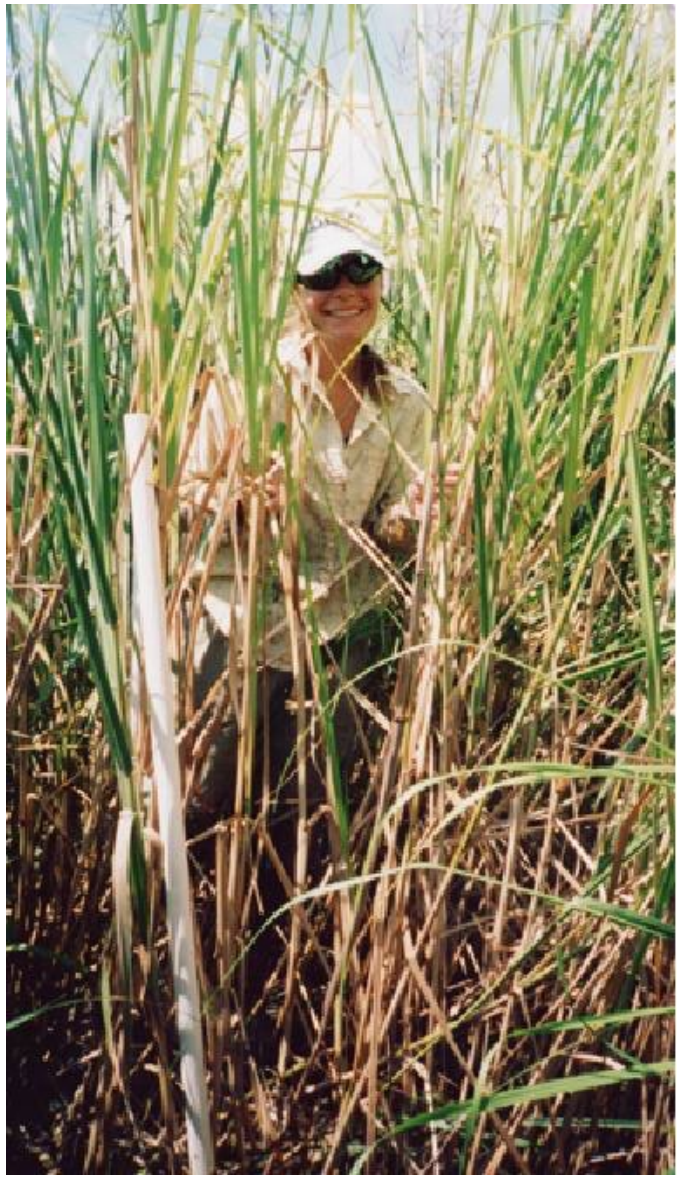
Water-Smart Futures: Resilience in a Rapidly Changing Climate

Susan White
Director
NC Water Resources Research Institute, NC Sea Grant,
NC Space Grant



State and National Partners

The Water Resources Research Institute of the UNC System

- Plan, conduct, and facilitate research
- Support students, early career research scientists, engineers, and technicians.
- Disseminate research results.
- Collaborate with other colleges and universities to solve state and regional water problems.

Urban Water Consortium & Stormwater Consortium

https://wrri.ncsu.edu/

North Carolina Sea Grant

- Conduct and fund research to support the environmental and economic health of our state's coasts, watersheds, and communities.

- Engage and support the state's coastal and watershed communities needs through extension expertise.

- Develop the next generation of educated, innovative, and technologically advanced students and professionals.

https://ncseagrant.ncsu.edu/

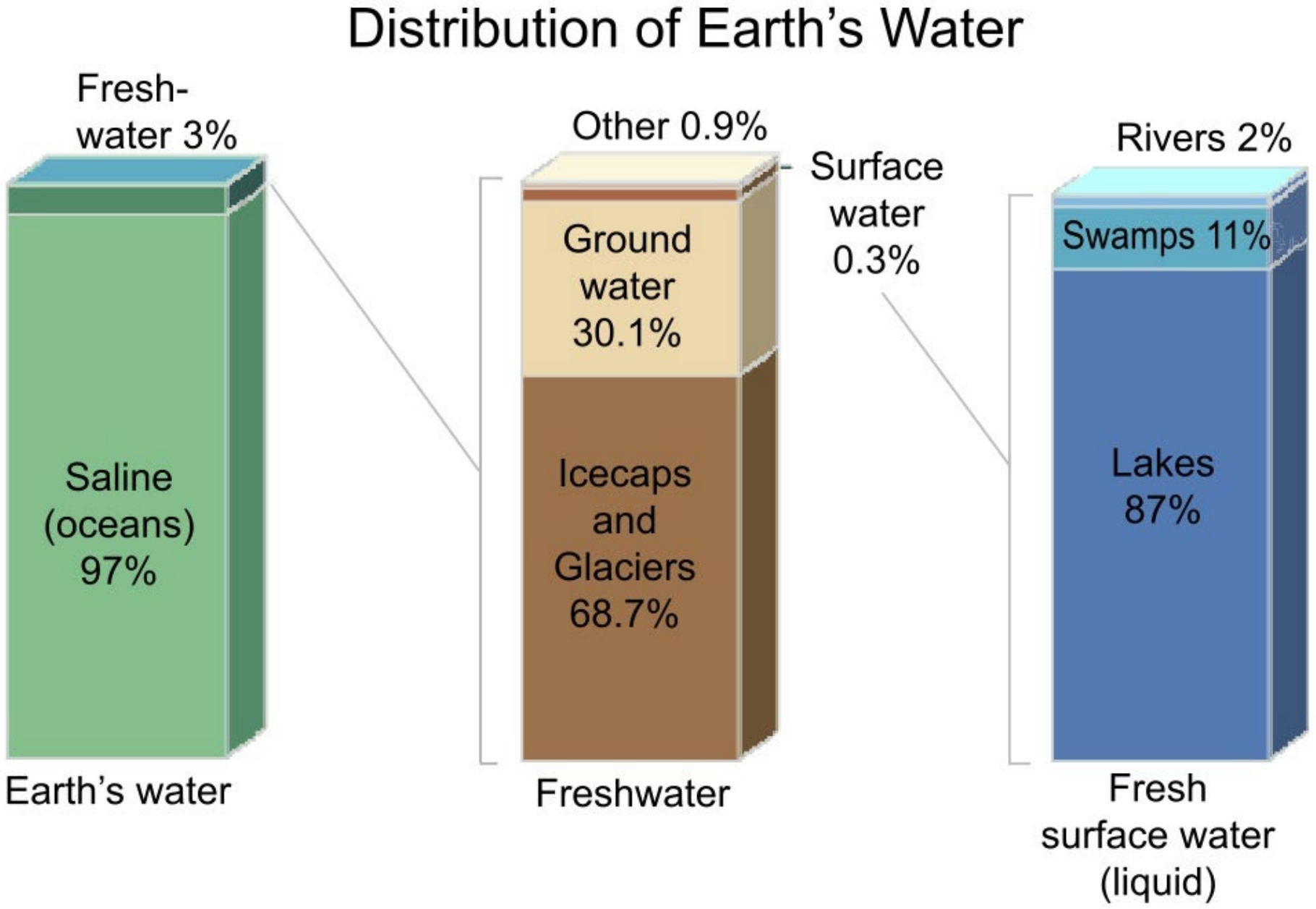
What Are Our Main Areas of Focus?

Sea Grant
North Carolina

- Resilient Communities and Economies
- Healthy Coastal Ecosystems
- Sustainable Fisheries and Aquaculture
- Environmental Literacy and Workforce Development

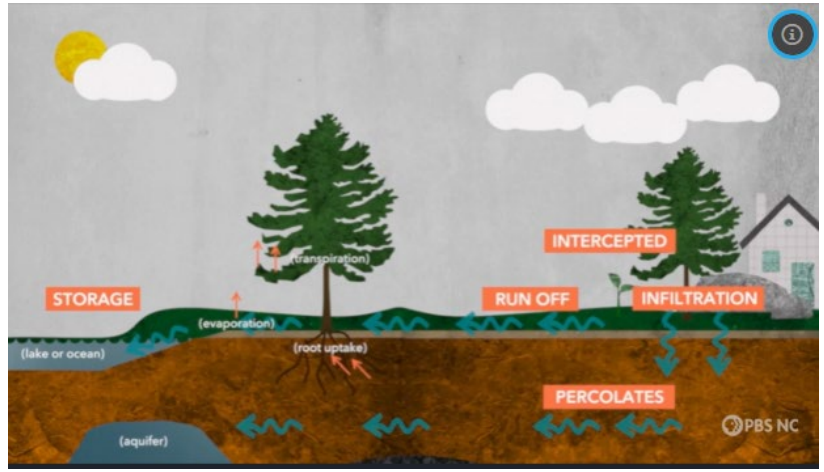
wrri
NC WATER RESOURCES RESEARCH INSTITUTE

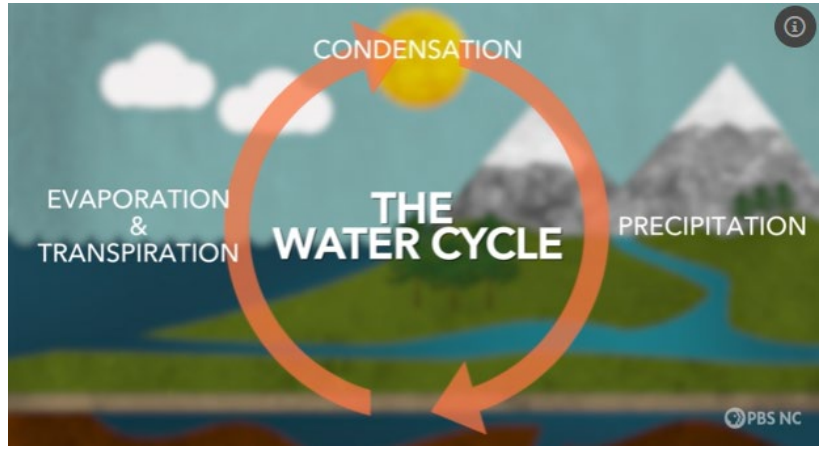
- Stormwater Management
- Drinking Water
- Wastewater and Water Infrastructure
- Groundwater and Surface Water
- Watershed Management



Gleick, P. 1993. Water in Crises; A Guide to the World's Fresh Water Resources


PBS NC


INTERCEPTED
(transpiration)
STORAGE
(evaporation)
RUN OFF
INFILTRATION
(lake or ocean)
(root uptake)
PERCOLATES
(aquifer)
PBS NC


CONDENSATION
EVAPORATION
&
TRANSPIRATION
THE
WATER CYCLE
PRECIPITATION
PBS NC

PBS NC 2022


URBAN
WATER CYCLE


USE
STORE
COLLECT
TREAT
TREAT
DISTRIBUTE
CITY WATER
(storm runoff)
WASTE WATER
DISCHARGED
PBS NC

PBS NC 2022

Complex Systems!

Nonpoint Sources Typically Discharge **Indirectly** to Waterways:

- Agriculture
- Hydromodification
- Urban Runoff
- Roads, Highways and Bridges
- Abandoned Mine Drainage
- Atmospheric Deposition
- Marinas and Boating
- Timber Harvest
- Septic System

Point Sources Typically Discharge **Directly** to Waterways:

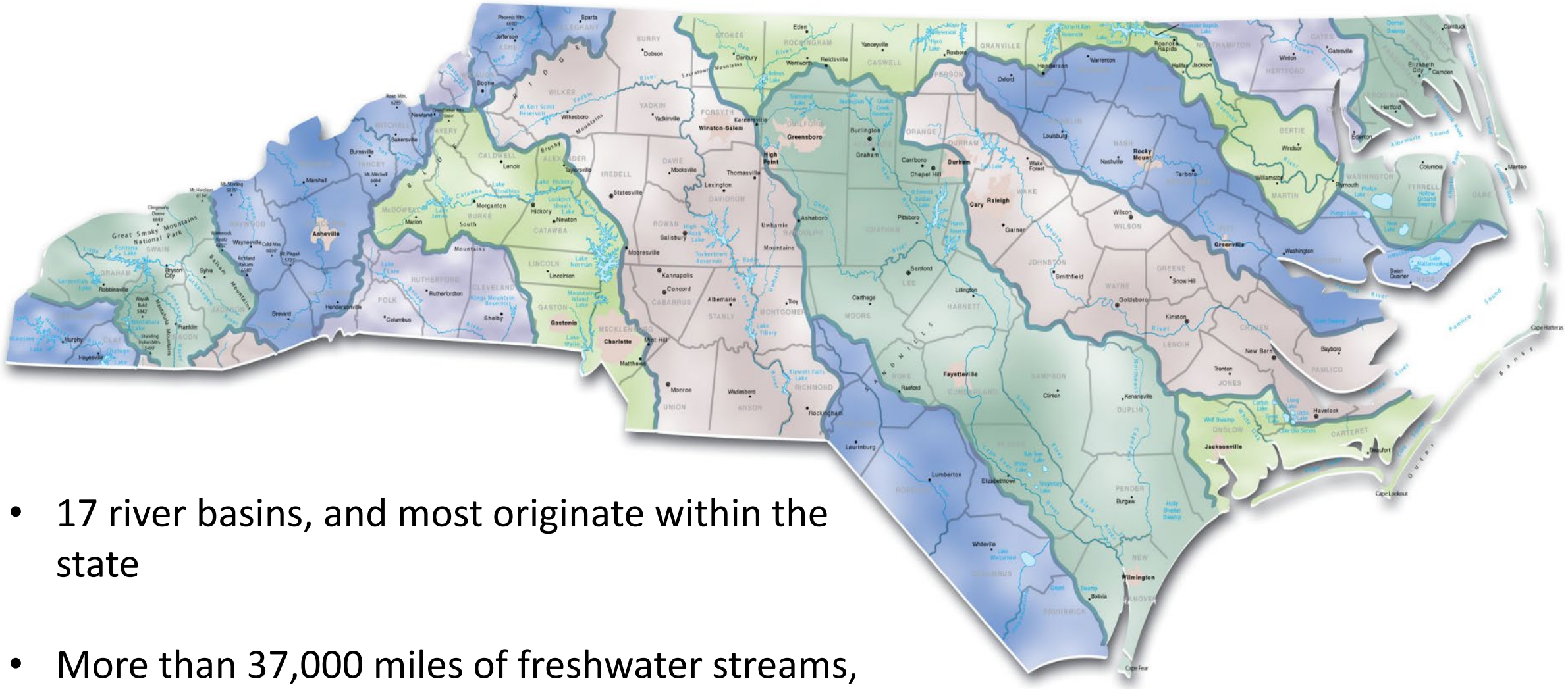
- Factory
- Wastewater Treatment Plant
- Stormwater Discharge

Hydrologic Cycle:

- Overland Flow
- Infiltration
- Groundwater Flow
- Transpiration
- Evaporation
- Rainfall
- Aquifer

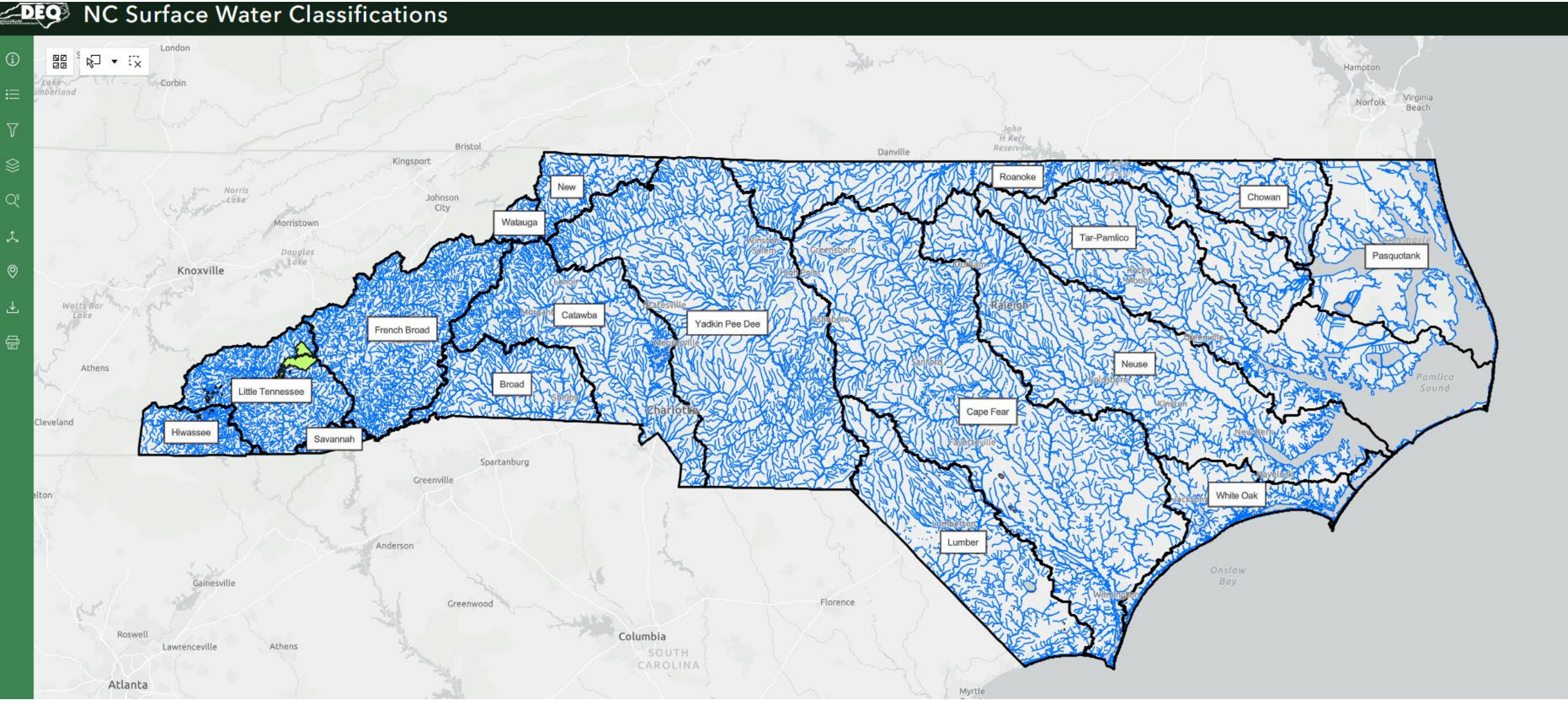
US Environmental Protection Agency (EPA), 2026

North Carolina's River Basins

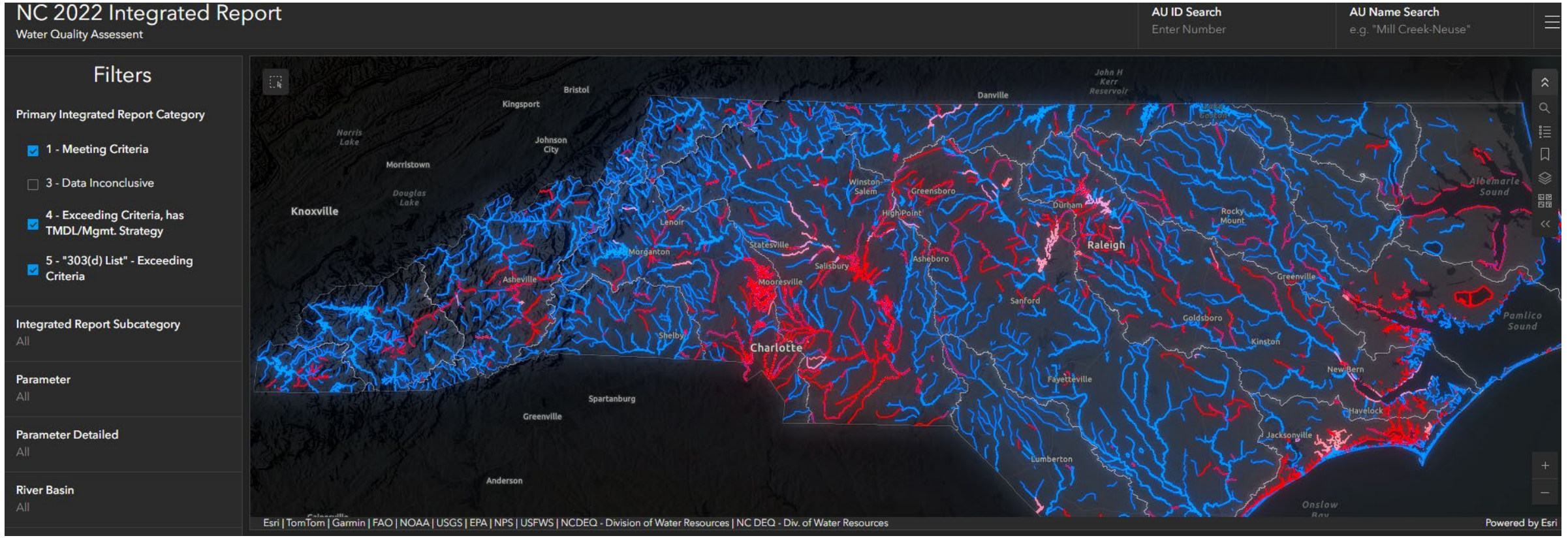


- 17 river basins, and most originate within the state
- More than 37,000 miles of freshwater streams, more than 1,500 lakes and reservoirs of 10 acres or larger

North Carolina's Streams

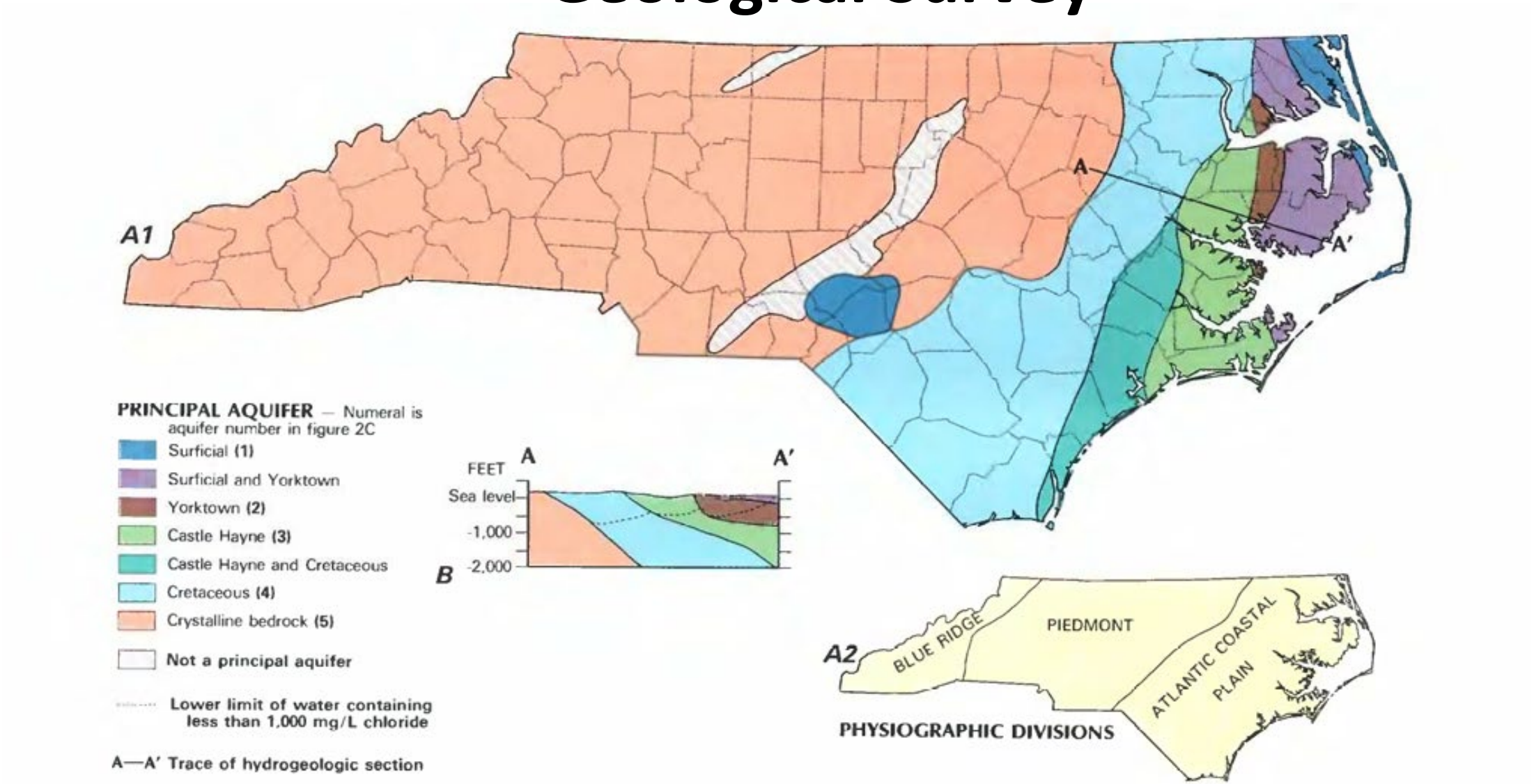


North Carolina's 2022 Water Quality Assessment Report

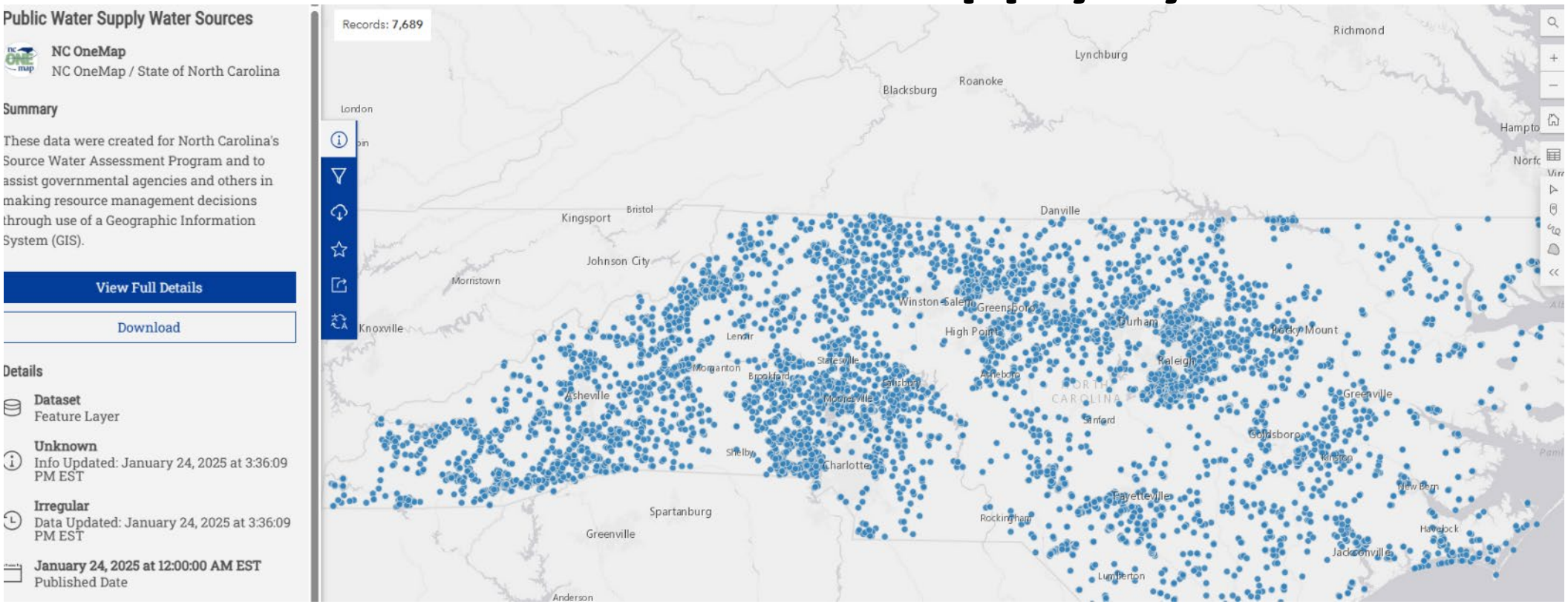


Blue: Meeting Criteria Red: Exceeding Criteria

Principal aquifers in North Carolina, US Geological Survey



North Carolina Public Water Supply System Sources



- ~ 6,000 public water systems, serving ~9.3 million customers (80%), using both surface and groundwater.

- ~ 1 in 4 residents rely on private wells for drinking water, ~2.4 million residents (20%). One of the highest number of private wells in the nation.

NC State University Institute for Emerging Issues

2026 Emerging Issues Forum: Future Forward Water Strategies for Strengthening Our Water Infrastructure

- Promote Economically Viable Water Systems
- Support Private Wells and Septic Systems
- Improve Planning, Land Use and Water Infrastructure
- Improve Water Policymaking
- Promote Workforce Development
- Take Advantage of Economic Development Opportunities

Additional excellent resource: UNC-Chapel Hill's Environmental Finance Center (https://efc.sog.unc.edu/) supports local governments in providing financially sustainable water, wastewater, and stormwater utilities.

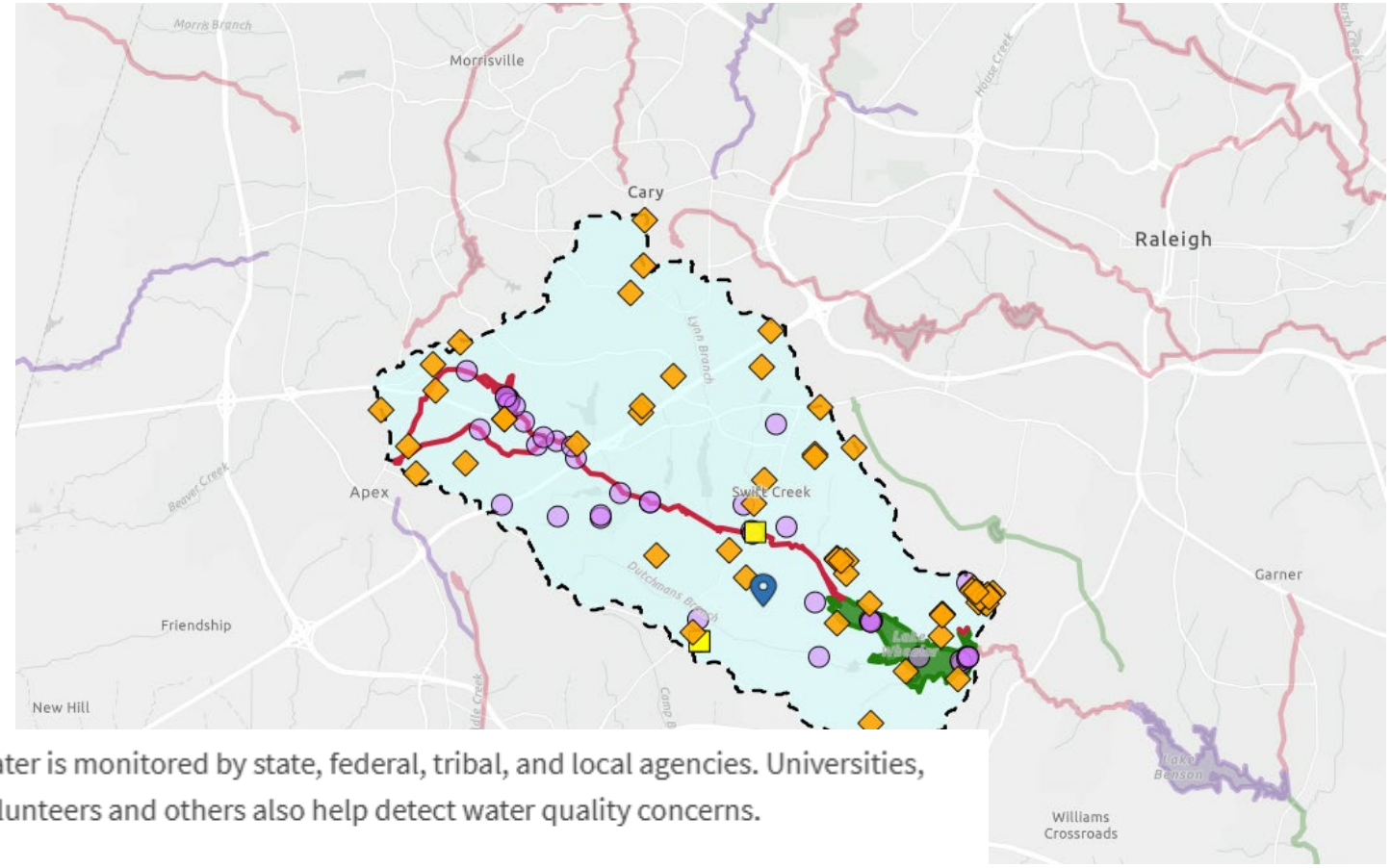
What's your ecological address?

River Runner https://river-runner.samlearner.com/

What's your ecological address?

EPA's How's My Waterway

https://www.epa.gov/waterdata/hows-my-waterway



FIFTH NATIONAL CLIMATE ASSESSMENT

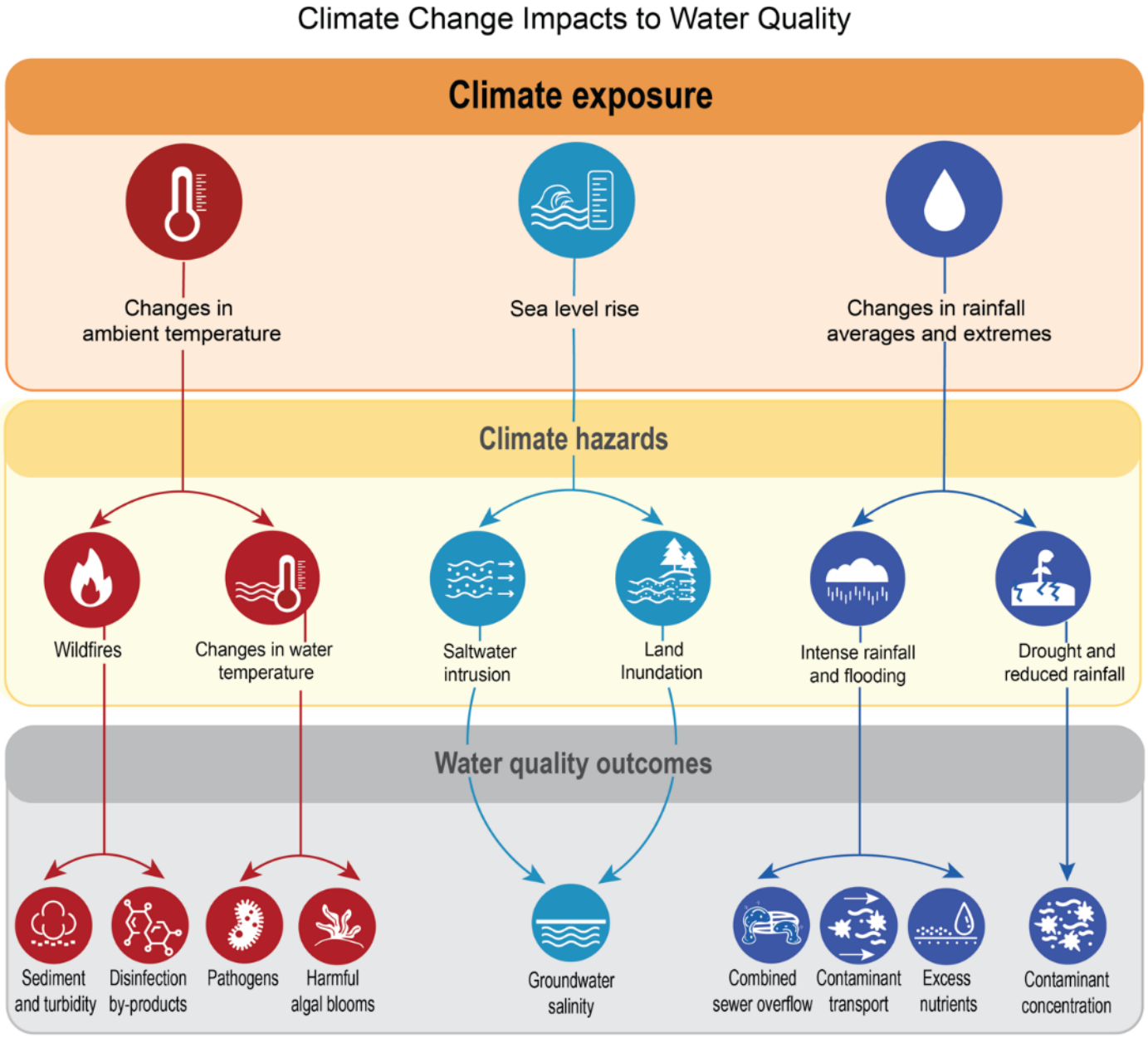
Chapter 4 | Water

Chapter 18 | Sector Interactions, Multiple Stressors, and Complex Systems

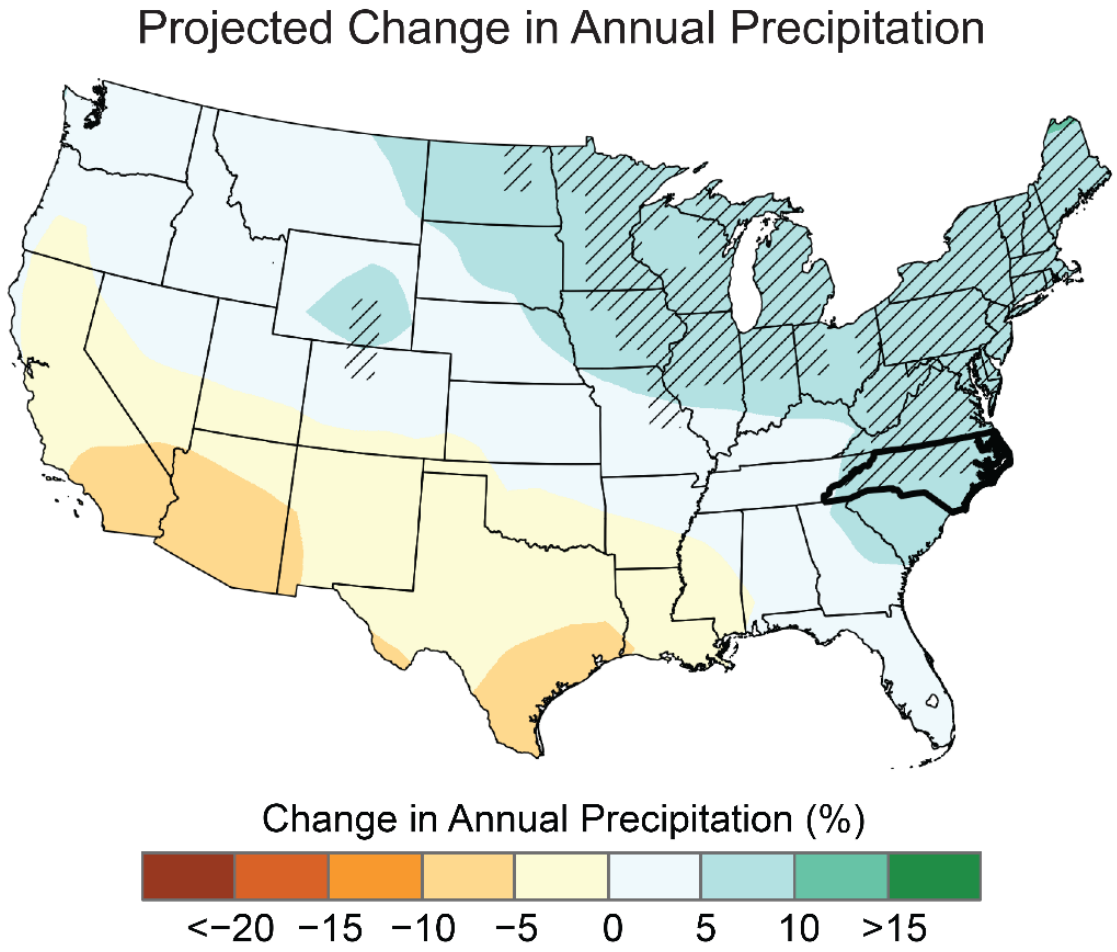
Chapter 22 | Southeast

Fifth National Climate Assessment (2023)

- Climate Change Will Continue to Cause Profound Changes in the Water Cycle
- Water Cycle Changes Will Affect All Communities, with Disproportionate Impacts for Some
- Progress Toward Adaptation Has Been Uneven



North Carolina Climate Science Report (2020)



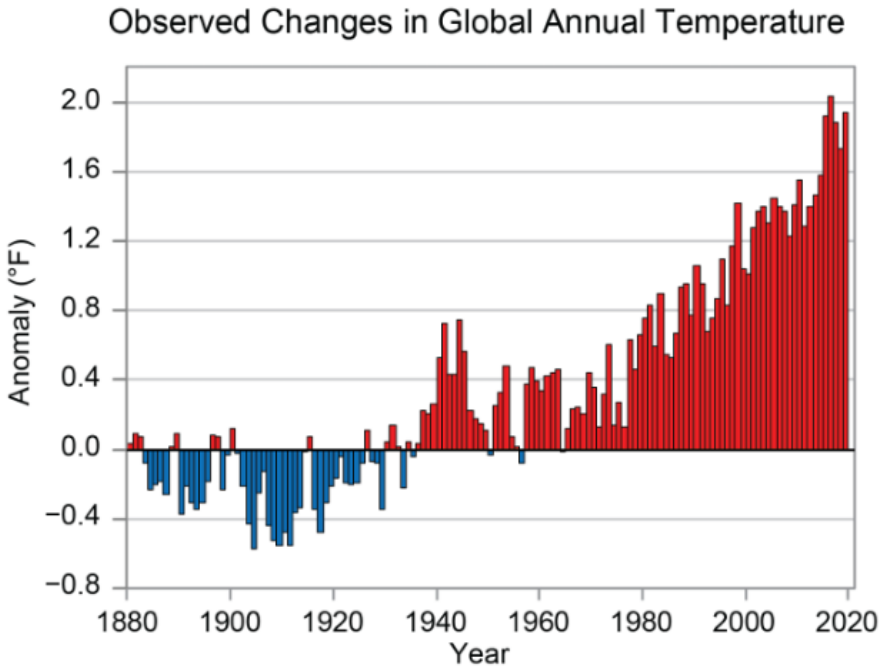
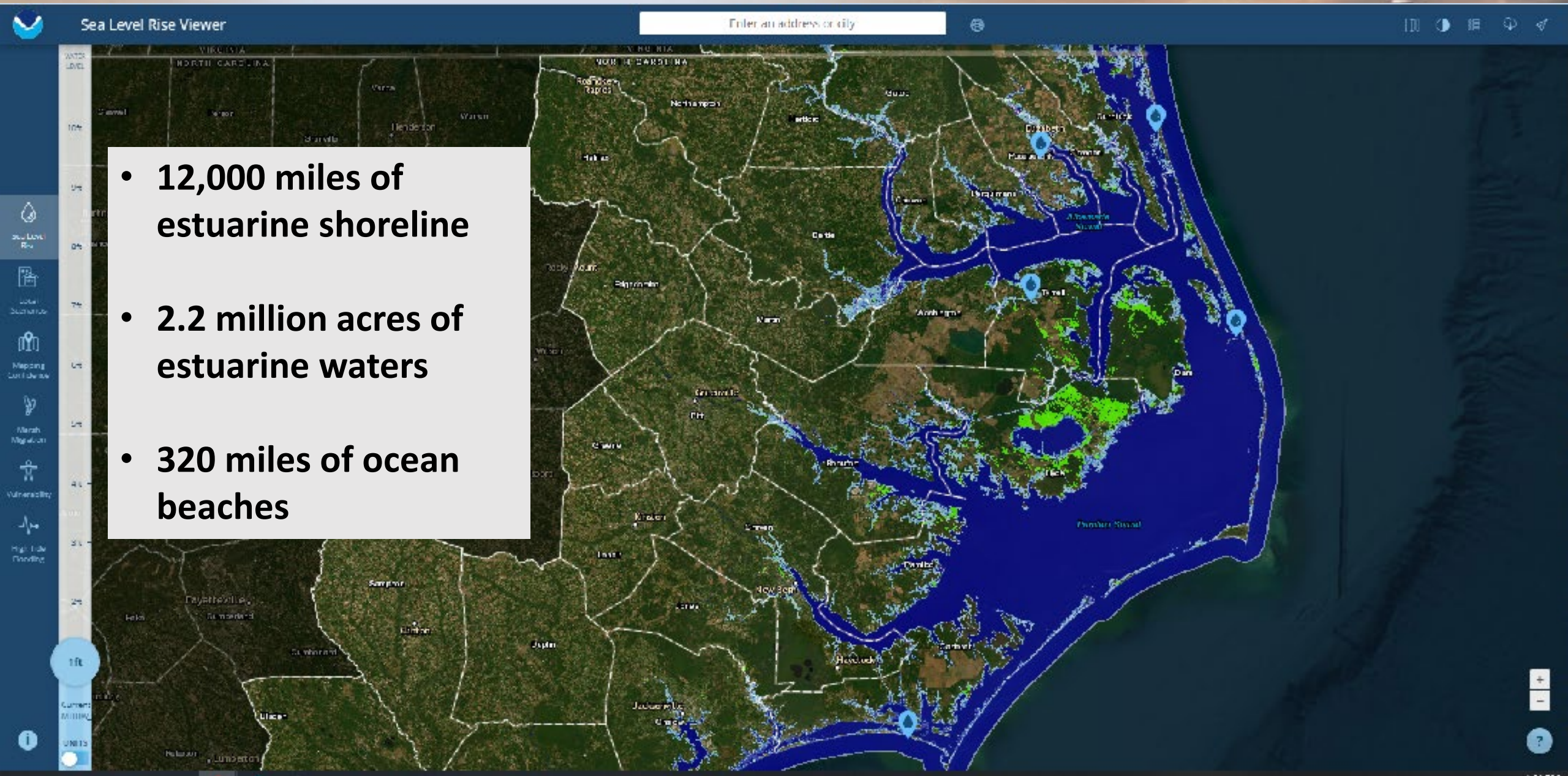


Figure 1.1. The graph shows the global annual average surface (land and ocean) temperature for 1880–2019, shown as differences from the 1901–1960 average. Temperatures vary from year to year throughout the record, but with a warming trend from around 1900 through the 1940s, relatively stable temperatures through the mid-1970s, and then a strong warming trend since the late 1970s. Temperatures have been more than 1.6°F above the long-term average in each of the last five years. Source: adapted from NCEI 2019.

NOAA National Centers for Environmental Information (NCEI)

NOAA Sea Level Rise Viewer – 1 Foot Scenario



- 12,000 miles of estuarine shoreline
- 2.2 million acres of estuarine waters
- 320 miles of ocean beaches

North Carolina Drought Update

Created By: North Carolina Drought Management Advisory Council — www.ncdrought.org

North Carolina CLIMATE OFFICE — climate.ncsu.edu — @NCSCO

NC STATE

For the assessment period ending **Apr. 7, 2026**

*From the US Drought Monitor, with input from the **NC DMAC***

The Main Takeaway

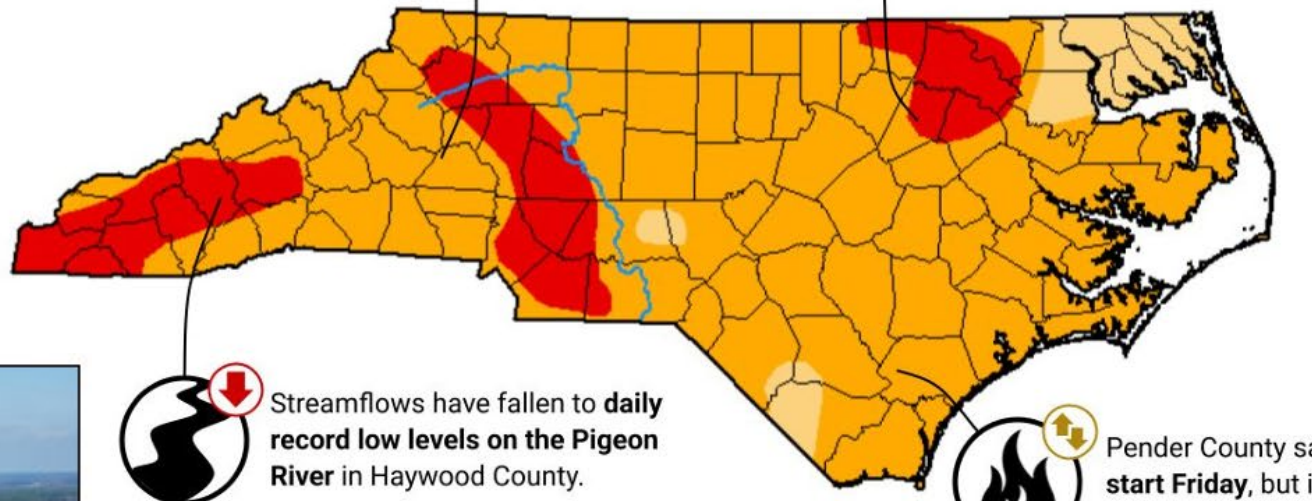
Severe (D2) and Extreme (D3) Drought has expanded in parts of the state, including into Asheville, across the upper Yadkin Valley, and in the northern Coastal Plain.

This Week's Summary

Showers along last Sunday's cold frontal passage were generally light, except in a few parts of the Mountains

Hickory is off to its 3rd-driest start to a year on record, with just 53% of its normal precipitation.

The town of Nashville is requesting voluntary water conservation, including by limiting lawn watering to early morning and evening hours.

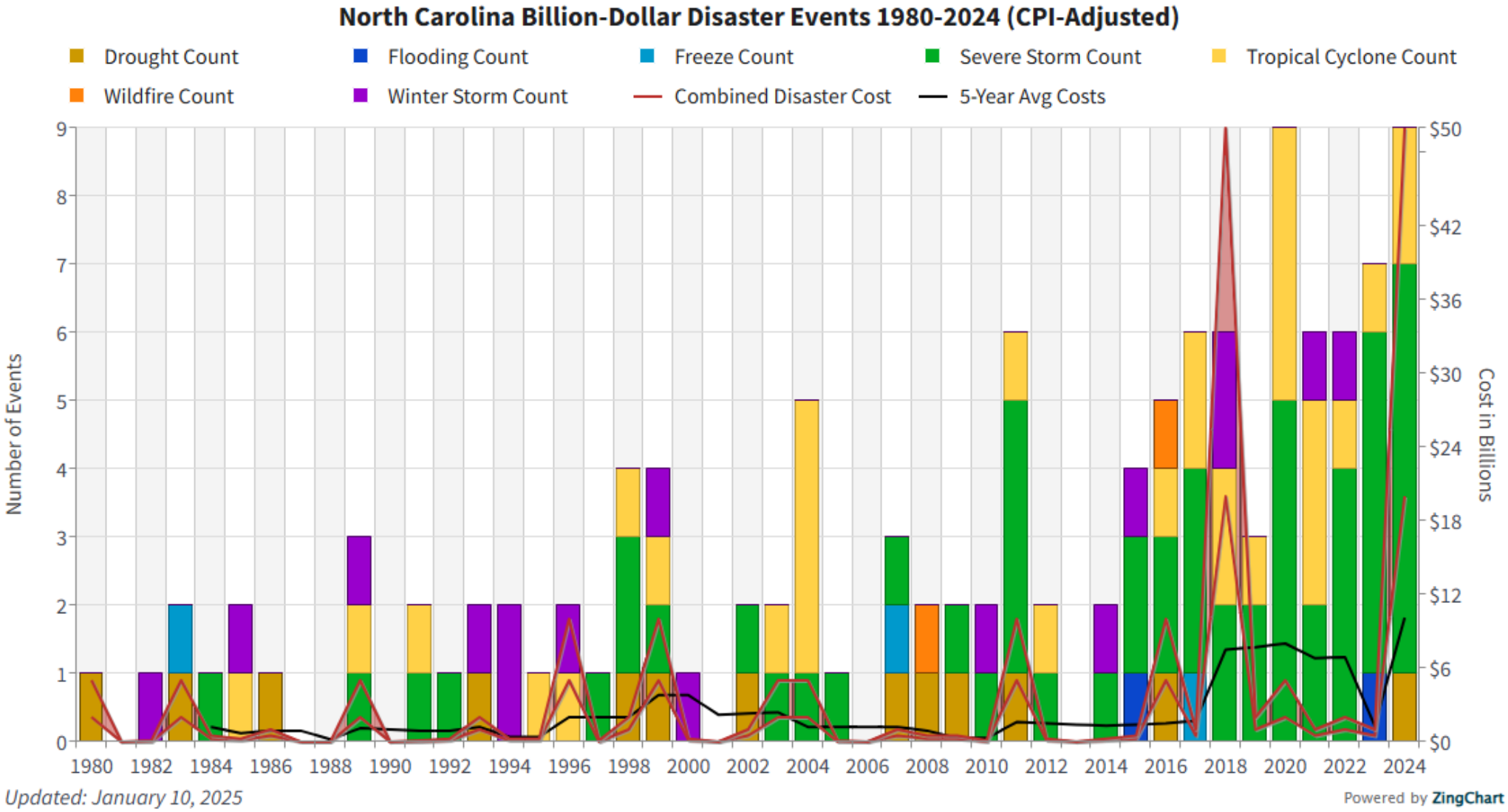


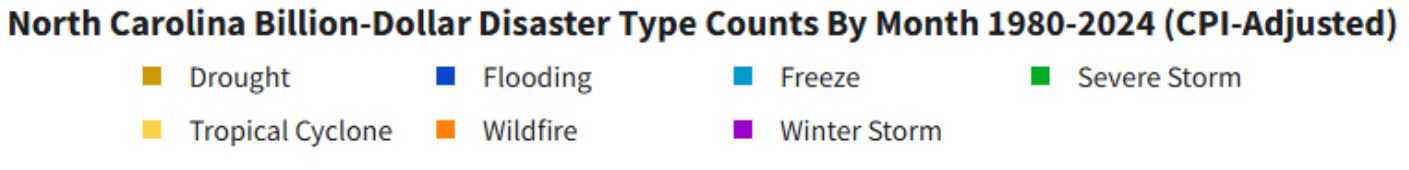
Streamflows have fallen to **daily record low levels on the Pigeon River** in Haywood County.

Pender County saw a **147-acre wildfire start Friday**, but it was contained with help from **an inch of rain on Sunday**.

Falls Lake, in central North Carolina, during 2008 drought.

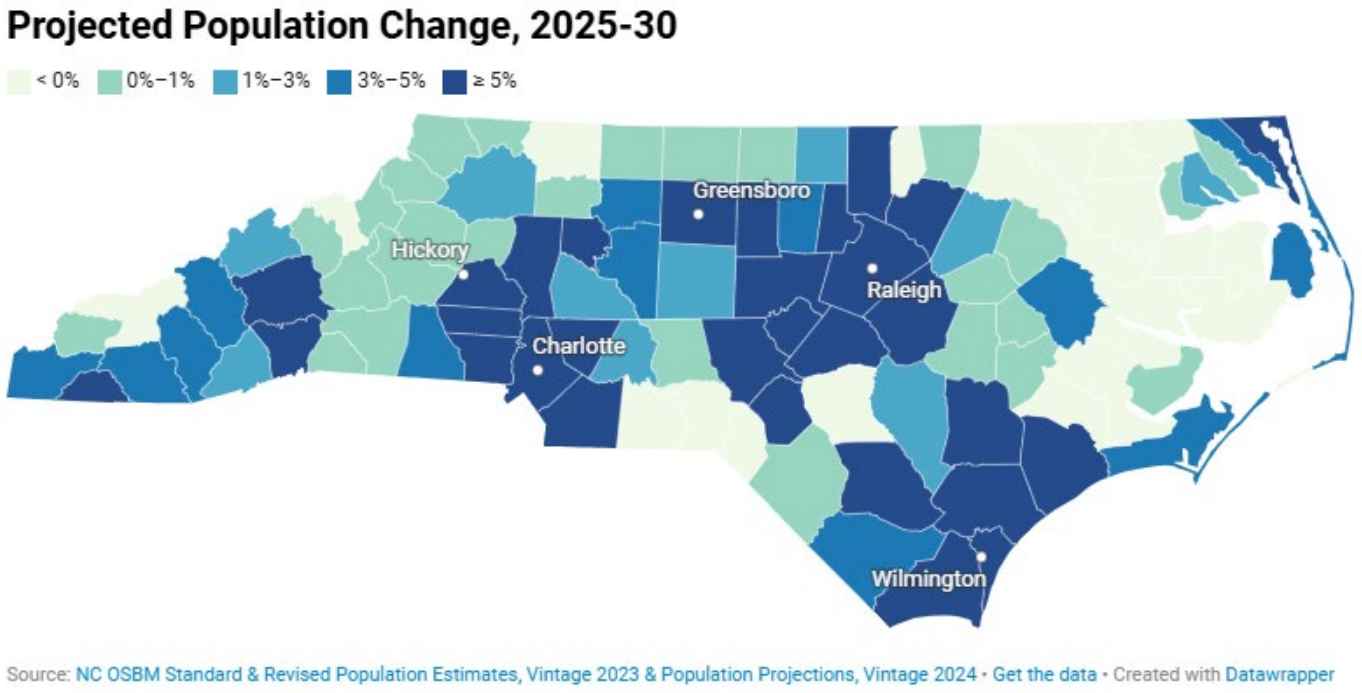
Jordan Lake, 2007

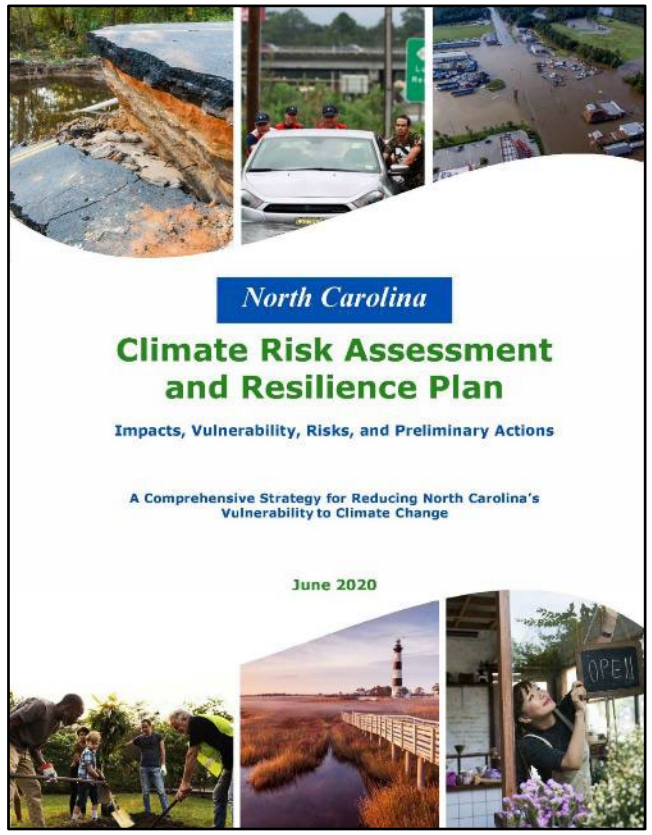




National Centers for Environmental Information (NCEI)

North Carolina's Projected Population Change (2025-2030)





- There are now over 11 million people living in North Carolina, projected growth is uneven.
- Projected population of 14.5 million by 2050.

Resources: NC Office of State Budget and Management, U.S. Census Bureau; Carolina Demography; NC Rural Center

Water For All- Water Users	
Category	**Impact of climate change**
Energy	Increased drought can lead to decreased stream flow for hydroelectric dams. Increased temperatures require more energy for air conditioning.
Fish & wildlife	Rising temperature and changing habitats threaten species' survival and/or change species' range.
Industry	More demand means less water available for industrial use, or at a higher cost.
Municipal/water authority	Increased demand means less water available per person. Water quality may also be affected by extreme weather events.
Agriculture	Drought, floods will affect crop yields.
Frontline community	Extreme rain events can flood homes and streets in low-lying areas, risking safety and damaging homes. Increased drinking water costs can be unaffordable.
Recreation	Decreased water quality in streams, rivers, lakes, oceans limits people’s uses such as wading, fishing and swimming.
Transportation	Flooded or damaged roads reduce ability to travel. Costs for maintaining/rebuilding damaged infrastructure will increase.

Community Collaborative Research Grant Program

- Support coastal challenges and statewide water resource issues through a collaborative research approach that requires integration of local ecological knowledge.

- Members of the public have local knowledge of their own communities and environments, they sometimes do not have the scientific, technical, or policy expertise to craft science-based solutions.

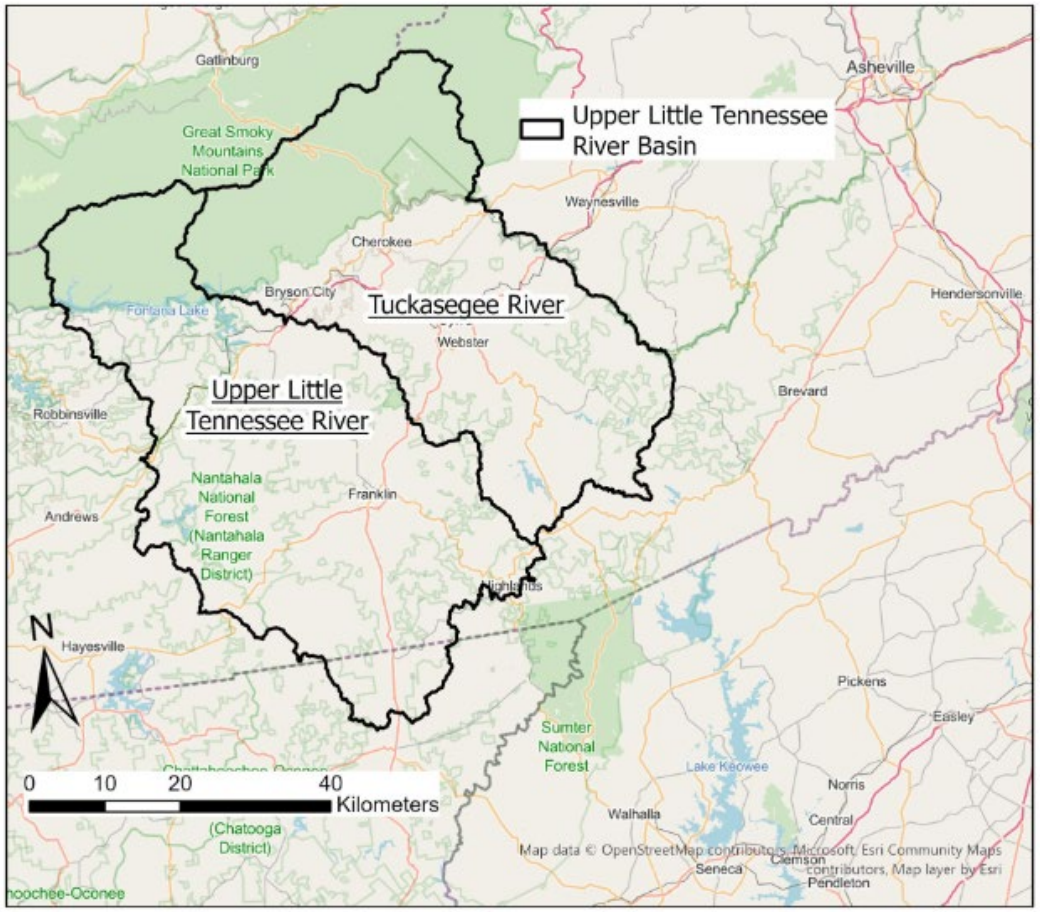
- Scientific experts are knowledgeable about scientific principles and potential solutions required to mitigate problems, but often lack the social and historical perspective that will aid in crafting solutions to meet the expectations of community members.

Sea Grant North Carolina

KENAN INSTITUTE
ENGINEERING, TECHNOLOGY & SCIENCE
NC STATE UNIVERSITY

WRRI

Subwatershed Health in the Upper Little Tennessee River Basin



A map of the Upper Little Tennessee River basin with neighboring towns, cities and states.

Goals:

- Improving water quality and aquatic ecosystem health.
- Supporting targeted protection and restoration priorities in the watershed.
- Land and resource management applications.
- Undergraduate research opportunities.

Partnerships: Eastern Band of Cherokee Indians, Little Tennessee Native Fish Conservation Partnership, Mainspring Conservation Landtrust, NC Wildlife Resources Commission, Tennessee Valley Authority

From the Mountains to the Sea: Researchers and Community Activists Focus on Plastic Pollution

Students help Jerry Miller pick up trash from a creek as part of the CCRG project. Photo credit: Western Carolina University.

Goals:

- Measuring microplastics in headwater basins in the Appalachian mountains, freshwater streams.
- Lack of data for freshwater systems, impacts on water quality and ecosystem
- Undergraduate research experiences.

Partnerships: Highlands Biological Reserve, Haywood Waterways Association, Mainspring Conservation Trust, MountainTrue, Virginia Tech, Tuscola High School

Western Carolina University

Flowing to the Sea…Connecting Citizen Science and Youth Action

East Carteret High School students participate in a community event to decorate storm drains.

Goals:

- Educate students and community members about the challenges of polluted stormwater in coastal ecosystems.
- Foster environmental literacy in the next generation of researchers and activists.
- Connecting students, community members, and scientists through art, “Adopt-A-Drain: Only Rain Down the Drain”.

Partnerships: Duke University Marine Lab, Coastal Carolina Riverwatch, East Carteret High School, local elected officials.

DUKE.

Charlotte Neighborhoods Recognize Their Waters and Their Voices, “Our Voice, Our Water”

Above: Ryan Bowen, Crystal Alford and Yvonne Adams participate in a stormwater cleanup and storm drain labeling event organized by Our Voice, Our Water in Historic Washington Heights in Charlotte, North Carolina.

Johnson C. Smith University

Goals:

- Understand behaviors and knowledge of stormwater issues with community citizens.
- Understand concerns and followup actions by Charlotte Mecklenburg through call center data.
- Increased community stream and residential cleanups.
- Build trust and understanding with neighborhood leaders and citizens through education and outreach.

Partnerships: Johnson C. Smith University, Lincoln Heights Neighborhood Association, Washington Heights, Northwood Estates, Regional Stormwater Partnership of the Carolinas, Rising Solutions, Making Charlotte Beautiful, NC AmeriCorps, WRRI Stormwater Consortium

Improving Hybrid Watershed Modeling: Falls Lake & Jordan Lake watershed management

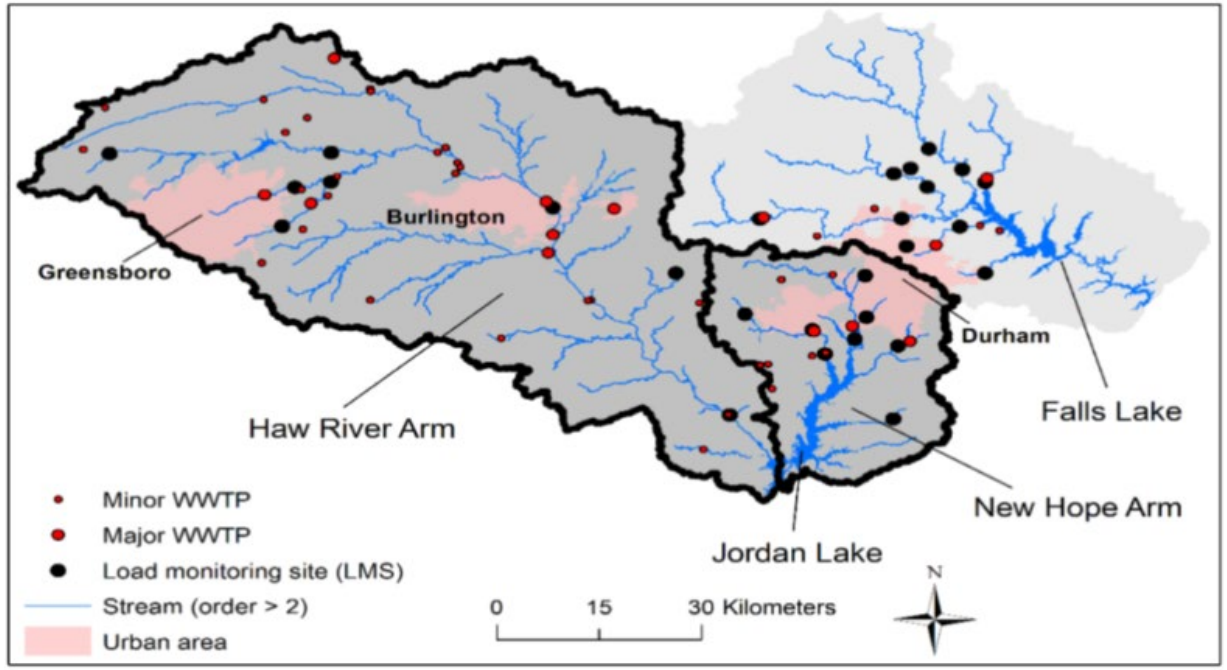


Figure 2.1: Jordan and Falls Lake watersheds. Jordan Lake is further split between the Haw River and New Hope creek watersheds. Nutrient load monitoring sites (LMSs), used to collect nutrient data for calibrating the model, and major and minor wastewater treatment plants (WWTPs) are also shown. Shading represents the entire Jordan and Falls Lake watersheds. Map courtesy of Daniel Obenour.

Goals:

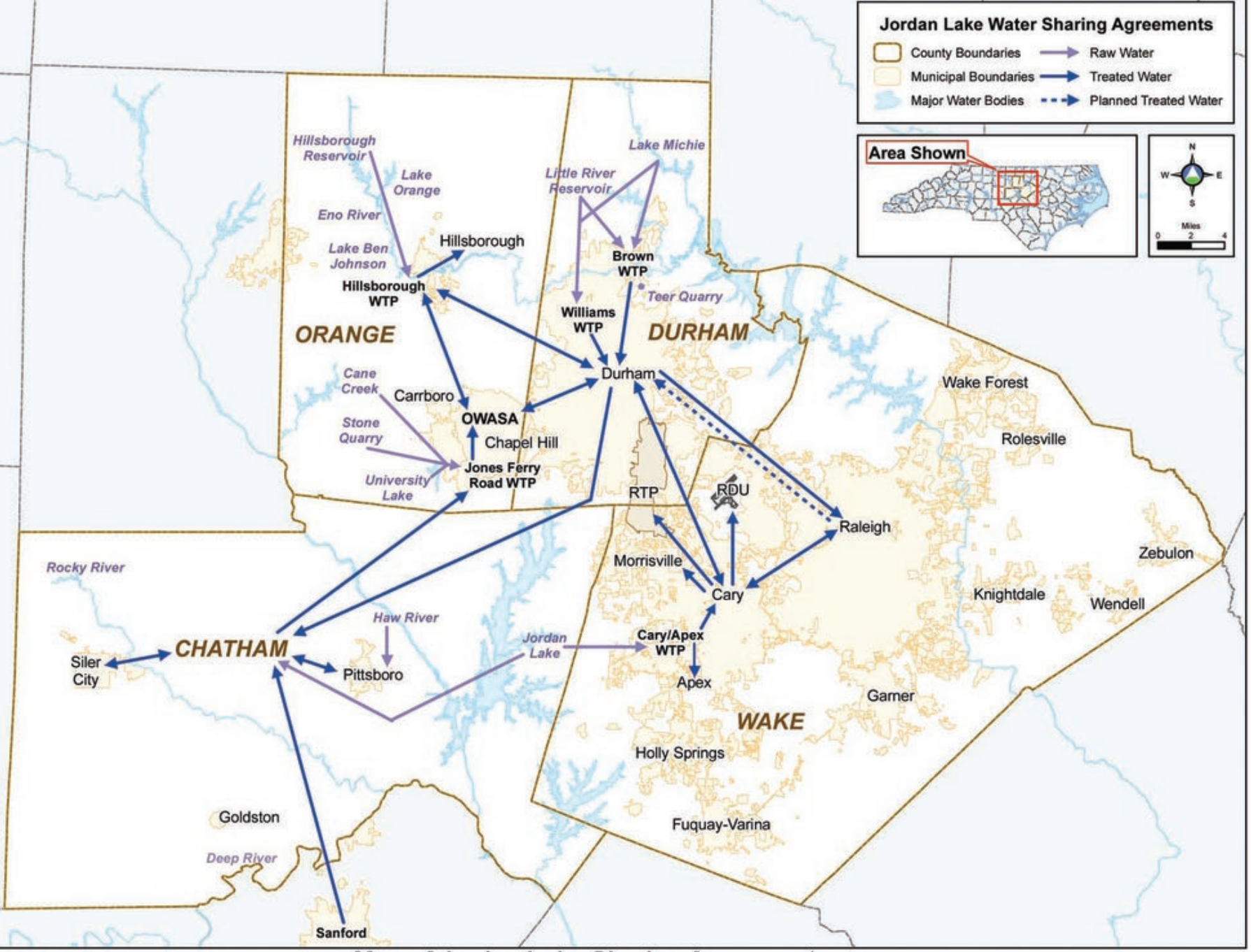
- Combining statistical and mechanistic models-merging estimations of future behavior based on past behavior with system changes from one state to the next on biological and physical processes!!

- Utility for future management scenarios, such as increased urban development or how watershed management approaches (e.g. stream buffers) can influence future nutrient nitrogen and phosphorus inputs.

Partnerships: Jordan Lake One Water, NC Department of Environmental Quality/Division of Water Resources

NC STATE UNIVERSITY

The University of North Carolina at Chapel Hill



Map of Jordan Lake Sharing Agreements

Jordan Lake Water Sharing Agreements

Cary, Apex, Chatham Co., Durham, Holly Springs, Morrisville, Orange Co., Orange Co. Water and Sewer Authority, Wake Co.-RTP South!

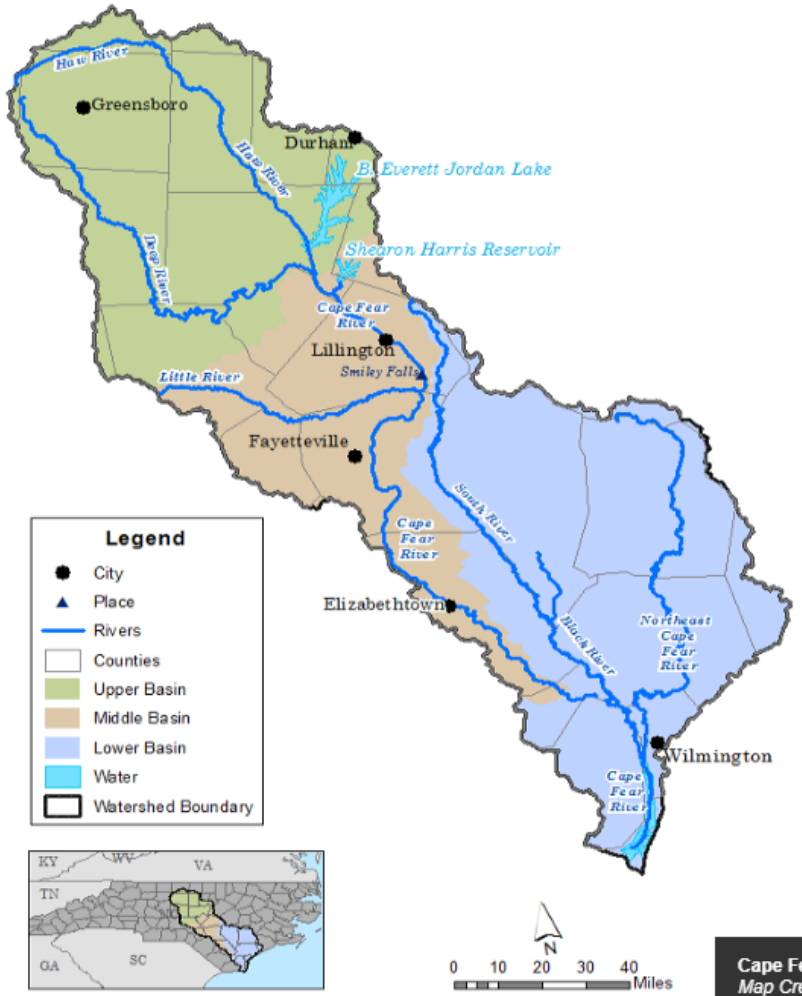
Raleigh's Walnut Creek Wetland Community Partnership

Goals:

- Engaging community in selecting, designing, and implementing park projects that meet multiple needs for nature and people.
- Implementing green infrastructure, stream restoration, art installations, accessibility options for park and surrounding neighborhoods.

Partners for Environmental Justice, NC State College of Natural Resources, College of Design, City of Raleigh, St. Ambrose Church, Neighborhood Ecology Corps, WRRI and many others.

“Soul of the Soil”



Cape Fear River Watershed Map
Map Credit: NOAA

Goals:

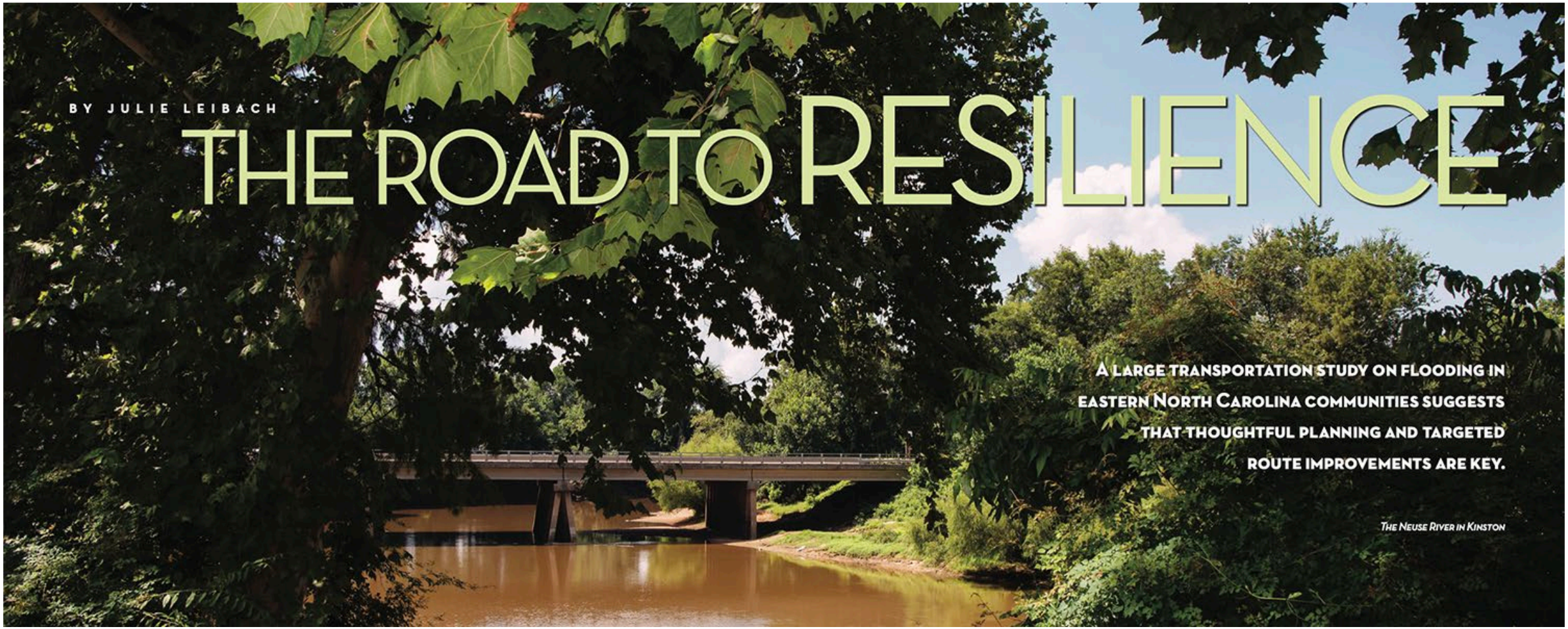
- Listening sessions.
- Assess soil contamination.
- Provide data for expanded state water testing for PFAS into Columbus County tribal grounds.

Partnerships: Waccamaw Siouan STEM Studio, Cape Fear River Association, University of North Carolina Wilmington

Credit: Ashley Lomboy

UNCW

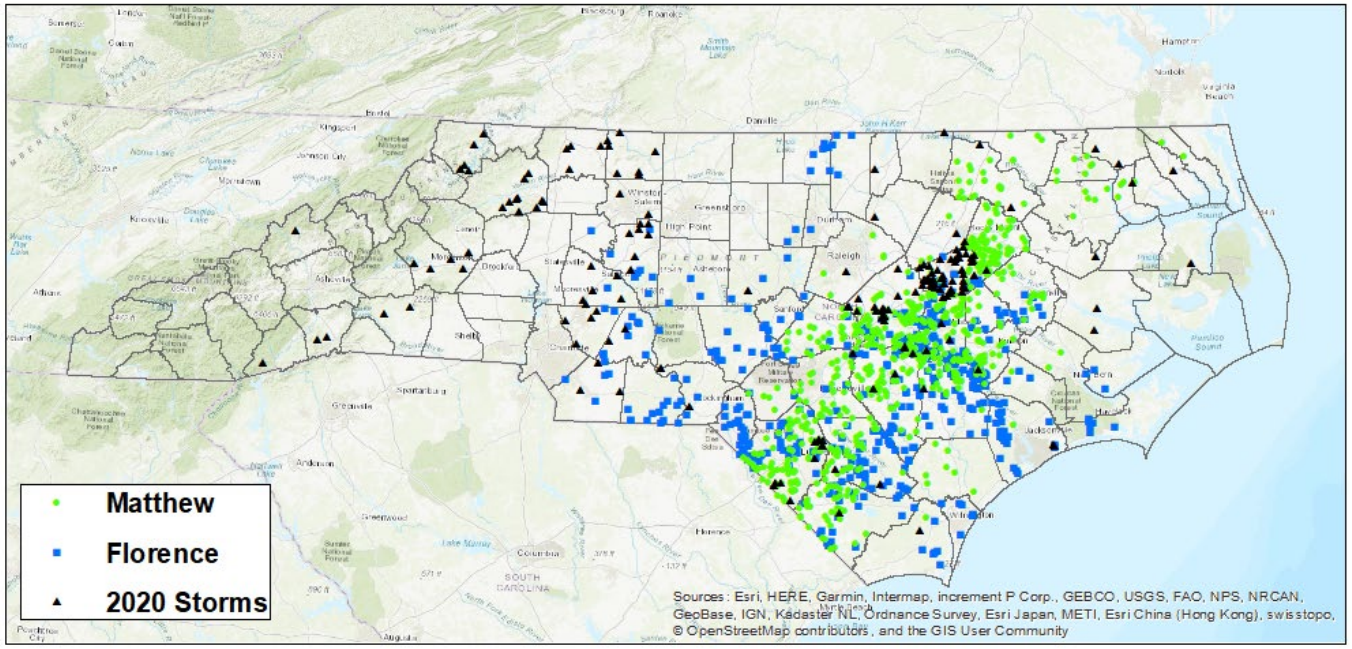
Resilient Transportation Routes & Infrastructure

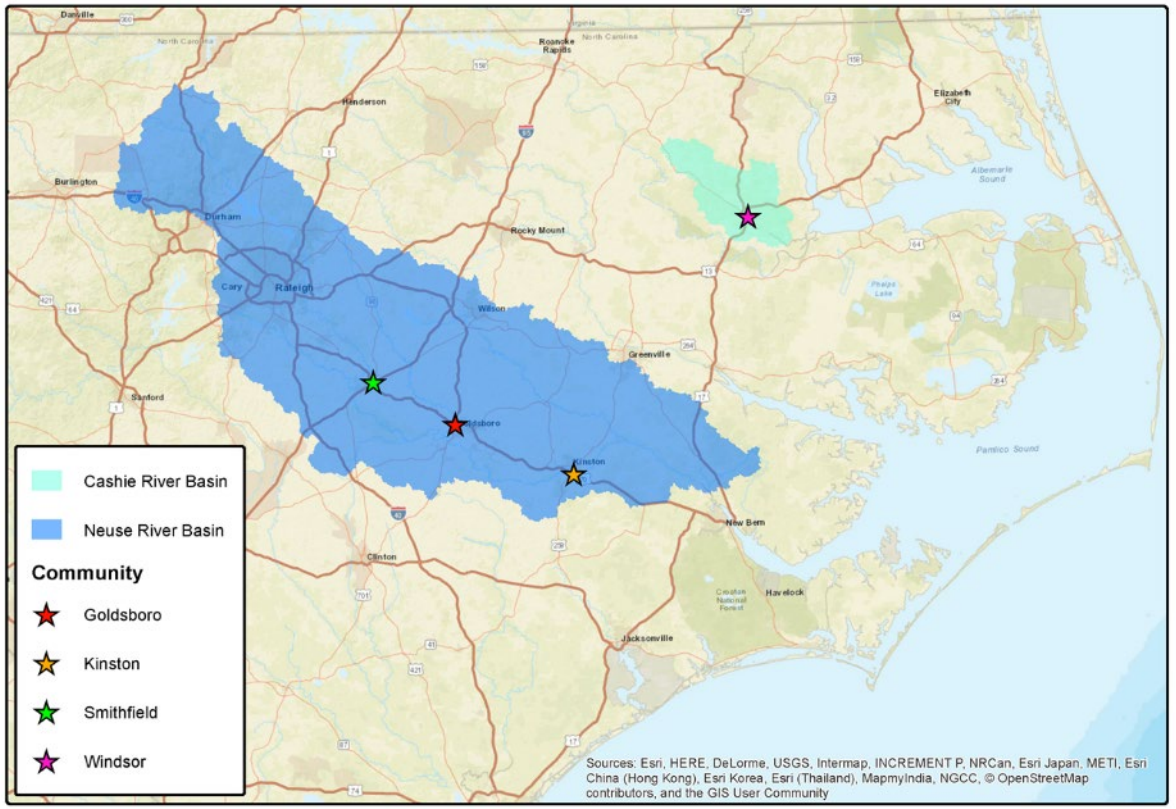


Resilient Transportation Infrastructure

Goals:

- Identify flood mitigation options for communities in eastern NC.
- Assist NC DOT with improving infrastructure resilience.
- Evaluate flood mitigation potential of natural infrastructure.





Sea Grant North Carolina **Coastal River Flood Studies**

NORTH 0 10 20 40 Miles

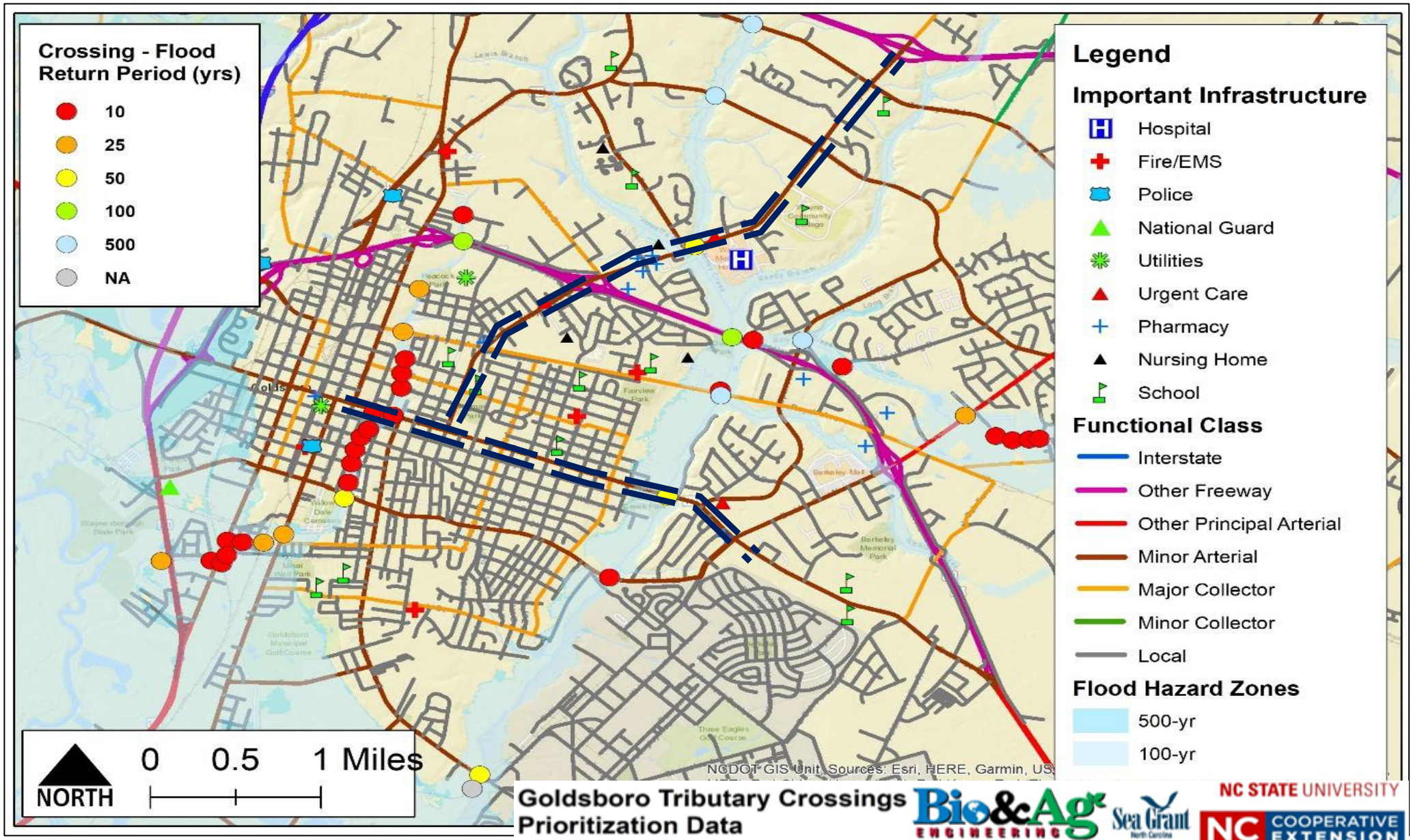
Storm road washouts

Hurricane Helene

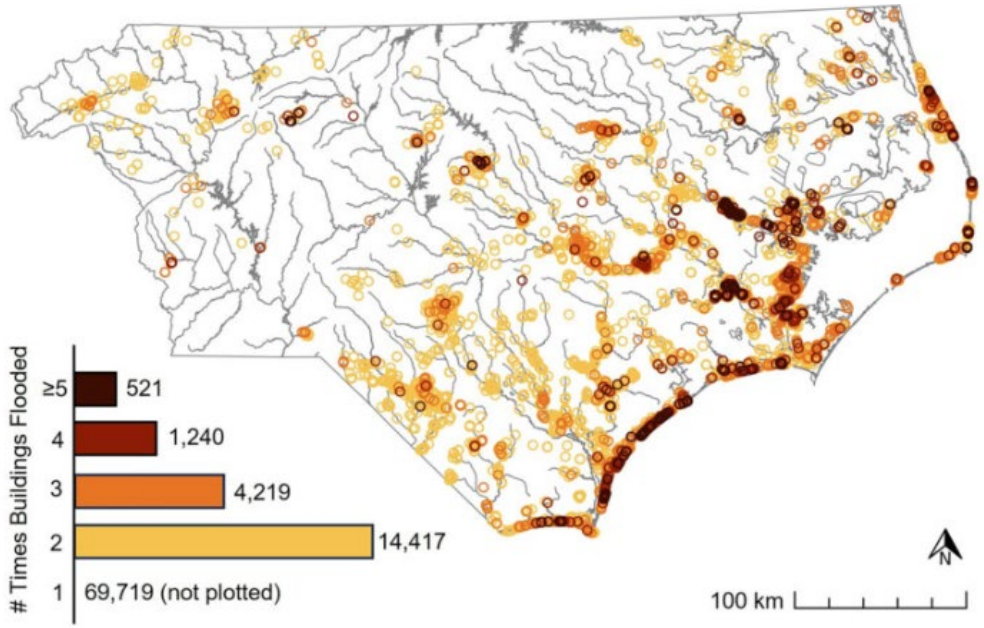
This collapsed bridge in Marion over the North Fork Catawba River was one of about 150 damaged bridges after Helene. (Photo by Travis England/US Army Corps of Engineers)

NCDOT crews worked to shore up the Pigeon River gorge last October — one of the first steps toward rebuilding Interstate 40 near the Tennessee border. (Photo by NCDOT)

Goldsboro Tributary Crossings: Critical Transportation Importance



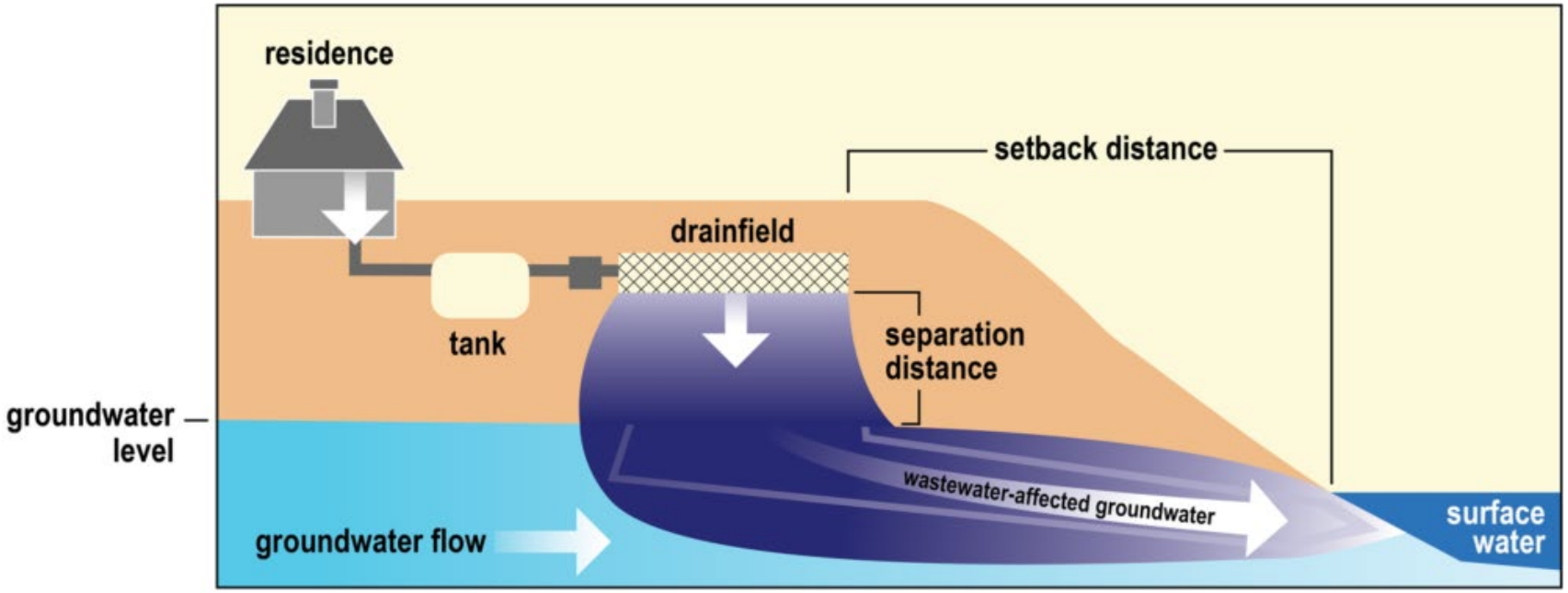
Repetitive Flooding…



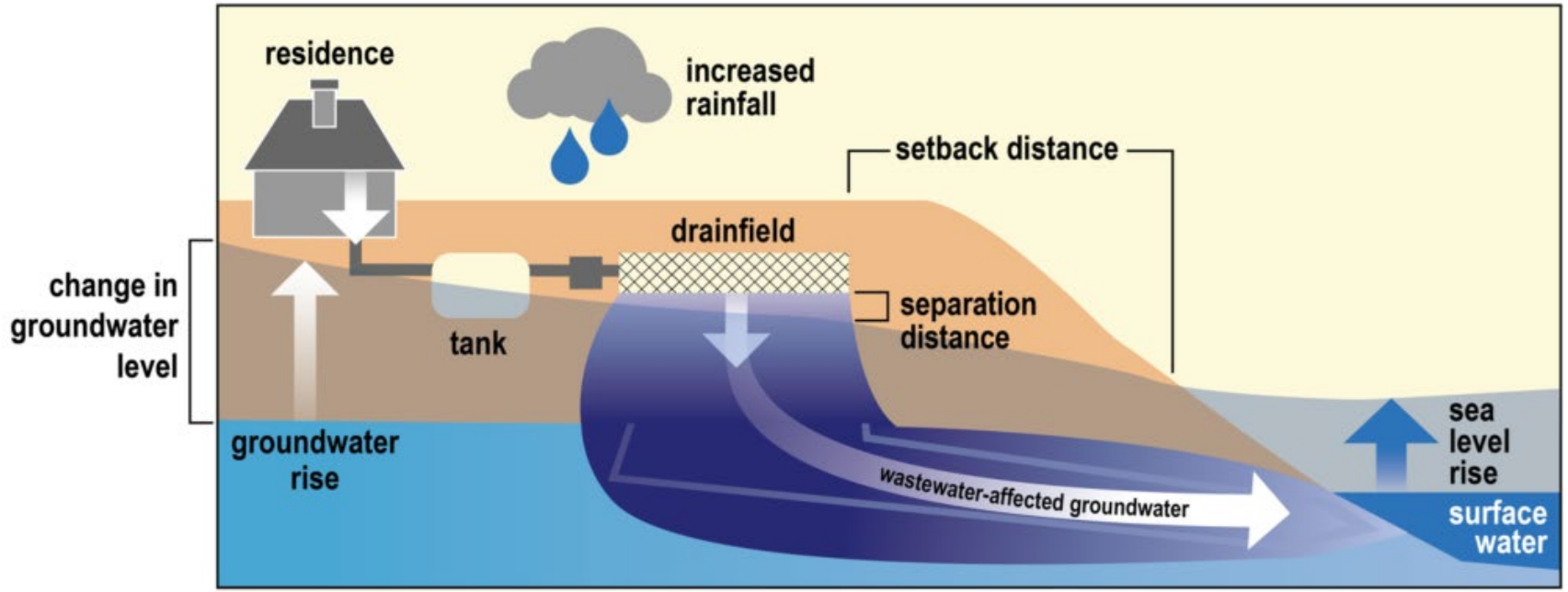
Properties that experienced repetitive flood events between 1996 and 2020, from the FLDEX database. (Map from Garcia et al.)

Floodwaters rose to near the roofs of homes in Swannanoa after Hurricane Helene last year. (Photo by Marcia Martin via North Carolina's Weather Authority)

Hurricane Matthew flooded Nags Head infrastructure (Hurricane Matthew, 2016)

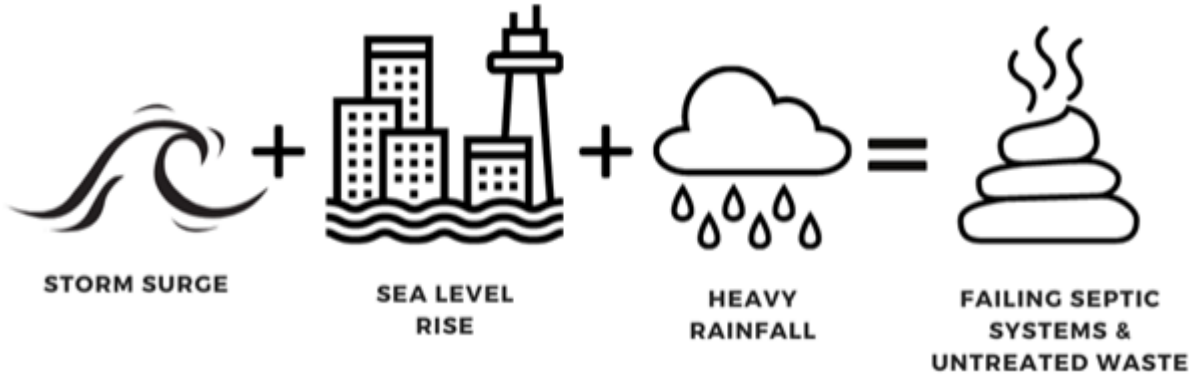


Soil treatment area underneath the drainfield is essential to functionality

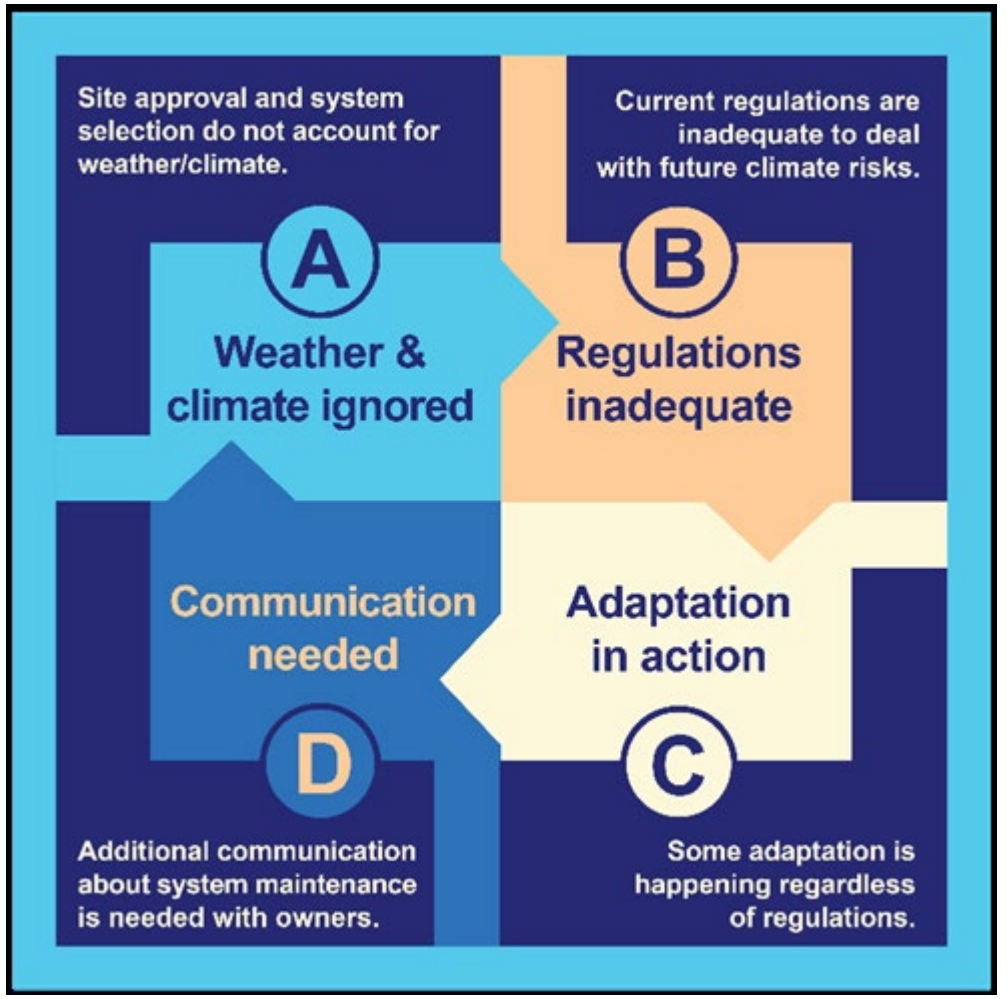


Rising groundwater levels decrease the separation distance between septic systemics and groundwater

Onsite Wastewater Treatment: Resilient Nags Head, NC



- Septic systems at increasing risk due to climate change.
- Impaired ability to process contaminants.
- Constrains development.
- Significant concern to rural and small towns.



ECU

Interdisciplinary Approach to Stormwater Management

Flood Control

Minimizing downstream effects of stormwater runoff

Water Quality

Reducing pollutants loads on our waterbodies

Natural Landscape

Encouraging vegetation preservation

Preserve Open Space

Maintain valuable features and function via conservation

Reduce Hardscapes

Through compact design and reduced impervious surfaces

Functional

Sustainable stormwater management

Cost-Effective

Flexibility with availability of low-cost practices

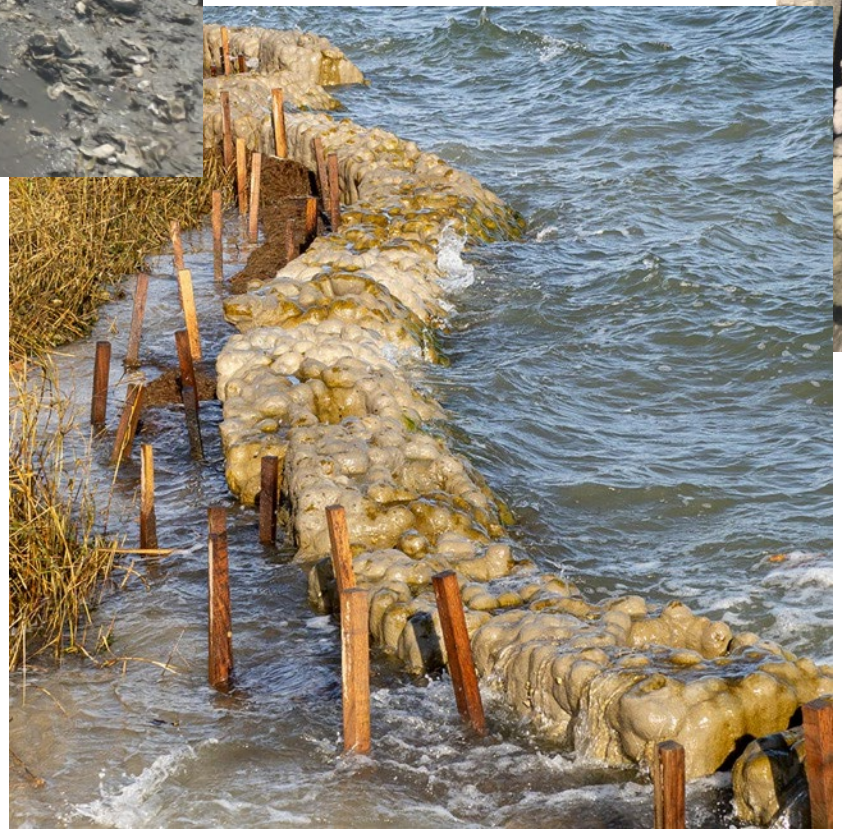
Character

Distinctive and attractive community landscapes

Nature & Natural Infrastructure (NNBI) Nature Based Solutions (NBS)

Nature-Based Solutions: Living Shorelines

Nature-based solutions…



SANDBAR
OYSTER COMPANY

NATIVE SHORELINES
a DAVEY company

NATRX
ADAPTIVE INFRASTRUCTURE

Watershed Natural & Nature Based Infrastructure

Reforestation

Wetland restoration

Stream restoration

Water Farming

Sea Grant North Carolina

NC COOPERATIVE EXTENSION

UNC SCHOOL OF GOVERNMENT

NC FOUNDATION for SOIL & WATER CONSERVATION

NC ASSOCIATION OF SOIL & WATER CONSERVATION DISTRICTS

NORTH CAROLINA SOIL & WATER CONSERVATION DISTRICTS *Yours for Life*

NC STATE UNIVERSITY Bio&Ag ENGINEERING

NC STATE UNIVERSITY College of Natural Resources

NC STATE UNIVERSITY College of Design

EDF ENVIRONMENTAL DEFENSE FUND

FARM BUREAU NORTH CAROLINA

NC STATE UNIVERSITY

NC Policy Collaboratory

Harmful Algal Blooms and Cyanotoxins in NC Waters: Chowan River

Eutrophication or Nutrient Pollution

- Recent recurrence of anoxia (low oxygen) and fis kills
- Light reduction and loss of benthic communities
- Water quality (public health, property values, tourism)

Chowan Edenton Environmental Group

Pamlico-Albemarle Sound (~7,800 km^2)

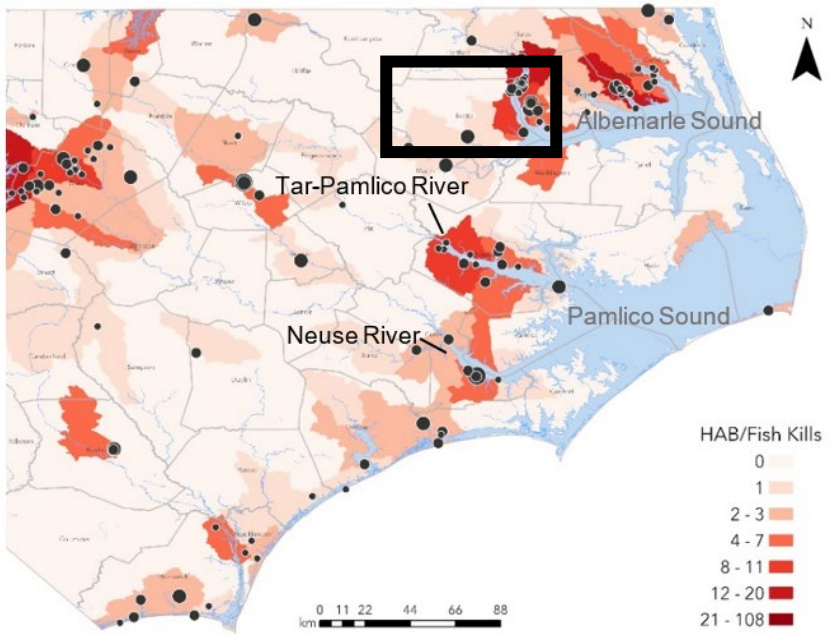
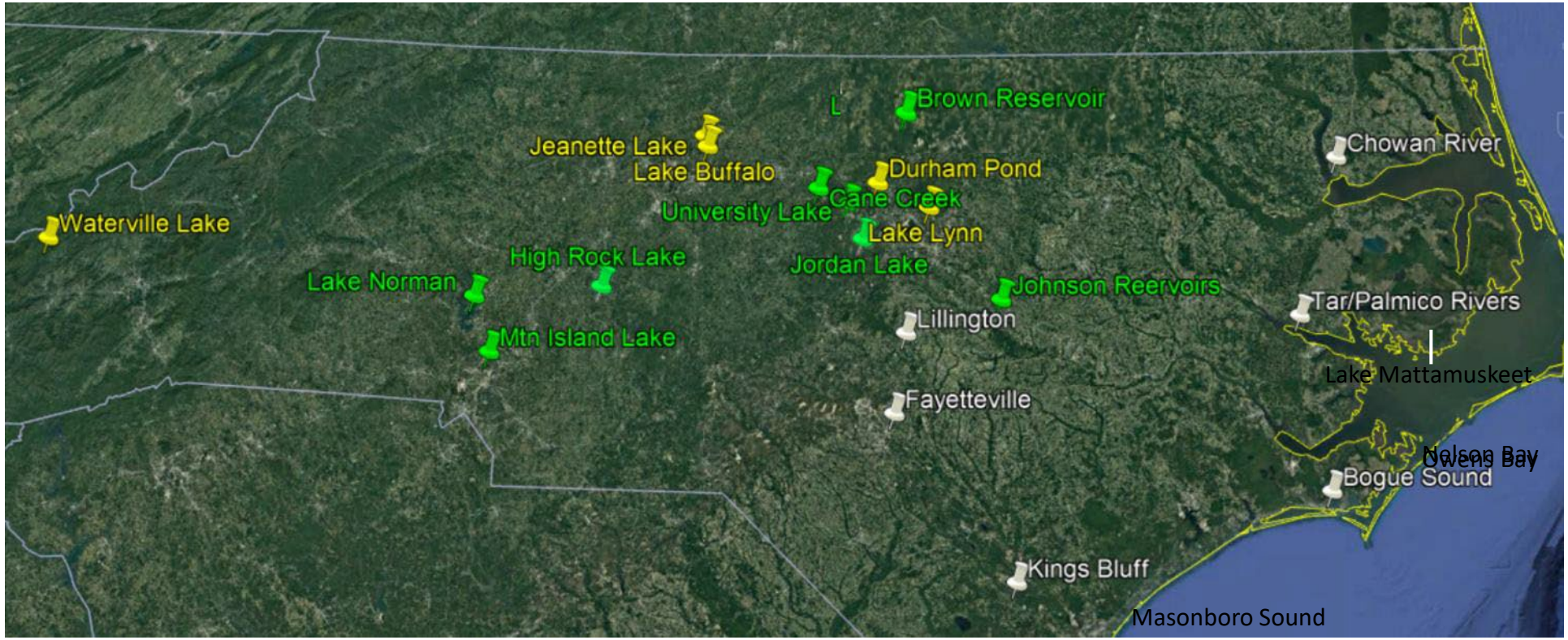


Fig. 1 *Public reports of HABs and fish kills from Jun 2020 to Sep 2022 (black dots). Watersheds are colored by number of blooms reported (NC DEQ).*

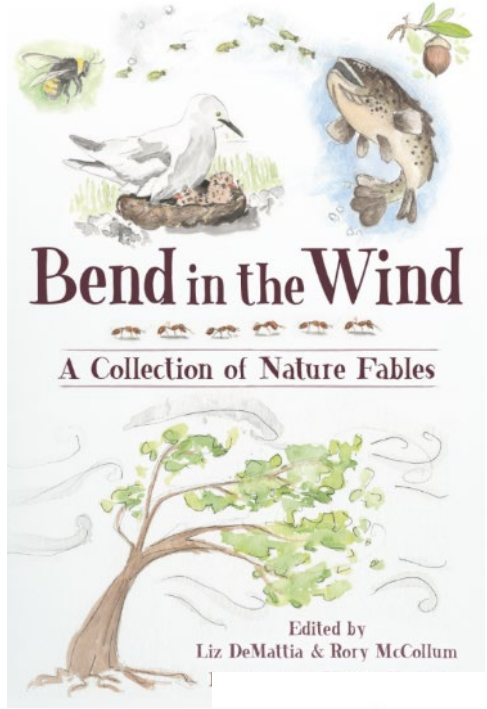
NC STATE UNIVERSITY

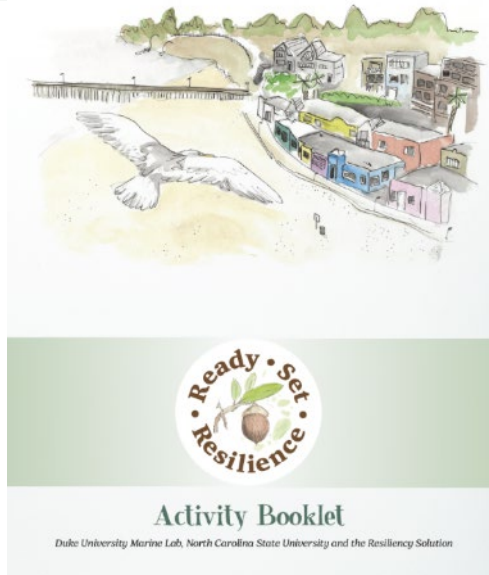
Expanding study areas…



Center for Human Health and the Environment

Ecological, Psychological & Community Resilience





A One Water Approach

Hallmarks of a One Water Approach

1. Value water at every stage and in every form
2. Focus on achieving multiple benefits
3. Approach decisions with a systems mindset
4. Use watershed-scale thinking and action
5. Intervene with right-sized solutions
6. Rely on partnerships and inclusion
7. Account for climate action urgency and opportunities

Realizing a Sustainable and Equitable Water Future

One Water is a transformative way of viewing, valuing, and managing water. The One Water approach manages all water—whether from the tap, a stream, a storm, an aquifer, or a sewer—in a collaborative, integrated, inclusive, and holistic manner. One Water can change and regenerate the way we live, the opportunities we have, our environment, and our society.

US Water Alliance

Just **one day** without water nationally would mean:

Over **$121 billion** in losses to the U.S. economy.

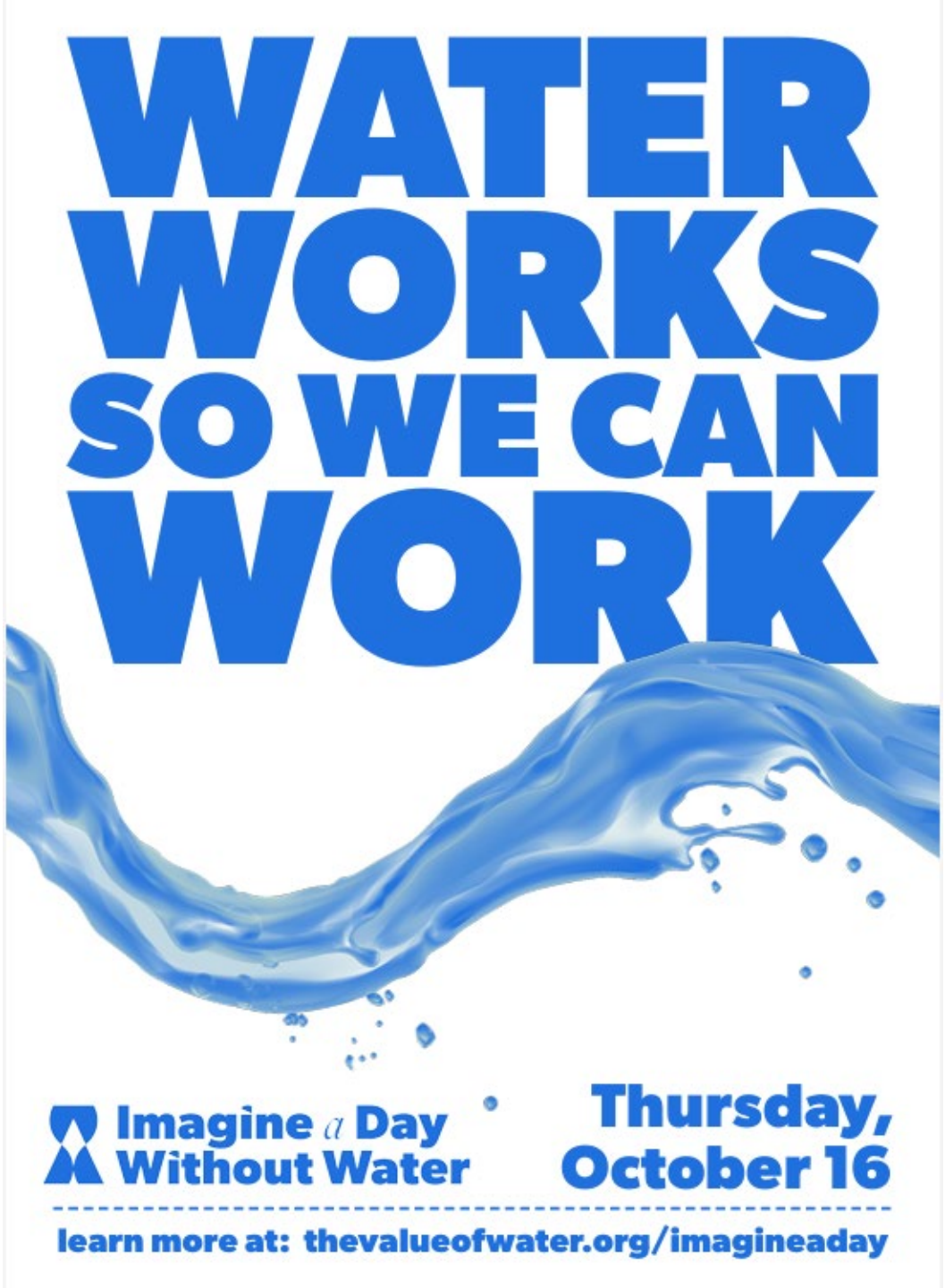
526,996 jobs placed at risk.

$39.2 billion in lost wages.

A **$69 billion** hit to GDP — a 10% reduction in typical annual U.S. economic growth.

40% daily losses in economic output for heavily water-dependent industries.

https://uswateralliance.org/



NC WRRI Annual Conference
March 23-24, 2027


North Carolina Coastal Conference
November 17-18, 2026
Chapel Hill, Friday Center
Knoxville
Raleigh
North Carolina
Charlotte
Pamlico Sound
Onslow Bay
Cape Fear
Columbia
South
Sea Grant
NORTH CAROLINA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