plan also explores examples of state agency vulnerability and provides potential resilience strategies. The purpose of this plan is to build state government capacity to understand and incorporate the impact of climate change into future decision-making.

The 2020 Resilience Plan builds upon the 2012 **Climate Ready North Carolina: Building a Resilient Future**[11] report and the resilience work conducted in North Carolina over the past decade. It also builds on our most current knowledge of climate science and applies accepted methods to evaluate vulnerabilities, risk, and additional action strategies. It adds new components into resiliency planning by considering impacts faced by North Carolina communities and accounting for climate justice issues. It recognizes the significant role nature-based solutions can play to enhance resiliency through the state's vast natural and working lands. It is meant to inform the governing bodies and decision-makers within state government of the climate impacts which affect the people, culture, environment, and other valuable assets within the state.

This 2020 Resilience Plan establishes the North Carolina Resilience Strategy, which is a compilation of documents organized into four elements: (1) The North Carolina Science Report, (2) State Agency Resilience Strategies, (3) Statewide Vulnerability Assessment and Resilience Strategies, and (4) the State of North Carolina Enhanced Hazard Mitigation (EHMP). This plan provides updates to elements one through three, as explained further in Chapter 7.

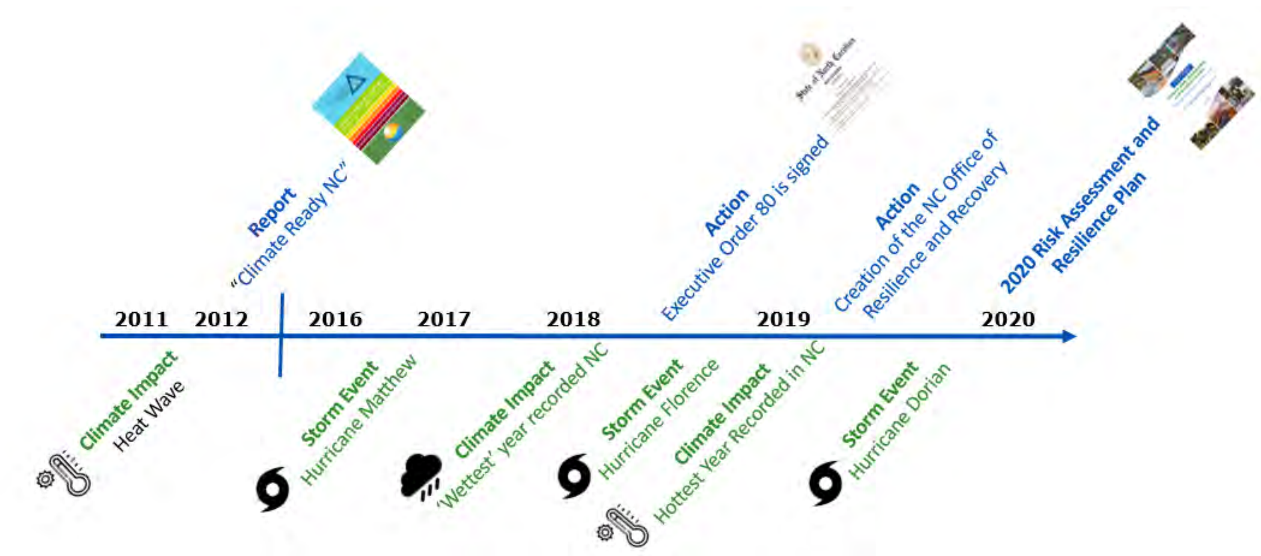
This Plan...

1. Provides updated, downscaled climate science data for North Carolina
2. Contains an inventory of state assets, programs and services for 11 sectors affected by climate and non-climate hazards
3. Provides a qualitative analysis of the vulnerability of state assets, services, and programs to climate hazards and impacts
4. Reflects input from local communities to understand their climate related impacts, vulnerabilities, and needs
5. Incorporates feedback to incorporate climate justice considerations into statewide resilience planning
6. Evaluates the role of nature-based solutions in building ecosystem resiliency
7. Builds state government capacity to understand and incorporate impacts into decision-making
8. Defines preliminary actions and recommendations to increase resiliency in North Carolina
9. Provides a path to greater climate resiliency by moving beyond assessments into actions and associated resources required

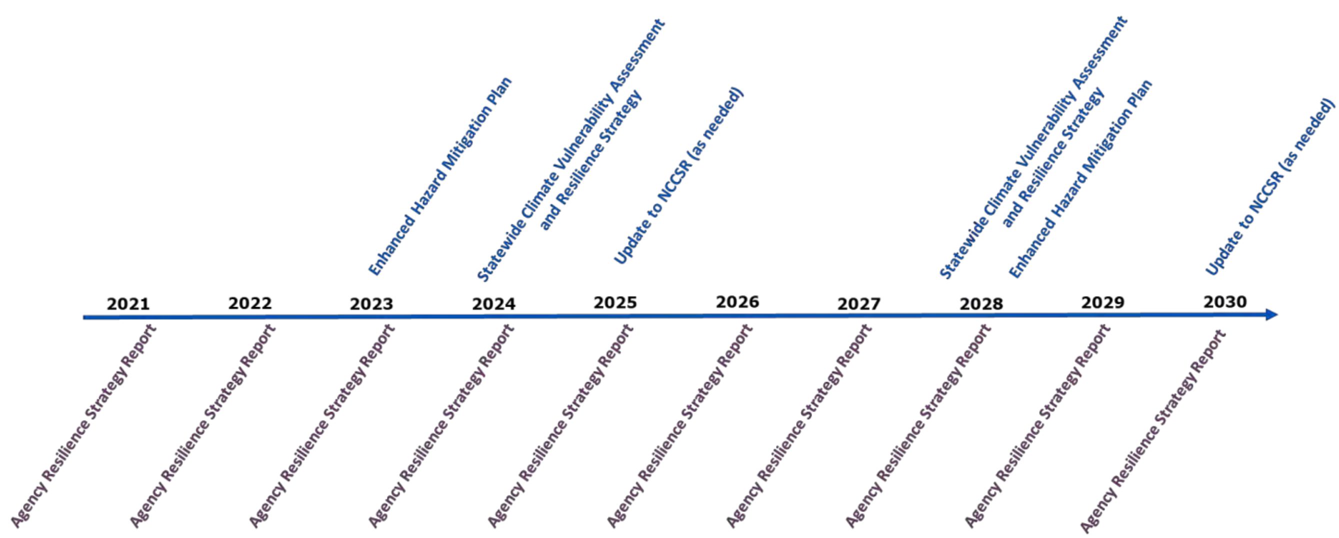
[11] http://www.climatechange.nc.gov/Climate_Ready_North_Carolina_Building_a_Resilient_Future.pdf

2. Timeline

Historic



Planned



3. North Carolina Climate Science Report

In support of EO80 Section 9 and the North Carolina Climate Risk Assessment and Resilience Plan, DEQ engaged with the leading climate experts at NCICS to develop an independent peer-reviewed scientific report describing the state of the knowledge of climate change in NC. With this collaboration, NCICS, along with an expert Climate Science Advisory Panel, have produced the NC Climate Science Report (NCCSR).[12]

This scientific report provides an overview of the physical science of climate change, detailed information on observed and projected changes in temperature and precipitation averages and extremes, hurricanes and other storms, sea level, and other relevant climate topics identified as needs. The NCICS team received input from DEQ, the NC Climate Change Interagency Council and its designees on the type of information needed such as temperature and precipitation averages and extremes, hurricanes and other storms, sea level, and other relevant climate metrics, geographic focus areas, and time horizon. Although the state agencies requested the information to evaluate its effects on their programs, the NCCSR remains an independent document that has gone through an expert review process.

The Climate Science Advisory Panel (CSAP) consists of the top climate scientists from universities across the state and was convened to serve as expert contributors and reviewers for the report. Authors of the report included the following:

Authors

Kenneth E. Kunkel, North Carolina Institute for Climate Studies, North Carolina State University
David R. Easterling, NOAA National Centers for Environmental Information
Andrew Ballinger, The University of Edinburgh
Solomon Bililign, North Carolina A&T State University
Sarah M. Champion, North Carolina Institute for Climate Studies, North Carolina State University
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Kathie D. Dello, State Climate Office, North Carolina State University
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Brooke C. Stewart, North Carolina Institute for Climate Studies, North Carolina State University
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Climate Science Advisory Panel

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[12] For More Information, see Appendix A: NC Climate Science Report and Chapter 3: NC Climate Science Report

Douglas K. Miller, University of North Carolina Asheville
L. Baker Perry, Appalachian State University
Walter A. Robinson, Dept. of Marine, Earth and Atmospheric Sciences, North Carolina State University
Adam J. Terando, U.S. Geological Survey, Southeast Climate Adaptation Science Center

This independent resource was developed to inform state agencies, local governments, the general public and related stakeholders of the latest climate science information for the State of North Carolina. Please refer to Chapter 3 of this report for the key findings and executive summary from the report and Appendix A for the full *North Carolina Climate Science Report*.

4. Community Level Input through Regional Resilience Workshops

In an effort to engage the local community in the state resilience planning process, DEQ, with help from regional Council of Governments, other state agencies, and public, private, and non-profit partners, planned and hosted seven Regional Resilience Workshops across the state (see Figure 2-2). These workshops were attended by over 300 stakeholders representing 82 of the North Carolina's 100 counties. Stakeholders from over 100 local governments, community organizations, local planners, business owners, tribal communities, and others joined in facilitated discussions led by cabinet agency representatives to identify regional climate impacts, and developed recommendations that could be implemented at the state level.[13]

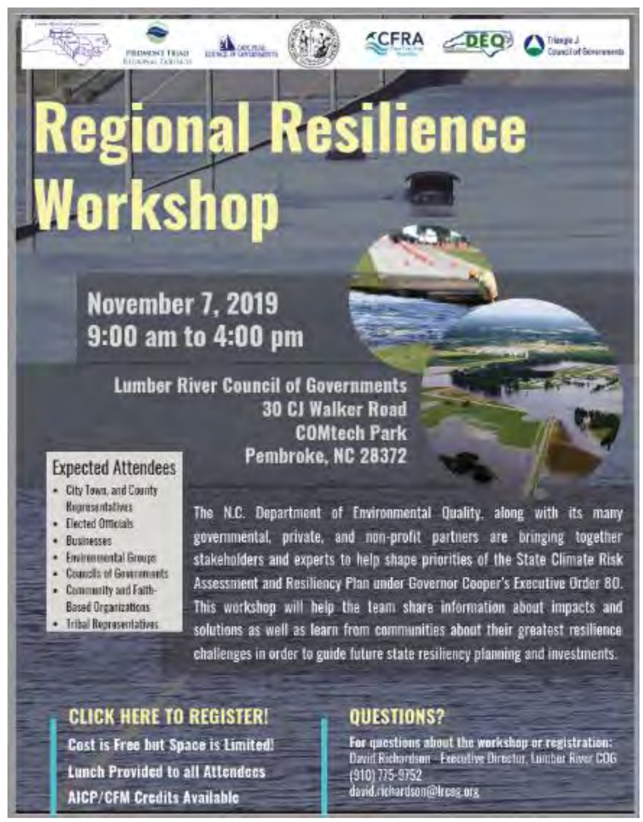

Figure 2-2: Example announcement for a regional resilience workshop

[13] For More Information about the NC Regional Resilience Workshops, See Appendix C: NC Mountain and Piedmont Regional Resilience Workshops Report and Appendix D: NC Coastal Resilience Workshops Report.

The objectives of these workshops were to convene stakeholders to:

- Present some of the latest climate science available for the state,
- Share regional climate change and resiliency challenges,
- Generate strategies that could be implemented at the local level,
- Generate recommendations that could be implemented at the state level, and
- Prioritize regional vulnerabilities to be addressed in the North Carolina Climate Risk and Resiliency Plan.

The Mountain and Piedmont Regional Resiliency Workshops were designed following the completion of two workshops in the Coastal region (see Figure 2-3). Workshops were hosted by partnering organizations on the dates shown in Table 2-2.

Table 2-2: Regional Resilience Workshops

Workshop Location	Workshop Date	Host Organization
Elizabeth City, NC	May 2, 2019	
Wilmington, NC	May 14, 2019	
Havelock, NC	June 11-12 (Coastal summit)	
Sylva, NC	October 15, 2019	Southwestern Community College
Hickory, NC	October 16, 2019	Western Piedmont COG
Kernersville, NC	November 4, 2019	Piedmont Triad Regional COG
Pembroke, NC	November 7, 2019	Lumber River COG
Wilson, NC	November 12, 2019	Upper Coastal Plain COG

Figure 2-3: Stakeholder representation at the NC Regional Resilience Workshops

In Technical Session I of the Mountain and Piedmont workshops, the agencies invited climate scientist and members of the climate science community to (1) provide an overview of historic, present, and projected regional climate patterns, and (2) help participants to understand global, state, and regional climate trends and stressors.

In Technical Session II, a panel of local government officials, state regional office staff, university partners, business owners, and non-government organization staff provided varied local perspectives on local hazards, impacts and challenges and share approaches to managing short- and long-term environmental, economic and societal changes by answering the following questions:

1. *What are the top two climate hazards and impacts to your region/community?*
2. *How are these impacts affecting the different sectors of the community?*
3. *How are local governments preparing for and responding to these impacts?*
4. *What are some knowledge gaps that you find as you engage with community members?*
5. *What strategy has been the most effective in community-level resilience planning?*

During the facilitated discussion portion of the workshop, participants were separated into six focus area groups based on interest and area of expertise. The following focus groups were facilitated by representatives from corresponding cabinet agencies:

Workshop Focus Groups
• Agriculture, Business, and Commerce
• Local Planning
• Environment and Natural Resources
• People and Community
• Transportation
• Public Health

The participants were asked to respond to the following questions in the context of their focus groups:

1. *How has your community been affected by natural hazards and long-term stressors?*
2. *What steps have you already taken to reduce future climate hazards and risks? What actions would you like to take and what are the barriers you face?*
3. *How can the state better support communities in addressing climate hazard risks and impacts?*

Stakeholder Feedback

Stakeholders prioritized actions that can be taken at the local level, and generated recommendations for state agencies to take in order to increase local capacity for resilience. Recommendations for state agencies fell within the following categories:

- Data and Research
- Technical Assistance
- Staff Resources and Connections
- Regulation and Policy Changes
- Funding
- Education, Training, and Outreach

Across the state, local stakeholders expressed similar concerns with the following overarching themes:

- Lack of local climate resilience knowledge and capacity

- Need for improved floodplain and watershed mapping and management tools
- Need for technical assistance with local hazard mitigation planning
- Lost revenue for small businesses, agricultural operations, and outdoor employees during climate events
- Lack of emergency access to rural communities during and after a disaster
- Need for comprehensive technical assistance with the federal recovery grant process
- Lack of reliable broadband access in rural communities during disasters

Additional feedback given by the stakeholders is provided in Appendix C: NC Mountain and Piedmont Regional Resilience Workshops Report and Appendix D: NC Coastal Resilience Workshops Report.

5. Climate Justice Considerations

In order to ensure the equity and inclusion of vulnerable, under-represented communities into statewide resilience planning, the members of DEQ Secretary's Environmental Justice and Equity Advisory Board: Subcommittee on Climate Change and Extreme Weather Resilience provided feedback and recommendations to identify key content and themes for inclusion in the Climate and Environmental Justice Chapter.

The Board itself is comprised of 16 members appointed by the Secretary of DEQ, who represent academic institutions, environmental and community organizations, and Native American Indian Tribes. The scope of the Environmental Justice and Equity Advisory Board is to assist the Department in achieving and maintaining the fair and equal treatment and meaningful involvement of North Carolinians regardless of where they live, their race, religion or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Feedback from the NC Regional Resiliency Workshops (discussed earlier) was used to identify recurring themes related to climate change and equity concerns described by local stakeholders and was distilled into a detailed outline provided to the Subcommittee members for their feedback. Members of the Subcommittee responded with detailed suggestions and comprehensive recommendations which were incorporated into Chapter 4: Climate and Environmental Justice.

6. Impact, Vulnerability, and Risk Assessment for Sectors Evaluated[14]

DEQ partnered with the NOAA and the authors of U.S. Climate Resilience Toolkit team (CRT team) to develop a collaborative work plan to lead state agencies to qualitatively asses the exposure, vulnerability, and risk of state agency assets and services to climate-related hazards. Additional facilitation and technical support were provided by UNC NEMAC and NCICS. Together, the Lead team guided participating state agency staff through a series of three workshops designed to (a) develop a clear understanding of state assets and climate-related hazards; (b) establish a process for assessing climate-related risks to those assets; and (c) agree on a framework and process for authoring a statewide resiliency plan.

U.S. Federal agencies have focused since the 1991 Global Change Research Act upon documenting sources and impacts of climate variability and change on local and national assets and populations. Thus, there is increasing awareness at local and regional levels about the need to improve resilience to climate-related hazards. The National Research Council has recommended that U.S. Federal agencies provide

[14] Gardiner E. P., Herring D. H., and Fox. 2019. The U.S. Climate Resilience Toolkit: evidence of progress. Climatic Change 153(4): 477-490. Also see https://toolkit.climate.gov/#steps

climate adaptation decision support.[15] They further suggested focusing first and foremost on end-user needs and investing in processes and relationships between those users and information providers.

During the risk assessment and resilience planning process, we qualitatively assessed the exposure, vulnerability, and risk of agency assets and services to climate-related hazards. Through a series of knowledge building workshops and a writing process, teams from throughout North Carolina's state government learned a set of terminology and documented their exposure to climate-related hazards (see Chapter 5 of this report). That qualitative process has established a shared understanding across departments and agencies, making it possible to quantify climate-related vulnerability and risk in a future stage of work.

The 2020 Resilience Plan development team adopted the Steps to Resilience Framework (Figure 2-4) to facilitate the required learning and documentation. Team members have gained an appreciation of the different outcomes and valuation systems that must be reconciled in future engagements across the North Carolina state government. The first step in the framework requires that teams coalesce around shared goals that address exposure to climate-related hazards. This report focuses attention on that shared understanding.

Figure 2-4 The U.S. Climate Resilience Toolkit's 'Steps to Resilience'

Sectors analyzed in this 2020 Resilience Plan were developed based on the sectors identified in the 2012 Report discussed earlier[16] and expanded to incorporate the needs and vulnerabilities identified by state agencies and local communities (see Table 2-3). These sectors cover the natural, built, economic, and social systems affected by climate hazards in the state. A complete risk assessment and determination of adaptation options was not possible given the large number of potential impacts, so agencies undertook an abbreviated assessment for a subset of those potential impacts. Out of 744 impact pairs identified, agencies conducted risk assessments for 48 impact pairs.

[15] National Research Council. 2009. Informing Decisions in a Changing Climate. Panel on Strategies and Methods for Climate-Related Decision Support, Committee on the Human Dimensions of Global Change. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
[16] http://www.climatechange.nc.gov/Climate_Ready_North_Carolina_Building_a_Resilient_Future.pdf

Table 2-3: Sectors Evaluated in the 2020 Resilience Plan

Sector	Contributing Department(s)	Examples of Assets, Services, Programs
Agriculture and Forestry	Department of Agriculture and Consumer Services	Endangered native plant species, agricultural sector, crop and pasture lands, forest-land, wildlife, livestock and poultry
Coastal Resources and Structures	Department of Environmental Quality	Natural buffers – wetlands and barrier islands, Public and private property, marine and estuarine habitats, Beach nourishment/channel dredging
Commerce and Business	Department of Commerce	Economic vitality, businesses
Cultural Resources	Department of Natural and Cultural Resources	State museums; state archives and records; state historic sites; historic structures; districts and landscapes; national register of historic places, properties, and districts
Ecosystems	Department of Natural and Cultural Resources, Department of Environmental Quality	Biodiversity, habitats, ecosystems, wildlife resources, inland and marine fisheries, threatened and endangered plants and animals
Housing, Buildings and Support Services	Department of Public Safety, Department of Military and Veterans Affairs, Department of Administration, Department of Environmental Quality	Infrastructure - homes/buildings, residential properties, commercial properties, critical infrastructure
Health and Human Services	Department of Health and Human Services, Department of Environmental Quality	Insect and water borne diseases, heat stress, air quality
Public Safety	Department of Public Safety	Emergency management, law enforcement, state-managed shelters, prison system, flood risk management
Transportation	Department of Transportation	Roads, bridges, railroads, ports, airports, infrastructure, maintenance, project development, planning and programming
Water and Land Resources	Department of Environmental Quality	Public water supply, industrial water supply, agricultural water use, water quality, wastewater
Energy	Department of Environmental Quality	Energy generating sources, transmission and distribution lines, power grid components, thermoelectric plant cooling systems, fuel pipelines, terminals and service stations

7. Natural and Working Lands Action Plan Process

Nature-based solutions (NBS) refer to reshaping the structure, management and use of North Carolina's NWL to tackle socio-environmental challenges, such as climate change, by leveraging the unique properties of these resources. They can be used to address infrastructure needs such as storm water retention, protect from climate impacts such as storm surge, and act as hazard mitigation strategies that contribute to increasing drought and flood tolerance. These solutions have been used successfully for many decades, most notably for stormwater management and watershed protection. Now, they are being recognized for their true economic potential to protect our ecosystems and citizens from the devastating impacts of climate change.

The NWL Action Plan took shape in the summer of 2018. The North Carolina Department of Environmental Quality (DEQ) was in the process of building a statewide GHG inventory that included the NWL sector. The inventory indicated that the NWL sector was sequestering significant amounts of carbon. The inventory indicated that the NWL sector was sequestering significant amounts of carbon. It was estimated that almost 25% of annual gross CO_2 equivalent emissions were removed from the atmosphere by forests and other lands.

In addition to this work, representatives from the state of North Carolina attended the U.S. Climate Alliance and American Forests' 3-day Learning Lab in Washington DC. The Alliance convened representatives from various states, who participated in a to learn about NWL and develop a framework for ongoing NWL stakeholder engagement in their home states.

The NWL Action Plan is a cornerstone of EO80 because it addresses both mitigation of GHG emissions and building community and ecosystem resilience. Chapter 6 discusses how state agencies and local governments can use the NWL Action Plan to build adaptive capacity and resilience to climate change-related weather events and stressors.

To explore opportunities in the NWL sector, DEQ convened a stakeholder group in October and December of 2018, to discuss potential carbon sequestration opportunities. The stakeholders represented the following entities:

- Public/private landowners and managers.
- Scientists.
- Policymakers
- State and local government planners.
- Universities.
- Consulting firms.
- Non-profit organizations.

Close to 100 people participated in the NWL Stakeholders Group's six subcommittees developing and vetting 25 priority recommendations for the NWL Action Plan over an 18-month period. The purpose of NWL Action Plan is to create opportunities and implement projects on North Carolina's NWL that achieve the following goals shared by the plan's stakeholders:

1. Enhance the ability of NWL to sequester carbon and mitigate GHG emissions.
2. Build resilience in ecosystems and communities.
3. Provide public health and ecosystem co-benefits.
4. Create economic opportunities for agribusiness, recreation, and tourism.
5. Ensure implementation of any action is a socially equitable process.

After the December Stakeholder Group meeting, attendees formed subcommittees that would focus on a particular land sector.[17] The land sectors focused on by the subcommittees are listed in Figure 2-5:[18]

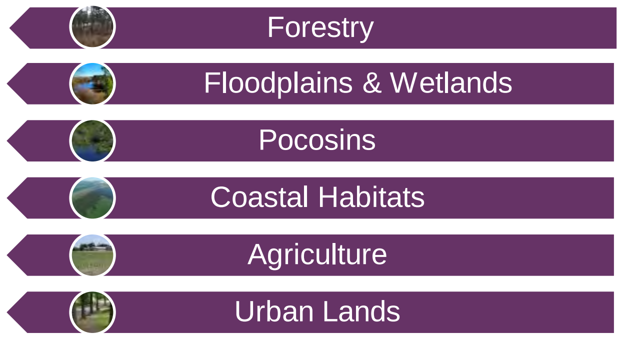

Figure 2-5: Natural and Working Land Subcommittees

The subcommittees met numerous times in 2019 to develop a set of actionable recommendations. The DEQ acted as a facilitator for the group, creating a work plan and assisting with documentation. A steering committee was also formed consisting of the subcommittee leaders, facilitators from DEQ and other lead, and key members of the 2020 Resilience Plan team. The steering committee guided the process and deliverables for the NWL Action Plan.

Over a two-day period in October of 2019, stakeholders prioritized the list of recommendations that would be included in the NWL Action Plan. An evaluation criterion was set prior to the meeting that was created by the steering committee. The recommendations that met the criteria and obtained a majority consensus as a priority are included in the plan. Figure 2-6 shows the process for developing the NWL Action Plan.

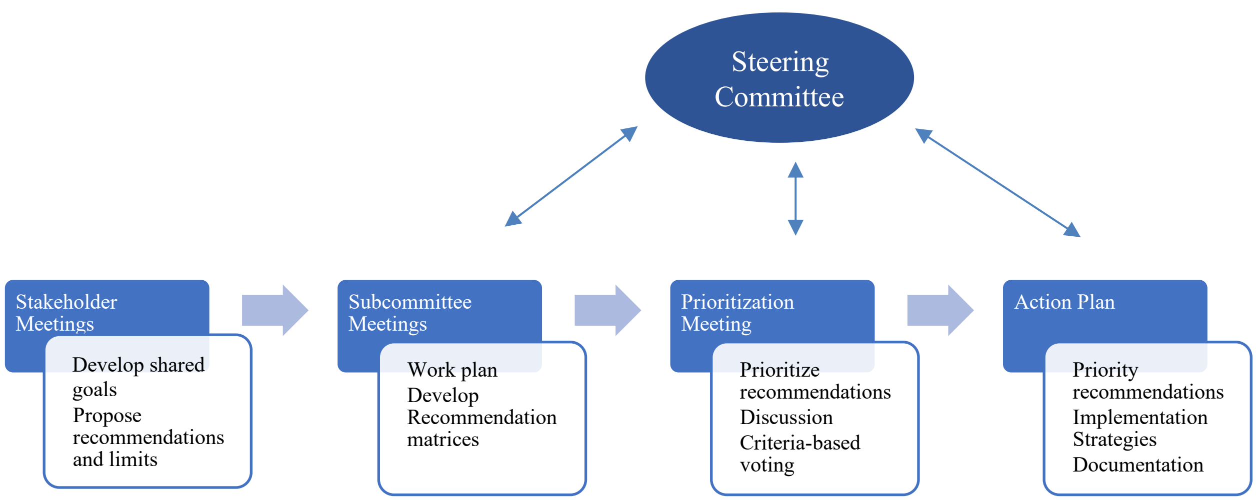

Figure 2-6: Process Flow for Development of the Natural and Working Land Action Plan

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[17] For a full list of subcommittee participants, see the full report in Appendix B.

[18] Pocosins are naturally-occurring freshwater evergreen shrub-dominated wetlands of the Coastal Plains with deep, acidic, peat soils.

The resulting 25 recommendations included in the NWL Action Plan are those that were prioritized by the majority of NWL stakeholders and did not require full consensus of all stakeholders. The stakeholders summarized the recommendations into four main categories:

- ***Transformative*** – cross-cutting actions that will result in large amounts of carbon sequestration and resilience.
- ***Protect Land*** – acquisition of land or conservation agreements to conserve additional natural areas.
- ***Restore Land*** – restoration of the ecological function to natural systems to increase carbon sequestration and resilience.
- ***Enhance Land*** – improved use and management of existing lands to increase carbon sequestration and resilience.

The stakeholders recognize that the state needs to act quickly to acquire and develop sufficient land area as "green-infrastructure" for mitigating climate change impacts and sequestering carbon. The NWL Action Plan recommendations, along with the expertise of the stakeholders who developed it, should be a first resource for building long-lasting resilience in North Carolina. A summary of each of the 25 priority recommendations is provided in Chapter 6: NBS for Resiliency. These recommendations are actionable by both state/local governments and impact partners such as universities and conservation organizations. Several subcommittees have formed teams working on their design and implementation. The full NWL Action Plan is included in Appendix B.

E. Future Updates to the Plan through the North Carolina Office of Recovery and Resiliency

In 2018, following the devastation of Hurricane Florence amidst the ongoing recovery from Hurricane Matthew in 2016, the NCORR was established to administer funds received by the state through the U.S. Department of Housing and Urban Development's Community Development Block Grants for Disaster Recovery Program. Working closely with North Carolina Emergency Management, the NCORR provides disaster recovery coordination with services that include oversight of recovery funding, processing of program applications, construction and vendor management, and public outreach and education, among other responsibilities.

In 2019, Governor Cooper appointed a state Chief Resilience Officer (CRO) to lead NCORR's resilience staff and direct the state's initiative to help storm-impacted communities rebuild smarter and stronger in the face of future natural disasters and long-term climate change. The NCORR's resilience staff works to improve collaboration between governments, non-profits, the private sector and academia, with a goal of developing solutions that enhance the resilience of communities and the natural environment while creating safe and affordable housing solutions. As part of that work, NCORR coordinates the State Disaster Recovery Task Force (SDRTF) and its subcommittees, the Recovery Support Functions (RSFs), which bring together experts in the field of recovery and resiliency, both within state government as well as federal and local government, industry and nonprofit organizations. Each RSF provides and promotes recommendations through NCORR and North Carolina Emergency Management (NCEM) to state government and the General Assembly on ongoing disaster recovery efforts and future resilience-building.

NCORR has been tasked with leading the state's future resilience efforts. This involves supporting coordination among state agencies and maintaining productive relationships and partnerships between state and local and regional governments, business and non-profit partners, and community stakeholders. Collaboration and interaction among partners inside and outside of state government helps all entities leverage expertise throughout the state to build a more resilient North Carolina.

The NCORR and key state agency staff have prepared a path forward strategy for the state to maintain and update a unified North Carolina Resilience Plan. The NC Resilience Plan is a living document, updated regularly, with four primary elements:

1. A Climate Science Report.
2. State agency-specific resilience strategies.
3. A statewide vulnerability assessment and resilience strategy with goals and action steps.
4. The North Carolina Enhanced State Hazard Mitigation Plan.

The path forward identifies priority initiatives and offers recommendations for state government to build resilience capacity and enhance the ability of residents, businesses, and communities to cope with climate change. The principles, plans, proposed initiatives, and strategies outlined in Chapter 7 implement recommendations and best practices on climate assessment and resilience planning.

F. Document Organization

Chapter 3 provides key findings and executive summary from the NCCSR.[19]

Chapter 4 describes the disproportionate burden that climate impacts have on socially vulnerable communities and provides a variety of recommendations to ensure equity in climate adaptation planning.

Chapter 5 is an assessment of critical vulnerabilities in each identified sector and provides potential actions which demonstrate how agencies, working both independently and cooperatively, may address the impacts of climate variability and change on citizens, infrastructure, and assets throughout the state.

Chapter 6 identifies opportunities to sequester carbon, provide ecosystem benefits, and enhance resiliency through project implementation within natural ecosystems.[20]

Chapter 7 outlines the next steps to advance climate resiliency throughout the state and provides a framework for the future of climate resilience and adaptation in North Carolina.

Appendix A presents the NC Climate Science Report.

Appendix B presents the Natural and Working Land Action Plan.

Appendix C and D presents Regional Workshop Reports for the Mountain and Piedmont region and the Coastal region, respectively.

Appendix E contains a glossary of key words and terminologies.

Appendix F contains a list of acronyms used in the report.

[19] For more information, refer to Appendix A: NC Climate Science Report
[20] For more information, refer to Appendix B: NC Natural and Working Lands Action Plan

Chapter 3

NC Climate Science Report

3. NC Climate Science Report

A. Overview

1. What is this Report?

The North Carolina Climate Science Report (NCCSR) is a scientific assessment of historical climate trends and potential future climate change in North Carolina under increased greenhouse gas (GHG) concentrations. It provides an overview of the physical science of climate change, detailed information on observed and projected changes in temperature and precipitation averages and extremes, hurricanes and other storms, sea level, and other relevant climate metrics.

Findings are presented for both the state as a whole and for each of three regions in the state: the Coastal Plain, the Piedmont, and the Western Mountains. The report also includes chapters on sea level rise, trends involving interactions of multiple aspects of the climate system (including inland flooding, wildfire, forest ecosystem changes, urban heat island effects, and air pollution), and findings relevant to engineering design standards.

2. Background

Governor Cooper's Executive Order 80 (EO80), "North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy," directed all cabinet agencies to integrate climate adaptation and resiliency planning into their policies, programs, and operations. The order specifies a number of emissions-reduction and clean-energy goals, establishes an interagency council on climate change, and calls for a range of other specific actions across the state government.

One provision of EO80 directed the North Carolina Department of Environmental Quality (DEQ) to develop a "North Carolina Climate Risk and Resilience Plan." The DEQ and other agencies recognized the need for an objective and credible climate science analysis to support the E080 activities and the development of the resiliency plan.

In response to this need and request, the North Carolina Institute for Climate Studies (NCICS), an inter-institutional research institute of the University of North Carolina system administered by NC State University, led the development of the NCCSR. This Report is intended to serve as an independent peer-reviewed scientific contribution to the E080 activities and the 2020 Resilience Plan and to inform the citizens of North Carolina about the state of knowledge on climate change in North Carolina

3. Report Authorship and Development

The report was prepared independently by North Carolina-based climate experts. While some authors (including those from NCICS) are employed by state universities, and state agency needs informed the selection of report topics, the authors based their analysis of the science on their own climate expertise informed by (a) the scientific consensus on climate change represented in the Fourth United States National Climate Assessment and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; (b) the latest research published in credible scientific journals; and (c) information in the North Carolina State Climate Summary.

Under the direction of Kenneth Kunkel, NCICS Lead Scientist for Assessments and NC State Research Professor, NCICS assembled an author team to write the report and an advisory panel to provide scientific oversight and expert reviews. The advisory panel ("Climate Science Advisory Panel") consisted of North Carolina university and federal research scientists with national and international reputations in their specialty areas of climate science. The author team comprised NCICS scientists and several members of the advisory panel.

The report leverages the expertise of NOAA's Assessments Technical Support Unit (TSU), which is staffed primarily by NCICS, and applies the methodologies and processes developed for the U.S. National Climate Assessment.

The report underwent several rounds of review and revision, including an anonymous peer review organized by NOAA's National Centers for Environmental Information (NCEI).

Please refer to the NCCSR full report for list of authors, advisory panel members, and other contributors who supported the technical analysis, report management and production.

4. Report Contents and Availability

The sections below provide the NCCSR Report Findings, the overarching key findings and conclusions of the NCCSR, and the NCCSR Executive Summary, which is a more detailed discussion of the key conclusions and report findings.

The full report is available via the NCICS website: www.ncics.org/nccsr.

B. NCCSR Report Findings

These findings present key conclusions of this report about observed and projected changes in the climate of the state of North Carolina. They are based on analyses using well-established and carefully evaluated observational and modeling datasets, national and international climate assessments, and an assessment of the latest peer-reviewed scientific literature, complemented by other sources where appropriate. All of these sources were determined to meet the standards of the federal Information Quality Act.

Climate projections for the NC Climate Science Report are determined using Representative Concentration Pathways (RCPs). RCPs are a set of hypothetical future scenarios used in climate model simulations to examine how Earth's climate would respond to differing levels of GHG concentrations. Most of the projections referenced in this report are based on two of the RCPs: a higher scenario (RCP8.5), in which GHGs continue to increase through the end of the century, and a lower scenario (RCP4.5), in which emissions increase at a slower rate, peak around the middle of the century, and then begin to decrease (Figure 3-1). Note, although annual emissions declined slightly in 2019 and the potential effects of coronavirus on emissions have not been fully quantified, recent evidence has shown that global emissions have been tracking close to the highest emission scenario – RCP 8.5.

Future increases in temperature are dependent on greenhouse gas emissions, with higher emissions resulting in greater warming. Qualitative projections are based on expert judgment and assessment of the relevant scientific literature and draw on multiple lines of scientific evidence as well as model simulations.

Global average temperature has increased about 1.8°F since 1895. Scientists have ***very high confidence*** that this warming is largely due to human activities that have significantly increased atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases. It is ***virtually certain*** that global warming will continue, assuming greenhouse gas concentrations continue to increase. By the end of this century (2080–2099), global average temperature is projected to increase by about 4°–8°F compared to the recent climate (1996–2015) under the higher scenario (RCP8.5) and by about 1°–4°F under the lower scenario (RCP4.5).

Global average sea level has increased by about 7–8 inches since 1900, with almost half of this increase occurring since 1993. It is ***virtually certain*** that global sea level will continue to rise due to expansion of ocean water from warming and melting of ice on land, such as the Greenland and Antarctic ice sheets.

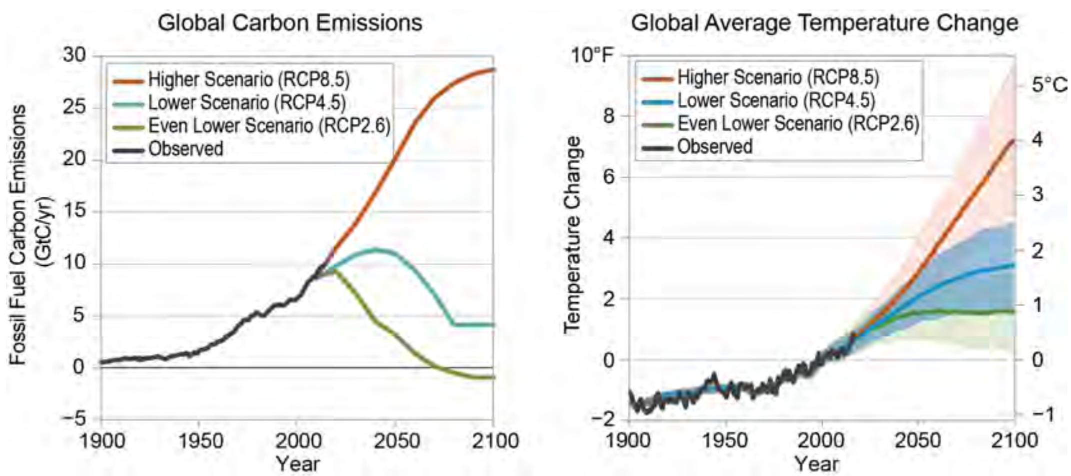

Figure 3-1: (left) Observed and projected global carbon emissions. The black line shows observed carbon emissions (1900–2016) resulting from human activities. Under the higher scenario used in this report (RCP8.5, burnt orange line), emissions continue to increase through the end of the century. Under the lower scenario used in this report (RCP4.5, blue line), emissions increase at a slower rate, peak around midcentury, and then decline in response to climate change mitigation policies. Also shown is an even lower scenario (RCP2.6, green line), which assumes rapid emissions reductions and eventually net negative emissions. (right) Observed temperatures and the projected future temperature changes associated with the three RCP scenarios shown in the left panel. Temperature changes are shown relative to the 1986–2015 global average. Source: Hayhoe et al. 2018.

1. Observed and Projected Changes for North Carolina

Except where noted, statements about future changes refer to projections through the end of this century. The following definitions apply:

Virtually Certain= 99-100% probability of outcome
Very Likely= 90-100% probability of outcome
Likely= 66-100% probability of outcome
About as Likely as Not = 33-66% probability of outcome
Unlikely= 0-33% probability of outcome
Very Unlikely= 0-10% probability of outcome
Exceptionally Unlikely= 0-1% probability of outcome

Our scientific understanding of the climate system strongly supports the conclusion that large changes in North Carolina's climate, much larger than at any time in the state's history, are ***very likely*** by the end of this century under both the lower and higher scenarios.

Temperature

- North Carolina annual average temperature has increased by about 1.0°F since 1895, somewhat less than the global average. The most recent 10 years (2009–2018), however, represent the warmest 10-year period on record in North Carolina, averaging about 0.6°F warmer than the warmest decade in the 20th century (1930–1939). Recently released data indicate that 2019 was the warmest year on record for North Carolina.

- Although regional changes in temperature can vary from global changes, it is ***very likely*** that North Carolina temperatures will also increase substantially in all seasons. Annual average temperature increases relative to the recent climate (1996–2015) for North Carolina are projected to be on the order of 2°–5°F under a higher scenario (RCP8.5) and 2°–4°F under a lower scenario (RCP4.5) by the middle of this century.
- By the end of this century, annual average temperature increases relative to the recent climate (1996–2015) for North Carolina are projected to be on the order of 6°–10°F under a higher scenario (RCP8.5) and 2°–6°F under a lower scenario (RCP4.5).
- North Carolina has not experienced an increase in the number of hot (daytime maximum temperatures of 90°F or higher) and very hot (daytime maximum temperatures of 95°F or higher) summer days since 1900. However, it has seen an increase in the number of warm (nighttime minimum temperatures of 70°F or higher) and very warm nights (nighttime minimum temperatures of 75°F or higher).
- It is ***very likely*** that the number of warm and very warm nights will increase.
- It is ***very likely*** that summer heat index values will increase because of increases in absolute humidity.
- It is ***likely*** that the number of hot and very hot days will increase.
- It is ***likely*** that the number of cold days (daytime maximum temperatures of 32°F or lower) will decrease.

Precipitation

- There is no long-term trend in annual total precipitation averaged across the state. However, there is an upward trend in the number of heavy rainfall events (3 inches or more in a day), with the last four years (2015–2018) having seen the greatest number of events since 1900.
- It is ***likely*** that annual total precipitation for North Carolina will increase.
- It is ***very likely*** that extreme precipitation frequency and intensity in North Carolina will increase due to increases in atmospheric water vapor content.

Sea Level

- Sea level along the northeastern coast of North Carolina has risen about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck, NC, and 0.9 inches per decade since 1935 at Wilmington, NC.
- It is ***virtually certain*** that sea level along the North Carolina coast will continue to rise due to expansion of ocean water from warming and melting of ice on land, such as the Greenland and Antarctic ice sheets. Under a higher scenario (RCP8.5), storm-driven water levels that have a 1% chance of occurring each year in the beginning of the 21st century may have as much as a 30%–100% chance of occurring each year in the latter part of the century. High tide flooding, defined as water levels of 1.6–2.1 feet (0.5–0.65 m) above Mean Higher High Water, is projected to become a nearly daily occurrence by 2100 under both the lower and higher scenarios.

Hurricanes

- On a global scale, the intensity of the strongest hurricanes is ***likely*** to increase with warming. The confidence in this outcome is ***high***. For individual regions such as North Carolina, the confidence in this outcome is medium. While confidence for North Carolina is lower than for the entire globe, there is no known reason that North Carolina would be protected from stronger hurricanes and this potential risk should be considered in risk assessments.
- Heavy precipitation accompanying hurricanes that pass near or over North Carolina is ***very likely*** to increase, which would in turn increase the potential for freshwater flooding in the state.
- There is ***low confidence*** concerning future changes in the number of landfalling hurricanes in North Carolina.

Storms

- It is ***likely*** that the frequency of severe thunderstorms in North Carolina will increase.
- It is ***likely*** that total snowfall and the number of heavy snowstorms in North Carolina will decrease due to increasing winter temperatures.
- There is ***low confidence*** concerning future changes in the number of winter coastal storms.
- There is ***low confidence*** concerning future changes in the number of ice storms in North Carolina.

Floods, Droughts, and Wildfire

- It is ***virtually certain*** that rising sea level and increasing intensity of coastal storms, especially hurricanes, will lead to an increase in storm surge flooding in coastal North Carolina.
- It is ***likely*** that increases in extreme precipitation will lead to increases in inland flooding in North Carolina.
- It is ***likely*** that future severe droughts **in their multiple forms** in North Carolina will be **more frequent** and intense due to higher temperatures leading to increased evaporation. As a result, it is ***likely*** that the frequency of climate conditions conducive to wildfires in North Carolina will increase.

Other Compound Events

- It is ***likely*** that future urban growth will increase the magnitude of the urban heat island effect, with stronger warming in North Carolina urban centers.
- There is ***low confidence*** concerning future changes in conditions favorable for near-surface ozone formation in North Carolina because of counteracting influences from increases in both temperature and water vapor.

Engineering Design Standards

- It is ***very likely*** that some current climate design standards for North Carolina buildings and other infrastructure will change by the middle of the 21st century. This includes increases in design values for precipitation, temperature, and humidity. Several professional societies, however, are actively working on methods to incorporate climate change into national standards, and updated standards appropriate for use in a changing climate may be available in the near future.

C. NCCSR - Executive Summary

Our scientific understanding of the climate system strongly supports the conclusion that North Carolina's climate has changed in recent decades and the expectation that large changes—much larger than at any time in the state's history—will occur if current trends in greenhouse gas concentrations continue. Even under a scenario where emissions peak around 2050 and decline thereafter, North Carolina will experience substantial changes in climate. The projected changes with the highest level of scientific confidence include increases in temperature, increases in summer absolute humidity, increases in sea level, and increases in extreme precipitation. It is also ***likely*** that there will be increases in the intensity of the strongest hurricanes.

A full appreciation for past and future changes in North Carolina's climate requires a global perspective. Earth's climate has warmed substantially since the late 19th century, with most of that warming occurring in the last 50 years. This warming trend is clear from global temperature records and many other indicators, including rising global sea levels and rapid decreases in arctic sea ice cover. Scientists have ***very high confidence*** that this warming is largely due to human activities that have significantly increased atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases. Extensive research has examined other potential causes of this warming, and the increase in greenhouse gas concentrations is the only plausible cause that is consistent with the observed data and the physics that governs the climate system.

1. Observed Changes

In North Carolina, annual average temperature has increased about 1°F since 1895, compared to the global average increase of about 1.8°F during that period. Annual average temperatures have been consistently above normal since the 1990s, with the most recent 10 years (2009–2018) representing the warmest 10-year period on record— about 0.6°F warmer than the warmest decade of the 1900s (1930–1939). Data for 2019, which were released during the review of this report, indicate that 2019 was the warmest year on record for North Carolina.

Most other temperature indicators also show warming. Average temperatures have increased in all four seasons. There has been an increase in the number of very warm nights. The length of the growing season has increased and is now about 1.5 weeks longer than the long-term average. There is an upward trend in the number of cooling degree days (a temperature indicator related to air conditioning demand) and a downward trend in the number of heating degree days (an indicator of heating demand)—both changes are consistent with a warming climate. However, a few indicators that would be expected to change with warmer conditions have not. For example, the number of very hot days has not increased, and there is no overall trend in the number of cold days and cold nights.

There is no long-term trend in annual total precipitation averaged across the state; however, 2018 was the wettest year on record, in part due to the torrential rainfall from Hurricane Florence. There has been an upward trend in the number of heavy rainfall events (days with more than 3 inches of rain), indicating that a larger portion of the annual total precipitation is occurring in heavy events. Temperature and precipitation trends in the three regions of the state (Coastal Plain, Piedmont, and Western Mountains) are generally similar to statewide trends.

Most observing stations outside of the mountains have experienced a downward trend in snowfall. In the Western Mountains, there is no century-long trend in snowfall, although stations in the southern mountains have seen decreasing trends over the last 50 years. Conditions favorable for snow-cover maintenance and snowmaking in the Western Mountains have been highly variable since 1981, but recent years have seen below average percentages of time when conditions are favorable.

Global average sea level has increased by about 7–8 inches since 1900, with almost half of this increase occurring since 1993—a rate of about 1.2 inches per decade. Sea level along the northeastern coast of North Carolina is rising about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck, NC, and 0.9 inches per decade at Wilmington, NC, mainly due to different rates of land subsidence.

2. Projected Changes

The projections of North Carolina climate conditions presented in this report are based on the ***virtual certainty*** that greenhouse gas concentrations, particularly CO_2, will continue to rise. It may take decades for non-carbon-based sources of energy to replace most of the production based on fossil fuels. The basic principles of physics dictate that increases in greenhouse gas concentrations will have a warming effect, with ***virtual certainty***, due to the increase in atmospheric absorption of infrared energy.

Quantitative projections for temperature, precipitation, and sea level rise are provided for two future scenarios: a higher scenario (RCP8.5), in which greenhouse gas emissions continue to increase through the end of this century, and a lower scenario (RCP4.5), in which emissions increase at a slower rate, peak around the middle of this century, and then begin to decrease. RCP8.5 and RCP4.5 are Representative Concentration Pathways—scenarios used in climate model simulations to examine how Earth's climate would respond to differing levels of greenhouse gas concentrations. The numbers 8.5 and 4.5 refer to the magnitude of the energy imbalance in the climate system (in units of watts per square meter) that would result in the year 2100 from the increases in greenhouse gas concentrations specified by the respective scenarios. By comparison, the increase in concentrations since the initiation of the Industrial Revolution has resulted in an imbalance of approximately 2.3 watts per square meter.

A very low scenario (RCP2.6) is also used occasionally in this report, but this scenario is very unlikely because there has been no slowdown in the annual growth rate of CO_2. Qualitative projections are based on expert judgment and assessment of the relevant scientific literature and draw on multiple lines of scientific evidence as well as model simulations. Except where noted, statements below about future changes refer to projections through the end of this century.

By the end of this century (2080–2099), global average temperature is projected to increase by about 4°–8°F compared to the current climate (1996–2015) under the higher scenario (RCP8.5) and by about 1°–4°F under the lower scenario (RCP4.5). The warming is projected to be greater in the middle and high latitudes and less at tropical latitudes.

Regional changes in temperature can differ from global changes, at least temporarily, as shown by the historical lower rate of warming in North Carolina compared to the global average. Seasonal and annual average temperatures, however, have been rising in North Carolina in recent decades, and it is ***very likely*** that North Carolina temperatures will continue to increase substantially in all seasons.

- By the middle of this century, annual average temperature increases relative to the current climate (1996–2015) for North Carolina are projected to be on the order of 2°–5°F under the higher scenario (RCP8.5) and 2°–4°F under the lower scenario (RCP4.5).
- By the end of this century, annual average temperature increases relative to the current climate (1996–2015) for North Carolina are projected to be on the order of 6°–10°F under the higher scenario (RCP8.5) and 2°–6°F under the lower scenario (RCP4.5).

Temperature extremes are also projected to change:

- It is ***very likely*** that the number of very warm nights will increase, continuing recent trends.
- It is ***likely*** that the number of very hot days will increase, although the level of confidence is lower than for very warm nights because of the lack of recent trends.
- It is ***likely*** that the number of cold days and very cold nights will decrease, but again the level of confidence is lower than for very warm nights because of the lack of recent trends.

Several additional climate features directly tied to temperature are also projected to change, with a high level of certainty:

- It is ***very likely*** that extreme precipitation frequency and intensity will increase because global ocean surface temperatures will continue to increase gradually. In turn, near-surface air temperature and absolute humidity will increase over the oceans because maximum water vapor content is strongly related to temperature, increasing by about 3.5% per °F.
- It is ***virtually certain*** that global sea level will continue to rise due to both the expansion of ocean water from warming and from the melting of ice on land, including the Greenland and Antarctic ice sheets. It is ***virtually certain*** that sea level along the North Carolina coast will also continue to rise. Under the higher scenario (RCP8.5), storm-driven water levels having a 1% chance of occurring each year in the beginning of the 21st century may have as much as a 30%–100% chance of occurring each year in the latter part of the century. High tide flooding is projected to become nearly a daily occurrence by 2100 under both the lower and higher scenarios.
- It is ***very likely*** that summer heat index values will increase because of increases in absolute humidity.
- It is ***likely*** that the probability of snowfall and snow cover will decrease nearly everywhere in North Carolina because of warmer temperatures.

For climate variables where the temperature dependence is more complex, projected changes are less certain:

- Inland flooding depends not only on extreme precipitation but also on characteristics of the land surface, including land use, land cover, and soil moisture conditions. It also depends on whether deliberate adaptive measures are implemented proactively. It is ***likely*** that the frequency and severity of inland flooding will increase because of increases in the frequency and intensity of extreme precipitation. This lower level of certainty compared to projections for changes in extreme precipitation stems from the additional factors that determine flooding.
- It is ***likely*** that annual total precipitation in the state will increase, but there is less certainty for annual total precipitation than for projected increases in extreme precipitation because total precipitation is a function of both atmospheric water vapor and the frequency and intensity of weather systems that cause precipitation. Future changes in the intensity and frequency of such weather systems are more uncertain.

Hurricanes have some of the most important impacts on the state, often catastrophic (storm surge, wind, and flooding damage) but sometimes beneficial (rainfall recharging soil moisture and groundwater aquifers). An understanding of future changes in hurricanes has been the subject of extensive research by climate scientists. While that understanding continues to evolve, a recent assessment of the science leads to the conclusion that the intensity of the strongest hurricanes is ***likely*** to increase with warming, and this could result in stronger hurricanes impacting North Carolina. Confidence in this result is ***high*** for tropical cyclone changes on a global scale. For individual regions such as North Carolina, the confidence in this outcome is medium. While confidence for North Carolina is lower than for the entire globe, there is no known reason that North Carolina would be protected from stronger hurricanes and this potential risk should be considered in risk assessments.

It is ***virtually certain*** that rising sea level and increasing intensity of coastal storms, especially hurricanes, will lead to increases in storm surge flooding in coastal North Carolina. There is ***low confidence*** concerning future changes in the total number of hurricanes. The total number of hurricanes depends on a variety of meteorological factors, such as vertical wind shear (changes in wind speed or direction with height in the atmosphere), and not just ocean surface temperatures, and there is considerable uncertainty about changes in these other factors. Heavy precipitation accompanying hurricanes is ***very likely*** to increase, increasing the potential for freshwater floods.

Severe thunderstorms (hail, tornadoes, and strong winds) are a regular occurrence in North Carolina, particularly in the spring. Severe thunderstorms require two primary atmospheric conditions: an unstable atmosphere and high vertical wind shear. It is ***very likely*** that vertical instability will increase, but it is also ***likely*** that vertical wind shear will decrease. These may counteract one another. Recent research suggests that the increases in atmospheric instability will dominate. While this remains an active area of research, it is ***likely*** that there will be increases in the frequency of severe thunderstorms.

Other important weather systems include snowstorms, winter coastal storms, and ice storms. There is considerable uncertainty about future changes in the number and severity of extratropical cyclones—the weather phenomenon that causes each of these winter storm types. In the case of snow, temperature is an important factor, and it is ***likely*** that total snowfall and the number of heavy snowstorms will decrease because of increasing temperatures. There is ***low confidence*** concerning future changes in the number of ice storms and winter coastal storms.

Drought can have major impacts on the state, including agricultural production, water availability in rivers, lakes, and aquifers, and wildfires. The impacts on these different sectors and systems varies depending on the duration and spatial scale of the precipitation deficits. Although overall precipitation is projected to increase, this is principally a result of larger amounts during heavy rain events. Intervening dry periods are projected to become more frequent and higher temperatures during those dry periods will more rapidly deplete soil moisture. Thus, it is ***likely*** that major droughts in their multiple forms will become more frequent and severe because of higher temperatures that will increase evaporation rates. As a result, it is ***likely*** that the climate conditions conducive to wildfires in North Carolina will increase in the future.

The major urban areas of the state have expanded substantially over the past few decades, and this trend shows no signs of abating. The urban heat island effect results from the conversion of vegetated surfaces (such as forests and farmland) to urban and suburban landscapes with substantial percentages of impervious, non-vegetated surfaces, reducing the amount of natural cooling from evapotranspiration (the combination of evaporation of water from the surface and transpiration of water vapor from vegetation) and increasing the amount of heat retained in darker, paved surfaces as compared to natural land cover. It is ***likely*** that future warming in urban areas will be enhanced by future growth of those areas.

Near-surface ozone is a major component of air pollution, and harmful levels of near-surface ozone result from a combination of climate conditions and human-caused emissions of compounds necessary for the formation of ozone, including nitrogen oxides, carbon monoxide, and volatile organic compounds (referred to as ozone precursor compounds). Near-surface ozone concentrations tend to increase with temperature. However, changes in other climate conditions, such as increased precipitation, can counteract the temperature effect. Overall, it is uncertain what the net effect will be. Thus, there is ***low confidence*** concerning future changes in the conditions favorable for near-surface ozone concentrations.

Climate design values, which provide information on the average and extreme climate conditions experienced in a given location, are important for planning and designing many types of infrastructure. Many climate design values are projected to change because of warming. Because of the high level of confidence in increased temperature and extreme precipitation, it is ***very likely*** that some current climate design standards for building and other infrastructure will change by the middle of this century. This includes increases in design values for precipitation, temperature, and humidity. In fact, current design values are based on historical data and do not incorporate recent trends; thus, some standards may already be out of date. Several professional societies, however, are actively working on methods to incorporate climate change into national standards, and updated standards appropriate for use in a changing climate may be available in the near future.

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Chapter 4

Climate and Environmental Justice

4. Climate and Environmental Justice

The state of North Carolina gratefully acknowledges significant input from the DEQ's Secretary's Environmental Justice and Equity Advisory Board's Climate Change and Extreme Weather Resilience Subcommittee to this chapter.

A. What Is Climate Justice?

Climate change does not affect all people equally. Some people live in places that are more vulnerable to climatic stressors. Others, by nature of their race, wealth, income, age, or other characteristic, are made more vulnerable to climate hazards. These demographic, economic, and social attributes are collectively described as **social vulnerability**. According to scholars, social vulnerability is "the characteristics of a person or their group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard."[1]

Different levels of social vulnerability reflect – and may magnify – historic, social, and economic inequalities. The impacts of natural disasters are often disproportionately felt in low-income communities and communities of color, who may face additional burdens like poor political representation, housing instability, or discrimination.[2] For example, the average black worker in New Orleans was seven times more likely to lose their job after Hurricane Katrina than the average white worker.[3]

The intersection of social inequality with environmental issues is not unique to climate change; it exists in many arenas of environmental decision-making and impact. **Environmental justice[4]** is defined by the U.S. EPA as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." So-called "fenceline" communities, which are those located closest to existing environmental hazards, may also be "front-line" communities, or those that experience negative impacts of climate change first and worst.

Climate justice refers to a social and political movement that acknowledges the deep inequities posed by climate change impacts and identifies opportunities to focus greenhouse gas mitigation and climate change adaptation efforts on the needs of those who are most vulnerable.[5] These inequities function at all geographic scales – from disparities among neighborhoods in one town to differences among the Global North and Global South. Climate justice efforts around the world focus on many topics. Often, climate justice advocacy aims at equity in greenhouse gas reduction schemes or in efforts to shift economic systems away from environmentally-unsustainable practices. Other climate justice work focuses on inequalities in climate outcomes. This chapter examines the inequalities in climate change impacts in North Carolina and actions that can achieve equitable resiliency. The 2019 North Carolina Clean Energy

[1] Davis, I., Blaikie, P.M., Wisner, B., Cannon, T. (2003). *At Risk: Natural Hazards, People's Vulnerability and Disasters*. Routledge.
[2] Elliott, J.R., & Pais, J. (2006). "Race, class, and Hurricane Katrina: Social differences in human responses to disaster." *Social science research* 35(2): 295-321.
[3] Elliott, J.R., and Pais, J. (2006). "Race, class, and Hurricane Katrina: Social differences in human responses to disaster." *Social science research* 35.2: 295-321.
[4] North Carolina is often cited as the birthplace of the Environmental Justice movement. Large protest against citing a toxic waste landfill in Warren County, North Carolina, shined a spotlight on the concentration of waste facilities and other contaminants in communities of color. Learn more about North Carolina Department of Environmental Quality's Environmental Justice Program at https://deq.nc.gov/outreach-education/environmental-justice. Since the First National People of Color Environmental Leadership Summit, the *17 Principles of Environmental Justice* have served to define the foundation of the EJ movement.
[5] Lee, C. (2014 April 24). *Climate Justice.* Retrieved from https://blog.epa.gov/2014/04/24/climate-justice/.

Plan provides more information about social equity in the reduction of greenhouse gases in North Carolina.[6]

North Carolina faces serious challenges to adapt to climate change, but an equitable and just resilience strategy has the potential to bring about positive change in many arenas. To achieve climate justice, climate solutions must be shared equitably. Climate resilience requires that all of our state's residents have access to opportunities and capabilities that enable healthy, secure lives. Once we achieve this level of wellbeing for all residents, communities will have greater abilities to cope with a flood, wildfire, or extreme heat. By marrying goals of social equity and climate resilience, we commit to the health and safety of all residents, the expansion of economic opportunities across the state, the sustainability of our natural resources, and the vibrancy of our state's heritage and many cultures. The resilience of our state depends on these conditions.

North Carolina is on the front line of climate change. Our state and people will experience countless effects from the changing climate in the coming years, decades, and centuries. It is no longer a question of whether North Carolina will experience these effects, arguably, the state has already indeed experienced varying impacts of the changing climate. Rather, the question becomes, how will the state equitably[7] address the challenges posed by climate change and seize the opportunities to mitigate risks and best adapt our communities to a climate-altered future? The vision for a climate-just North Carolina is one for a state that recognizes the inequities of both the past and of the present, in order to create a more equitable future for all. A state that prioritizes communities most vulnerable to the risks of climate change and strengthens North Carolina's resilience and adaptive capacity, while providing opportunities for meaningful involvement to everyone at every stage. Working together with communities, organizations, Tribes, and government agencies at all levels, we can improve outcomes for the future. When race can no longer be used as an indicator to predict life outcomes and outcomes for all people are improved, we will have achieved climate justice.

B. Inequity in Climate Vulnerability and Resilience

Different populations within the state experience varying exposures to and impacts from climate change, especially climate-related hazards. **Exposure** refers solely to the condition of living, working, recreating, or learning in a place that could be adversely affected by a hazard, while **impacts** are characterized by the actual effects that result from these hazards. Evaluating both exposure and impact is critical to assessing vulnerability, or the likelihood of adverse impact from hazards, because impacts may differ among different areas or populations that are exposed to the same hazard.

In this section, we start by discussing examples of socially vulnerable populations and reasons for their elevated vulnerability to climate change. Next, we consider major climate risks and discuss geographic disparities in exposure to climate hazards for socially vulnerable populations. For each climate hazard, we overview issues related to inequalities in impact and adaptive capacity. The following section examines how existing conditions of health, housing, and economic inequalities reinforce climate injustices.

[6] State of North Carolina (2019). *North Carolina Clean Energy Plan: Transitioning to a 21st Century Electricity System*. Retrieved from https://files.nc.gov/ncdeq/climate-change/clean-energy-plan/NC_Clean_Energy_Plan_OCT_2019_.pdf

[7] The authors intentionally use the terms "equity" and "equality" throughout this Chapter, noting the distinction, as the Government Alliance on Race and Equity defines "equity is about fairness, while equality is about sameness." For example, equally distributing a resource (example: food) means giving the same amount to every individual regardless of need. Equitably distributing that resource means giving more food to some people who need additional amounts of that resource (food), such as underweight or famished individuals.

Finally, we consider how existing tools for improving resilience serve some communities and populations more effectively than others.

1. Socially Vulnerable Populations

There are a variety of individuals and groups that systematically face disparate impacts from climate change and barriers to adaptation in North Carolina. For example, minority populations are more likely to experience the damaging and destabilizing effects of climate change and are less likely to be able to recover from a climate hazard.[8] This difficult truth about the racial disparity in climate change impacts is in large part attributed to centuries of structural racism. According to researchers, **structural racism:**

"[i]nvolves interconnected institutions, whose linkages are historically rooted and culturally reinforced. It refers to the totality of ways in which societies foster racial discrimination, through mutually reinforcing inequitable systems (in housing, education, employment, earnings, benefits, credit, media, health care, criminal justice, and so on) that in turn reinforce discriminatory beliefs, values, and distribution of resources, which together affect the risk of adverse … outcomes."[9]

Structural racism is different from intentional, interpersonal discrimination. These types of discrimination matter, but structural racism is a more powerful driver of racial inequality, working even in the absence of intentional, interpersonal discrimination. The result of centuries of structural racism is visible across the state and apparent in unequal **compounding vulnerabilities,** or climate burdens piled on top of environmental, social, economic, or health burdens, that many minority communities experience today.

Different minority populations may be vulnerable to climate change for different reasons. For example, historic Native American settlements often are located near water in coastal or riverine floodplains, increasing their exposure to flooding.[10] In addition, a diversity of Native American communities have strong cultural and/or economic relationships with land or specific sites, which makes them particularly sensitive to the effects of climate change.[11] North Carolina has more Native Americans than any state east

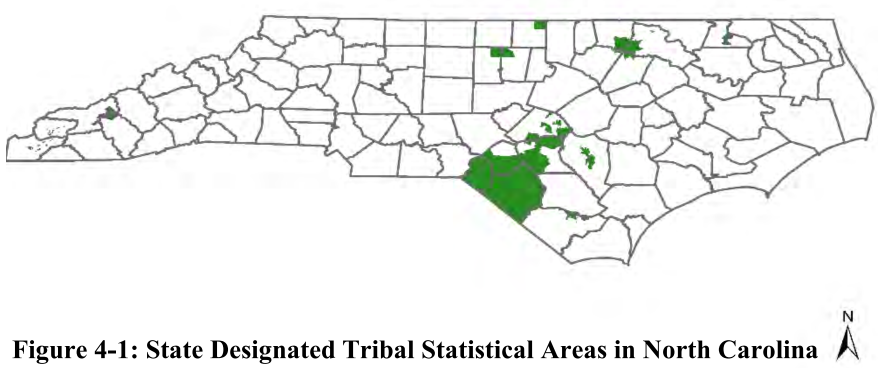

Figure 4-1: State Designated Tribal Statistical Areas in North Carolina

[8] Thomas, K., Hardy, R. D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., … Winthrop, R. (2019). Explaining differential vulnerability to climate change: A social science review. *Wiley interdisciplinary reviews. Climate change*, *10*(2), e565. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6472565/

[9] Bailey, Z. D., Krieger, N., Agénor, M., Graves, J., Linos, N. & Bassett, M. T. (2017). America: Equity and Equality in Health 3, Structural racism and health inequities in the USA: evidence and interventions. *The Lancet, 389,* 1453. Retrieved from: https://www.rootcausecoalition.org/wp-content/uploads/2017/04/Structural-racism-and-health-inequities-in-the-USA-evidence-and-interventions.pdf

[10] National Congress of American Indians. (n.d.) *Climate Change.* Retrieved from http://www.ncai.org/policy-issues/land-natural-resources/climate-change

[11] Wildcat, D.R. (2014). "Introduction: climate change and indigenous peoples of the USA." *Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions.* Springer.

of the Mississippi, and their diversity is partially reflected in the wide distribution of state designated tribal statistical areas, mapped in Figure 4-1.

Immigrants are at particular risk for climate change in North Carolina as well. According to the U.S. Census, nearly half a million North Carolina residents speak English less than "very well." Individuals with limited English proficiency encounter barriers to receiving information critical to their health and safety. For many immigrant communities where both documented and undocumented immigrants may live, risk of deportation and a historical mistrust of government officials in their home countries may lead to a lack of trust in government officials in the United States, which in turn may limit access to emergency services, recovery programs, and resilience resources.

Race, ethnicity, nationality and language are not the only drivers of unequal vulnerability. Income, age, disability, and location within the state also underlie inequities. Low-income households, including many seniors on fixed incomes, have few financial resources necessary to fix damage from hazards, afford increasing energy bills, or to absorb fluctuations in the cost of food. Homeless populations face exposure to the elements, limited access to medical and mental health services, and lack the financial resources to address impacts of climate change. Rural populations have a greater share of adults who work in weather-dependent environments like agriculture and forestry, where climate change may affect one's ability to earn a living.

Populations with elevated health stressors are also more susceptible to impacts of climate change. Many health stressors like diabetes and respiratory issues are themselves tied to the social and economic conditions of people's lives and the places they inhabit.[12,13,14] These conditions are often referred to as social determinants of health (SDOH) and they include economic stability, neighborhood conditions, access to healthcare, education, and other kinds of community context.[15] SDOH help us understand the compounding ways that social stressors like racial inequality and poverty increase the impact of climate change. These socioeconomic conditions shape our exposure to climate hazards, access to resources to cope with impacts, and sensitivity to health effects.

For example, poor households, already at increased risk for respiratory problems, are more likely to lack central air conditioning, which makes them more likely to suffer mold and poor indoor air quality after a flood. Low-income and minority neighborhoods experience elevated levels of diabetes and are more likely to be located in "food deserts," or areas without access to fresh food.[16] When climate stressors interrupt agriculture, food prices increase, exacerbating the affordability and availability of fresh food,[17] which worsens diabetes outcomes. These are examples of compounding vulnerabilities. While these examples comprise major dimensions of climate inequity in North Carolina, they are far from the only demographic, social or economic attributes that systematically elevate risk and lower resilience.

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[12] Garcia, J. G., & Sznajder, J. I. (2013). Healthcare disparities in patients with acute respiratory distress syndrome. Toward equity.
[13] Peek, M. E., Cargill, A., & Huang, E. S. (2007). Diabetes health disparities. *Medical Care Research and Review*, *64*(5_suppl), 101S-156S.
[14] Garcia, J. G., & Sznajder, J. I. (2013). Healthcare disparities in patients with acute respiratory distress syndrome. Toward equity.
[15] Centers for Disease Control and Prevention. (n.d.) *Social Determinants of Health: Know What Affects* Health. Retrieved from https://www.cdc.gov/socialdeterminants/index.htm
[16] [46] Walker, R. E., Keane, C. R., & Burke, J. G. (2010). Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & place*, *16*(5), 876-884.
[17]https://www.cdc.gov/climateandhealth/effects/default.htm

2. Unequal Exposure, Unequal Impact

Maps can help illustrate where socially vulnerable populations may have elevated exposure to climate hazards in North Carolina. To achieve this objective, this chapter uses the Department of Environmental Quality's environmental justice mapping protocol. Using standard environmental justice guidelines from the U.S. EPA and the National Environmental Policy Act (NEPA) guidance, the DEQ protocol identifies Census block groups as *potentially underserved* if their populations are disproportionately nonwhite and disproportionately experiencing poverty. Specifically, potentially underserved populations meet the following criteria for both race and poverty:

Racial composition:

- Share of nonwhites is over fifty percent OR
- Share of nonwhites is at least ten percent higher than county or state share

Poverty rate:

- Share of population experiencing poverty is over twenty percent AND
- Share of households in poverty is at least five percent higher than the county or state share

The concept and definition of *potentially underserved communities* is just one way to illustrate inequality in climate exposure. In this chapter's recommendations, we suggest experimenting with a diversity of mapping methodologies and data sources to better understand the distribution of climate exposure. One caveat related to the use of maps is that some factors that influence how a community or household is impacted by a climate hazard, like political influence or social capital, may never be particularly well captured by quantitative or spatial data. The maps in this chapter distinguish between a higher share of minorities or an elevated level of poverty compared to the county and the state. Comparing at a county level allows identification of potentially underserved areas within a specific county. This scale provides a localized understanding of underserved areas and may assist local officials in targeting specific areas in their county for enhanced engagement, mitigation, or services. Comparison with the state allows for a state level analysis of potentially underserved areas, which similarly may assist state officials in targeting areas that may be underserved on the state level.

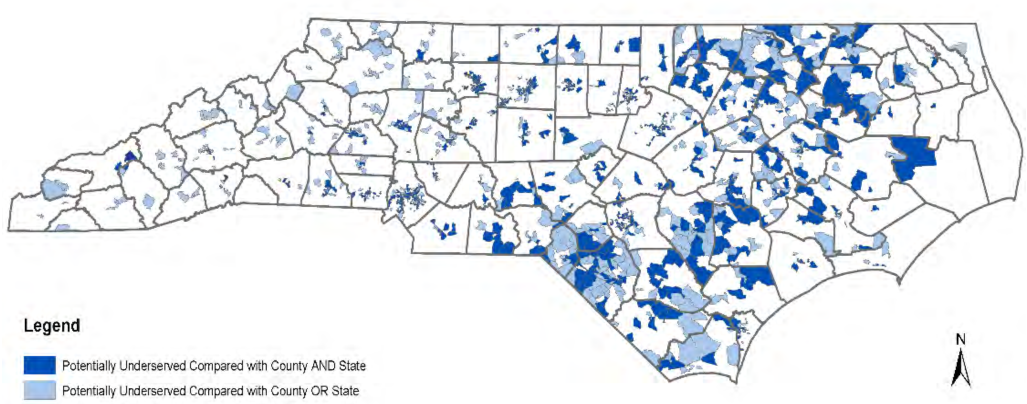

Figure 4-2: Potentially Underserved Populations in North Carolina[18]

[18] Data are derived from the *American Community Survey* (U.S. Census Bureau) 2017 Five-year estimates, using the following tables: *B03002- Hispanic or Latino Origin by Race* and *C17002- Ratio of Income to Poverty Level*.

Relying on data from the U.S. Census Bureau *American Community Survey* 2017 Five-year estimates, Figure 4-2 illustrates the distribution of potentially underserved populations across the state. Note that Census block groups are determined by population, not land area, so potentially underserved populations in rural areas display more prominently on a statewide map than those in dense, urban areas.

This chapter uses historical climate data to visualize the presence of potentially underserved populations in areas of elevated risk for five climate-driven hazards in North Carolina: wildfires, inland flooding, excessive heat, coastal flooding, and landslides. In the future, we recommend the development of maps that use projected climate data, when it is available at the statewide level, and updated U.S. Census data to further understand inequalities in climate exposure. In addition to mapping unequal exposure to the selected climate-driven hazards, we include a brief consideration of inequalities in impacts of exposure.

Wildfires

Climate conditions conducive to wildfire are likely to increase in North Carolina[19], as they will in many parts of the country and the globe.[20] As shown in Figure 4-3, wildfire risk is greatest among potentially underserved communities in the southern and western regions of the state. Some of the most affected counties include Robeson, Hoke, Brunswick, and Bladen in the southern region of the state, and Henderson, Buncombe, Cleveland, Burke, Catawba and Iredell counties in the western region of the state.

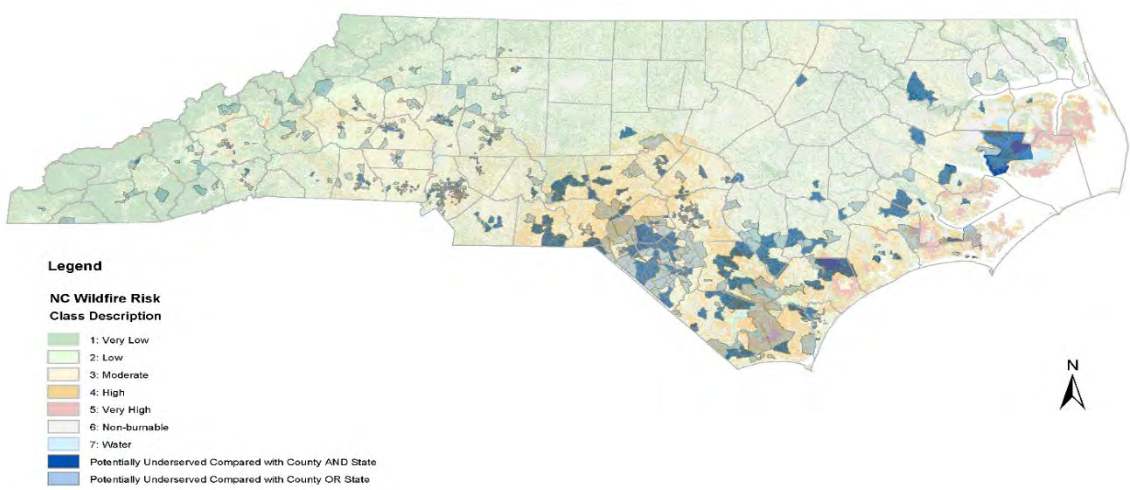

Figure 4-3: Potentially Underserved Populations and Current Wildfire Risk[21]

Wildfire poses many risks to the health and well-being of North Carolina residents. The North Carolina Department of Health and Human Services *Climate and Health Profile* indicates that air quality and respiratory diseases are the most significant public health impact of climate change in the state.[22] Wildfire causes deterioration in air quality, triggering respiratory and cardiac health problems. During the wildfires in Dare County in 2008, hospital emergency departments experienced an estimated 42 to 66 percent

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[19] For more information, see Chapter 3: NC Climate Science Report

[20] Liu, Y., Stanturf, J., & Goodrick, S. (2010). Trends in global wildfire potential in a changing climate. *Forest ecology and management*, *259*(4), 685-697. Retrieved from https://www.srs.fs.usda.gov/pubs/36444

[21] Data from: USDA Forest Service. (2018). *Wildfire Hazard Potential (WHP)*. Retrieved from https://www.firelab.org/project/wildfire-hazard-potential

[22] North Carolina Department of Health and Human Services. (n.d.). *North Carolina Climate and Health Profile.* Retrieved from https://epi.dph.ncdhhs.gov/oee/climate/ClimateAndHealthProfile.pdf

increase in visits for respiratory and cardiovascular problems.[23,24] Socio-economic variables affect the number of wildfires, their extent, and their impact. Wildfires that start in high-poverty communities are less likely to be extinguished quickly due to lack of resources.[25] Health impacts of wildfire smoke also have greater impact across social and demographic differences, like greater mortality among senior citizens.[26] Wildfire also has economic impacts on North Carolina. The ecological damage resulting from wildfires harms communities that derive economic activity and employment from scorched areas,[27] which could include Christmas tree farming operations, logging, or tourism. Workers in these industries are disproportionately at risk from economic burdens of wildfire, in addition to other elevated economic and health risks of outdoor work due to climate change.

Inland Flooding

Inland flooding is one of the most common natural hazards experienced in North Carolina, and climate change is projected to increase the frequency of extreme precipitation events that cause inland flooding.[28] Inland flooding is magnified by non-climate-related factors such as floodplain development, urbanization,

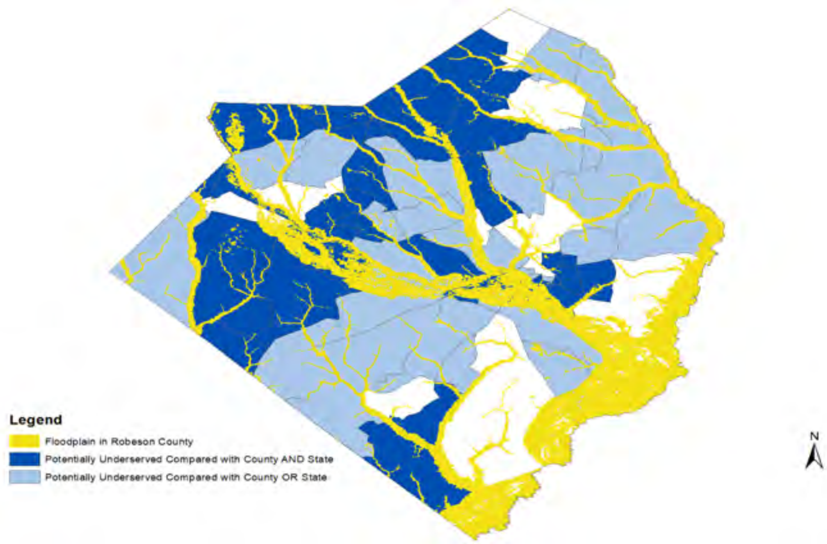

Figure 4-4: Potentially Underserved Populations and Floodplain in Robeson County, North Carolina[29]

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[23] Rappold, A.G., Stone, S.L., Cascio, W.E., Neas, L.M., Kilaru, V.J., Carraway, M.S., …Devlin, R.B. Peat bog wildfire smoke exposure in rural North Carolina is associated with cardiopulmonary emergency department visits assessed through syndromic surveillance. (2011). *Environmental Health Perspectives*. 119:1415-20. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21705297

[24] Tinling MA. Emergency Department Diagnoses in Eastern North Carolina Associated with Smoke Exposure from the 2011 Pains Bay Wildfire. 2012. Master's thesis. Cited in North Carolina Department of Health and Human Services. (n.d.). *North Carolina Climate and Health Profile.* Retrieved from https://epi.dph.ncdhhs.gov/oee/climate/ClimateAndHealthProfile.pdf

[25] Mercer, D. E., & Prestemon, J. P. (2005). Comparing production function models for wildfire risk analysis in the wildland–urban interface. *Forest policy and economics*, *7*(5), 782-795. Retrieved from https://www.fs.usda.gov/treesearch/pubs/21080

[26] Kochi, I., Champ, P. A., Loomis, J. B., & Donovan, G. H. (2012). Valuing mortality impacts of smoke exposure from major southern California wildfires. *Journal of forest economics*, *18*(1), 61-75. Retrieved from https://www.fs.fed.us/rm/pubs_other/rmrs_2012_kochi_i001.pdf

[27] Butry DT, Mercer DE, Prestemon JP, Pye JM, Holmes TP. (2001). *What is the price of catastrophic wildfire?* Retrieved from https://www.srs.fs.usda.gov/pubs/ja/ja_butry001.pdf

[28] United States Environmental Protection Agency. (2015). *Climate Action Benefits Report: Inland Flooding.* Retrieved from https://www.epa.gov/cira/climate-action-benefits-inland-flooding#findings. For more information, see Chapter 3: NC Climate Science Report

[29] Data from: EnviroAtlas. (2018). *Estimated floodplain map for the Conterminous United States.* Retrieved from https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7B4c37f02a-0c91-49b2-b7df-82ea4a6b9750%7D

and land-use changes.[30] It is one of the most widespread risks in the state, even as acute impacts are very localized. Inland flooding affects people of all socioeconomic backgrounds, but mapping demonstrates that exposure is often concentrated in areas of social vulnerability. An example from Robeson County in Figure 4-4 demonstrates the risk of inland flooding on potentially underserved communities in the county. Future maps should be downscaled further to better understand the location of housing and development in socially vulnerable areas with respect to flood risk. Regulatory floodplains have not proven consistent predictors of the location of flooding in recent storms, so improved modeling for inland flood risk would also improve the accuracy of exposure maps.

Socially vulnerable communities may be concentrated in areas exposed to inland flooding for many reasons. Land values are typically lower in a floodplain, making homes more affordable to build, sell, or rent. Historic patterns of racial housing discrimination have resulted in concentrations of communities of color, especially African Americans, living in flood prone areas. In addition, the impact of inland flooding disproportionately disrupts the lives of socially vulnerable populations. Low-income households, seniors, people with disabilities, and people with chronic illnesses may have less access to transportation, making evacuation or mobility difficult during a flood.[31] Individuals with low incomes have less ability to pay for hotels in the event they are evacuated or less disposable income to replace spoiled food in case of a power outage. Because of differences in the quality of housing and insurance coverage, wealthier communities often recovery more quickly from inland flooding.

Extreme Heat

Most areas of North Carolina have warmed in the last century, and this warming is projected to continue. Within 70 years, it is estimated that most of the state will experience between 20 and 40 days a year of temperatures above 95° F, defined as "extreme heat."[32] The Climate Science Report, summarized in Chapter III, projects that by the end of the century, annual average temperature will increase 5° to 10°F under a higher, "business as usual" emissions scenario (RCP8.5) and 2° to 6°F under a lower emissions scenario (RCP4.5).

Figure 4-5 illustrates that areas with elevated extreme heat days are largely concentrated in the Eastern part of the state, creating a band from Northampton and Hertford counties south to Robeson, Columbus, and Brunswick counties. Several counties, including Robeson, Sampson, Duplin, Wayne, Bertie, and Halifax have both high percentages of potentially underserved populations and elevated extreme heat days. High heat in urban areas is magnified by the urban heat-island effect. According to NASA, "an urban heat island occurs when a city experiences much warmer temperatures than nearby rural areas. The difference in temperature …has to do with how well the surfaces in each environment absorb and hold heat."[33] The heat island effect also triggers increases in energy consumption for air conditioning, which increases adverse public health impacts due to emissions from energy production and consumption.[34] Many households in potentially underserved areas are located in urban areas, including the cities of Charlotte, Raleigh, Durham, Fayetteville, Greenville, and Wilmington, which already experience an elevated number of extreme heat days.

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[30] United States Environmental Protection Agency. (2015). *Climate Action Benefits Report: Inland Flooding.* Retrieved from https://www.epa.gov/cira/climate-action-benefits-inland-flooding#findings.
[31] Ibid.
[32] Data from: EnviroAtlas. (2018). *Estimated floodplain map for the Conterminous United States.* Retrieved from https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7B4c37f02a-0c91-49b2-b7df-82ea4a6b9750%7D
[33] NASA (n.d.). *What is an Urban Heat Island?* Retrieved from https://climatekids.nasa.gov/heat-islands/
[34] United States Environmental Protection Agency. (2019) *Heat Island Impacts.* Retrieved from https://www.epa.gov/heat-islands/heat-island-impacts

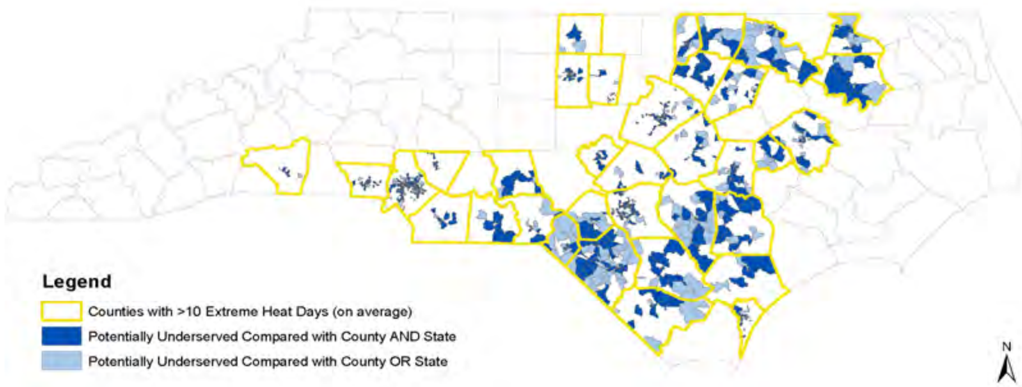

Figure 4-5: Potentially Underserved Populations in Counties with > 10 Average Extreme Heat Days Annually[35]

Individuals exposed to extreme heat are vulnerable to heat-related illness, and research shows that social characteristics exacerbate that risk. For example, in urban environments, poverty and low educational attainment are associated with increases in emergency department visits for heat-related illness.[36] In rural areas, the number of mobile homes and the labor intensity of agriculture are likewise associated with increased heat-related illness.[37]

Storm Surge

According to the 2020 North Carolina Climate Science Report (NCCSR), summarized in Chapter 3, it is “virtually certain” that rising sea level and increasing intensity of coastal storms will drive increases in storm surge flooding. This climate hazard will certainly impact high-value, ocean-facing properties, but communities on the Inner Banks or otherwise near coastal waters face significant risk too, like New Bern or the Down East villages of Carteret County. Many of these communities have unique, historic cultures and heritage, the continuity of which is threatened by climate change. In figure 4-6, potentially underserved communities at risk of storm surge exposure from a Category 5 hurricane are identified in blue against the storm surge areas in yellow. Clusters of potentially underserved communities exposed to storm surge exist along the entire North Carolina coastline and throughout the sounds, including Shallotte, Wilmington, South Jacksonville, New Bern, East Greenville, Edenton, and Elizabeth City. Differential impacts of storm surge are similar to those of inland flooding. Homes in higher poverty areas are less likely to be elevated, the burden of evacuating is greater for poor households and people with disabilities, and navigating insurance and government recovery programs favors people with more education.

[35] Data from: xmACIS2. (2019). *Temperature data 1996-2016.* https://xmacis.rcc-acis.org/
[36] Kovach, M. M., Konrad II, C. E., & Fuhrmann, C. M. (2015). Area-level risk factors for heat-related illness in rural and urban locations across North Carolina, USA. *Applied Geography*, *60*, 175-183. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0143622815000788
[37] Kovach, M. M., Konrad II, C. E., & Fuhrmann, C. M. (2015). Area-level risk factors for heat-related illness in rural and urban locations across North Carolina, USA. *Applied Geography*, *60*, 175-183. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0143622815000788

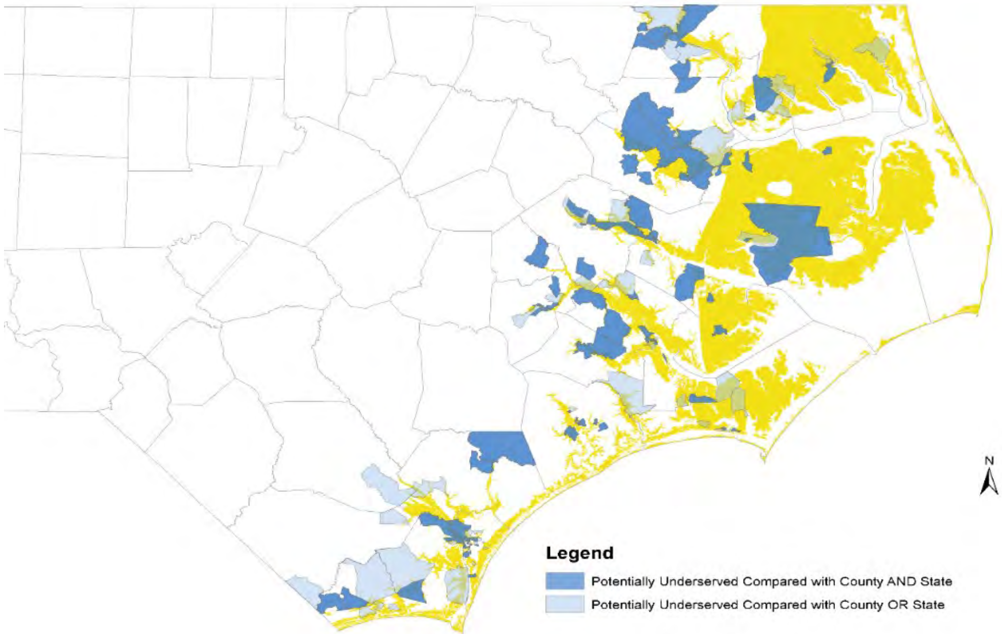

Figure 4-6: Potentially Underserved Populations in Storm Surge Areas[38]

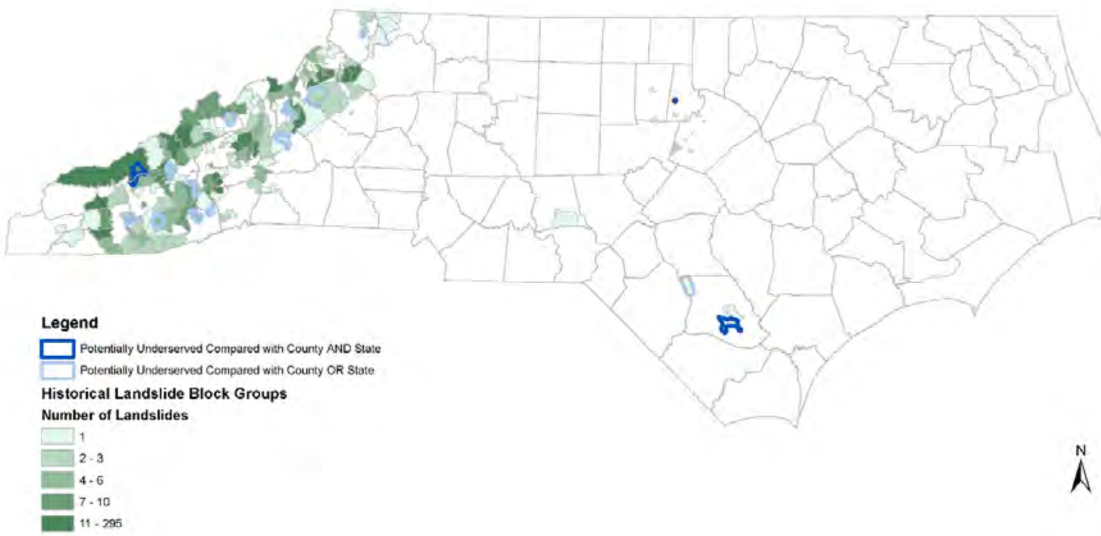

Figure 4-7: Potentially Underserved Populations in Historic Landslide Areas[39]

[38] Data from: NOAA. (2018). *National Storm Surge Hazard Maps- Version 2 (Category 5).* Retrieved from https://www.nhc.noaa.gov/nationalsurge/

[39] Data from: NC Geological Survey. (2019). *North Carolina slope movement-slope movement deposit database (NCSM-SMD database).* Retrieved from: https://www.nconemap.gov/datasets/landslides

Landslides

A changing climate can increase landslide risk via multiple pathways, including an increase in air temperatures, higher intensity and more frequent rain events, and drought (particularly in the summer).[40,41] As shown in Figure 4-7, the overwhelming majority of landslides occur in the western region of the state, with just a few occurring in central North Carolina. There are approximately twenty Census block groups classified as potentially underserved communities located in areas with a history of landslides. These areas are primarily located in the West but also present in other areas of the state.

Landslides often occur without warning. Populations with a limited ability to flee the impacted area due to the lack of vehicle access, older age, or limited mobility, are disproportionately more likely to experience adverse health and safety effects. Landslides also cause significant damage to private property and infrastructure. For households, recovery from this damage requires financial resources. Landslides tend to be localized, so they are unlikely to trigger a Presidential disaster declaration. Without federal recovery resources, state and local governments with infrastructure damage will need to spend their own funds on repair. Both of these realities favor landslide recovery in wealthier areas.

3. Physical Infrastructure and Housing Disparities

Housing and neighborhood conditions in North Carolina predispose socially vulnerable communities to greater impacts of climate change. The lack of affordable housing strains household resources at every income level, but especially for those who are very low-income. As a result, very low-income individuals are more likely to experience long-term displacement and homelessness as a result of climatic events.

The inability to remain in secure housing can affect a person's ability to attend and perform well in school or in a job. Housing security in the context of climate hazards is tenuous for socially vulnerable populations. Housing and infrastructure in low-income and minority neighborhoods tends to be older and less weatherized to cope with climate hazards.[42] Neighborhoods with greater shares of minorities, low-income households, and renters tend to have less vegetation like street trees, which would decrease heat health impacts.[43,44] Not even considering the worsening of some neighborhood conditions around housing due to climate change impacts, racial disparities of health outcomes may already be linked with past racial segregation in housing.[45] These underlying housing and neighborhood conditions reflect social inequalities and magnify climate injustices.

Despite longstanding inequalities in health, housing and economic wellbeing, there are examples of resilience that are present and sometimes concentrated in socially vulnerable communities. For example,

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[40] Crozier, M. J. (2010). Deciphering the effect of climate change on landslide activity: A review. *Geomorphology*, *124*(3-4), 260-267.Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0169555X10001881
[41] Borgatti, L., Soldati, M. (2010). *Landslides and Climatic Change.* Retrieved from https://books.google.com/books?hl=en&lr=&id=YlIwBQAAQBAJ&oi=fnd&pg=PA87&dq=Borgatti,+L.,+Soldati,+M.+(2010).+&ots=pi3y7GGkEX&sig=QZGtsJ0c01Tx16135FnmYwkbTB8#v=onepage&q=Borgatti%2C%20L.%2C%20Soldati%2C%20M.%20(2010).&f=false
[42] Tonn, B., Schmoyer, R., & Wagner, S. (2003). Weatherizing the homes of low-income home energy assistance program clients: a programmatic assessment. *Energy Policy*, *31*(8), 735-744.
[43] Landry, S. M., & Chakraborty, J. (2009). Street Trees and Equity: Evaluating the Spatial Distribution of an Urban Amenity. *Environment and Planning A: Economy and Space*, 41(11), 2651–2670.
[44] Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V., & Schwartz, J. (2009). Mapping Community Determinants of Heat Vulnerability. *Environmental Health Perspectives.* 117(11). Retrieved from https://ehp.niehs.nih.gov/doi/10.1289/ehp.0900683
[45] Williams, D., & Collins, C. (2001). Racial Residential Segregation: A Fundamental Cause of Racial Disparities in Health. *Public Health Reports*, 116, 404-416.

bonding social capital plays an outsized role in coping with natural hazards or climatic impacts.[46] Bonding social capital describes connections and relationships within a group or community that draws on similar demographic characteristics, attitudes, beliefs, and resources.[47]

Many socially vulnerable communities have strong family, ethnic, faith-based, cultural, and community ties. Day-to-day social connections can support communication, shared responsibility, and strong personal relationships that form the basis for communal and household recovery and resilience. In these instances, bonding social capital is particularly critical because vulnerable communities may lack easy access to government aid and external assistance. Instead, social groups provide avenues to recovery. On the other hand, displacement and disruption caused by climate change can physically dismantle the social ties that comprise these sources of support. Therefore, it is essential to integrate an understanding of bonding social capital assets in planning for disasters and climate change.[48]

The state of North Carolina recognizes the role of underlying inequalities in many of its recovery and resilience programs. For example, to address housing inequalities, Office of Recovery and Resiliency (NCORR) will be dispersing hundreds of millions of dollars in Community Development Block Grants (CDBG) across many sectors (housing, water infrastructure, recovery, etc.) to support recovery primarily among low- to moderate- income (LMI) households or to benefit neighborhoods where LMI households reside. NCORR also works with the Historically Underutilized Businesses program in the Department of Administration to conduct outreach to firms interested in contracting for recovery work. Contractors with NCORR programs are required to substantially employ low- and very low-income persons to the greatest extent feasible. These are examples of ways in which the state's recovery programs have sought to support recovery in ways that acknowledge and address pre-existing disparities.

4. Inequalities in Climate Adaptation Interventions

In addition to uneven exposure to climate hazards and inequitable distribution of the impacts of those risks, some resilience interventions serve households and communities unequally. These disparities are present on different geographic scales.

Climate Adaptation Development

As in most places around the world, the majority of policy changes that support resilience in North Carolina have taken place at the local level. On one hand, local governments are well positioned to improve resilience through best practices like land use provisions and to cater their strategies to the resilience needs of their own communities. On the other hand, the delegated nature of resilience efforts favors local governments with the staff and resources to dedicate toward this purpose. Stakeholders from across the state who participated in the 2019 Regional resiliency workshops talked about the difficulty that smaller cities and towns face in addressing resiliency without more resources from higher levels of government. They told state staff that many communities that most need resiliency thinking, where infrastructure is already failing, for example, have the least capacity to dedicate staff or financial resources toward solutions. The state is addressing this disparity in many ways, through state-level action like Executive Order 80, the 2020 Resilience Plan, and the unified North Carolina Resilience Plan detailed in Chapter 7, and through providing resources to local governments through the North Carolina Resilient Communities Program, also detailed in Chapter 7.

[46] Aldrich, D. P., & Meyer, M. A. (2015). Social Capital and Community Resilience. *American Behavioral Scientist*, *59*(2), 254–269. Retrieved from https://doi.org/10.1177/0002764214550299
[47] Lin, N., Cook, K.S. & Burt, R.S. (2001). *Social Capital: Theory and Research*. New York: Aldine de Gruyter
[48] Aldrich, D. P., & Meyer, M. A. (2015). Social Capital and Community Resilience. *American Behavioral Scientist*, *59*(2), 254–269. Retrieved from https://doi.org/10.1177/0002764214550299

Another way in which resilience initiatives tend to exclude socially vulnerable communities is through their governance and approach. Historically, resilience efforts have not engaged organizations that interface most frequently with socially vulnerable populations, such as public schools, social service and healthcare providers, houses of worship, faith-based organizations, and public transit systems. These kinds of organizations could be the basis of very successful resilience efforts in the future. Some aspects of resilience efforts rely heavily on science to the exclusion of local community knowledge and lived experiences. For example, official modeling for established flood zones may be dissimilar from areas where people actually experience regular flooding, which complicates insurance policies and eligibility for recovery programs. Social science may favor one type of resilience solution, but local residents may understand that the solution is likely to fail in that place for local reasons. Moving forward, resilience initiatives could enrich their fact base by soliciting local knowledge.

There are also systemic reasons why socially vulnerable populations may not be well represented in all public policy, including resilience policy and planning. Citizen involvement and participation in public policy requires volunteering one's time to attend public hearings and meetings, which is difficult for individuals who care for children or the elderly, or for people who either work more than one job or do not have flexibility in their working hours. The language and process of public policy is virtually inaccessible to individuals with less education. Segregation and other factors of some socially vulnerable populations limit connections to and representation in government and other institutions of influences, which researchers call "bridging social capital."[49] Further, as participants in the regional resilience workshops expressed, a general sense of mistrust in government and government programs by socially vulnerable populations and leaders hinders the creation of beneficial partnerships.

Climate Adaptation Implementation

At the household scale, many resilience measures target property owners, leaving renters vulnerable to climate change impacts and related risks. For example, many of the state's programs for home elevations or property buyouts prioritize owner-occupied homes, which leaves renters more exposed to flooding. Other federal and state recovery programs are designed to help both homeowners and renters, but because homeowners own more valuable assets, i.e. their houses, more recovery aid goes to homeowners. Even among homeowners, those who can afford insurance or have access to personal financial resources are better situated to rebuild faster and more effectively than those who must wait for government assistance. This leads to obvious inequalities in disaster recovery.

Another structural inequality in resilience interventions relates to real estate values. For example, to build levees or other flood protection infrastructure, a benefit-cost analysis is required. The benefit of the potential investment is typically based on the value of real property that the infrastructure would protect. Naturally, this methodology favors investments in areas with high property values. On the other hand, buyouts or managed retreat strategies of last resort are more likely to occur in areas with lower property values because each additional buyout costs less than an equivalent buyout where property values are higher.[50] Governments may use a variety of tools to encourage buyouts, like construction moratoria, condemnation, and "substantially damaged" declarations.[51] These tools are often more effective in low-income neighborhoods because these individuals often rely on outside public or insurance assistance for recovery. The role of real estate values in public policy decisions increases the likelihood of in-place solutions for areas with higher values and increases the likelihood of buyout in areas with lower property

[49] Lin, N., Cook, K.S. & Burt, R.S. (2001*). Social Capital: Theory and Research*. New York: Aldine de Gruyter
[50] Siders, A. R. (2019). *Social Justice Implications of US Managed Retreat Buyout Programs*. Retrieved from https://doi.org/10.1007/s10584-018-2272-5.
[51] "Substantially damaged" refers to the finding that the home is over 50% damaged, which requires the home to be brought to current code, even if it had been built at an earlier point under lower code standards. De Vries, Daniel H., and James C. Fraser. (2017). *Historical Waterscape Trajectories That Need Care: The Unwanted Refurbished Flood Homes of Kinston's Devolved Disaster Mitigation Program.* Retrieved from https://doi.org/10.2458/v24i1.20976.

values. While most researchers agree that buyouts are a more secure solution to flood vulnerability, buyouts also have significant social costs like breaking apart neighborhoods and the impact of vacant lots on the neighborhood.

Leveraging Social Capital

Despite longstanding inequalities in physical infrastructure, health, and economic wellbeing, there are examples of resilience that are present and can be stronger in socially vulnerable communities. For example, bonding social capital plays an outsized role in coping with natural hazards or climatic impacts.[52] Bonding social capital describes connections and relationships within a group or community that draws on similar demographic characteristics, attitudes, beliefs, and resources.[53]

Many socially vulnerable communities have strong family, ethnic, faith-based, cultural, and community ties. Day-to-day social connections can support communication, shared responsibility, and strong personal relationships that form the basis for community and household recovery and resilience. In these instances, bonding social capital is particularly critical because vulnerable communities may lack easy access to government aid and external assistance. Instead, social groups provide avenues to recovery. On the other hand, displacement and disruption caused by climate change can physically dismantle the social ties that comprise these sources of support. Therefore, it is essential to integrate an understanding of bonding social capital assets in planning for disasters and climate change.[54]

C. Climate Justice Spotlight Issues

This section examines climate and environmental issues which have drawn significant concern in North Carolina, including:

- energy cost burden and higher heat;
- workers, small businesses, and family businesses in vulnerable industries;
- African American property ownership; and
- insurance inequalities.

These issues have been highlighted by the DEQ's Secretary's Environmental Justice and Equity Advisory Board's Climate Change and Extreme Weather Resilience Subcommittee as well as the state Disaster Recovery Task Force's Recovery Support Functions. Additionally, the effect of changing climate on outdoor workers and small businesses was identified as a major consequence in the NC Regional Resilience Workshops.[55]

1. Energy Burden and Higher Heat

Home energy cost is a significant financial strain for many individuals and families in North Carolina. As the state experiences progressively more days of extreme heat, energy burden, or the percentage of household income spent on home energy bills, will also increase. Fuel poverty, or the inability of

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[52] Aldrich, D. P., & Meyer, M. A. (2015). Social Capital and Community Resilience. *American Behavioral Scientist*, *59*(2), 254–269. Retrieved from https://doi.org/10.1177/0002764214550299
[53] Lin, N., Cook, K.S. & Burt, R.S. (2001). *Social Capital: Theory and Research*. New York: Aldine de Gruyter
[54] Aldrich, D. P., & Meyer, M. A. (2015). Social Capital and Community Resilience. *American Behavioral Scientist*, *59*(2), 254–269. Retrieved from https://doi.org/10.1177/0002764214550299
[55] For more information, see Appendix C: NC Mountain and Piedmont Regional Resilience Workshops Report

households to afford adequate energy services, already exists in the state of North Carolina.[56] The U.S Department of Health and Human Services classifies an energy burden of above six percent of household income as unaffordable.[57] In North Carolina, many low-income homeowners and renters face an energy burden higher than 6%, with some county averages reaching 25% (shown in Figures 4-8 and 4-9). Higher rates of fuel poverty for low-income and minority households is a combined result of lower incomes and living in homes that are older and less fuel efficient, increasing the amount of energy required to maintain a healthy indoor temperature.[58,59] Renters are particularly vulnerable to energy cost burdens because landlords do not have a financial incentive to improve the efficiency of properties where tenants pay the utility bills.

Fuel poverty is particularly concerning in a warming North Carolina. Elevated levels of fuel poverty are present in all parts of the state. Figure 4-8 illustrates the geographic distribution of fuel poverty among homeowners overlaid with data on extreme heat and Figure 4-9 illustrates the same distribution among renters. Counties with the highest energy burden experience an elevated number of high heat days as compared to the rest of the state, include: Warren, Halifax, Northampton, Hertford, Bertie, Nash, Pitt, Sampson, Duplin, Bladen, Columbus, Anson, Richmond, and Caswell.

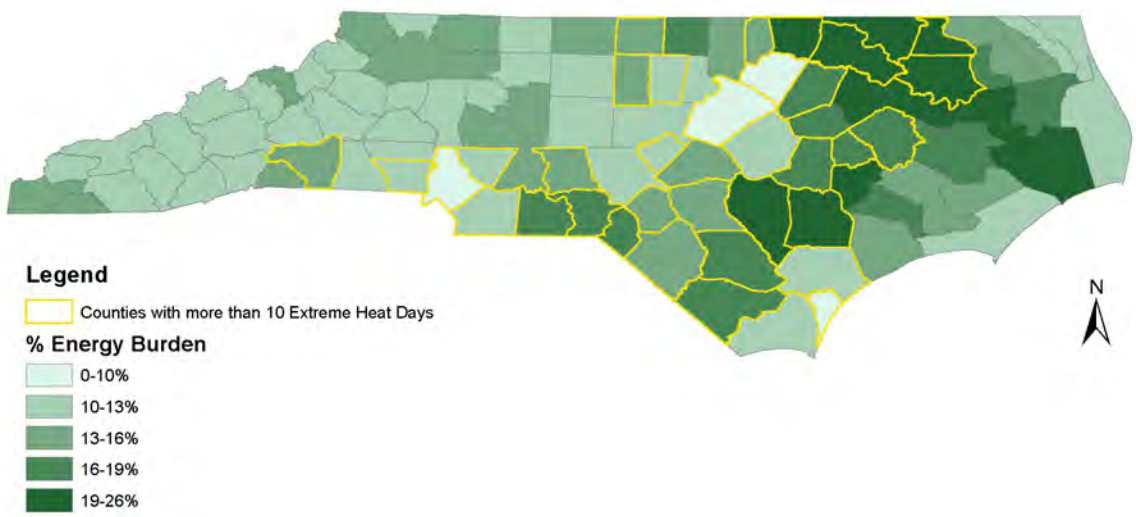

Figure 4-8: Energy Burden of Low-Income Homeowners by County[60] *Note that Figures 4-8 and 4-9 use different scales for rate of fuel poverty and therefore should not be compared on the basis of color gradient alone.*

[56] Moore, R. (2012). Definitions of fuel poverty: Implications for policy. *Energy policy*, *49*, 19-26. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301421512000833
[57] North Carolina Housing Coalition. (2018). *Housing Matters: Mapping Energy Burden.* Retrieved from https://nchousing.org/housing-matters-mapping-energy-burden/
[58] Nevin, R. (2010). Energy-efficient housing stimulus that pays for itself. *Energy Policy*, *38*(1), 4-11. Retrieved from https://www.sciencedirect.com/science/article/pii/S030142150900696X
[59] Lewis, J., Hernández, D., & Geronimus, A. T. (2019). Energy efficiency as energy justice: addressing racial inequities through investments in people and places. *Energy Efficiency*, 1-14. Retrieved from https://link.springer.com/article/10.1007%2Fs12053-019-09820-z
[60] Map data from: North Carolina Housing Coalition. (2019). *2019 County Data.* Retrieved from https://nchousing.org/county-fact-sheets/

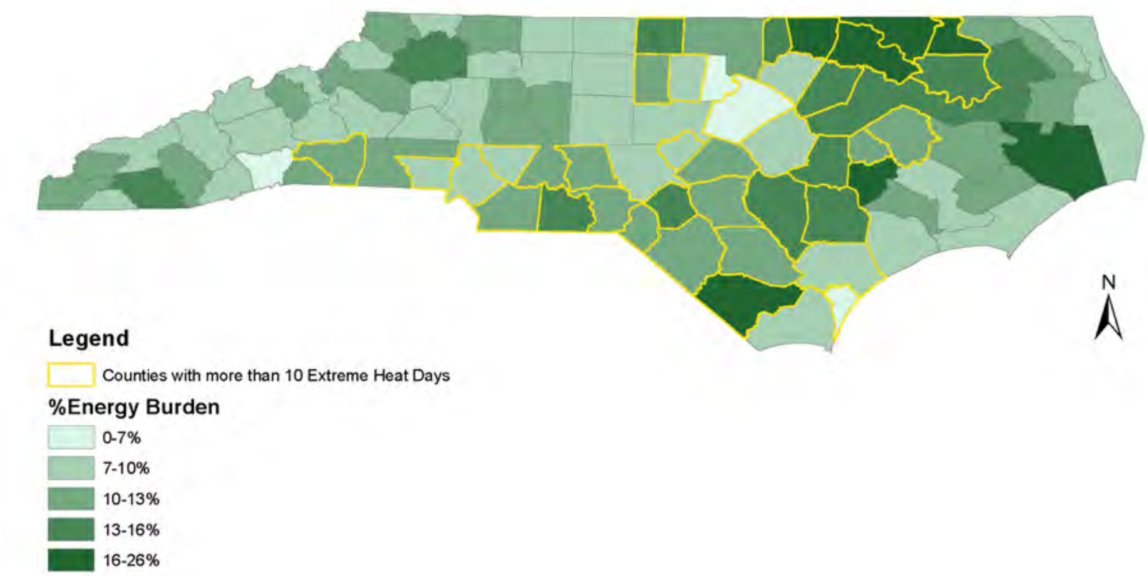

Figure 4-9: Energy Burden of Low-Income Renters by County[61] *Note that Figures 4-8 and 4-9 use different scales for rate of fuel poverty and therefore should not be compared on the basis of color gradient alone.*

Many low-income households and vulnerable populations face the "heat or eat" dilemma, in which they must choose to either pay for food or to pay for the energy to heat (or cool) their home.[62] As the number of high heat days is projected to increase, these households are at particular risk of being unable to afford to adequately cool their homes. Poor climate control is associated with adverse health outcomes and increased risk of death for seniors.[63] Higher temperatures and humidity can exacerbate poor indoor air quality and result in excess moisture, dampness, and mold in a home. These conditions can trigger respiratory illnesses, like asthma and increase susceptibility to heat-related illnesses.[64]

Energy efficiency and weatherization programs, such as North Carolina's Weatherization Assistance Program, attempt to address the problems exacerbated by fuel poverty. Weatherization programs also reduce greenhouse gas emissions that drive climate change in the first place. These programs, which often target those households most at risk for increased energy burden in the face of climate change, should be continued and expanded.

2. Workers, Small Businesses, and Family Businesses in Vulnerable Industries

Climate change will affect jobs, small businesses, and family-owned businesses, especially in traditional agricultural industries and tourism. Climate change may force growers to switch crops, or switch out of traditional lines of work all together. For example, Christmas trees are a major cash crop in Western

[61] Ibid.

[62] Bhattacharya, J., DeLeire, T., Haider, S., & Currie, J. (2003). Heat or eat? Cold-weather shocks and nutrition in poor American families. *American Journal of Public Health*, *93*(7), 1149-1154. Retrieved from https://ajph.aphapublications.org/doi/full/10.2105/AJPH.93.7.1149

[63] Klinenberg, E. (2015). *Heat wave: A social autopsy of disaster in Chicago*. University of Chicago Press. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12584383

[64] Clark, N. M., Ammann, H. M., Brunekreef, B., Eggleston, P., Fisk, W., Fullilove, R., ... & Von Essen, S. G. (2004). Damp indoor spaces and health. *Washington, DC*.

North Carolina, but increasing rain and warmer temperatures are starting to reduce crop yield.[65,66] Like some other agricultural industries, many tree farms are family-owned, and a sustained loss in crop yield could force the farm out of the industry.[67]

Some agricultural industries rely heavily on low-wage workers, who are also at elevated risk of economic disruption due to climate change. Low-wage workers generally have less flexibility and are more likely to lose their jobs if they are temporarily displaced or unable to go to work due to a natural hazard. In these cases, low-income workers may not be able to recover from a loss of income, which can be compounded if they experience other losses (e.g., home damage) due to the event.

North Carolina's tourism industry is also vulnerable to climate change. For example, following Hurricane Dorian in 2019, Ocracoke Island was closed to visitors for 77 days.[68] Many tourism industry employees are seasonal, low-wage workers often with minimal job security, particularly common in hospitality, restaurants, and retail. These workers are likely less able to cope with income interruptions. The entire state will experience the economic impacts of climate change due to decreasing tourism because visitor spending reduces the tax burden on each North Carolina household.[69]

3. African American Property Ownership

Property ownership has always been entangled with race in the United States, which creates particular sensitivities for African Americans coping with climate change in North Carolina. African Americans were not allowed to own property until Congress passed the Southern Homestead Act in 1866, ninety years after the founding of America. Following the Civil War, former slaves used this new right to build freedmen settlements across the nation. African Americans were typically limited to owning and settling land that white Americans did not want – like swamps or low-lying areas. Many of the settlements that remain today are susceptible to flooding.

In the twentieth century, public policy and sanctioned discriminatory practices limited the places where African Americans could live and restricted their opportunities to own property. Deeds that prohibited racial minorities from purchasing a particular property were popular until they were outlawed in 1948, and real estate brokers and property owners were permitted to discriminate on the basis of race until 1968. Employing a local development tool known as redlining, racial demographic data was used to advise and support real estate investors and developer's decisions against investing in neighborhoods of racial minorities for decades. These policies and practices resulted in steep declines in the property ownership and capital investment by African Americans. Repeated over generations, the inability to own land and property is estimated to cost hundreds of billions of dollars in unrealized wealth for African Americans.[70,71]

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[65] WFDD. (2019). *Climate Change Poses Threats to NC Christmas Tree Crop.* Retrieved from https://www.wfdd.org/story/climate-change-poses-threats-nc-christmas-tree-crop
[66] WRAL. (2019). *Warming temperatures may move NC farmers to switch crops.*
[67] WFAE. (2019). *How Climate Change Affects Fall Crops in North Carolina.* Retrieved from https://www.wfae.org/post/how-climate-change-affects-fall-crops-north-carolina#stream/0
[68] Charlotte Observer. (2019). *77 days after Dorian crashed into the Outer Banks, Ocracoke will reopen to visitors.* Retrieved from https://www.charlotteobserver.com/news/state/north-carolina/article237259289.html
[69] Curtis, S., Arrigo, J., Long, P., & Covington, R. (2010). Climate, weather and tourism: Bridging science and practice. *Publication of the Center for Sustainable Tourism, Division of Research and Graduate Studies. East Carolina University: Greenville, NC.*
[70] Presser, L. (2019 July 15). Their Family Bought Land One Generation after Slavery. The Reels Brothers Spent Eight Years in Jail for Refusing to Leave It. *ProPublica.* Retrieved from https://features.propublica.org/black-land-loss/heirs-property-rights-why-black-families-lose-land-south/.
[71] In North Carolina, the Land Loss Prevention Project has been working to curtail this trend for nearly forty years.

Barriers to property ownership have resulted in a number of climate resilience concerns specific to African American homeowners and historic African American communities. A disproportionate share of African Americans live in low-lying areas in the Southeast[72], which are more susceptible to drainage and flooding problems. Figures 4-10 and 4-11 illustrate this truth in two historic Black settlements, Princeville and James City. In both towns, a considerable extent of the communities' streets, and therefore development, lies in floodplain and floodplain-adjacent land.

Figure 4-10: Floodplain Covers much of Princeville, NC

Figure 4-11: Floodplain Encroaches on James City, NC

Given the barriers to property ownership among African Americans, land often holds particularly high historical and cultural value for Black households. In some cases, land has been in the same family for many generations. The decision to consider a buyout, if offered one by a state or local program, is particularly fraught for these homeowners. On the other hand, if owners do decide to accept a hazard mitigation buyout or relocate, generational land tenure (also known as heir or heirs' property) can be a barrier to selling the property to complete the buyout. Legal Aid of North Carolina and other pro bono legal services work hard to serve individual homeowners in such situations, but the scale of their property in North Carolina creates a legal barrier that is present for White and Native American property owners

[72] Jeff Ueland and Barney Warf. Racialized Topographies: Altitude and Race in Southern Cities. Geographical Review. Vol. 96, No. 1 (Jan., 2006), pp. 50-78

but especially prevalent among African American property owners.[73]Statutory and regulator treatment of their property has been cited repeatedly a driving forces of African American land and wealth loss. [74]

Other racial, cultural, and ethnic groups hold unique connections to particular land and land ownership. Specific sites or environmental functions of land are often important to the diverse cultural heritage of Native American tribal communities.[75] Some examples are burial grounds, sacred mounds, ceremonial places, and lands used for hunting, fishing, and gathering. Connectivity of land and heritage creates unique cultural risks associated with climate change impacts, especially the possibility of displacement or relocation.[76]

4. Insurance Inequalities

Insurance coverage is key to resilience to natural hazards. For one, insurance policies pay for the majority of costs for physical recovery of insured property damaged by weather. Public disaster recovery programs, such as those funded by FEMA, will never be able to provide the same level of quick and thorough loss recovery as insurance. In addition, insurance companies may provide incentives for investments in hazard mitigation, which creates more resilient housing stock.[77] Typically, mortgage lenders require property owners to hold all-hazard insurance for the life of the mortgage. All-hazard insurance does not cover flood losses, however, the purchase of flood insurance is only mandatory for all federal or federally related financial assistance for the acquisition and/or construction of buildings in Special Flood Hazard Areas (SFHAs), an increasingly poor predictor of the location of severe flooding. As North Carolina experiences progressively increased damage from natural hazards in the state, insurance access and coverage will influence the survival of entire neighborhoods and towns. However, homeowners across the state are not evenly covered by all-hazard or flood insurance.

Socially vulnerable populations have lower insurance coverage for several reasons. Often cited is prohibitive cost, and unsurprisingly, higher income households are more likely to hold insurance coverage.[78] Properties that are owned outright are no longer required to have insurance coverage due to a mortgage, so many long-time homeowners, such as senior citizens or households in properties passed down through generations, do not hold insurance. Insurance policies are difficult to decipher, even among highly educated homeowners.

However, even among those who hold hazard insurance, the process of making claims does not treat people equally. Making an insurance claim requires affected individuals, who have just experienced a traumatic event, to navigate a complicated insurance system. Many socially vulnerable communities experience barriers to successful claims or appeals, such as limited English proficiency, limited internet

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[73] Gaither, C.J. (2016 October). *Have Not Our Weary Feet Come to the Place for Which Our Fathers Sighed? Heirs' Property in the Southern United States*. United States Forest Service. Retrieved from https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs216.pdf

[74] Douglas, L. (2017 June 26). African Americans Have Lost Untold Acrres of Land Over the Last Century. *The Nation.* Retrieved from https://www.thenation.com/article/archive/african-americans-have-lost-acres/

[75] Wildcat, D.R. (2014). "Introduction: climate change and indigenous peoples of the USA." *Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions.* Springer.

[76] National Congress of American Indians. (n.d.) *Climate Change.* Retrieved from http://www.ncai.org/policy-issues/land-natural-resources/climate-change

[77]Kousky, C. (2019). The role of natural disaster insurance in recovery and risk reduction. *Annual Review of Resource Economics*, *11*, 399-418. Retrieved from https://www.annualreviews.org/doi/abs/10.1146/annurev-resource-100518-094028?journalCode=resource

[78] Landry, C.E., Jahan-Parvar, M.R. (2010). Flood Coverage in the Coastal Zone. *Journal of Risk and Insurance*. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1539-6975.2010.01380.x

access, cultural barriers, and limited access to government officials.[79,80] Even when individuals have insurance and successfully make claims, researchers have found differences in insurance settlement claims based on race. Minorities are more likely to receive insufficient settlement amounts even when they have appropriate insurance coverage.[81] The demographic, social, or economic characteristics that make a population vulnerable to negative disaster impacts may be the same as those that limit their ability to benefit from insurance, yet another compounding vulnerability.

Establishing equitable access and utilization of insurance policies is critical to resilience interventions. Government, nonprofit organizations, and community groups can provide information and training to individuals and assist them with both obtaining insurance and making claims on an insurance policy. Subsidies for hazard insurance policies should be carefully considered in a suite of resilience options for low-income homeowners. Currently, NCORR offers flood insurance support to participants in its ReBuild programs, and the General Assembly has set aside some additional funds for insurance subsidies as well.

D. Climate Justice Recommendations

To address the climate justice issues described in this chapter, the following recommendations are put forth by the authors of this chapter. These recommendations should be implemented with sufficient funding, staff or contracting support, and interagency cooperation to ensure effective action.

1. Recommendations for Cabinet Agencies

Entity Responsible	Recommendation
Interagency Climate Council	Develop an equitable public participation framework for all climate change mitigation and resilience efforts. For use by state agencies as well as boards and commissions.
	Design an interagency process to survey and educate staff on unified definitions of equity; vulnerability; climate risk; resilience and other terms needed to demonstrate state's understanding and to ensure common ground within resilience work.
	Release a North Carolina Climate Justice Report as part of future North Carolina Resilience Plans with opportunities for public involvement.
North Carolina Emergency Management	Increase emphasis on communication with non-English speakers, older adults, rural communities, etc. Explore new risk communication methodologies

[79] Bergstrand, K., Mayer, B., Brumback, B., & Zhang, Y. (2015). Assessing the relationship between social vulnerability and community resilience to hazards. *Social indicators research*, *122*(2), 391-409. Retrieved from https://link.springer.com/article/10.1007/s11205-014-0698-3

[80] Blaikie, P. M., et al. (1994). At risk: Natural hazards, people's vulnerability, and disasters. London: Routledge.

[81] Fothergill, A., Maestas, E. G. M., & Darlington, J. D. (1999). Race, ethnicity and disasters in the United States: A review of the literature. Disasters, 23(2), 156–174. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/1467-7717.00111

Entity Responsible	Recommendation
	Continue to update existing state hazard mitigation, emergency preparedness, and response plans with increased emphasis on protecting, communicating with and serving low-income populations, communities of color, older adults and people with disabilities during and after emergencies.
	Continue to support development of local hazard mitigation plans.
	Provide recommendations and guidance to local governments on maximizing the quality and effectiveness of local or regional hazard mitigation plans, especially in rural areas.
	Provide recommendations and guidance on stakeholder engagement in development and implementation of meaningful hazard mitigation plans and the inclusion of equity, diversity, and inclusion in local plans.
North Carolina Office of Recovery and Resiliency	Increase communication and interaction with all communities, including (especially) vulnerable and historically marginalized communities.
	Develop university partnerships to address gaps in research on climate resilience, especially issues that affect populations differently, and to offer capacity in the state to smaller and more rural communities to do effective and equitable resilience work.
	Develop a strategic plan for resilience-focused capacity building within socially vulnerable communities.
	Assist local governments in identifying additional resources to aid in advancing resilience.
	Seek funding that would be distributed to fund community based resilience projects.
	Create a Local Government Climate Resiliency Toolkit.
	Create and strengthen working relationships among state agency advisory boards that focus on equity and inclusion, such as the DEQ Environmental Justice and Equity Advisory Board.
NC Department of Commerce	Set aside clear, numerical percentages for the number of newly established jobs/ contracts/ projects that should go to vulnerable communities & for which historically marginalized business receive priority bidding.

Entity Responsible	Recommendation
	Partner with the DOA Office of Historically Underutilized Businesses, NC Institute of Minority Economic Development and other entities to increase outreach efforts of bidding and contracting opportunities for marginalized communities.
	Increase outreach efforts in impacted communities.
	Leverage Disaster Recovery Funds and other sources of capital to promote equitable job creation and inclusive business development in communities most vulnerable to climate change.
NC Department of Environmental Quality	Provide updated mapping when detailed climate projections come out, including overlap with socially vulnerable communities using 2020 Census and other up-to-date data.
	Continue enhanced engagement strategies for potentially underserved communities and translation and interpretation services for non-English speakers (as laid out in the DEQ's Public Participation and LEP Language Access Plans).
	Pursue continuation and expansion of Weatherization Assistance Program (WAP).
NC Department of Health and Human Services	Support the Building Resilience Against Climate Effects (BRACE) program and expand the tracking of epidemiological health impacts of climate change in North Carolina.
	Support increasing Back@Home initiative funding (post Hurricane housing initiative) to $16 million.
All Agencies Administering Disaster Recovery Funds	Increase outreach efforts in impacted communities. Implement a coordinated, strategic approach to increase communication and interaction, with an emphasis on vulnerable and historically marginalized communities.
	Offer adequate social services support to North Carolinians navigating the multitude of government processes during recovery.
	Increase the ability of community groups to communicate with state agencies on disaster recovery needs and the effectiveness of disaster recovery efforts.

Entity Responsible	Recommendation
	Publish clear, percentages of newly established jobs or contracts that should go to vulnerable communities and for which historically marginalized businesses receive priority bidding. Increase outreach efforts for hiring in communities where work will be completed.
	Continue to partner with the DOA Office of Historically Underutilized Businesses, NC Institute of Minority Economic Development and other entities to increase outreach efforts of bidding and contracting opportunities for underserved communities
	Leverage disaster recovery funds and other sources of capital to promote equitable job creation and inclusive business development in communities most vulnerable to climate change. Other sources of capital to explore include: Opportunity Funds, Donor Advised Funds, New Markets Tax Credits, Low Income Housing Tax Credits, activities of Community Development Financial Institutions, Small Business Investment Companies, Rural Business Investment Companies, and investments required by the Community Reinvestment Act.

2. Recommendations for All Branches of State Government

As the report describes, most resilience planning and programming in North Carolina has been led by local governments. However, imbalanced capacity and resources across local governments leaves smaller or poorer jurisdictions without resilience interventions. To equalize these opportunities, North Carolina must advance equitable resilience through state government policies and programs, and provide resources for communities to invest in their own futures.

Recommendation Type	Recommendation
State Policy Changes	Adopt the targeted universalism approach for resilience, in which policies and programs begin by addressing the needs of those who are most vulnerable to climate change, and seek to improve the resilience of the entire state.
	Develop metrics to determine progress of equity and resilience initiatives.
	Adopt incentive or funding programs that encourage best practices for equitable resilience within state government and quasi-governmental organizations and among local governments, businesses, and non-profit organizations. For example, competitive funding programs within the state might include a resilience component in their scoring rubric.

Recommendation Type	Recommendation
	Advocate for funding from the General Assembly for climate science specific to North Carolina and for resiliency programs, policies, and interventions that support our shared efforts to prosper into the twenty-first century and beyond.
	Work with agency Human Resource offices to set goals and strategies for diversifying staff and leadership in recovery and resilience, and for hiring disaster survivors into recovery and resilience positions.
	With agency communications offices, set goals and strategies to increase interaction with communities that have historically frayed relationships with government and government officials.
	Reduce substandard housing and increase access to adequate cooling and other climate risk reduction measures.
	Advocate for funding for new or continuing weatherization programs that target low-income homeowners.
State Role in Building Local Sources of Resilience	Build capacity and leadership within communities most vulnerable to climate change impacts by promoting, supporting and leveraging community-specific strategies, projects and events. This recommendation could be accomplished through the North Carolina Resilient Communities program detailed in Chapter 7. These initiatives could be led by local governments or by community or faith-based organizations.
	Identify and communicate resilience resources, including educational and funding opportunities, already available to local governments and communities.
	Fund a grant program to support community or regionally-based resilience projects. This program could be sponsored by public and private funds.
	Engage community and faith-based organizations that work on disaster response to incorporate other elements of resilience into their programming.
	Explore opportunities to provide financial resources for climate preparation efforts to culturally specific organizations

Recommendation Type	Recommendation
	Improve local resilience by ensuring that recovery programs, plans, and investments leave the community with additional capacity to cope with the next event. For example, a recovery program might include formal capacity building activities, a recovery fund might facilitate regional gatherings for grantees to share lessons learned, and planning efforts might identify clear, realistic implementation steps for after the plan is complete.
Information Needs	Improve the accessibility of hazard and climate change data to non-experts through web portals, infographics, classroom education modules, or other communication channels
	Provide resources for community and K-12 education on climate change and resiliency

3. Community Voice in Resilience Policy, Planning, and Programs

- Resilience plans and assessments should continue to engage local voices and focus especially on inviting the most impacted communities to drive the narrative about their resilience. Public participation should not be treated as a perfunctory requirement

- Resilience and resilience-related programs should engage new types of partners in their work, such as institutions that are frequent points of contact in the lives of socially vulnerable people, e.g. schools, medical clinics, retail outlets, houses of worship, and transit services.

- Resilience programs should recognize that community agency and bridging social capital are critical components of resilience. Enhancing capacity and social capital among socially vulnerable communities should be treated as equally important goals for state resilience programs as building the resilience of infrastructure and the built environment

4. Research Recommendations

North Carolina should continually learn from natural and social sciences about climate change, climate change impacts, and the effectiveness and equitability of our responses. The state should consider partnerships with universities to address the research needs identified by vulnerable communities. The state should engage with faculty who have recent publications or have been known to work alongside the vulnerable communities we seek to engage.

- Research that seeks to affect policy should engage government from the beginning to ensure that policy-relevant questions are asked and the knowledge of government officials is included in shaping research and reaching findings. This requires interest and initiative among researchers and responsiveness among government officials.
- Researchers should consider building long-standing and sustainable research partnerships with communities. Researchers should follow widely available best practices for building mutually beneficial community-based research partnerships.

Researchers within and outside government should consider the following research needs:

Research Recommendations
Examine the distribution of climate hazard exposure and impact, adaptive capacity, and benefits and burdens of resilience interventions among different groups of socially vulnerable populations.
Identify opportunities for citizen science and community observations to add value to research used by the state. For example, analyze ways for risk assessment to include qualitative methods and local knowledge.
Evaluate the effectiveness of methods for engaging different underrepresented groups in climate resilience plans, programs, and policies.
Investigate under-recognized sources of community resilience by learning more about the support systems local communities have created to 'fill in gaps' of disaster response.
Continue to map climate risks and social vulnerabilities together. Re-visit this mapping based on 2020 Census data. Use geospatial and other analyses to understand the distinction among different regions of the state and in urban, suburban, and rural areas. Extend this research to identify "hotspot" areas where climate justice issues are likely to be most severe.
Determine the best ways to measure and capture compounding vulnerabilities, or climate impacts that are experienced in the context of inequalities across health, housing, and economy.
Analyze the business and workforce development opportunities in risk and resilience fields. The results of such a study should inform programmatic decisions in the state's workforce development systems and organizations.
Analyze insurance coverage among socially vulnerable populations, especially in light of changing insurance markets and new developments with the National Flood Insurance Programs. Recommend strategies to improve insurance coverage among low-income households, including renters, in high-risk areas. Analyze insurance coverage of public assets in all communities, especially those with smaller budgets where insurance may have fallen to the wayside.

Chapter 5

Vulnerability, Risk, and Potential Options for Addressing Climate Related Hazards

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5. Vulnerability, Risk, and Resilience Strategies for Addressing Climate-Related Hazards

A. Building a Shared Understanding

1. Introduction

Collectively, North Carolina state Government serves people, safeguards natural and built infrastructure, maintains cultural resources, and supports the functioning of other public and private assets. This chapter focuses on ways in which climate-related hazards impact government functions and assets. It also explores the ways that vulnerability and risk profiles for those impacts could shift as a result of climate change.

In a changing climate, agencies will face increasing challenges in fulfilling their responsibilities. Building upon the North Carolina Climate Science Report (Chapter 3 and Appendix A), agency representatives describe ways in which climate-related hazards impinge upon the delivery of government services, the maintenance of physical assets, threaten personnel, or otherwise jeopardize the mission of the many agencies represented herein.

The best way to prepare for potential future impacts of climate change is to build resilience to present-day climate-related hazards while adding a margin of safety for changing conditions.[1] Such preparation can pay for itself in myriad avoided recovery costs. Preparing and planning for climate-related disasters can bring a benefit-to-cost ratio between 4 and 15.[2] An avoided disaster also defrays a cascading set of hardships for individuals, government at all levels, the economy, and more.

This chapter documents the work done by agency representatives from throughout North Carolina state government for 11 sectors (Chapter 2: Plan Development Process) to understand the implications of climate change on the success of agency missions and identified opportunities to build resilience at the state level.

Impact Assessments

The impacts in this chapter concern government agency *responsibilities* (such as state-owned natural or constructed assets) and *services* (such as regulatory functions and programs that provide funding, technical assistance, and other resources to communities, industries, and local governments). If those services and responsibilities had been or could be impacted by climate-related hazards, sector teams noted those impact pairs (*hazards* paired with *services and responsibilities*). In the sections that follow within this chapter, each sector provides a table that links *hazards* to impacted *services and responsibilities*. A complete risk assessment and determination of adaptation options was not possible given the large

[1] IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 869-898.

[2] Healy A and Malhotra N (2009) Myopic Voters and Natural Disaster Policy. American Political Science Review 103(3): 387-406.

number of potential impacts, so they undertook an abbreviated assessment for a subset of those potential impacts (Table 5A-1).

Table 5A-1: Sector teams and the number of impacts analyzed as part of the risk assessment documented in this chapter.

Sector	Impact Pairs	Risk Assessments
Agriculture and Forestry	92	7
Coastal Resources & Infrastructure	139	4
Commerce and Business	57	1
Cultural Resources	39	4
Ecosystems	91	3
Energy	57	3
Health and Human Services	55	4
Housing, Buildings, and Support Services	24	6
Public Safety	61	3
Transportation	35	4
Water and Land Resources	94	9
Total	*744*	*48*

This chapter establishes a baseline for a future quantitative risk assessment and resilience analyses to update the NC Resilience Plan. Employing the Steps to Resilience[3] (Figure 5A-1), team members qualitatively describe exposure to climate-related hazards, vulnerability and risk associated with those hazards, and provide some resilience strategies for adaptation. Both *climate* and *non-climate stressors* can alter the severity or likelihood of any given hazard (Figure 5A-2). This chapter focuses attention on hazards whose frequency or intensity can be altered by climate variability and climate change. These are called "climate-related hazards" throughout the text. Sector teams further identify actions to build climate resilience, meaning steps that could be taken to prevent or moderate potential impacts. Typically, actions for building resilience focus on non-climate stressors (for example via nature based solutions) and safeguarding services or responsibilities. Impact assessments should include indicators or measurable impacts so that impacts and adaptation actions can be evaluated through time. All of these concepts are interrelated, as shown in Figure 5A-2. When climate impact assessments include all

Figure 5A-1. The Steps to Resilience.

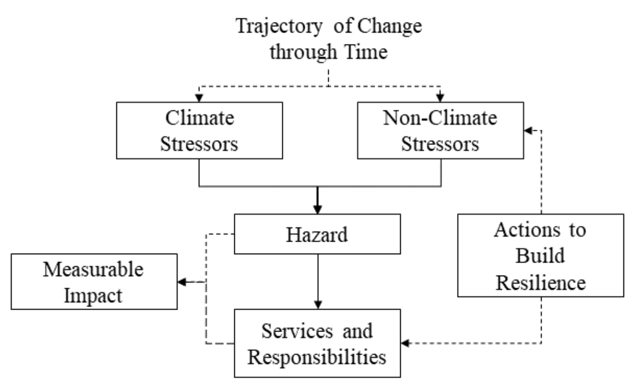

Figure 5A-2. A conceptual model of impacts and ways to address climate-related hazards.

[3] This is a risk management and decision-making framework designed to allow people from disparate backgrounds use climate information within their job functions. See https://toolkit.climate.gov/#steps

of these elements, it is possible to communicate clearly about climate resilience concerns and decisions.

2. Structure of Sector Contributions

In the following pages, each of the 11 sectors include an **overview** of the services, assets, and functions that state government provides followed by a description of **overall exposure** to climate-related hazards. Examples of **vulnerability, risk, and resilience strategies** detail how state agencies view the threat of climate change to meeting their missions and some ways to remediate the potential shortfalls introduced by climate-related hazards. Definitions and details about vulnerability and risk assessments are available elsewhere.[4] Finally, a **summary** recaps the most salient issues that climate change poses to each respective sector along with a concise list of recommendations that could follow this risk assessment to ensure continuity in delivering services and meeting responsibilities in the face of ongoing climate stressors and related hazards.

[4] Gardiner E. P., Herring D. H., and Fox. 2019. The U.S. Climate Resilience Toolkit: evidence of progress. Climatic Change 153(4): 477-490.

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Agriculture & Forestry

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B. Agriculture and Forestry

Key Observations

- Agriculture, forestry, and endangered native plants are tied to climate due to biological, physiological, and ecological constraints. Elevated night-time temperatures will have outsized negative impacts due to disruptions in plant physiology.
- Must attract and retain experienced personnel as well as maintain equipment to meet a growing set of hazards.

Critical Impacts and Resilience Strategies

- Inland flooding is the greatest climate-related hazard to North Carolina Department of Agriculture and Consumer Services (NCDA&CS) assets (research stations, state forests, and nurseries) and to private farms and forests. Must focus on adaptive capacity (e.g., levees) to protect crop and pasture lands statewide.
- Research and development are needed on adaptive varieties and species for crops, livestock, and poultry to more resistant to extreme heat.
- Education of stakeholders can provide adaptive capacity for drought and wildfire. This is personnel-intensive and personnel are currently directed toward response.
- Protecting North Carolina's endemic and nearly endemic species, species that exist only in our state or a handful of places is a unique responsibility of the state.
- Regenerative practices that sequester carbon.

1. Sector Overview

The mission of the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) is to provide services that promote and improve agriculture, agribusiness, and forests; protect consumers and businesses; and conserve farmland and natural resources for the prosperity of all North Carolinians.

Divisions throughout NCDA&CS regulate and serve diverse needs: agronomy; animal health; weights and measures; gas and oil inspection; crop and livestock statistics; USDA commodity distribution; food and drug protection; agricultural marketing and grading; research station operations; seed and fertilizer inspection; farmland preservation; nursery and plant pest eradication activities; protecting and conserving imperiled plant species; regulation of the structural pest and pesticide industries; agricultural environmental issues; soil and water conservation; forest management and protection; state and federal agricultural legislation; emergency programs; and agricultural economic analysis. These are the primary NCDA&CS staffs that are activated in response to emergency events.

The state's economy is highly dependent upon agriculture and agribusiness's ability to produce food, fiber, fuel, and forest products. Agriculture and forestry account for one-sixth of the state's income ($91.8 billion of the $538 billion of the gross state product) and employment. There are approximately 8.4 million acres of operating farm land and 18 million acres of operating timber land in the state accounting for just over **76% of the total land in North Carolina**.[1]

[1] Walden, M., (2019). *Agriculture and Agribusiness*: North Carolina's Number One Industry. Retrieved February 14, 2020 from, https://cals.ncsu.edu/agricultural-and-resource-economics/wp-content/uploads/sites/12/2019/05/agribusiness2019Brochure.pdf

2. Overall Exposure

Climate encompasses sunlight, temperature, precipitation, and basic soil conditions throughout the life cycle of a crop; so farm, forest, and fish productivity are directly linked to climate. Therefore, climate-related events directly influence management and strategic investments in this sector (Table 5B-1). The NCDA&CS acts as a living laboratory assessing climate and ecological issues faced by farm and forest landowners across the state. A goal of this effort is to address agency-wide exposure and risks to climate-related events and develop strategies that will serve the state's citizens and industries.

Table 5B-1. Exposure to climate-related hazards state of agriculture and forestry assets and services throughout the state.

Assets, Regulations, and Services	Air Pollution	Changed Seasons	Drought	Extreme Cold	Extreme Heat	Flooding (River and Land)	Forest Insects and Diseases (Native and Invasive)	Inundation (includes SLR)	Landslides	Non-Native Invasive Plants	Saltwater Intrusion	Severe Winter Weather	Storm Surge	Water Shortage (Drought)	Wildfire related Air Pollution	Wildfire	Wind
Crop and pasture lands	*		*		*	*		*	*	*	*	*	*	*		*	*
Livestock and poultry	*				*	*						*		*			*
Shellfish and freshwater aquaculture		*	*		*	*		*	*			*	*	*			*
Department-owned facilities						*		*	*		*		*			*	*
Department-sponsored programs and services	*	*			*	*		*	*		*	*				*	*
Emergency response and wildland firefighting resources and equipment	*	*			*	*		*	*		*					*	*
Forest resource and nursery	*	*			*	*	*	*	*	*	*	*		*		*	*
Forest Service employees; all services provided	*	*		*	*	*		*	*		*			*	*	*	*
Endangered and protected plant species.	*	*	*		*	*	*	*	*	*	*		*	*	*	*	

North Carolina Department of Agriculture and Consumer Services (NCDA&CS)

While there are expected to be many climate-related impacts on agriculture, the most significant are expected to be related to **flooding**, **drought** and **extreme heat**. Additional non-climate stresses include weeds, diseases, insect pests, and pollinator ecology. For this document, the term "farming" is all-inclusive, encompassing activities that fall under the broad umbrella of farming throughout the state, including livestock, poultry, aquaculture, and mariculture. Unless otherwise noted, all discussion of climate change impacts on the NCDA&CS's operations and assets directly reflects the same impact as those experienced by farmers and forest landowners.

The NCDA&CS is sometimes referred to as the state's largest farmer with 18 research stations across the state (Figure 5B-1). Each station is a laboratory where researchers from North Carolina State University, USDA, and North Carolina A&T State University work to solve problems facing agriculture today and into the future. Each station has unique climate and soil conditions and focuses on distinct regional crops, forestry concerns, livestock, poultry, and aquaculture. The NCDA&CS's Research Stations Division supports these studies by providing land, water, equipment, buildings, and staff who work around the clock to help build a stronger foundation for the future of agriculture.

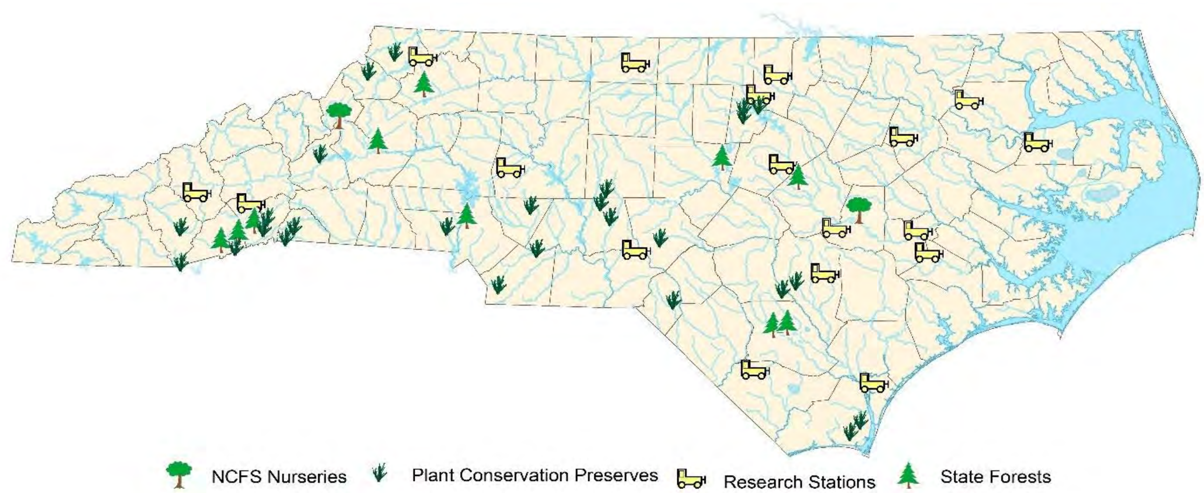

Figure 5B-1. A subset of assets managed by the North Carolina Department of Agriculture and Consumer Services across the state.

In addition to being the state's largest farmer, the NCDA&CS has considerable responsibility for managing a variety of state assets. The NCDA&CS has a physical presence in all 100 counties with responsibility for 1,190 buildings and nearly 96,000 acres of croplands, forests and plant conservation sites (Figure 5B-1).

When analyzing climate-related risk and resilience for agriculture and forestry, the NCDA&CS focuses on 6 key assets:

- Crop and pasture lands
- Livestock and poultry
- Shellfish and freshwater aquaculture
- Department-owned facilities
- Department-sponsored programs and services
- Endangered and Protected Plant Species

North Carolina Forest Service

The primary goals of the NC Forest Service are to protect, manage, and promote the state's forest as well as provide leadership on the issues concerning forest resources. To accomplish these goals in the face of a changing climate, the focus is on the following 3 critical assets and how they could be influenced by climate-related events:

- Forest Resource and Nursery
- Private Landowner Services
- Emergency Response and Wildland Fire Fighting Resources and Equipment

The NC Forest Service operates and maintains ten state forests, including DuPont State Recreational Forest, Bladen Lakes and Headwaters State Forests, and seven educational state forests. These forests provide services to the public, such as: educational courses; self-guided trails and recreation; and timber production for wood products, wildlife habitat, and hunting opportunities. The NC Forest Service Nursery Program annually produces nearly 15 million tree seedlings representing over 40 tree species. These seedlings are critical to meeting reforestation, restoration, and wildlife habitat improvement projects across North Carolina. When the NC Forest Service nursery lost nearly all its crop due to Hurricane Matthew’s flooding in 2016, the available seedling supply for numerous species was not adequate to meet the needs of seedling customers and natural resource partners.

Outside of state-owned forested lands and the nursery program, the NC Forest Service provides many programs and services for private landowners with the primary goal of keeping forested lands forested and ensuring standards for water quality are met.

The NC Forest Service is mandated by the NC General Statutes to detect and suppress all forest fires under the jurisdiction of the state. A combination of ground and aerial resources is required to provide for the safety of firefighters and the public to minimize the loss of forestland, homes, and personal property to wildfires. The service also responds to other natural disasters, including, but not limited to, winter weather events, tornadoes, hurricanes, and floods. The NC Forest Service operates in all 100 counties of North Carolina. There are also 13 district offices and three regional offices. Being established in all 100 counties allows for the NC Forest Service to operate quickly and efficiently during emergency events such as wildfires and flooding.

Current NC Forest Service capacity to respond to routine, short-term wildfire events and other natural disasters is adequate. Large-scale, long-term, and overlapping events such as the 2016 hurricane and fall fire season which required allocation of resources in multiple areas of the state at the same time overwhelmed the state’s capacity (available employees, equipment, and fiscal resources) to respond. During the 2016 fall fire season, personnel and equipment were needed from all around the country to help adequately respond to the numerous fires occurring on private, state, and federal lands in the state.

Key climate stressors that are amplifying the vulnerability and risk of forest resources in North Carolina include wildfire, extreme precipitation, and hurricane intensity. The most prominent are **wildfire** and the events and variables that induce wildfire. Increasing **heavy precipitation events** are leading to more frequent flooding, causing erosion and loss of tree seedlings. **Drought** induces stress to trees and makes forested lands more susceptible to insects, disease, and wildfires. Hurricanes cause damaging winds, coastal flooding, and facilitate saltwater intrusion, resulting in forest land loss. Each of these hazards also impacts the critical infrastructure needed to access and maintain forests and farms. As conditions for wildfires, tropical storm events, and flooding are predicted to increase, current and future capacity to respond as an agency have been taken into consideration in this report.

An increasing population in North Carolina is leading to not only increased demand for wood products for construction materials, fuel, and paper products, but is also stimulating increased development which causes land-use change and increasing forest fragmentation. Fragmentation of the state's forests creates several issues that make sustainable forest management more difficult. An expanding population is increasing the wildland urban interface which increases the public safety risks associated with wildfire. With the increase in impermeable surfaces, more water is being funneled downstream, causing increased flooding on farmland, forested lands, and rural communities. Other non-climate stressors include regulations and current abilities to manage fuel loads in the state's forests. Inability to manage fuel loads properly due to social, environmental, and economic variables greatly increases the risk of large and intense wildfires across the state. Many climate-related events directly (i.e. drought and extreme heat) or indirectly (i.e. storms, insect outbreaks, and disease) increase the risk of wildfires by increasing flammable vegetation that would ignite.

3. Examples of Impacts, Vulnerability, and Risk

Crop & Pasture Lands / Flooding, Drought, & Heat

Impact Summary

Flooding, whether from tropical cyclones or other heavy precipitation events, has proven to have tremendous negative impacts on farming throughout the state. Because agriculture has such a large footprint in North Carolina, flooding anywhere in the state can be destructive to this sector.

In September 2004, western North Carolina was hit by two hurricanes within nine days. Losses to crops, farm equipment, and farm infrastructure were estimated to be $129 million. Since most of agriculture in western North Carolina is associated with river-influenced soils, crop losses due to destruction, contamination, and subsequent plant and animal diseases associated with flooding were close to 100% in many locations.

In 2016, flooding in eastern North Carolina from Hurricane Matthew resulted in an estimated $544 million in agricultural losses, and in 2018, flooding from Hurricane Florence resulted in an estimated $2.4 billion in agricultural losses across the state (see figures 5B-1 and 5B-2). In most widespread flooding events, crops experience partial, if not complete destruction. Obviously, the timing of the flooding event is critical. The greatest impact occurs when crops are still in the field with little to no harvesting completed. For many crops, food safety rules prevent a crop from being used after it has been covered by flood waters. Inland flooding events are occurring more frequently, limiting farmers' ability to recover between events.

Figure 5B-1. Flooded NCDA&CS crop and pasture lands following Hurricane Matthew in 2016.

Figure 5B-2. NC Forest Service helicopter dropping resources to research stations inaccessible due to flood waters from Hurricane Matthew 2016.

Vulnerability and Risk

Agricultural lands are inherently susceptible to inland flooding due to soil type, lower elevation, proximity to available water, and upstream development, including increased impervious surfaces. Further, increasing population creates demand for more development, pushing farming practices to riskier sites.

The NCDA&CS has experienced direct and indirect losses from flooding. Research stations have lost their investment into many research projects due to crop loss. During and following Hurricane Matthew, the Cherry Research Station in Wayne County was effectively an island with hay and other feed stocks having to be air lifted to feed the station's livestock. Overbank flow events are expected in any floodplain agricultural system, so levies are typically built to accommodate floods. Levies reduce vulnerability but must be maintained. Hurricane Matthew compromised a levy system designed to protect the station from flooding. Because the levy system has not been repaired, subsequent storms have brought additional flooding.

While flooding is generally thought to be related to extreme storm events, the rise of sea level and water tables in coastal regions also threatens otherwise productive land with saturated, saline conditions. The blacklands area of eastern North Carolina (Beaufort, Hyde, Tyrell, and Washington Counties) are some of the most productive row crop areas on the East Coast. The NCDA&CS Tidewater Research Station is located in this area. Rising water tables and saltwater intrusion in some of the blacklands counties are already proving to be a challenge to crop production, especially in the Engelhard area.

North Carolina has suffered from severe drought conditions in recent years, and droughts will likely continue to be a risk that the NCDA&CS and farmers must deal with in the future. Many farmers can sustain their crops through normal periods of drought. However, a lengthy drought event may exceed their water storage capacity or the access to water needed for irrigation. Crops, livestock, and poultry cannot survive without water. Livestock and poultry can be sold off, but crops dry up in the field—all of which results in loss of income for farmers and a negative impact to the state's economy.

The impact of increasing annual temperature is more of an unknown to farming operations. Of particular concern is higher temperatures in the winter months, which can lead to premature sprouting and budding of plants. When this happens, those plants are susceptible to injury from subsequent frost and freeze events, resulting in lower yields or even complete loss. Some tree crops like peaches require a certain number of chilling days (normal colder winter temps) in order to flower and produce full yields. Warm winter months already compromise current peach varieties available in North Carolina.

Prolonged periods of higher temperatures in the summer months can also have a negative effect on crop production. Extreme drought conditions, which cause crop distress and mortality, often coincide with periods of prolonged higher temperatures. Many crops are able to tolerate high daytime temperatures and short periods of drought as long as sufficient cooling takes place at night to allow plants to recover. Future increases in nighttime temperatures during the summer could cause significant loss in photosynthetic energy due to increased nighttime respiration, resulting in reduced crop yields and decreased overall stress tolerance.

Resilience Strategies

To address persistent flooding, the system of levees in agricultural fields must be evaluated for efficacy and potential modification. Currently, the Cherry Research Station operates at diminished capacity due to a breached levy system that allows flood waters to flow through the farm rather than being trapped. More frequent flooding results in longer periods of flooded fields and pastures.

Researchers at North Carolina's land-grant universities, who heavily utilize the state's research stations, generally have a breeding objective of developing and improving crops that can tolerate and thrive in the face of emerging climate conditions. However, plant breeding is a long-term endeavor; it can take several years to develop and release new varieties of crops. A pertinent question, therefore, is how can the latest advances in technology be utilized to accelerate plant breeding efforts to keep pace with climate change? The state's research stations, and the deployment of technology will be key to these efforts.

The NCDA&CS has invested in irrigation infrastructure at its Research Stations, but long periods of drought negatively impact revenues and research at these facilities. Additional investments in irrigation at the stations across the state will be necessary to manage research projects. Other resilience strategies previously reported in the Climate Ready North Carolina: Building a Resilient Future[2] report include:

- Promote research and technological innovation for new crop types/varieties and improved pesticides/herbicides to adapt to changing growing conditions.
- Provide education/outreach to the farming community regarding recommendations for adaptation of new crops, varieties, or technologies.
- Ensure availability of adequate flood/crop insurance in order to maintain land in agricultural production instead of a more intensive land use that has the potential to be more susceptible to flooding events and will have higher damages when flooding events occur.
- Provide for maintenance of drainage infrastructure to minimize flood severity and duration.
- Encourage adoption of agricultural best management practices to conserve water, reduce erosion, and increase soil productivity.
- Provide technical and financial assistance to producers to encourage adoption of water storage/water use efficiency technologies.
- Increase available on-farm water storage capacity to minimize drought impacts.
- Improve the availability of irrigation infrastructure in order to relieve drought/heat stress.
- Promote adoption of more efficient irrigation technology to minimize drought stress and maximize the benefits of available water.

Livestock & Poultry / Flooding, Extreme Temperatures, & Drought

Impact Summary

Livestock and poultry operations, specifically confined animal feeding operations (CAFOs) for poultry and hogs, are especially vulnerable to inland flooding. Although planning and relocation of animals mitigate livestock loss, flood damage to structures and equipment, potential environmental impacts from manure, and residual impacts to local economies due to loss of production are significant. Extreme temperature fluctuations for animals produced in CAFOs may cause increased energy and water consumption to maintain healthy growing environments; pasture-raised livestock will be more susceptible to temperature extremes. Prolonged drought affects food, forage and water availability for pasture-raised animals. Drought extremes deplete aquifers and available water sources for production facilities that use water systems for cooling as well as animal hydration.

[2] NC Interagency Leadership Team. (2012). *Climate Ready North Carolina: Building a Resilient Future.* Retrieved February 14, 2020, from: https://connect.ncdot.gov/municipalities/InteragencyLeadership/Goals/Climate%20Ready%20North%20Carolina%20-%20Building%20a%20Resilient%20Future.pdf

Vulnerability and Risk

The impact of flooding on livestock and poultry may be more limited depending on the exact location of the flooding and the time farmers have to prepare for an anticipated event. Flooding events over the past few years have seen much less livestock and poultry mortality compared to earlier flooding events because farmers have made adaptive decisions to deal with a recurring issue. Livestock and poultry farmers, given enough time, can move their stock to safer locations or send them to market even if not at the desired time in the growing cycle. However, with major floods, there may be damage to infrastructure which will result in a farmer not being able place stock back into a housing structure in a timely fashion, resulting in loss of income.

Droughts are a natural part of the climate of North Carolina. Future droughts are likely to be more intense than they were historically, resulting in rapid drying and negative impacts on livestock production and performance. Water for livestock and poultry consumption is not thought to be a great concern unless the drought is prolonged and occurs during times of high temperatures. A prolonged and widespread drought can have a severe impact on feed stocks such as grains, hay, and grazing pasture lands. North Carolina is a grain-deficient state, meaning grain must be imported to meet demands.

Extreme temperature changes have a negative impact on livestock and poultry production systems. Prolonged exposure results in production losses across the board and higher input costs. Livestock and poultry operations are somewhat vulnerable to feed supply chain disruptions due to climate factors. In contrast, North Carolina is typically able to meet the need for hay. A statewide drought in 2006 resulted in the NCDA&CS becoming a hay broker transporting hay from the Midwest and Canada. Corn stalks were also baled in North Carolina and transported to impacted areas of the state. The estimate for drought damage to North Carolina agriculture in 2007 was $500 million.

Resilience Strategies

The NCDA&CS should monitor supply chain vulnerabilities to help producers in the state anticipate and respond to feed shortages. Other resilience strategies previously reported in the Climate Ready North Carolina: Building a Resilient Future[3] report include:

- Conduct research regarding breeds of livestock most suitable for current climatic conditions, as well as educate/advise the livestock sector of adaptive strategies for dealing with variation in climate.
- Encourage livestock producers to select breeds that are genetically adapted to prevalent climatic conditions.
- Support funding for programs that remove vulnerable livestock and poultry operations from flood prone areas.
- The NCDA&CS should monitor supply chain vulnerabilities to help producers in the state anticipate and respond to feed shortages.

[3] NC Interagency Leadership Team. (2012). *Climate Ready North Carolina: Building a Resilient Future.* Retrieved February 14, 2020, from: https://connect.ncdot.gov/municipalities/InteragencyLeadership/Goals/Climate%20Ready%20North%20Carolina%20-%20Building%20a%20Resilient%20Future.pdf

Shellfish & Freshwater Aquaculture Farmers / Temperature and Precipitation Extremes

Impact Summary

Short-term impacts of climate change on aquaculture and mariculture include the unpredictable nature of weather patterns, especially extreme high temperatures and excessive rainfall, both of which result in losses of production or infrastructure.

Shellfish and freshwater aquaculture farming occur in two completely different environments. Marine aquaculture, also called mariculture, takes place in the sounds, rivers, and creeks along the coast, while freshwater aquaculture can occur anywhere in the state where there is access to fresh water. North Carolina freshwater aquaculture is diverse. Farms typically grow trout, catfish, hybrid striped bass, prawn, crawfish, tilapia, and baitfish, depending on their environment and water source.

Mariculture in North Carolina, which is centered on oysters and clams, is performed on leased public bottoms using traditional methods such as cultch on bottom or modernized methods such as bottom cages or floating gear. The NC Division of Marine Fisheries administers the Shellfish Lease Program through the Habitat and Enhancement Section for the purposes of shellfish mariculture. In North Carolina, the leasing of public trust bottom for the use of shellfish aquaculture has been practiced for over 150 years. Recently, there has been tremendous growth in the industry, coupled with a shift to using intensive gear such as floating cages and bags. With more growers utilizing more gear, the cost of mariculture has increased, creating greater economic burdens for growers from coastal storms and flooding events.

Vulnerability and Risk

Coastal storms, with the associated **wind and waves** that destroy or wash away gear and inventory, can devastate production. Although mariculture has moved to growing oysters in vertical columns, there are still some growing operations where the cages sit on the bottom. During **heavy inland flooding** events, sediment is washed over the bottom cages, resulting in complete loss of production. Whether the loss is from wind and wave action or excessive sedimentation, the farmer has lost not only the gear but his entire inventory. Heavy rainfall accompanied by tropical cyclones can cause substantial coastal flooding, resulting in damage to wastewater treatment, agricultural runoff, and widespread closures of shellfish harvest areas. When wastewater enters shellfish growing areas due to flooding or excessive rainfall, the Division of Marine Fisheries issues a mandatory 21-day shellfish harvest closure. The closure results in loss of production and income.

The issues faced by freshwater farmers are different from mariculture farmers. Trout depend on cold water; 58°F is optimal. When the water temperatures exceed 65° F in the summer months, trout do not thrive. The producer can cut back on feed to avoid stress and manage the inventory by grading them, moving them, or even crowding them to load onto a hauling truck, all of which are challenging. These management actions, if done improperly, can lead to mortality.

The summer of 2019 was difficult for North Carolina trout producers. For two months, there was no rain, daytime ambient temperatures were in the mid to upper 90s, and water temperature exceeded 70° F. This created the perfect environment for bacterial diseases; medicated feed did little to thwart devastating losses, and often the water temperatures were too warm to feed. The combination of the hot days and warm water was the catalyst for disease and mortality. The western North Carolina trout industry lost productivity to mortality. To quote a major western North Carolina trout farmer, “It seems like the fall and spring are shorter and the summer is longer”. The primary growing season has been reduced by the delay of cooler temperatures in the fall and the earlier arrival of warmer temperatures in the spring.

Eastern pond producers face similar issues with climate-change-related extremes. Excessive summer pond temperatures limit production for hybrid striped bass and catfish, often forcing growers to halt feeding for extended periods. Unusually hot, cold, or cloudy weather can stress fish and cause disease. Catfish can be affected by off-flavor, making them unmarketable. Hybrid bass face an increased risk to bloating, often leading to major kills. Catfish and hybrids are more adaptable to warm water than trout; catfish prefer water temperatures in the 80s and hybrids in the 70s. When pond temperatures reach or exceed the upper 90s, issues can arise. There are reports from farmers where water temperatures have reached triple digits. These extreme temperatures affect optimum feed conversion and disease management, but also contributes to difficulty in managing dissolved oxygen. When water temperatures exceed 85°F, the pond water loses most of its ability to contain dissolved oxygen--leading to increased aeration costs and long nights battling dissolved oxygen levels in ponds.

Resilience Strategies

The NC Division of Marine Fisheries, in collaboration with growers and other partners, is working to develop a storm management plan for growers. Planning and preparing for extreme weather events can help mitigate economic damage to gear and product. The plan will include proactive measures for growers to consider when preparing for a storm event.

Production systems for trout must adapt to changing conditions. Two such considerations are to adjust fish stocking densities according to water flows and expected duration of favorable temperatures as well as utilizing smaller streams in more distributed production to compensate for lower stocking densities.

Adaptive practices are in place for controlling excessive rain water overflow. Due to oversight by the Division of Water Resources in DEQ, catfish farmers are currently required to mitigate impoundment overflow by using a 12-18 inch freeboard to catch excessive rainfall amounts. This practice can help them by limiting pumping requirements, but there is risk involved when drought occurs. Even with this practice, when excessive rainfall amounts occur, excess rainwater naturally leaves the farm; however, the Division of Water Resources does not recognize excessive rainwater overflow and treats all water leaving the farm as wastewater discharge.

Department-Owned Facilities / Extreme Weather & Sea Level Rise

Impact Summary

The NCDA&CS leases or owns facilities in 99 counties. Inland flooding is the major issue impacting those assets. In recent years, flooding has been mostly attributable to hurricanes and other severe weather events. Forest Service offices and research stations were heavily impacted by Hurricanes Matthew and Florence. Increased flooding also negatively impacts forest condition and composition often resulting in the need for reforestation. Facilities in the coastal region are likely to be susceptible to predicted sea level rise in the future. The following are damage estimates provided for two recent storms.

Hurricane Matthew

- $584,167 Forest Service
- $33,134 Plant Industry
- $775,134 Research Stations
- **$1,393,167 Total**

Hurricane Florence

- $5,607,107 NC Forest Service; $5 million of this represents damage sustained at the NC Forest Service Duplin/Pender Zone site
- $110,200 Research Stations
- $10,000 Plant Industry
- **$5,727,307 Total**

Vulnerability and Risk

Programs and services offered by the department, for example NC Forest Service's tree seedling production at Claridge Nursery, are critical elements to this sector's success. Claridge Nursery is currently highly vulnerable to flooding, as shown during the 2016 hurricane season. The ability to sustainably manage the state's forest resource and provide adequate tree seedlings for reforestation is essential to the NC Forest Service's ability to complete its mission. The rest of the department's divisions are consistently impacted by hurricanes and other extreme weather events.

Severe weather events, whether in summer or winter, tend to be in short duration and not widespread. If such weather events become more frequent and severe with climate change, their impact will become more problematic.

Figure 5B-3: 2016 Hurricane Matthew Flooding at Claridge Nursery (J. West)

Figure 5B-4: Aerial View of 2016 Hurricane Matthew Flooding at Claridge Nursery (J. West)

Resilience Strategies

To address risk and vulnerability to flooding, NC Forest Service offices can be relocated to higher ground, but that will be an expense the state must be willing to undertake. Research Stations cannot be relocated due to their size and the unique soils and climate they contribute to their research mission. Certain facilities on the stations can be relocated to higher ground, but again, the state must be willing to undertake that expense. Efforts are underway now to relocate offices and other structures at the Cherry Research Station. The NC Forest Service Duplin/Pender Zone site must be relocated because it was rendered unusable and beyond repair from Hurricane Matthew flooding. Although sea level rise is not generally a major concern for the department's facilities and assets, the Tidewater Research Station in Plymouth may be diminished in value in a few decades if sea level rise occurs as predicted. The same is likely true for selected NC Forest Service county sites.

Figure 5B-5. Hurricane Florence flooding at the NC Forest Service Duplin/Pender Zone site (2018)

Figure 5B-6. Flooding from Hurricane Matthew (2016) at Cherry Research Station and NCDA&CS First Responders

Endangered and Protected Plant Species / Flooding, Heat, & Wildfire

Impact Summary

The Plant Conservation Program is tasked with the conservation and protection of North Carolina's native flora under the authority of the NC Plant Protection and Conservation Act.[4] Under this act, the Plant Conservation Board creates and maintains the state's Protected Plant Species List (**02 NCAC 48F .0301)** which designates legally protected species as endangered, threatened, or special concern. The Plant Conservation Program implements the organizational rules and regulations related to the Act and carries out conservation programs including protecting listed plant species on Plant Conservation Preserves. These Preserves are state-dedicated nature preserves owned and managed by the Department for the protection of imperiled plant species in perpetuity. These Preserves are critical for the long-term survival of many of the state's listed species, and in the case of endemic species found only in North Carolina, survival in these sites is equivalent to their survival worldwide.

As an example of the impacts to natural resources and Departmental assets, a wildfire in 2011 caused severe damage to a stand of trees at a Plant Conservation Preserve. A salvage harvest was subsequently conducted to avoid a southern pine beetle outbreak. Not only did the salvage harvest require significant resources to manage, the full value of the harvested trees was also not obtainable, resulting in a net loss of both immediate and future assets. Similarly, flooding from recent hurricanes caused infrastructure damage at multiple Plant Conservation Preserves, including compromised culverts, washed out roads, and damaged structures. The damage to roads and culverts also caused severe delays in planned site management activities such as prescribed burning and tree harvest.

Vulnerability and Risk

The Plant Conservation Preserves are the only state-owned lands with the express purpose of protecting imperiled plant populations. Importantly, many of North Carolina's imperiled plant species are adapted to narrowly-defined environmental conditions. Additionally, many preserves protect some of the state's last remaining populations of the various target species. Safeguarding these sites is critical for the ongoing protection of North Carolina's natural heritage.

There are several concerns for preserves in the face of climate-related hazards. Flooding can cause damage to preserve infrastructure such as access roads and culverts, damage to natural resources such as inundation-caused death of trees and other plants, and the introduction of off-site materials detrimental to natural areas, including pollution, invasive plant seeds, etc. Increased heat and incidence of drought can also directly impact the survival of imperiled plant species, especially those with narrow climatic tolerances, such as high elevation species for which there is no further habitat to retreat to under rising temperatures. Importantly, these two risks amplify one another and also lead to an increased risk of wildfire.

[4] Plant Protection and Conservation Act, N.C. Gen. Stat. §§ 106-202.12 - 106.202.22

Figure 5B-7: 2018 Hurricane damaged road at Hog Branch Ponds Plant Conservation Preserve, Brunswick County

Although many species of plants in this state benefit from prescribed burning at suitably low intensities, wildfires tend to burn with higher intensity and over greater area. Wildfires and flooding can also cause detrimental turnover of species composition by enabling invasive exotic species to colonize previously undisturbed areas. Forests are especially vulnerable to these impacts, causing irrevocable damage to important natural communities. All these impacts are especially detrimental to small populations which are more vulnerable to stochastic events—this applies to many of the state's unique protected plant species.

Non-climate stressors such as increased urbanization (causing greater wildland-urban interface, increased impervious surfaces, and urban heat-island effects) amplify the impacts of climate-related risks such as increased flooding and extreme heat in and around Plant Conservation Preserves. Forest insect and disease outbreaks are other examples of non-climate stressors which will increase the impact of climate-related risks, especially wildfires. As an example, Hemlock Wooly Adelgid is causing hemlocks, which are a keystone species, to die off in great numbers in the mountain region of North Carolina. Having so many dead trees in a forest warms and dries the forest floor, which not only exacerbates the impacts of extreme heat under climate change, but also leaves the impacted areas more vulnerable to wildfire and storm damage.

Although forest insects and disease concerns tend to be somewhat localized, at least to a geographic region, there are examples of these same or similar concerns across the state, making the geographic variability of impacts similar, although via differing vectors. For instance, the Emerald Ash Borer is killing significant numbers of ash trees in the Piedmont region, while the coastal region is experiencing similar concerns over Red-bay Ambrosia beetle and the spread of Laurel Wilt Disease. Outbreaks of these insects and/or the diseases they spread can be rapid and difficult to treat or reverse. These outbreaks cause rapid changes in the natural community structure on Plant Conservation Preserves with negative impacts to the rare species populations protected therein.

The severity and scope of each of the different climate-related hazards will vary across the state given the geographic variability of North Carolina. For instance, flooding will likely be the most important concern for the Preserves in the coastal region which are at low elevation, have less variable topography, and are at the downstream end of most of North Carolina's rivers. In contrast, the impacts of extreme heat will likely be the most important concern for Preserves at high elevations, such as those the mountain region. Increased wildfire and invasions by invasive exotic species are likely to be of equal concern for all 26 of the Plant Conservation Preserves, regardless of geographic region.

The Plant Conservation Program has limited human or technological resources available to oversee the management and maintenance of present and future climate-related damages on Plant Conservation Preserves. Response to major events like wildfires or severe flooding would be beyond the capacity of the program to respond to without significant support from elsewhere, such as the NC Forest Service or with funds from state or federal programs like FEMA. Mitigating climate change hazards at the preserves is presently geared toward reducing the likelihood of wildfire and refining methods for repairing damaged infrastructure from floods.

Resilience Strategies

Adaptive Management

The Plant Conservation Program is working to increase ecosystem resilience to climate change within the Plant Conservation Preserves through adaptive management. This strategy includes prescribed burning and mid-story thinning which help remove excessive vegetation/fuels to lessen the vulnerability of these protected areas to wildfires. As wetlands are helpful in absorbing and slowly releasing flood waters, restoration of wetlands on Plant Conservation Preserves also reduces the negative impact of flooding.

These activities not only benefit the Preserves, but also to the surrounding communities to the extent that they are able to mitigate some fire and flooding impacts. These adaptive management techniques are helping to reduce the exposure and sensitivity of the current and increasing risk of wildfire and floods. These methods and other restoration efforts for wetlands can help reduce the sensitivity to increased flooding and increase the overall adaptive capacity at the Preserves.

Conservation efforts

The Plant Conservation Program is also working with state and regional partners to collect seeds and other germplasm from imperiled species at the Plant Conservation Preserves for long-term storage offsite. Seed-banking and other long-term storage techniques offer a complementary way to safeguard these populations from predicted and unforeseen negative impacts due to climate-related hazards. Offsite conservation efforts, such as long-term seed-banking, are increasing the adaptive capacity of the Plant Conservation Program for managing the imperiled plant populations at the Plant Conservation Preserves. The greatest barrier to implementing these and other adaptive management actions is a limit to available resources.

The prescribed burning that is possible with current capacity in the Plant Conservation Program and with support from NC Forest Service is helping to meet current burn management goals. However, additional resources in both of these divisions would be needed to adequately prepare for future climate-related hazards. Potential partners toward this goal include other agencies, like the U.S. Forest Service, NC Wildlife Resources Commission, or non-governmental organizations such as The Nature Conservancy, which itself manages considerable acreage across North Carolina. Additional funding to support effective wetland restoration projects would help mitigate localized flooding impacts at both the Plant Conservation Preserves and possibly their surrounding communities as well.

Plant Surveillance

Additional resources to monitor the responses of rare and imperiled plant species (as well as those which are common now but are predicted to be sensitive to future changes) to changing climate conditions would provide valuable information for determining future actions, including where and how to prioritize protecting the most vulnerable species and understanding which mitigation actions are the most effective. Potential partners in this effort include the NC Natural Heritage Program which conducts valuable field surveys of rare species and important conservation areas; research universities and institutions, especially those training future field biologists and ecologists; and federal agencies such as Department of Defense, Department of Interior, and U.S. Department of Agriculture which conduct similar research for similar purposes.

Personnel, Resources and Equipment Constraints / Wildfire

Impact Summary

There are approximately 23 million acres that fall under the state's jurisdiction where wildfire may flare up and require suppression. On average, North Carolina has around 4,000 wildfires annually that burn approximately 26,000 acres. Extreme drought conditions, coupled with other aberrant weather patterns like those seen in 2016, resulted in more than 5,000 fires and 88,000 scorched acres. Outside of wildfire, NC Forest Service employees respond to other natural disasters that include hurricanes, flooding, and winter weather events.

Vulnerability and Risk

The scale of wildfire across the landscape is increasing due to climatic changes including prolonged droughts, extreme wind events, and changing precipitation patterns as well as non-climate stressors such as increased flammable vegetation near inhabited areas. More specifically, North Carolina has 13.5 million acres in the Wildland Urban Interface (where homes meet woodland), which is the highest in the nation. North Carolina is also one of the fastest growing states by population, and with this growth the Wildland Urban Interface is expected to also increase and put further strain on the NC Forest Service to adequately suppress wildfires.

Human activity, another non-climate related stressor, is a major cause of wildfires across the state. Most wildfires result from careless use of fire or accidental ignitions. In any given year, only 1% of the wildfires that occur in North Carolina are a result of lightning. In 2018, arson accounted for 5%. The data on human-caused fires go back to 1971 and the trend is not expected to change as more and more people move into the state.

Although the NC Forest Service operates in all 100 counties, resources and manpower are often shared between counties, depending on the size and duration of an emergency event. The 2016 wildfire and hurricane season significantly strained the agency's capacity to respond, requiring additional resources from across the nation. The NC Forest Service employs 647 full time personnel, and of those, 330 are initial attack county level resources. However, during the peak of the 2016 wildfires, more than 3,000 personnel were engaged in wildfire control activities across the state.

Wildfires in the Wildland Urban Interface zone have a significant effect on real property in North Carolina, and in fiscal year 2017 there were 425 homes and structures destroyed, with an estimated financial impact of $8.9 million dollars. During that same period, 81,142 homes and structures were protected with an estimated value of $1.2 billion dollars, in part due to the significant support from out-of-state resources.

The tools used to fight wildfire in the state are aging, and current funding limits the replacement of high dollar items such as heavy equipment. The state fleet of bulldozers used to create fire breaks and the transport systems used to carry them are well behind the desired replacement schedule. There are currently 35 bulldozers (37% of the fleet) and 38 transport systems (25% of the fleet) on the replacement list. This aging fleet is resulting in increased maintenance costs and longer down times due to non-availability of parts. As incidence of wildfire is likely to increase under climate change conditions, there will be an even greater need for these critical resources to not only combat wildfire, but also preemptively protect against it.

Resilience Strategies

The NC Forest Service continues to look for options to deal with the state's wildfire problem. The NC Forest Service works year-round to educate the public on the wildfire problem and solutions to reduce risk and vulnerability. Fire itself is not the problem, as this state and its many ecosystems have evolved with fire over time. However, the timing of fires and their ignitions do pose a problem.

All wildland fire agencies understand that prescribed fire is the best tool to combat wildfires, but there is a need for greater public education promoting the value of controlled burns as well as other risk reduction activities. Examples include forest management techniques and removal of flammable fuels near homes and businesses. As more people move into the state from other parts of the country, this education piece becomes more necessary and more difficult. In many parts of the country, fire is not used to manage the environment on the scale that is needed here in this state, thus public education is critical. The recent wildfires in California are an example of what happens when fire is not used in the environment as it should be, regardless of the reason it was excluded[5].

In terms of equipment, the agency must work within the constraints of its budget to procure the tools necessary to fight wildfire in the state. To replace the heavy equipment that currently meets replacement criteria would require at least $16 million. In addition, the NC Forest Service is in the process of upgrading its radio system, but it is estimated to cost $1.76 million to complete the transition.

Departmental Workforce Capacity / All Climate Hazards

Impact Summary

NC Department of Agriculture and Consumer Services employees are responsible for conducting and assisting in emergency response to natural disasters and extreme weather events. NC Forest Service is specifically mandated to provide emergency response for wildfires and natural disasters such as hurricanes, flooding, and ice. Employees, both permanent and temporary, are located to provide the best

[5] Little, J.B. (2018). *Fighting Fire with Fire: California turns to Prescribed Burning.* Retrieved February 14, 2020, from: https://e360.yale.edu/features/fighting-fire-with-fire-california-turns-to-prescribed-burning

response times throughout the state and to allow prompt dispatching of additional resources when requested. Training is available to all employees on proper emergency response procedures. A timely response to any type of event is essential to reduce the impacts to this sector and North Carolina's citizens.

Vulnerability and Risk

The ability of the Department to respond to any emergency or natural disaster is dependent upon access to a full staff of trained employees. The current vacancy rate in NC Forest Service alone is close to 10%, with the majority of vacancies in entry-level positions. The current trend in NC Forest Service hiring has resulted in 50% of staff having fewer than 10 years of service, with 32% of those employees having fewer than 5 years of service. These employment trends have led to employees with minimal experience responding to these types of events which can increase the risk of loss of life or permanent injury.

Providing resources to respond to events such as the 2016 wildfires as well as Hurricanes Matthew and Florence required shifting employees statewide. This shifting of employees leaves minimal staffing at assigned duty stations to respond to everyday requests and local emergency response. As the climate changes, the potential for increased natural disasters may occur, putting additional requirements on current staffing levels.

There are many factors influencing the Department's ability to hire and retain employees. The current job market is extremely competitive, and current salaries are not aligned with private industry. Outside of the competitive job market, there are hazards and stresses associated with emergency response. This requires extra hours beyond the normal work day which impacts personal and family time and is not conducive to an acceptable work-life balance. Employees frequently responding to emergency events are more likely to become burnt-out and over-stressed, resulting in health issues, lost work time, and seeking alternate employment with fewer hazards and stresses.

Resilience Strategies

To retain and hire qualified employees, salaries need to be increased to a level that is competitive with the current market. NCDA&CS Human Resources Division has assessed those job classifications with the highest turn-over rates to identify equity issues and the funding needed to bring all employees in these classes to the appropriate salary level. The ability to retain employees that have been trained and to hire qualified employees will better prepare the department to respond to emergencies on a statewide level. Hiring qualified employees can also help reduce the time and funding needed to train staff. Fixing salary equity issues requires salary adjustment funding which must be approved by the NC General Assembly. Although requested, such funds have not yet been approved.

4. Summary

The Agriculture and Forestry sector, including protecting North Carolina's endangered plants species, is uniquely tied to climate due to the biological and physiological constraints of plants and animals. As stated by Walthall et. al. , "The vulnerability of agriculture to climatic change is strongly dependent on the responses taken by humans to moderate the effects of climate change."[6] The impacts to this sector directly reflect the impacts to North Carolina's rural and suburban citizens. The greatest departmental assets are experienced personnel, who interact with the public daily and in times of crisis to address a growing set of hazards related to a changing climate. Attracting, retaining, and protecting these personnel and addressing the upkeep and/or replacement schedule of aging infrastructure and equipment will be critical to meet future needs.

At present, inland flooding is the greatest climate-related threat facing agriculture and forestry statewide. However, during periods of extreme temperatures with associated drought, the threat shifts to wildfire and widespread loss of agricultural productivity. Most department-owned facilities, as well as crop and pasture lands, cannot be easily relocated to mitigate the risk of flooding due to the unique agricultural and climatic characteristics that tie them to the varied farming and forestry regions across the state. Options to mitigate extreme heat and drought include research and development of adaptive varieties and species of crops, livestock, and poultry and increasing available on-farm water storage capacity. Lastly, reducing wildfire risk hinges on public education and proactive actions to reduce the causes of wildfire. Response to increased emergency events and natural disasters, especially wildfires, will impact the department with an outsized impact on the NC Forest Service which is mandated by the North Carolina General Statutes to detect and suppress all forest fires under the jurisdiction of the state. Emergency events in the most recent past have highlighted the need for increased capacity and measures to improve resiliency in the future. Funding for necessary equipment, training, and salaries, as well as internal assessments of future capacity that allow the NCDA&CS to stay at the forefront of these issues, are imperative to the state's economy and overall resilience to climate change.

[6] Walthall, C. L., Anderson, C. J., Baumgard, L. H., Takle, E., & Wright-Morton, L. (2013). *Climate change and agriculture in the United States*: *Effects and adaptation*. Retrieved February 14, 2020, from: https://www.usda.gov/oce/climate_change/effects.htm

Coastal Resources & Infrastructure

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C. Coastal Resources and Infrastructure

Key Observations

- Flooding from storms and extreme tides, magnified by sea level rise, is severely affecting land use, public infrastructure, and natural resources along the coast of North Carolina
- The intensity of recent storms and flooding have challenged the state's response and recovery plans. We should plan for greater extremes in the future.
- Climate hazards intensify existing social inequalities and lack of ability to adapt in economically challenged counties in the coastal region.

Critical Impacts and Resilience Strategies

- Climate change is impacting coastal habitats, fisheries, and the ecosystem services provided in coastal communities. State monitoring, research, and education can enhance understanding of impacts and potential adaptation strategies.
- Immediate focus must be on developing strategic priorities for public and natural infrastructure improvements as well as actions that integrate climate resiliency into agency operations, local disaster recovery programs, and long-term planning.
- Future climate conditions and resiliency should be integrated into current public investment decisions in local and regional water and transportation infrastructure improvements and other critical assets.
- State leadership should model adaptive behavior and incentivize local resiliency efforts that balance protection of life, property, and the environment. Inter-agency coordination can help build local capacity and action through funding and technical assistance.

1. Sector Overview

Coastal North Carolina is known for its extensive natural resources, including 320 miles of ocean beaches, 12,000 miles of estuarine shoreline, the second largest estuary in the nation, and numerous coastal and estuarine protected areas. Approximately one-half of the oceanfront is developed, and there are over 100 miles of national seashore. From broad, shallow sounds such as the Albemarle and Pamlico, to narrow bodies of water such as Bogue and Masonboro sounds, North Carolina has 2.2 million acres of estuarine waters and 726,000 acres of coastal ocean waters. These features present a significant opportunity to protect, restore, and enhance our natural infrastructure to bolster community and ecosystem resilience, and to endure and recover from future storms.

Coastal N.C. is predominantly rural, with a diffuse population that is dependent on natural systems for its economic well-being. These same natural resources also provide important protection from storm surge, flooding, and other impacts associated with climate change. The North Carolina coast is complex and dynamic, with a diversity of demographics, hazards, jurisdictional authorities, and economic drivers, including agriculture, extractive industries, tourism, military, and shipping.
Most cabinet agencies have assets or responsibilities that intersect with the coast, including the Department of Environmental Quality's (DEQ) Divisions of Water Resources and Marine Fisheries (DMF), the Wildlife Resources Commission, and the Departments of Transportation and Public Safety, the latter of which houses the new Office of Recovery and Resiliency (NCORR).

This section primarily addresses programs and assets within DEQ's Division of Coastal Management (DCM), which houses DMF and the Albemarle-Pamlico National Estuary Partnership (APNEP). Other agency programs are discussed more in-depth in other parts of this document.

The ***DCM*** carries out the state's Coastal Area Management Act (CAMA), Dredge and Fill Law, and the rules and policies of the Coastal Resources Commission (CRC), in the state's 20 coastal counties. The CRC is charged under CAMA with the protection, preservation, orderly development, and management of the coastal area of North Carolina, including public trust resources. DCM, which provides staff support to the CRC, is responsible for several programs, including permitting, land use planning oversight, coastal policy, the Coastal Reserve program, and numerous grant programs.

DCM's Coastal Reserve protects and manages more than 44,000 acres of coastal and estuarine land and water for research, education, and compatible traditional uses at ten reserve sites along N.C.'s coast. Four of these sites comprise the National Estuarine Research Reserve, a state-federal partnership between DCM and the National Oceanic and Atmospheric Administration (NOAA).

The ***DMF's*** mission is to ensure sustainable marine and estuarine fisheries and habitats for the benefit of the people of North Carolina. This includes the management of North Carolina's marine and estuarine fisheries out to three miles offshore, and monitoring the state's fisheries habitat, encompassing all 2.9 million acres of coastal waters (marine and estuarine) and over 412,000 miles of coastline.

The ***APNEP's*** mission is to identify, protect, and restore the significant resources of the Albemarle-Pamlico estuarine system. The partnership is a cooperative effort hosted within DEQ under a cooperative agreement with the U.S. Environmental Protection Agency. APNEP works closely with the Commonwealth of Virginia, as the program area extends across both states, from its headwaters in the Virginia mountains and North Carolina Piedmont, through a broad coastal plain and out to the string of barrier islands bordering the sounds.

2. Overall Exposure

Climate Stressors

North Carolina is one of the states most impacted by, and vulnerable to, climate-related changes in coastal hazards such as storms, coastal flooding, beach erosion, and sea level rise. Flooding from precipitation, storm surge, and tides, amplified by sea level rise, has become a more frequent and damaging hazard in recent years. Storm floods are typically geographically limited, but devastating events. Sea level rise, by contrast, is a gradual but significant hazard that affects the entire coastal region. Unlike storm flooding, sea level rise does not recede.

Sea level rise intensifies other coastal hazards such as flooding, storm surge, shoreline erosion, and shoreline recession. Sea level rise can also pose a threat to freshwater resources and quality, private property and development, tourism and economic vitality, historic and cultural resources, agriculture, forestry, and public property and infrastructure. Proactive adaptation and resilience building can help to minimize economic, property and natural resource losses, minimize social disruption and losses to public trust areas and access, and lessen the need for disaster recovery spending.

Non-Climate Stressors

North Carolina has large areas of high social and economic vulnerability, and needs to build human and environmental capacity to adapt to the changing climate, particularly at the local community level. This lack of capacity is costly in economic, environmental, and most importantly, in human terms.

3. Examples of Impacts, Vulnerability, and Risk

Division of Coastal Management

Impact Summary

The most visible impacts of climate change on coastal resources and structures result from more intense storminess, precipitation, and flooding (Table 5C.1). Sea level rise, driven by warming ocean temperatures and melting land ice, amplifies these impacts. Catastrophic damage occurs to private and public property, both in the built and natural environment. While DCM does not own any physical property, the agency's programs and operations, and resources and uses that the division manages, are impacted by climate-related hazards. In addition, structures and activities that the division regulates, as well as public trust resources, are also impacted. Coastal flooding, from storms and sea level rise, impacts both the natural and built environment. Transportation, housing, critical facilities, businesses, utilities, and other infrastructure—many of which are located within DCM's jurisdictional Areas of Environmental Concern (AECs)—can be damaged or destroyed, and will require permits from DCM to be rebuilt.

Table 5C-1: Division of Coastal Management Exposure Table

Assets, Regulations, Services	Tidal Flooding	Flooding (River and Land)	Coastal Erosion	Storm Surge	Sea Level Rise	Saltwater Intrusion	Water Shortage (Drought)	Wildfire	Wind
Division of Coastal Management									
CRC rules & policies	*	*	*	*	*				*
CAMA permitting	*		*	*					*
Land use planning	*	*	*	*		*	*		*
Access grants		*	*						
Coastal resiliency initiative	*	*	*	*	*				*
Science & data	*		*		*				

Public trust resources such as beaches and wetlands can be damaged or lost due to climate-amplified processes. While sediment supply is a primary determinant of beach width, storms, sea level rise, and management decisions also contribute to beach and dune condition. In particular, powerful storms can remove huge volumes of sand from the beach and dunes, and erode wide swaths of coastal wetlands, in a matter of hours. The loss of public trust beaches, dunes, and wetlands equals a loss in wildlife habitat for sea birds, turtles, crustaceans, invertebrates, etc. Economic damage can be extremely high; damaged and destroyed buildings and infrastructure means less tourist revenue, and money spent on beach re-nourishment and habitat restoration.

DCM's mission statement focuses on the importence of a comprehensive approach to coastal issues, including not only permitting, but also planning, conservation, reearch, education, and outreach. As coastal development continues at a rapid pace, DCM's limited number of staff are already handling a significant volume of permitting, enforcing, rule development, and legal issues. In addition, DCM has limited financial resources to address the growing needs associated with climate adaptation and resilience planning. However, DCM is well situated to develop and implement a coastal resilience program given its exsiting state authorities, federal grants, local planning, grants, and technical assistance efoorts over the past several years. An expanded coastal resilience program at DCM wouold require additional staff support and a clearly defined partnership with NCORR, which is currently in development.

Figure 5C-1 North Carolina's 20 coastal (CAMA) counties

Vulnerability and Risk

Coastal AECs are tidal waters of the ocean, sounds and rivers, and the beaches, dunes and lands adjacent to them. As such, AECs, and the permitted development within them, are often the first areas to be affected by storms and chronic sea level rise. DCM's role is to authorize development in AECs according to standards established by the Coastal Resources Commission, but it is the permittee that bears the vulnerability and risk of damage. Sensitivity of structures and ecosystems varies by location and development patterns, including protective and avoidance measures, and the scale of impacts ranges from minor and temporary, to catastrophic and permanent. Financial ability to take adaptive actions varies across individuals and communities, and similarly, potential adaptive actions vary widely by complexity, cost, feasibility, and effectiveness. Along non-oceanfront shorelines, storms and sea level rise impact both natural and developed areas, putting both wildlife habitat, valuable marshes, and development at risk.

High water events, including storms, nor'easters, extreme tides, and other weather-related events cause surge and either erode sand out to sea, or cause overwash inland, covering roads, yards, parking lots, and other infrastructure. With sea level rise and higher storm intensity, erosion and overwash are becoming more frequent, removing sand from public trust beaches. Despite some localized natural accretion, there is usually a net loss of sand to an impacted area. Fully restoring the beach, or returning overwashed sand to the ocean beach, requires expensive intervention, and ideally a long-term program for beach and dune maintenance. Long-term programs require reliable funding and adequate sediment supply, coordination, and permitting. Good examples exist in North Carolina of successful long-term programs, but not all beach communities have the financial, sand, or organizational resources required to implement long-term beach maintenance programs. Beaches and dunes are among the first systems assessed for damage after a storm because of their high vulnerability and the importance of the protective, ecological, and economic services they provide. Beaches have no natural defenses, and most permanent structures to combat erosion are prohibited by law because they would protect one area at the expense of another or result in loss of public trust beaches over time.

Resilience Strategies

There are countless actions and strategies that may advance coastal resilience. A few are highlighted here, taken from local governments suggestions from two regional workshops in 2019, and others submitted by environmental NGOs.

Create and fund a program to build local capacity for climate resilience. The program should incentivize and reward communities for meeting defined standards for long-term planning, preparedness, and community engagement, and help them to plan shovel-ready projects in order to capitalize on federal and state funding opportunities. DCM and NCORR are currently researching other states that have created similar programs.

Incentivize communities to protect, enhance, and restore natural infrastructure that can provide flood protection, ecosystem, and economic benefits. Increase appropriations to natural resource trust funds for acquiring and/or enhancing priority coastal lands. Simplify rules for ditch clearing and make nature-based solutions easier to permit.

Identify and re-evaluate policies and subsidies that incentivize or allow risky investment decisions. Require or encourage rebuilds and retrofits to be constructed more resilient than pre-damaged condition. Consider climate change and sea level rise in future investments decisions. Incorporate more low impact development practices.

Provide data to local government staff through a best practices website, and assist with interpretation. Continue to do sea level rise assessments, and fund data collection, research, and monitoring. Integrate coastal hazards and rainfall data into updated spatial analysis of vulnerabilities, e.g., sea level rise, rainfall flooding, and storm surge. Host regular training webinars and workshops. Consider placing trained resiliency coordinators at regional councils of government or community colleges.
Strengthen hazard mitigation plan requirements based on updated county vulnerability analyses, and require CAMA land use plans to be consistent with updated hazard mitigation plans. Integrate resiliency planning into existing planning requirements, such as capital improvements, economic development, hazard mitigation, and comprehensive or land use plans.

Demonstrate state leadership. Prioritize major state investments using resiliency criteria. Create a scoring system to quantify risk of state-funded projects to communities of concern. Centralize resiliency programming into one agency or organization and assist with state match for federal funding opportunities. Strengthen interagency, local, private, and academic partnerships. Empower stakeholders to be equal partners.

Regulations and Policies

The division's legislative authorities are the N.C. Coastal Area Management Act (G.S. 113A-100 *et seq.*), the N.C. Dredge and Fill Law (G.S. 113-229) and the federal Coastal Zone Management Act (CZMA) of 1972, as amended. The division administers the rules set by the CRC in Title 15A, Section 7 of the N.C. Administrative Code. CAMA was enacted to fulfill four overarching goals, and the CRC's rules are all designed to meet the following mandates:

- To preserve and manage natural ecological conditions and productivity;
- To ensure that the development, use or preservation of land and water resources is consistent with ecological conditions;
- To ensure orderly and balanced use and preservation of coastal resources; and
- To establish policies, guidelines and standards for development, preservation, use, and protection of public trust rights and resources.

CAMA, Dredge and Fill, and the CRC's rules are all designed to protect property and the environment. To accomplish this, the statutes and regulations require that DCM's programs measure and account for dynamic and sometimes volatile conditions, shifting boundaries, flooding, storm surge, erosion, and any other processes or events that could undermine the desired protections. To date, DCM has done this by analyzing historic data, with the inherent presumption that future conditions will approximate past conditions. Climate change is forcing DCM to consider how best to account for future conditions in today's programs and operations.

Unlike the state's oceanfront shoreline where permanent erosion control structures are mostly illegal, North Carolina allows permanent hardening of estuarine shorelines using vertical bulkheads and other hardened erosion control structures. In recent years, DCM has been promoting "living shorelines" using constructed oyster reefs and marsh plantings for shoreline erosion control, as they mimic a naturally-occurring shoreline and deliver multiple benefits. Living shorelines are being found to outperform vertical bulkheads for storm protection and longevity, and also preserve vital intertidal habitat that would be lost as sea level rise approaches a vertical bulkhead.

The DCM is responsible for several programs, including:

Permitting

CAMA permits are required if a proposed project is in one of the 20 CAMA counties, in an area of environmental concern (AEC) designated by the CRC, meets the statutory definition of "development," and is not an exempt activity by rule or statute. CAMA defines development as: "any activity in a duly designated area of environmental concern ... involving, requiring or consisting of the construction or enlargement of a structure; excavation; dredging; filling; dumping; removal of clay, silt, sand, gravel or minerals; bulkheading; driving of pilings; clearing or alteration of land as an adjunct of construction; alteration or removal of sand dunes; alteration of the shore, bank or bottom of the Atlantic Ocean or any sound, bay, river, creek, stream, lake or canal; or placement of a floating structure in an Area of Environmental Concern" as designated by the CRC.

Land-use planning

CAMA requires each of the 20 coastal counties to have a local land use plan in accordance with guidelines established by the CRC; however, the policies included in the plans are those of the local government, not the CRC. As of 2020, nearly 40 cities and towns have also voluntarily adopted their own plans, although CAMA does not require them to do so. Each land use plan includes local policies that address growth issues such as the protection of productive resources (i.e., farmland, forest resources, fisheries), desired types of economic development, natural resource protection, and the reduction of storm hazards. Once a local land use plan is certified by the CRC, DCM uses the plan in making CAMA permit decisions and federal consistency determinations. Proposed projects and activities must be consistent with the policies of a local land use plan, or DCM cannot permit the project.

Beach and waterfront access

DCM awards about $1 million a year to local governments, as matching grants for projects to improve pedestrian access to the state's beaches and waterways. Funding for the Public Beach and Coastal Waterfront Access Program comes from the N.C. Parks and Recreation Trust Fund. North Carolina currently has approximately 1,000 beach, shoreline, and boating access sites, many of which received funding through this program for land acquisition and improvements.

Coastal resiliency

DCM's Coastal Adaptation and Resiliency website[1] provides links to climate data and forecasts, assessment and planning tools, adaptation examples, and sources of funding for planning and implementation. It is geared primarily towards local government staff and other stakeholders interested in coastal resilience in North Carolina. DCM's Resiliency Guide[2] is designed to walk users through some of the key steps and questions required for effective community-level resiliency planning. It presents a process for building resilience and climate change considerations into existing efforts such as comprehensive land use, hazard mitigation, or capital improvement planning, while also focusing on other co-beneficial strategies for risk reduction.

Federal consistency

Under provisions of the federal CZMA, DCM is authorized to review proposed federal actions such as permits or lease sales, and direct federal activities such as channel dredging or construction, to determine whether the proposed action or activity could have a reasonably foreseeable effect on resources or uses in the state's coastal zone. DCM coordinates with state resource and regulatory agencies, subject matter experts, and other interested stakeholders, to evaluate potential impacts and ensure that the proposed action or activity is maximally consistent with applicable state laws and regulations.

Science and data

The CRC's Science Panel prepared the state's first ever Sea Level Rise Assessment Report in 2010, providing projections to the year 2100. In 2015 the Science Panel released their second report, with regional projections to 2045. The Science Panel will release their third Assessment in 2020. DCM has also been building a geographic information systems (GIS) program since the early 1990s. Today, DCM is incorporating this technology into a number of its programs, using GIS to help support land-use planning and regulatory decisions. DCM is using GIS to better manage development in coastal high-hazard areas by analyzing data such as inlet dynamics and shoreline erosion patterns. The results help to determine setback requirements for oceanfront construction. DCM maintains an interactive map and smartphone app of public access sites and facilities. DCM also collects and analyzes data for erosion rates, wetlands conservation and restoration, and to assess the impacts of coastal development.
The N.C. Clean Marina Program rewards marina operators who help safeguard the environment by using management and operations techniques that go above and beyond regulatory requirements. Clean marinas may fly the Clean Marina flag and use the logo in their advertising, signaling to boaters that the marina cares about the cleanliness of area waterways. The Marine Sewage Pumpout and Dump Station Grant Program provides grants of up to $20,000, from the U.S. Fish and Wildlife Service, to marinas and other boat-docking facilities for the installation and renovation of pumpout and dump stations in North Carolina.

[1] https://deq.nc.gov/about/divisions/coastal-management/coastal-adaptation-and-resiliency
[2] https://ncdenr.maps.arcgis.com/apps/MapSeries/index.html?appid=e2eb18546943471b93f0264659744a81

North Carolina Coastal Reserve & National Estuarine Research Reserve

Impact Summary

Coastal storms and flooding, compounded by climate stressors, directly impact reserve ecosystems and the services they provide (Table 5C-2). Impacts include forest damage, wetland loss, sand movement and loss, habitat loss or conversion, damage to marine access infrastructure, loss of visitation and educational program days, loss of signage, increased marine debris including vessel groundings, and increased maintenance and repair costs.

Table 5C-2: Coastal Reserve & National Estuarine Research Reserve Exposure Table

Assets, Regulations, Services	Extreme Heat	Flooding (River and Land)	Coastal Erosion	Changed Seasons	Sea Level Rise	Saltwater Intrusion	Storm Surge	Tidal Flooding	Wildfire	Invasive Species & Species Range Shifts	Vessel Groundings
North Carolina Coastal Reserve & National Estuarine Research Reserve											
Reserve Sites		*	*	*	*	*	*	*	*	*	*
Site Support Structures		*	*		*		*	*	*		
Research Program	*	*		*	*		*	*	*	*	
Research Infrastructure		*	*		*		*	*	*		
Stewardship Program	*	*	*	*	*		*	*	*	*	*
Education & Training Program	*	*			*		*	*	*	*	

In recent years, hurricanes have been the primary impact to reserve sites. This includes damage to the Currituck Banks and Rachel Carson Reserves' boardwalks; downed trees at multiple sites that blocked trails, creating a hazard for staff and visitors; increased marine debris and vessel groundings on sites that also posed a hazard to staff and visitors; and erosion at multiple sites. Visitation to reserve sites is impacted when sites are closed to protect safety which has potential implications for local economies. Reserve programs are also impacted, as training and education programs are affected by delays or cancellations and the research program's sampling schedule is delayed. Storm impacts also increase

workload for staff during the immediate response and long-term recovery process. With the increasing frequency and intensity of storms, more resources are needed to facilitate response and recovery.
The reserve recognizes that the changing climate will have an impact on its sites and programs. The NCNERR Management Plan 2020-2025 identifies coastal hazards resilience as a cross-cutting topical area the reserve is currently working on that will continue into the future; an excerpt from the plan is below:

> *The natural geography and topography of North Carolina's coastline make it vulnerable to coastal hazards, such as flooding, coastal storms, shoreline erosion, and sea level rise. Assessing the vulnerability of coastal and estuarine ecosystems at reserve sites is accomplished through existing monitoring programs like the System-Wide Monitoring Program (SWMP), natural species surveys, habitat mapping, and elevation data analysis. The reserve's ability to monitor and characterize these processes and changes is increasingly important when it comes to understanding and planning for coastal hazards to ecosystems and coastal communities. The reserve is equipped to improve the knowledge of coastal communities about the necessity of establishing long-term resilience through education, training, research, and stewardship activities that promote monitoring programs, encourage implementation of adaptation strategies to address observations and plan for future scenarios, and the important role natural infrastructure plays in coastal resilience.*

The following objectives are part of the reserve's identified work in the plan:

- Assess vulnerability of reserve natural resources to coastal hazards and use results to inform management decisions.
- Increase understanding and communicate knowledge of the importance of natural infrastructure (e.g., oyster reefs, marsh, living shorelines) to coastal resilience.
- Increase understanding of sea level rise implications and resilience opportunities for reserve sites and coastal and estuarine ecosystems by participating in local, regional, and state initiatives.

Vulnerability and Risk

The reserve is working to better understand the specific vulnerability of its sites and habitats. Also, the reserve is assessing its adaptive capacity to protect representative coastal ecosystems and the services they provide in the face of a changing climate. Many reserve sites also serve as very important storm buffers to local communities. If the integrity of the sites is compromised due to climate change impacts, their protective services for these communities will decline, putting infrastructure and residents at greater risk. Currently, the vulnerability and risk are not known for all habitats at all reserve sites and work to better understand this is prioritized for sites that are generally understood to be vulnerable based on the site characteristics.

The sensitivity of the reserve sites is variable based on habitat type (e.g., salt marsh, tidal flat, ocean beach, maritime forest, dune ridge, non-riverine swamp forest) and location in the landscape (e.g., region of the coast and sea level rise rates, exposure to ocean energy within the region). It also varies based on event intensity, duration, and frequency. Lower-lying habitats are more sensitive to flooding, erosion, and shoreline recession from storm and king tides, and lower- to mid-range habitats to habitat transition as a result of higher water levels.

An example of an effort to better understand vulnerability and risk is the reserve's use of the Climate Change Vulnerability Assessment Tool for Coastal Habitats (CCVATCH) to evaluate the vulnerability of saltmarshes at the four NCNERR sites in 2017[3]. CCVATCH is a decision support tool that improves

[3]http://nerrssciencecollaborative.org/media/resources/Report_Salt_Marshes_Southeast_Climate_Change_Vulnerability_Assessment.pdf

understanding of the specific vulnerabilities of a habitat to climate change in order to inform current and potential management actions. Through this data assessment process, users of this tool determine the potential for applying adaptation strategies as well as the main sources of vulnerability.

The NCNERR sites scored as ‘high’ in sensitivity-exposure (SE) to climate impacts, but ranged from ‘low’ to ‘high’ in adaptive capacity (AC). The Currituck Banks Reserve scored ‘high’ for both SE and AC, for an overall ‘moderate’ vulnerability score. Sea level rise and storms were the overall highest scoring climate-exposures, and invasive species and erosion were the highest scoring stressors at this site. The Rachel Carson Reserve was divided into two sections, Middle Marsh and Town Marsh, both of which both scored ‘high’ in SE. The sites differed in AC, with Middle Marsh scoring ‘low’ and Town Marsh receiving a ‘moderate’ score, for an overall vulnerability assessed as ‘very high’ at Middle Marsh and ‘high’ at Town Marsh. At Middle Marsh, the direct effects of sea level rise and the interaction of erosion with sea level rise and extreme climate received the highest scores. At Town Marsh, the interaction of erosion and sea level and the direct effects of extreme climate events contributed the most to the SE score.

The Masonboro Island and Zeke’s Island Reserves both had ‘high’ levels of SE and ‘moderate’ scores for AC, for overall 'high' vulnerability scores. Impacts from climate exposures of sea level rise and storms scored highest for both reserve sites. The direct effects of climate change and erosion were overall the highest scoring stressors for Masonboro Island Reserve, while invasive species and nutrients had the overall highest stressor scores at Zeke’s Island Reserve. This assessment will be helpful as the program prioritizes sites or areas within these sites that present the most risk and considers potential adaptation strategies in the future to enhance resilience.

Resilience Strategies

The reserve is committed to taking actions to address climate hazards. On each site, the reserve will continue to employ the Steps to Resilience.[4] The reserve will collaborate with land managers, researchers, and relevant stakeholders to assess the vulnerability of natural resources and prioritize strategies based on the greatest vulnerabilities and risks. The reserve will implement strategies that are most likely to improve resilience and provide the greatest benefits overall, given available resources. For example, the reserve has sought funding to use existing research results and vulnerability assessments to develop an environmental resilience plan, including shovel-ready projects, for the Rachel Carson Reserve.

Adaptive capacity

One of the reserve’s greatest forms of adaptive capacity is its education, training, research, and stewardship programs. These programs are rooted in the local communities and professional networks, making them nimble in their response to changing conditions. This nimbleness also allows the programs to pivot their focus to achieve the reserve’s mission in the face of climate change. For example, the reserve’s training and education programs are increasingly incorporating climate science and resilience messages into programming as well as helping stakeholders work collaboratively on these issues. The research program is monitoring the impact of changing conditions on habitats, as well as supporting partners’ work on this topic, to help increase understanding of coastal habitat resilience. Research staff and partners are also examining different “living shoreline” stabilization techniques that both maintain ecosystem services and stabilize the shoreline under different water level and energy regimes. Stewardship staff are monitoring the reserve sites for change and working towards management actions to increase site resilience. Stewardship staff have also facilitated the acquisition of additional parcels of land

[4] Gardiner E. P., Herring D. H., and Fox. 2019. The U.S. Climate Resilience Toolkit: evidence of progress. Climatic Change 153(4): 477-490. Also see https://toolkit.climate.gov/#steps

which were incorporated into existing reserve sites to protect additional habitat and support habitat migration.

Efforts are underway to address lessons learned from recent hurricane events to enhance program preparedness and response in future events. This includes engaging resource agencies and organizations to proactively leverage assistance across agencies for event response and recovery; and work with DEQ agencies and other state agencies and organizations on event-related marine debris and grounded vessels removal and policy. Future options include:

- implementing shovel-ready projects to enhance site resiliency;
- conducting vulnerability assessments at additional reserve sites;
- considering land acquisition opportunities adjacent to existing reserve sites to facilitate habitat protection and migration; and
- improve understanding of reserve ecosystems, including the ecosystem services they provide, the threats they face, and how to best protect them.

Monitoring

The reserve will continue to implement the SWMP, sentinel site, and natural resource monitoring to understand vulnerability of species, habitats, and sites and changes related to climate hazards. This includes continuing to conduct and explore opportunities to expand the *Sentinel Sites for Sea Level Rise and Inundation* module of SWMP to assess the resilience of marshes to sea level rise, evaluate the performance of living shorelines over time and during storms, and assess the impact of shoreline hardening on marshes.

Education

The reserve's training program will use vulnerability assessments and resilience strategies to educate communities and coastal decision-makers on what coastal hazards are and the importance of natural infrastructure, such as living shorelines and coastal wetlands, for coastal resilience. This includes enhancing or developing educational materials, research presentations, training events, and hands-on stewardship activities that incorporate this information. The training program will assist coastal communities to implement actions that increase their resilience to coastal hazards through technical assistance. The reserve's education program will develop and deliver hands-on resilience related curricular activities to K-12 students and teachers.

The reserve will leverage its programs to support DCM and DEQ initiatives to address sea level monitoring, resilience planning, and public engagement. Additionally, the reserve will lead and/or participate in local, regional, and state initiatives to advance collaborative efforts to address climate hazards such as the N.C. Sentinel Site Cooperative[5] and the Coastal Resilience Community of Practice.

Regulations and Policies

The reserve's legislative authorities are the N.C. Coastal Area Management Act (G.S. 113A-129) and federal Coastal Zone Management Act of 1972, as amended. The reserve rules in the N.C. Administrative Code are in section 15A NCAC 07O. The NCNERR portion of the program must also comply with federal regulations for the NERRS, 15 C.F.R. Part 921.1(a). The N.C. Administrative Code and NERRS regulations require that the reserve maintain management plans for the sites. Management plans cover 9 of the 10 sites currently; the most recent update is the soon to be approved NCNERR Management Plan for 2020-2025. Dedicated Nature Preserve authority is the Nature Preserves Act (G.S. 143B-135.250-272) and N.C. Administrative Code rules are in section 07 NCAC 13H.

[5] https://oceanservice.noaa.gov/sentinelsites/north-carolina.html

The reserve will continue to meet its legislative authorities, regulations, and policies in light of climate-related hazards, yet the program's services will need to be nimble in response and the hazards to be addressed prioritized. Significant effort is needed to understand the reserve assets' vulnerability and to plan for and implement adaptation strategies. Reserve services will need to adapt accordingly to meet this need. Capacity at the reserve is limited to meet authorities, regulations, and policies currently and resources may need to be diverted from current topics to address increasing climate-related hazards.

The mission of the N.C. Coastal Reserve and National Estuarine Research Reserve (reserve) is *to practice and promote informed management and appreciation of North Carolina's coastal and estuarine ecosystems and provide protected sites for research, education, and stewardship.* The reserve, a program within DCM, accomplishes its mission and purposes identified in the N.C. Administrative Code (15A NCAC 07O) through its education, training, research and monitoring, and stewardship programs, each of which is devoted to fostering that aspect of the program.

The education program increases awareness of the importance of coastal and estuarine ecosystems and inspires protection of these ecosystems for K-12 students and teachers, educators and the general public through its programs and materials.

The Coastal Training Program promotes informed decisions regarding coastal resources by providing target audiences, such as local officials, realtors, state agency staff, resources managers, non-profit organizations and others, with science-based training opportunities on a variety of coastal topics.
The research and monitoring program conducts, promotes and facilitates research at Reserve sites focused on ecosystem dynamics, coastal hazards resilience and human influences on estuarine systems and also provides long-term data on water quality, weather, biological communities, habitat and land-use and land-cover characteristics through its System-Wide Monitoring Program (SWMP).

The stewardship program maintains and protects the natural character of 10 reserve sites by integrating science, community input and volunteer monitoring efforts to ensure suitable environments for research and education, and to protect and restore coastal and estuarine species and habitats of environmental, economic and traditional use value to North Carolina.

The reserve's 10 sites protect more than 44,000 acres of coastal and estuarine land and water along the coast of N.C. (Figure 5C-2), providing essential habitat for wildlife and serving as platforms for program implementation such as educational opportunities for students, teachers and the public, and living laboratories for scientists. Additionally, reserve sites are available for compatible traditional public trust uses and are popular places for ecotourism, nature observation, walking, boating, and hunting. Populations of feral horses roam on the Currituck Banks and Rachel Carson Reserves which are well-loved by N.C. citizens and visitors. Many of the sites provide a buffer to coastal communities from storms and rising sea levels.

The reserve was established as a multi-site reserve to take advantage of both the Virginian and Carolinian biogeographic regions in the state and as such, the sites are geographically disparate and represent diverse coastal and estuarine habitats. Four of the ten sites comprise the federally-designated N.C. National Estuarine Research Reserve (NCNERR). All sites, with the exception of the Permuda Island Reserve, are also Dedicated Nature Preserves through the N.C. Natural Heritage Program.
The NCNERR is one of 29 reserves within NOAA's National Estuarine Research Reserve System (NERRS), operated by the Office for Coastal Management (OCM). As such, the NCNERR is managed as a federal-state partnership between NOAA's OCM and DCM. The OCM implements the National Coastal Zone Management Program and NERRS with authorization from the federal Coastal Zone Management Act of 1972 (CZMA). The OCM provides funding, technical assistance, and national coordination and

oversight to reserves within the NERRS. The DCM manages the sites on behalf of the N.C. Department of Administration, and provides staff, programming, and matching funds for implementation of the NCNERR. The N.C. Coastal Area Management Act (CAMA) provides authority for the reserve at the state-level and officially includes the NCNERR in the program.

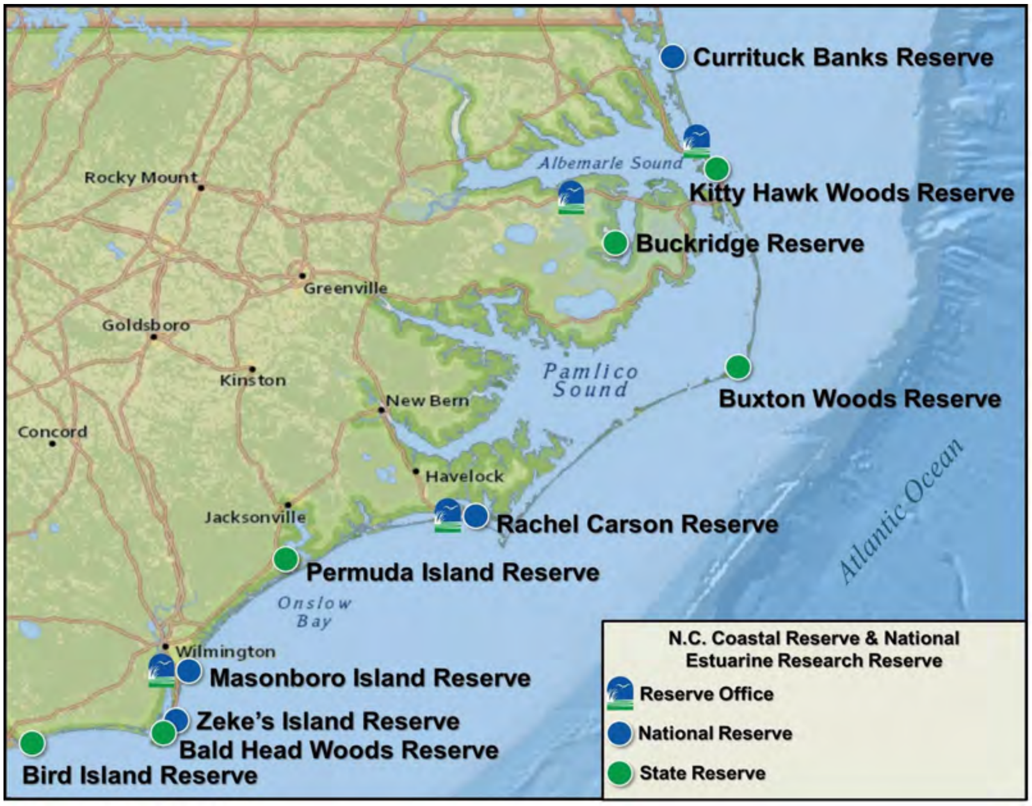

Figure 5C-2: Map of the North Carolina Coastal Reserve and National Estuarine Research Reserve Sites

Division of Marine Fisheries

Impact Summary

Climate change impacts such as salinity changes and saltwater intrusion from breached inlets and sea level rise, increasing water temperatures, shifts in currents and tides, and decreased water quality from increased storm runoff will have effects on all of North Carolina's coastal habitats and the marine organisms that call them home. As the distributions of coastal habitats changes, so will the distribution and abundance of the economically important fisheries species and the availability of the food they need to thrive. Climate adaptation for fisheries will involve continued adjustment of fishing regulations to maintain sustainable stock levels and acquiring the needed supporting science. Management based on changes in recruitment, growth, survival, and reproductive success can be done under the existing regulatory framework of the Fisheries Reform Act (FRA) by incorporating climate change science, more adaptive management actions, and ecosystem based management in the Fishery Management Plans (FMPs) and Coastal Habitat Protection Plan (CHPP) processes. Infrastructure supporting research-based management of fisheries and coastal habitats and the ability to enforce regulations will also be affected by climate change and will need to be addressed to ensure the continuity of the DMF mission statement (Table 5C-3).

Table 5C-3: Division of Marine Fisheries Exposure Table

Assets, Regulations, Services	Extreme Heat	Flooding (River and Land)	Water Shortage (Drought)	Changed Seasons	Inundation due to SLR	Saltwater Intrusion	Storm Surge	Tidal Flooding	Wildfire	Dam Failure	Invasive Species & Species Range Shifts	Wind
North Carolina Division of Marine Fisheries												
Fisheries Research	*	*	*	*	*	*	*	*			*	*
Division Infrastructure		*			*		*	*	*			*
Research Programs	*	*	*	*	*	*	*	*		*	*	*
Research Infrastructure		*			*		*	*	*			*
Fisheries Management	*	*	*	*	*	*	*	*		*	*	*
Fisheries Infrastructure (Commercial & Recreational)	*	*			*		*	*	*			*
Coastal Habitat Protection	*	*	*	*	*	*	*	*	*	*	*	*
Outreach Programs	*	*		*	*		*	*	*		*	*
Shellfish Sanitation	*	*			*			*				
Recreational Water Quality	*	*						*				

Vulnerability and Risk

Climate change increases the variability of ecosystem factors and will affect all coastal habitats and species in North Carolina. As climate change and related impacts continue, North Carolina will see warming water temperatures, rising sea level, and more intense tropical storms, which affect hydrodynamic flows as well as nutrient and carbon loading to North Carolina's coastal rivers, sounds, and ocean waters (Fig. 5C-3). Climate change may cause a regime shift in tropical cyclone flooding and associated ecosystem impacts. North Carolina has experienced very high precipitation rates since the late 1990s, with increasingly high precipitation associated with tropical cyclones, which could have major ramifications for hydrology, carbon, nutrients, habitat and water quality in North Carolina[6]. If we are seeing a regime shift in storms and rising temperatures, we can also expect to see species distribution shifts within North Carolina's coastal habitats. Changes to environmental variables such as salinity will also have impacts to both coastal habitats and the important species utilizing them.

The effects of the climate change-driven shift in distribution of coastal habitats will affect the aquatic organisms of the coast of North Carolina that use these important coastal habitats as nursery areas, refuge from predation, and for food supply. The changes in distribution of coastal habitats could indirectly affect fish populations due to limited habitat and food availability. Wetland loss to sea level rise and continued development will outpace the rate of wetland migration inland in many areas. In developed coastal waterfront areas, many wetlands cannot migrate landward due to hardening by vertical stabilization, topographic alteration, or structure obstruction. Loss of wetlands will result in habitat losses that will impact fisheries and degraded water quality due to the decreased in stormwater buffering capacity. Experts indicate the potential for increased Harmful Algal Bloom (HAB) occurrence is possible due to increased nutrient loading in the water and increasing water temperature attributed to changing climate.[7] Certain species of algae contain toxins that can be taken up by shellfish and cause health issues if consumed by humans. HABs can also harm humans and pets if exposed to contaminated waters.

[6] Paerl, H. W., Hall, N., Otten, T. G., Rossignol, K. L., Kudela, R. M., & Xu, H. (2019, December). Combating Global Proliferation of Harmful Algal Blooms Along River to Sea Continuum in the Face of Nutrient Over-Enrichment and Climate Change. In *AGU Fall Meeting 2019*. AGU

[7] Paerl, H. W., Hall, N., Otten, T. G., Rossignol, K. L., Kudela, R. M., & Xu, H. (2019, December). Combating Global Proliferation of Harmful Algal Blooms Along River to Sea Continuum in the Face of Nutrient Over-Enrichment and Climate Change. In *AGU Fall Meeting 2019*. AGU.

Figure 5C-3: Satellite images of river outflows to the Atlantic Ocean in the wake of Hurricane Florence show water discolored by organic matter including debris and pollutants. (Image credit: NASA)

Submerged aquatic vegetation (SAV), also known as seagrass or underwater grass, is a critical habitat to many important fishery species and serves as an ideal indicator for water quality and climate changes because its distribution is highly responsive to changes in salinity, water temperature, and water clarity. The expected changes to water conditions due to climate change are likely to result in reduced abundance of SAV. Eelgrass (*Zostera marina*) occurs at the southern limit of its distribution on the east coast and is the dominant seagrass species in North Carolina. Heat stress in the shallow waters is expected to cause a decline in that species in particular.

Shell bottom, which includes oysters, clams, and scallops, serves as both a fishery resource and an essential coastal habitat and will also be directly affected by climate change. Increased precipitation will increase the amount of polluted runoff entering the estuaries, resulting in more shellfish growing area closures and recreational swimming advisories issued by DMF. As sea level continues to rise, intertidal oysters will be inundated and have to adapt to the subtidal environment. The acidification of ocean waters, a consequence of excess carbon dioxide in the atmosphere, will also cause oysters and other shelled organisms like clams and mussels to be unable to grow their shells. The loss of shell bottom habitat will not only affect the fishery, but the marine organisms that rely on them for habitat.

Runoff containing excess nutrients can lead to hypoxic (low oxygen) conditions, resulting in mass mortality of oysters and fish. Additionally, increased water temperatures could result in more occurrences of illness from shellfish consumption, which is a significant public health issue and can also disrupt shellfish markets.

In addition to shifts in coastal habitat availability and species distribution, economic impacts and regulatory issues will need to be addressed. The predicted changes in temperatures, salinity, and ocean currents will also have a direct impact on the fish population of the North Carolina's coast. In recent years, it has been predicted that hundreds of fish and invertebrate species will be forced to move northward by climate change[8]. The range of valuable fisheries species in North Carolina, including black sea bass (*Centropristis striata*) and summer flounder (*Paralichthys dentatus*), have already been seen shifting northward while other species such as white shrimp (*Litopenaeus setiferus)* are shifting farther north or having greater biomass following warm winters[9]. Other species, such as spot *(Leiostomus xanthurus*) are shifting their migration route to occur further offshore or deeper in the water column, affecting catchability.[10] Environmental changes are affecting how species use certain estuaries and habitat types, such as bull sharks (*Carcharhinus leucas*) using North Carolina's estuary as a nursery area when in the past adult sharks only used the area as a place to feed[11].

It has also been noted that climate change may increase habitat suitability allowing some fish species, such as spotted seatrout, to expand their range. However, under the same climate change scenarios, their prey species show significant decreases which could result in a food-limited population.[9] North Carolina already exhibits one of the greatest northward shifts in commercial fishing effort, with average vessel landings occurring 24km further north each year.[10] As fish move north, the commercial fishermen follow, resulting in North Carolina fishermen landing more fish in North Carolina ports that were caught outside of state waters. This can cause confounding regulatory issues when trying to determine the new or expanded ranges and distributions of the fish species. The management of commercially and recreationally important finfish and shellfish species is vital to ensuring the sustainability of these species.

Infrastructure supporting research-based management of fisheries and coastal habitats and the ability to enforce regulations will also be affected by climate change and will need to be addressed to ensure the continuity of the DMF mission statement (Table 5C-3). This is especially important considering that several regional and field offices providing critical functions, personnel, and equipment for shellfish sanitation, marine patrol, and fisheries management have already been damaged or destroyed during hurricane Florence (2018). These damages caused major disruptions in work and displacement of staff (Figure 5C-4).

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[8] Morley, J. W., Selden, R. L., Latour, R. J., Frölicher, T. L., Seagraves, R. J., & Pinsky, M. L. (2018). Projecting shifts in thermal habitat for 686 species on the North American continental shelf. *PloS one*, *13*(5).

[9] Morley JW, Batt RD, Pinsky ML. Marine assemblages respond rapidly to winter climate variability. Glob Chan Bio. 2017; 23:2590–2601.

[10] South Atlantic Fishery Management Council. 2018. SAFMC Fishery Ecosystem Plan II Implementation Plan.

[11]Bangley, Charles & Paramore, Lee & Shiffman, David & Rulifson, Roger. (2018). Increased Abundance and Nursery Habitat Use of the Bull Shark (Carcharhinus leucas) in Response to a Changing Environment in a Warm-Temperate Estuary. Scientific Reports. 8. 10.1038/s41598-018-24510-z.

[9] Kearney, K. A., Butler, M., Glazer, R., Kelble, C. R., Serafy, J. E., & Stabenau, E. (2015). Quantifying Florida Bay habitat suitability for fishes and invertebrates under climate change scenarios. *Environmental management*, *55*(4), 836-856.

[10] Bradford A. Dubik, Elizabeth C. Clark, Talia Young, Sarah Bess Jones Zigler, Mikaela M. Provost, Malin L. Pinsky, and Kevin St. Martin. "Governing fisheries in the face of change: Social responses to long-term geographic shifts in a U.S. fishery." *Marine Policy*, Volume 99, Pages 243-251. 2019.

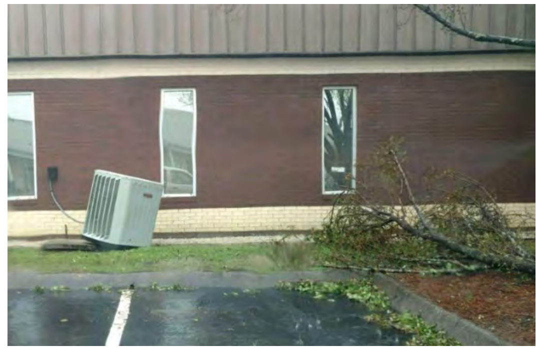

Figure 5C-4: Damage to sections of the Wilmington Regional Office where DMF is housed after Hurricane Florence 2018 disrupting work flow and causing displacement of staff for almost a year.

Resilience Strategies

Fisheries Management

Develop management based on changes in recruitment, growth, survival, and reproductive success. This can be done under the existing law by incorporating climate change science and more adaptive management actions in FMPs. Incorporate climate and environmental variables, when possible, into stock assessments and in rebuilding schedules with steps towards more ecosystem based management. Staff to review and incorporate, as applicable, the Atlantic States Marine Fisheries Commission (ASMFC) and federal fishery management councils developed stock assessments terms of reference for climate change into DMF assessments and plans. Continue participating in interstate & federal management based on shifting species distributions while recognizing historical importance of communities.

Coastal Habitat Protection

The CHPP Plan should be used to better outline the effectiveness of the actions in sequestering carbon, improving resilience of coastal habitats through restoration and protection of coastal habitats, and improving resilience of coastal communities and ecosystems. In conjunction with the 2018-2020 action items for the CHPP goal of "Develop metrics on habitat trends," integrate determining associated trends in marine and estuarine fish abundance and habitat usage in efforts to move towards more ecosystem-based management.

Coastal Habitat Conversation and Restoration

Help facilitate coastal habitat restoration by assisting state, federal, and local governments with incorporating climate change considerations into their planning processes to increase resilience. Help build understanding of the benefits of protecting and restoring coastal habitats to help ensure stakeholders and the public are aware of the importance of these actions including resilient ecosystems and communities.

Map, Assess, and Monitor

The extent and condition of coastal habitats should be mapped to inform models and enable detection of change over time, and to provide the best available scientific information for formulating actionable conservation, protection, and restoration strategies. Continued regular monitoring and analysis should be ensured to assess change in distribution and composition and to address potential impacts to dependent fish species. For example, SAV mapping on a regular basis has been difficult due to no dedicated funding. Algal monitoring should also be expanded using sentinel sites especially in North Carolina's coastal waters where it would have the potential to affect shellfish and human health.

Natural and Nature-based Solutions

Nature-based solutions, such as living shorelines, have the potential to restore coastal ecosystems and increase resilience to natural disasters and should be used whenever possible. Common living shoreline designs combine restored salt marsh with a breakwater constructed of granite rocks or oyster shells, designed to protect landward vegetation and encourage oyster recruitment. One study showed that living shorelines exhibited better resistance to landward erosion during Hurricane Matthew than bulkheads and natural marshes.11 Additionally, living shorelines were more resilient than hardened shorelines, as they maintained landward elevation over the two-year study period without requiring any repair. Living shorelines can also enhance marsh grass stem density over time when compared to natural marshes. Living shorelines have been shown to enhance services such as wave dampening, carbon sequestration, and nursery provision for juvenile fish.

Infrastructure

Funding is needed to invest in resilient planning and infrastructure maintenance and upgrades to ensure the continuity of the DMF mission statement. In the event of the loss of offices and/or equipment, contingency plans should be made for all sections within the division with a priority focus on the Shellfish Sanitation section and Marine Patrol because of their role in human health, public safety, and regulatory enforcement.

Climate Change Integration

DMF staff should review existing guidelines and strategic plans to develop and integrate climate change adaptation and resiliency strategies within these documents, and continue to monitor rule making authority (i.e., state, councils, federal government, ASMFC) for species of fish that may become more abundant in our waters as the ocean continues to get warmer. North Carolina's marine fishery resources are economically and socially important to many of the state's residents, visitors, and coastal communities requiring the state to acknowledge the impacts of climate change through management strategies to allow flexibility as fishery resources change.

Regulations and Policies

Recognizing the importance of protecting fish and their habitats, the N.C. legislature passed the Fishery Reform Act in 1997 (FRA), that required Fishery Management Plans (FMPs) and a Coastal Habitat Protection Plan (CHPP) be developed:

FMPs

- General authority for stewardship of the marine and estuarine resources by the DEQ is provided in G.S. 113-181.
- The DMF is the branch of the DEQ that carries out this responsibility.
- The Marine Fisheries Commission (MFC) was created to "manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the state of North Carolina including aquaculture facilities which cultivate or rear marine and estuarine resources" (G.S. 113-132

[11] Smith, C. Puckett, B., Gittman, R., and Peterson, C. (2018*). Living Shorelines enhanced the resilience of saltmarshes to Hurricane Matthew (2016)*. Ecological Applications, 8 (4), 871-877.

and 143B-289.51). The MFC can regulate harvest times, areas, gear, seasons, size limits, and quantities of shellfish harvested and possessed (G.S. 113-182 and 143B-289.52). General Statute 143B-289.52 allows the MFC to delegate authority to implement its regulations for fisheries "which may be affected by variable conditions" to the Director of DMF by issuing public notices called "proclamations".

- DEQ is the agency directed by North Carolina General Statute 113-182.1 to prepare FMPs for all commercially or recreationally significant species or fisheries that comprise state marine or estuarine resources.
- These plans must be approved and adopted by the North Carolina Marine Fisheries Commission (MFC). Many different state laws (General Statutes - G.S.) provide the necessary authority for fishery management in North Carolina.
- Marine Patrol under G.S. 113-136 is granted, as inspectors, the powers of peace officers anywhere in this state, and beyond its boundaries to the extent provided by law, in enforcing all matters within their respective subject-matter jurisdiction being wildlife and fisheries management.

CHPP

- G.S. 143B-279.8 requires that a CHPP be drafted by the DEQ, and reviewed every five years. The purpose of the plan is to recommend actions to protect and restore habitats critical to the enhancement of North Carolina's coastal fisheries. The Marine Fisheries, Coastal Resources, and Environmental Management commissions are required to approve the plan recommendations. DMF is the lead in administering the CHPP.
- The Shellfish Sanitation Program is conducted in accordance to guidelines set by the Interstate Shellfish Sanitation Conference and contained in the National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish Model Ordinance. The NSSP is administered by the Food and Drug Administration (FDA).
- The guidance for the Recreational Water Quality Program is set by the Beaches Environmental Assessment and Coastal Health (BEACH) Act, which is administered by the EPA.

Albemarle-Pamlico National Estuary Partnership

Impact Summary

APNEP works to protect and restore the coastal resources described elsewhere in this chapter, and other sectors including ecosystems and water resources, with a focus on estuarine ecosystems and the river basins and surrounding watersheds that flow into the Albemarle-Pamlico estuarine system. The impacts

to these resources have been thoroughly described elsewhere in this report. APNEP recognizes that the changing climate will have an impact on its partners and programs and existing and pending projects.

Vulnerability and Risk

In 2019 staff conducted an initial assessment of climate change impacts to implementation to the 2012 – 2022 CCMP. The exercise resulting in a ranking of none or minimal impacts to each of the CCMP implementation actions themselves. The greatest initial threats arise from impacts that directly affect APNEP partners and their infrastructure or ability to function. If the partners have reduced capabilities the partnership is equally impacted.

Additionally, changes in estuarine habitat may have impacts on APNEP priorities and abilities to implement the CCMP. These potential changes are mainly addressed by DMF in examples presented elsewhere in this chapter.

Resilience Strategies

APNEP will continue to work with partners to implement the actions identified in the CCMP and CHPP described above. The partnership will begin updating the CCMP in 2021 and will consider actions identified in this report and through the Natural and Working Lands stakeholder process as it develops future priorities and focus areas.

Staff have joined the DCM and the Reserve in a cross-agency effort to co-lead a Coastal Resilience Community of Practice. The workgroup consists of diverse coastal stakeholders including agency representatives, local governments, and non-profit organizations who have agreed to focus on how ecosystem resiliency can help build local community resilience.
APNEP pursues its mission with guidance and support from its overarching Comprehensive Conservation and Management Plan (CCMP), the Management Conference (advisory groups), and regional partners. APNEP was among the first of 28 National Estuary Programs established by the Clean Water Act in the late 1980's.

APNEP's staff works closely with diverse stakeholder committees whose members include citizens, local business leaders, environmental organizations, and local, state, and federal agencies. APNEP engages citizens and organizations through its committees to ensure a coordinated approach to managing the Albemarle-Pamlico estuarine system. By facilitating communication and collaboration among different organizations throughout the region, APNEP seeks to leverage its resources and those of its partners to accomplish more together than any individual organization could alone.
APNEP staff is advised by a Management Conferences authorized by N.C. Governor's Executive Order #26 (2017), The APNEP's guiding plan is its 2012-2022 Comprehensive Conservation and Management Plan[12] (CCMP), which was created in a stakeholder-driven process with an ecosystem-based management approach.

In conjunction with its partner organizations, APNEP has a long history of working closely with coastal communities as they face climate and natural hazard challenges. In addition to supporting research and the development of tools and models to help resource managers and local governments make informed decisions, APNEP continues to dedicate resources towards connecting communities to the best available science and tools as they develop adaptation planning strategies. APNEP initiatives related to climate change, sea level rise, ecosystem and community resilience are aligned with the following 2012-2022 CCMP actions:

- Create and improve projections of land use and climate change related impacts on the regional ecosystem.
- Support research on adapting to impacts associated with climate change and sea level rise.
- Develop and implement a strategy to improve decision makers' understanding of coast and benefits of environmental protection, restoration, planning and monitoring.
- Provide assistance to state, regional, and local governments to incorporate climate change and seal level rise considerations into their planning processes.

[12] https://apnep.nc.gov/resources/publications-and-reports/ccmp

In addition, APNEP works closely with DMF, DCM and DWR on implementing the CHPP. While differences in scope, geography and mission exist, implementation of APNEP's CCMP and the CHPP are complimentary with regard to coastal habitat protection and restoration strategies. Submerged aquatic vegetation mapping and oyster reef research and restoration are two areas where APNEP has tackled issues that are critical to both the CCMP and the CHPP. APNEP's Coastal Habitats Coordinator works closely with the three commissions and their divisions within DEQ to ensure that both plans are implemented in a coordinated and integrated fashion.

The specific actions within the CCMP that also align with the CHPP and need and policies for adapting to changing climate and include the following:

- Assist local governments in the development of incentives for protecting natural shorelines.
- Reduce wastewater overflows and spills
- Facilitate the restoration of riparian and estuarine shorelines.
- Construct new oyster habitats.
- Facilitate research to improve oyster restoration technologies and methods.
- Mapping and monitoring SAV

4. Summary

North Carolina is one of the three U.S. states that experiences the most tropical storm activity[13]. Coastal communities throughout North Carolina have been dealing with the impacts of coastal storms and sea level rise over their entire history, but vulnerability and risk continue to increase with rising population and growth. Storms and sea level rise will certainly continue, and recent storm trends and flooding have been at historical levels of intensity. To advance towards the goal of climate resiliency, cabinet agencies must work together with our local, private, and academic partners.

Increasing climate resilience in coastal North Carolina requires working together to adapt to climate-related extreme events and long-term risks, by integrating resilience thinking and actions into our way of working and living. Increased resilience in a changing climate preserves economic, natural, and cultural resources; minimizes social disruption and displacement from extreme events; and lessens the need for disaster recovery spending.

State agencies must work to increase adaptive capacity at multiple scales—internally, among partners and sister agencies, and most importantly at the local government level. The goal of local government capacity building is to ensure that all coastal communities attain a minimum level of risk awareness, planning, preparedness, and recovery capability, and can make continuous improvements with state and federal support. Ultimately, climate resilience should become business as usual, fully integrated in normal operations, existing planning efforts, and investment decisions.

[13] https://www.aoml.noaa.gov/hrd/tcfaq/E19.html

Commerce & Business

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D. Commerce and Business

Key Observations

- The greatest impact of recent climate hazards was business interruption. Getting people back to work and transitioning to a more resilient economy are critical.

Critical Impacts and Resilience Strategies

- Supporting rural economies with education, training and additional resources.
- Public/private partnerships help leverage risk. Government can help build resilience into infrastructure, which helps lower risks for small businesses.
- Include resilience training in North Carolina Main Street and Rural Planning programs for small towns and Main Street communities along with the businesses they support.
- The business sector needs to drive continual improvement of resource optimization.

1. Introduction to Sector

The ***North Carolina Department of Commerce (NCDOC)*** connects businesses with the site locations, workforce and infrastructure they need to succeed in one of the nation's top states for business. NCDOC also connects local communities with the grants and funding they need to attract new business and ensure future prosperity.[1]

Taking a comprehensive approach to economic development, the Department's work reaches many areas. The Department helps people find jobs and employers find and retain a qualified workforce. The Department administers the state's employment security system, supporting workers during career transitions. The Department provides local communities with grants and planning services to spur infrastructure development and economic growth and administers the state's economic incentive programs.

NCDOC executive branch agency administers the state's economic incentives program and publishes data and reports for those interested in the state's economy. Marketing North Carolina as a business and visitor destination is handled by the Economic Development Partnership of North Carolina (EDPNC), a public-private organization established by the North Carolina General Assembly in 2014.[2]

All North Carolina businesses are affected by weather and climate, no matter where they are located or what economic sector they represent. A changing climate brings some downsides, but there are also opportunities for new business creation. The NCDOC recognizes that businesses rely on a strong working relationship with their communities. Resilience plans must be holistic to cover issues such as supply chains, reliable transportation corridors for their employees to get to work, and a reliable source of power to support their businesses. In turn, communities rely on their businesses to provide sustainable income and careers for their citizens and tax revenue to support local needs.

[1] North Carolina Department of Commerce: https://www.nccommerce.com/ Retrieved February 10, 2020.
[2] Economic Development Partnership of North Carolina: https://edpnc.com/ Retrieved February 10, 2020.

The NCDOC recognizes the importance of resilience because a resilient state economy can "bounce back" more quickly from hazards and have less business interruption. Therefore, this chapter focuses on what the state can do to support its business sector in becoming more resilient with a focus on the following options:

- Building resilience to support business continuity and operations
- Supporting rural economies with resilience training as they expand existing businesses and capitalize on new opportunities
- Establish Public/Private Partnerships (like the Wanchese Seafood Industrial Park) to provide state assistance for small industry

Overview of the North Carolina Economy[3]

North Carolina has the 9th largest state population and had a GDP of nearly $566 billion in 2018. The state's economy is slightly larger than that of Sweden.[4] Over the previous century, it transformed from an agricultural state with a manufacturing base in tobacco, textiles, and furniture to an advanced economy with strengths in finance, biotechnology, advanced manufacturing, and the knowledge economy more broadly. Throughout this transformation, the North Carolina economy has, in many ways, become more like the U.S. economy.

North Carolina has benefitted from Sunbelt migration over the past several decades, particularly during the 1990s and 2000s. This developed large metro areas in Charlotte, Raleigh, and the Piedmont Triad, as well as the smaller, but fast-growing metros of Asheville and Wilmington. This process added people from other parts of the U.S. as well as through international immigration.

Still, North Carolina has the second largest rural state population in the U.S. with 34% of the state's residents living in rural areas.[5] The rural population, however, has not benefitted to the same extent from the transformation of the state and its economy. Out-of-county commuting has increased in recent years. Only 14 out of 100 counties in the state had more than 50% of their workers living and working in the same county as of 2017, down from 47 counties in 2002.[6]

North Carolina's population faces certain larger structural challenges including a slowing population growth rate, an aging workforce, along with issues of inequality and regional disparities. Like the U.S., the state has become less homogenous. There are prosperous urban areas (characterized by knowledge-intensive service industries) and less prosperous rural areas which are reflective of manufacturing's legacies. North Carolina is also experiencing larger changes to the economy due to technological advancements, global trade and interdependence, and the slowing of economic growth, new firm formation and productivity.

Any disruption caused by a climate-related hazard of either a person's workplace or the transportation route connecting his home to his workplace has a direct impact on that person's ability to collect a paycheck. Therefore, the growing vulnerability of the *Transportation* sector has a direct bearing on the *Commercial and Business* sector. Business disruption in our urban centers also has a direct economic impact on our rural communities through this live-work-commute relationship.

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[3] North Carolina Department of Commerce, Labor and Economic Analysis Division, *North Carolina Annual Economic Report* (2019).
[4] U.S. Census Bureau, Bureau of Economic Analysis, International Monetary Fund (2018)
[5] U.S. Census Bureau, 2010 Census (2010).
[6] North Carolina Department of Commerce, Labor and Economic Analysis Division, Quarterly Census Employment and Wages (2018)

Assets and Service

The NCDOC has several divisions and resources that may be impacted by climate related events:

The ***Division of Employment Security*** (DES)[7] is responsible for the administration of the unemployment insurance program in the state. This program is a federal-state partnership, funded by federal and state unemployment taxes, which employers pay on the wages of their employees. Benefits are paid to eligible workers who lose their job through no fault of their own and are able, available, and actively seeking work.

The ***Division of Workforce Solutions*** (DWS) administers a statewide system of workforce programs that prepare North Carolinians for employment, providing services for adults, veterans, and youth jobseekers as well as helping employers find the qualified talent they need. DWS has 80 certified Career Centers across the state, coupled with other NCWorks access points, that cover 85 of the 100 Counties in North Carolina.

The ***NC Seafood Industrial Park Authority***[8] operates the two marine parks, the Wanchese Seafood Industrial Park and the Engelhard Marine Industrial Park. These parks provide opportunities to foster fishing and marine industries in the eastern part of the state. These venues support marine industries such as seafood processing, boat building and fishing supplies.

The ***Rural Economic Development Division*** houses the Community Development Block Grant (CDBG) program, the Rural Grants program, the North Carolina Main Street program[9] the Rural Planning Center, and the Appalachian Regional Commission (ARC) Office. This division provides training, grants and other services for rural communities across the state.

The ***CDGB program*** administers federally funded grant programs such as building reuse grants, demolition grants, and community housing grants. Projects including CDBG grants from the division are located throughout the state (Figure 5D-1). CDBG[10] team, part of our Rural Economic Development Division, administers several federally-funded grant programs:

- A Building Reuse program, using CDBG-Economic Development funds
- Public Infrastructure grants, also from CDBG-Economic Development funds
- Demolition grants
- Community Housing Grants

The Rural Grant Programs[11] team, part of our ***Rural Economic Development Division***, administers several state-funded grant programs:

- The state Rural Building Reuse program

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[7] North Carolina Department of Commerce Division of Employment Security: https://des.nc.gov/des, Retrieved February 10, 2020.
[8] North Carolina Department of Commerce Seafood Industrial Park Authority: https://www.nccommerce.com/about-us/boards-commissions/nc-seafood-industrial-park-authority#perquimans-marine-industrial-park Retrieved February 10, 2020.
[9] North Carolina Department of Commerce Rural Economic Development Division: https://www.nccommerce.com/about-us/divisions-programs/rural-economic-development-division, Retrieved February 10, 2020.
[10] North Carolina Department of Commerce Community Development Block Grants https://www.nccommerce.com/about-us/divisions-programs/rural-economic-development/community-development-block-grants-cdbg Retrieved February 10, 2020.
[11] North Carolina Department of Commerce Rural Grant Programs: https://www.nccommerce.com/about-us/divisions-programs/rural-economic-development/rural-grant-programs Retrieved February 20, 2020.

- The state Public Infrastructure grants
- The state Demolition grants
- The special, legislatively directed grants to local governments for downtown revitalization and economic development from 2017, 2018 and 2019
- 2016 Disaster Recovery funds
- The Rural Housing Recovery Infrastructure Program

The ***NC Main Street & Rural Planning Center***[12] works in regions, counties, cities, towns, downtown districts, and in designated North Carolina Main Street communities, to inspire placemaking. The center works to build asset-based economic development strategies that achieve measurable results such as investment, business growth, and jobs. The staff provide program services such as economic development strategic planning, technical services and training.

NC Main Street program is a national program to develop vibrant downtowns through historic preservation, economic development, promotion and design. There are 88 Main Street Communities across the state

The ***Rural Planning Center*** has offices located throughout the state in each of the state's Prosperity Zones. These offices are in Asheville, Albemarle, Fayetteville, Greenville, Jacksonville, Lexington, North Wilkesboro, Sylva, and Wilson.

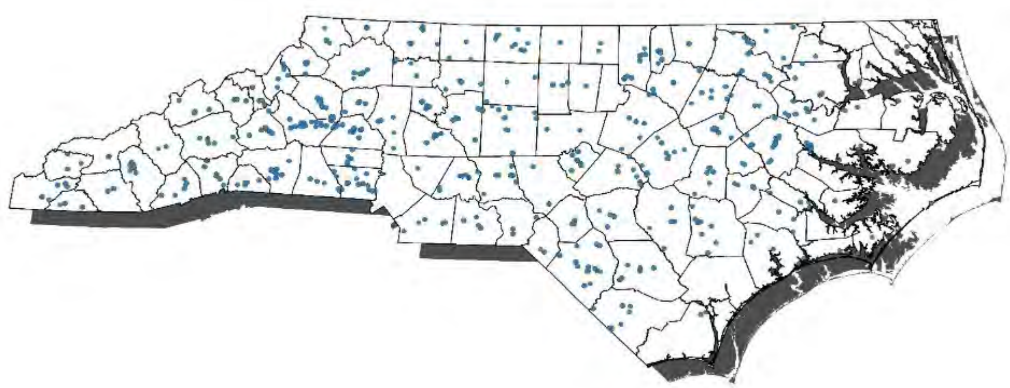

Figure 5D-1: Projects and assistance provided by the Rural Economic Development Division.

[12] North Carolina Department of Commerce Main Street and Rural Planning Center: https://www.nccommerce.com/about-us/divisions-programs/rural-economic-development/nc-main-street-rural-planning-center Retrieved February 20, 2020.

Figure 5D-2: The North Carolina Main Street and Rural Planning Center's Prosperity Zones.

The **Appalachian Regional Commission** (ARC)[13] is a unique federal-state partnership that provides social and economic support for a 13-state region stretching along the Appalachian Mountains from southern New York to northern Mississippi. Established by the United States Congress in 1965, when Appalachia was considered "a region apart" from the rest of the nation, ARC has worked to bring Appalachia's 22 million people into America's mainstream economy.

ARC supports economic development activities in 29 North Carolina counties: Alexander, Alleghany, Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Davie, Forsyth, Graham, Haywood, Henderson, Jackson, Macon, Madison, McDowell, Mitchell, Polk, Rutherford, Stokes, Surry, Swain, Transylvania, Watauga, Wilkes, Yadkin, and Yancey counties.

2. Overall Exposure

Climate Stressors

Climate stressors for the NCDOC will vary according to location (Table 5D-1). Each program will face different exposure to climate-related impacts.

DWS Career Centers, staff, and customers are vulnerable to a wide variety of climate change related disasters due to the geographic diversity of our state. For this reason, DWS operates a mobile unit capable of responding during disaster-related events. The mobile unit can assist first responders and provide humanitarian assistance, as well as temporarily assist those NCWorks Career Centers damaged by a natural disaster until more permanent locations have been secured. The mobile unit can also be used as a command center if DWS' central office is damaged by a natural/manmade disaster. Finally, the mobile unit allows DWS to work closely with the Division of Employment Security to expedite the processing of unemployment insurance claims for jobseekers impacted by natural disasters.

[13] North Carolina Department of Commerce Appalachian Regional Commission: https://www.nccommerce.com/about-us/divisions-programs/rural-economic-development/appalachian-regional-commission Retrieved February 20, 2020.

The Division of Employment Security (DES) faces ***flooding*** and ***extratropical storms*** as climate stressors and hazards. The current location of DES limits the vulnerability of climate related events. However, with increased climate stressors and the associated weather impacts, there is increased potential for inland hurricanes and damaging events such as tornadoes. The current disaster recovery plan for operations is a key step in resiliency for conducting these operations and ensuring unemployment benefits are not interrupted.

The NC Seafood Industrial Park Authority[14] operates the two marine parks, the Wanchese Seafood Industrial Park and the Engelhard Marine Industrial Park. These parks provide opportunities to foster fishing and marine industries in the eastern part of the state. These venues support marine industries such as seafood processing, boat building and fishing supplies.

For the seafood industrial parks, ***storm surge***, ***extratropical storms***, ***tidal flooding*** and ***sea level rise*** are important climate stressors and hazards. There are no known non-climate stressors for this physical asset. Impacts on this asset are:

- threat of storm surge and damage to real property and structures;
- interruption of financial processing, food processing, seafood distribution;
- loss of wages in the industrial park; and
- indirect costs losses

The climate stressors and hazards for Main Street communities would range from ***mudslides*** to ***flooding*** to ***storm surge***. The NC Main Street Program has low risks to disaster due to the location of state staff. Most can work remotely if needed in the event of a disruption of operations at the NCDOC. The NC Main Street Program can potentially assist communities to plan for disaster if funding and training are provided to the state staff.

The eight Rural Planning Center economic development planners are located across the state within the Prosperity Zones. The climate stressor and hazards in the communities served by Rural Planning are reflective of geographic vulnerabilities of that community and include ***landslides***, ***extratropical storms*** and ***flooding***. The biggest impact to these assets involves planners unable to travel due to hazards or threats from flooding and extratropical storms.

[14] North Carolina Department of Commerce Seafood Industrial Park Authority: https://www.nccommerce.com/about-us/boards-commissions/nc-seafood-industrial-park-authority#perquimans-marine-industrial-park Retrieved February 10, 2020.

Table 5D-1: Exposure to climate-related hazards of Commerce and Business assets and services throughout the state.

Assets, Regulations, Services	Extreme Heat	Flooding (River and Land)	Water Shortage (Drought)	Changed Seasons	Landslides	Saltwater Intrusion	Storm Surge	Tidal Flooding	Wildfire	Dam Failure
Division of Employment Security		*								
NC Seafood Industrial Park Authority (Wanchese, Engelhard)		*				*	*	*		
Division of Workforce Solutions		*								
Prosperity Zones										
North Central Prosperity Zone		*								
Northeast Prosperity Zone						*	*	*		
Northwest Prosperity Zone					*					
Piedmont Triad Prosperity Zone		*								
Sandhills Prosperity Zone		*	*							
Southeast Prosperity Zone		*				*	*	*		
Southwest Prosperity Zone					*					
Western Prosperity Zone					*				*	
Regional Planning Offices										
Southeast Regional Planning Office						*	*	*		
Western Regional Planning Office					*				*	
Rural Economic Development Division										
NC Community Development Block Grant Program (CDBG)	*	*	*	*	*	*	*	*	*	*
NC Main Street Program	*	*	*	*	*	*	*	*	*	*
NC Commerce Incentives and Grants	*	*	*	*	*	*	*	*	*	*
Appalachian Regional Commission		*							*	*

3. Examples of Impacts, Vulnerability, and Risk

Wanchese Seafood Industrial Park / Coastal Storms and Sea Level Rise

Impact Summary

The Wanchese Industrial Park is located in the unincorporated fishing village of Wanchese along the Roanoke Sound. The park has been affected by sea level rise and flooding. Extratropical storms also impact the site. The NC Seafood Industrial Park Authority, an eleven-member state board whose members come from counties in the region, operates three marine parks: the Wanchese Seafood Industrial Park, the Engelhard Marine Industrial Park, and the Perquimans Marine Industrial Park.

Wanchese Park is home to numerous marine businesses, including boat building, commercial fishing, marina, and supply chain operations. During hurricanes and other extratropical storms, storm surge leads to damage to property and structures. Additional impacts include interruption of financial processing, food processing, loss of wages in the Industrial Park, seafood distribution, and indirect costs losses.

Vulnerability and Risk

The park is vulnerable to sea level rise and flooding along with extratropical storm impacts due to its location on Roanoke Island. The building and its infrastructure are at risk to damage for wind and storm surge and inundation. The industries located in the park are at risk to damage from water and wind which will affect output and income would be lost if the facilities were damaged or destroyed.

The park is highly vulnerable to sea level rise and flooding associated with extratropical storms. The infrastructure is at risk to damage for wind, water and salt. Properties on Roanoke Island are the most vulnerable because they support a large amount of local business and the buildings are in an area exposed to coastal flooding.

Because the park was established in 1981, the design guidelines for the buildings did not require a base flood elevation building standard. Also, the road that serves as access to the Park does not have adaptive capacity integrated into its design. In 2015, the Wanchese Seafood Industrial Park had an annual economic impact to North Carolina of $105 million. This equates to a daily impact of $350,000[15]. That means that business interruption of even just three days has a $1 million consequence.

The industries located in the park would also be at risk to damage from water and wind, which would affect output and income would be lost if the facilities were damaged or destroyed. Risk is increasing due to increased chance (probability) of extreme storms causing damage to the park and limiting access.

Resilience Strategies

For the Wanchese Seafood Industrial Park, the facility has a hazard mitigation plan for severe weather for the physical site. Industries located in the park should have a business continuity plan that can deal with hurricanes, flooding and damages from other weather events. NCDOC can provide education/training for the industries in the Park about the increasing climate-related risk of flooding and related business interruption. Building resilience usually looks at three main categories - reducing exposure, building

[15] North Carolina Department of Commerce Seafood Industrial Park Authority: https://www.nccommerce.com/about-us/boards-commissions/nc-seafood-industrial-park-authority#perquimans-marine-industrial-park Retrieved February 10, 2020.

adaptive capacity, or supporting more response and recovery. Because this is a seafood industry park, it cannot be moved to reduce exposure. Economic incentives should be considered for either building adaptive capacity or supporting faster recovery.

4. Summary

Impacts of climate change have already been felt in the economic development and rural development sector through increased incidents of flooding and heavy precipitation, often associated with more severe hurricanes. Communities have already experienced damage to facilities, loss of records, financial expense, and damage to area infrastructure. Some of these procedures and rules may need updating to adapt to the realities of climate change driven impacts, such as repeated flooding. Development of adaptive capacity, where possible, will need to continue in coordination with all stakeholders to realize meaningful results.

As part of the NC Office of Recovery and Resiliency's Recovery Support Team, the Business Recovery Collaborative in a collection of partner agencies that have developed a process to deliver experienced business counseling resources to businesses impacted by a disaster in order to provide them with crucial information and resources.

The members of the Collaborative include the EDPNC, the NC Community Colleges' Small Business Center Network, the NC Department of Commerce, the NC Rural Center, the NC Small Business and Technology Development Center and the U.S. Small Business Administration.

A resilient state economy can "bounce back" more quickly from hazards and have less business interruption by identifying climate related impacts and reduce disruption to economic development in North Carolina. Although county and city jurisdictions are not in the hierarchy of Commerce Operations, the Rural Economic Development Division works directly with these communities. The NCDOC will continue to work to enhance climate resiliency efforts and identify resources to assist communities with climate resiliency planning.

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Cultural Resources

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E. Cultural Resources

Key Observations

- Cultural resources such as state and local historic sites and museums are irreplaceable, making them inherently sensitive to sea level rise and the increasing frequency and severity of heavy precipitation and flooding.
- The North Carolina Department of Natural and Cultural Resources (DNCR) is active across all 100 counties, so resources are limited. The threat of the hazard is growing.
- DNCR has regulatory authority over destruction of any public records managed on a local level.
- Much of the technical and constituent services for cultural assets are provided in a collaborative environment with federal, state, local, and private interests all having a stake in the solutions.

Critical Impacts and Resilience Strategies

- There is no single solution to protect cultural assets from “water where it doesn't belong”.
- The focus for now, and in the near-term, should be building resilience into assets owned and managed by the state, such as state museums, historic sites and parks.
- DNCR must provide greater services such as technical assistance to locally-owned cultural resources
- Develop and enhance federal, state, local, and private partnerships to build cross-boundary resiliency capacity for cultural assets.

1. Introduction to Sector

The rich and diverse cultural heritage of North Carolina is promoted, preserved, and enhanced through the efforts of the History and Arts units of the North Carolina Department of Natural and Cultural Resources (NCDNCR). Under state law, the department’s duty in this regard is:

“to provide the necessary management, development of policy and establishment and enforcement of standards for the furtherance of resources, services and programs involving the arts and the historical and cultural aspects of the lives of the citizens of North Carolina.”[1]

Many cultural resources exist within North Carolina, including music and the arts, archival records, museums with artifact collections, and historic and archaeological sites. North Carolina boasts many historic landscapes and structures, and historic districts within rural and urban settings, many of which, together with artifact and archival collections are in private ownership rather than under public stewardship. The History and Arts units of NCDNCR function under state and federal law to preserve and protect these resources and expand public awareness of the state’s cultural heritage through the direct management, operation, and/or support of these units, organizations, and facilities.[2]

[1] NC GS § 143B-50(1).

[2] Chapter 121 of the North Carolina General Statutes, including the North Carolina Archives and History Act, outlines much of the state statutory authority for these programs. Subsection 5 of Chapter 121 outlines the State Archives’ regulatory authority over the destruction of all public records. Article 2 of Chapter 143B likewise provides the legal authority for the department. The federal National Historic Preservation Act of 1966 is the underlying legal authority for the State Historic Preservation Office, and Chapter 70 (Indian Antiquities, Archaeological Resources and Unmarked Human Skeletal Remains Protections) and sections of Chapter 65 (Cemeteries) provide authority for archaeology and cemetery protection to the Office of State Archaeology.

NCDNCR recognizes the value and necessity of a prepared, climate-resilient North Carolina to sustain our efforts to directly manage state-owned cultural assets, as well as to provide constituent services for assets managed by local government and private entities. Climate-related hazards threaten the loss of irreplaceable cultural resources. Indeed, at risk is the continued survival and vitality of North Carolina's historic communities, sites and places, archival records, and artifacts – all of which serve to define our state's identity and to provide citizens with fundamental societal and economic stability.

Much of NCDNCR's mission rests in its **stewardship management role** for the direct management of historic properties, artifacts, and records and supporting facilities owned by the state of North Carolina on behalf of the people (Table 5E-1). Public accessibility and visitation drive many programs, and the irreplaceable nature of these assets makes their preservation paramount.

Table 5E-1. Public history and cultural resource units of the Department of Natural and Cultural Resources charged with direct management of or responsibility towards historical resources and cultural assets owned and managed by the state or constituents.

- The State Library
- The State Archives (including the Outer Banks History Center and the Western Regional Archives)
- 27 Historic Sites
- 7 History Museums
- The Historical Research Office (including the statewide Highway Historical Marker program in coordination with the NC Department of Transportation)
- The Office of State Archaeology
- The State Historic Preservation Office
- The Federation of North Carolina of Historical Societies
- The North Carolina Symphony
- The North Carolina Arts Council
- The North Carolina Museum of Art
- Facilities and historic assets at State Parks (including visitors' centers and amenities, including National Register listed cabins)

In specific instances, such as the state archives' oversight of the destruction of public records, the agency plays a **hybrid stewardship management and regulatory role** by encouraging public records not under the direct management of the agency to be properly preserved while maintaining authority over the destruction of those records if they are damaged in a weather-related event.

The department acts as a **constituent service and regulatory agency** to fulfill its duty for "establishment and enforcement of standards for the furtherance of resources, services and programs" to aid the public *and* private sectors through direct outreach, technical consultation, and constituent-oriented programs to foster private and public stewardship of irreplaceable cultural resources including:

State Archives is the official state agency and constituent service office for the preservation of public records, regardless of format. It maintains and provides access to records of permanent value, both public records and collections from private donations. It operates state records center facilities for the benefit of state agencies. It also operates two regional archival facilities at the Outer Banks History Center in Manteo and the Western Regional Archives in Asheville. Services to custodians of public records include consultations with government offices on records management and the delivery of training on the protection of and access to public records. Records retention and disposition schedules developed in consultation with and approval of the records creators serve as the primary means of promulgating normal records disposition instructions.

State Historic Preservation Office is the official state agency and constituent service office for historic preservation and revitalization of residential and commercial districts and individual properties.

Office of State Archaeology provides protection of archaeological sites, data and site inventory, technical assistance to and educational outreach for constituent (including cemetery and burial issues), permanent curatorial responsibilities for publicly owned archaeological artifacts, and project review. It includes terrestrial, underwater, and curatorial branches.

Liaison to the Federation of North Carolina Historical Societies (FNCHS) is a coalition of historical societies, museums, historic sites, associations, and commissions dedicated to preserving and promoting history. This statewide network of history organizations collaborates to share ideas, develop skills, and serve as local and regional partners for NCDNCR's Office of Archives and History.

Cultural Resources Emergency Support Team (CREST) is an interdivisional group of more than twenty collections preservation experts who regularly lead sessions for departmental staff and partner organizations to share disaster planning guidance and other preparedness techniques. Since 2011, the team has deployed help post-disaster for museums and libraries to recover collections.

A 2010 departmental survey of cultural heritage institutions (museums, libraries, archives, and historic house museums) identified nearly 1,000 entities statewide. Many are small, privately funded, and rely on volunteers for regular operations. Most local museums function with budgets of less than $50,000 per year. Through the Cultural Resources Emergency Support Team and the liaison, NCDCNR provides technical assistance to these partner organizations to help collection stewards prepare for and recover from disasters.

At the heart of its critical technical assistance role, NCDNCR collaborates, cooperates, and guides local efforts to preserve and protect the state's cultural assets, but ultimately **many of the decisions that may protect – or threaten – cultural resources rest in the hands of non-state entities at the local level**, such as city and county governing boards, clerks of courts and county and city clerks as official local record keepers, and planning and zoning departments as well as private property owners.

2. Overall Exposure

Climate stressors and hazards of greatest concern to our agency include multi-faceted "water-where-it-doesn't-belong" threats, particularly those posed by tropical cyclones, more frequent and intense heavy precipitation and flooding events, and sea level rise. Water, whatever the source, can produce catastrophic risks to cultural assets of all types. Erosion, drought, landslides, wildfires and heat waves likewise present serious challenges.

Contributing to these climate stressors are a variety of non-climate stressors, including development, marine traffic and dredging, infrastructure considerations (including inadequacies and means of installation), topographical considerations, impermeable surfaces, inadequate staff capacity, deferred property maintenance, and communication infrastructure.

Cultural resources are exposed to a broad suite of climate-related hazards (Table 5E-2), but our sector is particularly concerned about assets located in the Coastal Plain as well as flood-prone areas throughout the state. These areas are subject to direct impacts from hurricanes, flooding, heavy precipitation, and sea level rise. The Office of State Archaeology estimates nearly 5,800 prehistoric and historic archaeological sites in the Coastal Plain of North Carolina lie within 30 feet of mean sea level.[3] Many of these sites are already subject to severe damage from shoreline erosion and land loss due to flooding and wave action.

Table 5E-2. Exposure of cultural resources throughout the state.

Assets, Regulations, and Services	Coastal Erosion	Flooding (River and Land)	Landslides	Inundation (includes SLR)	Severe Winter Weather	Storm Surge	Tidal Flooding	Water Shortage	Wildfire	Wind
Archival repositories, historic properties and museums		*		*		*			*	*
Archaeological resources	*	*		*		*		*	*	
Near-shoreline resources, e.g., historic wharves, shipwrecks, cemeteries and other sites	*	*		*		*	*			
State-owned or controlled lakes								*		
Regulation of destruction of all public records		*		*		*				*
Technical assistance to federal and state agencies	*	*		*		*	*			*
Technical assistance to local preservation commissions and records officials at municipal and county level	*	*	*	*		*	*			*
Training and technical assistance for disaster preparations and recovery of object and archival cultural heritage collections in museums and libraries		*		*	*	*				*

[3] North Carolina Interagency Leadership Team. (2012). *Climate Ready North Carolina: Building a Resilient Future*.

Sea-level rise (SLR) will likely increase the rate of site damage and loss from inundation, as well as from the enhanced energy from waves and coastal storms. In the future, changes in sea level rise will result in the complete loss of certain types of archaeological sites, such as Middle to Late Woodland prehistoric shell middens (circa 300 B.C. to A.D.1600) and associated habitation sites (a near extinction of certain site types). In addition, significant resources in areas like Roanoke Island (site of the famous Lost Colony) may be completely inundated. "Water where it doesn't belong" is among the gravest climate-related threats to cultural resources throughout North Carolina.

A chief factor that affects the degree to which exposed assets, people and services are impacted include the widespread dispersal of historic resources across all 100 counties of the state. For example, following Hurricane Florence (2018), 20% of North Carolina's National Register of Historic Places listings (est. 16,000 buildings) were located in the most-impacted zone in counties where both FEMA public and individual assistance was offered. There are over 50,000 documented archaeological sites throughout the state, and over 1,000 cultural heritage institutions besides the state's 27 state historic sites, 7 history museums, and 6 state archival facilities.

While some assets can be relocated because of their portability (such as key public documents or museum artifacts), the scale of an archival or artifact collection and need for special packing and transportation considerations may make moving it out of harm's way difficult, if not impossible, when time is short in the days before a hurricane, or with little warning, such as a flash flood or wildfire. For the historic built environment and archaeological sites, moving a threatened building or performing salvage excavations are expensive and may not be practically feasible.

3. Examples of Impacts, Vulnerability, and Risk

To emphasize the danger posed to cultural resources by "water where it doesn't belong", this section concentrates on the triple threats of flooding, heavy precipitation, and sea level rise to cultural resources. Vulnerabilities and risks as well as recommendations and options may consequently overlap.

Hurricanes and Flooding

Impact Summary

North Carolina has been impacted by nearly 400 hurricanes since 1851.[4] Tropical cyclones and the associated storm surge, high winds, prolonged precipitation, and flooding together threaten museums, archival records, historic districts and other state historic and archaeological sites. Storm impacts result in disruption to utilities needed for climate control for historic asset protection. Facility closure, financial expense, loss of historical integrity, loss of critical documentation, loss of future economic development potential (including heritage tourism), and loss of community identity and cohesion are all possible impacts of climate stressors.

State Historic Preservation Office damage assessments for historic properties from Hurricanes Irene, Matthew, and Florence demonstrate the destructive effect of flooding, fallen trees, and wind-driven rain to historic structures, cultural institutions, and cemeteries alike. Storm surge has brought about fast-paced erosion to maritime archaeological sites, like the artifact rich colonial wharves at Brunswick Town and Civil War earthwork forts, such as Fort Anderson and Fort Fisher; dredging and marine traffic in the Cape Fear contribute to this situation.

[4] North Carolina Climate Office. (2019.) *North Carolina Tropical Cyclone Statistics (1851 - 2019)*. Retrieved January 16, 2020 from https://climate.ncsu.edu/climate/hurricanes/statistics.

Flooding from hurricanes (and seasonal storms with heavy precipitation) will continue to damage archaeological and historic sites on floodplains and terraces across all three physiographic regions and within every river basin in the state. Many of these sites will be damaged by accelarated riverbank and floodplain erosion, sediment transportation, and sediment deposition. Transportation and deposition of archaeological and structural materials lead to erroneous interpretation of prehistory and history. Flooding inundates and potentially destroys cultural resources, such as the following:

- state-owned facilities and historic sites
- privately owned historic properties listed in the National Register of Historic Places
- local records centers (like city halls and county courthouses)
- local cultural institutions with artifact and archival collections (e.g., house museums and historical societies)
- downtown historic districts

Vulnerability and Risk

Cultural resources are irreplaceable, making them inherently sensitive to hurricane-associated flooding. “Stall out” hurricanes like Matthew and Florence exacted significant damage to historic sites, historic structures and archival records located not only along the coast but also inland, particularly in riverine or flood prone areas with days of prolonged, sustained heavy rainfall in concentrated areas. Hurricane Florence brought widespread damage and effects to historic resources with over 400 National Register-listed properties located in flood zones in the affected counties, and many flooded during Florence.

Hurricane precipitation can damage buildings in a variety of ways, particularly when high winds are present. At landfall, Hurricane Florence arrived with 115 mph winds and with a zone of tropical storm force winds nearly 400 miles wide, and a soaking rain of several days’ duration. Wind damage to historic structures included “peeled” roofs and broken windows that allowed water infiltration as well as sustained wind-driven rain that penetrated the interior of masonry walls (for example, the Pender County Courthouse, as well as residences in the Wilmington National Register Historic District) damaging ceilings, floors, plaster walls, and electrical and HVAC systems.[5] Additionally, heavy precipitation loosens tree roots; historic grave markers in National Register-listed cemeteries suffered damage from falling trees after Hurricane Florence (example, Trinity Cemetery near Chocowinity in Beaufort County).[6]

Flooding during Hurricanes Matthew and Florence also impacted areas where little to no flooding had happened in previous memory. Fair Bluff, North Carolina, with a historic downtown, was severely flooded by the Lumber River in both Matthew and Florence, and local businesses have largely not reopened and may be unlikely to do so. The town hall was also flooded, and was rebuilt with federal funds after Florence on slab in the same flood prone location next to the river. Jones County’s county seat of Trenton is largely a National Register Historic District and experienced “bathtub-like” flooding from the Trent River during Florence, damaging its courthouse. The Town of Pollocksville in Jones County experienced flooding in its town hall, rendering it so damaged that records swollen with water blocked doors and prevented town officials from entering rooms. These events are harbingers of more severe hurricane damage and the need to prepare. Flooding in New Bern from a combination of storm surge and river rise inundated National Register Historic Districts as well as the North Carolina History Center at

[5] WECT News. (June 14, 2019). “Inside the damaged Pender County Courthouse in Burgaw.” Retrieved January 17, 2020 from https://www.wect.com/2019/06/14/highway-inside-damaged-pender-county-courthouse-burgaw/; State Historic Preservation Office damage assessment reports from constituents.
[6] State Historic Preservation Office staff reports from constituent reports and site visits.

Tryon Palace, damaging exhibits and closing the facility to the public for a time. [7]

In Windsor, 17 inches of rain in 72 hours from the remnants of Tropical Storm Julia brought flooding to town, including the town-owned Craftsman and Farmer Museum, damaging its artifacts, and triggering a CREST deployment of artifact preservation specialists to aid in saving the artifacts from mold and debris damage. Hurricane Matthew came on the heels of this storm and flooded the same area once again within weeks.[8]

Although the coastal plain gets much attention from hurricane-related flooding, the mountains are not immune from flooding from weather events, and subject to their own vulnerabilities and risks. Flooding from non-tropical seasonal storms over the mountains caused the French Broad River to rise seven feet in 12 hours in late December 2018 in Marshall, the county seat of Madison County. Flooding occurred at Blannahassett Island, site of the National Register-listed former Madison County High School, now art studios and important to the town's burgeoning arts community. Spring rains repeated the scenario in April 2019, this time sending floodwaters into its downtown streets, part of its National Register Historic District, and threatening the courthouse.[9] Even Asheville itself is not immune, with the Biltmore Village historic district being flooded regularly, disrupting businesses in this nerve center of western North Carolina heritage tourism.[10]

Damage to state-owned facilities and historic resources can lead to extended public closures and costly repairs; risk is itself a function of probability and potential consequence. Hurricane Matthew brought flooding to the basement of the Archives/Library building causing damage to the archival record facility for the State Historic Preservation Office's architectural survey records, costly repairs to records storage rooms, and restricted public access to records for a number of months while records were relocated during repairs to facilities. A 2019-2020 repair and renovation project on this building seeks to improve drainage around the building perimeter to reduce incidents of water intrusion during heavy precipitation events and to improve the resilience of the facility for future events.

In the case of the Brunswick Town / Fort Anderson State Historic Site, roof damage from Hurricane Florence allowed water infiltration, and combined with a lack of electrical power and road access because of a road washout, mold erupted in the building, rendering it uninhabitable for months and endangering the artifacts housed there. We expect future hurricane-related damage to the electrical grid and transportation network to disrupt preservation and recovery efforts for cultural resources in the future.

Hurricanes accompanied by heavy precipitation also threaten the public records of all levels of government, posing significant risk to the agency's archival and records mission. The majority of public records of permanent value created on the local level remain in the office of creation. Heavy precipitation risks the preservation of these resources, particularly for smaller municipal offices with limited resources to protect records in the face of oncoming hurricanes. Prior to the arrival of Hurricane Isabel in 2003, the Hyde County Register of Deeds relocated records stored below the high-water mark from flooding experienced after Hurricane Floyd in 1999. While that protected a large quantity of records, flooding in the courthouse after Isabel exceeded the record mark set during Floyd, devastating public records in all

[7] "Two Hurricanes, Two Floods: North Carolina Town Fights to Stay Alive." (June 5, 2019.) *Circle of Blue.* Retrieved January 17, 2020 from https://www.circleofblue.org/2019/world/fairbluff/; North Carolina State Historic Preservation Office notes.
[8] Campbell, Colin. "Experts help save artifacts from flooded Windsor farming museum." (September 30, 2016). *Raleigh News Observer*. Retrieved January 17, 2020 from https://www.newsobserver.com/news/politics-government/article105274651.html.
[9] "Marshall Flooding." (December 28, 2018.) *Asheville Citizen-Times.* Retrieved January 17, 2020 from https://www.citizen-times.com/story/news/madison/2018/12/28/marshall-nc-flooding-threatened-french-broad-river-asheville/2436125002/; "Landslide collapses apartment building in Marshall as French Broad rises." (April 19, 2019). *Asheville Citizen-Times.* Retrieved January 17, 2020 from https://www.citizen-times.com/story/news/madison/2019/04/19/landslide-collapses-apartment-building-marshall/3526595002/.
[10] "Some Asheville streets reopen after flooding; swollen rivers have crested." (April 20, 2019.) *Asheville Citizen-Times*. Retrieved January 17, 2020 from https://www.citizen-times.com/story/news/local/2019/04/20/asheville-flooding-biltmore-village-streets-reopen-french-broad-swannanoa-river-crest/3528081002/.

offices of the building. Records from courthouses, municipal buildings, universities, libraries, and local medical providers have all been damaged in the last decade when hurricanes impact the state.

Non-climate stressors may become more acute in the future, particularly development pressures that bring more impermeable surfaces for parking. Adjacent jurisdictions with differing policy approaches and ordinances may bring about a fragmented, uncoordinated approach to land use rules and floodplain management. Limited funding for infrastructure solutions may exacerbate the situation. Regional topography will continue to be a consideration with anticipated upslope development in the mountains and interest in developing heretofore undeveloped land with wetlands in the Coastal Plain. Urban impacts may be more variable because of the higher population density, diversity of economic opportunity, and availability of local funding versus a depopulating rural North Carolina with fewer financial resources and less robust economic development.

Resilience Strategies

Staff capacity to deal with these issues is limited at all levels because of existing workloads and focused programs. Regional disasters, such as major flooding events, can quickly deplete the staff capacity of NCDNCR's Cultural Resources Emergency Response Team (CREST). Options to addressing climate-related threats to cultural resources are detailed below.

Constituent education

Broader constituent education for resiliency measures, such as restoration workshops on how to flood-proof or dry out buildings, CREST-led disaster planning training, and Register of Deeds training, would aid in better statewide preparation for flooding events. The Historic Preservation Office (HPO) has incorporated the NC Department of Public Safety's hazard mapping layers, especially for flood zones and flood prone areas, into its mapping enterprise HPOWEB for historic resources in the state, which can aid long-term planning capacity for local governments. Staff capacity and current funding are limitations.

Essential records protection program

The State Archives offers a program to back up essential minutes for local government offices. They also offer consultations and training on protection of all vital records. Staff capacity and current funding are limitations.

Building modifications

Building adaptations include elevating buildings, wet or dry flood-proofing, site and landscape adaptations, protection of utilities, filling basements, elevating on a new foundation or through the interior structure, abandoning the first story, or moving the building to a less vulnerable location. Building adaptations for government offices also serve to protect the essential records stored within. Grants and incentive programs should include criteria for these resiliency measures.

The Technical Preservation Services unit of the National Park Service has recently developed national flood adaptation guidelines to the elevations and other design solutions for historic buildings threatened by flooding. This document endeavors to balance design and floodplain management considerations with historic preservation.[11] Our agency will encourage local jurisdictions to incorporate these guidelines into local planning efforts and regulatory schemes as well as departmental capital projects; they likewise could be adopted by private constituents on a voluntary basis.

[11] National Park Service. (November 2019.) *Guidelines on Flood Adaptation for Rehabilitating Historic Buildings*. Retrieved January 17, 2020 from https://www.nps.gov/tps/standards/rehabilitation/flood-adaptation.htm.

Other states, namely Florida and Maryland, have developed state-specific disaster planning and hazard mitigation guides for historic resources, which recommend many of the options set forth in this section.[12] North Carolina should follow their lead.

Over the last years, multiple private property owners on Ocracoke Island preemptively elevated their historic buildings (often residences) with sensitivity to their historic nature, and consequently had reduced or no damage from flooding from Hurricane's Dorian heavy rain and storm surge. We note that many of these elevation projects were accomplished as projects using the federal and/or state rehabilitation tax credit program as administered by the National Park Service and/or State Historic Preservation Office. We would like to encourage more of this activity in flood prone areas.

Certified Local Governments

A federal designation for local jurisdictions with an active historic preservation program are eligible for 10% of the state's federal Historic Preservation Fund grant monies, and implementation of guidelines and adaptive strategies for resiliency could be fostered through this grant program.

Infrastructure approaches

Engineering solutions for flood control, such as levee systems, dams, and other stormwater drainage means exist. For example, Asheville is working with the U.S. Army Corps of Engineers to reduce Biltmore Village flooding by 2023 through a flood mitigation project.[13] Funds to undertake large scale infrastructure projects to control or reduce flooding are expensive and beyond the scope of our agency's independent capacity, and would have to be planned and funded in collaboration with a wide range of partners.

Strategic siting / relocations

Archival or artifact collections can be relocated from vulnerable locations or re-housed in more strategically selected sites, but the critical question of where is difficult because of storage, accessibility, and security requirements. Funding remains an issue.

- Archaeological sites need to be assessed and prioritized for potential salvage excavations in vulnerable locations.
- To reduce vulnerability for directly managed state assets, controlling agencies should consider strategic siting, such as farther inland or out of flood plains, and building adaptation, including potentially elevations.
- Threatened archaeological sites can be excavated and their artifacts salvaged, but their locations are not always known, and it may not be financially feasible to do so on a large scale. Cemetery relocation is likewise fraught with difficulty, including how and where to relocate remains legally; state law requires descendant notification. Historic building or historic district relocation

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[12] Division of Historical Resources, Florida Department of State, Division of Emergency Management, Florida Department of Community Affairs, & 1000 Friends of Florida. (2006.) *Disaster Planning for Florida's Historic Resources*. Retrieved January 31, 2020 from https://1000fof.org/wp-content/uploads/2019/08/disaster-planning.pdf; University of Florida Levin College of Law, Conservation Clinic. (June 2017.) *Protecting Florida's History from Hazards: A Guide to Integrating Cultural Resources into Disaster Planning.* Retrieved January 31, 2020 from https://www.law.ufl.edu/law/wp-content/uploads/2017/07/Protecting_Floridas_History_20July2017_1Sided.pdf; 1000 Friends of Florida, Florida Department of State, Division of Historical Resources, Florida Division of Emergency Management. (August 2008). *Disaster Mitigation for Historic Structures: Protection Strategies.* Retrieved January 31, 2020 from https://dos.myflorida.com/media/697182/fdem-disaster-mitigation-for-historic-structures.pdf. Preservation Design Partnership, LLC. (2018). *Flood Mitigation Guide: Maryland's Historic Buildings*. Retrieved January 31, 2020 from https://mht.maryland.gov/documents/PDF/plan/floodpaper/2018-06-30_MD%20Flood%20Mitigation%20Guide.pdf.

[13] WLOS. (April 22, 2019.) "New project could reduce flooding in Asheville." Retrieved January 17, 2020 from https://wlos.com/news/local/new-project-could-reduce-flooding-in-asheville.

is even more complex, because the site itself is important to the resource's historic significance and integrity. Moving structures is expensive, particularly when distance and utility relocation are factors for transit.

Heavy Precipitation

Impact Summary

Heavy precipitation can put a facility out of service and threaten the artifact or archival collection in turn. If the damage is severe enough, the facility may be destroyed, requiring a replacement for records storage or visitors' facilities. The situation is more acute if the resource is an irreplaceable archaeological site or historic building.

Changing climate will increase the frequency and intensity of storms and heavy precipitation events across the state. These include impacts from more intense rain, nor'easters, and associated tornados. These types of storms will pose major threats to cultural resources from wind and water damage to historic structures and districts, historic records and archives, museum collections, cemeteries, and archaeological sites. Two specific issues related to increased and more intense precipitation include erosion and flooding.

After the heavy precipitation of Hurricane Florence, State Historic Preservation Office staff noted large piles of debris from historic buildings in the multiple National Register Historic Districts in New Bern. Owners discarded historic materials, such as mantelpieces, flooring, and wainscoting because of water damage and fear of mold. However, through our staff's intervention and technical assistance with drying techniques, some of these elements were subsequently salvaged.

Inability to access damaged artifacts and documents in 24 to 36 hours following exposure dramatically increases the risk of damaging mold growth. More intense tropical storms that bring widespread flooding increase the likelihood of a delay in getting access to buildings with damaged cultural assets before mold damage.

Vulnerability and Risk

Heavy precipitation regularly causes street flooding near the Archives/Library building in Raleigh. Unable to keep up with the water capacity, storm drains back up water into the building loading dock which can cause subsequent water incursions into the Archives' sub-basement security vault. These water incursions threaten a collection of security microfilm stored in the vault.

Mold infiltration in flooded or otherwise compromised buildings multiplies the repair cost, and for some people, makes the building less attractive for continued occupancy because of the fear of mold-related health issues in the future, threatening the long-term preservation of the building.[14]

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[14] North Carolina Department of Health and Human Services. (September 21, 2018.) "Mold in Buildings Flooded by Hurricane Florence Presents Health Risks; Health Officials Encourage Precautions." Retrieved January 17, 2020 from https://www.ncdhhs.gov/news/press-releases/mold-buildings-flooded-hurricane-florence-presents-health-risks-health-officials; North Carolina State Historic Preservation Office staff reports based on site visits and constituent outreach; Wallace, Lewis Raven. (January 22, 2019.) "Lingering long after a storm, mold and mental health issues: North Carolinians are organizing against 'toxic resiliency,' focused on healing from trauma." *Environmental Health News*. Retrieved January 17, 2020 from https://www.ehn.org/lingering-long-after-a-storm-mold-and-mental-health-issues-2625546179.html?rebelltitem=2#rebelltitem2; New Hanover Regional Medical Center. (October 10, 2018.) "Mold: A Serious Threat after Hurricane Florence." Retrieved January 17, 2020 from https://www.nhrmc.org/blog/2018/10/mold.

Heavy precipitation from any source that infiltrates a building can foster mold growth. However, heavy rain during hurricanes is even more hazardous to cultural resources when it combines with high winds and loss of electrical power, because flooded buildings experience mold growth from standing water in interior spaces and further exposure to wind-driven rain from compromised roofs, windows, and masonry.

The Brunswick Town / Fort Anderson visitors' center remained closed for several months after Hurricane Florence because of mold remediation after rain collected inside the building through the hurricane-damaged roof, and a loss of electrical power and washout of the main road to the site exacerbated the situation without climate control and access to the building for an extended period. CREST deployed to aid the Public Schools of Robeson County Indian Education Program Museum at the National Register-listed Pembroke High School, and discovered mold damage to tribal artifacts after rain infiltrated its roof during Hurricane Florence.

Impermeable surfaces, such as parking lots, roads, and other modern development are exacerbated during periods of heavy precipitation. These surfaces have altered the natural water flow, exacerbating flooding and sending floodwaters in areas previously viewed as "high and dry." This non-climate stressor makes flooding potential for cultural resources more difficult to predict and therefore widens the scope of areas in need of adaptability or other resiliency solutions.

Non-climate stressors may become more acute in the future, particularly development-related increases in impermeable surfaces, fragmented policy and legal approaches taken by separate local jurisdictions in land use rules and floodplain management, and limited infrastructure funding.

Resilience Strategies

Options available to address heavy precipitation include not only expansion of the aforementioned constituent education statewide but also include the following:

Essential records protection program

The State Archives offers a program to back up essential minutes for local government offices. They also offer consultations and training on protection of all vital record. Staff capacity and current funding are limitations.

Disaster response program

The State Archives and CREST leadership consult with public and private custodians of cultural assets on the development of a robust disaster response plan, including comprehensive response contact information and action steps. A thorough plan also includes regular facility reviews and steps to increase protection of collections in situ. Staff capacity and current funding are limitations to expanding this option for increased adaptive capacity.

Building adaptation / strategic siting

In addition to the adaptations identified for flooding, more resilient roofs with redundant features, such as hurricane clips, are important. Regular roof maintenance is also key. Historic tax credits can be helpful to make these adaptations. To reduce vulnerability for directly managed state assets, controlling agencies should consider a combination of strategic siting and building adaptations.

Infrastructure approaches

In addition to the large-scale infrastructure solutions identified for flooding, installation of gas-powered generators for cultural institutions can provide continued climate control to help prevent mold growth.

Sea Level Rise

Impact Summary

Rising sea level does and will continue to pose a threat to numerous state historic sites, museums, and other cultural institutions within the Coastal Plain. North Carolina's low-lying Coastal Plain and barrier islands include many famous historic towns and villages. These sites draw thousands of visitors each year, generating significant economic benefit in that region. Many of these resources may be inundated or subject to increased coastal and shoreline erosion and ultimately damaged or destroyed. It is likely that disruptions to or limitations on utility and transportation infrastructure that serve these areas, such as saltwater intrusion into drinking water sources and recurring flooding on roadways, may independently set a trajectory for adaptive strategies for and/or abandonment of historic resources.

The Coastal Plain contains thousands of our state's cherished historic houses, downtown buildings, public buildings, churches, and cemeteries. These coastal counties and municipalities also manage records of permanent value to the state. Many private properties in the Coastal Plain are considered significant and are listed on the National Register of Historic Places.

Sea level rise will cause loss of economic development opportunities, community identity, and historic resources; population migration; and abandonment of communities. Given the very direct and devastating nature of the impacts from sea-level rise, cultural resources are expected to be at risk within the Coastal Plain.

Vulnerability and Risk

Protecting and preserving historic and cultural sites is critical to our state's heritage. The type of construction material (e.g., masonry versus wood frame) and elevation status for historic buildings are crucial to climate vulnerability assessments. Site location and determining whether something can be easily moved is also an important component in rehabilitative or adaptive planning for sea level rise.

From our perspective, flooding and storm surge events are temporary precursors to what can be expected from permanent sea level rise inundation, which will leave many areas, including its historical resources and institutions, inundated or island-like. These areas will be surrounded by inundated land and marooned from the utility and transportation infrastructure networks, forcing the state and its citizens to plan for retreat or adjusting to new realities in place.

The State Historic Preservation Office projects that 76 National Register districts and property will be directly affected by inundation from a two-foot sea level rise.[15] Sea level rise may very well lead to wholesale abandonment of communities and the immovable cultural resources contained within, and to societal disruption and a loss of community identity on a scale hard to contemplate.

Sea level rise projections indicate that the rising waters make no distinction as to jurisdictional boundaries, such as county lines or city limits, or road maps. The risk derived from this vulnerability is that affected areas will think and act "small and local" when we need to think and act "big and regional" to develop solutions and options on the scale posed by the sea level rise threat.

[15] In January 2020, the State Historic Preservation Office compared the GIS data of the Sea Level Rise Viewer of the NOAA Office for Coastal Management (available at https://coast.noaa.gov/digitalcoast/tools/slr.html) to its own GIS enterprise HPOWEB (which includes mapping of National Register listed properties in North Carolina).

Resilience Strategies

More research is needed to determine at a more granular level the scope of risk for these resources, type of impacts, and needed adaptation strategies. There will also be the need to consult and coordinate climate resilience efforts with other federal and state governmental agencies, private individuals, municipal and county governmental agencies, and private organizations.

Regional planning coordination

Other states, including Florida and Virginia, have begun to work on these issues on a regional, rather than individual local jurisdictional, basis. This approach will be meaningful for North Carolina, particularly given its dispersed coastal geography.[16]

Resource adaptation

Adaptation strategies identified for flooding are applicable for sea level rise but relocation of historic resources will be the most likely solution in many cases.

Essential records protection program

The State Archives offers a program to back up essential minutes for local government offices as well as consultations and training on protection of all vital records. Staff capacity and current funding are limitations.

Abandonment versus relocation

Critical will be a triage methodology to determine what should be moved and to where or otherwise salvaged versus documented and abandoned in place. The survivability and adaptability of transit and utility infrastructure and portability of resources (artifact / archives versus building or archaeology site) will likely impact this decision making. Archaeological sites need to be assessed and prioritized for potential salvage excavations in vulnerable locations.

Inventory of threatened sites

Approximately one hundred of North Carolina’s cultural heritage collecting institutions would be affected by a three-foot sea level rise. If these institutions do not relocate, the cultural assets they steward will be lost. As water levels rise, it will be important to strengthen NCDNCR’s network with an inventory of threatened repositories, especially in eastern North Carolina, to begin discussing the possibility of a regional collections storage facility, which would likely need state funding.

The time frames for these options are highly dependent on further study of SLR with North Carolina specific projections. As a result, it is difficult to provide a time horizon needed for these strategies. Constituents and partners in both the private and public sectors and levels of government should be involved. The insurance industry is emerging as a leader in these discussions.

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[16] Examples include the Southeast Florida Climate Change Regional Compact (https://southeastfloridaclimatecompact.org/) and efforts of the Hampton Roads Planning District Commission (https://www.deq.virginia.gov/Portals/0/DEQ/CoastalZoneManagement/FundsInitiativesProjects/task54-13.pdf).

Wildfire and Drought

Impact Summary

Extended and/or intense drought is likely to increase the probability of wildfire and extensive forest fires. These climate stressors have the potential to destroy or heavily damage historic structures and create exposed landscapes, facilitating erosion. Other indirect impacts may result from the necessary efforts to fight fires, such as construction of fire lines, backfires, and heavy water use from lakes. The Office of state Archaeology works closely with agencies such as the U.S. Forest Service (USFS) in North Carolina to assess the impacts to cultural resources from activities associated with containment and suppression of fires within the major national forests within the state.

Vulnerability and Risk

Lack of proper forest maintenance because of staff capacity or private party decision-making can exacerbate wildfire risk. The heat of fires and their duration can adversely affect the underlying topsoil, destroy intact archaeological resources (as well as the built environment), and set up a scenario where reforestation is difficult because of erosion and lack of host soil. Choice of construction materials for buildings and their landscaping present in wildfire-prone areas can likewise exacerbate the spread of wildfires – a flammable wood frame building with close-in undergrowth versus a masonry building with metal roof and a "swept" yard – and can determine survivability of the buildings (and what they contain) during a fire event.

Intense and prolonged drought will cause certain types of vegetation to die and in some cases produce exposed landscapes denuded of a protective vegetative cover. For historic sites and archaeological sites, the lack of covering vegetation will likely facilitate greater levels of erosion whenever precipitation resumes, particularly on exposed slopes, including mountainous terrain, river bluffs, and military earthworks. This type of erosion may serve to destroy or heavily damage the integrity and context of some of these sites. Once damaged in this manner the interpretive quality of some sites is irreparably destroyed. In addition, certain types of historic structures on exposed slopes such as early tobacco barns, ordering rooms, cabins, and tenant houses will likely be heavily damaged by increased or more intensive erosion.

Increased drought will likely impact cultural resources present within certain lakes across the state (e.g., Phelps Lake, Lake Mattamuskeet, Pungo Lake, New Lake, Lake Waccamaw, Falls Lake, Kerr Lake, and others), such as prehistoric Native American dugout canoes or evidence of earlier settlements. Extended drought could cause significant drops in lake levels and in some cases would expose these archaeological resources to the damaging effects of air and sunlight. Many of these resources are located at relatively shallow depths and may possibly be exposed if the lake level drops significantly during a prolonged drought. Once exposed, these types of resources will be damaged rather quickly and subject to looting.

Resilience Strategies

Working with its partners in state and local government as well as federal agencies such as the USFS, the DNCR anticipates it will adjust to most of the impacts from drought and wildfire. Currently, programmatic agreements with USFS to address compliance with Section 106 of the National Historic Preservation Act provide opportunities to address these issues further.

Additionally, funding and staff capacity for survey and documentation of threatened resources would aid in better long-term planning for their preservation.

4. Summary

Impacts of climate change have already been felt in the cultural resources sector through increased incidents of flooding and heavy precipitation, often associated with more severe hurricanes. Communities have already experienced damage to facilities, loss of archival records, financial expense, loss of historical integrity, loss of critical documentation, and damage to heritage tourism. In addition to flooding and heavy precipitation, sea level rise also presents a real threat to assets in this sector.

NCDNCR is already working to incorporate resilience strategies that will increase our adaptive capacity to mitigate risks and reduce vulnerabilities. Because NCDNCR conducts so much of its critical technical assistance and constituent services work in a collaborative environment, it should be reiterated that many of the decisions that could protect cultural assets that are not under direct state management rest in the hands of local government entities and private property owners. Promulgation of regulations and provision of resources to increase adaptive capacity may also be tied to federal regulations. Some of these rules may need updating to adapt to the realities of ongoing and persistent climate change impacts, such as repeated flooding. Sector development of adaptive capacity where possible will need to continue to be done in coordination with all stakeholders to realize meaningful results.

A one-size-fits-all expectation or approach is not appropriate for assessing how cultural assets will respond to climate hazards. An archaeological site located on a property outside of a flood zone or coastal surge area may be least affected. A high altitude historic district in the mountains that is also in a river valley could experience devastating flash flooding. A well-maintained building with a resilient roof (perhaps featuring hurricane clips or structural redundancies) versus a dilapidated one with an older roof may better survive high winds from a tropical cyclone, and a masonry building may be better poised to weather a flooding event than a wood frame one on the adjacent parcel.

Development pressure, local land use planning rules, jurisdictional divisions, and private property rights will shape adaptation strategies and local and regional solutions. An additional consideration is the matter of staff capacity. Disaster situations put our agency into response mode, even though the regular business of the mission must continue to function. In these circumstances, people power is stretched thin, and constituent assistance is highly dependent on face-to-face interaction and relationships with constituent associations, such as the Administrative Office of the Courts and the North Carolina Association of Registers of Deeds. A related issue is how best to provide educational outreach to help constituents consider climate-related factors in planning at the community and individual property level, especially if the time horizon for action is uncertain or the most recent disaster past.

Our sector is highly dependent on cell phone communication for disaster response between field staff and Raleigh headquarters. If cell towers are not functional, our communication network is compromised to the detriment of our mission. To this end, updates of known information, including the location and the relative importance of various cultural resources, should be ongoing through updated surveys and communication with constituents.

To protect irreplaceable cultural resources from these multifaceted climate threats, complacency and delay are not options. Continued constituent education for resiliency measures should be expanded statewide and made available more often. Regional solutions to these large scale threats should be fostered through the cooperation of multiple local jurisdictions, supported by necessary state level frameworks and funding. Discussion of where we may need to relocate moveable cultural resources, such as archival and artifact collections, and how best to protect or adapt our built environment should be happening now, not the day before the hurricane arrives, the flood comes, or when sea level rise is more evident. The state's efforts to these ends can serve as models for local and regional institutions, especially:

- more extensive and frequent constituent education and training for records and artifacts preparation and protection, as well as resiliency adaptation or modification for the built environment;
- interagency collaborations with local governments and private and non-profit constituents for planning;
- development of a state-specific hazard mitigation guide for historic resources (following the example of Florida and Maryland);
- continued documentation of historical resources (for example, architectural survey, artifact and archival databases, 3-D scanning of buildings and artifacts);
- strategic siting and/or relocation of cultural repositories, including those for long-term storage;
- prioritization of archaeological site protection, especially those increasingly at risk;
- infrastructure solutions to protect historic resources better; and
- adaptation or relocation of historic resources, such as appropriate and historically sensitive elevations.

Through concerted effort and purposeful action, North Carolina’s irreplaceable cultural resources have survived wars, social upheaval, and natural disasters. The responsibility to steward them for future generations must be done in concert with local partners, and with enhanced staff capacity and appropriate funding to address preparation, organization, and adaptation.

Ecosystems

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F. Ecosystems

Key Observations

- The North Carolina Natural Heritage Program assessed ecosystem vulnerability in 2010 and updated the assessment in 2019.
- Ecosystems in all 100 counties are affected by climate change and numerous land use changes that have occurred in recent decades.
- The ecosystems with the highest risk support a high concentration of rare species and have a low tolerance of environmental variation.
- Ecosystems are shaped by climate. Human impacts reduce ecosystems' natural resilience to disturbance and change.
- Conserving and managing land for key ecosystems yields benefits to other sectors, including water resources, tourism and commerce, and public health.
- Minimizing non-climate stressors will reduce the overall stress on ecosystems and help avoid catastrophic change and loss.
- Need multi-agency understanding of the financial value of ecosystem services.

Critical Impacts and Resilience Strategies

- To improve overall landscape resilience, create nature preserves as large as possible and maintain habitat connectivity across the landscape.
- Preserve and restore wetlands and natural areas alongside rivers and streams.
- Manage land for natural processes, such as prescribed fire and restoration of natural stream flows.
- Establish natural recreation areas such as parks, trails, and greenways that will improve resilience and public health, and become valued community assets that improve quality of life.
- Increase public awareness of the importance of land conservation, planning for resilience, and the value to people of ecosystem function and services.
- Business must adopt biomimicry practices to provide holistic regenerative economic value.

1. Introduction

To ensure the long-term health and functionality of North Carolina's ecosystems, we must understand how climate change will affect our natural areas and the species that inhabit our land and waters. North Carolina is a global center of diversity for many groups of organisms, including mountain trilliums and animals that rely on aquatic systems, such as salamanders and freshwater crayfish. North Carolina has a wide variety of habitat types, and this remarkable diversity is only partly explored. New species are still being discovered. Among the species found in the state, about 3% of plants and 6% of animal species are critically imperiled and at risk of extinction on a global basis.[1] Considering only their numbers and ranges within the state of North Carolina, 15% of plants and 8% of animal species are considered Endangered, Threatened, or Special Concern by the NC Department of Agriculture and the Wildlife Resources Commission. Every native species has its place in North Carolina's natural heritage, and we are already

[1] *North Carolina Natural Heritage Program Biotics Database*. (2020). NC Department of Natural and Cultural Resources, Raleigh, NC. (Accessed: January 16, 2020).

seeing changes in some natural communities that will make it impossible for some species to survive in areas of their current range.

North Carolinians have a long heritage of appreciating and caring for the land and water. North Carolina government agencies work together, along with federal and local organizations, to identify, understand, and protect the plants and animals that live in North Carolina, to ensure these species continue to thrive in their natural ecosystems for future generations. These public trust resources are protected through laws, policies, and state conservation lands that provide space, shelter, and food for the species and places for the public to visit their habitats.

North Carolina’s government plays a crucial role in efforts to protect our state’s ecosystems. Agencies directly involved with managing and regulating North Carolina’s ecosystems include programs and divisions within the Department of Natural and Cultural Resources (DNCR), the Department of Environmental Quality (DEQ), the Department of Agriculture and Consumer Services (NCDA&CS), and the Wildlife Resources Commission (WRC).

Department of Natural and Cultural Resources

The Natural Heritage Program maintains North Carolina’s inventory of biodiversity information and administers the North Carolina Nature Preserves Act, protecting 440,737 acres of Dedicated Nature Preserves and 783,488 acres of Registered Heritage Areas.

The Division of Parks and Recreation conserves and protects representative examples of North Carolina’s natural beauty, ecological features, recreational and cultural resources within the state parks system; provides and promotes safe, healthy and enjoyable outdoor recreational opportunities throughout the state; and provides educational opportunities that promote stewardship of the state’s natural and cultural heritage. Manages 82 sites including state parks, state natural areas, and state trails, totaling 287,011 acres under the state Parks Act and the state Nature and Historic Preserve Dedication Act.

The Clean Water Management Trust Fund (also known as North Carolina Land and Water Fund) awards grants to non-profit and governmental organizations to protect land for natural, historical and cultural benefit, limit encroachment on military installations, restore degraded streams, and develop and improve stormwater treatment. This is a primary source of grants allowing local governments, state agencies, and conservation nonprofits to address water pollution, protect clean water supplies, and conserve land.

The Parks and Recreation Trust Fund (PARTF) supports land acquisition and improvements within the state park system. PARTF is the main source of funding for local parkland acquisitions, facility improvements, and public beach and estuarine access.

Department of Environmental Quality

The Division of Marine Fisheries (DMF**)** mission is to ensure sustainable marine and estuarine fisheries and habitats for the benefit and health of the people of North Carolina. This includes the management of North Carolina’s marine and estuarine fisheries out to three miles offshore, and monitoring the state’s fisheries habitat, encompassing all 2.9 million acres of coastal waters (marine and estuarine) and over 412,000 miles of coastline. The DMF carries out the rules and policies of the Marine Fisheries Commission (MFC).

The MFC is a nine-member board appointed by the Governor to manage, restore, develop, cultivate, protect and regulate the state's marine and estuarine resources. It does this by adopting rules and policies, implementing management measures for fisheries and advising the state on marine fisheries within the jurisdiction of regional and federal boards and councils.

The Division of Coastal Management (DCM) carries out the state's Coastal Area Management Act (CAMA), Dredge and Fill Law, and the rules and policies of the Coastal Resources Commission (CRC), in the state's 20 coastal counties. The CRC is charged under CAMA with the protection, preservation, orderly development, and management of the coastal area of North Carolina, including public trust resources. DCM, which provides staff support to the CRC, is responsible for several programs, including permitting, land use planning oversight, coastal policy, the Coastal Reserve program, and numerous grant programs.

DCM's Coastal Reserve protects and manages more than 44,000 acres of coastal and estuarine land and water for research, education, and compatible traditional uses at ten reserve sites along NC's coast. Four of these sites comprise the National Estuarine Research Reserve, a state-federal partnership between DCM and the National Oceanic and Atmospheric Administration (NOAA).

The Division of Water Resources (DWR) ensures safe drinking water in accordance with federal requirements, evaluates environmental water quantity and quality, and carries out enforcement actions for violations of environmental regulations. This division administers the laws, policies, and rules established by the U.S. Environmental Protection Agency, the state's Environmental Management Commission, and the NC General Assembly.

The Albemarle-Pamlico National Estuary Partnership's (APNEP) mission is to identify, protect, and restore the significant resources of the Albemarle-Pamlico estuarine system. The partnership is a cooperative effort hosted within DEQ under a cooperative agreement with the U.S. Environmental Protection Agency. APNEP works closely with the Commonwealth of Virginia, as the program area extends across both states, from its headwaters in the Virginia mountains and North Carolina Piedmont, through a broad coastal plain and out to the string of barrier islands bordering the sounds. The Coastal Habitat Protection Plan (CHPP) recommends actions to protect and restore habitats critical to the enhancement of North Carolina's coastal fisheries. The Marine Fisheries, Coastal Resources, and Environmental Management commissions are required to approve the plan recommendations.

Department of Agriculture & Consumer Services

The NC Forest Service manages 58,967 acres of state forests and provides forest management advice and assistance to private landowners; protects state and privately owned land from wildfires and provides assistance with prescribed fire.

The Plant Protection Section manages 14,205 acres of plant conservation preserves and administers the Plant Protection Act.

The Wildlife Resources Commission

The Wildlife Resources Commission conserves and sustains the state's fish and wildlife resources through research, scientific management, wise use, and public input; is the regulatory agency responsible for the enforcement of NC fishing, hunting, trapping and boating laws, maintaining endangered, threatened, and special concern species, and stewardship of public trust fish and wildlife. Manages 520,424 acres of game lands for nongame and game species and their habitats.

2. Overall Exposure

North Carolina's three physiographic regions differ from each other in terms of their most critical climate stressors and their adaptive capacity. Western North Carolina hosts a diversity of elevations, precipitation patterns, and geologic formations, and therefore supports a diversity of ecosystems and many endemic species known from nowhere else in the world. Drought, heat, and extreme precipitation could easily shift conditions to regimes that will not support the diversity of life that currently characterizes this region.

North Carolina's biggest cities and highways are in the Piedmont. The rivers and streams of the Piedmont region are especially important ecologically, harboring a diversity of aquatic species including some endemic organisms such as the Neuse River Waterdog (*Necturus lewisi)*. The presence of rare and endemic fish, mussels, and amphibians in Piedmont rivers indicate places where water quality remains clean enough to support animals that are sensitive to pollution and sedimentation. Water temperature change, sedimentation, and pollution runoff associated with extreme precipitation compound stresses already threatening the aquatic species associated with Piedmont streams and small rivers.

In the Coastal Plain, the people and natural communities in closest proximity to major rivers, sounds, and the ocean are most vulnerable to flooding from extreme precipitation and sea level rise. Coastal streams, floodplains, and freshwater tidal wetlands are all vulnerable to flooding, saltwater inundation, and invasion of nonnative species. Coastal fringe areas are losing habitat due to erosion, and marine species are responding to changes in coastal water temperatures.

A risk assessment of North Carolina's Ecosystems[2] was originally conducted in 2010 and updated in 2019. As part of this assessment, the Natural Heritage Program, with input from other conservation agencies, evaluated the likely effects of climate change on North Carolina's ecosystems and species and then integrated this information with knowledge of ongoing threats, particularly habitat loss and invasion of exotic species. This analysis was conducted at several levels of biological organization and, where appropriate, over several different regions of the state: The Mountains, Piedmont, and Coastal Plain (Table 5F-1).

[2] *North Carolina Ecosystem Response to Climate Change: DENR Assessment of Effects and Adaptation Measures*. (2010). Department of Environment and Natural Resources, Raleigh, NC.

Table 5F–1: Exposure matrix listing the most vulnerable NC ecosystems (taking into account sensitivity to threats and adaptive capacity) and climate hazards that affect them.[1]

Most Vulnerable Ecosystem Types	Change in Seasons	Coastal Erosion	Dam Failure	Extreme Heat	Flooding	Inundation due to Sea Level Rise	Landslides	Saltwater Intrusion	Severe Winter Weather	Storm Surge	Tidal Flooding	Water Shortage due to Drought	Wildfire	Wind
Coastal Plain Floodplains	*		*		*			*	*	*	*			*
Coastal Plain Large River Communities				*	*			*		*	*	*		
Coastal Plain Nonalluvial Mineral Wetlands								*		*	*		*	
Coastal Plain Stream/Swamp Communities			*	*	*			*		*	*	*		
Estuarine Communities	*	*				*		*		*	*			
Freshwater Tidal Wetlands	*	*				*		*		*	*			
High Elevation Forests and Outcrops	*			*					*			*	*	*
Maritime Grasslands	*	*		*		*		*		*	*	*		
Maritime Upland Forests		*								*	*			*
Maritime Wetland Forests		*				*		*		*	*			*
Mountain Streams	*		*	*	*		*					*	*	
Mountain Bogs and Fens	*			*	*							*		
Piedmont Streams and Small Rivers			*	*	*							*		
Shell Bottom (estuarine)	*					*		*		*	*			
Soft Bottom (estuarine)	*					*		*		*	*			
Submerged Aquatic Vegetation (Seagrass)	*					*		*		*	*			

Climate stressors and hazards were identified for each ecosystem group and then rated by a team of biologists based on likelihood of impact (high, medium, or low), effect (positive, negative, or mixed) and magnitude (high, medium, or low). Predictions of future ecological conditions are complicated by the interactions among climate, biological, and ecological processes. Because of the emerging nature of the impacts, many ratings were based on expert opinion drawing from first-hand field experience observing the species and ecosystems, rather than from extensive experimental research or modeling.

The ecosystems analysis is represented by 45 groups of ecosystems that share certain ecological characteristics and are likely to respond to climate change in similar ways. Species included in this analysis incorporate the majority of federal and state Threatened and Endangered species that occur in North Carolina, as well as those considered Significantly Rare by the Natural Heritage Program and the majority of animals identified as Priority Species in North Carolina's Wildlife Action Plan. These analyses enumerate impacts that cascade from higher to lower hierarchical levels (i.e. from ecosystems to species), although some impacts are likely unique to each separate unit within the levels.

Climate Stressors and Hazards of Greatest Concern

The many climate stressors each act on North Carolina's ecosystems in different ways, as shown in Table 5F-1. At the same time, many of North Carolina's ecosystems are already strained by other human-caused changes in the environment. Climate change can magnify the stress from other ongoing impacts, including land use changes, invasive exotic species, habitat fragmentation, and fire suppression.

Heavy precipitation events are expected to damage waterways and riparian zones by causing excessive flooding and scouring. Hurricane-related impacts are not limited to coastal regions. Flooding and scouring from heavy rainfall due to hurricanes has affected all 100 counties in North Carolina. In the estuarine environment, flooding from extreme precipitation events can lead to high loads of organic matter, organic nitrogen, and phosphorus which fuels phytoplankton production resulting in algal blooms and associated hypoxia. After Hurricane Florence (2018), many fish species were affected by this condition, including largemouth bass (*Micropterus salmoides*) and Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*).

Winds associated with storms are expected to damage trees and forests across the state. Wind intensity and frequency appear to be two key factors that determine the extent of wind effects on forest dynamics and diversity in the Piedmont. Canopy gaps created by wind damage provide places for invasive exotic and shade-intolerant plant species to become established. At the coast, changes in wind driven tides increase tidal flooding and shoreline erosion. Salt laden tropical cyclone and extratropical nor'easter winds often adversely affect vegetation near the ocean and estuarine waters.

Storm surge erodes shorelines and kills vegetation in maritime grasslands, tidal marshes, estuaries, lower reaches of Coastal Plain rivers, and low-lying wetlands near estuaries. Increased saltwater from storm

Figure 5F–2: Tidal Freshwater Marsh at Pine Island (photo credit: Michael Schafale), Sensitive jointvetch (*Aeschynomene virginica)* (photo credit: Misty Buchanan).

surge damages Tidal Freshwater Marsh, habitat for Sensitive Jointvetch (*Aeschynomene virginica)* which is considered Threatened under the U.S. Endangered Species Act (Figure 5F–2)

Sea level rise affects coastal ecosystems in several ways. Saltwater intrusion due to sea level rise is expected to change the salinity of estuarine communities and convert lower coastal floodplains from swamp forest to marsh. Inundation due to sea level rise is expected to submerge some freshwater tidal wetlands and convert some maritime forests to grasslands. Coastal erosion will reduce the extent of freshwater tidal wetlands, maritime uplands, and maritime wetlands. Endangered and threatened species that are vulnerable to storm surge and erosion on beaches are likely to decline, including seabeach amaranth (*Amaranthus pumilus*), nesting sea turtles, and nesting shorebirds such as piping plover (*Charadrius melodus*) (Figure 5F–3).

Figure 5F–3: Threatened Seabeach Amaranth (*Amaranthus pumilus*) at base of coastal dunes (photo credit: Dale Suiter), Piping plover *(Charadrius melodus)* on ocean beach (photo credit: Scott Pohlman).

Extreme heat and extended periods of hot weather negatively impact mountain streams, mountain bogs, high elevation forests and rock outcrops, Piedmont headwater streams, and Piedmont small rivers (Figure 5F–4). The North Carolina Climate Science Report[3] predicts overall average temperatures in NC are very likely to increase by 2 - 5°F by mid-century and 5 -10°F by the end of this century, and it is very likely that summer heat index values and the number of very warm nights each year will increase.

Many animal species are not able to tolerate increased temperatures and even those that can tolerate some changes in temperature may still be affected. Animal breeding behavior, gender, parasites, and food availability can all be affected by temperatures. For aquatic species, higher water temperatures often contribute to lower dissolved oxygen levels in water. As water temperatures increase with climate change, aquatic species may experience more frequent and extended periods of low dissolved oxygen, causing physiological stress that can interfere with feeding and reproduction. This would be in addition to both natural and pollution-caused anoxic episodes, which already periodically kill large numbers of fish and other aquatic species.

[3] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. P. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: *North Carolina Climate Science Report*. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

Figure 5F–4: Little Lick Creek reservoir in Durham County during severe drought of 2005 (photo credit: Natural Heritage Program Staff).

Water shortage due to **drought** increases the exposure to and risk of catastrophic wildfire, temporarily reduces availability of suitable habitat for wetland and aquatic animal populations and can cause outright mortality for individual animals and plants that are not able to migrate to suitable habitat.

Mild winters are expected to promote the expansion of invasive exotic species. This will be a factor in many ecosystems, including aquatic as well as terrestrial, with the greatest impacts anticipated in Coastal Plain and Piedmont floodplains. Cogon grass (*Imperata cylindrica*), Chinese tallowtree (*Triadica sebifera*), and fire ants (*Solenopsis invicta*) are all examples of invasive species that may spread to more parts of North Carolina with warmer winters.

Increasing air temperatures contribute to warming streams, lakes, and ocean temperatures, with impacts to marine and aquatic animals including increased stress and higher metabolic rates, and loss of habitat as waters warm.[4] Warmer waters may remove suitable habitat for species already at the edge of their thermal tolerance, including native brook trout. Climate change vulnerability depends on whether organisms can disperse rapidly enough to keep pace with shifting temperatures and find suitable habitat along the way. Nonnative fishes which may prey on and compete with native fishes are likely to increase in numbers and distribution as climate changes.

Ocean temperatures are expected to increase, which will have far-reaching and complex impacts on marine fisheries and estuarine habitats. Warmer ocean temperatures may disrupt migratory pathways for anadromous species. Warmer waters often contribute to lower levels of dissolved oxygen, leading to fish kills in coast waters. Warmer water temperatures also allow some species of aquatic animals to expand into areas that were previously too cold for them to survive. DMF has already recorded a northward range

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[4] Williams, J. E., Isaak, D. J., Imhof, J., Hendrickson, D. A., and McMillan, J. R. (2015). *Cold-Water Fishes and Climate Change in North America. Reference Module in Earth Systems and Environmental Sciences*. Retrieved from http://dx.doi.org/10.1016/B978-0-12-409548-9.09505-1

shift for summer flounder off the coast of North Carolina[5] and the center of the Atlantic Croaker population is forecast to shift 50–100 km northward before the year 2100.[6] Fisheries management will need to adapt to a changing definition of sustainable harvest that may shift with warming waters and find a way to be dynamic in managing capture fisheries due to this complexity.

Non-climate Stressors of Greatest Concern

Changes in **land use** (e.g., conversion from natural systems to commercial and residential development), continues to affect ecosystems across the state, including direct impacts to uplands and floodplains and secondary impacts to aquatic ecosystems and wetlands.

Changes in hydrology are of great concern for wetlands, rivers, and streams across the state, from mountain bogs to coastal wetlands. Impacts include flood regime alteration, groundwater depletion and water withdrawal, and impoundment of streams and rivers.

Water pollution threatens aquatic communities, including rivers, streams, and estuarine communities. In North Carolina, 22 species of aquatic animals are already listed as federally Endangered or Threatened.[7]

Loss of **riparian vegetation** threatens large rivers, streams and estuarine ecosystems, which rely on intact riparian zones for shade, bank stabilization, and filtration of pollutants and nutrients.

Invasive exotic species have already changed the species composition of many floodplain forests, rock outcrops, freshwater marshes, mountain bogs, and aquatic communities, and they continue to spread. Invasive species reduce the diversity of local native species, affect water availability and soil nutrients, and interrupt natural ecological interactions and processes. Chinese privet (*Ligustrum sinense*), Japanese knotweed (*Reynoutria japonica*), phragmites (*Phragmites australis*), and hydrilla (*Hydrilla verticillate*) are a few of the many invasive exotic plants in North Carolina that have been shown to damage the ecosystems where they dominate and outcompete native plants.

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[5] Dubik, B. A. Clark, E.C. Young, T., Jones Zigler, S. B., Provost, M. M., Pinsky, M. L., and Martin, K. S. (2019). *Governing fisheries in the face of change: Social responses to long-term geographic shifts in a U.S. fishery*. Marine Policy, 99, 243-251.
[6] Hare, J., Alexander, M., Fogarty, M., Williams, E., and Scott, J. 2010. *Forecasting the dynamics of a coastal fishery species using a coupled climate-population model*. Ecological Applications, 20 (2), 452-464.
[7] Ratcliffe, J. (2019). *Natural Heritage Program List of Rare Animal Species of North Carolina*, Department of Natural and Cultural Resources, Raleigh, North Carolina.

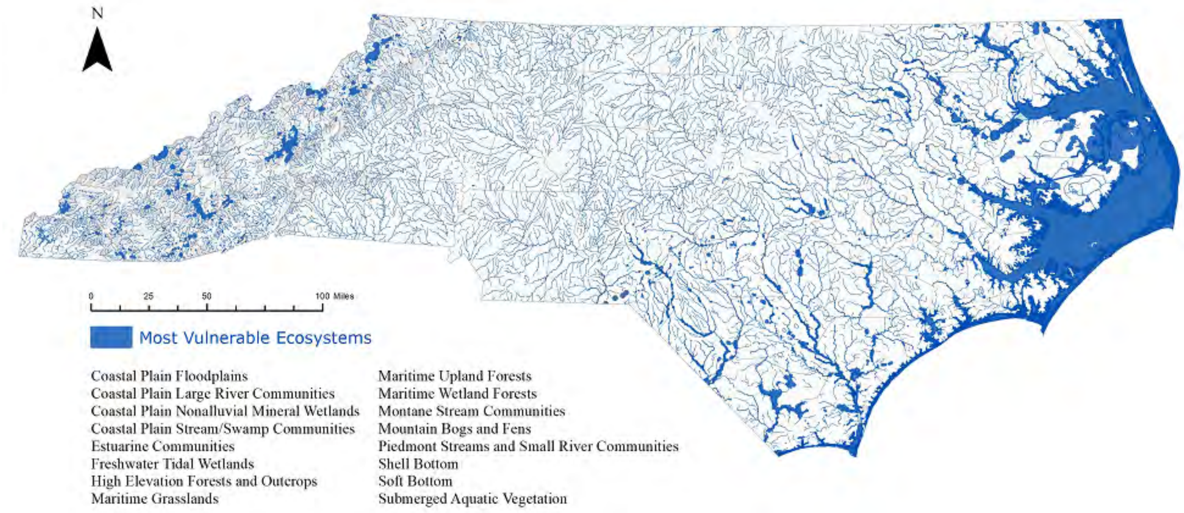

Figure 5F–5: Most vulnerable ecosystems identified by Ecosystem Risk Assessment Committee.

State-Owned Ecosystem Assets at Greatest Risk

We assessed the risks to state-owned lands by reviewing the climate-related stressors and hazards associated with each of 45 biological themes (broad ecosystem types) [8] and then we used maps of the themes and state-owned protected areas[9] to determine which state conservation lands are most vulnerable (Figure 5F–5). Based on this data-driven approach, the assessment showed that **four of the five state-owned conservation lands with the highest number of stressors and hazards are in the Coastal Plain** region of the state. These areas illustrate the breadth of potential impacts and the scope of concern.

Of the five sites, four are near the coast: **Bertie County Game Land** is composed of 3,880 acres of swamps, floodplains, and bottomlands along the Cashie River near Windsor. The **Emily and Richardson Preyer Buckridge Coastal Reserve** covers 28,766 acres along the Alligator River in Tyrell and Hyde counties. **Neuse River Game Land** is located in Craven and Pamlico Counties, in multiple patches north and south of New Bern, totaling 4,898 acres. **Roanoke River Wetlands Game Land** occupies 20,541 acres in Bertie, Halifax, Martin, and Northampton counties between Weldon and Williamston. These areas top the list of state-owned sites with multiple climate stressors and threats because they occur far enough inland to contain river floodplains, nonalluvial wetlands, and even some uplands, and extend down to sea level. Hazards unique to sea level areas include inundation due to steady sea level rise, tidal flooding, and storm surge during severe storms. Intrusion of saltwater, harmful or fatal to most of the freshwater plants and animals that occupy these lands, is associated with all of these hazards. The same waters that caused widely reported damage along the Neuse River in New Bern in recent hurricanes brought major disturbance to the natural systems in the Neuse River Game Land. In the meantime, ghost forests of dead trees where there once were dense swamp forests attest to effects of gradually rising sea level and increased penetration of normal tides.

[8] *North Carolina Ecosystem Response to Climate Change: DENR Assessment of Effects and Adaptation Measures*. (2010). Department of Environment and Natural Resources, Raleigh, NC.
[9] North Carolina Natural Heritage Program. (2020). *Geographic Information System (GIS) data*. NCDNCR, Raleigh, NC. Available at www.ncnhp.org. (Accessed: January 2020).

These areas, being close to the coast, also bear the brunt of the winds from hurricanes, tropical storms, and extratropical nor'easters. Increased severity or frequency of storms may push forested Coastal Plain ecosystems beyond the limit of what their natural adaptations can tolerate. More upstream parts of all these sites support Coastal Plain Floodplain ecosystems that can be affected by increased river flooding associated with extreme rainfall events. These four sites are also subject to many of the climate stressors and hazards that are more widely distributed across the state, including changes in timing of seasons, extreme heat, winter cold snaps, drought, and altered wildfire patterns.

The state-owned conservation land with the next most vulnerable ecosystems is **Pisgah Game Land,** covering 4,272 acres in multiple tracts scattered in Avery, Burke, Caldwell, McDowell, and Mitchell Counties. The ecosystems in Pisgah Game Land most threatened by climate stressors are high elevation forests and outcrops, as well as mountain streams and rivers. Changes in seasons, extreme heat, drought, and heat waves all affect plants and animals that were adapted to live in conditions unique to the high elevation mountaintops.

The Linville River, Wilson Creek National Wild and Scenic River, Harpers Creek, Roaring Creek, Bear Creek, and numerous other small streams and tributaries are featured at Pisgah Game Land. These waterways are known for their trout waters and scenic, recreational, and cultural/historical value. Changes in seasons, extreme heat and heat waves, cold snaps and low temperatures are likely to affect the aquatic environment and species that are not tolerant of changes in average temperatures. Severe weather, flooding, and landslides may increase erosion and add more sediment to waterways. Wildfires may also increase stream sedimentation. Wildfire can also damage high elevation forests and streams if they cause tree mortality leading to stream sedimentation.

Figure 5F–6: Clear waters of the Cane River, Mount Mitchell State Park in Yancey County (left); Shut in Creek near Cherokee in Jackson County (photo credits: Damon Hearne).

3. Examples of Impacts, Vulnerability, and Risk

High Elevation Forests and Rock Outcrops

Impact Summary

High elevation forests and outcrops are among the ecosystems most vulnerable to the effects of climate change of any in the state (Figures 5F–6 and 5F–8). The general pattern of **warmer temperatures, longer growing season, more hot spells, droughts, and severe storms** are expected to occur. **Drought** and associated **wildfire** are among the greatest risks of climate change in the high elevations. Plants occurring at rock outcrops can be dramatically affected by droughts because of the limited water available in shallow soils around the crevices of rocks. Changes in total precipitation may not be drastic but an increase in frequency or severity of drought is a threat, particularly if it brings wildfire into these non-fire-adapted areas.

Wildfire is a severe threat to spruce-fir forests. These forests almost never burned naturally, and most of their component species, including spruce and fir themselves, are not adapted to fire. Much of the environment at high elevations depends on moisture and thermoregulation from fog and cloud cover. It is uncertain if cloud cover will change in these high elevation communities, potentially altering moisture from fog deposition, but this could also contribute to water stress for high elevation plants.

Communities and species associated with this ecosystem are likely to be affected both by **warmer summer temperatures** and by **milder winters**. Warmer temperatures in winter could lead to an increase in damage to trees from **severe winter weather**, as precipitation trends from snowstorms toward more ice storms. As **temperatures increase**, native and exotic species from lower elevations may be able to invade these areas more easily. Thus, managing invasive species and protecting or restoring areas is critical to protect these habitats against these threats.

Given the high number of endemic and disjunct species, and the limited amount of land with the specific environmental conditions found above 5,000' elevation, **high elevation forests and outcrops are among the ecosystems in North Carolina where threats to biodiversity are the greatest.** Ecosystems on Mount Mitchell (North Carolina's oldest state park (1915) and the highest mountain (6,683') east of the Mississippi) are vulnerable. Grandfather Mountain and Cold Mountain are also among 17 high elevation state-owned conservation lands most vulnerable to climate-related impacts (Table 5F-2). Several species on these mountains face outright extinction.

Others, if lost, are unlikely to ever recover within the region. Although this ecosystem survived historical times when temperatures were substantially higher than they are now, the landscape is more fragmented with human-caused impacts than it was in historic times. Priority should be given to management actions that may secure them enough time and space to survive both short-term environmental disturbances as well as adapt to longer-term changes in the climate. Since almost all examples of this ecosystem group are located on public lands and already managed to preserve their natural features, implementation of recommended interventions should be more feasible than for many of the other ecosystems.

Table 5F–2: -owned, high elevation lands most vulnerable to climate-related hazards.

State-Owned Asset Name
Bear Paw State Natural Area
Beech Creek State Natural Area
Cold Mountain Game Land
Elk Knob Game Land
Elk Knob State Park
Grandfather Mountain State Park
Mount Jefferson State Natural Area
Mount Mitchell State Park
NC Division of Mitigation Services Easement
NC Forest Service Easement
Paddy Mountain Plant Conservation Preserve
Pisgah Game Land
Pond Mountain Game Land
Silver Game Land
Tater Hill Plant Conservation Preserve
Three Top Mountain Game Land
Yellow Mountain State Natural Area

Vulnerability and Risk

Most of the high elevation mountaintops in North Carolina are covered in spruce-fir forests. Both the Fraser-fir-dominated forests of the very highest peaks and the mixed red spruce-Fraser-fir-yellow birch forests of the rest of the spruce-fir zone have dense canopies under natural conditions, except where recently disturbed by storms. The introduced balsam **woolly adelgid has killed all of the mature Fraser fir in the last 60 years**, leaving a broken canopy or dense young stands in many places.

A variety of distinctive shrubs and herbs, many of them more common in the northern United States but some endemic to the southern Appalachians, occur beneath the canopy. Lush beds of moss and ferns cover the rocky soil, abundant fallen logs, and tree trunks in some areas. Animal species are a similar mix of northern and endemic species (Figure 5F–7). Some, such as the spruce-fir moss spider (*Microhexura montivaga*) and Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*), are federally Endangered. Some, such as several species of ground beetles of the genus *Trechus*, occur on only a single mountain range. Numerous species of plants and animals are listed as Threatened or Endangered in North Carolina by North Carolina's Plant Conservation Program and Wildlife Resources Commission.

Figure 5F–7: Northern pygmy salamander (*Desmognathus organi*) (left) and Weller's salamander (*Plethodon welleri*), both endemic to high elevation forests (above 4000') of NC, VA, and TN (photo credit: Nathan Shepard).

Figure 5F–8: High Elevation Rocky Summit natural community at Paddy Mountain (left) and Spreading Avens *(Geum radiatum)*, components of high elevation ecosystems threatened by climate change. (photo credit: Natural Heritage Program staff).

Northern Hardwood Forests are found on high mountain slopes with a cool climate and high levels of rainfall. They are dominated by combinations of moist-site hardwoods such as yellow birch, beech, yellow buckeye, and sugar maple. The herb layer is often lush and may range from low to fairly high diversity. These forests are subject to periodic widespread disturbances, such as ice storms or severe winds, which provide canopy openings, but probably seldom or never remove the whole canopy at once. The name refers to the resemblance of these forests to those in the northeastern United States, which have similar canopies, but the presence of Southern Appalachian endemic species makes the community types in North Carolina different from those of the north.

Figure 5F–9: Spruce-Fir Forest and High Elevation Rocky Summit natural communities at Grandfather Mountain (left) (photo credit: Wade Stubbs); Threatened Heller's Blazing Star (*Liatris helleri*) (photo credit: James Padgett).

Roan Mountain bluet (*Houstonia montana*), Heller's blazing star (*Liatris helleri*), spreading avens (*Geum radiatum*), rock gnome lichen (*Gymnoderna lineare*), and Blue Ridge goldenrod (*Solidago spithamaea*) – state and federally Threatened or Endangered plants – occur at high elevation rock outcrops (Figure 5F–9). If conditions become too warm and dry for these species, they are unlikely to migrate north because of the limited habitat available for migration corridors (mountaintops are effectively isolated from one another, making migration difficult or impossible for species with limited dispersal capabilities). Endemic species should be monitored closely for declines in the near future, and intervention may be required to prevent extinction.

Resilience Strategies

Protection from Wildfire

Fire suppression is one of the most important actions that can be taken to save the remnants of these communities. Fire suppression is probably already the policy of all current land managers, but suppression may take increased vigilance and effort if conditions become drier. Spruce-fir forests are not very flammable under the current climate but may become more so in the future. Increased **prescribed burning** in fire-prone lower elevation oak and pine forests, in addition to benefiting those forests, should make it easier to control wildfires and prevent them from spreading into the high elevation forests.

Conservation and Restoration

Historical timber harvest and slash fires have greatly reduced the extent of several large spruce-fir patches and broken them into fragments that may not be well connected. Restoration of spruce and fir canopy in these areas, especially in the higher elevation portions, would allow the species pool to expand back through a larger area, producing larger, more robust, and better distributed populations that would be better able to survive the future loss of lower elevation portions. Reintroduction of rare species to patches or mountain ranges where they have been lost, as well as to restored areas, would improve their prospects for survival in the future climate. The Great Balsam Mountains, Black Mountains, and portions of the Great Smoky Mountains are the places with the greatest potential to benefit from this kind of restoration.

Protection from Trampling

For rock outcrops, trampling associated with recreation is one of the biggest threats. Although most examples occur in conservation lands, this threat is difficult to control. Better management of trampling on currently accessible outcrops would allow rare and characteristic species to occupy more of the suitable habitat, producing larger, more robust populations that would be better able to survive climate-related stresses. Reintroduction of rare species to patches or mountain ranges where they have been lost, as well as to restored areas, would improve their prospects for survival in the future climate.

Mountain Streams

Impact Summary

Mountain streams (Figure 5F–10) contain many rare species that are vulnerable to extinction. Climate change is not the most severe threat to these systems. Pollution, sedimentation, and changes in hydrology caused by development and lack of riparian corridors all imperil these globally important ecosystems. Climate and non-climate factors may stress these systems to the point where several species are unable to persist. Because mountain streams exist at high elevations in separated headwaters, threatened species may not easily migrate to connected, cool, high quality habitat, thus resulting in possible extirpation or extinction.

Vulnerability and Risk

Cold water streams, found at higher elevations in the mountains, can be home to important native fish species. Representative habitats exist on a larger set of state lands (Table 5F-3).

Figure 5F–10: Big Creek in Great Smoky Mountains National Park (left)(photo credit: Nathan Shepard), Tuckasegee Stream Crayfish (photo credit: Michael Perkins).

Table 5F–3: State-owned lands with significant mountain streams.

State-owned Asset Name	
Armstrong Fish Hatchery	NC Division of Mitigation Services Easement
Beech Creek State Natural Area	NC Forest Service Easement
Beech Creek Unique Wetland	NC State University Easement
Buffalo Cove Game Land	NC Wildlife Resources Commission Easement
Bullhead Mountain State Natural Area	Needmore Game Land
Cedar Mountain Plant Conservation Preserve	New River State Park
Cold Mountain Game Land	Old Man’s Meadow Wildlife Conservation Area
Dulany Plant Conservation Preserve	Paddy Mountain Plant Conservation Preserve
Dupont State Forest	Pisgah Game Land
Elk Knob Game Land	Pond Mountain Game Land
Elk Knob State Park	Rendezvous Mountain Educational State Forest
Gorges State Park	Silver Game Land
Grandfather Mountain State Park	South Fork New River-Boone Greenway
Green River Game Land	South Fork of the New River State Natural and Scenic River
Headwaters State Forest	South Mountains Game Land
Horsepasture State Natural and Scenic River	South Mountains State Park
Linville River State Natural and Scenic River	Stone Mountain State Park
Melrose Mountain Plant Conservation Preserve	Tater Hill Plant Conservation Preserve
Mitchell River Game Land	Three Top Mountain Game Land
Mount Jefferson State Natural Area	Thurmond Chatham Game Land
Mount Mitchell State Park	Toxaway Game Land
NC Agricultural Development and Farmland Preservation Trust Fund Easement	Upper Mountain Research Station
NC Department of Cultural Resources Easement	Wolf Creek Watershed Preserve
NC Department of Transportation Mitigation Site	Yellow Mountain State Natural Area

The degree that warming and disturbances impact particular habitats and species depends on the natural resilience of the habitat or species in question and is also based on the interactions of biological, geomorphic, and hydrologic systems. Impacts from climate change are likely to be more severe where stream and lake habitats are degraded or fragmented and less severe where habitats are robust and connected.[10] Disturbances such as **landslides, wildfires, and floods** are a historical part of the landscapes inhabited by trout and coldwater fishes.

Historically, these disturbances have been infrequent and short-lived, allowing the systems to recover between events or even improve conditions as new habitat patches were created in formerly homogeneous landscapes. In interconnected stream networks, native trout and other fishes may be able to escape

[10] Williams, J. E., Isaak, D. J., Imhof, J., Hendrickson, D. A., and McMillan, J. R. (2015). *Cold-Water Fishes and Climate Change in North America*. Reference Module in Earth Systems and Environmental Sciences. http://dx.doi.org/10.1016/B978-0-12-409548-9.09505-1

wildfires or floods and find suitable habitat conditions elsewhere within the stream network. However, **the same type of disturbance may eliminate the native fish populations if habitat is fragmented**, meaning fish may not be able to relocate to suitable conditions.

Changes in precipitation patterns may have numerous and varied effects. Severe and prolonged **droughts** may decrease streamflow, decrease groundwater recharge, and increase evaporation, varying with site-specific conditions in these coldwater systems. These effects can reduce the area of suitable habitat and cause habitat fragmentation. **Increased storm intensity** can lead to **flash flooding** and more prolonged flooding, with increased **stormwater runoff** and **increased erosion**, resulting in an increase in loading of sediments, nutrients, and contaminants into streams and potential negative effects on biota, such as fish kills. With a change in intensity and variability of rainfall, there are potential changes to streamflow patterns, channel hydrodynamics, and the volume of groundwater, all of which will affect fish habitat within the streams.

Many of the water quality and water quantity impacts resulting from climate change can be expected to exacerbate the impacts from economic development and population growth in North Carolina. Land use, development, and land conversion from forest continues to threaten the integrity of some streams through increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials. Economic growth and development increase water supply demands. Historical streamflow patterns are projected to be altered due to climate change impacts; however, these are already being altered due to rapid urbanization. An increase in impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems. Riparian vegetation is critical to the overall stream and streambank stability. Lack of riparian vegetation or inadequate width of forested buffer can increase streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation serves as nutrient input to the stream community and helps regulate stream temperature by providing shade.

Resilience Strategies

Riparian Zone Protection and Restoration

Naturally vegetated riparian areas stabilize streambanks and provide erosion control, allow for sediment and pollutant deposition (by dissipating energy from runoff and allowing for filtration), allow infiltration of water runoff to recharge groundwater, regulate stream temperature by providing shade, provide flood control by attenuating storm flows, sequester and store carbon in mature woody vegetation, increase stream habitat complexity by contributing woody debris, provide habitat for terrestrial wildlife species, and serve as corridors for movement of terrestrial wildlife.

Riparian areas with forested vegetation have a greater capacity to serve these numerous functions, compared with riparian areas of grass, little mature vegetation, or no vegetation. Riparian areas are important for aquatic ecosystem health, in general, but they can also help mitigate for and provide resilience against climate change effects. Riparian vegetation is more resilient to flooding and drought than upland vegetation and should be restored in areas where it is lacking to establish native vegetation and manage for genetic diversity. Riparian areas can serve as movement corridors, and, because they occur along streams, can increase connectivity between habitats and across elevational zones. In addition, animals with thermoregulatory limitations are most dependent upon shaded refuge, and this will become increasingly important with anticipated increases in air temperatures.

To gain the most benefit from stream restoration efforts, **watershed-scale restoration** projects should target areas that are less susceptible to climate change, e.g., sites where models suggest thermal refuge will exist in the future, and that are more likely to harbor trout and native salmonids in the future.

Erosion Control

Erosion control is critical to protecting these waterways from excessive sedimentation. Bare or disturbed ground anywhere in the watershed allows mobilization of sediment that is likely to end up in streams. Most crucial is protection of riparian vegetation.

Bridge and Culvert Design

Future increases in precipitation and flash floods should be taken into consideration when designing bridges and culverts to allow for stream movement, aquatic organism passage, and road stability. Instream barriers and poorly designed culverts can prevent migration of aquatic animals along streams, impeding them from moving freely within the stream network to find suitable habitat and from fulfilling the migration required by their specific life histories, thus fragmenting populations. Improving culverts, bridges, and other stream/road crossings can enable the watershed to handle floods and large storms and increase the connectivity of stream systems.

Translocation and Propagation

Developing techniques for propagation of species–particularly those that are rare, at high risk of extinction or extirpation, and are difficult to maintain in a laboratory setting–is critical for preserving those species and their genetic stock. Propagation facilities can serve as gene banks for aquatic species. Translocation, or moving aquatic species, can involve reintroduction of species or augmentation – adding individuals to an existing population. This technique can be useful for rare species populations that are too sparse for successful reproduction in the wild.

Restoration of populations to places where they have been lost but which remain or have returned to suitable habitat can improve resilience to a species as a whole. Augmentation and reintroduction are techniques that have been and are currently being used, for example, in areas where there have been significant improvements in water quality or available habitat and species are either slow to or unable to recolonize the area on their own. Refinement of these techniques and careful monitoring of habitats that may worsen or improve over time will allow for successful intervention and the possible continuation of a full suite of aquatic species.

Submerged Aquatic Vegetation (Seagrass and Underwater Grass)

Impact Summary

North Carolina is home to the largest and most biodiverse Submerged Aquatic Vegetation (SAV) resource on the Atlantic seaboard and the second largest in the continental U.S (Figures 5F–11 and 5F–12, and Table 5F–4). Submerged aquatic vegetation is the foundation for ecological services that directly benefit coastal communities.[11] These services include primary production, habitat for aquatic species, shoreline and sediment stabilization, water purification, and carbon sequestration. Many organisms use SAV for refuge, spawning, forage, and nursery areas. Submerged aquatic vegetation is designated as Essential Fish Habitat by the South Atlantic Fishery Management Council for some important fisheries species, including penaid shrimps, and species in the snapper-grouper complex. Red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*) and blue crab (*Callinectes sapidus*) are also highly dependent on

[11] NCDEQ (Department of Environmental Quality). 2016. *North Carolina Coastal Habitat Protection Plan*. North Carolina Department of Environmental Quality, Raleigh, NC

SAV, and bay scallops occur almost exclusively in SAV beds. It has also been shown that SAV may reduce bacterial pathogens in the water column that can cause disease in humans and marine organisms.[12] Submerged aquatic vegetation provides ecosystem services that make habitat protection and restoration a priority in terms of its contribution to coastal resilience as well as economic and cultural values.[13]

Figure 5F–11. Submerged aquatic vegetation, also known as seagrass and underwater grass (photo credit: Casey Knight).

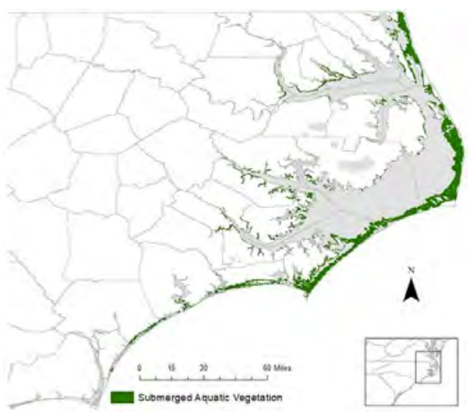

Figure 5F–12. Submerged aquatic vegetation (SAV), also known as seagrass or underwater grass, mapped at different points in time from 1981 to 2015. These delineated areas represent current and historic SAV habitat.

[12]Lamb, J. B., Van De Water, J. A., Bourne, D. G., Altier, C., Hein, M. Y., Fiorenza, E. A., … & Harvell, C. D. (2017). *Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates*. Science, *355*(6326), 731-733.
[13] Ibid

Table 5F–4: State-owned assets with Submerged Aquatic Vegetation (SAV), also known as seagrass or underwater grass.

State-owned Asset Name
Alligator River Game Land
Bald Head Island State Natural Area
Big Foot Island
Browns Island
Bull Neck Swamp
Buxton Woods Coastal Reserve
Carteret County Game Land
Currituck Banks Component of the North Carolina National Estuarine Research Reserve
Currituck Banks Game Land
Emily and Richardson Preyer Buckridge Coastal Reserve
Fort Fisher State Recreation Area
Fort Macon State Park
Goose Creek Game Land
Goose Creek State Park
Gull Island Wildlife Conservation Area
Gull Rock Game Land
Hammocks Beach State Park
Jockeys Ridge State Park
Kitty Hawk Woods Coastal Reserve
Masonboro Island Component of the North Carolina National Estuarine Research Reserve
NC Department of Transportation Mitigation Site
NC Division of Energy, Mineral, and Land Resources Easement
NC Submerged Lands
New River Inlet Islands
North River Game Land
Oregon Inlet/Roanoke Sound Islands
Port of Morehead City
Rachel Carson Component of the North Carolina National Estuarine Research Reserve
Roanoke Island Festival Park
Theodore Roosevelt Maritime Swamp Forest Unique Wetland
Theodore Roosevelt State Natural Area
White Oak River Game Land
Zekes Island Component of the North Carolina National Estuarine Research Reserve

Figure 5F–13: Submerged Aquatic Vegetation (SAV) in Carteret County (top) and Dare County (bottom) (photo credit: RK&K).

Two types of SAV ecosystems are found in North Carolina. One group includes underwater vascular plants that thrive in low salinity riverine waters, which are referred to as underwater grass, and a second group occurs in high salinity waters of the bays and sounds, which are referred to as seagrass. The two groups are distinguished by different species composition and living requirements. What distinguishes North Carolina from other coastal seagrass systems on the Atlantic seaboard is the overlapping distribution of temperate and tropical seagrasses in the higher salinity waters: eel grass (*Zostera marina*), a temperate grass at the southernmost extent of its range, and tropical shoal grass (*Halodule wrightii*) at the northern most extent of its range.

Submerged Aquatic Vegetation occurs in subtidal, and occasionally intertidal, areas of sheltered estuarine and riverine waters where there is sediment, adequate light reaching the bottom, and moderate to negligible current velocities or turbulence (Figure 5F–13). The primary factors controlling SAV distribution are water depth, sediment composition, energy, and the penetration of light through the water column.[14] Most seagrass habitat in coastal North Carolina occurs along the Outer Banks estuarine shoreline (Pamlico and Core/Bogue sounds), with sparse coverage along the mainland shores. Estuarine SAV occurs to a smaller extent south of Bogue Inlet to the South Carolina border. Waterbodies documented to support seagrass include: New River, Alligator and Chadwick bays, Stump and Topsail sounds, and areas along the Intracoastal Waterway and marsh creeks through northern New Hanover County.

As the system changes from open sound to riverine, low salinity SAV is abundant in larger blackwater systems, but rare in small blackwater streams due to irregular flows and shading from forested wetlands. Low salinity SAV can be extensive in low-salinity back bays and lagoons, such as Currituck Sound, and in coastal lakes such as Lake Mattamuskeet.

Due to its stringent water quality requirements and sensitivity to physical disturbance, SAV, (also known as seagrass and underwater grass) can be considered a "canary in the coal mine" serving as bioindicator of the overall health of our coastal ecosystems. Nutrient and sediment runoff increases with land use change in and adjacent to wetlands. Runoff can reduce water clarity, thus reducing light availability. Nutrients

[14]Thayer, G.W., Kenworthy, W.J., & Fonseca, M.S. (1984*). Ecology of eelgrass meadows of the Atlantic Coast: a community profile.*
Biber, P. D., Gallegos, C. L., & Kenworthy, W. J. (2008). Calibration of a bio-optical model in the North River, North Carolina (Albemarle–Pamlico Sound): A tool to evaluate water quality impacts on seagrasses. *Estuaries and Coasts*, *31*(1), 177-191.

can favor growth of algae and plants that outcompete seagrasses. Physical disturbance from construction, shoreline hardening, some aquaculture practices, and propeller scarring from boat traffic can cause uprooting, increased sedimentation, and over-shading, all of which contribute to the loss of SAV habitat. **Extreme rainfall, flooding,** increasing water temperatures, increasing salinity, and flow changes could further degrade environmental conditions favorable for SAV. Water quality degradation, given expected increases in **extreme rainfall events** and **flooding** associated with climate change, could be catastrophic to the future of SAV and the marine organisms that use them in North Carolina.

Vulnerabilities and Risk

In the U.S., SAV along the Atlantic seaboard has experienced significant declines directly or indirectly attributed to the stressors associated with degraded water quality. Submerged Aquatic Vegetation is especially sensitive to water quality impairment from nutrient and sediment pollution associated with land use, including urbanization, agriculture, and forestry. Due to its stringent water quality requirements, the presence of SAV is considered a barometer of water quality and serves as a valuable bioindicator of the overall health our coastal ecosystems. Conversely, the impairment of water quality is one of the most widespread threats to SAV ecosystems, with global losses estimated at over 29% during the last century. [15]

The majority of SAV loss can be attributed to large-scale nutrient enrichment and sedimentation, which reduces light penetration to the leaf. Nutrient enrichment and/or increased sediment loads affect light for SAV by:

- Reducing water clarity with suspended sediment or phytoplankton associated with algal blooms,
- Increasing epiphytic growth, sedimentation, drift algae coverage,
- Diminishing dissolved oxygen concentrations as photosynthesis from SAV beds decreases, coupled with increasing concentrations of hydrogen sulfide, resulting in toxicity.[16]

[15]Orth, R. J., Bieri, J., Fishman, J. R., Harwell, M. C., Marion, S. R., Moore, K. A., ... & Van Montfrans, J. (2006*). A review of techniques using adult plants and seeds to transplant eelgrass (Zostera marina L.) in Chesapeake Bay and the Virginia Coastal Bays*. In Proc. Conf. Seagrass Restoration: Success, Failure, and the Costs of Both. March 11, 2003. Sarasota, Florida (pp. 1-17).
Waycott, M., Duarte, C. M., Carruthers, T. J., Orth, R. J., Dennison, W. C., Olyarnik, S., ... & Kendrick, G. A. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the national academy of sciences*, *106*(30), 12377-12381.
Lefcheck, J. S., Orth, R. J., Dennison, W. C., Wilcox, D. J., Murphy, R. R., Keisman, J., ... & Patrick, C. J. (2018). Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region. *Proceedings of the National Academy of Sciences*, *115*(14), 3658-3662.
[16]Greening, H., Janicki, A., Sherwood, E. T., Pribble, R., & Johansson, J. O. R. (2014). Ecosystem responses to long-term nutrient management in an urban estuary: Tampa Bay, Florida, USA. *Estuarine, Coastal and Shelf Science*, *151*, A1-A16.
Ruhl, H. A., & Rybicki, N. B. (2010). Long-term reductions in anthropogenic nutrients link to improvements in Chesapeake Bay habitat. *Proceedings of the National Academy of Sciences*, *107*(38), 16566-16570.

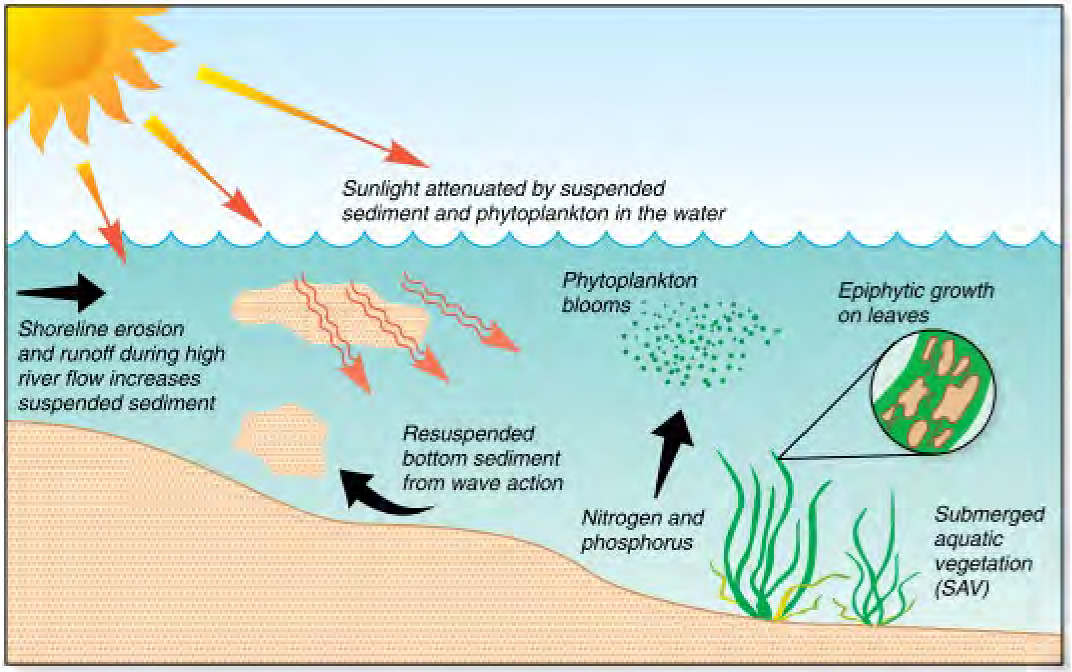

Figure 5F–14: Increased precipitation related to climate change impacts submerged aquatic vegetation (SAV) by increasing shoreline erosion, sedimentation and nutrient-rich runoff (and accompanying algal blooms), and epiphytic growth, all of which can affect the amount of sunlight reaching the plants (figure credit: Phillips, S.W., ed., 2007, Synthesis of U.S. Geological Survey science for the Chesapeake Bay ecosystem and implications for environmental management: U.S. Geological Survey Circular 1316).

Physical disturbances can directly affect SAV (Figure 5F–14); these include bottom-disturbing fishing gear, navigational dredging, dock, marina and aquaculture operation siting, propeller scarring by boats and personal watercraft, vessel wakes, mooring scars, and shoreline stabilization. Dredging causes physical loss of SAV and SAV habitat, but impacts extend beyond the dredge footprint from sloughing into the channel and sedimentation coverage on nearby SAV. Impacts from marina construction to SAV come from pile jetting/driving, shoreline stabilization, excavation, shading, wave attenuation, and construction of associated high ground facilities. Lesser recognized impacts come from associated boating activities. Some types of aquaculture for the production of oysters have been shown to impact SAV in the area through direct disturbance during placement and harvest, increased carbon content, sedimentation, and erosion, and over shading.[17] Mariculture is discussed more in section 5B.

As climate changes continue, North Carolina will continue to see **warming temperatures, rising sea levels**, and **more intense tropical storms**, which affect hydrodynamic flows as well as nutrient and carbon loading to North Carolina's coastal sounds and rivers. In turn, these will have major effects on the SAV ecosystem.

Extreme precipitation events result in flooding which leads to high loads of organic matter and organic nitrogen and phosphorus, fueling phytoplankton production and resulting in algal blooms and associated

[17] Everett, R. A., Ruiz, G. M., & Carlton, J. T. (1995). Effect of oyster mariculture on submerged aquatic vegetation: an experimental test in a Pacific Northwest estuary. *Marine Ecology Progress Series*, *125*, 205-217.

hypoxia. Runoff from agricultural fields and urban development also add to the contamination of floodwaters into the watershed. These impacts to water quality could have major detrimental effects on the SAV beds and SAV habitat in North Carolina.

If we are seeing a regime shift in storms because of rising temperatures, we can also expect to see species distribution shifts within state's SAV ecosystem and the organisms that use these SAV beds. The distribution of eelgrass could be altered, with the potential for the southern range to shift north resulting in the extinction of eelgrass in North Carolina. It has been suggested that under the current emissions scenario, it is very likely that eelgrass will be extirpated in North Carolina and the Chesapeake Bay with the new southern range as far north as Long Island Sound by 2100. Research has shown that shoal grass could possibly exist in present-day eelgrass habitat should eelgrass disappear. However, there will be a loss of overall ecosystem services from eelgrass, resulting in a loss of eelgrass-associated species diversity.[18]

The effects of the climate-change-driven shift in distribution of SAV species will affect the aquatic organisms of the coast of North Carolina that use the SAV meadows as nursery areas, refuge from predation, and for food supply. The anticipated change in species composition could indirectly affect fish populations due to limited habitat and food availability. The **change in temperatures**, **salinity**, and **ocean currents** predicted due to climate change will also have a direct impact on the fish population of the NC coast. In recent years, it has been predicted that hundreds of fish and invertebrate species will be forced to move northward by climate change.[19] The ramifications of climates change on fisheries management is discussed more in section C, Coastal Resources and Infrastructure.

Resilience Strategies

Mapping and Monitoring

Understanding the distribution and health of SAV in North Carolina is critical to understanding the dynamics of shifts in SAV species extent, distribution, and compositions. Traditionally, SAV mapping is accomplished by taking aerial photos and delineating around the SAV habitat from the photos using computer software. Randomly generated sites within the mapped area are selected to ground-truth, to confirm what the images depict, including whether SAV is present, density and species of SAV, and environmental conditions (Figure 5F–15). Routinely monitoring changes in SAV habitat of North Carolina will allow managers to see the effects of climate and non-climate stressors on the estuarine ecosystem. By monitoring and protecting this habitat, we can improve the resiliency of the entire coastal ecosystem.

[18]Wilson, K. L., & Lotze, H. K. (2019). Climate change projections reveal range shifts of eelgrass *Zostera marina* in the Northwest Atlantic. *Marine Ecology Progress Series*, *620*, 47-62.
[19] Morley, J. W., Selden, R. L., Latour, R. J., Frölicher, T. L., Seagraves, R. J., & Pinsky, M. L. (2018). Projecting shifts in thermal habitat for 686 species on the North American continental shelf. *PloS one*, *13*(5).

Figure 5F–15. Picture of submerged aquatic vegetation (SAV) and a quadrant used to collect biological information and confirm the presence of SAV in areas identified by aerial photo sampling for submerged aquatic vegetation (photo credit: Casey Knight).

Water Quality Improvements and Protection

Degraded water quality is the leading driver of SAV habitat loss. Protecting and preserving the water quality of the rivers and sounds of North Carolina will directly benefit the SAV ecosystem. Land conservation and land use planning can help prevent erosion and sedimentation, increase buffers to absorb nutrients and sediment from runoff, and decrease the amount of shoreline stabilization and hardening.

Improvements in stormwater and wastewater management can also be made to help reduce the loading rate of nutrients and sediments entering estuaries via runoff during high rainfall events. Maintaining wastewater infrastructure can prevent inflow and infiltration issues, which can lead to untreated sewage entering estuarine waters. These efforts will result in a more resilient coast not only for SAV and other aquatic ecosystems, but also for the coastal community.

Protection from Physical Disturbance

While SAV is offered some protections from physical disturbance under several state, federal, and interstate policies and plans, further protections and increased mitigation requirements for impacts to SAV beds, such as restoration efforts, could be beneficial to the SAV ecosystem and add the its resiliency and the resiliency of the coastal community.[20]

[20]Kenworthy, W. J., Fonseca, M. S., Whitfield, P. E., Hammerstrom, K., & Schwarzschild, A. C. (2000). A comparison of two methods for enhancing the recovery of seagrasses into propellor scars: mechanical injection of a nutrient and growth hormone solution vs. defecation by roosting seabirds.

4. Summary: Proposed Mitigation/Protection Strategies for all Ecosystem Groups

Recommendations for Increasing Resiliency of North Carolina's Ecosystems:

- **Increase funding for land conservation**: Land conservation can help reduce vulnerability by protecting the natural resiliency of North Carolina ecosystems and by sequestering and storing carbon to reduce greenhouse gases in the atmosphere. Conservation lands also increase the quality of life for North Carolinians by providing natural areas for recreation, hunting, fishing, and education.
- **Protect riparian habitat**: Floodplains and wetlands enhance ecosystem resilience by providing wildlife habitat and migration space, flood water storage, erosion control, bank stabilization, regulation of stream temperature, and overall protection of water quality.
- **Restore floodplains, wetlands, and coastal habitat**: Restoration planning should combine first-hand knowledge of natural resources with historical data and future flood models to target areas that will provide the most resilience for human communities and natural systems.
- **Increase land-use planning**: Green infrastructure concepts can be used to 1) design the most cost-effective strategies for conserving forests, open space, farmland, rural landscapes, park lands, and cultural sites; 2) reduce fragmentation and habitat damage caused by development and human uses of land and water; 3) increase landscape resiliency to climate-related hazards and stressors.
- **Manage stormwater**: Plan for stormwater management to reduce the rate of runoff during rainfall events, limit erosion, and decrease sediment and nutrient inputs to streams. Structures such as stormwater wetlands, bioretention cells (rain gardens), cisterns, permeable pavement, vegetated swales, and filter strips can be used as stormwater best management practices. Good housekeeping of materials stored or left in the open can also be an important stormwater management measure. Limiting the impervious surface of new structures and removing existing impervious surface area when possible is the surest way to reduce stormwater volume and allow for the natural treatment of runoff pollutants.
- **Monitor environmental variables and ecosystem response:** Monitoring will help detect change over time, provide the scientific basis for future projections, and help inform management, restoration, and conservation strategies. Monitoring is especially important for inland and coastal fisheries management, game and nongame wildlife species, and threatened, endangered, and vulnerable plants and animals.
- **Increase public awareness**. Education and outreach efforts are needed to help people understand climate hazards and how they will affect NC ecosystems, engage the population in contributing to solutions, and recruit assistance through citizen science and environmental stewardship.
- **Design bridges and culverts to allow for increased stream flow**. Bridge and culvert design should account for increases in precipitation, to allow stream movement and aquatic animal passage. Avoiding culvert failure prevents sediment input and keeps roads passable during storms. Poorly designed culverts prevent animal movement and fragment wild populations, making them more vulnerable to climate changes.
- **Increase funding for land management**. Government agencies and private landowners can enhance ecosystem resiliency through land stewardship activities that improve natural ecosystem functions and wildlife habitat. Managing with prescribed fire, removing invasive

exotic species, avoiding excessive use of herbicides and pesticides, and restoring natural forests and riparian vegetation can all help support healthy resilient ecosystems.

Ecosystems across North Carolina from the mountains to the sea are already affected by climate and land use changes that have occurred in recent decades. The most vulnerable ecosystems, i.e., ecosystems supporting a high concentration of rare species and demonstrating a low tolerance of environmental variation, are the highest priorities for conservation, planning, and adaptive management. To help bolster ecosystems' natural resilience, negative impacts from human actions should be reduced. Reducing human impacts and conserving and managing land for key ecosystems also benefits North Carolina's economy, water resources, and public health.

Health & Human Services

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G. Health and Human Services

Key Observations

- The health of the environment impacts the health of all people.
- Cumulative hazards from heat and flooding are diminishing health.
- Existing inequities in environmental health exposures are exacerbated by climate change.

Critical Impacts and Resilience Strategies

- Ongoing medical and public health services to residents are impacted.
- Increased staffing needs during hurricanes, especially for NC Emergency Operations Center, emergency shelters, coordinating emergency services, and seeking administrative waivers for benefits.
- Need additional support for North Carolina Department of Health and Human Services (DHHS) programs: Building Resilience Against Climate Effects program, Back@Home program, mold and moisture education, and infectious disease tracking.
- Strategies for creating resilience should address existing toxic exposures, such as hazardous waste and lead in water or homes, in low-income communities and communities of color.

1. Introduction to Sector

Department of Health and Human Services (DHHS), in collaboration with state and local agencies, provides essential services to improve the health, safety, and well-being of all North Carolinians. DHHS tracks prioritized public health effects of climate change (e.g., heat-related illness), provides services in response to increasing extreme weather and wildfires (e.g., staffing medical shelters, deploying mobile hospital), and continues to provide daily services in the face of climate-related disruptions.

Divisions within the purview of DHHS include Public Health; Social Services; Aging and Adult Services; Mental Health, Developmental Disabilities, and Substance Abuse Services; state-operated Healthcare Facilities; and more. In addition to DHHS, this section includes impacts to the Department of Military and Veterans Affairs (DMVA) and the Department of Environmental Quality's Division of Air Quality due to a shared focus on public health and human services.

2. Overall Exposure

Across these departments, the health and human services sector is exposed to climate-related hazards in myriad ways (Table 5H-1). Health impacts associated with climate-related changes in the frequency or intensity of extreme events such as heat, heavy precipitation and flooding, and wildfires include excess emergency department visits for injury and illness.

Some communities, such as those in the eastern part of the state, are already experiencing the cumulative impacts of climate and social stressors such as an increase in warmer night-time temperatures overnight, inadequate access to cooling, and increasingly intense precipitation and flooding incidents (Figure 5H-1).[1] Additionally, the most vulnerable residents (e.g., socially isolated, low-income earners) are

[1] Harrison, C., et al. (2011). "Because you got to have heat": The networked assemblage of energy poverty in Eastern North Carolina. *Annals of the Association of American Geographers.* Vol 101, No 4.

disproportionately impacted by increasingly frequent[2] or intense floods, hurricanes, tornados, and storm surge as a result of sea level rise.[3] Due to the breadth of health impacts of climate change, a reduction in greenhouse gas (GHG) emissions is needed immediately.[4,5,6]

The military bases located in North Carolina are major drivers in our communities, through the synergy and partnerships that have developed between local and state government, military and defense sectors, and local businesses. The DMVA owns and oversees four skilled care state veteran homes whose housing capacity is 449 veterans and spouses whose health and safety DMVA plays a role in protecting. The DMVA is committed to providing facilities to meet the needs of a growing veteran population of older adults requiring skilled care and who are often vulnerable to extreme heat and extreme weather events. Additionally, four existing state-owned veteran cemetery sites with chapels have experienced site impacts from climate-related extreme weather that jeopardize staff working conditions and grave site visitation by family and friends.

Figure 5H-1. Hurricane Florence flooding, Lumberton, North Carolina.

Several population stressors may also combine with vulnerabilities and climate hazards to worsen public health impacts from climate change. These stressors include population growth, an aging population, deteriorating critical infrastructure, and coastal development.

Age, minority and veteran status, income, and existing health conditions all influence vulnerability to climate change impacts on health:

Children

Children can be impacted by an intense storm, loss of home or possessions, and dislocation. Dislocation is an Adverse Childhood Experience, a type of adverse health impact that impacts lifelong wellness.[7] Children are also more vulnerable to extreme heat.

Older adults

Older adults, those over the age of 65, are vulnerable to extreme heat and extreme weather events due to a higher prevalence of pre-existing health conditions, social isolation, and reduced ability to physiologically respond to extreme heat.

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2 VosIzNeias. (2019). *Lumberton, NC: Flooding from Hurricane Florence swamps neighborhoods.* Accessed January 28, 2020: https://vosizneias.com/2018/09/17/lumberton-nc-photos-flooding-from-hurricane-florence-swamps-neighborhoods/.

3 National Association for the Advancement of Colored People. (2018). *In the eye of the storm* [White paper]. Retrieved January 10, 2020: https://live-naacp-site.pantheonsite.io/wp-content/uploads/2018/09/NAACP_InTheEyeOfTheStorm.pdf

4 Watts, N., et al. (2019). The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *The Lancet.* Vol 394.

5 World Health Organization. (2020). *Climate change*. https://www.who.int/health-topics/climate-change#tab=tab_1.

6 American Public Health Association. (2020). *Climate changes health: clean energy*. https://www.apha.org/topics-and-issues/climate-change/clean-energy

7 Centers for Disease Control and Prevention. (2019). *Preventing adverse childhood experiences* [White paper]. Retrieved January 26, 2020 from: https://www.cdc.gov/violenceprevention/pdf/preventingACES-508.pdf.

Low-income populations

Populations with limited financial resources are less likely to have access to adequate cooling and heating, resilient housing, medical care, and healthy food, which are all important measures of adaptive capacity in the face of climate change.[3]

Minority populations

Where North Carolinians live is based in part on historical housing policy, which means that African-Americans, Latinos, and Native Americans are more likely to live in flood plains and experience increased risk to flooding from climate change.[8]

Veterans

North Carolina has one of the largest military footprints of any state in the country, with over 100,000 active military personnel and over 730,000 military veterans. Military and defense industries are the second largest employers in our state, and the military has an economic impact of $66 billion annually. Veterans are more likely to be older, minority, and residents of flood-prone areas.[9,10]

Climate change and public health resilience are inseparable from issues of injustice and the history of inequity in North Carolina, manifesting in the proximity of residential and industrial siting in locations susceptible to flooding and other hazards. For example, landfills, toxic waste sites, and industrial livestock operations are more frequently placed near communities of color or low-income communities. Cumulative impacts of climate events make it harder for people to climb out of poverty.

North Carolina DHHS is actively preparing for climate change. Since 2010, DHHS has used the Centers for Disease Control and Prevention's Building Resilience Against Climate Effects (BRACE) framework to prioritize public health adaptation to climate change through:

- Tracking heat-related illness patterns
- Community pilot projects for adapting to increases in temperature and air quality impacts of wildfire

BRACE helps public health officials understand and document exposure and responses in a changing climate and adapt to the changing climate's impact on health.[11,12,13] Based on that work, we understand the main hazards intensified by climate change, concomitant public health impacts, population vulnerabilities, and DHHS resources that can help North Carolinians adapt. Expanding the tracking of epidemiological health impacts of climate change in North Carolina is and will continue to be important for climate change adaptation.

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[8] Kennedy, B. (2018). '*Hurricane Florence is exposing North Carolina's racial and geographic inequalities'*, NC Policy Watch, 19 September, https://libguides.ioe.ac.uk/c.php?g=482485&p=3299819.
[9] Department of Veterans Affairs. (2017). *Minority veterans report* [White paper]. Retrieved January 16, 2020 from Department of Veterans Affairs: https://www.va.gov/vetdata/docs/SpecialReports/Minority_Veterans_Report.pdf.
[10] North Carolina Department of Military and Veterans Affairs. (2020). *Military bases in North Carolina*. Retrieved January 27, 2020: https://www.milvets.nc.gov/services/military-bases-north-carolina.
[11] Sun, X., et al. (2015). Pollen concentration and asthma exacerbations in Wake County, North Carolina, 2006-2012. *Science of the Total Environment.* Vol 544.
[12] North Carolina Department of Health and Human Services. (2019). *Climate and health.* Retrieved January 27, 2020: https://epi.dph.ncdhhs.gov/oee/programs/climate.html.
[13] North Carolina Department of Health and Human Services. (2016). *North Carolina climate and health climate adaptation plan.* Retrieved February 13, 2020: https://epi.dph.ncdhhs.gov/oee/climate/ClimateAndHealthAdaptationPlan.pdf.

Table 5H-1 Exposure of health and human services functions to climate-related hazards.

Assets, Regulations, Services	Wildfire	Flooding (River and Land)	Extreme Heat	Storm Surge	Tidal Flooding	Saltwater Intrusion	Dam Failure	Landslides
Health and Human Services								
Population Exposure	*	*	*	*	*	*	*	*
Vulnerable Populations: Children, Older Adults, Low-Income, Minority, Veterans	*	*	*	*	*	*	*	*
Health Service Infrastructure	*	*	*	*	*	*	*	
First Responders, Town Staff, Environmental Health Specialists	*	*	*	*	*	*	*	*
Toxic Waste Facilities		*		*	*	*	*	*
Livestock Waste Lagoons		*					*	
Infectious Disease Management		*		*				
Sewage		*		*	*			
Stormwater Runoff	*	*		*	*			*
Indoor Air Quality	*	*	*	*	*		*	
Outdoor Air Quality[14]	*	*	*	*	*			

In the following section, we provide additional detail about some of the impacts, vulnerabilities, risks, and strategies for resilience so that the state can meet its responsibilities for health and human services in the face of climate change.

3. Examples of Impacts, Vulnerability, and Risk

Outdoor Air Quality / Increased Precipitation

Impact Summary

The North Carolina Division of Air Quality (DAQ) works to protect and improve outdoor air quality by operating a statewide air quality monitoring network to measure pollutant levels, implementing plans to meet future air quality initiatives, ensuring compliance with federal and state rules, and assisting and educating the public about air quality issues. The DAQ air quality assets sensitive and vulnerable to climate stressor impacts range from a variety of support services to physical ambient air monitoring

[14] Flooding and storm surge impact DAQ's physical assets that work to monitor and protect outdoor air quality.

stations. There are various competing factors influencing air quality in addition to climate change impacts, including, changes in air pollutant emissions, changes in meteorology and land use, population growth, economic growth, and federal air quality standards. Despite this complexity, there are several DAQ service and physical assets likely to experience increased impacts under changing climate conditions discussed in the Fourth National Climate Assessment, Volume II for the southeastern United States and the North Carolina Climate Science Report Findings presented in this report.[15] These assets include planning services, ambient monitoring, and wildfire services.

Vulnerability and Risk

Planning Services

DAQ provides air quality planning services to support protection of public health through air quality implementation plans, rulemaking services, and through communication of current and future air quality impacts to the public. These planning services were evaluated for vulnerabilities to air quality impacts from 1) temperature and precipitation changes and 2) droughts.

Temperature and Precipitation Changes

Based on the North Carolina Climate Science Report findings, near-surface ozone concentrations tend to increase with temperature. However, changes in other climate conditions, such as increased precipitation, can counteract the temperature effect. Overall, it is uncertain what the net effect will be. Thus, there is low confidence concerning future changes in the conditions favorable for near-surface ozone concentrations. While there are projected future increases in non-climate stressors such as popoulation and economic development in North Carolina, continued advances in technology and health protective regulatory frameworks are expected to offset those factors. That, coupled with the uncertainty and the numerous competing meteorological factors under future climate change scenarios leads to a conclusion that the risk to ozone and air quality planning services due to climate change alone is considered low.

Drought

The North Carolina Climate Science Report findings states that it is likely that future major droughts in North Carolina will be more severe because of higher temperatures that will increase evaporation rates. As a result, it is likely that the climate conditions conducive to wildfires in North Carolina will increase in the future. Since rainfall is one of the primary mechanisms for removing $PM_{2.5}$ from the air, $PM_{2.5}$ concentrations can be impacted during droughts. It is not clear that the increasing intensity of droughts due to climate change will lead to significantly increasing the concentration of $PM_{2.5}$. However, it is reasonable to anticipate some occasional, localized increases in particulate matter emissions generated from activities such as construction, agriculture, road travel, quarrying, and wind-blown dust. An increase in particulate matter negatively impacts public health, especially populations sensitive to respiratory issues. In addition, workers in certain economic sectors such as agriculture, construction and mining, are at higher risk for exposure to elevated concentrations of particulate matter during periods of drought.[16]

Monitoring Services

The DAQ manages ambient air quality monitoring equipment located throughout North Carolina to meet federal National Ambient Air Quality Standards (NAAQS) and to protect public health. The equipment and monitoring services located in the coastal plain are vulnerable to climate stressor impacts including

[15] Fourth National Climate Assessment, Volume II (Chapter 19, Key Message 1, Air Quality and Human Health, p755

[16] Fugitive dust mitigation is often required to protect workers in these sectors.

sea level rise and other coastal flooding events (e.g., hurricanes, storm surges and king tides). For example, before Hurricane Florence landfall near Wilmington in September of 2018, hundreds of thousands of dollars in ambient monitoring equipment had to be shut down and evacuated from ambient monitoring stations located in the coastal plain around Wilmington. This effort cost DAQ hundreds of man-hours and increased risks to personnel during both the shutdowns and re-starts of this very expensive scientific monitoring equipment at these coastal stations. What's more, valuable air quality monitoring data was missing for several days from these shutdown stations leading to failed third quarter completeness requirements for the year 2018, which in turn negatively affects annual data completeness requirements. These completeness requirements enable the agency to demonstrate compliance with the NAAQS and maintain the attainment status for the counties in southeastern North Carolina.

Wildfire

Smoke from wildfire is the chief driver of fine particulate matter during wildfire events. They can occur in areas with high numbers of residents with asthma, diabetes, and cardiovascular conditions that place them at higher risk for adverse health effects from smoke exposure. The DAQ prepares and communicates wildfire air quality forecasts to first responders, local governments, and the general public. Climate change impacts in the form of an increased frequency and intensity of weather events, including but not limited to droughts, heat waves and wildfires, raises the potential for a growing threat of wildfire smoke posing a public health and safety risk. A non-climate stressor to wildfire is the increase of wildland urban interface (where homes meet woodland), currently estimated at 13.5 million acres (See Section 5.B Agriculture and Forestry). The number, size, and location of fires and the ability of the NCFS to respond to these fires also affect the air quality and public health impacts of wildfires. In 2017, the Division of Public Health and its partners developed a smoke vulnerability map for North Carolina as well as an elementary education program on wildfire prevention and health-related impacts.[17]

Pollen

The DAQ prepares and communicates pollen counts as part of the air quality forecasting services. The fast growth rate of urban areas in North Carolina contributes to aeroallergens, which are known to aggravate respiratory diseases such as asthma. Urban areas have higher concentrations of CO_2, which causes allergenic plants, such as ragweed, to grow faster and produce more pollen than in rural areas. Higher temperatures and atmospheric CO_2 levels are projected to further contribute to aeroallergens in cities.

Resilience Strategies

Air Quality Planning

The DAQ must continue to review research and modeling efforts to quantify the expected changes in regional meteorological parameters influencing ozone and $PM_{2.5}$ formation under various climate change scenarios. In addition, DAQ should review current $PM_{2.5}$ attainment status of various regions and how that status might be impacted by more intense drought conditions. For the regions that potentially have impacts, DAQ should review how the current implementation plans would lower concentrations of PM in these regions in the event of an exceedance. Lastly, DAQ should develop education and outreach materials to protect outdoor workers and others who may be exposed to localized high levels of particulate matter during droughts.

[17] https://epi.dph.ncdhhs.gov/oee/climate/SmokeIMSNorthCarolinaExecutiveSummary.pdf

Air Quality Monitoring

DAQ should continue to evaluate all ambient monitoring sites located in low drainage areas and where needed elevate the sites to minimize potential damage from water intrusion and/or potentially relocate the monitoring site to a higher elevation. DAQ should also develop and maintain a staffing and resource plan for securing monitoring sites and equipment in the event of extreme weather taking into account the possibility of prolonged shutdown of sites and/or equipment due to extreme weather.

Wildfires

The DAQ should ensure adequate staff and resources are available to monitor, forecast, and communicate air quality impacts from wildfires. This may include developing a program to share air quality staff and resources with other states, similar to state forest fighting services, to respond to these events. North Carolina currently allows controlled, also called prescribed, burning to manage habitat, agricultural productivity, and to reduce the amount of fuel available in forests and other fire-sensitive ecosystems. While this activity significantly reduces the risk of wildfires, it also produces smoke, but its effects can be mitigated to occur on days with less impact to air quality and communities. The DAQ currently works with a variety of stakeholders in order to ensure prescribed fires are conducted when conditions are favorable for dispersion of smoke. See Section 5B: Agriculture and Forestry for more information on resilience strategies for wildfires.

Human Services / Hurricanes and Flooding

Impact Summary

Climate change-intensified hurricanes and flooding have a tremendous cost to DHHS. Table 5H-2 demonstrates the cost of Hurricane Matthew – over $700,000 in unbudgeted labor expenses among nearly 1,500 staff that contributed approximately 23,000 overtime hours. Unbudgeted labor expenses impacts meeting the DHHS mission.

Table 5H-2: Hurricane Matthew labor hours and costs (2016).

Hurricane Mathew	Staff	Overtime Hours	Cost
State Medical Support Shelters	28	1,343	$44,833
Div of Public Health	40	547	$30,590
Div of Social Services	9	536	$22,139
Div of State Operated Healthcare Facilities	1398	20,349	$636,371
Office of Public Affairs	6	78	$3,272
Admin			$5,950
Totals	**1481**	**22,853**	**$743,155**

Hurricanes Matthew and Florence brought record rainfall and flooding that challenged communities in southern and eastern North Carolina (Table 5H-2).[18,19] The health issues among affected residents included: physical, mental, emotional trauma from the incident or the recovery; injuries from the flooding or clean-up; loss of housing; damage to housing that resulted in lasting poor indoor air quality; loss of classroom instruction time; degradation of community and cultural resources; and water contamination. During hurricanes, DHHS mobilizes a coordinated response based on the event, with an incredible breadth of services provided across the state.

Vulnerability and Risk

Human Services

Divisions across DHHS currently engage on many levels to respond to extreme events such as Hurricane Matthew. These activities can be considered part of the state's adaptive capacity as it exists today.

During a hurricane, the DHHS Division of Public Health staffs the State Emergency Operations Center and deploys and staffs the mobile hospital to affected areas. Public Health supports local and federal response teams and staff emergency shelters including deploying nurses.

The Divisions of Health Services Regulation, Public Health, and Social Services recruit and assemble volunteer teams of Environmental Health Specialists to conduct site visits of food, lodging, and institutions; other food establishments; private septic systems and private drinking wells and support mosquito abatement initiatives in impacted counties. These Divisions together also distribute Naloxone kits to shelters, call nursing and adult care homes to activate emergency plans, work with counties and other partners to ensure shelters are accessible and supportive of those with behavioral illnesses or intellectual and developmental disabilities. Divisions also ensure behavioral health providers and other resources are available in shelters and communities for those who need it.

These Divisions alert local emergency management of Medicaid beneficiaries who use medically necessary medical equipment that requires electricity. These Divisions seek federal waivers to allow for Medicaid flexibility; early refills of prescriptions; Special Supplemental Nutrition Program for Women, Infants, and Children and distribute Disaster Electronic Benefit Transfer cards. Finally, these Divisions secure assistive technology devices and equipment to help individuals who are displaced due to the storm or who have devices or equipment that is destroyed or lost.

The ***Division of Health Services Regulation*** works with local and federal response teams, serves as command and control/state liaison during the incident and staffs regional coordinating centers. Health Services Regulation also reviews requests from licensed facilities seeking temporary waivers of state rules to allow facilities to provide temporary shelter.

The ***Division of Social Services*** coordinates with Federal Emergency Management Agency to canvas neighborhoods and support impacted residents, issue disaster food stamps, and provide local agencies with resource referrals. Social Services also supports the needs of residents in state operated facilities directly impacted by storm related flooding. Social Services ensures continued safety of children in the child welfare system and track any displaced children in foster care. This division also determines the status of services and needs of older adults, including meal provision.

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[18] National Weather Service. (2017). *Hurricane Matthew in the Carolinas: October 8, 2016*. Retrieved January 27, 2020: https://www.weather.gov/ilm/Matthew.

[19] National Weather Service. (2019). *Hurricane Florence: September 14, 2018*. Retrieved January 27, 2020: https://www.weather.gov/ilm/HurricaneFlorence.

The ***Office of Rural Health*** monitors status of safety net providers and assists with accessing generators and medications.

The ***Department's Division of Behavioral Health and Intellectual and Development Disabilities*** manages the Hope 4 NC Program, providing crisis counseling services to Hurricane Florence survivors in 28 counties. The goal of this program is to help people learn coping skills and strategies to reduce the trauma, loss and stress they experience from the storm and employ an on-the-ground approach to crisis counseling. A total of 267,863 individual survivors have been served through Hope 4 NC since September 14, 2018. More than 10% of the total population in the 28 most impacted counties have received Hope 4 NC crisis counseling services; 38,812 individuals were referred for more intensive community services, including health, behavioral health and disability services. Thousands more have benefited through collective impact of community engagement, social media and printed information shared widely.

Individuals in nursing homes, adult care homes, older adults, and those with disabilities are disproportionately impacted. Behavioral health services (mental health and substance abuse) to individuals and communities are impacted, as are state operated facilities for individuals with mental health and developmental disabilities. Services to residents are provided in a decentralized manner through local/regional health departments and departments of social services, as well as Local Management Entity/Managed Care Organizations for Behavioral Health and numerous non-governmental agencies through grants and contracts.

Hurricane-associated Health Impacts

Climate change intensified the heavy precipitation and associated flooding the state experienced during Hurricanes Matthew and Florence, increasing population exposure to dangerous conditions, particularly among vulnerable residents.[20] Young children and infants have higher sensitivity to flooding. Any extreme weather event that delays education or impacts the overall health of caregivers also impacts children.

Climate change-intensified precipitation events are playing out across the world. Migrating populations to NC from the US and around the world will stress our public health and human services resources.

Record-level flooding brought on by Matthew and Florence disrupted housing, provision of government services and access to health support services. Unmet needs for sheltering during Hurricane Florence were apparent among those living with disabilities, people with functional and access needs or persons with existing health conditions.

Hurricane-associated injuries, illness, and mental stress among residents of impacted areas were especially prevalent among veterans and their civilian families. Reduced indoor air quality from flooding, and subsequent mold and moisture, is a threat to those living in substandard housing. Poor indoor air quality and moisture/mold have been a problem for many veterans throughout the state and more recently reported at some military installations. DMVA staff spend a large amount of time responding to extreme weather events.

The impacts of these hurricanes were distributed inequitably. Historical housing policies resulted in disproportionate impacts based on race and ethnicity, placing minority and low-income communities in floodplains and in substandard housing. The burden of multiple flooding incidents, disproportionate numbers of housing in floodplains, and existing environmental injustice weighs heavily on some

[20] Reed, et al. (2019). Forecasted attribution of the human influence on Hurricane Florence. *Science Advances*. Vol 6, No 1.

communities of color and low-income communities. Figure H-1 highlights Hurricane Florence flooding in Robeson County, the home of the Lumbee tribe. For example, those living near existing industrial livestock operations experienced groundwater contamination due to flooding.

Resilience Strategies

Reducing inequity to all environmental hazards will increase communities' resilience in the face of climate change-intensified precipitation. For example, preventing pollution in communities of color and low-income communities will minimize exposure and increase these communities' abilities to regenerate after hurricanes and flooding. Incentivizing housing integration across race, ethnicity, and income, as well as reducing substandard housing, will reduce exposure to floods and poor indoor air quality resulting from flooding. Providing information on minimizing effects of moisture and mold will help those in housing with lasting flooding impacts.

Disaster Recovery Programs. One ongoing program, the Back@Home initiative, helps vulnerable residents secure housing, an important need post-hurricane. Funding the Back@Home initiative at a higher level will help those living with housing insecurity caused by climate change-intensified hurricanes. The additional funding would provide more affordable housing units for those currently displaced and would prepare for housing impacts of future storms.

Adequate social services for navigating recovery are needed, as navigating recovery services requires significant resources of time, energy, and money. Without adequate support, residents will be unable to utilize government services to support health and recovery post-hurricane.

Renewable energy and microgrids will provide resilient energy infrastructure to support communities and protect health during hurricanes. Examining the viability and benefit of microgrids in health care and emergency facilities located in storm-prone areas may more quickly restore vital services and contribute to on-going clean low-cost energy generation, providing more continuous care for those people with functional and access needs or persons with existing health conditions.

Heat

Impact Summary

The entire state is experiencing more frequent extreme heat, high heat days, higher nighttime temperatures, and more prolonged periods of high heat. From 2009-17, there has been an overall increase in emergency department visits due to heat-related illness (Figure H-3).[21] Pregnant people and children experience disproportionate impacts, as extreme heat is associated with an increased risk of preterm birth.[22,23] Those who cannot avoid exposure to the heat, such as outdoor workers and those who cannot afford adequate cooling are also at increased risk for heat exposures. Rising heat and poor air quality have disproportionate impact on maternal and infant mortality, young children, and older adults.

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[21] Hawaldar K, et al. (2019). *Changes in the Distribution of Heat-Related Illness Emergency Department Visits – North Carolina, 2009-2017.* Presented at Council of State and Territorial Epidemiologists, 2019.
[22] Centers for Disease Control and Prevention. (2019). *Preterm birth*. Retrieved January 29, 2019: https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pretermbirth.htm.
[23] National Institutes of Health. (2016). *Extreme temperatures could increase preterm birth.* Retrieved January 29, 2019: https://www.nih.gov/news-events/news-releases/extreme-temperatures-could-increase-preterm-birth-risk

Vulnerability and Risk

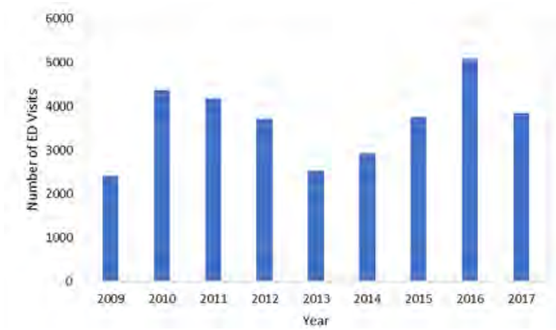

Figure H-3: Number of Heat-Related Illness Emergency Department Visits by Year, 2009-2017.

Access to a few hours of cooling during high temperatures helps reduce the likelihood of heat-related illness. However, many residents cannot afford to cool their living places because of low-income levels and inefficient or substandard housing. Poverty limits residents' access to adequate cooling. Improving substandard housing and providing the ability to cool off for several hours daily during high temperatures protects health in the face of increasing temperatures. Older adults are at increased risk for heat-related illness due to social isolation, decreased ability of the body to cool itself, and potentially fixed or limited income.

Resilience Strategies

Expanding energy efficiency and renewable energy programs specifically targeted at underserved markets and low-income communities will allow communities to regenerate in the face of higher temperatures. Improving housing and access to adequate cooling will also help communities adapt.

Infectious Disease / Changing Weather Patterns

Impact Summary

Infectious diseases sensitive to changing weather patterns are present in North Carolina. A general increase in reported cases of vibriosis, typically manifesting as gastrointestinal illness, has been documented in the state. Similarly, increases in reported cases of *Legionellosis* have been documented throughout the United States.[24] Historically, North Carolina has had a high burden of tick and mosquito-borne diseases.

Vulnerability and Risk

Increased surface water temperatures and salinity can increase the abundance and exposure risk from *Vibrio vulnificus*.[25] Legionellosis is a temperature and precipitation sensitive respiratory illness that can be severe. The severity of resulting respiratory infections, and an increasing aging population at risk, make it imperative to increase our ability to prevent, detect and respond to waterborne infections including vibriosis, Legionnaires', and primary amoebic meningoencephalitis (very rare disease that is climate-dependent). Further, climate change may allow for the expansion of disease-causing ticks and mosquitoes or may allow for the introduction of non-native ticks and mosquitoes.[26,27,28]

[24] Rubin, R. (2018). Why are Legionnaires Disease diagnoses becoming more common in the United States? *Journal of American Medical Association*. Vol 319 Issue 17.
[25] Deeb, R., et al. (2018). Impact of climate change on *Vibrio vulnificus* abundance and exposure risk. *Estuaries Coast.* Vol 41 Issue 8.
[26] Githeko, A., et al. (2000). Climate change and vectorborne diseases: a regional analysis. *Bulletin of the World Health Organization.* Vol 78 Issue 9.
[27] Kilpatrick, A., et al. (2008). Temperature, viral genetics, and the transmission of West Nile virus by Culex pipens mosquitoes. *PLoS Pathogen*. Vol 4 Issue 6.
[28] North Carolina Department of Agriculture and Consumer Sciences. (2018). *Longhorned tick found in Polk County.* Retrieved January 29, 2020: http://www.ncagr.gov/paffairs/release/2018/LonghornedtickfoundinPolkCounty.htm

Resilience Strategies

Enhanced and Ongoing Surveillance

It will be imperative for public health to develop and maintain comprehensive tick and mosquito surveillance, and to increase its ability to prevent, detect, and respond to waterborne infections.

4. Summary

The health of our environment and the health of North Carolina residents are directly linked (Table 5H-3). The connection between weather and health is established, and changes to weather patterns from climate change will unequivocally impact health. Air pollution, rising heat, and flooding events affect vulnerable populations. During events, staff are deployed to emergency operations and this impacts the entire department. A summary of proposed strategies to protect public health amidst a changing climate follows:

- Reduce Earth-warming air pollution. Reduces smoke exposure to sensitive populations.
- Reduce pollution in communities of color and low-income communities.
- Incentivize housing integration. Reduce substandard housing. Increase access to cooling.
- Increase social and behavioral health supports in vulnerable communities.
- Expand energy efficiency and renewable energy programs specifically targeted at underserved markets and low-income communities
- Deploy micro-grids of solar arrays with battery back-up in hurricane-prone areas to provide power after storm events, reduce overall operational energy costs, increase usage of renewable energy sources, and decrease carbon emissions.
- Support the Building Resilience Against Climate Effects program and expand the tracking of epidemiological health impacts of climate change in North Carolina.
- Invest $16 million in Back@Home initiative.
- Provide information on minimizing effects of moisture and mold.
- Offer adequate social services support to North Carolinians navigating the multitude of government processes during recovery.
- Examine the viability and benefit of microgrids in health care and emergency facilities located in storm-prone areas to more quickly restore vital services and contribute to on-going clean low-cost energy generation

Table 5H-3: Resources Needed to Address Prioritized Public Health Impacts.

Climate Hazard	Public Health Impact	Populations of Concern	DHHS Resources Needed
Wildfires	Decreased air quality, respiratory illnesses	Persons with existing health conditions, children, older adults, pregnant women, disabled veterans	Continued staffing and support resources to develop DAQ air quality forecasts (see Section 5.B Agriculture and Forestry for other needs)
Flooding	Injuries, exposures to floodwater (toxic substances, animal waste, sewage), contaminated drinking water, property damage, infectious disease, crop loss, mold/endotoxins, gastrointestinal illnesses	Persons living in the flood plains, low income persons, minority populations, veterans	Reducing pollution in communities of color and low-income communities Provide information on minimizing effects of moisture and mold
Increased Frequency and Intensity of Hurricanes	Injuries, loss of housing and essential health services, displacement, mental and psychological impacts	Low income earners, minority populations, persons with functional and access needs, children, persons with existing health conditions, first responders, veterans	Increase Back@home funding Incentivize housing integration, reduce substandard housing Offer adequate social services support to North Carolinians navigating recovery
Extreme Heat	Heat related illness, respiratory diseases such as asthma, allergies, cardiovascular disease	Farmworkers and other outdoor workers, children, low income persons, minority populations, pregnant women, veterans, those living in mobile homes	Improving housing and access to adequate cooling Renewable energy resources to reduce utility costs of low-income families and maintain power during emergency events.

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Housing, Buildings & Support Services

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H. Housing, Buildings, and Support Services

Key Observations

- Critical infrastructure and cross-agency assets make this sector important but difficult to prioritize.
- Need to have detailed, quantified risk assessments at a local level.

Critical Impacts and Resilience Strategies

- Flooding is the biggest hazard.
- Aging infrastructure is vulnerable, so many solutions will be costly and take time to implement.
- State-managed recovery is an immediate and growing need which shows that building resilience is important to reduce recurring impacts.
- Meet the growing demand of housing for veterans. Promote building resilience strategies for vulnerable VA hospitals.
- Waste management and its planning are important prior to and after any damage caused by environmental impacts.

1. Introduction to Sector

The Housing, Buildings, and Support Services Sector is made up of those agencies within the Department of Commerce, Department of Environmental Quality, Department of Public Safety, Department of Administration, Department of Military and Veterans Affairs, and Department of Information Technology that provide a broad range of diverse services to the citizens of North Carolina pertaining to the built environment.

The ***Department of Commerce, Rural Economic Development Division*** maintains business, community, and military base contacts that supports the data/communications and infrastructure for emergency management, public safety, medical facilities, communications, and non-government emergency services.

The ***Department of Environmental Quality (DEQ)*** manages permitting, inspections, and compliance enforcement for solid waste management and hazardous waste facilities. The DEQ directly manages the public water supply, industrial water supply, and agricultural water use, as well as directs the cleanup of non-permitted releases of petroleum and other hazardous substances from pipelines and storage tanks to protect the water quality. The DEQ also provides safety inspections, condition assessments, plan review approvals, and enforcement for dams across the state. The DEQ maintains regional office buildings, state-owned vehicles, furniture, field equipment, and staff to provide continuous service to all regions of North Carolina.

The ***Department of Public Safety (DPS)*** administers recovery programs for critical infrastructure managed by counties and municipalities and local governments. They also manage recovery programs for recurring pre- and post-disaster mitigation. The DPS includes the Division of Emergency Management, which provides technical and logistical support to local partners for emergency operations services before, during, and after disasters. The DPS also includes the Division of Prisons, which provides humane living conditions for incarcerated individuals. The Department of Administration (DOA) provides technical and maintenance oversight for approximately 68 buildings over 3,000 square feet in size each in Wake County.

The ***Department of Military and Veterans Affairs*** supports over 730,000 veterans. North Carolina has one of the largest military footprints of any state in the country. Military and defense industries are the second largest employers in our state, and the military has an economic impact of $66 billion annually. Veterans and immediate family of veterans are housed in the Department of Military and Veteran Affairs nursing homes facilities. The Department plans to continue to develop more homes to further support a growing veteran population of older adults. A secondary service provided to veterans includes the four existing state-owned veteran cemetery sites with chapels.

The ***Department of Information Technology*** administers data centers and communication transmission infrastructures at and for state property and buildings which support emergency management communications capabilities, public safety services, medical facilities and services communications, sensors/monitoring tools, and non-government emergency services.

The ***Department of Administration*** acts as the business manager for North Carolina state government. The department oversees Government Operations such as building construction, purchasing and contracting for goods and services, managing state vehicles, acquiring and disposing of real property, and operating auxiliary services such as courier mail delivery and the sale of state and federal surplus property.

In addition, the department provides facility services and advocacy programs. Facility services include the maintenance of state-owned buildings and grounds, and the department's advocacy programs provide advocacy, assistance and services to diverse segments of the state's population that have been traditionally underserved.

2. Overall Exposure

There are several climate stressors that are increasing vulnerability and risk to housing, buildings and support services in North Carolina. Increasing heavy precipitation, most frequently associated with tropical cyclones, is leading to more flooding and dam failure. Rising sea level is leading to increases to storm surge, coastal flooding, and saltwater intrusion. Heat waves and associated droughts are increasing in severity and frequency.

Climate Stressors

Heavy precipitation

Heavy precipitation events, especially tropical storms and its associated flooding, can cause significant damage to public and private structures in the floodplain and infrastructure such as roads, utility services, and dams. Flooding can directly contaminate source waters, resulting in drinking water service interruptions and the potential for adverse public health outcomes. Transportation infrastructure (land, air and marine-based) can be inundated and/or damaged, disrupting the movement of people and goods as well as the provision of emergency services.

Rising sea levels and accompanying storm surge

In coastal areas, sea level rise and increasing storm surge can result in damage to and loss of homes and businesses; transportation, energy, water/sewer and communications infrastructure; and other coastal structures. Rising sea level can negatively impact water supplies for municipalities and industries. There are additional vulnerabilities to public water supply associated with rising sea level including salt water intrusion that could affect water supply and quality.

Heat waves

Heat waves create higher demands for cooling and water supplies to buildings. Heat waves and high temperature days have the potential to produce significant increases in ground-level ozone, particularly for the highest-ozone events. Heat waves can also affect transportation facilities and operations, such as rail lines and associated rail passenger service.

Drought

Increased temperatures can compound the availability of water during times of drought. Reduced public and industrial water supplies can threaten public health, business continuity and employment, while reduced stream flows can reduce electric generation from hydropower projects.

Wildfires

Higher ambient temperatures in combination with declines in precipitation create the conditions conducive to wildfires. Climate projections show that the frequency of drought conditions in North Carolina will increase the risk of wildfires.

Table 5H-1. Exposure of housing, building, and support services assets and services to climate-related hazards.

Assets, Regulation, Services	Changed Seasons	Extreme Heat	Flooding (River and Land)	Inundation (includes SLR)	Landslides	Severe Winter	Storm Surge	Water Shortage (Drought)	Wildfire	Wind
Prison facilities	*	*	*	*			*	*		*
DOA-administered state buildings in Wake County	*	*	*			*		*		*
State-owned underground and above ground storage tanks			*							
Emergency management communications; DEQ/DOT Sensors/monitoring tools		*	*							
DEQ regional offices, office buildings, state-owned vehicles, furniture, field equipment, staff			*							
Regulatory oversight over public or private landfills, transfer stations, temporary disaster debris sites, solid waste management facilities			*			*				*
Regulatory oversight over the long-term cleanup of non-permitted releases of hazardous substances, support in emergency situations.			*				*			
Petroleum and hazardous substance spill response teams			*							
NIST Risk Management Framework (RMF) 800-53 Security Controls. General Statute Chapter 143B, Article 15; approvals, inspections, compliance										*

Non-climate Stressors

Non-climate stressors are also increasing vulnerability and risk to housing, buildings, and support services in North Carolina. An increasing population in North Carolina is leading to not only increased demand for water and related services but is also creating land use change and increased runoff in many areas of our state. Aging infrastructure and limited surface water storage are increasing the stress on our state's water and land resources. This issue is exacerbated by limited resources available for maintenance and replacement of growing water distribution and treatment infrastructure as well as for dams. Additionally, there is the challenge of protecting private development rights without sacrificing public trust rights and resources.

3. Examples of Impacts, Vulnerability, and Risk

Housing and Infrastructure / Inundation

Impact Summary

North Carolina's Coastal Plain counties contain a diverse mix of natural and built environments within a few feet of sea level. The risk of flooding will be highest for these low-lying areas of the state, and this threat is growing due to increases in frequency and severity of heavy rainfall events including tropical storms. The Coastal Plain typically has lower population density, but the topography is not as steep as in the Piedmont and Mountain regions, which correlates to longer periods of inundation, especially as floodwaters from inland sources make their way to the Coast.

Homes, businesses, and associated infrastructure may fail due to inundation. Water and wastewater may derive from overland (pluvial), riverine (fluvial), or man-made sources such as septic tanks, sewer lines and pump stations. Septic systems failures in poorly drained soils require alternative waste treatment systems.

Vulnerability and Risk

Rising sea level poses a significant threat to public infrastructure, public trust resources and private property and development along the coast. The consequences of inundation include loss of life, damage to property and agricultural production, and damaged infrastructure and utilities. Many homes and businesses are in low-lying areas, where they already face risk of storm-related damage. Already, shoreline erosion has required structural defense and loss of homes along the beach. Decisions will need to be made about the long-term sustainability of some communities.

Flooding risk varies by location within the state. Floodplains, are inherently susceptible to significant impacts. In the Piedmont and Mountain Provinces, historical and cultural centers are situated along watercourses, concentrated within floodplains. In the coastal region, development has occurred everywhere from the oceanfront beaches to the protected sandhills on the southern Coastal Plain, to the flatter and wetter pocosins and farmland on the northern Coastal Plain.

Development patterns are nearly as diverse as the natural environment, from modest inland cottages to oceanfront mansions to multi-million-dollar condominium towers. The diversity of coastal landscapes and development creates a high level of complexity for assessing potential risks from climate change, as well as possible strategies for adaptation.

Adding to the complexity is the challenge of protecting development without sacrificing public trust rights and resources. Beach tourism is one of the state's biggest economic engines, and commercial fishing remains an important cultural and economic activity. Public waters and beaches will be adversely impacted if the response to climate change and sea level rise are not properly managed.

Resilience Strategies

Recovery Programs

When pump stations, sewer lines, and wastewater treatment plants are inundated, the infrastructure must be replaced and the surrounding contaminated environment must be remediated. When flooding occurs and causes enough qualifying damage for federal or state disaster declarations to be approved, recovery programs may be available to repair damage not otherwise covered by flood insurance. Some programs from FEMA and CDBG-Mitigation can be used preventively on qualifying projects to anticipate and reduce flood risks.

Adaptive Development Strategies

Across the state, programs should be established to educate residents about the dangers of building within floodplains. For infrastructure components that have to be placed within the floodplain, evaluate the implications of defensible estimates of increased risks associated with changes in climate patterns. Adapt development policies and construction techniques to minimize the detrimental impacts related to increased levels of risk. The Department of Insurance's Building Code Council should reestablish the two-foot freeboard requirement for new or substantially improved buildings within the regulatory floodplain, and consider a four-foot freeboard for the twenty coastal counties regulatory floodplains. Advancing this program and securing the outstanding EAPs and Dam Safety Education is an ongoing priority and a key way to build resilience.

Risk Assessments

North Carolina will need to work with local governments to evaluate climate risks to their buildings, structures and support services. This work should consider incorporating the most current scientific and valid studies for future hurricane, flooding, and inundation risks. Local partners should also receive recommendations for cost-effective measures to improve their climate resiliency.

For the highest risk areas (i.e., the twenty coastal counties), the state should provide local governments and coastal residents information on sea level rise trends, projections, implications, and adaptation options through ongoing collaboration with federal and other state agencies and the scientific community. The Coastal Resources Commission (CRC) should provide an assessment of sea level rise to the twenty coastal counties at least every five years to include projected flood inundation in local land-use and hazard mitigation planning. Session Law 2012-202 requires the Coastal Resources Commission's Science Panel to update its 2010 report on sea level rise in North Carolina every 5 years.

The CRC's charge to the panel is to conduct "a comprehensive review of scientific literature and available North Carolina data that addresses the full range of global, regional and North Carolina specific sea level change." The CRC further directed the panel to include scenarios of sea level rise on at least a 30-year time frame, and the panel is beginning its next update cycle in 2020. The review is required to tailor its findings to consider regional trends and differences in subsidence rates along North Carolina's coast.

Because sea level rise is not uniform across the state's coastal zone, the state should support the development and dissemination of scientific data that are tailored to the different regions of the coast, and encourage coastal communities to consider regional trends and projected rates of sea level rise in hazard mitigation, local land use, and development planning.

Management of Disaster Debris / Extreme Weather

Impact Summary

The Division of Waste Management within the Department of Environmental Quality is the agency that ensures the proper management and disposal of all solid waste, including debris generated from hurricanes and floods, for the purposes of protection of public health and the environment.

Throughout the United States, managing storm-generated debris is one of, if not the highest costs, associated with storm response and recovery over the last 30 years. Therefore, having support services in place that promote pre-planning efforts and efficient and timely management of debris are essential to lowering those direct costs. The longer debris stays in communities, the more severe the economic impacts are on restoration of other public services, redevelopment, and tourism.

More frequent and severe weather events are generating larger quantities and varieties of wastes at one time, including atypical wastes for those communities' normal waste infrastructure. In addition, the wastes are being generated across multiple county areas, placing a greater emphasis on the proper and timely management of debris and the possible need for regional approaches to management.

Non-climate stressors include local development pressures (increasing or decreasing population), access to contractors and equipment to collect and manage debris, as well as proximity and transportation routes to disposal facilities and re-use markets to take the growing volumes of generated debris. Given this assortment of stresses, pre-planning efforts are even more critical. Regionally, this hazard has a greater impact and frequency on the Coastal Plain communities due to tropical cyclones, but is shared across the state in those areas that have experienced tornado outbreaks, winter ice storms, and inland flooding.

Vulnerability and Risk

Having a statewide program that can provide guidance and training, and maintaining a network of pre-approved temporary debris staging sites is critical to our local governments, businesses, and state and federal agency partners to assist in speeding recovery efforts. Often, the economic burden on the state and its communities can greatly shift if resources are not in place and procedures are not being followed in the days **before** a storm occurs. Existing adaptive capacity hinges upon pre-planning activities, including partnering with the NC Department of Transportation and Department of Public Safety – Emergency Management, FEMA and local governments across the state to provide training on proper debris management, developing policy and procedures, and discussing the implementation of strategies to assist communities in lessening their vulnerabilities and risk.

The management of storm-generated debris carries a huge cost from collection, processing and final disposition. The recovery of these costs is critical to the budgets of local governments especially those in the more rural communities. Temporary debris site approvals and compliance with state laws and rules is required by FEMA for cost reimbursement, therefore not following that process can prevent a local government from getting funding, or at the minimum, add weeks or months delay.

An often overlooked impact to the mis-management of debris is that it can lead to additional climate impacts, both short and long term, primarily from greenhouse gas emissions due to increase volume of trucks traveling in and out of already impacted communities, along with prolonged operations of heavy equipment such as loaders, grinders, etc. The division has also seen a recent increase in requests from local governments for permits to burn vegetative debris, either through open or air-curtain burners, in many cases due to delays due to widespread impacts in recent storms.

The unusually large volumes of debris generated from a hurricane could easily overwhelm the operations and capacity of a smaller local government owned landfill. In many areas in NC, landfills have closed, and daily generated waste is managed through a transfer station, shipping waste to other communities in NC and beyond. Having plans and procedures in place that allow debris to be managed separately or in alternative ways to the normal day-to-day promotes the opportunity to sort and recycle some materials lessening the impact on disposal facilities and also allows those facilities to return to normal operations sooner as waste will continue to be generated by citizens and businesses.

Managing hurricane generated storm debris in an inland county presents different challenges than the barrier island communities. Inland areas tend to have a well-maintained road system with multiple travel options and access to disposal and recycling opportunities for both vegetative and demolition wastes within the county and surrounding communities. Outer Banks communities, such as Ocracoke Island, have faced collection, storage and transportation challenges. Many areas on the island are restricted and off limits to manage debris; whereby, getting debris off the island is highly dependent on the passenger ferry system to either community to the north or to the mainland.

Resilience Strategies

The Division of Waste Management will continue to work with local, state, and federal partners to participate in and conduct training and to provide guidance via division webpages. Additionally, the division will pursue the approval of rules regarding the establishment of temporary debris sites.

The division should also work with other local, state and federal entities, and waste and recycling facilities to improve and/or develop and implement strategies that promote the proper management of storm debris and its impacts to statewide communities by:

- increasing waste segregation efforts facilitates reuse, recycling, and proper disposal of the various waste streams;
- expediting the removal of disaster-related waste from impacted communities;
- maximizing reuse and recycling opportunities available to impacted communities;
- growing waste reduction programs to maintain landfill capacity to withstand periodic influx of storm related debris;
- promote local ordinances in building practices that eliminate exposure risks resulting in less waste being generated during storm events;
- working with public and private waste management facilities to ensure their acceptance of disaster-related wastes.

Spills from Underground and Aboveground Storage Tanks / Extreme Weather

Impact Summary

The Underground Storage Section within the Division of Waste Management, Department of Environmental Quality is the agency that has statutory responsibilities to ensure petroleum releases (above and below ground) are properly cleaned up and/or restored as closely as possible to previous conditions. A regulatory function of the agency involves developing guidance, providing training to facilities, and maintaining an assessment team for identifying, logging and responding to petroleum releases.

This vital support service functions to assist local governments, businesses, and state and federal agency partners in speeding recovery efforts to return their communities to normal function. Therefore, having support services in place that promote pre-planning efforts, efficient and timely management of stabilizing and removing petroleum contamination are key to lowering those direct costs and protecting soil, groundwater and surface water within those impacted communities.

More frequent and severe weather events are generating larger numbers of individual releases, including residential heating oil tanks, oil water separators and other containment systems that are typically not associated with a high number of releases.

Vulnerability and Risk

The risks associated with degraded water quality due to storm water runoff are high due to probable health and ecosystem impacts. The growing population of North Carolina demands more drinking water. Petroleum-contaminated soil can leach into the groundwater, contaminating aquifers. Contamination can disperse wherever it remains in contact with water. Petroleum-impacted groundwater requires long-term monitoring and/or remediation systems.

The most vulnerable area of North Carolina is the Coast. The coastal region sees the most intense rainfall events and suffers from some of the most severe impacts of flooding which causes the transport of petroleum contamination via storm water runoff.

Non-climate stressors include local development pressures (increasing or decreasing population) and the accompanying increased transportation and storage of petroleum products. Regionally, this hazard has a greater impact and occurs more frequently in Coastal Plain communities due to tropical cyclones, but it is shared across the state in those areas that have experienced tornado outbreaks, winter ice storms, and inland flooding.

Resilience Strategies

The division will continue to work with our local, state, and federal partners. We will participate in and conduct training and provide current guidance on our Division webpages. To improve and/or implement strategies to properly manage petroleum storage, we propose the following:

- increase UST facility awareness and preparation prior to hurricane season;
- increase involvement in County Local Emergency Planning Committees (LEPC);
- identify unpermitted petroleum storage containers (Above Ground Storage Tanks); focused within flood zones but including all of NC facilities in an outreach program consisting of awareness and preparation prior to hurricane season

State Buildings and Facilities / Storms and Heavy Precipitation

Impact Summary

Electrical power is essential to the proper operation of all buildings. Major climate-related hazards that can shut down building electrical systems include: high winds, storms, and flooding, each of which may be associated with hurricanes and other high wind events. Ice storms and heavy snowfall may also result in loss of electrical power. Loss of electrical service in any of the downtown Raleigh complex buildings would necessitate evacuation of the building until the electrical outage is resolved. If the outage is for an extended period, below-grade spaces may need pumping if pumps were disabled during the power outage. Additionally, a waiting period may be necessary for cooling, heating, and potable hot water services to stabilize after an extended power loss.

Vulnerability and Risk

The vulnerability and risk of electrical power loss to the downtown Raleigh complex is considered low to moderate, depending on the severity and duration of the storm or flooding event. There is a low likelihood of extended electrical power loss but a moderate likelihood of temporary electrical power loss. It is likely that electrical power loss in the Raleigh complex will affect much of the downtown area in addition to the state's complex of buildings. Although we have not quantified it, the risk is growing due to increases in frequency and severity of heavy rainfall, storm and hurricane events in North Carolina.

Resilience Strategies

Emergencies related to extreme events (e.g. hurricanes) resulting in the loss of main electrical power can possibly be offset by the rental of large trailer-mounted temporary electrical generators. This option assumes that generators will be available in the quantity and electrical capacity necessary to power key buildings in the downtown Raleigh complex. Rental of temporary generators is a very expensive alternative to hardening the electrical infrastructure serving the downtown complex.

Resilience and adaptive capacity can be improved by establishing the necessary temporary electrical hookups, at predetermined locations, at all key buildings if temporary generators need to be brought in. A transfer switch will be needed at each location where a temporary generator is installed. A single point electrical hookup for all state buildings in the downtown complex is not feasible.

State Buildings and Facilities / Extreme Heat

Impact Summary

The Department of Administration, through the Facilities Services Group, provides chilled water to many state-owned buildings in the downtown Raleigh complex. Chilled water supplied to these buildings is supplied by large chillers located at two primary chilled water plants, plus smaller chillers available at several individual buildings. This chilled water is piped through numerous air handling units in the downtown complex buildings to cool the buildings in spring, summer and fall seasons. During periods of extreme heat, the ability of the chilled water system to provide adequate quantities of chilled water may cause loss of building use. Potential consequences of loss or inadequacy of chilled water capacity range from uncomfortably warm buildings to complete loss of building use due to excessive interior heat and/or humidity.

Vulnerability and Risk

Adequate chilled water system capacity currently exists to handle the summer cooling load in DOA buildings and to maintain current levels of indoor comfort if average summer temperatures increase by no more than one to two degrees Fahrenheit in the foreseeable future. It is important to note that loss of one existing chiller will lead to unacceptably high interior temperatures in DOA buildings under current climate conditions. A major non-climate stressor is the aging infrastructure of the downtown complex chilled water system.

Resilience Strategies

Funding for additional chiller capacity has been requested in order to improve system reliability if one or more chillers experience mechanical failure. It is anticipated that additional chiller capacity would be online within two years after funding is appropriated for this additional chiller capacity. Since new equipment can be brought online within two years, the DOA should be able to stay ahead of climate-related load changes assuming that funds are appropriated in a timely manner for the necessary equipment.

Information Technology / Extreme Precipitation and Flooding

Impact Summary

Information technology, including data collection resources, can be sensitive to climate-related hazards. This infrastructure supports emergency management, public safety, medical communications, and non-government emergency services. When information technology is impacted by flooding, additional sites are needed to meet operational requirements, which increases operational costs.

Vulnerability and Risk

Exposure to flooding varies by location (e.g., urban vs. rural or watershed position). Enclosed facilities are more sensitive than open ones. Those with redundant power supply have built-in adaptive capacity that others do not have. Potential consequences of flooding include loss of operations, property damage, and environmental contamination. The risk of these events needs to be calculated on a site by site basis.

Resilience Strategies

IT infrastructure may be made more resilient by installing protective bulwarks and redundant power sources. Some specific options include:

- adding green roofs to deal with rainwater and heat;
- increasing air conditioning systems that are more efficient and less dependent on fossil fuels;
- incentivizing lighter-colored roofs for data centers;
- installing devices to prevent flooding;
- raising information technology buildings near flood-prone areas.

4. Summary

North Carolina's buildings and the associated infrastructure and state services that support these physical assets are at increasing risk from climate change stressors and impacts. Historically, damage or destruction to these assets has principally resulted from flooding associated with extreme precipitation events. A warming global climate that contributes to a rising sea level will likely produce additional coastal flooding, inundation and possible destruction of these state facilities. All agencies within this sector can expect an increase in risk and damage costs to their facilities/assets, as well as the continued increases in demand for their services and higher operating costs. State managed recovery programs are facing an increasing need to enhance existing or develop new resilience strategies, and efforts to promote building resilience is important to reducing the climate change impacts.

Climate impacts will have environmental, societal, and economic consequences, and will be most severe for the coastal region of the state. However, all regions of the state will have to contend with the challenges of a warmer climate and the associated increase in frequency and severity of extreme flooding events. State programs associated with housing, buildings, and support services need to immediately start outreach and educational efforts to inform policy makers and residents about the dangers of increased flooding and avoiding increased investments within floodplains. For existing assets and infrastructure components that have limited adaptive capacity many of the solutions will be costly and take time to implement. Future assets and infrastructure need to be evaluated to consider the implications of defensible estimates of increased risks within the content of associated changes in climate patterns.

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Public Safety

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I. Public Safety

Key Observations

- A permanently funded resiliency office, requiring personnel and budget, is needed.
- Public Safety is the largest state government cabinet agency with over 25,000 employees. It manages response and recovery for climate hazards and the growing number strains resources. North Carolina is viewed as a nationwide leader for these services.
- Resilience services will require greater interagency support and resources. Operational, logistical, maintenance, and resiliency challenges are synergistic in nature. All must be simultaneously addressed.
- Correctional facilities will require substantial upgrades. North Carolina is responsible for the custodial care of more than 35,000 inmates and 200 juveniles, vulnerable groups with higher exposure and low adaptive capacity.

Critical Impacts and Resilience Strategies

- Building resilience into critical infrastructure that supports response and quality of life must be an immediate priority.
- Working with local governments to build resilience is critical but will require time to build trust, institute new policies and regulations, and properly allocate resources.
- Long-term master planning is needed to determine the most cost-effective means to address, maintain, and operate resiliency plans through their life cycles.
- New and more strategically located facilities may serve well during a natural disaster.
- Training, tabletop exercises and continuity of Operation Plans for each of our divisions need to occur on an annual basis.

1. Introduction to Sector

The ***North Carolina Department of Public Safety*** (NCDPS) is the primary state agency affected by or responsible for climate-related impacts to the Public Safety Sector. The NCDPS includes the Divisions of Adult Correction and Juvenile Justice, North Carolina Emergency Management (NCEM), North Carolina National Guard, Administration, state Capitol Police, state Highway Patrol, Professional Standards, Policy, and Strategic Planning, and the North Carolina Office of Recovery and Resiliency (NCORR). The NCDPS occupies or operates over 700 sites and 19 million gross square feet (GSF)[1] of space and 32,000 acres spread throughout the state of North Carolina.

The mission of NCDPS is to safeguard and preserve the lives and property of the people of North Carolina through prevention, protection and preparation with integrity and honor. The NCDPS goals are to strengthen the department's unity of effort as a consolidated and allied entity, to create a true culture of prevention, protection, and preparedness, and to create and maintain an environment where NCDPS employees are engaged, accountable, and recognized for the contributions they make to enhance public safety in North Carolina. NCDPS has 25,000 employees and a general fund of $2.2 billion.

NCDPS primarily provides services and enforces existing laws, regulations and rules. The primary climate change impact to NCDPS mission is in the services NCDPS provides. Climate-related impacts

[1] Franklin, C. Central Engineering. "NCDPS Asset – FTE Chart1 Derived from Department of Insurance and State Property Office Data 2018" report compiled by Central Engineering.

primarily affect Adult Correction and Juvenile Justice, Emergency Management, NC National Guard, state Capitol Police, state Highway Patrol, and the North Carolina Office of Recovery and Resiliency. Some of these services are provided to local governments (counties and municipalities), while others involve direct services provided to the public.
The only permitting responsibilities under NCDPS are related to alcohol, precious metals businesses, private protective services businesses, and alarm system licensing. The direct impact of climate change on these permitting activities is judged to be minimal. Additionally, any climate change impact on changes in criminal laws and regulations would be minimal, and NCDPS would appropriately respond to and enforce any such changes.

2. Overall Exposure

There are several factors or climate stressors that are increasing vulnerability and risk to emergency management services, NCDPS Correctional Institutions, and NCDPS employee health and safety (Table 5I-1). Given the impacts of recent hurricanes, much attention has been on the drivers of riverine and overland flooding and storm surge. A recent example just occurred in February 2020 when Neuse Correctional Institute was evacuated as a precautionary measure due to potential flooding after heavy rainfall from a strong low-pressure system with an associated cold front. In the long run, sea level rise and tidal flooding will become larger drivers of permanent land loss, potentially affecting evacuation routes. Wildfire and extreme heat will also be major concerns. Drought and water shortages will require emergency responses.

As North Carolina is a geographically and climatically diverse state with a climate already defined by extreme and changeable weather it is highly likely that the climate impacts identified in this report will exacerbate the frequency and impact of natural hazard events across all regions of the state. It is important to note that response to extreme weather events and disasters are a routine part of NCDPS mission and services.

Because of North Carolina's naturally variable climate, plans and protocols already exist for response to the existence of the natural hazards outlined in the Climate Science Report[2], including the North Carolina Emergency Operations Plan and the North Carolina Hazard Mitigation Plan. Trainings are already offered on many of these hazards across each Division, and tabletop exercises allow the testing of responses to hazard scenarios. This effort needs to be strengthened through the addition of the Department of Corrections (Prisons and Enterprise) and Central Engineering.

The overall impact of climate change will then be shifts in the frequency, magnitude, duration, or scale of the responses to hazards North Carolina already experiences. Plan and process improvements will be needed to accommodate extreme events that occur more often, more intensely, last longer, or cover broader areas of the state.

[2] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. P. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: *North Carolina Climate Science Report*. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

Table 5I-1. Exposure to climate-related hazards of public safety assets and services.

Assets, Services, Regulations	Extreme Heat	Flooding (River and Land)	Water Shortage (Drought)	Changed Seasons	Severe Weather	Landslides	Saltwater Intrusion	Storm Surge	Tidal Flooding	Wildfire	Dam Failure
Emergency Management: mitigation, preparedness, planning, response, recovery	*	*	*	*	*	*	*	*	*	*	*
Employee Safety	*	*			*			*		*	*
Law Enforcement	*	*			*			*	*	*	*
Emergency Sheltering support		*			*			*			
Flood Risk Management		*			*			*	*		
Correctional Institution Inmate Health and Safety	*	*			*					*	*
Correctional & Juvenile Justice Institutions	*	*	*		*			*	*	*	
Prison Wastewater Treatment		*									*
Prison Food: Caledonia Farmland	*	*	*	*	*						*
State-managed recovery programs (FEMA PA, HUD CDBG-DR, State DRA) for critical infrastructure managed by counties and municipalities	*	*						*	*	*	
State-managed recovery programs for housing (FEMA IA, HUD CDBG-DR, State DRA, Hazard Mitigation Grant Program)	*	*						*	*	*	

Climate Stressors

Extreme heat will lead to more and longer summer heat waves. Exposures will be across NCDPS during events, with employees who work outside needing to be concerned about adverse impacts to their health. Adult and juvenile inmates in state custody will be affected in facilities with old or inadequate HVAC systems.

Storm-related heavy precipitation and flooding will affect rivers as well as increase flash flood events. NCEM and the National Guard assist in the provision of emergency response services during events, and NCEM and NCORR provide recovery services after large events that qualify for state and/or federal disaster declarations. Expanding mapping of these hazards through NCEM Risk Management programs would assist local governments who lack capacity for such mapping. Adult corrections and Juvenile Justice also have to evacuate the inmate population from affected facilities. Wastewater treatment facilities and crop yields from correctional institution agricultural facilities are also negatively impacted.

When ***droughts*** occur, NCEM assists other state agencies in preparation and response. Droughts also negatively impact yields at prison agricultural facilities, which serve as part of the food supply for the correctional institution system and provide work opportunities for inmates. Droughts that affect water supply to prison facilities would increase costs to provide drinking water.

A ***longer freeze-free season*** will affect productivity and yields on prison farmland. Changed seasons may also impact the patterns of disasters when extreme events compound unusually wet or dry seasons, changing the scale of an emergency response. Warming seasons may change the nature of mosquito habitat and the risk of vector-borne disease. Vector-borne disease plans would need to be updated to accommodate these changes.

Any changes in other ***extreme weather*** event frequency or severity will change the length or scale at which emergency response services must deploy. Frequent events in short succession may begin to fatigue existing disaster response and recovery resources.

Landslides require NCEM to assist when affected county emergency services' response capacities are exceeded. Landslides large enough could qualify for disaster declarations, requiring continued and coordinated state recovery services.

Salt water intrusion during drought could pose a threat to water supplies. NCEM would need to consider how to provide emergency assistance to communities if drinking water treatment facilities were unable to provide drinking water on a scale in excess of the response capacities of affected county governments.

North Carolina's coast is already highly vulnerable to storm surge, but ***sea level rise*** and ***stronger hurricanes*** and ***extratropical storms*** could exacerbate both oceanfront and sound side surge heights. In addition to above discussion of changes in preparedness, response, and recovery services needed, infrastructure is particularly vulnerable. By 2050, the Southeast is the region expected to have the most vulnerable bridges. Bridges serve as important human evacuation outlets, but can be impacted by increased wave loads from storm surges and in areas where sea level rise is pronounced.

High tide flooding is now posing daily risks to businesses, neighborhoods, infrastructure, transportation and ecosystems in the Southeast. ***Sea level rise*** will result in the rapid conversion of coastal, terrestrial and freshwater ecosystems to tidal saline habitats. NCEM and NCORR recovery and resiliency services will need to adapt the planning and technical support they provide to local communities who retain control of local land use decisions.

New collaborative partnerships with local governments can help direct development out of places at risk, reducing the scale of services needed during emergencies. Expanding mapping of these hazards through NCEM Risk Management programs would assist local governments who lack capacity for such mapping. Some correctional and juvenile justice institutions are located in areas vulnerable to sea level rise, storm surge, and tidal flooding.

Intra-annual droughts are expected to increase, which would require NCEM and other agencies to scale up responses to wildfires. Correctional institutions which are located in areas vulnerable to wildfire would need to consider response and planning options.

Greater increases of ***flooding*** could further stress aging dam infrastructure. NCEM partners with DEQ and other agencies on mapping risks and providing response to dam failures. Employee safety could also be affected across NCDPS for responders or for facilities downstream of failed dams. Correctional institution facilities, particularly wastewater treatment plants and farmland, could be exposed to flooding and increased flows.

3. Examples of Impacts, Vulnerability, and Risk

Emergency Response and Disaster Recovery

Impact Summary

The North Carolina Division of Emergency Management (NCEM) coordinates response and recovery in communities that have been impacted by natural and human-caused hazards beyond their local capacity. Impacted communities are provided assets from other local agencies, state agencies, assistance from states with mutual aid agreements, and federal agencies. The NCEM and its sister agency, the North Carolina Office of Recovery and Resiliency (NCORR), together provide financial and technical support to local governments throughout the long-term recovery of communities from disasters and resilience to future disasters by administering disaster recovery funds. Because those disaster recovery dollars are to support local reconstruction, hazard mitigation, and relocation of housing and infrastructure, impacts to those services are discussed here, despite overlap with the Housing, Building, and Support Services sector.

The NCORR was established at the end of 2018 in response to North Carolina's qualification for the U.S. Housing and Urban Development's Community Development Block Grant–Disaster Recovery (HUD CDBG-DR) for both Hurricanes Matthew (2016) and Florence (2018). NCORR's mission is to provide general disaster recovery coordination and public information; citizen outreach and application case management; audit, finance, compliance, and reporting on disaster recovery funds; and program and construction management services. It is the grantee for all CDBG-DR and CDBG-Mitigation funds received by the state of North Carolina. Because these programs are not authorized by Congress, with each disaster Congress must publish new rules in the federal register before grantees may develop action plans and receive approval to withdraw funds. This process takes time; 500 days elapsed between the landfall of Hurricane Florence in September 2018 and the publication of the federal register notice in January 2020. This lapse allowed NCORR to develop a draft action plan to spend CDBG-DR funds allocated for that event. This delay underscores the need to coordinate the multiple disaster recovery programs from state, FEMA, other federal agencies, and HUD to speed aid to disaster survivors.

This impact summary will focus on disaster preparedness and response services, which are the primary domain of NCEM at the state level in support of the counties, and disaster recovery services provided by both NCEM and NCORR. It is important to also note that NC General Statutes Chapter 166A, the North Carolina Emergency Management Act, leaves many emergency services responsibilities to the counties, and climate impacts to county-level emergency services are outside the scope of this impact summary.

NCEM's primary resources are personnel and to a limited degree communications equipment and a small store of emergency supplies including tarps, bottled water and emergency food rations. During a disaster, counties manage local emergency responses, including the establishment of emergency shelters. Counties then make resource requests to NCEM when county resources are insufficient. NCEM personnel may provide supplies or services including assistance with interpreting risk information, supplying additional rescue teams, establishing or guaranteeing access to sheltering, conducting damage assessments, or other services including advice on procurement.

While NCEM's typical response is to weather events, impacts of climate change will almost certainly increase the frequency of response, the magnitude of certain events, and the size of the geographic area impacted. In addition to changes in frequency, intensity or duration of events, climate change may also usher in a regime in which multiple hazards such as wildfire, flooding and intense storm events may overlap in both the temporal and spatial scale resulting in increased drain on local, state and federal resources calling for more personnel, equipment and supplies to build an adequate response and insure successful and timely recovery.

Vulnerability and Risk

Recent extreme events have heighted the sense of risk within both NCEM and NCORR. Tropical Storm-related flooding impacts on North Carolina, in particular from Hurricanes Matthew in 2016 and Hurricane Florence and Tropical Storm Michael in 2018, have been out of scale with previous impacts in terms of intensity and geographic extent. Flooding for all three events involved significant impacts outside of previously mapped flood hazard areas. Wildfire has also shown a marked increase in intensity and area involved in recent years.

As the population and built environment in North Carolina continue to grow and expand in the coming decades, more people and property will be exposed to hazards that are anticipated to increase in both frequency and intensity. The degree of this exposure will also depend upon local land use decisions and economic drivers of development in areas at risk, like current and future floodplains, in the wildland-urban (especially pertinent to wildfire exposure) interface, or in places where the pace of development exceeds the future capacity for safe and adequate drinking water supply.

Should the state arrive at a point where statewide flooding, severe weather, wildfire or other impacts occur, or where various multiple hazards impact diverse areas of the state or region simultaneously, the response and recovery capacity of all partners shall be challenged. To date tipping points have not been reached, but resources have been stretched and challenged particularly in the area of temporary and replacement housing because of an existing and ongoing affordable housing crisis throughout the state.

The closest threat to serious drought-related impact on water supply was observed in 2008. Fortunately, interconnected water systems and luck factored into recovery when a tropical storm brought higher than average rainfall to most of the state in a short period. Aging infrastructure will likely place additional demand on the water supply system.

The sensitivity of communities and individuals to extreme events are affected by the complex nature of state and federal recovery assistance programs. Housing damage leads to displacement or to negative health impacts of residing in moldy or unlivable conditions. Displacement for households with fewer resources leads to greater poverty, homelessness, adverse health impacts, stress, and negative educational effects for children. Inundation of flood waters can also cause loss in property values and can substantially damage the residence. Flood damage can necessitate retrofits to meet current building and safety codes, or in extreme cases may require demolition and relocation of residents. The housing stock needing recovery assistance is privately owned by individuals, but the state must administer disaster recovery programs. Eligibility for individual programs varies and is subject to changes in FEMA policy, individual guidelines published in Federal Register for CDBG-DR, and state programs developed or funded by the North Carolina General Assembly. Income requirements must be met, and these vary from program to program. Additionally, these programs may not duplicate benefits from either insurance or volunteer disaster recovery groups.

NCDPS staff administer and deliver these recovery programs to eligible applicants. As events become more frequent, the complexity of recovery integration across programs increases as duplications of benefit must be tracked across events. Staffing will need to keep pace with the scale of these events, but percentages of each program that can be used for administrative purposes are capped. The quantity of funds received from the federal government or allocated by the state must also be sufficient to cover unmet recovery needs. Repeated disasters also strain volunteer donations and group labor that fills critical gaps in meeting unmet needs when recovery dollars are not sufficient to cover uninsured damages.

Recovery failure could leave people with unsafe living conditions, and potentially cause severe property damage (e.g., homes, businesses, roads) and negatively impact local economies and utilities.

Federal and state policies on disaster funding eligibility and availability are important bulwarks for adaptive capacity within the state. FEMA, the White House and state Government will likely be pressed with more requests for disaster declarations and assistance requiring policy decisions concerning prioritization and allocation of funding and other resources. Any potential adaptation actions will need to be consistent with federal law, including the Stafford Act, and state law, including NCGS Chapter 166A, the North Carolina Emergency Management Act. The sensitivity factors that public safety officials must address include population density, economic health and stability, income, education, age of infrastructure, condition and availability of housing and shelter, relative health of the local environment, local government capacity, and recent disaster experience.

Given recent events, climate change trends, and non-climate factors, there is a risk that a tipping point exists beyond which emergency response and recovery service provision could be compromised. The ability of these systems to cope with climate change will be limited if federal and state funding are not adequate for the intensity, frequency, and duration of events experienced in North Carolina. This funding is needed both for personnel cross all phases of disaster at state and county levels, and for logistics and equipment needed during response.

Though it serves as a model for many other states, a traditionally robust NCEM has been under almost constant pressure for the past two decades. Through the use of both strategic and operational planning, training and outreach, NCEM has developed a robust and scalable program that could be expanded or contracted through use of contractors, temporary hires, volunteers and federal assistance. Absent a healthy NCEM program, many rural and economically distressed counties would not have sufficient capacity in regard to preparedness, response, recovery and mitigation activities.

It is highly likely that climate change will increase the demand for traditional emergency management services at the local and state levels. North Carolina also has mutual aid agreements with multiple states that may create a further drain on resources in times of widespread disaster, either through the need for NC to provide aid to other states or through other states' reduced abilities to provide aid to NC because of disasters there. These risks for capacity strain are sensitive to the intensity, duration, and frequency of extreme events both in NC and elsewhere.

Resilience Strategies

Cross-agency Coordination

NCEM recognizes the continued need to maintain and develop its cross-agency relationships across all levels of government to ensure the provision of emergency and recovery services remains robust under the impacts of climate change. This includes efforts to support county emergency services, like launching the statewide "Know Your Zone" campaign to support improving evacuation coordination. It also encompasses the continued need for engagement at the federal level on needs for aligning disaster response and recovery funding to ensure that response capacity is maintained and enhanced across federal, state, and local levels. It also includes efforts from NCORR and NCEM, like the Recovery Integration Team and the State Disaster Recovery Task Force (SDRTF), to continue finding efficiencies in internal recovery operations and identify opportunities external to state government recovery programs to fill gaps on unmet needs.

Risk Information Sharing

NCEM can also help leverage efforts to get risk information to local governments who lack the ability to produce it on their own. NCEM hosts vast amounts of spatial and geographic data that inform a growing number of risk identification and assessment tools, and partners with numerous university efforts. The

NCEM flood mapping program (NCFMP), the Flood Inundation Mapping Information Program (FIMAN) and the integrated stream gage system are three examples of data-based products that help provide a detailed and common operating picture for flood hazard events. Continued data development and application of these tools must be included in future plans addressing climate change impacts.

Land Use Planning

Actions to reduce climate change vulnerability (reducing exposure and sensitive and increasing adaptive capacity) must take place in a concerted fashion involving the public along with private and government enterprises through activities such as zoning and land use planning. Traditionally, this has not been a formal function of emergency management. The growing emphasis on resilience, as well as expanding literature on the nexus between disaster risk reduction and climate adaptation recognizes the long-term importance of using wise land use planning and directed economic development to reduce the burden on emergency services.

Local Partnerships

NCEM's sister agency NCORR includes a Resilience Team, established in 2019. While this team's role is still evolving, its interaction with local governments on disaster resilience with co-benefits for climate adaptation is an early activity. All additional supportive activities may require additional funding. The legal environment also provides an important constraining factor, as all land use decisions remain in the purview of local governments. This means that partnerships and trust must be established to find solutions for local governments that respect this responsibility but still meet local needs for growth and economic development.

NCDPS Correctional Institutions and Juvenile Justice

Impact Summary

The NC Department of Public Safety operates over 13 million gross square feet (GSF) of Public Order & Safety housing and correctional facilities, Juvenile Justice and Youth Development Centers and National Guard Readiness Centers statewide. Rising sea levels as well as more intense hurricane and heavy precipitation events affect the department's buildings, and, in turn, critical operations. During Hurricanes Florence (2018) and Matthew (2016), the Division of Prisons over 4,950[3] inmates were moved to other prisons and jails further inland and staff moved to those prisons to maintain security. In February 2020 Neuse Correctional Institution was evacuated due to flooding.

Prisons are built for a standard operating capacity, but during these evacuations, receiving facilities are stretched well beyond a sustainable capacity, even with the additional staff. When evacuations are required, food, clothing, bedding, medical supplies and staffing coordination must occur. The kitchens are required to produce substantially more food than usual; water and sewer utilization grows beyond capacity; and limited health care resources are overextended. As an additional result, a large number of employees who reside in affected coastal areas are displaced during the storm and its immediate aftermath and are not able to assist in storm response. On a more lasting level, as the sea level rises, there will be a number of prisons within the state that cannot continue to operate.

As part of its custody mission, the Division of Prisons is responsible for feeding its 35,000 inmates three meals a day. While the department purchases a large amount of food, it also produces food for the inmate population at the 7,000-acre farm at Caledonia Correctional Institution in Halifax County. This land, which is crucial to prison operations statewide, is vulnerable to extreme rainfall events, riverine flooding,

[3] Sutton, L. February 13, 2020. Email: *RE: How Many Inmates Were Relocated During Hurricanes Matthew and Florence.*

and eventually sea level rise. Loss of production capacity at this farm would require a vast increase in the amount of food purchased at a much greater budgetary impact.

Every evacuation event (emergency operation) requires a significant amount of planning and execution with already understaffed departments. Facility system obsolescence is further accelerated when maintenance gives way to emergency operations. In addition, these are evacuations of a population requiring close supervision and care. To a certain degree, safety cannot be assured at the same level when inmates are in a transitional stage in lieu of a stable environment.

Many correctional facilities have infrastructure and building systems that have exceeded their planned life expectancy. Heavier rain events and more frequent flooding will further exacerbate our aging roof inventory, and over burden our obsolete electrical distribution systems and aged air conditioning systems.

Extreme heat events will impact the inmate population in the number of correctional institutions (CIs) which have old and outdated HVAC systems. During heat events – which include not just the magnitude of extreme daily high temperatures, but heat stress from the number of nights in a row with extremely high minimum temperatures – inmates may be more vulnerable to heat-related illness. Adding air conditioning will be a substantial financial burden from both a construction and operational perspective, and, will increase our carbon footprint – further exacerbating climate stressors.

Vulnerability and Risk

NCDPS will require additional spatial climate information to quantify the vulnerabilities of and risks to correctional institutions from flooding and wildfire. Because prisons are often built on land that is not otherwise desirable for farming or development, they are frequently found in areas that are very vulnerable to rising sea level and heavy precipitation events. Many correctional institutions are also in remote locations, and in areas surrounded by forest in which wildfire will be an additional risk.

The vulnerability and risks for our Correctional and Juvenile Justice facilities will continue to increase with more frequent floods and heavier precipitation events, each of which exacerbate deferred maintenance challenges.

We are exposed by physical risk with facilities that cannot handle current let alone future impacts. The average age of our correctional facilities is 50 years.[4] A rough estimate of $200 million is needed to address current known issues.[5] Over 3.3 M square feet of roof on 195 buildings has been identified as a high priority for replacement.[6] We are exposed to production risk should our Correctional Enterprise operations not be capable of meeting their agricultural production quotas, which are necessary for feeding inmates.

Our correctional facilities will require substantial upfits to address resiliency, including physical and operational challenges. Almost 30% of these facilities are not air conditioned, subjecting a large segment of the population within our custodial care to a high level of sensitivity to climate change and with low adaptive capacity. To air condition these spaces will require approximately $28 million and is estimated to add an additional yearly utility cost of $2 million.[7] Many of our electrical distribution systems have surpassed their expected lifespan by 20 to 30 years. Water distribution systems are increasingly leaking

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[4] Cunningham, R. Central Engineering. February 2020. "DOP Maintenance Conference Presentation 032020 By Central Engineering".

[5] All numbers cited are orders of magnitude/rough estimates and subject to current market conditions, inflationary pressure, and continued refinement in understanding and evaluating of our facility conditions. These are NCNCDPS Central Engineering estimates February 2020.

[6] Cunningham, R. Central Engineering. February 2020. "DOP Maintenance Conference Presentation 032020 By Central Engineering".

[7] Stout, M. Central Engineering. Order of Magnitude Estimate. Email. September 20, 2019.

since the systems are past their design life. Last year leaking water distribution systems at Nash CI resulted in over $550,000 in lost water, sewer and heating costs.[8]

Over the coming decades, the state will need to construct bed space for its inmate population in less vulnerable locations than current facilities. Where sea level rise is the main vulnerability leading to permanent loss of land, this will also mean intensified economic stress on areas affected by the loss of prison jobs when facilities must be relocated. Many rural communities depend upon correctional institutions for local employment, and the loss of any jobs due to facility loss would be felt even in nearby communities at higher elevations further inland.

As with correctional institutions, National Guard Readiness Centers are often in areas vulnerable to climate-related hazards, and they are key locations for disaster response. Loss of readiness centers close to disaster sites, such as in the aftermath of a hurricane, may cause greater delay in reacting to the disaster. The primary purpose of these readiness centers is to be an armory for national defense, and strategic military considerations must come ahead of the centers' role as an emergency management hub in weather events. In recent years, many National Guard readiness centers have been relocated, but additional spatial analysis is needed to determine remaining vulnerabilities and risks.

Resilience Strategies

Logistical Operations

Additional information needs include more specific analysis of the potential impact of drought and flooding to the farmland at Caledonia Correctional Institution. To determine NCDPS's ability to adapt to threats to this food supply, NCDPS should evaluate at what tipping point this land would no longer produce a reliable food supply, identify any alternatives at less vulnerable institutions, and determine the costs to re-establish production capacity. NCDPS would then need to compare these costs to the costs of simply purchasing more food for the inmate population and evaluate any loss of benefit from inmates receiving fresher locally grown food.

Correction Enterprises has a "Continuity of Operation" Plan for emergency operations. This is updated yearly and table-top simulations are held to continually improve the effectiveness of this plan. A similar plan for Adult Corrections would further enhance Enterprise and Corrections ability to handle their response to these events.

Maintenance and Upfit

All resiliency efforts have synergistic relations with site facilities maintenance, correctional officer operations, emergency event planning and logistics, and design/new construction/renovations. Therefore, all these challenges must be addressed. We can do so by addressing on a site by site or building by building basis, or from an overarching master planning effort potentially involving fewer but new sites. Several important factors must be considered to determine which strategies will be the most life cycle cost-effective means of addressing these challenges.

There are concerns for addressing sites/buildings individually. Anecdotally, Central Engineering is seeing renovation costs approach new construction costs[9]. In addition, renovating existing buildings/sites in the correctional arena requires relocating inmates (on the site or across the state). There is a significant construction premium when working at an existing site due to security logistics.

[8] Szigeti, M. Sud & Associates. June 18 2019 "Leak Detection Summary Report DRAFT". JO 3846
[9] Central Engineering Staff Discussion. February 12, 2020

Many individual projects will generally be costlier to execute than fewer, larger projects. Exceeding certain thresholds will trigger Americans with Disabilities Act of 1990 (ADA) accessibility requirements and will be included in the upfit costs.

Our large number of sites, spread across almost every county in the state, requires substantial "windshield"/non-productive time for Regional Maintenance and Central Engineering staff as they work to maintain/upfit/repair these facilities.

Decentralized HVAC systems generally require more maintenance than centralized systems. Utility costs will also generally be higher. Energy efficiency opportunities may or may not be addressed in the required upfits.

We are having a difficult time staffing remotely located sites/facilities. Logistics (soft costs) are higher because of the number of sites and locations.

Opportunities and Challenges for New Construction

There is a present need for increased energy and water efficient systems to be installed. Water and energy costs will likely be less. Sites and buildings will likely be easier to maintain with fewer, more centralized systems. Building new sites out of harm's way with excess capacity could reduce logistical challenges and logistics should improve if there are fewer sites to maintain. If a dormitory requires renovations, the inmates could simply move from one building to the next at the same site. ADA accessibility costs could be much lower in new facility/site construction. Other Executive Order 80 initiatives including zero emission vehicles and charging stations can be more easily integrated into fewer and new facilities.

For these reasons, Central Engineering recommends a comprehensive masterplan be undertaken that addresses all the logistical (both normal and emergency), operational, staffing and resiliency needs. A comprehensive plan engaging all stakeholders will result in best outcomes. New and more centrally and strategically located sites and/or facilities may prove to be the answer addressing all these challenges. A current order of magnitude cost estimate is $25 million.

Employee Health and Safety

Impact Summary

The Department of Public Safety is a statewide operation that deploys employees into communities across North Carolina for a variety of purposes. The most significant community presence is with the state Highway Patrol and the Division of Community Corrections, as well as juvenile court counselors. Employees in these divisions are on the state's roads every day enforcing the law and protecting the public. As such, these critical functions are dependent on passable roads. As flooding becomes more frequent, our department's ability to fulfill its community presence is impinged. During extreme heat events, employees from across the department may also be required to work outdoors in extreme conditions.

Flooding and hurricane evacuations affect the state Highway Patrol and the North Carolina National Guard in multiple ways. First, the Highway Patrol is the lead agency to enforce and facilitate evacuations. When the Governor declares a state of emergency, coastal communities are routinely encouraged to evacuate. The patrol pulls resources from across the state to manage the surge of traffic leaving the coast to safer ground. This means that highway safety coverage for the rest of the state is reduced. Following a flood event, roads may be impassable due to high water or completely washed out. The Patrol cannot respond to calls for assistance beyond these cut-off points, leaving communities isolated and unsafe.

Similarly, it is the mission of probation officers and juvenile court counselors to enforce court orders and work with offenders in their homes to reduce recurrent criminal activity. When roads are impassable, these officers cannot reach their caseload in person, and cannot assure compliance with court-imposed sanctions. This can lead to relapse on the part of offenders and reduced safety for their families. When communities are evacuated, it can become difficult for these officers to know the whereabouts of offenders on their caseload, elevating the risk of offenders absconding from supervision.

Vulnerability and Risk

The department's vulnerability to this impact needs additional quantitative analysis. If catastrophic flooding becomes a more regular occurrence, it will significantly impact NCDPS operations. Additional spatial information is needed on both sea level rise and changing flood frequency to quantify the magnitude of exposure on each facility. This specific exposure information can then be used to identify facilities most at risk and identify tipping points beyond which it is more beneficial to relocate facilities.

Resilience Strategies

NCDPS currently does not have a plan to address the impact of flooding and road closure on community operations. The department can work with the Department of Transportation to identify high-risk roads and communities and develop location-specific responses to local flooding. The Division of Community Corrections has protocols for maintaining contact with offenders during evacuations that will be refined over time.

With more frequent extreme heat events, NCDPS may need to examine best practices for employee training that helps those who must work outdoors to acclimate. For other workers, operations plans could be developed to shift outdoor responsibilities outside of peak hours for extreme heat.

4. Summary

The NC Department of Public Safety (NCDPS) routinely experiences, manages, and provides services during extreme weather events and disasters. As climate changes, shifts in the intensity, duration, frequency, and scale of these events will increase demand for emergency services from NCEM. Vulnerabilities to correctional institutions from flood, sea level rise, drought, extreme heat, and wildfire will have significant impacts on future capital budgeting needs for the agency. NCDPS will also need to develop plans for employee health and safety during more frequent extreme events.

In addition to traditional agency services, NCDPS will continue to evaluate and develop additional ways to support local governments to ensure that public safety remains protected as the climate changes. In some cases, this may mean that counties may require more targeted assistance with services in their traditional purview, including evacuation and sheltering. Because land use decisions are in the power of local governments to make, new initiatives will be needed to determine appropriate ways to partner with local governments to help them understand risk and use beneficial land use practices to guide development towards less risky areas under climate change and therefore improve public safety.

The NCDPS is the largest state agency in North Carolina with approximately 25,000 employees. In addition to safeguarding lives and property in the state, the department is responsible for the well-being of 35,000+ inmates and 79,000+ parolees in the state's correctional system.

The list of services that NCDPS provides include: law enforcement, emergency management coordination, floodplain and other hazards mapping and surveillance, adult and juvenile corrections and justice and supports the North Carolina National Guard. As such, NCDPS plays a crucial role in preparedness, response, recovery and mitigation activities across the state. Local Emergency Response is a local responsibility, but NCDPS, including NCEM, the North Carolina National Guard, North Carolina

Highway Patrol, and the North Carolina Office of Recovery and Resiliency provide critical support and services when conditions are beyond the response and recovery capabilities of local government.

Although North Carolina's climate has long been defined (as compared to other states and regions) as consisting of widely variable and sometime extreme weather, all indications point to a continuation of that pattern with more frequent and more intense extreme weather events (Chapter 3). In addition to consequences from flooding, wind, wildfires, and landslides, the chronic impacts of climate change, such as rising temperatures, will also have an effect on NCDPS facilities and services across the agency.

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Transportation

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J. Transportation

Key Observations

- The core of NCDOT's mission—connecting people, products and places safely and efficiently—is being heavily impacted by a growing number of climate-related hazards.
- NCDOT directly owns and maintains a large and diverse number of assets statewide. Storm-related damage threatens public safety, creates economic disruptions and impacts the budget, requiring a strategy to reprioritize spending.

Critical Impacts and Resilience Strategies

- Maintaining critical connections and access must be the immediate near-term priority. Whether it is coastal during major storms, or the piedmont during heavy precipitation, or the mountains due to landslides.
- All modes of transportation must be assessed for resilience to build adaptive capacity and redundancy moving forward.
- NCDOT is committed to collaborating and partnering with communities and businesses to build the resilient infrastructure they require.
- NCDOT will develop and apply resilience policies in three main areas: (1) long range transportation planning; (2) individual project planning and design; and (3) operations and maintenance.

1. Introduction to Sector

Increasing frequency, intensity, and variability of extreme weather events is detrimentally affecting the NC Department of Transportation's ability to fulfil its mission. The NCDOT operates and maintains an 80,000-mile roadway network. Six intercity passenger trains operated by Amtrak currently serve cities in North Carolina with NCDOT operating trains between Raleigh and Charlotte. Commuter rail is available in Charlotte. Freight rail service is provided in 86 of the state's 100 counties, with most of the almost 3,500-mile rail system owned, operated, and maintained by the private sector. The NCDOT's Ferry Division operates the second largest state-run ferry system in the United States. The North Carolina state Ports Authority owns and operates the Ports of Wilmington and Morehead City, and there are inland terminals in Charlotte, the Piedmont Triad at Greensboro, the Global Transpark in Kinston, and the new CCX Intermodal Terminal near Rocky Mount. North Carolina has 72 publicly owned and nearly 300 privately owned airports. Of the 72 publicly owned airports, 11 have scheduled service and the remaining 61 are for general aviation.

The North Carolina Department of Transportation's mission is connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina.

Transportation is the backbone of North Carolina's economic activity, connecting manufacturers with supply chains, consumers with products and tourism, and people with their workplaces, homes, and communities across both urban and rural landscapes. During disasters, roads, airports, and harbors can serve key modes of evacuation or become hubs for emergency personnel. Post-disaster they are the lifeline for relief

NCDOT Average Annual Storm Costs
2004 – 2016 = ~$65 Million
2017 – present= >$222 Million

and rebuilding supplies. In addition to loss of life and negative effects to businesses and the state economy, the NCDOT has seen a dramatic rise in its operating costs, with a significant portion of that rise due to post-storm recovery repair.

Table 5J-1. Exposure to climate-related hazards of transportation assets and services throughout the state.

Assets, Regulations, Services	Changed Seasons	Coastal Erosion	Extreme Heat	Flooding (River and Land)	Landslides	Severe Winter Weather	Storm Surge	Tidal	Water Shortage (Drought)	Wildfire	Wind
Transportation Sector											
Operation and maintenance of land transportation including state roads, bridges, and culverts		*	*	*	*	*	*		*		
Pavement resurfacing operations and budgets			*								
Employee Safety			*	*		*				*	
Aviation Operations and Maintenance			*	*		*				*	*
Marine Transportation Operations and Maintenance		*				*	*	*			*
Ports (Marine and Inland)		*	*	*		*	*	*			*
Rail			*	*	*	*					
Public Transport			*	*		*					
Bicycle/Pedestrian	*		*	*						*	*
Freight and Logistics Plan			*	*						*	
2023-2032 STIP Development		*	*	*		*	*	*	*		
NC Moves 2050 Plan		*	*	*		*	*	*	*		
Stormwater Management				*				*			
Roadside Environmental (vegetation management)	*		*	*		*			*		
Roadside aesthetics (Lights)Rail			*	*	*	*					*
Public Transport Roadside aesthetics (Lights)			*	*		*					*

2. Overall Exposure

North Carolina's transportation sector consists of an interconnected system of assets and derived services. A changing climate undermines the system's ability to perform reliably, safely, and efficiently. Heavy precipitation, coastal flooding, heat, and changes in average precipitation and temperature could impact individual assets across all modes (Table 5J-1). These impacts threaten the performance (defined by national goals listed in 23 U.S.C. § 150) of the entire network, with critical ramifications for safety, environmental sustainability, economic vitality, congestion and mobility, and system reliability.

Freight movement at major ports can be delayed under extreme weather events that include heavy rains and/or high winds affecting crane operations and truck service.

For North Carolina, transportation systems that are most vulnerable to the recent observed and projected increases in precipitation intensity are those where stormwater drainage is already at capacity, where projected heavy rainfall events will occur over prolonged periods, and where changing winter precipitation increases transportation hazards from landslides and washouts.

Climate Stressors of Concern

Tropical Storms/Hurricanes

North Carolina has suffered the effects of numerous tropical storms and hurricanes. Changing air and ocean temperatures mean that storms may become more frequent and will very likely be more intense. These storms bring multiple damaging actions including wind, rain, storm surge, and increased wave activity. Hurricanes are usually associated with coastal areas where all these actions can impact transportation facilities. However, hurricanes often track inland and while they usually downgrade to tropical storms or depressions, they can still bring with them damaging winds and rain. A few examples include: Hurricane Hugo (1989), Hurricane Fran (1996), and Hurricane Florence (2018).

Increasingly, it is the varying combination of impacts associated with tropical storms and hurricanes that are causing disruptions to North Carolina's transportation infrastructure. Storm timing, wind intensity, speed, and direction can compound lunar tides exacerbating storm surge flooding, all of which will be increased by rising sea levels. Storm speed and track also play a role in the length of time that winds or rain act on a given area. Lower category hurricanes or tropical storms may cause less wind damage but they can still bring significant rainfall.

Storm-related disruptions include road closures due to debris, rainfall or storm surge flooding and wash out; bridge damage due to debris, flooding (overtopping), wave action damage, or foundation scour; pipe or culvert failures (washouts); airport disruptions or closures; port disruption or closures; and ferry terminal disruption or closures.

North Carolina's transportation system has already experienced the impacts associated with damage from past hurricanes. More intense tropical storms in the future could produce even more damage. The impact of tropical storms on land transportation could include more debris on roads and rail lines, interrupting travel and movement of people and goods. Storms of this magnitude could generate increased damage to signs, lighting fixtures, and supports. Along the coast, highways that are exposed to storm surge could be expected to have shorter functional life spans.

For air transportation, hurricane force winds can produce significant damage to airport facilities, including signals, signage and ground transportation, runways and terminals, parking structures, and facilities. In addition, such storms can cause more frequent interruptions in air service including system functionality and reliability, operations of runways and terminals, as well as internal and external vehicular access routes.

The impact of tropical storms on marine transportation could include damage to port and ferry infrastructure resulting from wave action and storm surges. Implications for facility maintenance and safety management include operations of ferry services and ports and facility safety. Tropical storms can also cause marine channels to fill in. This may impede general mobility along the waterways and the state's ferry service along the marine highway system.

Extreme Rainfall/Precipitation

Changing weather patterns are projected to concentrate rainfall into more intense storms. Changes in the amount, intensity, frequency, and type of precipitation could have a serious impact on transportation.

Heavy precipitation events, often associated with tropical storms, have resulted in severe problems for transportation infrastructure and operations. Rainfall from these events typically falls over multiple days, with increased runoff filling streams and rivers (fluvial runoff) leading to flooding of pipes and culverts, bridges, and roads.

Changing weather patterns may be producing more intense, isolated rain events not necessarily associated with tropical storms. These intense rain events generate significant localized runoff (pluvial runoff) that can result in dangerous driving conditions and can overload drainage systems causing water backups, resulting in street and highway flooding. Flooding can also disrupt rail operations. Flooding can impact railroad embankments and bridges, compromising railroad integrity. In addition, transportation construction activities can be disrupted by flooding and inundation. Intense rainfall can inundate partially constructed projects which can lead to costly delays as well as downstream sediment/water quality problems.

Sea-level rise

Low-lying coastal areas of North Carolina and the state's fragile barrier island system are immediately vulnerable solely to relative sea level rise. As sea level rises, the frequency of high-tide flooding (events typically without a local storm present) has increased by an order of magnitude over the past several decades, turning it from a rare event into a recurrent, and often, disruptive problem.[1,2]

When added to local storm effects, higher sea levels worsen the impacts of storm surge, high tides, and wave action[3], absent any changes in storm frequency and intensity. The long-term, upward shift in sea level is an underlying driver of impacts to the coast, essentially creating a new baseline upon which the effects of day-to-day tidal fluctuations and wave action are magnified.

The impacts of sea level rise could potentially affect the infrastructure and operations of both land and marine transportation systems in the coastal areas of North Carolina. Transportation infrastructure may be impacted by the inundation of roads, more frequent or severe flooding of low-lying infrastructure, the erosion of road base and bridge supports, and the loss of barrier shoreline due to sea level rise. Increased storm surges may also cause more frequent interruptions in travel on coastal and low-lying roadways and may also require evacuation of vulnerable areas.

The state's marine transportation system could also be affected. Rising sea levels may require some changes in port and ferry facilities to accommodate higher tides and storm surges. More severe storm surges may also result in interruptions to ferry services, shipping services, and port operations.

A few general aviation airports in close proximity to the water may be vulnerable to the impacts of sea level rise. Sea level rise could also increase maintenance and repair costs and result in a reduction of overall system reliability in vulnerable areas.

Temperature

Extended periods of high temperatures can cause significant damage to transportation infrastructure. Pavement and structure design parameters and material choices are derived from research regarding the impact of climate stressors, distress of materials, and estimates of service life.

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[1] Sweet, W., M. Menendez, A. Genz, J. Obeysekera, J. Park, J. Marra (2016). *In Tide's Way: Southeast Florida's September 2015 Sunny-day Flood* [in "Explaining Extremes of 2015 from a Climate Perspective"]. Bull. Amer. Meteor. Soc., 97 (12), S25–S30, doi:10.1175/BAMS-D-16-0149.

[2] NC King Tides Project. http://nckingtides.web.unc.edu/ Retrieved January 30, 2020.

[3] Theuerkauf, E. J., A. B. Rodriguez, S. R. Fegley, and R. A. Luettich Jr. (2014). *Sea level anomalies exacerbate beach erosion,* Geophys. Res. Lett., 41, 5139–5147, doi:10.1002/2014GL060544.

Higher temperatures could lead to softening of asphalt, the buckling of pavements, and traffic related ruts. Extreme heat can also produce unanticipated expansion and movement of bridge materials, and misalignment of rail lines. At airports, heat waves can produce heat-related weathering and damage to pavement.

Elevated temperature, combined with increased salinity and humidity, can accelerate deterioration in bridges and roads constructed with concrete.[4] Higher ambient temperatures and extreme heat events can negatively impact pavement performance and, in turn, increase costs due to increased maintenance or material upgrades to accommodate higher temperatures. Material upgrade costs are only modestly offset by less frequent maintenance.

It is possible that projected warmer conditions could have some positive effects. Milder winters may mean fewer winter storms reducing disruptions associated with snow, ice, and freezing rain.

Drought

While drought may not have many notable effects on transportation infrastructure in North Carolina, drier conditions could have impacts on the safety of the transportation system. Roadways, bridges, and airports located in drought-susceptible areas may be affected by the potential increase in wildfires. Smoky conditions could decrease visibility for road, air, and ferry travel, potentially causing delays and reduced safety.

Non-Climate Stressors of Concern

Land Use

According to the U.S. Census Bureau**,** North Carolina's population grew to an estimated 10.5 million people as of July 1, 2019[5]. From July 1, 2018 to July 1, 2019, the state's population increased by nearly 106,500 individuals. This marks the fourth year in a row that North Carolina has grown by more than 100,000 new residents. Only Texas (367K), Florida (233K), and Arizona (121K) gained more residents over the past year. With a growth rate of 1.0% since 2018, North Carolina grew twice as fast as the national average (0.5%) and was the 10th fastest-growing state.

With this population growth comes the need for more housing, transportation services, and infrastructure. Development associated with increased population requires changes in land use which in turn increases impervious surface area, decreasing rainfall infiltration and increasing runoff. Roadway embankment heights, bridge lengths and heights, as well as culvert and pipe sizes are based on certain land use characteristics within a watershed. As these characteristics change, stream and river flows change particularly in response to storm events. Increased urbanization is also linked to flashy stream flow, stream incision, and bank erosion, which can lead to the build-up of sediment that can block bridge and culvert openings.

Maintenance/Debris

The need for maintenance of all transportation facilities will likely increase as the effects of severe weather events increase. Pavement management, bridge maintenance, shoulder maintenance, asset management, maintenance of traffic, road weather management, vegetation management, and emergency repairs are all areas that will need to be addressed in response to storms, flooding, winter weather, and heat. Maintenance operations usually operate on a fixed annual budget cycle making it difficult to meet any emergent demands in addition to the life cycle needs of an aging system. For this reason, it is important for maintenance operations to prioritize needs and carefully allocate resources to achieve

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[4] Khatami, D., and B. Shafei, (2017). Climate change impact on management of deteriorating bridges: A case study of US Midwest region. In 96th Transportation Research Board (TRB) Annual Meeting, January 8-12, Washington, DC., No. 17-04849

[5] United States Census Bureau - https://www.census.gov/newsroom/press-releases/2019/popest-nation.html

maximum long-term effectiveness[6]. Climate change and the associated increase in extreme weather occurrences is an important factor in the yearly estimation of maintenance operating budgets.

Pipes and culverts are common roadway features typically managed by maintenance units. Culvert failure can be gradual, as evidenced by dips in the overlying embankment, or failure can be catastrophic resulting in sudden loss of integrity threatening both the traveling public and downstream residents. Increased rainfall intensity and the associated increases in stream flow beyond culvert capacity can cause flows to back up, building hydraulic head and the risk of catastrophic failure. This situation is especially possible for poorly maintained culverts plugged with woody debris and sediment.

Aging Infrastructure

The increasing age of all transportation assets makes them more vulnerable to extreme weather events. While all fixed assets adhere to this concept, it is particularly applicable to North Carolina's older bridges, culverts, and pipes. For the first few decades of their useful life, properly designed culverts require little maintenance beyond clearing the occasional build-up of debris. However, as decades pass, steel and concrete age, watersheds urbanize, and maintenance forces will likely find themselves increasingly busy with demand maintenance. Older water conveyances are more likely to be under-designed for the changed watershed conditions around them. Older steel and concrete may also be degraded making it more susceptible to failure during runoff events at peak capacity.

Dam Breach

Many transportation facilities are located downstream of dams. Dam breach often results in sudden increases in stream flow that can be catastrophic downstream, washing out roadway embankments and inundating bridges and culverts that may already be at their limit of conveyance during an extreme rainfall event.

3. Examples of Impacts, Vulnerability, and Risk

Hurricane Florence / Record Breaking Rainfall and Storm Surge

Impact Summary

On September 14th, 2018, Hurricane Florence made landfall just south of Wrightsville Beach, NC. Florence was only a Category 1 storm when it struck, but the storm's massive wind field brought a huge storm surge to the coast, with water levels recorded at 10.1 feet above ground in New Bern, NC. Although the storm weakened as it slowly moved inland, it became the wettest tropical storm recorded in North Carolina with many places receiving record-breaking rainfall. More than 30 inches of rainfall was recorded in multiple locations. For example, Elizabethtown had 35.9 inches (913mm) and Swansboro had 33.9 inches (861mm).

[6] National Academies of Sciences, Engineering, and Medicine (2014). *Strategic Issues Facing Transportation, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report*. Washington, DC: The National Academies Press. https://doi.org/10.17226/22473.

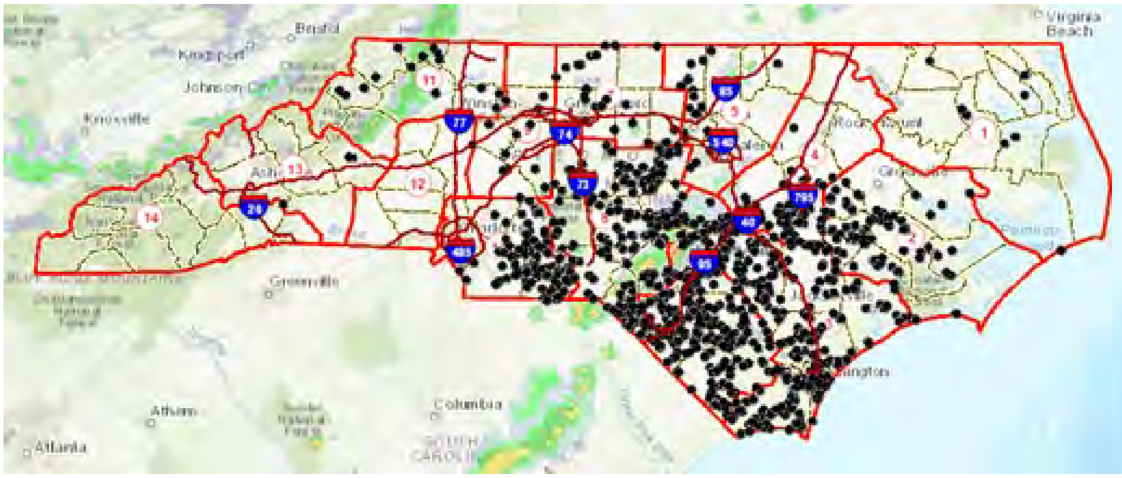

Figure 5J- 1: Approximately 2,500 individual road closures (black dots) resulted from Hurricane Florence

Wilmington International Airport and the Port of Wilmington were both closed. The City of Wilmington became entirely isolated as all roads to the city were flooded and deemed impassable. This included sections of I-40 and US 421. In addition, sections of I-95 in Lumberton and Fayetteville were also flooded and impassable. About 2,500 road closures were recorded.

Figure 5J- 3: I-40 near Wallace was closed for 9 days.

Figure 5J- 2: US-421 at the Pender/New Hanover County Line was closed for 10 days

Vulnerability and Risk

Hurricane Florence highlighted multiple vulnerabilities in the transportation network of eastern North Carolina. Around Wilmington, the *exposure* of coastal communities to storms was evident, as was the *sensitivity* of coastal regions to the compounding effects of wind, rain, wave action, and storm surge. System redundancy was also tested as multiple road routes, as well as air and port facilities were affected, effectively isolating the town of Wilmington for approximately 24 hours.

Figure 5J- 4: I-95 near Lumberton was closed for 8 days

Major highways in coastal areas serve as **critical evacuation routes**. Evacuation routes must be protected from flooding and damage, so they may be used for emergencies. Major highways in coastal areas also serve as critical routes for emergency personnel and supplies for post-storm recovery. Away from the coast, low-lying areas of the Coastal Plain are still vulnerable to heavy rainfall from slow moving storm systems.

Resilience Strategies

Update Engineering Standards

Instead of simply replacing the washed-out culverts on US 421 at the New Hanover/Pender County line, NCDOT engineers chose to design for better resilience. The culverts were replaced with two, 2-lane bridges at 562 feet long, providing significantly greater hydraulic. The first bridge is already complete, and the other is expected to open in 2020.

Improve Traffic Operations

As Hurricane Florence evacuation orders took effect, the NCDOT began implementing evacuation routing plans to support the additional traffic demands. During the storm, staff at the statewide Transportation Operations Center (STOC) established a routing room that was focused on monitoring real-time conditions and defining passable routes for emergency responders and critical freight movement to reach impacted areas. For the first time during a major weather event, the NCDOT used its newly developed drone program with resources from the Division of Aviation. This activation provided real-time imagery and video of affected routes, allowing staff to confirm if roads were passable for the public or accessible as detours for emergency vehicles.

Traffic operations preparation has continued after major events with procedural assessments, improving the real-time availability of traffic count data, coordination with partner agencies, and coordination with navigation companies to provide even better service during future storm events.

Flood Resilience Assessment

Following the effects of Hurricane Florence and a preceding event in 2016, Hurricane Matthew, an I-95/I-40 Flood Resilience Feasibility Study was commissioned to identify improvement options and estimated costs to increase flood resilience along the following corridors: I-95 from Benson to South Carolina; I-40 from Benson to Wilmington; and the NC-24 Connector from I-95 to I-40. The results and recommendations from the I-95/I-40 Flood Resilience Feasibility study are being considered in the I-6064 project which is widening and improving I-95 through Lumberton, NC.

U.S. 401 Washout in Rolesville (~1000-year rainfall event)

Impact Summary

On June 8, 2019, an intense rain storm caused the headwaters of the Little River to flood, washing out part of highway US-401 near Rolesville, northeast of Raleigh. The storm dropped between 6 and 9 inches of rain between Rolesville and Youngsville in less than 5 hours. NOAA calculations estimated this rain event had a 1-in-1,000 chance, or 0.1%, of happening in any given year.[7] The rapid increase in runoff to the Little River inundated the existing 4-barrel culvert, overtopping the roadway and ultimately washing out the roadway embankment on either side of the structure.

Figure 5J-5: The Little River washed out US- 401 in northeast Wake County

[7] NOAA Atlas 14. Precipitation-Frequency Atlas of the United States - Volume 2. Version 3.0: Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia; rev. 2006

Vulnerability and Risk

Flooding vulnerability is not confined to the coastal and low-lying areas of North Carolina. Likewise, it is not only associated with tropical storms or hurricanes. Changes in land use can lead to increased storm water runoff, which when combined with aging pipes or culverts can result in hydraulic conditions near design limits. Warming atmospheric conditions will mean that the air can hold more water vapor, likely leading to more frequent extreme precipitation events that could lead to failures like the one near Rolesville.

Resilience Strategies

Rehabilitation and armoring

Rehabilitation of existing pipes and culverts by adding headwalls or wingwalls where water enters the structure can protect the pipe and roadway embankments from washing out. Low-lying road embankments vulnerable to overtopping by floodwater can also be armored with riprap to protect them until the water recedes. Both these options make the roadway resilient to floods but do not protect the traveling public.

Real-time/Early Warning Systems

North Carolina Emergency Management (NCEM) has developed a Flood Inundation Mapping and Alert Network (FIMAN). The system provides real-time data on stream elevation, rainfall, and weather parameters from over 550 gages across the state. The data are posted on the internet to provide real-time flood inundation maps and alerts. NCDOT has collaborated with NCEM to produce a pilot version of FIMAN for transportation (FIMAN-T). By combining the FIMAN real-time gage data and flood prediction models with roadway and bridge data, NCDOT will be able to provide real-time flood inundation maps and alerts. NCDOT will even be able to predict 24 to 48 hours ahead when roadways and bridges may flood.

Collaboration

Partnering with local governments and planning organizations to better contain stormwater runoff in developing watersheds protects infrastructure and improves downstream water quality. Planning concepts like Low-impact development (LID) promote land planning and engineering design to manage stormwater runoff as part green infrastructure.

Coastal Highways / Storm Surge

Impact Summary

On September 6th, 2019, Hurricane Dorian made landfall at Cape Hatteras, as a Category 1 Hurricane. Ocracoke Island just south of Cape Hatteras took the main hit. The storm moved quickly, but it left the island ravaged from waters that rose like a tidal wave in only two hours. An approximately 7-foot storm surge from the Pamlico Sound inundated the village of Ocracoke flooding homes and destroying businesses. Floodwaters in the village reached the greatest depths since a 1944 storm.

The storm destroyed the protective dune line between NC-12 and the ocean, as well as breaking and buckling about 1,000 feet of pavement. Damage to NC-12 in Hatteras Village, just north of Ocracoke Island, prevented access to the Hatteras-Ocracoke Ferry Terminal. For days the only people who could get to the island were emergency relief personnel and resources.

Figure 5J- 5: NC-12 on Ocracoke Island washed out after Hurricane Dorian

Repairs began immediately with contractors installing sandbags, reconstructing the dune line, and completely rebuilding and repaving the roadway. The NCDOT Ferry Division's dredge, the *Manteo*, pumped sand from the old Hatteras ferry channel to supply sand for the reconstruction. NCDOT's total repair costs for Hurricane Dorian were approximately $45 million.

Additionally, powerful storms impacted the area in mid-October and mid-November, causing additional damage to NC 12 near Rodanthe and delaying the re-opening of NC-12 on Ocracoke Island. These storms were nor'easters—non-tropical, low-pressure systems that usually remain offshore and produce strong northeast winds along the coastline. While nor'easters are not uncommon during the fall, winter, and early spring, these were particularly strong.

Vulnerability and Risk

The vulnerability and fragility of North Carolina's Outer Banks and NC-12 is well established. The Civilian Conservation Corps constructed dunes to establish and protect sections of the Outer Banks in the depression-era, and the highway has been experiencing storm-related disruptions since during its construction in the late 1940's. While NC-12 has been washed out before, Hurricane Dorian and the subsequent nor'easters highlighted specific problems and costs associated with multiple storm events, both hurricanes and non-tropical storms, in close succession.

Resilience Strategies

Short Term

Beach and dune nourishment projects provide short-term solutions to help preserve NC-12 and other properties on the Outer Banks. In response to severe beach erosion and a breach of NC-12 caused by Hurricane Sandy, the Federal Highway Administration in March 2013 approved emergency relief funds to pay for a beach nourishment project that used 1.6 million cubic yards of sand dredged from two sandbars in the Atlantic Ocean. The project – a short-term solution to preserve the highway until a long-term solution to the breach could be developed and built – was completed in fall 2014.

Long Term

As the long-term solution, NCDOT is elevating a portion of NC-12 onto a 2.4-mile bridge over the Pamlico Sound that extends from the southern end of the Pea Island National Wildlife Refuge into northern Rodanthe. This includes the section of NC-12 known as the "S-curves" that was washed out during Hurricane Sandy in 2012, and Hurricane Irene in 2011.

Real-time/Early Warning Systems

NCDOT is also collaborating with NCSU and the UNC-Institute of Marine Science to improve computer-modeled storm surge data with that available through the Coastal Emergency Risk Assessment (CERA) in order to predict storm surge conditions 24 to 48 hours ahead. These data are being incorporated into FIMAN-T for coastal areas to predict where storm surge may affect roads during storm events.

Rockslides / Extreme Precipitation

Impact Summary

Rockslides (and smaller landslides) can damage and disrupt transportation corridors leading to roadway and railway closures which in turn lead to economic losses and expensive repairs. The causes of landslides are directly related to geology, hydrology, topography, vegetation, and human-related ground disturbing activity that has destabilized slopes. While rockslides themselves are not specifically a climate hazard, their occurrence is directly linked to the frequency and magnitude of precipitation events.

In the western counties of North Carolina, a December 2018 snowstorm with 10 inches of accumulation in many locations (maintenance/repair costs $45 million), followed by a January 2019 snow/ice event (maintenance/repair costs $20 million), then a third storm occurred in February 2019 leading to a February 22nd rockslide in Haywood County. The rockslide closed I-40 in both directions for five days (maintenance/repair costs $16 million). This section of road carries over 26,000 vehicles a day with significant truck traffic. NCDOT's detour was a long but familiar one of approximately 150 miles.

Figure 5J-6: Boulders blocking I-40 in both directions following a 2009 rockslide

This portion of I-40 is notorious for rockslides and rocks falling onto the highway. In 1985, a severe rockslide buried the westbound entrance to one of two tunnels that carry the highway through the gorge. Repair of the slide area and the tunnel required shifting westbound traffic to the eastbound tunnel, while eastbound traffic was diverted onto a temporary viaduct around the tunnels. In July 1997, a rockslide near the Tennessee state line closed the entire road for nearly three months.

On October 25th, 2009, a large rockslide occurred at mile marker 2.6 along I-40 near the Tennessee state line. The 150-foot-tall rockslide closed the interstate in both directions for several weeks. Engineers installed 543 bolts into the rock face designed to keep the rock wall from shearing off in the future.

Vulnerability and Risk

While smaller-scale slope failures or debris flows are known to have occurred in the Piedmont and Coastal Plain of North Carolina, the most vulnerable transportation assets to slope failures are the roads and rail lines in the foothills and mountains of western North Carolina. The mountainous topography of western counties often means that these vulnerable transportation links have little redundancy, with road closures resulting in very long detours or sometimes, no detour at all.

Resilience Strategies

Presently, the NCDOT has two avenues of response to rockslides: (1) ***emergency mitigation*** and (2) the ***consideration of resilience in slope design***.

NCDOT's biggest asset in the mountains is a small but well-trained and credentialed staff capable of producing specific mitigation plans within 24 to 72 hours.

The NCDOT Geotechnical Engineering Unit has developed an asset management framework with ratings that take in to consideration the impact of a potential failure along a route and consider impacts of detour disruption. The NCDOT is carefully evaluating approaches to new designs and mitigation of landslides. These approaches consider the likelihood of any geotechnical assets failing and potential consequences. With changing weather conditions and the increased likelihood of more intense precipitation events, the designing slopes is a moving target due to the wide-ranging sensitivity of inputs. Topographic and environmental restrictions on right-of-way constrain slope designs and make recommendations such as wider shoulder widths not feasible.

Preliminary investigations have also begun into known high levels of Magnesium oxide (MnO) in certain weathered rock and soils. Indications are that high MnO levels may be associated with increased failure risk. Mapping of high MnO areas need to be incorporated with existing North Carolina Geologic Survey (NCGS) County Hazard Maps.

4. Summary

NCDOT has already begun multiple individual or regional projects and initiatives to address past weather-related disruptions and to develop adaptation strategies to prepare for, withstand, and recover from future events. These individual efforts will need to be aligned and combined into a more holistic, statewide approach to resilience.

The STC is a network of critical multimodal transportation corridors considered to be the backbone of the state's transportation system. These 25 corridors, 5 international or major freight airports, and 3 seaports, move most of our freight and people, link critical centers of economic activity, and support interstate and international commerce. They must operate well to help North Carolina attract new businesses, grow jobs and catalyze economic development. These strategic corridors are considered the state's highest priority when analyzed within the framework of regional or local transportation plans.

NCDOT secured funding in November 2019 through the NC General Assembly with Senate Bill 356 to:

- Establish the Transportation Emergency Reserve as a specific fund within NCDOT
- Expand FIMAN-T to other areas of the state
- Perform a Flood Risk and Vulnerability Assessment of the state's Strategic Transportation Corridors (STC; see text box).
- Expand NCDOT's work with Living Shoreline projects

The ***American Transportation Infrastructure Act (ATIA) of 2019***, currently before the Senate, will authorize $287 billion from the Highway Trust Fund over the next 5 years. The five-year funding level is more than a 27% increase above the Fixing America's Surface Transportation Act (FAST Act) of 2015. While resiliency was already a required planning factor in the state Transportation Improvement Program under the FAST Act, ATIA will specifically invest $4.9 billion on a new resiliency program for roads and bridges. NCDOT will work to secure a portion of these funds for NC projects.

Forward-looking plans and policies will need to be developed, and NCDOT is currently finalizing its ***NC Moves 2050 Plan***. This is the culmination of a two-year, multi-phased study that involves examining all aspects of North Carolina's transportation system. Input has been collected from local governments, planning organizations, and the public about transportation performance and anticipated challenges in the future. The plan is focused on creating a more responsive, diverse and inclusive transportation system for keeping people and freight moving safely and efficiently.

NCDOT has been working closely with the Department of Public Safety (NCDPS), specifically Emergency Management, to develop early warning strategies (FIMAN-T) and develop emergency response plans. NCDPS's newly formed ***Office of Recovery and Resiliency*** provides another collaborative opportunity to provide resources and tools to communities with vulnerable populations and help them become more resilient. NCDOT is also working locally in eastern North Carolina in partnership with the North Carolina Division of Coastal Management and the North Carolina Coastal Federation to implement Living Shoreline projects and LID practices.

Continued collaboration and information sharing with the U.S. Department of Transportation's Volpe National Transportation Systems Center, Federal Highway Administration, other state DOT's, and international partners like Rijkswaterstaat (part of the Dutch Ministry of Infrastructure and Water Management) will help NCDOT stay at the forefront of innovation, adaptation practices, and design concepts.

Moving forward, NCDOT will develop a comprehensive resilience policy to guide decision making in long-range transportation planning; individual project planning and design; and operations and maintenance. By addressing these three main areas, the department will be able to deliver a robust transportation system that can adapt to, withstand, and quickly recover from climate-related hazards.

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Water & Land Resources

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K. Water and Land Resources

Key Observations

- Reliable, clean supplies of freshwater and land resources are essential to human and ecological health.
- Water availability affects all sectors and is vulnerable to climate change and increased demands from a growing population.
- The Water and Land Resources sector has directly managed assets and provides a number of services that require a uniquely trained and experienced workforce.
- Water infrastructure funding programs cannot meet existing demand to help communities meet their water infrastructure needs without considering additional needs due to climate change.

Critical Impacts and Resilience Strategies

- Dam and water infrastructure impacts from flooding are a big concern.
- Landslides are increasing due to extreme rainfall events.
- Water quality impacts to our drinking water and ecosystems as a result of polluted runoff are a continuing issue. Sediment is the largest pollutant by volume of our surface waters and carries excess nutrients and many other pollutants with it.
- Stormwater requirements and design specifications including rainfall intensity statistics should be assessed for future needs and revised as needed.

1. Introduction

The Water and Land Resources sector is made up of those Divisions within the North Carolina Department of Environmental Quality (DEQ) that regulate, protect, conserve and provide technical assistance on matters of water quality, water quantity, water supply, land and mineral resources, wetlands, dam safety, landslide mapping, stream and wetland restoration, and water infrastructure. Together, this sector provides oversight for more than 5,300 public water supply systems, 6,000 dams, 730 mines, 8,000 active construction sites, 18,000 state and National Pollutant Discharge Elimination System (NPDES) stormwater facilities, 2,857 wastewater discharge permits, 17 river basins, 1.6 million acres of shellfish growing waters, and 285 miles of recreational “swim” beaches throughout the state. Its management and planning activities are critical for the welfare and safety of the public, the continued growth of the economy, and the ecological health of water and land resources. The assets and responsibilities of primary concern to the Water and Land Resources sector are as follows:

- Land and Water Quality
- Water Quantity
- Water Infrastructure
- Dams
- Mines
- Mineral Resources

The primary Divisions of DEQ performing these efforts are:

- The ***Division of Water Resources (DWR)*** is responsible for surface and groundwater quantity and quality throughout the state. DWR issues pollution control permits, monitors permit compliance, evaluates environmental water quantity and quality, and carries out enforcement actions for violations of environmental regulations.

- The ***Division of Energy, Mineral, and Land Resources (DEMLR)*** has responsibilities that include environmental permitting and compliance for activities and developments that include mining and mine reclamation, dam safety, stormwater quality, sedimentation and erosion control, and landslide and geologic mapping.
- The ***Division of Mitigation Services (DMS)*** is a DEQ initiative that restores and protects streams, wetlands and buffers to offset unavoidable environmental impacts.
- The ***Division of Water Infrastructure (DWI)*** provides financial assistance for projects that improve water quality. Programs within DWI fund many types of projects, including sewer collection and treatment systems, drinking water distribution systems, water treatment plants, stormwater management systems, and stream restoration.
- ***The Division of Marine Fisheries (DMF)*** is responsible for monitoring water quality in the coastal region for recreational use and classifying shellfish growing waters.

Reliable, clean supplies of freshwater and land resources that meet their intended uses are essential to human and ecological health. The Water and Land Resources sector supports effective management of lands, wetlands, water resources, and floodplains to meet those goals. The sector is central to the economy and contributes significantly to the resilience of many other sectors, including Agriculture, Ecosystems, Energy, Health and Human Services, Public Safety, Transportation, Coastal Resources, Commerce and Business, and Housing, Building and Support Services. Because of a growing population and aging infrastructure, water supply systems, sewerage systems, and dams face considerable risk, even without anticipated future climate change impacts.

Providing environmental protection and promoting wise use of land and water resources for the citizens of North Carolina are the primary responsibilities of all the Divisions within DEQ through multiple avenues:

- administration of the laws, policies and rules established by the U.S. Environmental Protection Agency;
- administration of laws, policies and rules established by the N.C. General Assembly and several state commissions including the Environmental Management Commission, Coastal Resources Commission, Sedimentation Control Commission, Mining Commission, Oil and Gas Commission, Marine Fisheries Commission; and
- permitting, compliance, technical assistance, education, stream and wetland mitigation, emergency response, grants and river basin and watershed planning efforts.

2. Overall Exposure

As a result of the increasing stress imposed by a changing climate as well as the pressure imposed by an increasing population, the hazards that historically impacted assets managed by the Water and Land Resources sector of the North Carolina government will be of increasing concern in future years. This is demonstrated in the exposure matrix below (Table 5K-1).

Table 5K-1: Exposure of assets, regulated activities, or services provided to the state of North Carolina through the Water and Land

Assets, Services, Regulations	Extreme Heat	Flooding (River and Land)	Water Shortage (Drought)	Changed Seasons	Landslides	Saltwater Intrusion	Storm Surge	Tidal Flooding	Wildfire	Dam Failure
Land and Water Quality										
Sedimentation, stormwater and wastewater permitting	*	*	*			*	*	*	*	*
State-owned groundwater monitoring wells		*				*		*		
Monitoring, survey and invasive species removal programs for waterbodies	*	*	*	*		*				
State stream and wetland restoration sites	*	*	*			*				*
Landslide mapping program	*	*			*				*	
Shellfish Growing Area Program	*	*		*		*	*	*		
Recreational Water Quality Program	*	*		*			*	*		
Water Quantity										
Municipal water supply			*		*	*			*	*
Agricultural water use	*	*	*	*		*	*			*
Various water supply watersheds statewide		*				*				*
Water Infrastructure										
Public water systems	*	*	*		*	*	*	*		*
Wastewater treatment plants	*	*					*	*		*
Septic systems		*				*	*	*		
Water treatment plants	*	*	*			*	*	*		*
Dams										
State-owned dams		*			*				*	*
Dam safety program		*			*					*
Privately owned dams		*			*				*	*
Mines										
Regulation of active mines	*	*	*		*		*		*	*
Other										
DEQ staff	*	*	*		*		*	*	*	*
Floodplain development		*								*

Climate Stressors

Heavy precipitation events (3 inches or more in a day) are on the rise in North Carolina, with the last four years (2015–2018) having seen the greatest number of events since 1900.[1] When extreme rainfall exceeds the limits of engineering design standards set by law that are used to design dams, stormwater, sediment control and flood control structures, both the rainfall and associated flooding can cause dams and flood control structures to overtop and/or fail. The resulting rapid release of stored water can cause significant damage downstream in the floodplain, including houses, roads, utility services, surface water pollution and even additional dams. The destruction of dams and surface water pollution can jeopardize municipal drinking water, health of streams, damage transportation and utility corridors and impact cooling water for thermo- and hydro-electric plants.

Heavy precipitation events can deliver sediment, untreated sewage, and animal waste into waterways, contaminating water supplies, and flooded lands degrading water quality and causing health hazards. Sediment and other accompanying pollutants degrade biotic integrity in streams. It may also make septic tanks and spray fields inoperable. Contaminated source waters can interrupt drinking water service when water treatment plants cease to function nominally as well as degrade their overall ecosystems. Heavy precipitation events can also trigger precautionary shellfish harvest closures and recreational swimming advisories.

Rising sea level can impact water supplies for municipalities and industries. The degree of impact may vary, depending on whether it is caused by temporary flooding during storm surge or extreme high tides, or because a low-lying area becomes permanently inundated. Treating saline water for drinking water is very costly. Infrastructure improvements and interconnections to other water systems (septic tanks and pump stations) may be needed. Saltwater intrusion can also negatively affect ecosystems and agriculture as waters shift from fresh to brackish.

Drought emerges from many factors, including prolonged high temperatures combined with decreased precipitation. A vicious cycle can emerge since drought conditions tend to increase water demands for agriculture, human consumption, energy, and in-stream uses. Droughts have the potential to impact the state's economy through agricultural losses and water restrictions. It is likely that future severe droughts in North Carolina will be more intense due to higher temperatures leading to increased evaporation.

Non-Climate Stressors

An increasing population in North Carolina is leading to not only increased demand for water and related services but is also creating land use change and increased runoff in many areas of our state. As a result, water resources stressed by climate change will be further impacted by a growing population in many areas of the state.

It is also important to recognize that as rural water (i.e., both drinking water and wastewater) utilities face these climate change issues, it is in the context of socio-economic changes that also impact the system's resiliency. While the state may be increasing in population overall, many rural areas are losing populations and larger water customers such industrial and commercial facilities. In addition, like many urban areas, water customers are using less water (which is good from a water conservation point of view). All of these issues result in less revenue. At the same time, costs are increasing for construction and operations. These all dictate higher water bills since most water utility expenses are fixed. This leads to a deficit in management capacity in these smaller systems to implement utility best practices, such as asset management planning, needed to provide safe and environmentally sound water and sewer services. All of these issues create water affordability pressures for low-income residents in these rural

[1] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. P. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: *North Carolina Climate Science Report*. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

communities. Looking ahead, these systems will need significant resources to address both socio-economic and climate change concerns.

Aging infrastructure and limited surface water storage are increasing the stress on our state's water and land resources. This issue is exacerbated by limited resources available for maintenance and replacement of growing water distribution, treatment infrastructure and dams. In North Carolina this infrastructure is privately and publicly owned. Private water providers and dam owners, like their public counterparts, find maintenance, repair and replacement challenging due to limited resources. Whereas public providers have governmental mechanisms such as municipal bonds, property and taxing assessments, private operators have fixed incomes and may find maintenance and repair prohibitive in some cases.

All of these issues create challenges in planning for water infrastructure projects and paying for those projects. For example, drought can increase efforts to conserve water during the drought which can create permanent reduction of water usage. For example, a study of 119 utilities in North Carolina by the UNC Environmental Finance Center indicate that while the number of connections increase by 382,359, water usage over that same time period decreased by 11.7 millions of gallons per day (MGD). This success in water conservation can also result in a long-term reduction in water utility revenue. At the same time, additional rainfall will create more financial stress if the utility has significant inflow and infiltration on the sewer portion of the utility increasing utility sewer expense. As the climate oscillates between extremes, it creates challenges to utilities to determine the appropriate capital improvement priorities while trying to keep water bills affordable for the community's water and sewer users. This will increase the demand on the water infrastructure funding grants to provide subsidized financing that can significantly increase infrastructure needs over the next 20 years. These estimates were generated before the impacts of Hurricanes Matthew and Florence.

In the following section, we provide examples of impacts, vulnerabilities, risks, and resilience strategies for nine of the principal climate-related hazards that the Water and Land Resources sector will remain responsible for addressing within North Carolina's state government.

3. Examples of Impacts, Vulnerability, and Risk

Dam Failure/Flooding and Heavy Precipitation

Impact Summary

The Dam Safety Program within DEMLR is a regulatory agency and as part of its responsibilities responds to emergency situations and incidents that could cause dam failure. Dam failure can be lethal, damage property, and disrupt local or regional economies. Long-term economic impacts may include diminished property values around or below the impoundment.

Following an incident such as dam overtopping, dam staff must respond in a timely manner with Emergency Management to assess the situation and deploy resources needed to avoid a failure situation. Examples include installing pumps, sandbagging, and using heavy equipment to move earth. In times of imminent threat of failure, evacuation protocols must be initiated. During recent hurricanes in 2016 and 2018, greater than 50 dams failed in North Carolina, causing millions of dollars in damage and forcing the evacuation of more than 500 homes. In 2017 and 2018, the state breached two dams under controlled and permitted conditions as a result of damage from Hurricane Matthew in 2016.

Vulnerability and Risk

All regulated dams in the state are inspected on a tiered priority basis ranging from once per year for "High Hazard Coal Ash Dams" to once every five years for "Low Hazard Dams." Hazard Classification

(Table 5K-2) does not measure likelihood of failure but rather the negative consequence should the dam fail. For example, if a dam were to fail and the consequence would be loss or life due to impact to a home or cause over $200,000 in property damage it would be considered "High Hazard". There are nearly 1,300 "High Hazard" dams in NC, second highest in the United States.

The *sensitivity* of any given dam relates to its age, structural integrity, design impoundment capacity, spillway capacity, design certification, integrity of the building materials, industrial activities that put loading on the dam (e.g., coal ash), maintenance and operation status, and financial resources of the owner/operator. Deterioration in any one or a combination of these factors could result in dam failure. The potential consequences of dam failure include loss of life, property damage, damage to the environment from pollutants stored in the dam impoundment, and health and economic impacts due to damaged utilities.

Table 5K-2: Hazard Classification of dams subject to inspection by the Dam Safety Program.

Hazard Classification	Description	Quantitative Guidelines
Low	Interruption of road service/low volume roads	Less than 25 vehicles per day, Less than $30,000
	Economic Damage	
Intermediate	Damage highways/interruption of service, Economic Damage	25 to less than 250 vehicles per day, $30,000 to less than $200,000
High	Loss of human life, Economic damage, Probable loss of human life due to breached roadway or bridge on or below the dam	Probable loss of 1 or more human lives, More than $200,000, 250 or more vehicles per day

The adaptive capacity of any given dam hinges on the financial, engineering, and construction resources of the owner or operator to correct deficiencies and relieve threat to that dam's safety. This ability requires time and financial resources, however. During an emergency situation, engineering responses and modifications are limited. Pumping impoundments down or performing emergency breaches are risky and require human and financial resources that are not always readily available.

Adaptive capacity by dam owners and the state agency that regulates dams in North Carolina varies widely. Solutions to correct deficiencies and respond appropriately to emergencies depend on the financial resources of the dam owners and the state's resources. The risk of dam failure is growing due to increases in frequency and severity of heavy rainfall events, including hurricane events. Risk varies depending on location within the state.

The Piedmont and Mountain regions of North Carolina have a higher number and density of dams, as well as a higher population and population density, than the Coastal Plain due to topography and stream density. The majority of recent dam failures occurred in the Coastal Plain due to a number of recent heavy precipitation and hurricane events that have struck that region. The Coastal Plain typically has lower population density, more erodible soils, but the topography is not as steep as in the Piedmont and Mountain regions giving longer times for inundation. In contrast though, had the western regions of the state received the same storms there would have been greater impact to lives and property and therefore a much higher risk for our state.

Resilience Strategies

Enhance Dam Safety

Increasing the adaptive capacity of the state Dam Safety Program rests within the tools and resources it is provided. North Carolina has 17 Full Time Equivalents (FTEs, i.e., budgeted positions) funded through appropriations, receipts and federal grants to ensure compliance on 6,000 dams that have been inventoried in North Carolina. These FTEs have been distributed throughout 8 offices around the state to address construction plan approvals, Emergency Action Plan approvals, inspection and compliance and respond to emergency situations on dams as they arise resulting in an average of 353 dams per FTE. Resources to increase staffing and salaries in this very focused field of engineering and safety should be addressed to accomplish the missions of the dam safety program and to meet the needs of North Carolina. That is on average 353 dams per FTE. Also, because of the varying financial abilities by dam owners to operate and maintain their dams the state needs to develop new options and funding resources to address, at least on an emergency basis, ways to respond to those emergencies, including enhancing the capability to drain impoundments and implement emergency breaches to render the dam safe.

Increase Dam Releases

During large rainfall events, either from large tropical cyclones or heavy precipitation events, the state Emergency Response Team (SERT) might require dam owners to increase discharges to prevent overtopping. Such procedures have not been tested and studied. In most cases, the Dam Safety Program would look at evacuation of the downstream vulnerable population as the appropriate emergency action. A widespread, extreme precipitation impact from a slow-moving extensive tropical cyclone could be reduced by a coordinated SERT message to dam owners to increase dam releases to drawdown impoundments. The volume of releases prior to such events may reduce flooding downstream and would definitely reduce impacts from dam failure. One of the issues that remains an obstacle here is the inability of many dams to drain their impoundment levels.

Advance Emergency Action Plans

North Carolina also has requirements for dam owners to submit Emergency Action Plans (EAPs) which lay out a plan to the owner and the state on what to do and whom to contact in the event of an emergency. The state has had this requirement for the last 5 years for "High" and "Intermediate" Hazard dams and has received and approved over 50% of these. Advancing this program and securing the outstanding EAPs and dam safety education is an ongoing priority and a key way to build resilience. Resources to permanently fund four EAP FTEs are imperative to re-establish this program which was only marginally funded by non-recurring funds between 2014 and 2017.

Modeling and Predictions

The state Dam Safety Program is currently performing hydrologic and hydraulic (H&H) modeling, using hurricane disaster recovery funding, on many “High” Hazard dams in the Neuse and Lumber river basins and plans to initiate a study in the Cape Fear river basin in 2020. These studies will determine hydraulic loading of the dams and the hydraulic capacity of their spillways. This information helps the state to understand the current predicted resiliency of the dams in the study and to help focus its limited resources in times of heavy rainfall or emergency.

Resilience development for dams and the Dam Safety Program will continue to require resources, public and private, to further develop the EAP program, expand the H&H modeling efforts to all river basins in the state, provide education and resources to dam owners and to upgrade or remove existing dams that do not meet the engineering standards required by law. Increased studies on these dams, updated statutory language in our law, along with the efforts mentioned above will support improvements in resilience for North Carolina.

Water Quality/ Flooding and Heavy Precipitation

Impact Summary

Extreme storm events increase nonpoint source pollutant loading due to the larger volume of runoff, exceedance of stormwater control capacities, and increased mobilization of pollutants, sediment, and sediment-associated pollutants. Flooding can result in increases in inflow and infiltration and more frequent sanitary sewer overflow events. In addition, wastewater plants, onsite septic systems, hog manure lagoons, and other sources of pollutants can become inundated and release pollutants which would be controlled under normal conditions. The frequency and magnitude of extreme storm events is expected to increase.

Vulnerability and Risk

Nutrients, sediment, pathogens, and chemical constituents are transported in runoff to surface waters during rain events. Extreme events greatly increase the loading of these nonpoint source pollutants. Many areas do not have stormwater controls and runoff directly enters surface waters. Urban areas frequently have stormwater controls, but these are usually not sized to handle events greater than the 1-year, 24-hour storm.

Sewer lines often occur in low-lying areas and may be susceptible to inflow and infiltration. When an area is inundated, water can enter sewer systems through manholes and cracks in lines resulting in the treatment plant being overwhelmed with the additional load. Sewage can also leak from sewer lines in parts of the system away from flooded areas or cause a sanitary sewer overflow (SSO) at manholes or treatment plants.

Unanticipated releases of pollutants can occur from inundation of storage facilities, such as hog lagoons and onsite septic systems, which may be located in floodplains. The result is that surface waters receive loadings of a wide variety of pollutants that result in exceedances of the state water quality standards for human health and aquatic life. Increased nutrient loading, in addition to warmer water temperatures, also creates additional environmental and public health concerns over the potential influx of harmful algal blooms.

The sum of these pollutants found in runoff also poses the risk of increasing the amount of closures to shellfish growing areas and recreational waters along the coast. Using standards set forth by the Food and Drug Administration (FDA) and Environmental Protection Agency (EPA), bacteria levels must remain below a certain threshold to maintain usability for harvest of shellfish as well as recreational use. As pathogens and nutrients increase in the watershed beach closures will increase and result in a shortened shellfish harvest season.

Resilience Strategies

There are several strategies to increase North Carolina’s resilience to water quality impacts from flooding, including the following:

Land use guidance

One critical strategy is to guide land use in riparian zones and floodplains. Natural land adjacent to waterways attenuates pollution from overland runoff. Several watersheds in North Carolina have rules that protect riparian buffers, typically enacted due to nutrient over-enrichment. The NC Flood Act of 2000 requires that communities regulating land uses prohibit certain uses in the 100-year floodplain, including new solid waste disposal facilities and sites, hazardous waste management facilities, salvage yards, and chemical storage facilities shall not be permitted, except by variance. Expanding and enforcing these protections statewide would increase the capacity of the landscape to assimilate pollutants before they enter waters of the state. In addition to the water quality benefits, riparian buffers slow down and store water from precipitation events which helps reduce the severity of flooding.

Through ordinances and regulations, state and local government can encourage siting development and pollution sources away from riparian areas and floodplains. Utilities can continue to flood-proof assets and rehabilitate sewer infrastructure to reduce the risk of inflow and infiltration and sanitary sewer overflow. Government and extension agency staff can also work with land owners and operations managers to plan for extreme floods.

Voluntary Removal

A near-term priority is to identify animal operations, waste lagoons, wastewater treatment plants, industrial facilities, fields for land application of wastes, and other potential sources of pollution that are located within floodplains or flood prone areas. In some cases, these facilities can be moved or removed. The Department of Agriculture and Consumer Services manages a buyout program that provides financial assistance to owners of high risk and previously flooded animal operations to voluntarily close out their facilities. Bolstering this program and creating similar programs for other facilities in floodplains would make it possible for more potential contaminant sources to be voluntarily moved out of these high-risk areas.

Stormwater Control Measures

Another strategy is to encourage stormwater control measures to be incorporated into new development as well as implemented as retrofits to existing development or other activities (e.g. agriculture). Stormwater control measures capture precipitation close to where it falls and facilitate treatment and storage, reducing the amount of pollution that ends up in nearby streams. These practices can include cisterns, rain gardens, constructed wetlands, bioretention, and permeable pavement. Where there are issues with sanitary sewer overflows, implementation of distributed stormwater control measures can help reduce the occurrence and severity of overflows.

Asset Mapping

The state can also encourage sewer and stormwater infrastructure mapping and inventory efforts. DWR administers several grant programs that provide assistance for these activities; Nonpoint Source Management grant program, Water Quality Management grant program, and the Water Resources Development grant program. These programs should be continued and expanded where possible. When municipalities understand where their assets are, how they are connected, and the condition they are in, they can make informed decisions about capital improvements.

Data-driven Decision Making

As with any environmental program, more data and research support better resiliency planning and decision-making. DWR can, either internally or with academic partners, investigate data needs to better understand the sources and amount of nonpoint source pollution, as well as evaluate effectiveness of the DWR permitting requirements and programs that are intended to manage nonpoint source pollution.

Adaptive capacity of the Shellfish Sanitation and Recreational Water Quality Program to meet growing needs associated with increased rainfall and flooding is dependent upon continued adherence to guidelines set by the Interstate Shellfish Sanitation Conference contained in the National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish Model Ordinance, EPA’s BEACH Act, and the National Beach Guidance and Required Performance Criteria for Grants Program.

Water Availability / Drought, Heat, and Precipitation

Impact Summary

Historical data for North Carolina indicate that precipitation has become more variable, stream low flows are decreasing in many areas, and drought frequency is increasing. Longer-term droughts are expected to intensify in the Southeast due to longer periods of dry weather and more extreme heat.[2]. An increase in drought frequency and/or intensity, coupled with higher demands from an increasing population, could compromise stream ecology, threaten water supply reliability, and affect treatment requirements for both water users and dischargers.

Vulnerability and Risk

Water resources are critical needs for a wide variety of sectors including Agriculture, Ecosystems, Public Water Supply, and Energy production. In many cases, water requirements are sensitive to timing and quantity. For example, municipal water supplies see their highest demands during the summer. The predicted increase in precipitation variability and evapotranspiration due to higher temperatures will disrupt the current balance between supply and demand.

In North Carolina, irrigation is not widespread and farmers generally rely on rainfall to provide water for crops. Timing of rainfall is critical, needing to occur during specific periods of the crop cycle. Droughts, even those less than a few months, can result in extensive crop losses and have significant economic impacts. Each crop is a large investment for farmers and a lost crop can completely bankrupt an operation.

River ecosystems also require some minimum rainfall, runoff, water levels, and discharge to provide habitat and ecosystem services. Long-term drought would reduce available habitat, increasing water temperatures, and harming native species. Reduced flows may result in degraded water quality and standards violations.

Many municipal and industrial water supplies in North Carolina use surface waters as their primary source. Low stream flows resulting from drought can result in poor water quality, high turbidity, and even an inability for water intakes to function properly. Some municipalities and industries withdraw water from reservoirs, but reduced inflow would also compromise the reliability of these resources. Some coastal towns and industries have been affected by drought as the saltwater reaches further upstream and impacts freshwater intakes. Past droughts have required water restrictions affecting millions of North Carolina residents.

Power generation in North Carolina is predominantly thermoelectric and is the largest water user. Generation facilities use either stream flow or reservoir water to generate power using steam driven turbines. Some of the water that is withdrawn is lost to evaporation while the majority is returned to surface waters. Power plants may face reductions in power or temporary shutdowns if water supply is insufficient.

Water quality impacts may be seen during drought periods. Point source discharge limits are based on the assimilative capacity of the receiving water, and that capacity is calculated based on historic low flows. If flows fall below this level, conditions may not meet water quality standards due to the limited assimilative capacity of the water body. If droughts occur during spates of high temperature, biological

[2] Georgakakos, A., P. Fleming, M. Dettinger, C. Peters-Lidard, Terese (T.C.) Richmond, K. Reckhow, K. White, and D. Yates, 2014: Ch. 3: Water Resources. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 69-112. doi:10.7930/ J0G44N6T.

and chemical oxygen demand may increase, or harmful algal blooms may proliferate. As noted earlier, water resources are also becoming stressed due to higher demands as a result of population growth.

Resilience Strategies

The scale and magnitude of drought makes increasing resiliency a challenge. Public water systems and agriculture may have the most options for adaptation but face challenges. Reservoirs provide water during dry periods, but changes to or construction of large water supply reservoirs is land-intensive, expensive, and faces many environmental and regulatory requirements. Long-range planning with a focus on conservation, water reuse, interconnections between systems, and emergency supplemental supplies are key components of resilience for municipal and industrial supplies.

Drought-tolerant Crops

Irrigation can meet crop needs but increasing irrigation can further stress surface water resources during drought and irrigation from groundwater is not always feasible. Coordination with agricultural extension offices to identify drought-tolerant crops is one solution for resilient agriculture.

Monitoring and Protection

The scale of natural ecosystems makes providing supplemental water infeasible, but protection and enhancement of natural lands can provide flow resilience that developed land cannot because rainfall infiltrates into the soil and slowly returns as base flow. Monitoring and protection of groundwater levels and instream flow are also necessary to meet the potential changes associated with climate change.

Power generators

Power Generators can improve water efficiency in existing plants and transition to recirculating cooling systems.

Public Water Supply and Irrigation Water in Coastal Regions / Sea Level Rise

Impact Summary

Among the many consequences of sea level rise is saltwater intrusion into freshwater sources. Saline water is not suitable for irrigation or as a drinking water source. Saltwater intrusion due to sea level rise will limit agricultural productivity as irrigation water becomes saline and salt builds up on fields. Public water systems may need to switch sources or build reverse osmosis systems to provide potable water in the future.

Vulnerability and Risk

Sea level along the northeastern coast of North Carolina has risen about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck, NC, and 0.9 inches per decade since 1935 at Wilmington, NC.[3] Projections show the rate of sea level rise will increase.

Irrigation water from shallow groundwater or surface water in some areas has already become more saline. Slightly saline water can be used for irrigation but fields will see salt buildup, reducing productivity. Large areas of agriculture that rely on irrigation during dry periods may be affected in the future.

[3] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. P. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: *North Carolina Climate Science Report*. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

Public water supplies that rely on groundwater are also vulnerable. In most cases, groundwater systems only need to provide minimal treatment of the groundwater before supplying it to their customers. Some systems have already reported the need to abandon wells due to high salinity.

Resilience Strategies

New wells can be drilled deeper to tap into different aquifers or drilled further inland to avoid the saltwater intrusion zone. Water systems and farmers can utilize surface water supplies but in many cases these sources may already be over-utilized. Reverse osmosis treatment can allow a water system to continue to utilize their current sources, but the construction and operation costs can be burdensome.

Long-range planning with a focus on conservation, water reuse, interconnections between systems and emergency supplemental supplies are key components of resilience for municipal and industrial supplies. Coordination with agricultural extension offices to identify drought or salinity-tolerant crops is a solution for resilient agriculture.

Stormwater and Water Quality / Flooding

Impact Summary

DEMLR's Stormwater Program is responsible for regulating stormwater runoff through various programs. The federally mandated National Pollutant Discharge Elimination System (NPDES) Program regulates over 4,000 industrial sites and 122 municipal separate storm sewer systems (MS4s). The state post-construction stormwater program regulates over 15,000 development sites statewide for long-term stormwater management. The state Water Supply Watershed Program regulates stormwater discharges in watersheds designated for water supply.

During rainfall events, pollutants such as sediment, nutrients, heavy metals and pathogens are collected from land surfaces by stormwater runoff, which eventually ends up in the state's lakes, rivers, estuaries and the Atlantic Ocean. Development increases both the amount of stormwater runoff and the concentration of pollutants in runoff that is discharged, ultimately affecting water quality and other issues such as streambank erosion. Increasingly frequent and intense storms exacerbate these issues and can cause the discharge of significant amounts of untreated stormwater, as well as damage to stormwater infrastructure and increased maintenance requirements.

Vulnerability and Risk

Water quality is directly tied to a variety of important ecological and economic benefits, and the risks associated with degraded water quality due to stormwater runoff are high due to adverse health and ecosystem impacts. Pollutants associated with stormwater runoff, such as sediment, excessive nutrients, fecal coliform and petroleum products all impair water quality in streams, rivers, reservoirs, and coastal estuaries.

Pollutants from stormwater runoff, particularly nutrients, have also been shown to contribute to water quality impairments in water supply reservoirs, such as Jordan Lake and Falls Lake. Poor water quality can contribute to negative health impacts, increased cost of water treatment, degraded water quality and negatively impact recreation and other water uses, such as fishing, boating and swimming. Industrial sites have the potential to discharge high levels of pollutants, including heavy metals, oils, grease, and toxic chemicals. Stormwater runoff has resulted in closures of beaches and shellfish growing areas, which are important economic drivers for coastal North Carolina.

The growing population of North Carolina is causing further development of open areas of the state, which increases impervious coverage. This in turn directly increases the amount of stormwater runoff and the pollutant concentrations. Traditional stormwater management techniques aim to reduce the pollutant concentrations and sometimes the runoff volumes leaving the site through on-site stormwater control measures. These stormwater control measures require frequent maintenance, and increasingly intense storms increase the risk of damage to the existing and future stormwater management devices that are being installed throughout the state. Further, it has proven a challenge to ensure that the approved and existing stormwater control measures are owned and operated by the proper party and that frequent maintenance is occurring. This further increases the risk of damages due to stormwater runoff.

The coastal region is the most vulnerable to heavy precipitation events and suffers from some of the most severe impacts of stormwater runoff (e.g., beach closures, shell fishing closures). It is for this reason that the coastal post-construction stormwater management program was created in 1988. Since that time, over 14,000 permits have been issued to development sites in the 20 coastal counties. These permits address the design and implementation of stormwater control measures for water quality purposes, as well as operation and maintenance of the permitted systems. The increasing frequency and intensity of heavy precipitation events overwhelms the treatment capacity of these systems and can cause infrastructure damage, greatly increasing the cost of regular maintenance, which is often paid for by homeowners.

The Stormwater Program also regulates development in High Quality Waters (HQW) and Outstanding Resource Waters (ORW) watersheds. These are watersheds that are rated excellent based on biological and physical/chemical characteristics through monitoring or special studies, primary nursery areas designated by the Marine Fisheries Commission, and other functional nursery areas designated by the Marine Fisheries Commission. These include specific water supply watersheds and commercial shell fishing waters. Stormwater pollution is a threat to the unique characteristics of these watersheds and must be managed closely to maintain their important ecological and economic functions.

Resilience Strategies

The ability to further improve the way that stormwater is managed is a major challenge. Traditional stormwater management techniques are limited in their ability to treat large storm events and the economic return decreases with increasing treatment requirements. Further review of storm patterns and design standards could help to indicate the best treatment goals to adapt to changing climatic conditions.

Increased resources to aid the stormwater program in managing existing permitted sites would be very useful to ensure that existing stormwater control measures are built and maintained in accordance with permitted standards. Further expansion of stormwater programs into areas that are currently without a program would help curb unregulated development. Finally, the current stormwater regulations are limited in scope to addressing primarily water quality. The state should consider options to determine the use of this program to also regulate stormwater quantity up to the 25-year design storm. This would not only increase water quality treatment but also address reducing runoff that contributes to some flooding events.

Landslides

Impact Summary

The greatest landslide hazard is in the western North Carolina Mountains, but localized landslides also occur on steep slopes in the Piedmont and Coastal Plain. Rapidly moving landslides like debris flows (mud flows) are the most frequent type of landslide and pose the greatest threat to public safety as they can travel at speeds of 30 miles per hour. Rock slides and other landslide types damage and disrupt transportation corridors, utilities, homes, business, surface waters and other cross-sector entities leading to expensive repairs and economic losses.

The causes of landslides are directly related to geology, hydrology, topography, vegetation, and human-related ground-disturbing activity that has destabilized slopes. Since 1876 there have been 9 major storms, including tropical cyclones, that each produced hundreds or thousands of landslides resulting in many fatalities and widespread damage throughout the Mountains. The average frequency of these major landslide events is about 16 years. However, damaging landslides occur on an annual basis. There have been 11 fatalities and 30 destroyed homes (uninsured) from landslides since 1977. A conservative estimate of losses from landslides since 1977 of $48 million does not include many NCDOT direct costs, and indirect economic losses from disrupted transportation corridors.

Vulnerability and Risk

The North Carolina Geological Survey (NCGS) responds to many requests for technical assistance on landslides from emergency managers, federal, state and local agencies as well as the public. Reports prepared from responses to over 300 landslides document impacts and factors that contribute to landslides and their dissemination improves knowledge to help reduce losses from future landslides.

Landslide mapping identifies locations vulnerable to damage from landslides. The greatest exposure to landslides is in the mountains. Sensitivity is related to past landslide activity, geology, topography (slope and position on the landscape), vegetation (or lack thereof due to wildfire), and ground disturbance due to improperly located, constructed and maintained slopes and drainage systems. Less rainfall is required to trigger landslides on slopes destabilized by human activity than is required to trigger landslides on natural forested slopes, thereby increasing the vulnerability of some disturbed slopes.

The risk of damage and loss of life from landslides is high as the frequency of extreme precipitation events increases in areas of continued population growth and past and current development in vulnerable locations in the Mountains. Heavy rainfall events are the main trigger for landslides. The frequency of landslide events is directly linked to the frequency and magnitude of extreme rainfall events and weather patterns. As population increases so does the dependence on critical infrastructure. When major transportation corridors like I-40 are impacted by landslides, disruption and economic losses are felt over large areas in the Mountains because alternate routes are limited by terrain constraints.

The likelihood of repeated, and potentially increased, landslide occurrence is very high as evidenced by landslides from tropical cyclones that impacted the Mountains since 2004: Frances, Ivan (2004), Cindy (2005), Ernesto (2006), Fay (2014), Alberto (2008), and Florence (2018). Recurring extreme weather patterns such as record annual rainfall amounts in 2013 and 2018 led to increased landslide activity. During these extended periods of above-normal precipitation, numerous lower intensity storms triggered hundreds of landslides because of persistent, elevated levels of soil moisture. Aging infrastructure increases the likelihood of landslides related to failing drainage systems and deteriorating slopes on major transportation routes like I-40, I-26, the Blue Ridge Parkway, and other highways.

Resilience Strategies

Landslide hazard maps show where landslides have happened or are happening; where landslides like debris flows are likely to start; and, if debris flows start, where they are likely to go. Therefore, continued and recurring funding for four to nine FTEs to provide this response capacity and reporting, and to increase the coverage of landslide maps is important to meet the future resilience needs of North Carolina.

Other options include enhancing collaboration to anticipate and communicate the threat of landslide hazards, and coordinate emergency responses to landslide events. State and local governments could provide incentives for smart growth and development in safe locations and discourage development in vulnerable locations. Because local jurisdictions, homeowners and homeowners' associations are often financially incapable of funding major slope stabilization or mitigation projects, the state should improve and develop landslide mitigation funding strategies.

Mining / Flooding

Impact Summary

The Mining Program within DEMLR is a regulatory agency that issues permits to mining operations requiring environmental compliance and ultimately site reclamation when mining is complete. The Stormwater Program also within DEMLR is also a regulatory agency that issues NPDES permits for mining operations that discharge stormwater or process wastewater to surface waters.

Flooding impacts can cause environmental harm to receiving waters and other property, as well as damage and harm the mining operation, its materials and equipment. Riverine water flooded several mines during Hurricanes Matthew (2016) and Florence (2018), causing damage to equipment and rendering the mines unusable until floodwaters could be pumped out per permit conditions. Impacts in future events on other mines could include tons of sediment loss, sediment loading of surface waters, water quality impacts, and economic impacts to the mine operations and downstream public.

Vulnerability and Risk

The sensitivity of environmental and property exposure of a mine site to heavy precipitation events and hurricanes and resulting damage varies based on the following:

- installation and maintenance of Erosion and Sediment Control best management practices (BMPs);
- up-to-date maintenance of those BMPs, engineering design standard used (currently 25-year design storm, set by statute and rule);
- water classification (ex. Class C versus High Quality Water or Trout Water, measure of quality of use); and
- physical location of project (in floodplain, near floodplain, out of floodplain, topography).

If BMPs are implemented and maintained correctly, they provide adaptive capacity to counteract exposure and damage, and reduce water quality sensitivity at least up to their design storm size. A 25-year design storm is required for all mines in all water classes per current statute and rule. Location matters as sites subject to flooding are not only threatened by flash flooding of the mine site, but by riverine flooding that could be a result of a precipitation event upstream of the site that may have received little or no direct precipitation.

Vulnerability is also a function of land use (urban -vs- rural, population, development density), size of mine, location within a watershed (ex. in floodplain -vs- not, this relates to sensitivity within the environment), location (Mountains, Piedmont, Coastal Plain), types of soils, type of mineral mined, type of onsite processing and topography (slope) among others.

Construction requirements in NC require a 25-year frequency design storm for BMPs on mine facilities. Even given the best construction practices and if every operator met every legal requirement during construction, multiple 25-year and larger storms in multiple locations throughout NC (all of which have been observed and are likely in the future) will likely overwhelm the intended design capabilities of BMPs. Because of this, it becomes evident that our Intensity, Duration, and Frequency (IDF) curves need updating or replacing. IDF curves are the tools that engineers, hydrologists and other professional consultants use to size constructed BMPs for control of erosion, sedimentation and stormwater.

Resilience Strategies

Adaptive capacity varies with input by the state and by individual mine operators. Education for designers, developers and mine operators to properly design and install appropriate measures is relatively easy. Some workshops are taught in NC and online by DEQ, NCSU, NCDOT, International Erosion

Control Association (IECA) and the National Association of State Land Reclamationists (NASLR). More education and training and resources for these efforts on a state level can lead to a better understanding of potential impacts, improved siting determinations for facilities to relocate out of sensitive areas where possible, choosing appropriate measures based on location to avoid or minimize impacts and adequate emergency response and ultimately reduced enforcement actions. Statutory and rule changes are required to update design standards and IDF curves, the latter of which will also require scientific study and review.

Stream and Wetland Mitigation / Flooding

Impact Summary

Stream, wetland and buffer mitigation is realized by way of restoration. Successful restoration is dependent on the degree of functional improvement attained by the restorative process and the ability to demonstrate water quality and aquatic habitat improvement over a 7-year monitoring period. Increases in precipitation and/or changes in precipitation magnitude, duration, intensity and frequency can negatively impact restoration projects. These changes will affect the magnitude, duration, intensity and frequency of stream discharge and overland flow.

Increased discharge will result in increased streambank erosion rates and the delivery of sediment and phosphorus to streams. Increased overland flow due to intensity and frequency of precipitation will likely result in the accelerated delivery of pollutants (e.g., nitrogen, fecal coliform) to streams. If the rate of pollutant abatement associated with restoration is outweighed by the rate of pollutant delivery, the ability of DMS to achieve improvements in water quality by stream, wetland and buffer restoration will be affected. The increased variability of climatic conditions will affect DMS and mitigation providers by amplifying monitoring data variability and putting into question the success of restoration projects.

Vulnerability and Risk

A restoration project is considered a state asset with an environmental value as well as a monetary value. From the mountains to the coast on over 600 projects, DMS works to protect more than three million feet of stream and 76,000 acres of natural areas. These projects are required to offset stream and wetland impacts resulting from transportation and development. The success of DMS projects directly effects DWR and USACE permitting as well as DMS compliance.

Resilience Strategies

The variability of climatic changes (i.e., increase/decrease in precipitation/discharge/overland flow), is a challenge to resiliency. However, some resiliency may be achieved by tracking overall success rates and by analyzing monitoring data for trends. DMS currently has databases to facilitate data analysis. Observation and analysis may help to inform restoration providers to design projects with data trends in mind.

Sedimentation and Erosion Control / Heavy Precipitation

Impact Summary

The Sediment Program within the DEMLR is a regulatory agency that issues Erosion and Sedimentation Control Plan Approvals to developments subject to the Sediment Act and requires environmental compliance and ultimately site stabilization upon completion of construction. The Stormwater Program also within DEMLR is also a regulatory agency that issues National Pollutant Discharge Elimination System (NPDES) permits for construction.

Heavy precipitation events and associated flooding impacts can cause environmental harm to receiving waters and other property and can also cause environmental and property damage not only to the development but to receiving surface waters and other property. These issues occur during heavy rains and hurricanes resulting in environmental violations dozens of times each year. Best Management Practices (BMPs) are designed for 10- and 25-year return frequency storms depending on water zone classifications in the state. North Carolina is seeing more and more recurring 10- and 25-year storms multiple times each year causing us to question the validity of IDF curves used in design of BMPs.

Vulnerability and Risk

A variety of factors, such as location (i.e., urban vs. rural), size of development, terrain position (e.g. in floodplain vs. not), physiographic region (Mountains, Piedmont, Coastal Plain), soil type, and topography (slope), all affect the sensitivity of source watersheds and receiving waters. Furthermore, exposure of a construction site to heavy precipitation events (including hurricanes) varies based on pre-existing adaptive capacity due to installation and maintenance of Erosion and Sediment Control BMPs, up-to-date maintenance of those BMPs, design standard used (10 year or 25-year design storm, set by statute and rule), water classification (e.g. Class C versus High Quality Water or Trout Water), and physical location of project (e.g., in floodplain, near floodplain, out of floodplain).

BMPs provide adaptive capacity on construction and development sites. If BMPs are installed correctly and well maintained, they are less sensitive to exposure and damage at least up to their design storm size. A 25-year design storm is less sensitive than a 10-year design storm but 25 years is the maximum required for HQW zones classifications only and the predominating requirement is for 10-year design per current statute and rule. Also, location plays a big part here as site subject to flooding are not only threatened by flash flooding of the construction site but by riverine flooding that could be a result of a precipitation event upstream of the site that may have received little or no direct precipitation.

Resilience Strategies

Education and training for designers, developers and contractors to properly design and install appropriate measures is relatively easy and workshops are taught in NC by DEQ, NCSU, NCDOT and the International Erosion Control Association (IECA) multiple times each year. Adaptive capacity for design standards and Intensity/Duration/Frequency (IDF) curves is low to intermediate because that will take statutory and rule changes and IDF curves will require a different way of putting together with scientific review.

More data and research addressing new materials, siting, buffers and processes will support and improve resilience efforts moving into the future. DEQ has worked with several universities, especially with North Carolina State University's Soil Science Department, and has been the recipient of their research in efforts to improve BMPs and processes used in construction to reduce erosion of the land and sedimentation of our surface waters. DEQ can and should continue to work closely with these research efforts to identify funding, continue research, reduce sedimentation pollution and improve resilience from construction impacts to the state due to heavy precipitation events.

DEQ can and should continue to work closely with these research efforts to identify funding, continue research, reduce sedimentation pollution and improve resilience from construction impacts to the state due to heavy precipitation events.

4. Summary

A central challenge to water and land planning and management is learning to plan for plausible future climate conditions that are wider in range than those experienced in the 20th century. Doing so requires approaches that evaluate plans over many possible futures instead of just one. Real-time monitoring and forecast products allow better management decisions, especially in the face of extreme precipitation and drought, whose impacts are described above. A thorough risk assessment of the state's water infrastructure would provide essential insight into the potential costs and impacts associated with climate-related hazards.

We note several opportunities to update policies and engineering principles. For example, we recommend new research and implementation of IDF curves and Probable Maximum Precipitation (PMP) studies be incorporated into storm design standards using the best available geoscience-based understanding of planetary change. Recent examples of adaptation responses undertaken by large water management agencies, including major metropolitan water utilities and the U.S. Army Corps of Engineers, are promising. These examples include development of climate change based IDF curves for Alexandria, Virginia and Raleigh, North Carolina, a new surge wall and levees built in New Orleans, and infrastructure adaptation engineering in New York City as a result of hurricane impacts in those areas.

Water management during droughts is coordinated by DWR and the North Carolina Drought Management Advisory Council. Federally owned and licensed dams have protocols in place to manage reservoir storage and releases during high water and drought events. The state also requires local governments and large community water systems to have a Water Shortage Response Plan in place that specifies water restriction levels and associated conservation efforts based on measurable conditions such as reservoir or stream levels. The state also encourages resiliency efforts such as interconnections and regionalization to provide emergency water supplies.

Water and land impacts and strategies are closely inter-related. The condition of the land, i.e. natural, managed, or impervious, directly affects the volume and quality of runoff. This in turn influences the availability of water, erosion, sedimentation, landslides, dam safety, pollutant loading to receiving waters, and ecosystem health. The condition of North Carolina's water and land resources are also closely connected to most other sectors which support the state's human and ecological health and economic prosperity. For this reason, strategies to meet the challenges posed by climate change will also require close coordination with these other sectors.

Planning and response to emergency events and natural disasters, especially heavy precipitation and hurricanes, will impact DEQ with an exceptional impact on the landslide, dam safety, stormwater, erosion & sedimentation control, water quality, and water supply programs which are mandated by North Carolina General Statutes to address development in a responsible manner to provide for the life, health, safety and protection of property. Emergency and disaster events in the recent past have showcased the need for increased capacity and additional measures to improve resiliency in North Carolina for the future. Resources, specifically funding, for increased necessary permanent personnel for example in the landslide mapping and dam safety emergency action planning programs, equipment such as laboratory equipment and high capacity pumps, training for very specialized staff in all Divisions, and appropriate salaries, as well as internal assessments of future capacity that allow DEQ to keep up with these issues, are an absolute necessity to the state's lives, health, safety, economy and overall resilience to climate change.

Energy

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L. Energy

Key Observations

- Energy drives commerce, transportation, environmental controls, emergency response, agriculture, housing, and many other parts of our economy and therefore solutions must be integrated across these sectors.
- Energy resources, regulations, technology innovation, consumer demand, carbon reduction goals, and market pressures are rapidly changing the industry. This creates an opportunity to build resilience through the modernization of the energy supply and delivery infrastructure.
- North Carolina utilities, regulators, policy makers, energy planners, and emergency response planners should develop resiliency metrics to quantify human and economic costs of power outages and apply a risk-based framework to accelerate decision making related to energy infrastructure planning and operations.

Critical Impacts and Resilience Strategies

- Disruptions to the electric power grid from increased storm intensity can be mitigated by securing a diverse source of utility scale and distributed generation assets such as microgrids equipped with renewable energy and battery storage devices, hardening the grid/transmission infrastructure, reducing demand for power, and modernizing existing grid assets with smart meters, controllers, automation, and analytics to manage a diverse source of power supply, transmission, and distribution system components.
- Stress on thermoelectric power plant cooling due to drought can be addressed with non-traditional water and energy sources, water capture and dry cooling to protect water quantity and quality, and demand side management programs.
- Fuel supply chains disruption from increased storm intensity may benefit from alternative fuel infrastructure and hardening existing pipelines, terminals, and fuel stations to facilitate evacuation routes and protect critical infrastructure.
- The North Carolina Disaster Recovery Framework, led by NC Emergency Management, should expand to focus on how to integrate resiliency planning for both storm-related outages and cyberattacks into its disaster recovery planning. The effort should evaluate how new and existing infrastructure can best be deployed to reduce recovery efforts.

1. Introduction to Sector

The energy sector is the engine that drives our state's growing economy and population. In 2018, North Carolina had the 11th largest economy in the nation at gross domestic product (GDP) of nearly $566 billion.[1] North Carolina is also one of the most populous states in the nation, ranking ninth at about 10.4 million people in 2018. In 2020, North Carolina's population is expected to reach 10.6 million people.[2]

North Carolina's thriving economy and communities consume about 2.6% of the total energy consumed in the nation, ranking 12th within the residential, commercial, industrial, and transportation sectors.[3] At

[1] Steven Pennington, NC Annual Economic Report: Gross Domestic Product, NC Department of Commerce, November 4, 2019. Retrieved from https://www.nccommerce.com/blog/2019/11/04/nc-annual-economic-report-gross-domestic-product

[2] North Carolina Budget and Management, Facts and Figures. Retrieved from https://www.osbm.nc.gov/facts-figures

[3] U.S. States Profiles and Energy Estimates, U.S. Energy Information Administration, 2017. Retrieved from https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_te.html&sid=US

annual consumption rate of 2,500 trillion British Thermal Units (TBtu) of energy, North Carolina relies heavily on imported fuel and energy sources; 74% of the state's annual consumption is imported. Figure 5L-1 shows energy consumption by fuel type and by the end use sectors.

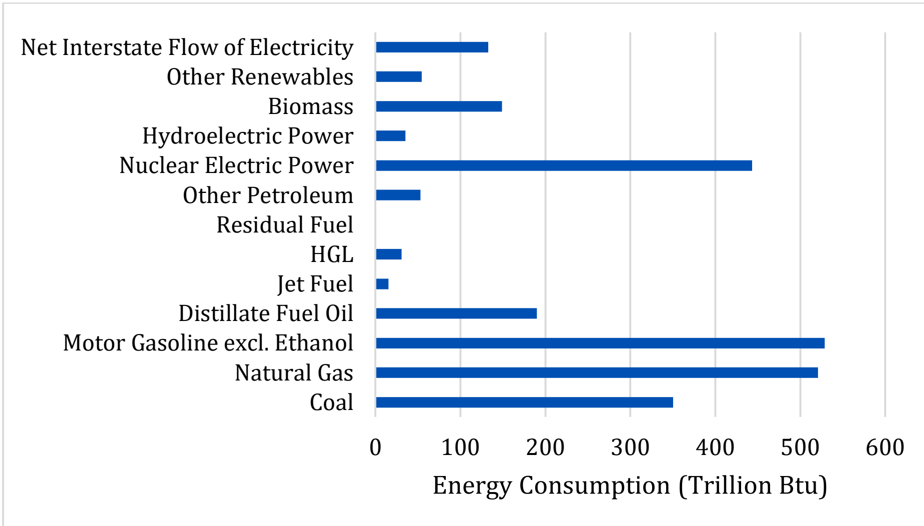

Figure 5L-1. North Carolina Energy Consumption by Fuel Type

Motor gasoline and diesel fuel used by cars and trucks on North Carolina's heavily traveled highway system and jet fuel consumed at airports make the transportation sector the largest end-use energy-consuming sector in the state, with a state ranking of 7th highest vehicle miles traveled in 2017.[4] Approximately 3% of all U.S. refined petroleum is consumed in North Carolina.[5]

The residential sector follows the transportation sector, accounting for one-fourth of North Carolina energy consumption. The residential sector is a significant consumer of electricity, ranking as the fourth highest in the nation.[6] The commercial and industrial sectors each consume slightly more than one-fifth of the state's total energy consumption.[7]

North Carolina is also among the top 10 electricity-generating states in the nation. The state's nuclear power plants produced nearly 5% of the nation's total electricity net generation in 2018 (5th among all the states).[8] During the same year, North Carolina ranked second after California in the amount of installed solar power generating capacity. Natural gas is the primary source of fuel for electricity generation in North Carolina, increasing from 15% to 65% of state consumption in the past decade, while coal use has declined significantly.[9]

North Carolina's energy infrastructure is owned and operated by the private sector, rural electric cooperative, and local governments and is regulated by federal bodies, state utility commission, and the

[4] U.S. EIA, State Energy Data System, Table C3, Primary Energy Consumption Estimates, 2017.
[5] Petroleum Industry Preparation, Response & Recovery to Hurricane Florence, presented by David McGowan, NC Petroleum Council, NC Energy Policy Council Meeting, Archdale Building, February 20, 2019 meeting, Raleigh, NC. Retrieved from https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Energy/Energy%20Policy%20Council/EPC-Combined-Presentations.pdf
[6] U.S. EIA, North Carolina State Energy Profile. Retrieved from https://www.eia.gov/state/print.php?sid=NC
[7] U.S. EIA, State Energy Data System, C1, Energy Consumption Overview: Estimates by Energy Source and End-Use Sector, 2017.
[8] U.S. EIA, Electric Power Monthly (February 2019), Tables 1.3.B, 1.9.B.
[9] U.S. EIA, North Carolina Natural Gas Deliveries to Electric Power Consumers, 1997-2018.

legislature. The North Carolina State Energy Office (SEO), housed within the Department of Environmental Quality, does not have direct responsibility for the state's energy infrastructure. Nevertheless, the SEO has conducted a qualitative assessment of the climate and non-climate impacts, risks and vulnerabilities based on available information, assistance from public/private partners, and information on current projects led by energy providers, regulators, planners, and other stakeholders.

Pursuant to Governor Cooper's executive order 80, the Department of Environmental Quality released a Clean Energy Plan[10], which contains a set of recommendations to help create a modern, resilient, and low carbon electrical energy system in the state. The plan calls for requiring utility companies to develop projects focused on distributed energy resources (DERs), community solutions, and microgrids at critical infrastructure locations (e.g. hospitals, shelters) to enhance resilience and to coordinate resilience planning with disaster recovery operations center.

The Department of Energy's Grid Modernization Laboratory Consortium (GMLC) defines resiliency as "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[11] In the following sections, we provide an overview of exposure to climate-related hazards (section 2), examples of impacts, vulnerabilities, risks, and resilience strategies for three potential impacts from climate-related hazards (section 3), and a framework based on federal guidelines, to help policy makers identify energy infrastructure resilience issues, resilience barriers, and enhancement options (section 4). A combined effort among the private sector, utilities, regulators, and local, state, and federal governments would be necessary to prioritize state investments to build energy system resilience capacity.

2. Overall Exposure

A 2012 Congressional Research Service report estimates that storm-related power outages cost the U.S. economy $20-$55 billion annually, and outages from weather-related events are increasing.[12] These outages are the result of both climate (increasing storm intensity and frequency) and non-climate stressors (aging infrastructure and increasing development). In recent years, the number and cost of billion dollar disasters have increased nationally, including many in North Carolina. As a result of the increasing stress imposed by a changing climate as well as the pressure imposed by non-climate stressors, the hazards impacting energy sector assets and services will be of increasing concern in future years as shown in Table 5L-1.

[10] North Carolina Clean Energy Plan – Transitioning to a 21st Century Electricity System, Policy and Action Recommendations, North Carolina Department of Environmental Quality, October 2019. Retrieved from https://deq.nc.gov/energy-climate/climate-change/nc-climate-change-interagency-council/climate-change-clean-energy-16

[11] "Grid Modernization: Metrics Analysis Reference Document, Version 2.1," Grid Modernization Laboratory Consortium, May 2017. Retrieved from https://gmlc.doe.gov/sites/default/files/resources/GMLC1%201_Reference_Manual_2%201_final_2017_06_01_v4_wPNNLNo_1.pdf

[12] CRS 2012. Weather-Related Power Outages and Electric System Resiliency. 5-5700 R42696 Washington D.C.: Congressional Research Service. Retrieved from http://www.fas.org/sgp/crs/misc/R42696.pdf

Table 5L-1. Exposure of assets and services related to the energy sector

Assets, Services	Extreme Heat	Flooding (River and Land)	Water Shortage (Drought)	Strom Intensity	Changed Seasons	Landslides	Saltwater Intrusion	Storm Surge	Tidal Flooding	Wildfire	Dam Failure
Power Generation											
Nuclear and Hydrocarbon Power Plants		*	*	*			*	*			*
Renewable Energy Generating Facilities		*			*	*				*	
Hydroelectric Power Plants		*	*	*				*			*
Electric Power Delivery											
Transmission and Distribution Grid	*	*		*		*	*	*	*	*	*
Substations and Other Support Systems		*		*		*		*	*	*	
Fuel Supply Chain											
Natural Gas Pipelines		*		*		*		*			
Petroleum / Gasoline Pipelines		*		*		*		*	*	*	
Petroleum Storage and Bulk Terminals		*		*	*			*	*		
Gasoline Distribution and Fueling Stations		*		*	*	*		*	*		
Ports, rail and roads	*	*		*		*		*	*		

Climate Stressors and Climate-Related Hazards

Heavy Precipitation and Flooding

Energy-generating facilities are often located along inland watersheds and coastal areas in order to take advantage of available water resources. Though the location is beneficial for operation purposes, infrastructure near water sources is subject to fluctuations in river discharge and flooding from heavy precipitation.[13]

Energy storage and transport infrastructure are vulnerable to inundation and other related damage. For instance, buried pipelines which have been exposed due to flooding can be damaged further by debris. This is true of both inland and coastal infrastructures. Coal and petroleum transported by rail lines or highways which parallel rivers can flood, disrupting the energy supply chain. These same transport routes provide access to critical energy infrastructure, so flooding can cause service disruptions.

[13] Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

Sea Level Rise and Coastal Storms

North Carolina, especially the Outer Banks, is often hit by severe tropical storms and hurricanes, and is second only to Florida in tropical cyclone landfalls.[14] Rising sea level and continual increase in coastal storm intensity is a risk for exposed energy infrastructure on the coast. Low-lying thermoelectric power plants and energy infrastructure housed on the coast are vulnerable to saltwater intrusion and corrosion, as well as coastal erosion. Hurricanes Florence and Matthew caused historic flooding in the Carolinas with about 3 million customers losing power within the Duke Energy territory. Duke Energy reported that power for 90% of customers was restored within three days for both storms.[15] The storms resulted in one of the largest mobilization of power restoration activities in the company's history. In rural areas of the state, the NC Electric Cooperatives reported about 350,000 customers without power between the two storms.[16]

Damage to this infrastructure can cause delays in the electricity supply chain.[17] Following Hurricane Fran, the Brunswick nuclear power plant shut down temporarily and was operating at 15% of capacity one week after landfall. The Sutton natural gas combined cycle plant near the coast went offline for six days after landfall, and operated at partial capacity seven weeks after landfall.[18] The outages were due to: (1) excessive flooding, (2) storm damage to the fencing around the plant's security zone, (3) down power lines, also due to storm damage, and (4) storm debris that made the 10-mile emergency evacuation routes inaccessible. Disruptions to central power plant operation cascade to the bulk transmission and distribution system, where other connected distributed energy systems are unable to deliver power to customers. For example, during hurricane Florence, 5 of 403 utility-scale photovoltaic (PV) systems surveyed (1.2%) were damaged by tornadoes while the remaining systems were producing electricity. The disruptions to central power plants and the electric grid prevented the PV systems from being able to deliver the energy until the grid was able to come back up.[19]

Exposure of coastal energy infrastructure to large coastal storms is magnified by sea-level rise, which amplifies the size of storm surges. Critical production and transmission infrastructure on the coast is vulnerable to physical damage from inundation as well as water and-air-borne debris during a coastal storm. Coastal ports and terminals which transport energy products are vulnerable to high winds and storm surge. This can disrupt or even halt energy production across the state. A recent study by Moody's Investor Services cited Duke Energy as one of the top three utilities facing "red flag" (highest) hurricane risk in the U.S.[20]

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[14] Donegan, Brian, "North Carolina Second Only to Florida for U.S. Tropical Storms and Hurricanes," The Weather Channel, September 11, 2018.

[15] Duke Energy's Hurricane Preparation, Impacts, and Response, presented by Duke Energy, NC Energy Policy Council Meeting, Archdale Building, February 20, 2019 meeting, Raleigh, NC. Retrieved from https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Energy/Energy%20Policy%20Council/EPC-Combined-Presentations.pdf

[16] Hurricane Florence & Tropical Storm Michael, presented by S. Lee Ragsdale, NC Electric Cooperatives, NC Energy Policy Council Meeting, Archdale Building, February 20, 2019 meeting, Raleigh, NC. Retrieved from https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Energy/Energy%20Policy%20Council/EPC-Combined-Presentations.pdf

[17] US Department of Energy. 2015. Climate Change and the US Energy Sector: Regional Vulnerabilities and Resilience Solutions. Retrieved from https://www.energy.gov/sites/prod/files/2015/10/f27/Regional_Climate_Vulnerabilities_and_Resilience_Solutions_0.pdf

[18] Renewable Energy, Energy Assurance, and North Carolina Energy Policy, presented by Ivan Urlaub, NC Sustainable Energy Association, NC Energy Policy Council Meeting, Archdale Building, February 20, 2019 meeting, Raleigh, NC. Retrieved from https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Energy/Energy%20Policy%20Council/EPC-Combined-Presentations.pdf

[19] Ibid

[20] Moody's Investor Services. 2020. *Regulated electric utilities – US Intensifying climate hazards to heighten focus on infrastructure investments.*

Hurricanes can also damage wetlands and natural barriers which help to protect energy infrastructure from storm surge.[21] Damage to these barriers increase vulnerability to subsequent storms. Disruptions in service during a disaster can have further implications on emergency services such as trains, subways, data clouds, medical systems, and telecommunication services which are all reliant on the functionality of the grid system.[22]

Increased Temperature and Drought

Under the business as usual emissions scenario, North Carolina is projected to experience 2°– 5°F temperature increase by the middle of this century and 6°– 10° by the end of the century.[23] Studies have found that increased temperatures and an increase in the number of days above 65°F lead to an increase in energy consumption, especially in the summer and during peak demand hours.[24] Conversely, higher temperatures during the winter months will decrease the demand for heating, reducing energy consumption. However, energy saved by decreased heating in the winter will only marginally offset the pressure on the energy sector and will lead to an overall net increase from average higher annual temperatures.[25] In response to warmer temperatures, customers who use alternative energy sources such as propane and natural gas for heating are expected to decrease consumption, increasing demand for electricity for cooling purposes.

Another consequence of higher temperatures is the likelihood of increased evaporation and drought. Thermoelectric power plants, which require cold water to cool steam used to power a turbine-generator, are subject to decreases in efficiency due to the lack of available water in reservoirs. Additionally, increasing water temperatures could cause thermoelectric power plants to exceed thermal discharge limits and force a temporary shutdown.[26]

Hydroelectric power plants are especially affected by severe drought. There are 38 hydroelectric power plants using over 7,500 million gallons of water a day on thermoelectric power generation in North Carolina.[27] Hydroelectric power plants require enough water in their reservoirs to provide the pressure needed to drive turbines and produce energy. Severe droughts are expected to decrease hydroelectric efficiency and generation, especially in the western region of the state.[28]

[21] Ibid
[22] Myers-Jaffe, A., Busby, J., Blackburn, J., Copeland, C., Law, S., Ogden, J.M., Griffin, P.A. 2019. *Impact of Climate Risk on the Energy System.* Center for Geoeconomic Studies. Retrieved from https://cdn.cfr.org/sites/default/files/report_pdf/Impact%20of%20Climate%20Risk%20on%20the%20Energy%20System_0.pdf
[23] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K. Dello, J. Dissen, G. Lackmann, R. Luettich, B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A. Terando, 2020: North Carolina Climate Science Report. North Carolina Institute for Climate Studies.
[24] Sullivan, P., Colman, J., Kalendra, E. 2015. Predicting the Response of Electricity Load to Climate Change. National Renewable Energy Laboratory (NREL). Retrieved from https://www.nrel.gov/docs/fy15osti/64297.pdf
[25] Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II.* U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.
[26] US Department of Energy. 2015. Climate Change and the US Energy Sector: Regional Vulnerabilities and Resilience Solutions. Retrieved from https://www.energy.gov/sites/prod/files/2015/10/f27/Regional_Climate_Vulnerabilities_and_Resilience_Solutions_0.pdf
[27] Dieter, C.A., Linsey, K.S., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Maupin, M.A., and Barber, N.L., 2018, Estimated use of water in the United States county-level data for 2015 (ver. 2.0, June 2018): U.S. Geological Survey data release. Retrieved from https://doi.org/10.5066/F7TB15V5
[28] Dieter, C.A., Linsey, K.S., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Maupin, M.A., and Barber, N.L., 2018, Estimated use of water in the United States county-level data for 2015 (ver. 2.0, June 2018): U.S. Geological Survey data release. Retrieved from https://doi.org/10.5066/F7TB15V5

Non-Climate Stressors

Growing Population

North Carolina's population increase makes it one of the top 10 growing states in the country. With an expected population increase of almost 18% from 2020-2039, it can be expected that demand for energy products and services will increase significantly, requiring the need for a stronger, more efficient, and resilient energy system.[29]

Aging Infrastructure

Higher temperatures and increased demand on the electric grid reduce the generating capacity and efficiency of thermoelectric power plants and reduce the capacity of distribution lines. Extended periods of added demand on the electric power grid can cause outdated electric systems to fail.[30] Increased strain during peak hours could result in disruptions in generation and service, including widespread outages throughout service areas. Energy systems in North Carolina will ultimately benefit from modernization and installation of preventative infrastructure to protect from flooding and sea level rise, as well as a diversified electricity supply system to meet demand. Mitigation of these disruptions can be done by updating existing infrastructure, building additional infrastructure, and enabling alternate, renewable sources of energy, all of which will be reflected in retail costs.

Supply Chain Interruptions. Our economy is becoming more vulnerable to supply chain interruptions. Direct and intentional attacks on the energy system are becoming increasingly prevalent, such as physical attacks on the energy infrastructure and cyber-attacks on communications, control and operational equipment. The state of North Carolina – like any state in the U.S. – is prone to such attacks, which are a growing concern as the state becomes more reliant on third-party owned devices and distributed generation systems. Extreme electromagnetic incidents caused by an intentional electromagnetic pulse (EMP) attack or a naturally occurring geomagnetic disturbance (GMD, also referred to as "space weather") could damage significant portions of the critical infrastructure, including the electrical grid, communications equipment, water and wastewater systems.

Interconnected Nature of the Energy System

The energy sector infrastructure is comprised of a complex array of physical assets such as power plants (both utility scale and non-utility scale distributed between customers and central power stations), electricity transmission and distribution grid, natural gas pipelines, petroleum delivery systems, and other ancillary structures such as bulk gasoline terminals, gasoline distribution stations, railways, compressor stations, poles and wires, and electricity substations. This infrastructure is highly interconnected with other critical infrastructure systems, i.e., communications, transportation, agriculture, manufacturing, pollution control.

North Carolina relies on two pipelines to transport refined petroleum products (gasoline, diesel, jet fuel, home heating, military fuels) from the Gulf Coast refineries to East Coast markets. The Colonial Pipeline transports approximately 70-75% of daily volume, and the Kinder-Morgan/Plantation Pipeline supplies the remaining volume.[31] These pipelines support petroleum products to six major bulk terminal

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[29] US Census Bureau. 2019. North Carolina OSBM, Standard Population Estimates, Vintage 2018 and Population Projections, Vintage 2019. Retrieved from https://www.census.gov/programs-surveys/popest.html

[30] Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

[31] Petroleum Industry Preparation, Response & Recovery to Hurricane Florence, presented by David McGowan, NC Petroleum Council, NC Energy Policy Council Meeting, Archdale Building, February 20, 2019 meeting, Raleigh, NC. Retrieved from https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Energy/Energy%20Policy%20Council/EPC-Combined-Presentations.pdf

complexes in Charlotte, Greensboro, Selma, Apex, Fayetteville, and Wilmington, which in turn use trucks to distribute the fuel to approximately 4,550 filling stations.

Severe weather events can adversely affect the state's petroleum and natural gas infrastructure. Direct impacts of delays in fuel transmission and distribution lines include revenue losses, disability of critical services like public transit and emergency services, evacuation options, and associated macroeconomic consequences. Maintaining a continuous supply of fuel and electricity is crucial to North Carolina's economy and quality of life. Large-scale disruptions to the energy supply and delivery system is an area of great concern at both federal and state levels and has led to renewed efforts within all levels of the government, private sector, and communities to ensure the resilience of our energy systems.

Disruptions to energy infrastructure in the form of extended power outages or delays in fuel supply can lead to cascading and escalating failures that can propagate across multiple jurisdictions and affect the economic viability of a region for a long time after a disaster occurs. Even business owners without direct physical damage to their workplaces may be shut down temporarily by loss of power, because employees are unable to come in to work as a result of road closures, or due to personal property damage. As discussed in North Carolina's Hazard Mitigation Plan, many businesses that shut down after a major disaster never re-open their doors, which can have a major negative impact on local economies, especially in smaller communities.[32]

If power or communications systems are damaged or temporarily shut down, some aspects of the built environment will be impacted such as traffic lights, streetlights, and cell phone towers. Electronic equipment and control systems, water and wastewater systems, gas stations, and pipelines could all be damaged or their operations could be disrupted.

Loss of power can create very cold indoor conditions for residents. Residents may try to heat their home using alternative means, which runs the risk of carbon monoxide poisoning caused by improperly ventilated heating sources. In addition, dangerously cold temperatures increase the risk of wind chill, frostbite, and hypothermia. Another indirect impact is on public and private schools due to closings and delays due to the lack of power and heat. During times of extreme heat, air conditioning units work harder and require more electricity, making brownouts and blackouts possible if electricity demands exceed generation. Power outages occurring in the summer result in similar financial and societal impacts to the public and businesses.

[32] North Carolina Department of Public Safety, Division of Emergency Management, State of North Carolina Hazard Mitigation Plan (February 2018), page 3-207. Retrieved from https://files.nc.gov/ncdps/documents/files/State%20of%20North%20Carolina%20Hazard%20Mitigation%20Plan%20Final%20As%20Adopted.pdf

3. Examples of Impacts, Vulnerability, and Risk

Electric Power Grids / Intense Storms

Impact Summary

Increased storms across North Carolina have the most tangible and visible impact on the power grid and transmission system. Downed power lines, frequent or extended outages, and delayed repairs due to flooding and reduced access to the system all lead to impacts large and small on businesses and consumers. Companies suffer business interruption and costs of repairs; retail customers have myriad inconveniences and loss of property and productivity; and schools and work places shut down. The North Carolina Climate Science report indicates that the frequency and intensity of severe thunderstorms in North Carolina are ***very likely*** to increase.[33]

Rising average temperatures in the summer months put greater stress on the grid as air conditioners strain to provide relief from hotter days. At the same time, North Carolina's growing population and business community are increasing demands on the energy system, while demand side management, energy efficiency and customer cited energy sources are reducing some of this demand growth.

Vulnerability and Risk

North Carolina has approximately 13,600 miles of transmission infrastructure, 68,100 miles of overhead distribution pole miles, and 20,600 miles of distribution underground lines.[34,35] Transmission and distribution systems in North Carolina have been designed, built, and have been operating safely and efficiently by local electric utilities for decades. By adhering to good design standards, maintenance practices, and inter-cooperation, the electric utilities in North Carolina have a good reputation for providing highly reliable, low-cost electricity.

The goal of the power grid and transmission system is to deliver reliable electricity at a reasonable cost. Climate-related hazards and other stressors to the system work against these goals by lowering the efficiency of the grid and transmission system and reducing the overall capacity. This is in addition to the more obvious impacts of outages, especially long duration and high impact outages such as those in rural or remote areas, or those impacting hospitals and other critical services.

The existing energy and distribution infrastructure is evolving as renewable energy adoption grows due to lower costs, environmental goals, innovation and other market forces. Distributed energy resources (DER) such as small-scale wind, solar, electric vehicles (EV), or battery storage are creating new types of load impacting the grid.[36] These multiple, small- scale and intermittent resources are gaining ground,[37]

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[33] Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K. Dello, J. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: North Carolina Climate Science Report. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

[34] United States Department of Energy. (2015). State of North Carolina Energy Sector Risk Profile. Retrieved from https://www.energy.gov/sites/prod/files/2015/05/f22/NC-Energy%20Sector%20Risk%20Profile.pdf

[35] North Carolina Utilities Commission. (2003, November). Feasibility of Placing Electric Distribution Facilities Underground. Retrieved from http://www.ncuc.commerce.state.nc.us/reports/undergroundreport.pdf

[36] BusinessWire (2019). *Navigant Research Report Shows Global Revenue from DER Capacity Is Expected to Experience a Compound Annual Growth Rate of Nearly 16%.* Retrieved from https://www.businesswire.com/news/home/20190619005076/en/Navigant-Research-Report-Shows-Global-Revenue-DER

[37] Public Service Commission of North Carolina (2019). Duke Energy Docket no. E-7 Sub 1214. Retrieved from https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=cb13c39e-5f6b-457d-be23-5cc33ffa8d7f

fueled in part by a flurry of new EV charging stations across the state in areas both remote and densely populated.[38]

Utility-scale renewable energy is also growing across the state as costs plummet and demand escalates for energy options with lower emissions. Although the overall percentage of renewables in North Carolina's electricity mix is still small,[39] it is likely to increase due to Duke Energy's carbon neutrality by 2050 commitment, corporate interest in renewables, and bipartisan voter interest in clean energy deployment. The current transmission system is ill-equipped to capture the full capacity and value of these new resources, leading to lower returns on investment in generation when curtailment is necessary.

New investments in microgrids and distributed/community energy are developing to satisfy the demands of under-served or vulnerable markets, or to simply create a sense of empowerment for local jurisdictions, but these efforts bring new challenges to the traditional system by peeling off revenue that would otherwise support the traditional grid for the majority of communities that still rely on it.

Without sufficient transmission and load-balancing capacity, these resources can reach a saturation point where additional generation does not provide anticipated kilowatt hours and revenue, leading to a less efficient than anticipated system.[40] Energy storage options are continuing to develop to capture the full value of these resources,[41] but potential for curtailment from renewable energy resources remains until storage or transmission lines can capture all the generation.

Environmental commitments for corporations, including utilities, are driving action and creating policy signals across the nation, fostering increased adaptive capacity towards resilience goals. In North Carolina, 39 companies doing business in the state have set goals to be powered by 100% renewable energy, and 21 of these companies have already achieved 100% or plan to within the next 6 years.[42] Companies in a range of industries doing business in North Carolina have set clean energy goals, including major technology companies Amazon, Apple, Facebook, Google and SAS as well as American Express, BlueCross Blue Shield North Carolina, Ikea, Kohl's, New Belgium Brewing and Starbucks.[43]

In addition to these goals, more companies are committing to disclose their climate risks, leading these companies to look more closely at the impacts of climate change across their operations.[44] Globally, 340 investors representing nearly $34 trillion in assets have committed to engage the world's largest companies in evaluating and disclosing their climate risks,[45] which will lead to pressure on these companies to understand and address the underlying issues. Fueled in part by investor interest and corporate disclosures, more data are now available to pinpoint climate risk by geography, industry and corporation.[46]

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[38] Public Service Commission of North Carolina (2019). Duke Energy Docket no. E-7 Sub 1214. Retrieved from https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=cb13c39e-5f6b-457d-be23-5cc33ffa8d7f

[39] North Carolina Clean Energy Plan (2019). Retrieved from https://files.nc.gov/ncdeq/climate-change/clean-energy-plan/NC_Clean_Energy_Plan_OCT_2019_.pdf

[40] Rackliffe, G. (2019). *Duke University Energy Conference 2019: Energy Resilience & Climate Change – A Grid Perspective.* Retrieved from https://www.youtube.com/watch?v=RynPq40cxcw&feature=youtu.be

[41] National Governors Association (2017). *Powering Up: State Trends For Advancing The Use Of Energy Storage.* Retrieved from https://www.nga.org/center/publications/powering-up-state-trends-for-advancing-the-use-of-energy-storage/

[42] Ceres (2019). *NC Clean Energy Plan Stakeholder Workshop Presentation: Corporate Support for Clean Energy. Presented at CEP Facilitated Workshop #4*.

[43] Ibid

[44] Task Force on Climate-Related Financial Disclosures (2019). *Task Force on Climate-Related Financial Disclosures: Status Report.* Retrieved from https://www.fsb-tcfd.org/wp-content/uploads/2019/06/2019-TCFD-Status-Report-FINAL-053119.pdf

[45] Ibid

[46] Mazzacurati, E. (2019). *Scenario Analysis for Physical Climate Risk: Equity Markets*. Retrieved from http://427mt.com/2019/06/18/scenario-analysis-for-physical-climate-risk-equity-markets/

For the first time, climate change is becoming a credit risk issue potentially impacting access to and cost of capital.[47] Moody's, one of the big three credit rating agencies worldwide, has acquired a climate data company and recently identified Duke Energy as one of the nation's top utilities at risk from hurricanes due to climate change, with the most severe risks along Duke Energy's coastal Carolina operations and parts of their Florida service area.[48] Overtime, these risks can impact bond ratings, resulting in increased cost of doing business.

Resilience Strategies

There are opportunities for North Carolina power generation, transmission, and distribution system owners and operators to add technology and system improvements to increase reliability and resilience. Also, as the location and production of the new generation sources change, the need for and use of transmission, and especially distribution systems, must change. Accordingly, there may be opportunities for infrastructure owners to integrate grid modernization into future plans.

For weather-related risks, numerous actions have been planned or proposed by Duke Energy in their recent rate case filings with the Public Utilities Commission.[49] Targeted undergrounding of transmission lines in high risk and/or high impact areas is a key strategy to reduce the potential for physical damage and resulting outages.[50] In addition, there is an array of means to hardening grid and transmission infrastructure and increase the intelligence and security of these systems.[51] Renewal of existing energy infrastructure assets, automation and analytics may all help foster a more resilient grid.[52]

To address the impacts of increasing generation from intermittent and distributed renewable energy resources, we must develop *"load that can use it, transmission that can move it, or storage that can save it.*"[53]

For **load management**, ongoing efforts are underway to reduce peak demand and to shift demand to meet generation. The NC Electric Cooperatives are piloting and implementing a variety of energy efficiency, load management, and distribution system operation methods to reduce peak demand. Other possible options are to determine the drought conditions that would cause the State of North Carolina to put limits on electricity production and to add back-up power supply for grid disruptions.

On the transmission side, we can improve reliability of grid systems through back-up power supply, intelligent controls, smart analytics, micro-grids, and distributed generation to better respond to disruptions. We must continue to build out lines to capture generation from renewable energy resources and DERs and to increase transmission capacity within and between regions to overcome localized disruptions.

Storage solutions are under development nationwide with efforts to reduce costs, increase capacity and innovate. Storage solutions can buffer peak demand and add capacity to minimize disruptions.

Coordination with **local governments** should continue through efforts such as the Environmental Defense Fund's Cities Initiative which has a series of meetings scheduled in 2020 and offers an opportunity for

[47] Moody's (2020). *Research Announcement: Moody's US regulated electric utilities face varied exposure to climate hazards.* Retrieved from https://bit.ly/2u7MH9V
[48] Downey, J. (2020). *Duke Energy ranks high among utilities at risk from hurricanes, other impacts of climate change.* Retrieved from https://www.bizjournals.com/charlotte/news/2020/01/16/duke-energy-ranks-high-among-utilities-at-risk.html
[49] Public Service Commission of North Carolina (2019). Duke Energy Docket no. E-7 Sub 1214. Retrieved from https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=cb13c39e-5f6b-457d-be23-5cc33ffa8d7f
[50] Ibid
[51] Ibid
[52] Rackliffe, G. (2019). *Duke University Energy Conference 2019: Energy Resilience & Climate Change – A Grid Perspective.* Retrieved from https://www.youtube.com/watch?v=RynPq40cxcw&feature=youtu.be
[53] Ibid

collaboration on initiatives and new perspectives. In addition, energy providers need to coordinate with local essential services and consider Business Continuity Planning.[54]

Physical resilience can also be achieved through renewal of existing energy infrastructure assets and **building redundancy** into facilities to allow for continued operation during partial disruptions. This may include storm-hardening energy infrastructure and/or elevating water-sensitive equipment to address high water levels.

Microgrids – used for both community-scale applications and critical infrastructure – could have significant benefits in many parts of North Carolina. A microgrid is a small electric system that combines local energy resources and control technologies to provide power to a defined area. They are typically deployed at critical infrastructure locations such as hospitals, but they can also be deployed for all or part of a community. These microgrids allow entities to operate as small islands when the larger grid is experiencing a major outage, and thus they represent an excellent opportunity for providing greater resiliency in the face of weather-related disasters. In many cases, these microgrids can utilize renewable resources and battery-based energy storage.

Both investor owned utilities and cooperatives have been able to benefit from the distributed resources installed as part of a larger microgrid. The state should encourage its utilities and rural cooperatives to consider additional microgrid projects to improve recovery from storm-related issues.

For all of these efforts to bear fruit, *the state must continue the work of the* **North Carolina Clean Energy Plan** *to build capacity of stakeholders in all areas*. Currently, combined PV and energy storage are probably not economical in North Carolina under most traditional cost-benefit calculations as confirmed by the recent energy storage study in North Carolina.[55] If one places a value on the losses incurred from grid disruptions; however, PV+ storage can potentially become a fiscally sound investment.[56] The state should examine the viability and benefit of installing several projects at state or locally owned facilities that are in particularly storm-prone areas. As these projects proceed, the state should disseminate the results to promote similar thinking in the private sector.

Power Plant Cooling / Water Shortage

Impact Summary

Historical data for North Carolina indicate that precipitation has become more variable, stream low flows are decreasing in many areas, and **drought** intensity is increasing. Projected temperature and rainfall estimates indicate that this trend may continue. If there is a severe drought and adequate water is not available to cool thermoelectric power plants, or if the water becomes too warm, these plants may operate inefficiently and may risk partial or full shutdowns. Priority given to electricity production may decrease water supply availability for residential, commercial and industrial customers. Decreased power generation also means other, more expensive plants will need to produce electricity that use costly fuels or purchase from other utilities raising the cost of operations.

The utility companies may experience strains on power supplies as people increase power usage through increased use of air conditioning in times of excessive heat. Increased energy demand during heat waves

[54] National Governor's Association (2020). *State Strategies To Improve Energy Resilience Through Distributed Technologies* (webinar). Retrieved from https://www.nga.org/webinars/eie-webinars/state-strategies-to-improve-energy-resilience-through-distributed-technologies-webinar/
[55] https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf
[56] https://www.energy.gov/sites/prod/files/2018/03/f49/Valuing-Resilience.pdf

and drought periods can lead to greater emissions of greenhouse gases and air pollutants, decreased air quality, and public health concerns.

Vulnerability and Risk

Droughts have multiple implications for power systems, ranging from reduced hydroelectricity generation, to limited availability of cooling water for power stations, or to increased demand for power needed for pumping and treatment. Some examples of these vulnerabilities, as outlined in a 2013 Department of Energy report, follow.[57]

The average summer capacity at thermoelectric power plants by mid-century (2031-2060) is projected to decrease by between 4.4 and 16%, depending on climate scenario, water availability, and cooling system type, as compared to the end of the 20th century.[69]

Increasing air and water temperatures can reduce the **efficiency** of thermoelectric power generation and could reduce available generation capacity. Power plants using natural gas, coal, nuclear fuel, bioenergy, and geothermal are all affected by elevated air temperatures. One such event occurred in August 2007, when drought, heat waves, and elevated water temperatures forced Duke Energy to curtail operations at two coal-fired power plants, causing scattered power outages. In August 2006, two nuclear units at Exelon's Quad Cities Generating Station in Illinois reduced electricity production to less than 60% of available capacity because the temperature of the Mississippi River was too high to discharge heated cooling water from the reactors.

Power plants are at risk of exceeding thermal discharge limits established to protect aquatic ecosystems and incurring financial penalties or forcing curtailments. In 2007, 2010, and 2011, the Tennessee Valley Authority's (TVA) Browns Ferry Nuclear Plant in Athens, Alabama, had to reduce power output because the temperature of the Tennessee River was too high to receive heated cooling water without risking ecological harm to the river. Such incidents have forced the TVA to curtail power production of its nuclear reactors, in some cases for nearly two months. The cost of replacement power was estimated at $50 million. In July 2012, four coal-fired power plants and four nuclear power plants in Illinois requested permission to exceed their permitted water temperature discharge levels because the temperature of their cooling water pond is regulated to prevent adverse ecological impacts. The Illinois Environmental Protection Agency granted special exceptions to the eight power plants, allowing them to discharge water that was hotter than allowed by federal Clean Water Act permits.

Low flow conditions in rivers and low lake levels due to drought pose an operational risk to power plants. Most of the plants use once-through cooling systems, which are particularly vulnerable to low streamflow conditions due to the large volumes of water withdrawn. For example, in 2007, severe drought in the Southeast caused the Chattahoochee River, which supports more than 10,000 MW of power generation, to drop to one-fifth of its normal flow. Overall, hydroelectric power generation in the Southeast declined by 45%. In July 2012, power production from U.S. nuclear plants hit their lowest seasonal levels in nine years as drought and extreme heat forced plants from Ohio to Vermont to cut back on output.[58] According to a 2010 study on coal-fired power plants in the U.S. conducted by the National Energy Technology Laboratory, 580 plants (60% studied) are located in areas subject to water stress (i.e., limited water supply and/or competing water demand from other sectors). Most are in the Southeast as shown in Figure 5L-2. Note, several of the coal-fired power plants in North Carolina have shut down since the study was conducted.

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[57] U.S. Department of Energy, U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather, July 2013, DOE/PI-0013.

[58] Natural Resource Defense Council. Issue Brief, April 2014. Power Plant Cooling and Associated Impacts. Retrieved from www.nrdc.org/policy

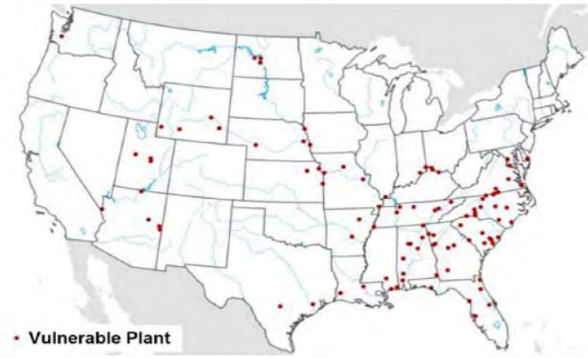

Figure 5L-2. The 100 most vulnerable coal-fired power plants based on water stress.

Resilience Strategies

The magnitude of the impact from increasing air and water temperatures on specific power plants can vary based on plant- and site- specific factors. The water use intensity and the impact of decreasing water availability depends on the type of power plant, cooling system employed, geographic location of the plant, and source of cooling water.

Most of the water withdrawn by thermoelectric power plants is for once-through cooling systems. Figure 5L-3 shows cooling configurations of North Carolina's plants. [59] Once-through cooling systems are particularly vulnerable to low streamflow conditions due to the large volumes of water withdrawn. Adaptation measures that use technologies and practices that are more climate-resilient should be considered. Several commercial options are currently available. Closed cycle systems (recirculating) use lower water withdrawals per unit of power produced compared to once-through systems, but evaporative loses could require cooling towers to need more water as compared to lower ambient temperatures. Dry-cooling technology rather than recirculating cooling systems can be used, thus dramatically reducing water requirements and lowering vulnerability to reduced water availability. Dry-cooling systems have been installed in several natural gas-fired combined cycle power plants in the U.S.

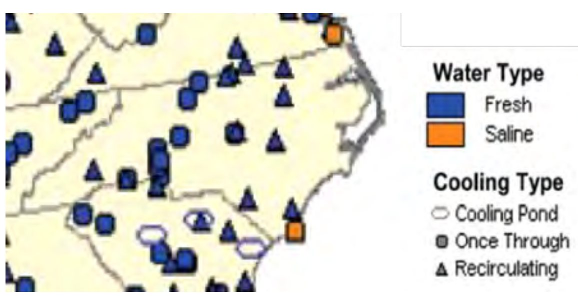

Figure 5L-3. Locations of plants requiring cooling water and their cooling types

[59] NETL (National Energy Technology Laboratory). 2008. Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements. DOE/NETL-400/2008/1339. Retrieved from http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/2008_Water_Needs_Analysis-Final_10-2-2008.pdf.

Other options for actions related to vulnerability and risk include:

- expanding the use of water recapture and reuse technologies for existing and future thermoelectric power plants;
- using nontraditional waters such as brackish and saline groundwater and municipal wastewater, or reclaimed water for cooling existing and future thermoelectric power plants;
- integrating improved design and placement of cooling water intake and outflow system channels and pipes to address changes in water levels and temperatures;
- building redundancy into facilities to allow for continued operation during partial disruptions;
- deploying more energy-efficient freshwater extraction, distribution, use and treatment technologies;
- locating new facilities to areas with sustainable water supply;
- adding peak generation and power storage capacity to minimize disruptions; and
- assuring regional fuel product reserves to address vulnerable fuel supply disruptions.

Alternatively, measures that reduce the amount of power needed or shifting to less resource-intensive generation methods could be employed. For example, utilities can increase the deployment of enhanced demand-side management strategies and use of energy efficient appliances, equipment, buildings, and processes. Utilities can also increase the use of non-centralized and non-water intensive energy technologies (e.g., wind, photovoltaic solar, battery storage, microgrids).

Fuel Supply Chain Disruption / Increased Storm Intensity

Impact Summary

Extreme storm events can impact the natural gas pipeline infrastructure and petroleum pipeline, storage, and distribution infrastructure. Excessive **flooding** from a storm event can disrupt upstream compressor stations which would be unable to pump the fuel through the pipeline system. Excessive flooding, **landslides** or other storm-related hazards can damage the pipelines, interrupting the flow of fuel to end users. Flooded roads can disrupt trucking operations from delivering fuel to gas stations which can create long gas lines and hinder emergency response operations. These impacts can cascade into other disruptions such as power plant operations, evacuation routes, public safety, emergency response, critical infrastructure operations, business operations, and many other micro and macro-economic operations.

Vulnerability and Risk

North Carolina relies on a limited number of natural gas pipelines and petroleum pipelines to support the electricity, transportation, and industrial sectors. North Carolina's electric infrastructure is increasingly tied to the natural gas infrastructure as power generation shifts away from coal burning plants. Gas-dependent electrical generators can experience outages at the same time as gas supply disruptions caused by extreme storm events. In its 2013 Infrastructure Report Card, the American Society of Civil Engineers (ASCE) stated that North Carolina "is almost entirely dependent on [the] Transco Gas Pipeline for its natural gas requirements" and this heavy reliance on Transco Pipeline for natural gas availability presents fuel supply vulnerabilities.[60,61]

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[60] American Society of Civil Engineers. (2017). North Carolina Infrastructure Report Card. Retrieved from https://www.infrastructurereportcard.org/state-item/north-carolina/

[61] Energy Policy Council. (2016, March). Energy Policy Council Report, pp. 4. Retrieved from https://ncdenr.s3.amazonaws.com/s3fspublic/documents/files/Energy%20Policy%20Council%20Report%20March%202016.pdf

Related to the transportation sector, North Carolina acquires all of its petroleum products from other states and from abroad. The Colonial and Plantation pipelines from the Gulf Coast supply the state with petroleum products. The Dixie Pipeline, a major supplier of propane to the Southeast, terminates in Apex, North Carolina, where a terminal and above-ground storage tanks are located. Tankers from other states and other countries deliver a very small amount of North Carolina's total petroleum products to the Ports of Wilmington. Disruptions to both the natural gas and petroleum pipeline systems create further vulnerabilities in systems that depend on them, and pose public health, safety, economic, and other risks to the state's population and economy.

Resilience Strategies

Fuel terminal resilience can be enhanced through existing emergency plans for severe weather events. Fuel terminals can undertake appropriate hardening and resilience measures to protect their facilities from future storms and make provisions to restore operations after storms. Example includes back-up generators that can be mobilized and manually hooked into the terminal power feed to operate main terminal pumps.

The State Emergency Response Team (SERT) monitors energy security and energy assurance issues related to severe weather events. The SERT keeps in close communication before, during, and after storms with fuel terminals regarding the adequacy of their fuel supplies to meet demand from residential, commercial and industrial customers. It is organized by the North Carolina Division of Emergency Management (EM) to provide, coordinate, and arrange for emergency assistance to the counties. It is responsible for coordinating and directing state government and emergency management field activities in response to emergencies and recovery from disasters.

DEQ's State Energy Office (SEO), supports EM's Emergency Support Function, ESF-12 (Energy) and serves within the Operations Section Infrastructure Support Group during all SERT activations. The SEO provides information about the condition of the state's energy supply and infrastructure from commercial news sources, government information sharing systems, industry information services and private sector contacts. It shares pertinent information with EM, Federal ESF-12, and energy industry partners as appropriate.

An **Energy Assurance Plan** has been written and exercised by state emergency managers in collaboration with the SEO. The plan includes procedures to coordinate the permitting necessary to bring repair equipment into the state, as well as waivers for the seasonal change in motor vehicle fuel composition. Pipeline companies have been included in these exercises, as well as representatives from the fuel marketers trade groups. The Energy Assurance Plan can integrate resilience strategies by coordinating with the NC Utilities Commission to evaluate completeness and integrate into SERT activities such that all activities under the emergency support function – energy can be covered.

North Carolina should also develop and implement an **Alternative Fuel Infrastructure Plan** for storm resilience to enhance alternative fuel vehicles fleet and to improve the disaster preparedness of fueling facility, recovery planning, and resilience by increasing alternate fuel diversity including electrical vehicle infrastructure options. Under a recent Department of Energy award, E4 Carolinas, SEO, federal and local governments, advocacy groups, utilities, fuel suppliers, and many other partners in North and South Carolina are conducting infrastructure disruption research, assessing potential for future disruption, and developing a plan that lays out best practices for resilience or recovery strategies.

4. Framework for Energy System Resiliency Planning

The NC Disaster Recovery Framework (NCDRF) was developed by NC Emergency Management (NCEM) and is updated on an annual basis. The Framework describes the role of state agencies and their partners in assisting with recovery efforts and is designed to address the complex and unique nature of disasters. Successful recovery efforts rely upon the whole community. The NCDRF considers the impacts of grid-related disasters, including threats from tropical cyclones, winter storms, and cyberattacks. The framework is an evolution from the operational plan previously maintained by the state.[62]

The current framework is focused on how the state should respond to and recover from disasters. Inherently, the approach is focused on recovery. Recent studies have shown that every dollar spent on disaster preparedness can offset as much as six dollars spent on recovery efforts.[63] The state should thus consider how to integrate resiliency planning into its disaster recovery planning, including how assets can best be deployed to reduce recovery efforts. For example, microgrids installed at critical infrastructure such as hospitals and first-responder facilities can potentially make first response efforts more effective. The state should study the impact of such investments and potentially consider several pilots. Ultimately, such planning should be incorporated into the NCDRF.

Investing in resources that provide greater resiliency can be very expensive. For example, grid-hardening measures and selective installation of microgrids may be excellent for preventing major long-term outages, but the cost must be borne by the ratepayers and those costs may be deemed too high for ratepayers to bear. If one begins to consider the total cost of outage prevention – including the regional economic impact and the impact on individual families that come from large storms – it is possible that the upfront cost of targeted resiliency measures can become more palatable. The state should encourage a deeper investigation into this question, and this investigation should be based on the true **social and economic costs** of recent events in NC. This analysis should be conducted in a way that promotes social and economic equity, for example by being careful not to calculate the human cost of outages differently for communities of different economic means.

One starting point is to apply the Resilience Analysis Process developed by the Sandia National Labs.[64,65] This process (shown in Figure 5L-4) provides methods for measuring and increasing energy resilience,

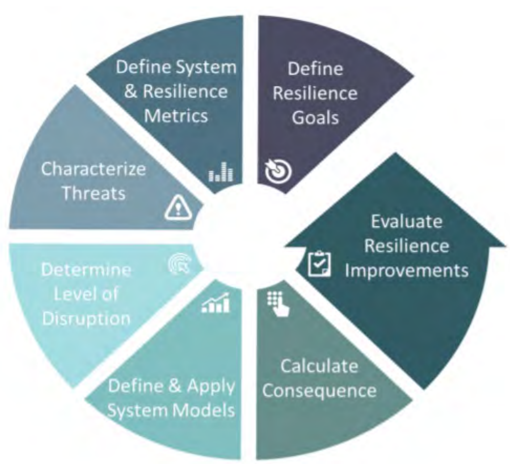

Figure 5L-4. Resilience Analysis Process starting with defining resilience goals (Sandia National Laboratory)

[62] https://files.nc.gov/ncdps/documents/files/2018%20NC%20Disaster%20Recovery%20Framework_Final_0.pdf
[63] https://www.bloomberg.com/news/articles/2019-06-11/u-s-hurricane-season-is-unnecessarily-dangerous
[64] Jean-Paul Watson, Ross Guttromson, Cesar Silva-Monroy, Robert Jeffers, Katherine Jones, James Ellison, Charles Rath, Jared Gearhart, Dean Jones, Tom Corbet, Charles Hanley, La Tonya Walker. *Conceptual Framework for Developing Resilience Metrics for the Electricity, Oil, and Gas Sectors in the United States*, Sandia National Laboratories, Albuquerque, New Mexico, SAND2014-18019, September 2015. Retrieved from https://www.energy.gov/sites/prod/files/2015/09/f26/EnergyResilienceReport_Final_SAND2014-18019.pdf
[65] Other examples include Argonne National Laboratory's *State Energy Resilience Framework and National Academies of Sciences*, Engineering and Medicine's *Enhancing the Resilience of the Nation's Electricity System*.

including definitions, means of measuring, and analytic methodologies that can be used to make decisions for policy, infrastructure planning, and operations. The risk-based framework contains a standard definition of resilience metrics and explains how the metrics can be applied to accelerate the resilience of energy infrastructure.

Currently in North Carolina, a collaborative study on resiliency metrics is underway between the SEO, UNC Charlotte EPIC, North Carolina State Clean Technology Center, and the DOE that attempts to develop a method to quantify the human costs of power outages from certain North Carolina storm events, and integrate these costs when evaluating grid modernization plan components related to resilience.[66] Others have developed metrics shown in Table 5L-2 to recognize additive property to reliability metrics that recognize low-probability, high-impact events have on outages and system recovery.

Table 5L-2. Example Resilience Metrics for Measuring social and economic impacts[1]

Consequence Category	Resilience Metric
Direct	
Electrical service	• Cumulative customer hours of outages • Cumulative customer energy demand not served • Average number (or percentage) of customers experience an outage during a specified time period
Critical electrical service	• Cumulative customer hours of outages • Cumulative customer energy demand not served • Average number (or percentage) of critical loads that experience an outage
Restoration	• Time to recovery • Cost to recovery
Monetary	• Loss of utility revenue • Cost of grid damages (e.g., repair or replace lines, transformers) • Cost of recovery • Avoided outage cost
Indirect	
Community function	• Critical services without power (hospitals, fire stations, police stations) • Critical services without power for more and N hours (e.g., N>hours or backup fuel requirement)
Monetary	• Loss of assets and perishables • Business interruption costs • Impact on Gross Municipal Product (GMP) or • Gross Regional Product (GRP)
Other Critical Assets	• Key production facilities without power • Key military facilities without power

[66] University of North Carolina Charlotte Energy Production and Infrastructure Center, N.C. Department of Environmental Quality and N.C. Clean Energy Technology Center. Planning an Affordable, Resilient, and Sustainable Grid in North Carolina, December 12, 2019. Retrieved from https://nccleantech.ncsu.edu/2019/12/12/planning-an-affordable-resilient-and-sustainable-grid-in-north-carolina/

Utilities, state regulators, elected officials, local governments, energy planners, emergency response planners, and others take disaster preparedness seriously but are often working in their own jurisdictions to fulfill their administrative mandates. It is suggested that North Carolina stakeholders develop an effective collaborative process to ensure a cost-effective statewide resilience framework and develop resilience metrics that are tied to measured outcomes for the affected residences and communities.

Case Study Example

As mentioned earlier, a collaborative study on resiliency metrics is being conducted between the SEO, UNC Charlotte EPIC, the North Carolina Clean Technology Center, and the DOE. The project team is utilizing the Resilience Analysis Process (RAP) outlined in Figure 5L-4 to evaluate the potential impact that various grid-modernization investments might have in achieving a desired set of resiliency goals.

RAP is a framework that provides a state or region with a methodical approach for evaluating resiliency investment. The method can be used to understand how various measures could have improved performance in past storms, or it can be used in a stochastic manner to understand how future storms might impact a region. The team is applying the RAP to understand measures that could have benefited North Carolina in recent storm events, using Hurricanes Matthew and Florence as canonical examples. In this case, the team is working in two specific steps. First, the team is conducting a baseline resilience assessment to compare grid performance during and after Hurricanes Matthew and Florence to specific resilience targets. Second, the team is evaluating which investment options would better improve the resilience of the system in the face of a storm similar to Matthew or Florence.

The team is considering a mix of alternatives that include both proposals from Duke Energy's Grid Improvement Plan as well as other potential solutions such as microgrids sited to serve facilities performing key community functions. The focus of the work is to demonstrate how resilience metrics and targets can be defined for North Carolina, using the impact on the Wilmington area during Matthew and Florence as illustrative examples. This section provides a brief overview of that process.

Define Resilience Goals

The first step in resilience assessment is to define the goals that establish the scope. Table 5L-2 lists specific metrics that others have defined as additive beyond traditional reliability metrics related to recovery following an outage. The team is performing its analysis using historic data from Duke Energy to understand the extent and duration of power outages to critical and non-critical loads. The work recognizes the role that the utility plays in enabling basic community functions, and that some of these functions were interrupted due to storm-caused power outages. The team is also reaching out to community leaders to understand municipal and community needs and weaknesses. Utilizing a detailed stakeholder engagement process, the team seeks to identify and quantify key objectives. Potential examples include the following:

- The storm's effect on power delivery to hospitals, waste-water plants, police stations, and fire stations, and other key community facilities.
- The extent and duration of power outages.
- The cost borne by the utility to restore power following an outage.

The specific metrics will be identified through a process of analysis and stakeholder engagement.

Define Consequence Categories and Resilience Metrics

Once goals have been identified through a stakeholder engagement process, the team will work to quantify specific resilience targets. Examples could include the following:

- Zero hospitals, police stations, and fire stations without power for more than 48 hours.

- No more than a specified number of customer-days without power. Depending upon the number of customers, this would translate to an expected number of outage hours per customer.
- Restoration costs below a specified threshold.

The goal of the RAP is to select investments that satisfy these requirements. The specific targets will be identified through the stakeholder engagement process already described.

Characterize Threats and Determining the Level of Disruption

The goal of the RAP is to propose and evaluate measures that can achieve the resilience targets noted previously. To do so, it is essential to understand the specific ways in which past storms have impacted the region. Much of the damage caused by Hurricane Florence, for instance, resulted from flooding. The storm produced rainfall exceeding 10 inches across much of southeastern and southcentral North Carolina and northeastern South Carolina, with totals exceeding 20 inches from the North Carolina-South Carolina border eastward across southeastern North Carolina. The slow forward speed of Florence prior to and after the hurricane made landfall resulted in persistent rain bands moving inland off the Atlantic Ocean and training over the same area from Wilmington to Elizabethtown, North Carolina, resulting a narrow swath of rainfall totals exceeding 30 inches. Figure 5L-5 shows rainfall analysis for the eastern seaboard from 13 to 18 September 2018[67].

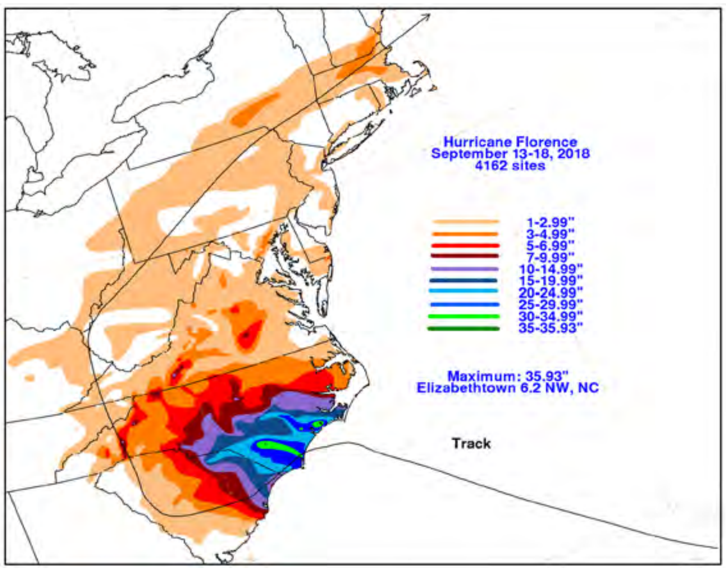

Figure 5L-5: Rainfall totals on the eastern seaboard during Hurricane Florence[68].

The catastrophic flooding resulting from the tremendous rainfall had a significant impact on inland waterways such as the Cape Fear River. During the initial period following Florence's landfall, every major road into New Hanover County was impassable, including I-40 and I-140. Such road closures can have a major impact. For example, on Sunday September 16, Cape Fear Public Utility Authority issued a dire warning that without an influx of diesel and gasoline, it would run out of fuel for its water-treatment plant, cutting off both drinking water for many customers as well as water for the major regional hospital[69]. This issue was caused by impassable roadways.

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[67] S. Stewart and R. Berg. "National Hurricane Center Tropical Cyclone Report - Hurricane Florence", National Oceanographic and Atmospheric Administration, SAND2014-18019, May 2019. Retrieved from https://www.nhc.noaa.gov/data/tcr/AL062018_Florence.pdf

[68] Ibid

[69] P. Sullivan and K. Zezima, "Florence has made Wilmington, NC, an island cut off from the rest of the world," Washington Post, September 16, 2018.

Evaluate and Propose Resilience Improvements

The goal of the RAP is to evaluate various measures that could meet the targets identified in the early stages of the process. For example, the analysis of the impacts from Hurricane Florence indicate that Wilmington is extremely vulnerable to the impacts of flooding and can be effectively cut-off for substantial periods of time. The team is considering two sets of investments that could potentially improve the targets outlined previously. These include the following:

- Proposals included in the North Carolina Grid Improvement Plan filed for both Duke Energy Carolinas and Duke Energy Progress[70]
- Proposals beyond the Grid Improvement Plan including techniques such as customer-sited microgrids

The effectiveness of these measures will be evaluated as a means for achieving the targets outlined previously. As an example, the Grid Improvement Plan recommends measures such as targeted undergrounding and substation hardening. Several of these measures are planned for the Wilmington area, and include measures such as moving feeder exit cables from overhead supports to underground enclosures. Such measures will most certainly improve goals for minimizing the number of customer-hours without power, but they may not necessarily have a strong impact on other indirect community functions. For instance, a potential resilience goal might be to ensure that an important community facility such as the water-treatment plant are never without power. This would, of course, require a robust back-up power solution that does not rely on fuel that must be transported via roadway. Localized natural gas generation or a microgrid consisting of some form of renewable power could be one solution that would prevent such failures.

The wastewater treatment facility is a key example of the type of measure not necessarily included in utility rate plans. Localized generation does not necessarily benefit all ratepayers on a normal basis, but it may be essential to meeting key community functions during and after major storms. The stakeholder process is intended to quantify these indirect community benefits. Legislative change may be needed for the utility commission to be able to evaluate such proposals, but a key outcome of the process is to expose such issues for further evaluation and discussion.

5. Summary

North Carolina's energy infrastructure, with its diversified generating plants, robust transmission and distribution infrastructure, fuel pipeline systems and renewable resources, is susceptible to both natural and man-made incidences that may result in local or statewide energy emergency events. As current operations evolve in response to changes in fuels and electricity production technologies, various areas of the energy sector should consider future hazards, and then plan ahead to reduce vulnerabilities and risks to achieve a reliable supply of energy.

For the transmission and grid participants in the energy sector, planning ahead means hardening and modernization of the grid, targeted undergrounding and renewing existing assets with automation, intelligent devices and controllers, and successful integration of distributed energy resources. For power plants, getting ahead of future water shortages may involve alternative or lower volume water resources. To protect North Carolina's heavily imported fuel and gas supplies during storm disruptions and other power emergencies, alternative fuel infrastructures and hardening existing fuel pipelines, terminals and distribution infrastructure may be needed to protect emergency evacuation options and critical infrastructure.

[70] https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=cb13c39e-5f6b-457d-be23-5cc33ffa8d7f

All of these resiliency efforts will benefit from improved metrics for measuring and increasing resiliency across the energy sector. North Carolina's policymakers and regulators can turn these metrics into actions and create accountability for energy providers for delivering resilience and other customer value.

Cross-Sector Impacts

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M. Cross Sector Impacts and a Coordinated Action on Resilience

1. Introduction

The integration of climate risk management into existing agency missions and operations can help state government agencies coordinate and plan their response to climate impacts and inform state-level adaptation and resilience solutions in both the short and long terms. The following synthesis draws upon the expertise of 11 sector sectors to outline common themes, provide recommendations to reduce impacts, and offer an opportunity to focus inter-agency efforts on shared priorities. Each impact assessment focused on state agency assets, services, and responsibilities. This synthesis uses that framework and can be used to guide a strategic approach to climate resilience prioritization, planning, and action in future phases of work in the state of North Carolina.

2. State-Owned Assets: Forward-Looking Infrastructure Design and Planning

The state of North Carolina owns and manages a limited number of assets, but those that it does are critical to all sectors of life and the economy. The focus of this section is on integrating climate resilience into the state-level designing and planning process those state owned and managed assets which include but are not limited to public roads, buildings, dams, and other infrastructure**.**

Road Design

Chief among the assets owned and managed by the state are its roads. Primary roads throughout the state support commerce in all sectors and provide critical conveyance for citizens and emergency responders during and after climate-related events.

> **"NCDOT directly owns and maintains a large and diverse number of assets statewide. Storm-related damages are threatening public safety, creating economic disruptions, and causing budgetary shortfalls that require a strategic refocusing."**
>
> *Transportation*

The *North Carolina Department of Transportation (NCDOT)* is committed to working with and serving local government and the citizenry (**Section 5J**). Doing so will require a forward-looking road infrastructure design and planning process. This is one of the greatest priorities of a future North Carolina resilience plan because roads are integral to so many other functions of government and daily life within the state. The challenges identified in **Section 5J** differ by physiographic province. For instance, storm surge and flooding all affect coastal roads, but landslides are the primary drain on financial resources otherwise dedicated to road maintenance in the mountains.

The importance of the transportation network is underscored within the ***Coastal Resources and Infrastructure*, *Commerce and Business*, *Energy*, *Health and Human Services***, ***Water and Land Resources,*** and ***Public Safety*** sections which highlight the work of *the Department of Environmental Quality (DEQ), Department of Commerce (DOC), and the Department of Health and Human Services (DHHS).* These sectors have a vested interest in climate-informed investment decisions pertaining to transportation. Pre-planning with these departments is an essential component of *adaptive capacity* within the **Department of Transportation.** For example, the NCDOT works with the **Departments of Public Safety and Environmental Quality** within state government, FEMA at the federal level, and local governments across the state to reduce vulnerability and risk associated with landslides and debris.

Building and Site Design

New design and engineering standards should be incorporated into the design of new structures. Building design was mentioned within the ***Housing, Buildings, and Support Services*** assessment above (**Section 5H**) in discussions of veterans housed within the Veterans Affairs hospital system, in the discussion of prisoners, and in the discussion of minors housed in North Carolina facilities.

The *Department of Agriculture and Consumer Services* owns and maintains buildings across the state, as do the *Department of Administration, Department of Commerce, Department of Natural and Cultural Resources*, and others. Buildings can be protected by implementing reasonable new building standards, including freeboard that incorporates expected conditions during the lifetime of the property. Some buildings should be moved, as suggested in the ***Agriculture and Forestry*** analysis (**Section 5B**).

Extreme Precipitation and Landslides

Landslides are most common in the mountain areas of western North Carolina, though they do occur on steep slopes in the Piedmont and Coastal Plan. The frequency of landslides is directly linked with the frequency and magnitude of prolonged or heavy rainfall. Potential consequences of these events include loss of life and injury, property damage, and impeded response capacity of critical emergency response services. Aging infrastructure increases the likelihood of landslides related to failing drainage systems and deteriorating slopes on major transportation routes resulting in economic losses from disruptions to transportation networks. Impacts cut across the ***Public Safety, Water and Land Resources, Commerce, Transportation, Public Health,*** **and** ***Coastal Resources and Infrastructure*** sectors.

Cross-agency options include each of the following:

- Enhance state and local collaboration to (a) anticipate and communicate the threat of landslide hazards and (b) coordinate emergency responses to landslide events.
- Provide incentives for smart growth and development in safe locations.
- Improve and develop landslide mitigation funding strategies.

3. Regulations and Policies: Strengthening Climate Resilience across State Agencies

Allocate Resources and Support for Interagency Resilience Efforts

A recent publication by the Governors' Institute encouraged state governments across the nation to ensure that there is a clear line of authority from the governor to an individual authorized to coordinate resilience activities across cabinet agencies.[1] This recommendation is echoed in the Public Safety narrative (**Section 5I**), which calls for a resiliency office whose new staff positions would be permanently funded. These

[1] Building Resilient States: A Framework for Agencies. 2015. Governor's Institute for Community Design, SmartGrowth America.

staff would serve numerous roles, including annual table-top exercises focused on Continuity of Operations that involve all aspects of state government.

In addition, the ***Public Safety*** sector recommends strengthening the state's hazard mitigation plan, allocating resources to response and recovery, and authorizing a quantified risk assessment as part of the Steps to Resilience (Figure 5A-1).

The quantified risk assessment could build on previous efforts by the *Natural Heritage Program* (**Section 5F**) and ***Water and Land Resources*** **(Section 5K)** sector, each of which has a system in place for measuring vulnerability and risk for the assets they manage. If a water supply risk assessment were conducted, for example, local governments would have better information about the rationale and importance of collaborating with neighboring authorities to manage water supply in the face of drought, flooding that brings contamination, and other water management concerns that arise in relation to climate-related hazards.

The **NCDOT** has secured funding from the state legislature for a Flood Risk and Vulnerability Assessment of the Strategic Transportation Corridors which focuses on the most vital transportation corridors within the state (**Section 5J**).

Quantitative spatial analysis of correctional institutions, readiness centers and other facilities used by the *Department of Public Safety* to maintain a community presence is needed to identify facilities most at risk. Addressing these risks would require a comprehensive master plan to balance maintenance, logistics, and relocation requirements (**Section 5I**).

DEQ has also secured disaster recovery funding from the General Assembly to address recovery and resilience projects within the *Divisions of Water Infrastructure, Waste Management, and Energy, Mineral, and Land Resources.*

Strengthen Workforce Capacity and Response/Recovery Resources

The capacity of state government is only as strong as the people who comprise its workforce. This theme emerged in many ways throughout the risk assessment process. The ***Health and Human Services*** sector (**Section 5H**) and ***Water and Land Resources*** sector (**Section 5K)** highlighted the critical need for personnel during and after hurricanes to serve at North Carolina Emergency Operations Centers, shelters, as emergency responders, and in supporting administrative roles critical to the delivery of services and support. Along with staffing, funding, medicine, food, and other resources are also needed in order to meet the need of North Carolinians suffering immediate setbacks as well as longer term obstacles to recovery.

The ***Agriculture & Forestry*** **(Section 5B),** ***Commerce and Business*** **(Section 5D),** ***Public Safety*** **(Section 5I),** ***Transportation*** **(Section 5J), and** ***Water and Land Resources*** **(Section 5K)** narratives each mention the need to increase funding to attract and add human resources and retain qualified staff who understand the complexity of their job function well enough to adapt and respond amidst the duress imposed by emergency response or chronic stresses on the resources they manage, as well as their own physiology. A hotter climate system which brings longer and more frequent heat waves will chronically stress anyone whose job requires they work outside, such as environmental inspectors, transportation workers, Highway Patrol, Marine Patrol, Wildlife Officers, and National Guard employees.

Conserve and Maintain Ecosystems Services

"Conserving/managing land for key ecosystems yields benefits to other sectors, including water resources, tourism and commerce, and public health."
Ecosystems (Section 5F)
"The health of the environment impacts the health of all people."
Health and Human Services (Section 5H)

Land use regulations and policies can lead to effective and inexpensive ecosystems services, a term that encompasses the benefits to society and typically at no charge, such as water quality, flood management, and preserving the valued natural heritage of a place. The ***Ecosystems*** **(Section 5F),** ***Water and Land Resources*** **(Section 5K), and** ***Agriculture and Forestry*** **(Section 5B)** sector each mention the value of improving water infiltration through wise land use. The benefits include reducing pollution to waterways, including nutrients and sediment which are the most abundant and widespread source of turbidity and contamination (**Section 5K**).

When toxic waste, livestock waste lagoons, wastewater treatment plants, and other sources of potential contamination are exposed to floodwaters, a complex set of engineering, water quality, ecological, and public health issues ensue. Because of the complexity of such problems, cross-sector and cross-departmental coordination will continue to be essential to implement wise land use and regulatory decisions in concert to preserve ecosystem services, such as clean water, that protect humans and other values to the state of North Carolina.

The same land use strategies that yield high water quality and reduce flooding also protect endangered species. For example, the DEQ Stormwater Program regulates development in the Goose Creek, Six-mile Creek and Waxhaw Creek watersheds. These waters are important for threatened and endangered species, most notably the endangered Carolina Heelsplitter (*Lasmigona decorate*) (see **Section 5F**). As the authors of the ***Water and Land Resources*** (**Section 5K**) state:

"Water and land impacts and strategies are closely inter-related. The condition of the land, i.e. natural, managed, or impervious, directly affects the volume and quality of runoff. This in turn influences the availability of water, erosion, sedimentation, landslides, dam safety, pollutant loading to receiving waters, and ecosystem health. The condition of North Carolina's water and land resources are also closely connected to most other sectors which support the state's human and ecological health and economic prosperity. For this reason, strategies to meet the challenges posed by climate change will also require close coordination with these other sectors."

Multiple Climate Hazards Create a Cascade of Tipping Points

Recent extreme events signal the risk that tipping points exist beyond which state and local emergency response and recovery service provision can be effective. In the event that the state arrives at a point where climate-related hazards co-occur (e.g., statewide flooding, severe weather, or wildfire), or where multiple climate hazards impact diverse areas of the state or a region simultaneously, the response and recovery capacity of state agencies will be challenged.

The most recent threat to reaching a tipping point involved the serious drought and extreme heat-related impact on water supply during the 2007-2008 drought in which 30 cities around the state were within 100 days of running out of water. In addition to changes in water supply, the drought fueled 30% more wildfires and negatively impacted agriculture, public health, economic activity, and resulted in energy loss. Relief came from both (a) emergency water supply from an interconnected water supply system and (b) a tropical storm which brought higher than average rainfall to most of the state within a short period of time.

4. Resources and Services: Support Community-Driven Resilience

Build Capacity and Meaningfully Engage Local Leaders

Working with local governments and communities to build resilience will require time to "... build trust, institute new policies and regulations, and properly allocate resources" (**Section 5I**). Regional and local government support is a vital service that any state government provides. For example, state governments are responsible for applying to the U.S. Housing and Urban Development Department for Community Development Block Grants that address mitigation of hazards as well as disaster recovery. Those funds are then disbursed statewide to regional and local agencies. Climate change necessitates a means of prioritizing the planning and execution of those grants in light of the climate-related hazards that have been experienced or that are anticipated. If North Carolina establishes an interagency resilience capacity (see Regulations and Policies above), this program would provide resources and services to regional and local governments (i.e., through risk-based prioritization, planning, grant allocation, support during and after emergencies, and new initiatives).

"Long-term master planning is needed to determine the most cost-effective means to address, maintain, and operate resiliency plans through their life cycles."

-Public Safety (Section 5I)

Complementarily, other departments and agencies will adopt their own climate resilient policies to provide resources and services at more local levels of government. The ***Cultural Resources*** (**Section 5E**) sector highlights numerous ways that its policies can filter down and support the local entities entrusted with assets valued by the entire state. Protecting or preserving archeological sites, museums, specimens, and manuscripts requires a common set of methods whether managed by the state or local entity, so the state *Department of Natural and Cultural Resources* can provide leadership in setting appropriate standards for taking appropriate actions to mitigate the greatest risks.

The ***Coastal Resources and Infrastructure*** (**Section 5C**) sector has elaborated on a variety of ways that state leadership can incentivize communities to protect, enhance, and restore infrastructure. They recommend a program be funded to build local capacity to assess risk and incorporate that understanding into the implementation of policies such as land use planning and zoning.

The Housing, Buildings, and Support Services **sector (Section 5H)** has outlined the *DEQ Division of Waste Management's* proposed efforts to work with local, state, and federal entities' waste and recycling facilities to improve and/or develop and implement strategies that promote the proper management of storm debris and its impacts to statewide communities.

Expand Incentives, and Partnerships to Increase Resilience of Local/Community Infrastructure, Services, and Natural Resources

The ***Coastal Resources and Infrastructure*** sector (**Section 5C**) highlights that the coast is the most vulnerable area in the state in terms of infrastructure damage. The coastal region sees the most intense rainfall events and suffers from some of the most severe impacts of stormwater runoff. It will be imperative to incorporate future climate change and sea level rise scenario information into long-term investment decisions in local and regional water and transportation infrastructure improvements (**Section 5C**).

The ***Commerce and Business*** sector (**Section 5D**) of North Carolina's government underscores the value of education, training, and additional resources specifically targeting rural parts of the state. Their NC Main Street and Rural Planning programs for small towns and the businesses they support represent existing capacity that could be augmented with locally relevant climate adaptation resources.

The ***Agriculture and Forestry*** sector (**Section 5B**) encourages stakeholder engagement and education specifically focused on drought and wildfire—two climate-related hazards that particularly affect natural and working lands. Engagement should also include the effects of extreme rainfall and inundation.

The ***Public Safety*** sector highlights the connection between climate-smart land use planning and reduced burden on emergency services. The North Carolina Coastal Area Management Act provides the Division of Coastal Management the authority to provide land use planning oversight in twenty coastal counties. The *Public Safety* sector recognizes the importance of building partnerships, such as with the Division of Coastal Management, that are supportive yet mindful of local control over land use decisions. However, while the Coastal Area Management Act provides the *Division of Coastal Management* the authority to provide land use planning oversight in twenty coastal counties. Such state-level regulatory influence may be lacking elsewhere. Accordingly, the ***Public Safety*** sector recognizes the importance of building partnerships that are supportive yet mindful of local control over land use decisions.

Several other sectors also mentioned options to provide specific guidance for policies to be implemented within municipalities or North Carolina Soil and Water Conservation Districts. For example, the ***Water and Land Resources*** (**Section 5K**) sector recommends a systematic evaluation of best management practices, levies, and dams, given changing engineering requirements under new precipitation and river discharge regimes.

Leverage Services to Vulnerable Communities for Multiple Benefits

The ***Health and Human Services*** (**Section 5G**) and ***Coastal Resources and Infrastructure*** (**Section 5C**) sectors both emphasize the notion that the most vulnerable populations that have pre-existing illnesses due to exposure to polluted air and water, toxins, or other morbidities associated with low income, racial disparities, age-related risk, or other related factors. Heat islands and heat waves often affect targeted populations that can be mapped and prioritized for mitigation actions.

Expanding energy efficiency and renewable energy programs specifically targeted at underserved markets and low-income communities would allow communities to function in the face of higher temperatures (**Section 5L**). Improving housing and access to adequate cooling would help communities adapt.

5. Advancing Science-informed Data, Technology, and Tools

The ***Coastal Resources and Infrastructure*** sector (**Section 5C**) urges state government to provide data and best practices to equip local government to perform and regularly update county vulnerability assessments. Their *Division of Coastal Management* Coastal Adaptation and Resiliency website provides links to climate data and forecasts, assessment and planning tools, adaptation examples, and sources of funding for planning and implementation.

> **"Strategies for creating resilience should address existing toxic exposures, such as hazardous waste and lead in water or homes, in low-income communities and communities of color… Existing inequities in environmental health exposures are exacerbated by climate change."**
>
> ***-Health and Human Services (Section 5G)***

The *NC Department of Transportation* (**Section 5J**) is collaborating with NCSU and the UNC Institute of Marine Science to improve computer modeled storm surge and other data through the Coastal Emergency Risk Assessment (CERA) to predict storm surge conditions 24 to 48 hours in advance. These data are being incorporated into the Flood Inundation Mapping and Alert Network (FIMAN-T) for coastal areas to predict where storm surge may affect roads during storm events, thus providing critical warning and support for coastal communities.

The *Department of Environmental Quality's* Dam Safety Program (**Section 5K**) is working with the Division of Emergency Management to identify and model dam impoundment capacity and breach inundation areas as well as identify state and local government owned dams to install water level monitoring systems in order to prioritize resilience plans, emergency action planning, and emergency response protocols. These efforts will also serve to improve communication and response efficiency.

Case Study: Hurricane Florence (2018)

Record-level heavy precipitation and associated flooding brought about by Hurricane Florence disrupted the provision of state government services and resulted in wide-ranging impacts across multiple sectors, including:

- ***Agriculture*:** flooding resulted in an estimated $2.4 billion in agricultural losses across the state (**5B**).
- ***Coastal Resources / Ecosystems:*** increased nutrient loading in storm water runoff post-storm resulted in unsafe water quality and fish kills (**5C**) and the increased risk for harmful algal blooms (**5F**).
- ***Commerce and Business:*** storm surge during hurricanes damages property and infrastructure resulting in economic and supply chain interruptions in coastal communities (**5D**).
- ***Cultural Resources*:** heavy precipitation brought about significant damage to historic cultural resources along the coast and inland in flood prone areas (**5E**).
- ***Health and Human Services:*** storm and related flooding resulted in a number of adverse public health impacts including physical injuries, loss of life, mental/emotional trauma, and air, water, and environmental contamination, as well as loss of housing (**5G**).
- ***Transportation:*** record breaking rainfall and storm surge highlighted multiple vulnerabilities in the transportation network and resulted in more than 1,200 individual road closures (**5J**).
- ***Energy*:** historic flooding resulted in ~3 million customers losing power and resulted in one of the largest mobilization of power restoration activities in Duke Energy’s history (**5L**).

The provision of emergency response and recovery services during events such as Hurricane Florence requires shifting employee staffing levels statewide. A consequence of these shifts involved disruptions in work flow resulting in understaffed duty stations that quickly become overtaxed in responding to everyday request and local emergency response needs.

Due to the ongoing affordable housing crisis throughout the state there is a shortage of temporary and replacement housing. Extreme weather serves as an affordable housing crisis multiplier and disproportionately impacts low-income neighborhoods and communities of color during recovery efforts. More federal and state funding is needed to enhance personnel capacity across all phases of disaster at state and county levels, derive equitable response and recovery solutions, and increase availability of coordinated logistics and equipment needed during response.

Rising sea level and increasing coastal storm intensity is a risk for exposed energy infrastructure on the coast. Hurricane-related storm damage often results in a loss of electrical power and transportation access due to road washout. Disruptions to the electrical grid and transportation network result in compromised response and post-recovery efforts.

N. Conclusion

1. Summary: A Coordinated Action

This chapter has proposed dozens of resilience strategies for addressing the hazards, impacts, and risks introduced by a changing climate on State Government Assets, Regulations and Policies, and Resources and Services.

The greatest number of assets owned and managed by the state are the roads under the purview of the *NC Department of Transportation (NCDOT).* The NCDOT has undertaken vulnerability assessments in the past and recognizes the importance of the transportation network to the citizens, economy, and the State Government itself. Due to the critical nature of these assets, the NCDOT must maintain working relationships with local government, institute a transparent policy of vulnerability and risk assessment, and incorporate climate science updates into its capital planning for maintenance and improvements to the state's transportation system.

The *Department of Administration, Department of Public Safety, and the Department of Agriculture and Consumer Services,* manage most buildings under the state's ownership. The recommendations in this chapter highlight engineering requirements that need to be addressed to prevent future buildings from being designed and constructed in a way that puts them at undue risk of climate-related hazards and impacts. In some cases, buildings are small and can be moved out of harm's way. Older facilities that cannot be moved can be bolstered against climate impacts through raising the foundations or other bulwarks. For critical infrastructure such as correctional institutions and other facilities used by the *Department of Public Safety,* comprehensive master planning may be required.

Some states that have undertaken resilience plans, such as California and Rhode Island, have recognized the importance of ensuring that all investments by the state, whether in the form of operations, maintenance or new facilities, increase resilience to flooding and other climate threats.

This chapter presents three sets of Regulations and Policies subject to adaptation measures to accommodate climate change. Much of the content of this chapter touches on issues that affect more than one sector of government and the public. Policies could be implemented to allocate resources to support interagency resilience efforts to streamline the planning and implementation of adaptation or resilience efforts that do require cooperation among many departments and/or members of the public outside of state government. Such a plan might include a permanent role for a recognized resilience officer, with support from sub-cabinet representation across all departments. Such an arrangement could allow for coordination where needed.[1]

Many of the impacts of a changing climate will be felt by state personnel, especially those whose jobs require outdoor working conditions. These people (exposed to flooding, heat, wildfire, and other meteorologically driven events) will need training, resources, and incentives to deliver the highest level of service possible in the face of increasing frequency, duration, or intensity of climate-related hazards.

Watershed protections, best management practices, protecting endangered species, protecting open space, and other ecosystem management practices may be the least expensive ways to deliver clean water,

[1] Building Resilient States: A Framework for Agencies. 2015. Governor's Institute for Community Design, SmartGrowth America.

protect lives and property, and maintain the quality of life for which North Carolina is known for Regulations and Policies can orient toward the preservation of these ecosystem services.

State Resources and Services could increasingly support local action informed by a clear understanding of climate-related risk. The NC state government is a constitutionally mandated go-between for local government and federal resources. Therefore, state employees and programs can hone their capacity to understand and meet the requirements of local officials to protect lives and property by supporting risk assessment, planning, and project implementation. In parallel, the state government can use its understanding of local requirements to hone its requests of the Federal Government to best serve North Carolina's citizens.

Such service delivery will be a long-term engagement involving relationship-building in tandem with climate analyses. Existing programs that serve water utilities, business, natural resource management, and other aspects of local government can be augmented to include climate-smart service delivery.

Departments throughout North Carolina's state government enterprise are committed to using science, data, technology, and tools to make better decisions. This chapter provides examples of the appropriate blending of those themes to improve decision making, for example the Coastal Emergency Risk Assessment and the NCDOT Flood Inundation Mapping and Alert Network.

In addition to expanded use of quantitative information to make decisions at the state level, North Carolina also has the opportunity to provide this information and related expertise to local communities. Several states, including California, Massachusetts and Rhode Island, have made this a priority to enable resilience planning at the municipal level

The development of this report is yet another example of that blend of science and decision making, for it came about through close collaboration among the NC state government, academics, especially at NC State University, and federal partners, especially through the U.S. Climate Resilience Toolkit, and input by community organizations and local stakeholders.

2. Next Steps

This chapter was developed to build capacity for agency staff so they might continue identifying and prioritizing resilience actions in an informed way beyond March 2020. Many agencies and departments have already learned from extreme events of the past. This report identifies many potential avenues for augmenting that work and developing initiatives that would expand the capacity of the state government to respond to climate-related hazards. In order to prioritize which programs to augment or initiate, each department must agree on how they will describe climate-related hazards and impacts.

This chapter presents a qualitative evaluation of exposure, vulnerability, and risk. Its preparation helped establish a shared vocabulary and catalogued exposure of exemplary state-level responsibilities to climate-related hazards. A clear next step would be to establish and conduct a quantified risk assessment of critical infrastructure and assets managed by the state so that resources can be allocated to the address the greatest risks to North Carolina. Once a quantified vulnerability and risk assessment is done, it will be possible to prioritize adaptation actions.

Flooding is often cited by the authors of this chapter as the most frequent, devastating, and important climate-related hazard to focus upon. The state should consider a pilot project focused on flooding. Flooding occurs due to tidal events, storm surge along the Coast, along rivers ("fluvial" flooding), and due to overland flow and accumulation of water ("pluvial" flooding). Modeling, observational data, mapping, and socioeconomic analysis could be brought together to evaluate the spatial extent of exposure. A quantified assessment could reveal the degree of vulnerability and risk of property, people, and other resources. Options for adaptation could then be considered with a clear understanding of how those factors differ through space and time throughout the state.

An even more focused project might exclude analyses to coastal flooding to reveal the many ways that resources can be garnered to understand, plan for, and respond to the devastating impacts of climate-related hazards. A detailed exercise in partnership with local governments that focuses on one set of hazards within a constrained geographic extent would help state agencies prioritize the delivery of services as well as provide information for communities to undertake local resilience planning.

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Chapter 6

Nature Based Solutions to Resilience

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6. Nature-Based Solutions for Resilience

Nature-based solutions (NBS) refer to conserving, restoring, and managing North Carolina's natural and working lands (NWL) to tackle socio-environmental challenges, such as climate change, by leveraging the unique properties of these resources. NBS can be used to address infrastructure needs such as storm water retention, protect from climate impacts such as storm surge, and act as hazard mitigation tools such as increasing drought and flood tolerance. These solutions have been used successfully for many decades, most notably for stormwater management and watershed protection. Now, they are being recognized for their true economic potential to protect our ecosystems and people from the devastating impacts of climate change.

Nature Based Solutions fall into three basic categories given below:

Projects that use existing or rebuilt natural landscapes
Example: restoring forests and wetlands in floodplain areas

Hybrid projects that combine gray infrastructure with NBS
Example: rewetting peatlands using water control structures

Projects that change aspects of how land is used or managed
Example: implementing agriculture practices that retain soil carbon

NBS are a unique win-win answer to both mitigating and responding to climate change impacts because of their long-term cost-effectiveness and many co-benefits compared to grey infrastructure. Their advantages over grey infrastructure include:

- Mitigation of GHG emissions and sequestration of carbon is improved,
- Build out has a smaller carbon footprint than grey infrastructure,
- Effectiveness normally grows overtime rather than degrading,
- Economic opportunities increase for food/fiber producers and the rural workforce,
- Communities develop long-term sustainability,
- Quality of water, air, soil and ecosystems improves, and
- Aesthetic natural beauty is maintained for recreation and tourism.

When state/local government and business leaders choose projects to build resiliency, cost-effectiveness is a basic requirement. Currently, investors and decision makers do not have uniform methods for comparing the NBS to more traditional approaches to building resiliency in communities. In addition, NBS may appear to be "new" or "unproven" uses of precious recovery dollars. Therefore, implementation of NBS in place of grey infrastructure requires developing economic analysis methods and financial tools that acknowledge the special properties of NBS, such as longer time periods, growth over time, sustainability, risk reduction, economic and ecosystem benefits. A good starting point for cost-effectiveness is US EPA's Green Infrastructure program.[1]

[1] "Green Infrastructure" US EPA, Accessed on February 21, at https://www.epa.gov/green-infrastructure.

A. North Carolina Natural and Working Lands Action Plan

1. Purpose of the Plan

The purpose of the Natural and Working Lands Action Plan, located in Appendix B, is to identify and create opportunities and outline specific projects for North Carolina's natural and working lands (NWL) that sequester carbon, build resilience, provide ecosystem benefits, and enhance our economy.

This action plan is intended to be used by 1) public and private landowners and managers, 2) impact partners such as universities and non-profit organizations, corporations, land-use consultants and investors, and 3) federal, state and local government, resiliency and local planners, and NWL policymakers to facilitate meeting North Carolina's goals identified under the plan. Specifically, the Action Plan addresses the following issues:

- Define the stakeholders' shared goals developed for the action plan,
- Present the current state of our natural and working lands,
- Quantify the potential impact of various actions,
- Recommend specific actions that facilitate meeting the shared goals,
- Identify implementation pathways, partners, and funding to facilitate taking action,
- Discuss roadblocks currently preventing the use of certain action pathways, and
- Encourage working on broad policy initiatives that would greatly enhance meeting our goals.

The North Carolina Natural and Working Lands (NWL) Action Plan is the first step toward utilizing NBS to build resiliency in our state. Many of its recommendations can be implemented by state and local government in our communities. These actions also require effort on the part of our "impact partners" – public and private landowners/managers, universities, non-profit organizations, corporations, land-use consultants, and investors. However, the large-scale change required to truly reduce risk and build resiliency to climate change impacts will require policymakers and the Legislature to work together to create new mechanisms for NBS.

The large-scale change required to truly reduce risk and build resiliency to climate change impacts will require North Carolina to redirect political commitments and investments.

The primary driver in building the plan was Section 9 of Governor Roy Cooper's Executive Order 80[2] issued in October of 2018, which laid out two primary goals; to reduce statewide greenhouse gas emissions to 40% below 2005 levels, and develop the North Carolina Climate Risk Assessment and Resilience Plan.

The second driver was the DEQ GHG Emissions Inventory issued in January of 2019. The inventory estimated agriculture emissions at 10.5 million metric tons of carbon dioxide equivalent GHG emissions (MMT CO_2e) as shown in Figure 6-1. On the other hand, the land use and forestry sector sequestered carbon on the order of 34 MMT CO_2e in 2017. This is a significant portion, 23%, of the gross GHG emissions emitted by all other sectors combined. This figure indicates the land use and forestry sector has the potential to offset significant GHG emissions from other sectors.

[2] Executive Order No. 80: North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy, signed October 29, 2018, accessed at https://governor.nc.gov/documents/executive-order-no-80-north-carolinas-commitment-address-climate-change-and-transition

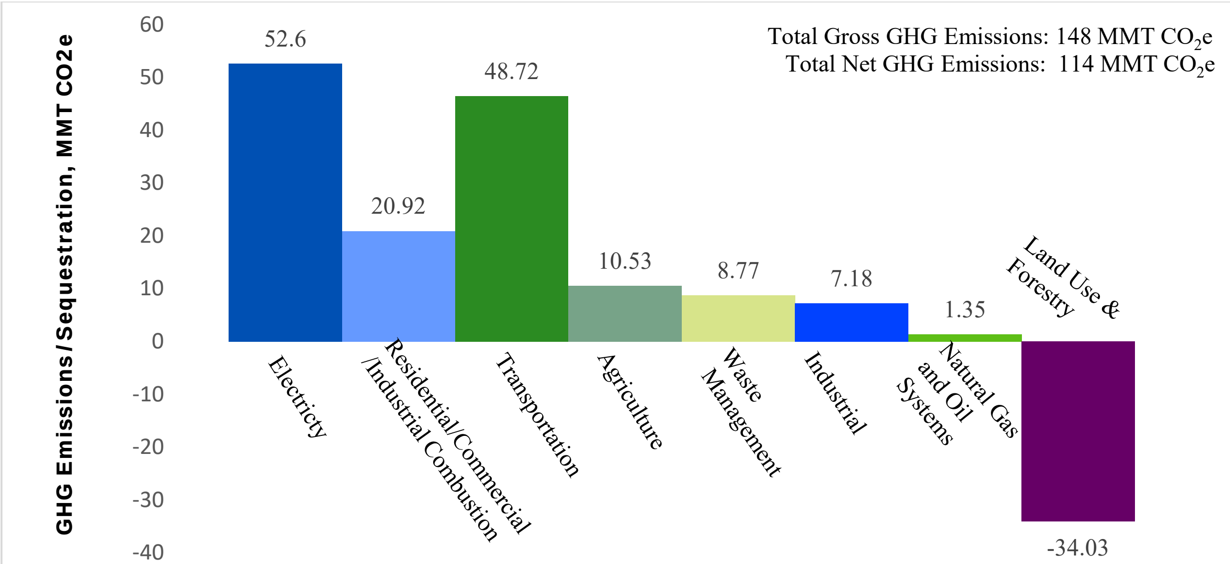

Figure 6-1: North Carolina GHG Emissions Inventory in MMT CO2e, 2017

The NWL Action Plan was a stakeholder driven process. Close to 100 people participated in six subcommittees developing and vetting 25 priority recommendations for the plan. The purpose of NWL Action Plan is to create opportunities and implement projects on North Carolina's natural and working lands that achieve the following goals shared by the plan's stakeholders:

1. Enhance the ability of natural and working lands to sequester carbon and mitigate emissions.
2. Build resiliency in ecosystems and communities.
3. Provide public health and ecosystem co-benefits.
4. Create economic opportunities for agribusiness, recreation, and tourism.
5. Ensure implementation of any action is a socially equitable process.

The recommendations in the plan were developed during 2019 by the six subcommittees listed in Figure 6-1.[3] Each subcommittee met numerous times to develop concrete recommendations that were supported by the majority of the members. In October of 2019, a 2-day meeting was held with all six subcommittee members to prioritize the recommendations that would go into the plan.

Figure 6-2: Natural and Working Lands Subcommittees

[3] For a full list of subcommittee participants, see the full report in Appendix V: NC Natural and Working Lands Action Plan.

2. Natural and Working Lands Basics

North Carolina consists of 31.1 million acres of land area and 2.6 million acres of open water. Figure 6-3 presents the percentage of each land type in acres for 2016. [4] Forests make up 18.1 million acres or 42% of the area. About 85% of this forest land is owned by private individuals and families. Agriculture is the next largest land area at 6.9 million acres. Woody and herbaceous wetlands span 4.9 million acres of the land area, while "other use" makes up 1.6 million acres. Developed land area is currently 3.6 million acres, or 11% of North Carolina's land area use. This is an increase of about 1.1 million acres from the 1990 developed land area. This figure indicates that the majority of North Carolina is natural and working lands.

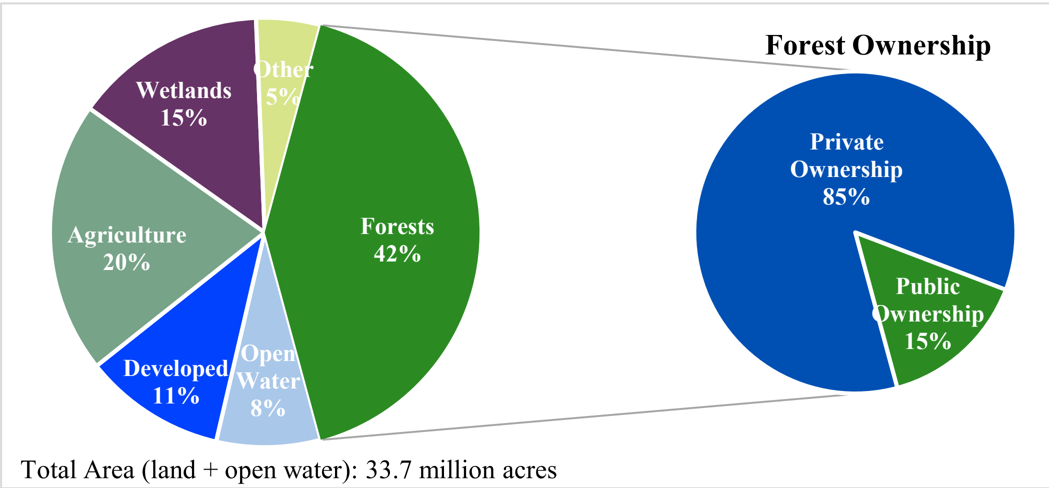

Figure 6-3: Total Land Use in North Carolina, 2016

North Carolina is one of the fastest growing states in the nation. **Since 1990, the population has increased by 55% while developed land area has increased by 1.16 million acres, a 3.7% increase relative to the state's total land area over**. [5,6] Despite this high conversion rate, in 2015 the urban tree canopy was estimated at 54%, the fourth-highest urban tree canopy in the US. While our canopy percentage is currently high, it is in decline and we need to promote the retention and management of this canopy as our population continues to grow.[7]

North Carolina has a substantial land connected to waterways and has 17 river basins. Table 6-2 presents the miles of rivers and coastline in the state.[8] **Restoration of riparian corridors along the 38 thousand miles of river has a large potential for flood protection and carbon sequestration**.[9] North Carolina's 320 miles of ocean beaches and 12,000 miles of estuarine shoreline are a key component to resiliency in coastal communities, including flood and storm surge protection. It also provides many co-benefits to

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[4] Data extracted from the National Land Cover Database (NLCD) 2016, Multi-Resolution Land Characteristics (MRLC) Consortium, accessed at https://www.mrlc.gov/ and retrieved by Duke University's Nicholas Institute for Environmental Policy in 2019.
[5] North Carolina census data provided by North Carolina Office of State Budget and Management in January 2018.
[6] Developed land-use area was approximately 2.4 million acres in 1990 based on "Urban Forest Data for North Carolina", US Forest Service, US Department of Agriculture, last updated December 8, 2008, accessed at https://www.nrs.fs.fed.us/data/urban/state/?state=NC.
[7] Urban canopy is being lost at a rate of 4,500 acres/year and impervious surface is increasing based on Nowak D. J., and E. J. Greenfield, "US Urban Forest Statistics, Values, and Projections", Journal of Forestry, March 2018, accessed at https://www.fs.fed.us/nrs/pubs/jrnl/2018/nrs_2018_Nowak_003.pdf.
[8] Data extracted from the National Land Cover Database (NLCD) 2016, Multi-Resolution Land Characteristics (MRLC) Consortium, accessed at https://www.mrlc.gov/ and retrieved by Duke University Nicholas Institute for Environmental Policy in 2019.
[9] Riparian land refers to land adjacent to rivers.

communities beyond resiliency such as carbon sequestration, ecosystem preservation, improved water quality, habitat for fisheries, and corridors for species migration.

Table 6-2: Miles of Coastline and Rivers in North Carolina

Waterways	Length (miles)
Miles of Rivers	37,853
Miles of Ocean Coastline	320
Miles of Estuarine Coastline	12,000

2. Mapping Resilience Opportunities

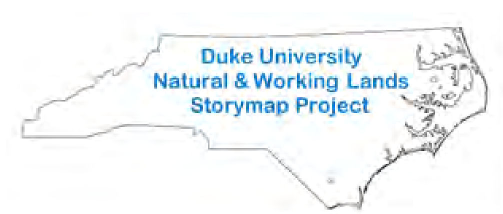
An example of how the recommendations offer opportunities to increase ecosystem and community resilience and sequester carbon is given in Figure 6-4. Protecting existing forests and woody wetlands and creating new forests through reforestation projects can enhance community resilience by 1) reducing flood risks to people and property; 2) removing air and water pollutants; 3) preserving high-quality drinking water supplies and 4) cooling air and water. Opportunities to reduce flood risks are concentrated in the coastal plain, especially along major rivers, while opportunities to enhance the quality of water supplies and benefit urban areas occur throughout the Piedmont and mountains. Protecting and restoring forests also provides carbon benefits by removing $CO_2$from the atmosphere and storing in forests.

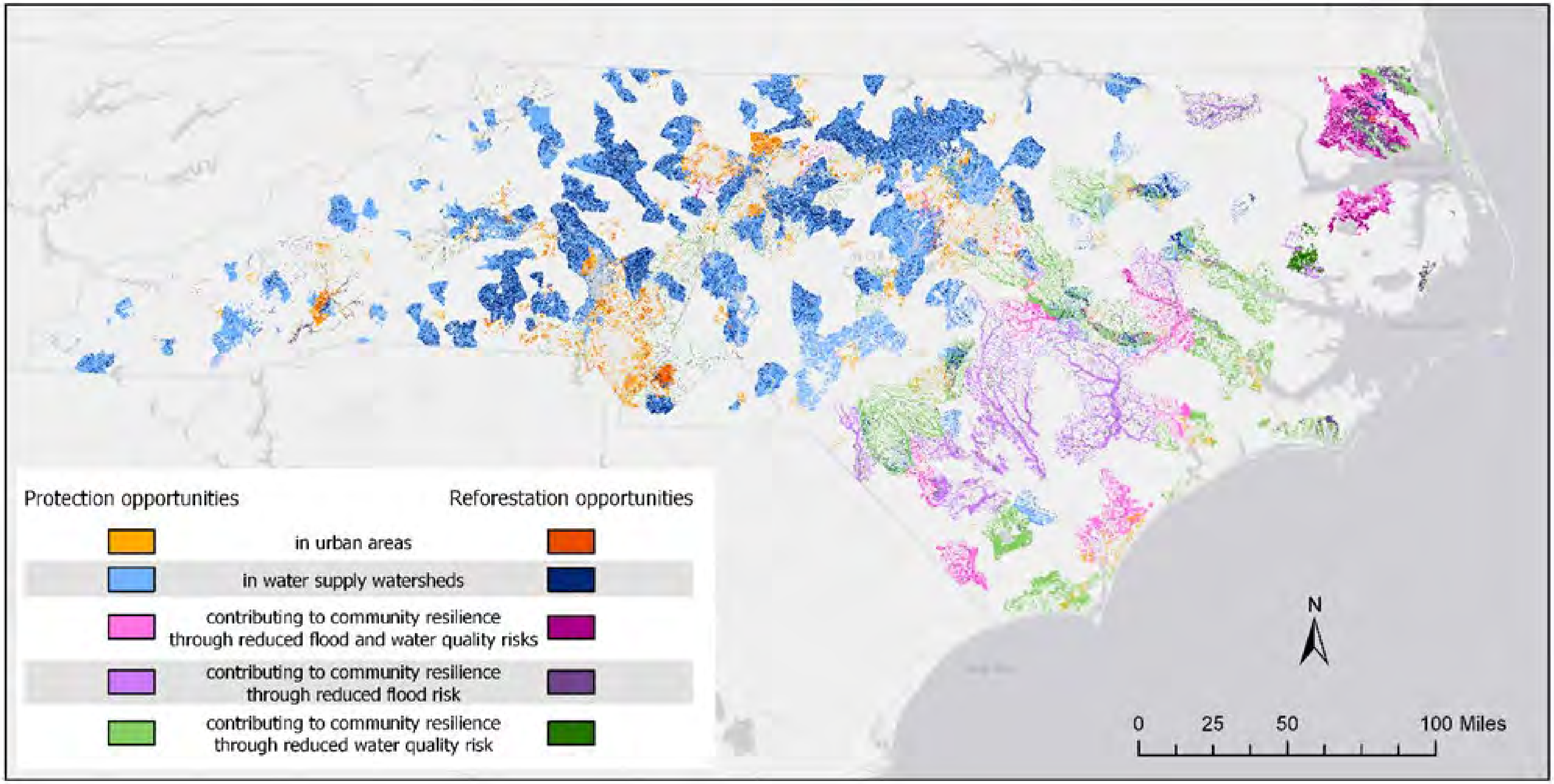
The NWL recommendations that are reflected in this map include:

- Protect forest lands;
- Restore forest lands;
- Promote urban forests; and
- Protect forested lands in water supply watersheds.

More information on the methods used to identify these areas is available in Appendix B: NC Natural and Working Lands Action Plan.

For in depth information on North Carolina's current land use and its ability to both sequester carbon and build community and ecosystem resilience, click on the link and access **Duke University's Natural and Working Lands Storymap.**





Source: Nicholas Institute for Environmental Policy Solutions at Duke University

Figure 6-4: Protection and Reforestation Opportunities with Community Resilience Benefits

B. Natural and Working Lands Recommendations

The Natural and Working Lands Action Plan seeks to identify and prioritize short-term, cost-effective, and pragmatic solutions to achieving the shared goals for NWL. It also identifies longer-term actions that require more effort and funding, such as legislative support or programmatic changes. There are four basic types of recommendations in the plan to increase resilience and sequestration of carbon as shown below.

1. ***Transformative***: cross cutting actions that will result in large amounts of NWL sequestration and resilience
2. ***Protect Land:*** acquisition of land or conservation agreements to develop additional natural areas
3. ***Restore Land*** restoration of land to a natural state to increase sequestration and resilience
4. ***Enhance Land***: improved use/management of existing NWL to increase sequestration and resilience

1. Summary of Recommendations

A summary of each recommendation is presented below. These recommendations are actionable by both state/local governments and impact partners such as universities and conservation organizations. Several already have teams working on their design and implementation including two of the transformative recommendations; 1) catalyze a state facilitated voluntary carbon offset program and 2) build a multi-state natural and working lands solutions toolbox. In some cases, the recommendations appear to have a heavy lift and significant barriers. However, the stakeholders feel their cost and complexity may be reasonable given the tremendous economic losses and cost to human health and wellbeing that the people of North Carolina has suffered in recent years because of the changing climate.

Table 6-3: Natural and Working Lands Action Plan Recommendations

Transformative Recommendations
1. Protect and restore forests and wetlands within flood prone areas. This recommendation seeks to significantly increase funding or create a funding mechanism for conservation and restoration of forest land. Conservation of 1.0 million acres of existing forest land with potential to protect against climate change impacts protects 170 MMT CO_2e of stored carbon and 1.7 MMT CO_2e that the forests sequester each year. Reforestation of 1.0 million acres would sequester 3.1 MMT CO_2e annually.
2. Facilitate voluntary landowner participation in carbon offset and ecosystem services markets. Given our potential to sequester carbon in forests and the growing carbon offset and ecosystem services markets, North Carolina should develop a state program to coordinate and encourage private landowner participation in carbon offset markets.
3. Build a multi-state NWL solutions toolbox. Establish ongoing funding for a state-supported toolbox with mapping capability that identifies the areas and communities most vulnerable to climate-related disasters and displays how NBS can reduce risks and impacts.
4. Integrate climate adaptation and resiliency strategies into local government comprehensive plans. NC General Statutes, Chapter 160D should be amended to mandate that all North Carolina counties and municipalities incorporate climate adaptation and resiliency strategies into their comprehensive plan.

Recommendations for Forest Lands	
Protect	**5. Conserve forest lands through easements and acquisition**. Protecting forests from conversion to other land uses maintains our current level of carbon sequestration and resilience. Land acquisition by public agencies and nonprofit conservation organizations provides permanent protection. Increased and recurring funding of land acquisition grants by the legislature and private entities would expand the scale and rate of forestland conservation.
	6. Modernize forest policy and tax incentives. A few changes in forest policy can reduce the threat of converting forests to other land uses and maintain our current level of carbon sequestration and resilience. Modernization of forest policy includes 1) expanding aspects of the current present use value (PUV) system, 2) creating conservation tax credits, and 3) implementing a "No Net Loss" forest policy. These changes encourage landowners to retain their forestland and invest in management and restoration rather than harvesting prematurely or even selling the land for financial gain.
Restore	**7. Expand restoration efforts on publicly owned lands**. Publicly owned lands may require restoration due to 1) land use/management before its acquisition or 2) removal of invasive exotic species or diseased trees. Restoring forest lands increases aboveground storage of carbon and ecosystem services such as resiliency/water quality. Restoration should focus on publicly owned pocosin wetlands, riparian lands, and coastal zones to provide the highest carbon sequestration and resilience benefits.
	8. Encourage restoration and reforestation on private lands. Several forest management practices improve forest health, productivity, and increase carbon sequestration. However, landowner access to existing programs for assistance with these practices is limited. Additional resources are needed to 1) enroll landowners; 2) develop private forest management plans; and 3) to cost-share costs implementation of practices.
Enhance	**9. Increase access to forest management technical assistance for landowners.** A number of forest management practices strengthen forests and increase carbon sequestration. However, access to existing programs to educate and assist landowners with these practices is limited. Additional resources and funding are needed to 1) enroll more landowners 2) develop more private forest management plans and 3) to share costs of these management activities.
	10. Support the wood products markets. Landowners need a strong wood products market to provide financial incentives to actively manage their forestland. Trees store about 80 tons of carbon per acre when they are actively growing. When trees are turned into products, much of that carbon stays in those products and out of our atmosphere. Access to strong and diverse markets for forest products, especially in long-lived products such as furniture and building supplies, provides incentives for forest landowners.

Recommendations for Floodplains and Wetlands	
Protect and Restore	**11. Coordinate the state's floodplain buyout and restoration program to increase resilience.** Federal and state programs buy flood-damaged properties on a voluntary basis after natural disasters. These often result in a "checkerboard" pattern of land acquisition within communities. It is recommended that state government develop a coordinated program to utilize the buyout processes to create functional floodplain areas and greater resilience. Connected, natural, permeable floodplains build flood resilience within at-risk communities while reducing costs for local governments and sequestering carbon. Local governments can create parks, trails, and greenways in floodplains, returning these areas to productive use and enhancing communities. The program should include farmland and be tied to the local planning process.

Recommendations for Coastal Habitats	
Protect	**12. Provide incentives to stakeholders for coastal habitat protection**. Protecting coastal habitats, such as natural shorelines, coastal wetlands, oyster beds, and submerged aquatic vegetation (SAV), through landowner incentives will provide benefits to community and ecosystem resilience and increase carbon sequestration. Providing these incentives can ensure protection of coastal habitats and the ecosystem services they provide. This protection will result in increased hazard mitigation and decrease costs required to repair assets and property and restore coastal habitats after major storm events.
	13. Facilitate salt marsh migration through protection of migration corridors. There is significant need for the state to facilitate conservation of migration corridors (natural areas without barriers such as development) for salt marsh, and other coastal habitats. Ensuring these migration spaces remain undeveloped is key to facilitating marsh migration with sea-level rise, and therefore preserving the coastal protection, ecological functions, and carbon benefits of North Carolina's marshes. Minimizing risk and expenses of hazard damage by ensuring protection and migration of salt marsh and other coastal habitats will increase ecosystem and community resilience.
Restore	**14. Prioritize climate change and sea-level rise in coastal habitat restoration planning**. Climate change and sea-level rise considerations need to be incorporated into planning processes for coastal habitat restoration by state, federal, and local governments. Currently, federal habitat restoration programs consider the impacts of climate change and SLR, and North Carolina should also require these impacts be considered when planning habitat restoration projects. Improved restoration planning will allow for more targeted and cost-effective efforts that will increase coastal resilience and carbon sequestration.

Recommendations for Pocosins	
Restore	**15. Rewet hydrologically altered peatlands to prevent soil loss and catastrophic fire**. Over 70% of North Carolina's peatlands have been ditched and drained resulting in substantial loss of soil carbon, land subsidence, and increased wildfire risk. Rewetting altered peatlands, using approved and verified methods, reverses the soil carbon loss and land subsidence while increasing adaption and resilience of coastal communities/ecosystems to sea-level rise and extreme weather events. Restoration costs are relatively low and provide co-benefits in addition to those listed above. Implementation can begin immediately on tens

Recommendations for Pocosins	
	of thousands of state-owned and private lands using the return on restoration investments that come from selling verified credits in carbon offset markets. Educating and engaging private landowners is also key.
	16. Reforest peatlands with Atlantic White Cedar. Large areas in eastern NC will be flooded by rising sea-level during the next century, resulting in major losses in plant and animal communities, some of which are rare and threatened. Healthy forests that are adapted to wetter conditions will be important for climate adaptation and resilience of eastern ecosystems. Atlantic white cedar (AWC), a historically important species classified as "threatened", occurs mostly in peatland swamps in eastern NC and does not tolerate saltwater. There is a potential for these stands to be lost unless we establish a plan and prioritize areas for mitigation plantings further inland and fund it using cost sharing programs and tax incentives.
Enhance	**17. Enhance soil health and retention on working peatlands via best management practices and drainage management**. Traditional agricultural practices and drainage on these soils result in high soil and soil carbon losses. Holistic planning of agricultural operations, water management, and adoption of existing technologies/practices, such as no-till and drainage management systems, would significantly decrease this loss. These improvements maintain or even increase carbon sequestration and reduce GHG emissions. They also improve sustainability of the farms and surrounding communities in the face of climate change. Existing Natural Resource Conservation Service cost-share and state grant programs could be utilized to facilitate planning and installing systems.
	18. Implement targeted interventions to protect peatlands from sea-level rise and saltwater intrusion guided by scenario-based modeling. Artificial drainage, extensive timbering and agricultural activities have altered the natural hydrological processes of the pocosins region. These alterations increase the vulnerability of the land to salinization and eventual loss of the freshwater ecosystems. This recommendation assists stakeholders in prioritizing locations for climate change defense and adaptation of peatlands. Existing models for hydrology, saltwater intrusion and habitats can be used to predict outcomes under various management scenarios to facilitate decision-making.

Recommendations for Urban Lands	
Protect	**19. Promote urban forests through statewide programs to foster the retention of urban trees and their proper management**. The NC Forest Service's Urban & Community Forestry program should be expanded to provide hands-on assistance to NC communities to manage their urban canopy. The Forest Service already has the program in place but due to limited resources they provide mainly guidance and recommendations through a 2-person team. Staffing for this program should be expanded to at least 4-person team to assist local governments with their forestry programs and to help homeowners/landowners better manage their urban trees. Funding would be needed through the NC Department of Agriculture and Consumer Services and the NC Legislature to permanently support the new positions.

Recommendations for Urban Lands	
Protect and Restore	**20. Protect and restore forested lands in water supply watersheds.** Water supply watersheds already have limits on development to protect the quality and quantity of water supply systems. However, preservation and restoration of forested lands in these watersheds may mitigate the impacts of future urban and suburban population growth and water demand. Key steps include 1) facilitate regional planning, 2) prioritize areas with high hydrology/water quality benefits within the watershed, 3) implement a stakeholder approach, 4) employ new funding mechanisms, and 5) determine the appropriate agencies and authorities to implement.
Enhance	**21.Improve site preparation and soil amendment during land development**. Urban planning and development should utilize a set of best practices that include using soil with adequate organic content, maintaining tree stands in high-value habitats, planting native vegetation, maintaining streams/wetlands, and reducing impervious surface. Best practices would have many benefits including sequestering carbon and building resilience by increasing soil carbon and water capacity, and reducing soil erosion, stormwater runoff, and pollutant loading of waterways. Developers will require incentives to use BMPs and create green infrastructure, carbon sequestration, and manage stormwater for the future.
	22. Urban forestry climate adaptation research and urban canopy baseline needs. Research on understanding the impact of climate change on urban forests and ecosystem services is still needed. This includes 1) developing a template for canopy studies for each region, 2) compiling existing urban tree canopy assessments into a database, 3) funding additional urban tree canopy assessments and inventories. This research would allow for state-level management and priority setting for urban forests.

Recommendations for Agriculture	
Enhance	**23. Encourage adoption of high mitigation agricultural conservation practices on croplands and pasturelands**. The adoption of conservation practices that produce GHG mitigation co-benefits has been dominated by conservation tillage (69%) in North Carolina; however, other well-established practices also have a substantial potential to mitigate GHG emissions through biological carbon sequestration in croplands and pasturelands. Adopting these practices conserves farmland by increasing the productivity/profitability of farms, restoring soil health, and enhancing climate resilience of agricultural businesses and rural communities. The existing network of Soil and Water Conservation districts is well-positioned to promote these practices; however, these programs are chronically underfunded. Additional funding from the Legislature and/or other public and private sources would increase the adoption of these practices by North Carolina farmers.
	24. Improve manure management on North Carolina farms. This recommendation focuses on installing anaerobic digesters with methane capture coupled with combustion of the methane either on-farm or off-farm for energy recovery. This approach is a near-term, cost-effective management system that will lead to substantial GHG emission reductions. However, RTI International is currently tasked with studying the costs, impacts, resilience, and equity of large-scale implementation of off-farm use of renewable natural gas (RNG). The outcome of this study will determine the feasible of off-farm RNG across the state. In the long-term, alternative non-methane generating manure management systems and add on

Recommendations for Agriculture	
	technologies to further reduce pollutants should be explored and supported by the state and its impact partners.
	25. Food system efficiency through reducing food loss and waste. Food loss/waste occur at the farm, within the supply chain, during processing, at retail stores and food service facilities, and with the consumer. There are various options for reducing this loss and waste including field gleaning, tax credits for donations, farm to food bank initiatives, redirecting waste from landfills to animal feeding or composting. Developing coordinated mechanisms, creating new strategies, and educating stakeholders to address food loss/waste will be required to realize the GHG mitigation potential of reducing food loss and waste.

C. Implementing Solutions in Time for Our People

Implementation of NBS across the natural and working lands of North Carolina requires a focused commitment of financial and human capital. In order to protect existing NWL areas and have the required land area in a functional "green-infrastructure" state to help mitigate climate change impacts and sequester carbon, we need to act quickly. The time to implement NBS is *now* due to the time required to plan, implement and grow these solution**s**. Some solutions begin working in a short time frame, such as improved crop practices or rewetting drained pocosins, where the carbon and soil benefits are realized quickly and extend out for the life of the restoration. Others, such as reforestation, may take decades to fully realize the carbon and ecosystem co-benefits. Given its carbon sequestration potential, sustainable management and financial support of the 14 million acres of forest owned by North Carolina's private forest landowners must be a cornerstone of any NWL actions taken by the state.

Funding for NBS is taking shape. The recommendations call for expansion of traditional funding from federal/state/local governments and philanthropic sources. Recent projects are using carbon offset markets as an alternative to traditional funding. Disaster funds can also be used to build resilience with NBS in local communities. Increasingly, NBS are being recognized as a cost-effective tool to reduce rick and increase sustainability for private entities as well.

A key element of success, however, is the leadership and support from state agencies**.** Agencies can "lead by example" and begin to integrate NBS into the 2020 Resilience Plan. This will encourage the people of North Carolina to look to these innovative ways to build resilience and sequester carbon while providing economic and ecosystem benefits.

The NWL Action Plan recommendations, along with the expert stakeholders who developed the plan should be the first resource for agencies building resilience in the state

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Chapter 7

Path Forward to Climate Resilience

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7. The Path Forward for a Climate Resilient North Carolina

A. Introduction

The climate is changing in North Carolina. Our own experiences, big and small, confirm what the science tells us. In recent years, we have experienced the devastating flooding and storm surges of Hurricanes Matthew, Florence, and Dorian; landslides in the mountains; and one of the earliest spring "leaf outs" along coastal North Carolina in the last forty years, as trees began to bud and flowers bloom this year almost a month earlier than normal; all against the backdrop of a global pandemic.

But there is cause for optimism. North Carolina has the resources—in our government, economy, and communities—to rise to this challenge. We will build a resilient North Carolina, where our communities, economies, and ecosystems are better able to rebound, adapt, and thrive amid changing conditions and challenges, including natural hazards and climate change. This shared vision of resilience will enable us to maintain and improve quality of life, nurture healthy growth, and ensure long lasting and sustainable social, economic, and environmental systems. A resilient North Carolina will also safeguard our ability to conserve resources for present and future generations. This chapter outlines the path forward.

First, this chapter lays out the Guiding Principles that frame North Carolina's action on climate resilience, based on the analyses and recommendations of this plan's authors and contributors. Next, it reviews the progress that the state has made to date through Governor Cooper's 2018 Executive Order 80 (EO80) and this 2020 Resilience Plan, which build on earlier efforts included in the 2012 Climate Ready North Carolina: Building a Resilient Future plan. This chapter then explains the four elements of the North Carolina Resilience Strategy, including how the contents of this 2020 Resilience Plan contribute to that plan. Finally, the path forward identifies priority initiatives and offers recommendations for state government to build resilience capacity and enhance the ability of residents, businesses, and communities to cope with climate change.

The principles, plans, proposed initiatives, and strategies outlined below implement recommendations from experts in the fields of climate science and environmental policy, as well as from local government, community partners, and the members of the public via pubic workshops and presentations. They incorporate best practices on climate assessment and resilience planning, including practices and approaches from the U.S. Global Change Research Program's Climate Resilience Toolkit Steps to Resilience, [1] reports on using climate science for making decisions from the Independent Advisory

[1] U.S. Global Change Research Program. (2016). *Steps to Resilience*. Retrieved February 18, 2020, from https://toolkit.climate.gov/#steps.

Committee on Applied Climate[2,3], and nationwide analyses of implementation status from resilience and climate adaptation plans published in peer-reviewed academic literature. [4]

B. Guiding Principles

The following principles will guide North Carolina's decision making and actions as we continue to address the effects of climate change on our state. They serve as both values and goals. The threat of climate change requires effective and decisive action, made with a clear-eyed understanding of the very real challenges we face in our state and in our world. These principles light the path.

Principle 1: Act quickly and decisively to reduce the most harmful impacts of climate change—flooding, drought, landslides, and wildfires

As our communities continue to recover from the devastation caused by recent hurricanes and flooding, we must act quickly and deliberately to address the most damaging effects of climate change—many of which we are already experiencing. The following actions further this principle:

- Incorporate resilience into state programs, policies, properties, and investments, through both budget neutral initiatives and through added resources not currently available
- Use interagency collaboration to continuously build resilience in state government policies and operations
- Align federal, state, and local funding and project prioritization to promote multiple natural and community benefits
- Incentivize local government and private endeavors that minimize and address future risks
- Protect existing natural infrastructure and invest in additional natural infrastructure to enhance existing natural features, processes, and solutions

Principle 2: Act thoughtfully and collaboratively to develop equitable solutions for the most socially challenging effects of climate change

Many of the current and anticipated effects of climate change challenge the way we think about our communities and live our lives. Only by coming together in pursuit of shared solutions can we address these challenges in a way that builds, rather than undermines, equity and fairness. The following actions further this principle:

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[2] Moss, R.H., S. Avery, K. Baja, M. Burkett, A.M. Chischilly, J. Dell, P.A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M.C. Lemos, J. Melillo, R. Pandya, T.C. Richmond, L. Scarlett, J. Snyder, M. Stults, A. Waple, J. Whitehead, D. Zarrilli, J. Fox, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, & Zimmerman, R. (2019). A Framework for Sustained Climate Assessment in the United States. Bulletin of the American Meteorological Society 100, 897–907, https://doi.org/10.1175/BAMS-D-19-0130.1

[3] Moss, R.H., S. Avery, K. Baja, M. Burkett, A.M. Chischilly, J. Dell, P.A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M.C. Lemos, J. Melillo, R. Pandya, T.C. Richmond, L. Scarlett, J. Snyder, M. Stults, A.M. Waple, J. Whitehead, D. Zarrilli, B.M. Ayyub, J. Fox, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, and R. Zimmerman, 2019: Evaluating Knowledge to Support Climate Action: A Framework for Sustained Assessment. Report of an Independent Advisory Committee on Applied Climate Assessment. *Weather, Climate, and Society*, 11, 465–487, https://doi.org/10.1175/WCAS-D-18-0134.1

[4] Woodruff, S.C., Meerow, S., Stults, M., & Wilkins, C. (2018). Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change. Journal of Planning Education and Research. 10.1177/0739456X18801057.

- Engage diverse groups of stakeholders across the state to develop a common understanding of goals, values, and ideas for creating a resilient North Carolina under these future scenarios and to communicate the current level of knowledge on impacts and best practices for implementing equitable solutions
- Build new and existing partnerships with academia; federal, state, local, and tribal governments; industry representatives; and nongovernmental organizations to evaluate the cross-sector impacts of long-term changes to the climate on people, communities, businesses, industries, and infrastructure in North Carolina, along with opportunities to address them
- Center issues of social equity and social vulnerability in state resilience efforts, and provide state agency staff with the training to do so and the time built into project timelines for authentic and equitable engagement
- Support community-based resilience efforts and community leadership development
- Ensure that disaster recovery efforts provide impacted communities with new capacities to cope with the next event or take the next steps towards resilience

Principle 3: Invest in safe, affordable, and connected communities

The investment required to address the effects of climate change provides an opportunity to create a safer, more affordable, and more connected North Carolina. As North Carolina builds climate resilience, we can also build a stronger and more livable state for us all. The following actions further this principle:

- Prioritize building a portfolio of resilience efforts, including serving both places and populations likely to experience the most challenging impacts and places and populations least able to cope with or adapt to climate change
- Accelerate public and private funding to locate affordable housing in low-risk, low-vulnerability areas
- Partner with organizations that represent diverse professions and communities, and engage in resilience conversations across public, private, and community-based leadership
- Connect local workers and businesses to opportunities created by investments in safe, affordable, and connected communities
- Develop "safe corridors" with redundant transportation routes within and between communities to maintain supply chains, emergency access, and evacuation routes
- Promote multimodal transportation options that reduce greenhouse gas emissions while improving reliability, access, and mobility

Principle 4: Strengthen regional economies

North Carolina's economy is strengthened by its diversity—from biotech to agriculture to tourism, in small towns and big cities. North Carolina is only as resilient as its regional economies. Resilience requires continued investment in regional and local infrastructure, government, and community capacity. The following actions further this principle:

- Promote economic growth that aligns with healthy populations
- Support agricultural, forestry, and seafood workers and related industry jobs
- Expand entrepreneurial opportunities, especially in rural communities and towns
- Support regions, towns, cities, and state- and federally-recognized Tribes in becoming more resilient through providing information, capacity building, and funding

- Support, foster and, promote a healthy and sustainable economy by attracting and retaining industrial and commercial businesses and jobs that protect and support our natural environment and the health of our communities

Principle 5: Support healthy communities, local identity, and recreational access to nature

From the Blue Ridge Mountains to the Outer Banks, and the farmlands and urban centers of the Piedmont in between, North Carolina's strong local communities and the beauty of our state are a source of pride and enjoyment for residents and tourists alike. Supporting our unique and diverse rural communities, towns, and cities and their connection to the natural world protects our individual and collective health and our economy. The following actions further this principle:

- Preserve what makes local communities unique
- Harness public and private research to inform communities of risk and vulnerability using easily understandable language and formats
- Increase access to nature for healthy outdoor recreation and ecotourism
- Identify opportunities when natural infrastructure can be used to improve resilience and fund the use of nature-based practices when feasible

Principle 6: Implement resilience best practices

We achieve a resilient and prosperous North Carolina through everyone's continuous hard work and collaboration. As the principles above are implemented, state agencies and other actors can ensure that all actions taken embody the most up to date best practices in building resilience:

- Begin all resilience efforts by establishing clear purposes, visions, goals, and objectives
- Base resilience efforts on the best available state of knowledge on climate change exposure, risks, vulnerabilities, and options for action
- Recognize potential sources of uncertainty in climate science and impacts, and provide support for using multiple scenarios to develop flexible strategies and identify "no-regrets" actions
- Provide guidance across agencies and levels of government on strategies to prioritize and make decisions that ensure resilience goals are achieved
- Acknowledge the diversity of stakeholders affected by decisions that build resilience and ensure equitable engagement of all in developing and implementing solutions
- Ensure resilience policies and actions will not have discriminatory effects
- Support local and tribal governments and industries in identifying opportunities to incorporate resilience building into everyday practice
- Recognize when new sources of funding are needed for resilience challenges and identify significant and sustainable funding sources to address those challenges
- Establish platforms for coordinating across local, state, and federal decisions that affect adaptation options
- Develop metrics and best practices for measuring progress toward resilience goals, and provide support across the state for monitoring and regularly adjusting action plans when needed

C. Resilience and Climate Change Mitigation Accomplishments

This 2020 Resilience Plan builds upon significant resilience work in North Carolina over the past decade. The following list is not comprehensive, but it highlights some of the milestones in state government. Communities, universities, businesses, and non-profits have provided invaluable leadership and expertise during this period to increase North Carolina's resilience, and those efforts are gratefully acknowledged.

1. Executive Order 80: North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy

In 2018, Governor Roy Cooper issued **EO80**, which laid out a series of goals for the state to strive to accomplish by 2025:

- Reduce statewide greenhouse gas emissions (GHG) to 40% below 2005 levels
- Increase the number of registered, zero-emission vehicles (ZEVs) to at least 80,000
- Reduce energy consumption per square foot in state-owned buildings by at least 40% from fiscal year 2002-2003 levels

EO80 also required state cabinet agencies to evaluate the impacts of climate change on their programs and operations and integrate climate change mitigation and adaptation practices into their activities. It created the **Climate Change Interagency Council** (Council), comprised of representatives of each cabinet agency and chaired by the Secretary of the Department of Environmental Quality (DEQ). EO80 directed the Council to finalize strategic plans in key action areas and directed the creation the 2020 Resilience Plan.

In 2019, the Department of Environmental Quality published the **North Carolina Greenhouse Gas Inventory (1990-2030)**, a detailed account of GHG emitted or stored from 1990 to 2017, as well as a projection of North Carolina's anticipated GHG emissions from 2018-2030.

2019 also saw the development of the **North Carolina Clean Energy Plan: Transitioning to a 21st Century Electricity System** by the DEQ, a plan required by Governor Cooper's EO80. The plan, which is intended to be revised every three to five years, identifies the following goals:

- Reduce electric power sector GHG by 70% below 2005 levels by 2030 and attain carbon neutrality by 2050
- Foster long-term energy affordability and price stability for North Carolina's residents and businesses by modernizing regulatory and planning processes
- Accelerate clean energy innovation, development, and deployment to create economic opportunities for both rural and urban areas of the state

The Department of Transportation developed in 2019 the **Zero Emission Vehicles (ZEV) Plan,** also called for by EO80. The plan recommends strategies for increasing the number of ZEVs on North Carolina roads. These strategies are organized into four action areas: education, convenience, affordability, and policy.

To address the use of ZEVs by state government, the Department of Administration developed the **2019 Motor Fleet Zero Emission Vehicles Plan**, also called for under Governor Cooper's EO80 mandate. The plan identified 572 traditional vehicles for replacement with ZEVs, finding that doing so would save taxpayers an estimated $3.8 million and reduce emissions by over 22,000 metric tons over the lifetime of the vehicles.

Governor Cooper's EO80 also required the Department of Commerce to issue **Clean Energy and Clean Transportation in NC: A Workforce Assessment**, which it did in the fall of 2019. This assessment evaluates the clean energy and clean transportation sectors in North Carolina, assesses the skills and education needed in these sectors, and recommends actions for supporting an expanded workforce in North Carolina.

2. State agency resilience-building programs

The **North Carolina Interagency Leadership Team** issued the **Climate Ready North Carolina: Building a Resilient Future** report in 2012, which identified climate trends and risks associated with those trends, and recommended overarching cross-sector strategies. This report established critical information and analysis for the 2020 Resilience Plan. Since that time, numerous state agencies built on the report by developing programs to address climate change impacts. Selected initiatives are described below.

In 2018, following the devastation of Hurricane Florence amidst the ongoing recovery from Hurricane Matthew, the **North Carolina Office of Recovery and Resiliency** (NCORR), a division within the Department of Public Safety (DPS), was established to administer funds received by the state through the U.S. Department of Housing and Urban Development's Community Development Block Grants for Disaster Recovery Program. Working closely with **North Carolina Emergency Management** (NCEM), whose **Hazard Mitigation** and **Recovery** Programs administer funds received from the Federal Emergency Management Agency (FEMA), DPS provides disaster recovery coordination with services that include oversight of recovery funding, processing of program applications, construction and vendor management, and public outreach and education, among other responsibilities such as creating safe and affordable housing solutions.

The **NCEM** in the Department of Public Safety runs the state's **Hazard Mitigation Grant Program (HMGP)** under the state **Enhanced Hazard Mitigation Plan (EHMP)**. The HMGP enables North Carolina families to move out of dangerous flood zones, have their homes elevated, or have their homes torn down and rebuilt to enhanced flood safety standards. The EHMP is described in detail for its continuing role in the North Carolina Resilience Plan, in Section D below. The 2018 iteration of the EHMP met FEMA's requirement to include consideration of future conditions by using data from the Southeast chapter of the Third U.S. National Climate Assessment (NCA), the version of the NCA most recent at the time of EHMP publication.

In 2019, Governor Cooper appointed a state **Chief Resilience Officer (CRO)** to lead NCORR's resilience staff and direct the state's initiative to help storm-impacted communities rebuild smarter and stronger in the face of future natural disasters and long-term climate change. NCORR's resilience staff works to improve collaboration among state agencies, local governments, non-profits, the private sector and academia, with a goal of developing solutions that enhance the resilience of communities and the natural environment. As part of that work, the NCORR resilience staff coordinates the State Disaster Recovery Task Force (SDRTF) and its subcommittees, the Recovery Support Functions (RSFs). The RSFs bring together experts in the field of recovery and resiliency within federal, state, and local government, as well industry and non-government organizations. Each RSF provides and promotes recommendations through NCORR and NCEM to state government and the General Assembly on ongoing disaster recovery efforts and future resilience-building.

In 2019, DEQ's **Division of Coastal Management (DCM)** built an online **Coastal Adaptation and Resilience Clearinghouse**, intended to help local governments find information, tools, and technical resources (e.g., geospatial data, policy guidance, case studies, and funding opportunities) to help them build resilience. A companion tool, the **North Carolina Coastal Community Resiliency Guide**, is an ArcGIS Story Map that helps local government understand the sequencing of steps they can take to build their team, assess their climate vulnerability and risk exposure, and identify and implement adaptation strategies.

DEQ has also developed the **North Carolina Beach and Inlet Management Plan** (BIMP) (2009 and 2016) as an inventory of projects and resources for maintaining ocean beaches and navigational waterways. The BIMP also recommends strategies for identifying sand and financial resources needed to protect this infrastructure. Maintaining healthy beaches and dune systems, and repairing damage to these systems after storms, is vital to protecting the social, economic and environmental benefits that these systems provide.

The Coastal Resources Commission's Science Panel produced the **Sea Level Rise Assessment Report** in 2010 and 2015 and is currently drafting its 2020 report. The reports include sea level rise projections based on Intergovernmental Panel on Climate Change (IPCC) emissions scenarios, broken down by different sections of the coast, and takes into account the rates at which coastal land is sinking. The commission provides these reports as an informational resource for local governments and other interested parties for use at their discretion.

The **Albemarle-Pamlico National Estuary Partnership** issued **Climate Ready Estuaries: A Blueprint for Change** report in 2012, which provides findings and recommendations for increasing the region's climate resilience, compiles a resource of up-to-date science on sea-level rise impacts, and serves to educate the public and decision makers about the opportunities and challenges inherent in becoming a climate ready estuary. Additionally, APNEP conducted **Climate Resilience Evaluation and Awareness Tool Exercise** with towns Manteo and Columbia to examine the potential impacts of rising sea levels on their wastewater infrastructure using the Environmental Protection Agency (EPA) Climate Risk Evaluation and Assessment Tool (CREAT) as part of the EPA's Creating Resilient Water Utilities (CRWU) initiative. The report provides engineering and financial recommendations for realistic measures the towns might take to improve their resiliency to coastal hazards and flooding to consider for integration into their capital improvement planning processes.

The **North Carolina Climate and Health Program** in the Department of Health and Human Services (DHHS) is part of a national public health effort to anticipate and prepare for human health effects related to global and local climate change. The program is supported by the Centers for Disease Control and Prevention's Climate and Health program. DHHS implemented the **Building Resilience Against Climate Effects (BRACE) Framework** to identify likely climate impacts, potential health effects associated with these impacts, and the most vulnerable populations in the state. This funding initiative led to the development of the 2015 Climate and Health Profile Report, which determined the health impacts of heat-related illness and wildfire smoke as the greatest concerns in North Carolina. DHHS continues to track public health effects of climate change, to provide services in response to increasing extreme weather and wildfires, and to accommodate disruptions from climate-related conditions to the daily services DHHS provides.

D. North Carolina Resilience Strategy

To guide the path forward, the state will maintain and update the North Carolina Resilience Strategy. The North Carolina Resilience Strategy is a compilation of documents organized into four elements: (1) The North Carolina Science Report, (2) State Agency Resilience Strategies, (3) Statewide Vulnerability Assessment and Resilience Strategies, and (4) the North Carolina state EHMP.

Table 7-1: North Carolina Resilience Strategy Elements

North Carolina Resilience Plan Element	Current Components	Earlier Versions	Update Cycle
1. Science Report	2020 North Carolina Climate Science Report	Chapter 2 ("Climate Trends") of 2012 Climate Ready NC	As needed to incorporate new decision-relevant information
2. State Agency Resilience Strategies	Chapter 5 ("Climate Impacts, Risks and Vulnerabilities") of 2020 Resilience Plan		Agency Resilience Strategies finalized March 2021, and annually thereafter.
3. Statewide Climate Vulnerability Assessment and Resilience Strategy	Chapter 4 ("Climate Justice"), Chapter 6 ("Nature-Based Solutions"), Chapter 7 ("Path Forward") of 2020 Resilience Plan; Chapter 3 ("Impacts, Risks and Vulnerabilities for North Carolina"); Appendices B through E of 2012 Climate Ready NC	Chapter 4 ("Cross-Sector Strategies") of 2012 Climate Ready NC	• Priority 1: 2022 and every 4 years thereafter • Priority 2: 2024 and every 4 years thereafter
4. State Hazard Mitigation Plan	2018 North Carolina state Hazard Mitigation Plan	2013, 2010, 2007, 2004 SHMP	Current FEMA mandate: every 5 years

Table 7-2: North Carolina Resilience Plan Going Forward

PLAN ELEMENTS	NEXT STEPS	PARTICIPATION	RESOURCE NEEDS
1. North Carolina Climate Science Report	• Update 2020 Climate Science Report as deemed necessary • Synthesize decision-relevant studies and contracted analysis from Elements 2 and 3	• Universities • Federal agencies • State agencies • External contractors	• U.S. National Climate Assessment updates • Contracting funds for scientific expertise • State agency staff participation
2. State Agency Resilience Strategies	• Develop Agency strategies based on 2020 Resilience Plan Chapter 5 ("Climate Impacts, Risks, and Vulnerabilities") • Agencies seek advisory capacity on strategies from NCORR State Disaster Recovery Task Force Recovery Support Function teams (RSFs) as needed • Agencies publish Agency Resilience Strategy	• State agency resilience lead staff • NCORR resilience staff (general guidance; administration of SDRTF RSFs) • Universities • External contractors • Local governments • Stakeholders representing agency priority areas	• Funding for state agency resilience leads (1 new FTE per agency) • Each agency will have different resource needs for implementing resilience in its programs, which may include: o Contracting funds for agency-specific quantitative and qualitative risk and vulnerability assessments o Contracting funds for facilitating prioritization discussions and strategy development • NCORR guidance
3. Statewide Climate Vulnerability Assessment and Resilience Strategy	Identify, perform supporting vulnerability assessment, and develop Resilience Action Plan for Cross-Cutting Challenges: • Priority 1 Challenges: extreme events and actions potentially eligible for federal funding, such as Enhanced Hazard Mitigation Plan funding • Priority 2 Challenges: long-term issues not addressed through Priority 1	• Statewide Strategy development process established by NCORR, with advisory input from Interagency Resilience Team and SDRTF RSFs	• Contracting funds for facilitating prioritization discussions and strategy development to gather input and prioritize actions
4. State Enhanced Hazard Mitigation Plan	• Incorporate climate science data into FEMA required Risk and Vulnerability Assessment process • Incorporate Element 3 Priority 1 Cross-Cutting Resilience Action Plan items into FEMA required Hazard Mitigation Strategy	• NCEM Hazard Mitigation, with advisory input from NCORR resilience staff (Resilience Strategy support and SDRTF administration)	• Contracting funds for quantitative and qualitative risk and vulnerability assessments • Contracting funds for facilitating prioritization discussions and strategy development to gather input and prioritize actions across levels of government

1. North Carolina Climate Science Report

The 2020 North Carolina Climate Science Report (NCCSR) provides a rigorous, comprehensive, peer-reviewed assessment of the weather and climate future of North Carolina. This report relies upon the best available research and modeling about climate change in North Carolina, thoroughly documenting all sources and using best practices for peer review. The current Climate Science Report can be found in Appendix A of this document. A summary of the Report is included in Chapter 3 ("North Carolina Climate Science Report"). The NCCSR updates Chapter 2, "Climate Trends," of the 2012 *Climate Ready North Carolina* report.

The Climate Science Report will help inform all levels of decision making, including state government, local government, farmers, businesses, researchers, households, and others. The report will also help to reduce the complexity, uncertainty, and ambiguity that are a part of resilience-oriented decision making by describing the projected weather changes this state will experience due to climate change. Report data help to define vulnerabilities and quantify risks to ensure that decisions and policies are appropriately implemented. Going forward, the Climate Science Report will be updated as needed as new decision-relevant information becomes available, which will ensure that North Carolina has the best available fact base from which to consider how to build resilience. This allows North Carolina to focus future efforts in ways that implement the recommendation of Moss et al. (2019) to assess climate knowledge in the decision-making context in which it will be applied.[3] This "as needed" update cycle will provide flexibility to dedicate time and resources to tailoring climate information toward solving North Carolina's practical challenges and to supporting new avenues of scientific research and policymaking as our understanding of climate science and our state's needs develop over time.

The science of climate adaptation is constantly evolving to best inform the kinds of practical challenges that agencies identified in Chapter 5. Fortunately, North Carolina is home to a robust climate science community, including the State Climate Office of North Carolina (housed at North Carolina State University), the North Carolina Institute for Climate Studies, and many other federal and university-based climate science and impact programs. Agencies can work with the scientific community to identify the best possible uses of existing climate science to address risks identified. Likewise, the scientific community will find the resilience goals and action steps of the North Carolina Resilience Strategy to be valuable resources for identifying future climate research needs. The Statewide Climate Vulnerability Assessment and Resilience Strategy (discussed below) should capture these ongoing collaborations and provide a means for tracking their findings, in addition to building on the findings of the NCCSR and the U.S. National Climate Assessment.

The NC Climate Science Report was written by a multi-institutional team led by North Carolina Institute for Climate Studies, in partnership with the National Oceanic and Atmospheric Administration's National Centers for Environmental Information, all working on a pro bono basis for the state. Future updates to this report will require funding, as well as state agency staff time to manage production, coordinate state resources, and provide information.

2. State Agency Resilience Strategy Reports

The second element of the North Carolina Resilience Strategy addresses the resilience of state agencies' missions, assets, and programs. Through development of this 2020 Resilience Plan, state agencies analyzed the vulnerabilities and risks associated with two to three climate stressors, such as flooding, drought, and extreme heat events. By this effort, agencies were able to outline the climate stressors that affect them and the impacts of those stressors, while increasing institutional understanding of climate change and interagency collaboration to address those threats.

Chapter 5 of this plan constitutes the second element of the North Carolina Resilience Strategy, which will be updated and enhanced as agencies develop Agency Resilience Strategies. Agencies each will develop an Agency Resilience Strategy to be published by March 1, 2021, and updated annually thereafter. Each agency's Agency Resilience Strategy will build on the work that agency has completed for Chapter 5 of this plan, describing any changes or additions to the agency's latest understanding of its climate vulnerabilities and risks. It will also briefly outline the agency's current and planned actions to increase resilience. Because of the diversity of state agencies and the scope of their missions and jurisdictions, these strategies will likely include a range of actions, from proposed studies and planning activities to capital projects. In some cases, an agency may already have adequate scientific and risk information to take specific action to build resilience. In other cases, where agencies have identified long-term challenges needing more research and engagement before implementing a project or policy, agencies can outline their plans, funding needs, and timelines to accomplish such work. These strategies also should report progress on implementing strategies previously identified by the agency.

Agencies will each develop an Agency Resilience Strategy on an ongoing basis, with a progress report published annually, beginning on March 1, 2021. Annual updates will reflect the agency's deeper understanding of its vulnerabilities and provide specific strategies and recommendations for mitigating those vulnerabilities. These updates also should report progress on implementing strategies previously identified by the agency. The iterative process of annual report updates allows agencies to maintain a custom resilience strategy that aligns with agency needs and resources. It also helps the public and stakeholders understand each agency's priorities and how to support agencies.

Agencies should designate a resilience lead to provide a primary point of coordination to accomplish this work across divisions within the agency. This lead will also serve on the Interagency Resilience Team, described below. Agencies would benefit from a senior advisor for climate change and resilience (described in Section F below), which could serve as the agency's resilience lead. Additional funding would enable each agency to establish such a full-time advisor. The quality and scope of Agency Resilience Strategies and agencies' ability to implement priority strategies will depend upon available funding for contracting and analyses.

NCORR will provide guidance to agencies in the development and updating of their Agency Resilience Strategy. Additionally, through communication with NCORR, the state agencies will be able to access the subject matter expertise of relevant Recovery Support Function subcommittees of the SDRTF. The SDRTF and its constituent RSFs are advisory bodies that inform disaster recovery and resilience in the state. Annual updates to and implementation of Agency Resilience Strategies are steps consistent with Section 2 of Executive Order 80: "Cabinet agencies shall evaluate the impacts of climate change on their programs and operations and integrate climate change mitigation and adaptation practices into their programs and operations."

3. Statewide Climate Vulnerability Assessment and Resilience Strategy

The third element in the North Carolina Resilience Strategy is a statewide climate vulnerability and impact assessment that establishes resilience action steps. This Statewide Climate Vulnerability Assessment and Resilience Strategy (Statewide Assessment) encompasses the information and the strategic direction that guide decisions where climate change is a relevant factor. These decisions are made by state government, as well as local and tribal governments, businesses, nonprofits, and residents.

In order to accomplish these goals, the Statewide Vulnerability Assessment will need to rely not only on academic research, but also the everyday experiential knowledge of North Carolina's public and private leaders.

The current Statewide Climate Vulnerability Assessment and Resilience Strategy is summarized in multiple sections of the 2012 Climate Ready North Carolina: Chapter 3 ("Impacts, Risks and Vulnerabilities for North Carolina") and Appendices B through E. Various sections of this document complement and enhance the Climate Ready North Carolina report: Chapter 4 ("Climate Justice"), Chapter 6 ("Nature-Based Solutions"), Chapter 7 ("Path Forward"). In this way, sections of this plan round out and update the second element of the North Carolina Resilience Strategy.

In future updates, the Statewide Assessment will use information from analyses of impacts, along with the expertise of stakeholders, to recommend action on resilience. This may include a variety of approaches, from tackling our largest climate resilience problems to modernizing routine, discrete tasks so they consider future weather. The Statewide Assessment should identify challenges to building resilience that cut across different sectors of our society and economy and different levels of federal, state, local, and tribal government. These cross-cutting challenges require multidisciplinary, regional-scale solutions that may be implemented over the course of decades — such as the coastal impacts of sea level rise or drinking water availability during drought — and propose actions to address those challenges.

Prioritizing feasible, effective actions to build resilience will require additional user-driven, quantitative and qualitative assessments. These assessments should encompass both physical and social science approaches to inform all aspects of how implementation decisions are made. Analysis could include investigating impacts previously identified in the 2012 Climate Ready NC and in Chapter 5 of the 2020 North Carolina Resilience Plan in more detail, and identifying as well as investigating additional significant impacts to people, the economy, the built environment, and natural resources.

Developing solutions to the biggest climate change risks for the state will require not only interagency collaboration, but also collaboration across state, local, and tribal governments and with other stakeholders, including community-level engagement. Accordingly, updates to the Statewide Resilience Strategy can provide information that supports decision making at all levels to address the climate crisis. Updates also can outline pathways to implementing those solutions, including identifying challenges such as needed capacity and funding. Concrete, measurable action steps designed to address implementable solutions to our most significant climate vulnerabilities will provide a path forward for all types of stakeholders across state, regional, and local government and in the public and private sectors.

Many of the cross-cutting climate resilience challenges identified in the Statewide Resilience Strategy will take years to solve. Thus this chapter proposes a two-phased approach to updating the Statewide Resilience Strategy. The first phase of this process will examine challenges related to extreme events. These "Priority 1 Challenges" will be addressed first so that they may inform the next update of the state EHMP, due in 2023 (described further below), and other near-term funding opportunities from the federal government or elsewhere. The EHMP identifies needs and actions required to address extreme events, which actions may then be eligible for federal funding. By first examining these Priority 1 Challenges in the Statewide Strategy, North Carolina can take efficient advantage of this funding opportunity.

Other cross-cutting climate resilience challenges, such as long-term drinking water availability or planning for sea level rise over a number of decades, require additional attention and resources outside of established federal funding opportunities like the EHMP process. While these challenges are no less important, these "Priority 2 Challenges" will be addressed in phase two of the Statewide Resilience Strategy with a long timeline for initial planning and future updates. These two phases of the Statewide Resilience Strategy will be updated every four years, with the initial Priority 1 Challenges Statewide Resilience Strategy published in October 2022 and the initial Priority 2 Challenges Statewide Resilience Strategy published in October 2024.

Strategic stakeholder engagement will be important in developing and implementing the Strategy. Updates to the Statewide Resilience Strategy will depend upon investment of both staff time and significant funding for data gathering and scientific research, engagement with subject matter experts and stakeholders, action prioritization, and monitoring implementation progress.

NCORR will coordinate updates to this third element of the North Carolina Resilience Strategy. The Interagency Resilience Team, described below, will support NCORR to make certain that state agencies' expertise is incorporated throughout this process. The SDRTF RSFs, when not otherwise engaged in providing advisory knowledge and expertise on disaster recovery, may also provide input and guidance on the Statewide Resilience Strategy process.

4. State of North Carolina Enhanced Hazard Mitigation Plan

The Statewide Climate Vulnerability Assessment and Resilience Strategy will be incorporated into the EHMP, which is a critical means for the state to access federal funding for disaster resilience. This constitutes the fourth element of the North Carolina Resilience Strategy. FEMA currently recognizes the quality of the North Carolina State Hazard Mitigation Plan by designating North Carolina an "Enhanced Plan Status" state. This status increases the amount of Hazard Mitigation Funds the state is eligible for after a disaster.

The current EHMP was released in 2018, and federal law requires it to be updated every five years. Future updates of the EHMP will integrate into aspects of the North Carolina Resilience Strategy as appropriate, such as statewide and agency-specific vulnerabilities and resilience strategies and climate science. North Carolina Emergency Management and NCORR will partner to ensure that this future EHMP process encourages both a focus on large scale extreme events and to climate-driven changes in localized, small scale, repetitive hazard events. An integrated EHMP — meaning one that includes both hazard mitigation and climate adaptation and resilience — benefits North Carolina by identifying hazard mitigation activities that also benefit climate adaptation. In addition, this guidance assists local governments and regional coalitions of counties on planning activities that could be eligible for non-emergency Stafford Act assistance and FEMA disaster mitigation grants when funding is available.

E. Priority Resilience Initiatives

The following priority resilience initiatives complement the North Carolina Resilience Strategy by implementing recommended actions and providing opportunities for education and collaboration across stakeholder groups and sectors. This section describes the initiatives and identifies funding needs.

1. Manage and coordinate statewide resilience

The NCORR team will lead the state's resilience efforts. This involves supporting coordination among state agencies and maintaining productive relationships and partnerships between state, tribal, and local and regional governments, business and non-profit partners, and community stakeholders. Collaboration and interaction among partners inside and outside of state government helps all entities leverage expertise throughout the state to build a more resilient North Carolina.

NCORR provide resilience expertise to state government across the executive and legislative branches and all state agencies. The CRO also facilitates strategic planning and supports state agencies and offices as they continuously expand their capacity for and attention to resilience. Among other responsibilities, NCORR issues guidance to state agencies as they develop and annually update their Agency Resilience Strategy.

2. Convene a dedicated Interagency Resilience Team

The CRO will convene an Interagency Resilience Team, which will include at least one resilience lead from each agency. These leads should be staff experts from each agency who have the authority, capacity, and expertise to collaborate on resilience work among agencies. This team will provide a coordinating structure for tackling interagency resilience issues. It also will support the development and release of updates to the North Carolina Resilience Plan in collaboration with the Climate Change Interagency Council. Ideally, this team will include representation from all state agencies, not only cabinet agencies.

3. Continue resilience efforts through the North Carolina Climate Change Interagency Council

The Climate Change Interagency Council is an interagency leadership body for the state's efforts in climate change mitigation and adaptation. Per Executive Order 80, its charge includes:

- Recommend new and updated goals and actions to meaningfully address climate change;
- Develop, implement, and evaluate programs and activities that support statewide climate mitigation and adaptation practices;
- Establish workgroups, as appropriate, to assist the Council in its duties;
- Consider stakeholder input when developing recommendations, programs, and other actions and activities;
- Review and submit to the Governor plans, recommendations, and/or assessments that further North Carolina's commitment to address the effects of climate change on the state and its residents.

The Climate Interagency Council will continue to serve as a public forum for state agencies to provide updates on their work to reduce emissions and increase resilience. It is also a setting for the public and Climate Interagency Council to learn from subject matter experts about resilience and other topics as well as hear recommendations and input from residents

4. Establish the North Carolina Resilient Communities Program

Building resilient communities is critical to protecting North Carolina's residents from the effects of climate change. Communities in North Carolina's mountains, Piedmont, and coast are on the frontlines of climate impacts. In public listening sessions, meetings, and events across the state during development of this 2020 Resilience Plan, community leaders and residents repeatedly emphasized that building local resilience required access to resilience expertise, support for analysis planning, and funding to implement measures that advance long-term resilience.

To address these local needs, North Carolina will establish the North Carolina Resilient Communities Program. The program will build capacity, incentivize and reward action, and produce coordinated, holistic, and continuous progress.

Components of the North Carolina Resilient Communities Program may include the following:

Develop an online Climate Resilience Clearinghouse and Toolbox. This online resource would point users to relevant climate data and best practices for building resilience in an equitable way. It would also house the North Carolina Resilience Plan and related state resources on resilience.

This online tool will fill an information gap for local communities, regions, and sectors. Critical climate data and guidance on best practices are often not available to support these stakeholders' decisions. Serving internal and external partners with this resource will move North Carolina toward preparing diverse networks of leaders to make decisions about climate-related risks. With a menu of options, stakeholders can reach their own conclusions about the options that are best suited to them. This resource could be developed by federal, state, local, university, and nongovernmental organizations as partners.

Resilience training program for communities. Trainings would help communities develop and deliver consistent resilience goals, principles, and strategies applicable to local government actions. This could include robust training programs and ongoing collaborations for local and tribal governments, regional councils of government, and nonprofit and business entities on how to use emerging climate information and established best practices to build climate resilience.

North Carolina Resilient Communities grant funding. A key aspect of community resilience programs in Massachusetts, Rhode Island, Florida, and other states is resilience grant funding. Local governments and other entities use these grants for resilience education, planning, and strategic investments consistent with priorities identified in their resilience plans.

The local governments in North Carolina that have made progress with climate resilience planning include municipalities that have partnered with universities to access academic grants and with state and federal agencies to leverage funding and expertise. These partnerships have achieved results. For example, DCM conducted a Coastal Resilience Pilot Program that helped the Towns of Oriental, Edenton, Duck, Pine Knoll Shores, and Hatteras Village map community assets that may be vulnerable to coastal hazards and climate change. These successes demonstrate that local governments are willing and able to make progress on resilience when they have access to subject matter experts, capacity building resources, and funding for implementation.

If funded, this program would provide additional grants to local and tribal governments and other community entities for education, planning, and investment in resilience strategies and projects.

F. Cross-Sector Resilience Strategies

This section recommends various cross-cutting resilience strategies that would advance resilience planning and implementation across agencies, sectors, and communities statewide. These and similar recommendations may be addressed in more detail in future updates to the Statewide Resilience Strategy discussed above. These cross-cutting resilience strategies are an evolution from the cross-sector strategies identified in the 2012 resilience report. For a list of those cross-cutting strategies and how North Carolina has implemented them, see Chapter 2.

1. Consider resilience criteria in making state investments

The state can take a leadership role in assessing and mitigating against the potential for climate risks to people and property. For example, state agencies can continue to evaluate current and future climate risks to programs, investments, construction and other activities and develop sensible standards of safety and risk tolerance. Reviews will utilize, and supplement as necessary, the state's data on future climate conditions to ensure that state activities occurring in or near risk areas avoid adverse impacts and remain reasonably safe from climate risk for the lifetime of the project or activity. Where activities within areas at risk cannot be avoided, the agencies should employ the appropriate solutions to mitigate risk or to improve resilience, including those relying on or incorporating natural features. The State Construction Office in the Department of Administration has a critical role in setting goals, criteria, and scopes of work used to develop Requests for Proposals for the state, and it should be engaged in identifying concerns and developing solutions.

2. Update plans, standards, and design values

Planning documents, standards, design values, and cost-benefit analyses offer opportunities to integrate resilience into all sectors. State agencies, local governments, and other decision-making bodies can work with stakeholders and industry to identify opportunities for incorporating climate science information into plans, standards, designs, and budgeting. Updates could occur in the following areas: incentivizing or requiring low impact development, including for stormwater management; engineering designs for infrastructure; comprehensive land use planning and zoning to protect lives and property from impacts from flooding, erosion, and wildfire; updating building codes for flood, wind, and fire resilience; economic valuing of natural infrastructure; grant selection criteria; and insurance requirements. Examples of design standards and values that must be updated include the "Probable Maximum Precipitation" study and "Intensity, Duration, and Frequency" curves used in design of water management structures and facilities.

3. Increase resilience capacity in state agencies

To become sufficiently resilient to the effects of climate change outlined in the Climate Science Report and the 2020 Resilience Plan, state agencies will need to significantly enhance in-house expertise and incorporate resilience practices throughout each agency.

Agencies would benefit from hiring at least one full-time employee, such as a senior advisor, to focus on climate change mitigation and resilience. This subject-matter expert would coordinate resilience activities and communicate resilience practices across agency divisions. This advisor would coordinate the continued development and implementation of its Agency Resilience Strategy, participate on the Interagency Resilience Team, and support updates to each element of the North Carolina Climate

Resilience Strategy. In addition, the advisor would enable agencies to regularly evaluate their resilience programs to measure performance and build upon past work. Regular training and professional development for state agency employees on resilience will also be beneficial.

4. Identify sustainable funding sources for resilience

Some resilience actions are no-cost or low-cost, but many will require significant investment. For example, ongoing projects in neighboring states like in Norfolk, VA, or Charleston, SC, suggest that major transportation, riverine flood mitigation, or coastal protection efforts could cost millions to billions of dollars and take decades to complete. Today, state and local governments and nonprofits often fund resilience investments through a variety of federal, state, and local sources. These funding sources often target specific types of infrastructure and may not describe resilience as a core objective of the fund. Some funding sources are good fits for one-time projects, while other sources are better suited to sustaining long-term programs. A comprehensive understanding of funding options for building North Carolina's resilience is needed, along with recommendations of novel financing approaches. Research on this topic would explore financing for state, local, tribal, and private resilience efforts in the built environment as well as funding for data and planning. Such research would address the following:

- Analyze existing state and federal programs that currently fund resilience efforts in North Carolina or in other states. For example, state revolving loan funds, FEMA mitigation funds, HUD mitigation funds, and mitigation banking.
- Identify resilience financing best practices and innovative policies in other states and municipalities, such as resilience bonds, public-private partnerships, resilience bank or revolving loan funds, resilience trust funds, revenue streams from excise taxes, and proceeds from cap-and-invest programs that govern greenhouse gas emissions.
- Make recommendations about the most promising funding sources and the steps needed to make more resilience funds more available to state government and local government, state and federally recognized tribes, nonprofits, and the private sector as appropriate.

5. Increase communication, outreach, and engagement on climate change

The state would benefit from agencies using a targeted approach to increase communication and interaction with all communities, especially with socially vulnerable and historically marginalized communities. Resilience-relevant programs should engage new types of partners in their work, such as institutions that are frequent points of contact for socially vulnerable people, e.g., schools, medical clinics, retail outlets, houses of worship, and public transit services.

Community agency and bridging social capital are critical components of resilience. Enhancing capacity and social capital among socially vulnerable communities are equally important goals to building the resilience of infrastructure and the built environment.

Other ways to increase communication and collaboration to address climate change include:

- Improving the accessibility of hazard and climate change data to non-experts through web portals, infographics, classroom education modules, or other communication channels.
- Building a North Carolina research network of scholars and students leading resilience-related work. National networks, such as the American Geophysical Union's Thriving Earth Exchange or

the Science to Climate Action Network, can serve as models. This network could leverage the model of the North Carolina Policy collaboratory or ongoing efforts of the Office of State Budget and Management to link researchers in the state to state agency research agendas.

- Providing resources for community and K-12 education on climate change and resiliency.

G. Conclusion

The path forward to greater climate resiliency relies on moving beyond assessment into action. The principles, plans, initiatives, and strategies set forth in this chapter outline a process for North Carolina to become more resilient to the impacts of climate change, even as we work to limit the magnitude of that change by reducing GHG emissions and transitioning to clean energy.

Supporting this ambitious path will require staff and funding. The ongoing process explained in this chapter acknowledges that everyone must commit to action – from state agencies to local and tribal governments, businesses to community stakeholders. It recognizes that building resilience requires supporting collaboration on developing solutions to North Carolina's most challenging climate resilience problems. Because climate-related initiatives touch everyone, including all business sectors, the public, and federal, state, and local agencies in different ways, statewide planning efforts can become overwhelmed with extensive analysis, writing, and meetings. There will be a need to keep this structure and process as simplified, streamlined, and nimble as possible in order to remain effective, while balancing the need for inclusiveness, thoughtfulness, and due diligence in prioritizing significant state investments in resilience initiatives. With adequate funding, the process proposed here for updating the North Carolina Resilience Strategy achieves this balance by ensuring state agencies are collaboratively planning to adapt to climate change. Quantitative and qualitative studies will help agencies, local and tribal governments, and stakeholders base resilience efforts on the best available science and practices. Providing adequate time and support in each Plan element for broad and sustained engagement will ensure that resilience priorities and actions are implemented equitably and meaningfully across North Carolina.

Designating clear leadership and communication structures is important to building climate resilience successfully. This chapter identifies NCORR as the lead to present, promote, coordinate, and manage efforts as described in this plan to prioritize and implement resilience activities in North Carolina. The Interagency Resilience Team will assist NCORR as necessary to carry out these duties. This structure will ensure that even as state agencies continue their own strategies to build resilience to climate impacts, North Carolina has the ability to coordinate and leverage efforts within and across agencies and sectors.

By setting clear goals, taking action, and evaluating progress on a regular basis, North Carolina can ensure that our resilient state thrives amid changing conditions and challenges. This shared vision of resilience will enable us to maintain and improve our quality of life, healthy growth, and durable systems and to conserve resources for present and future generations. The state of North Carolina will lead by example through its own agency actions and will support everyone in the state as we work together toward our shared vision of a more resilient North Carolina.

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