Roadmap to a Cleaner Yadkin

August 2020

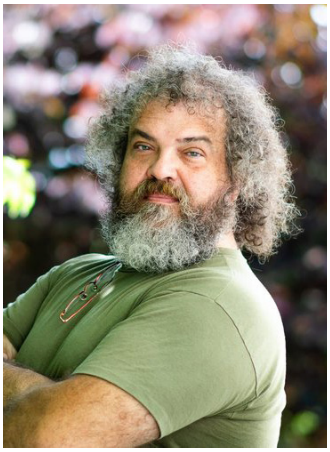
PREPARED BY:
The Piedmont Triad Regional Council
for The Yadkin Riverkeeper

FUNDED BY:
National Fish and Wildlife Foundation's
Wells Fargo Resilient Communities Program

Greetings from the Riverkeeper

In late 2016, the Yadkin Riverkeeper (YRK) received a $50,000 grant from the National Fish and Wildlife Foundation's Wells Fargo Resilient Communities Program. As part of this project, we worked with the Piedmont Triad Regional Council (PTRC) to develop a Geographic Information System (GIS) based tool to assess potential sources of non-point source pollution in the Yadkin River watershed above High Rock Lake. Using this tool, we developed and are pleased to release the report, "A Roadmap for a Cleaner Yadkin."

Edgar Miller



Brian Fannon

The report is based on a review of previous nutrient modeling for High Rock Lake (HRL), the results of the nonpoint source pollution assessment tool, and the input of the YRK Watershed Protection Task Force. The task force consisted of representatives from water and sewer utilities, soil and water conservation districts, regional land trusts, and a stream restoration expert. YRK shared the preliminary report and its findings and recommendations with members of the Yadkin Pee Dee River Basin Association (YPDRBA), the Yadkin Pee Dee Water Management Group (YPDRWMG) and several county soil and water conservation districts for input and feedback on the model.

The findings and recommendations in the report have not been endorsed by any task force members or other organizations. Yadkin Riverkeeper is solely responsible for its contents and conclusions. The purpose of the model and report is to help YRK more effectively target limited resources to sub-basins in the High Rock Lake watershed that have the greatest potential for nonpoint source pollution. The recommendations in the report are YRK's best attempt to use the results of the model and our knowledge of what is going on in those sub-basins to prioritize where we can get the biggest bang for the buck in our conservation and stream restoration efforts.

Of significance, is the report's finding that developed land in the watershed will nearly double from its current 13 percent to 32 percent by 2060, only exacerbating water quality issues related to nutrients and sediments. The findings also note the problem of reducing nonpoint source pollution is multi-faceted, with many different sources of nutrients and sediment. This model focuses on potential sources of nonpoint source pollution and does not consider impacts of point source pollution from wastewater treatment plants or industrial discharges.

The report identifies seven sub-basins where collective actions and strategic partnerships will have the greatest impact on reducing nonpoint source pollution. It also includes maps that highlight priority conservation areas that need to be protected to reduce stormwater runoff and sediment transport and strategies to implement the recommendations, including working with local and state government agencies to explore innovative financing mechanisms and incentives.

This report does not recommend specific new water quality standards, but does conclude there is a need for chlorophyll-a, nutrient and bacteria standards for HRL to improve overall water quality in the basin. YRK's objective is to work with state regulatory agencies, local governments, the YPDRBA, YPDWMG, soil and water conservation districts, land trusts and other stakeholders to implement the recommendations in the report and develop reasonable water quality standards to protect drinking water supplies and recreational uses of the River and HRL.

Edgar Miller
Executive Director

Brian Fannon
Yadkin Riverkeeper

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Disclaimer: The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions of the National Fish and Wildlife Foundation or its funding sources. Mentions of trade names or commercial products does not constitute their endorsement by the National Fish and Wildlife Foundation or its funding sources.

Existing Conditions

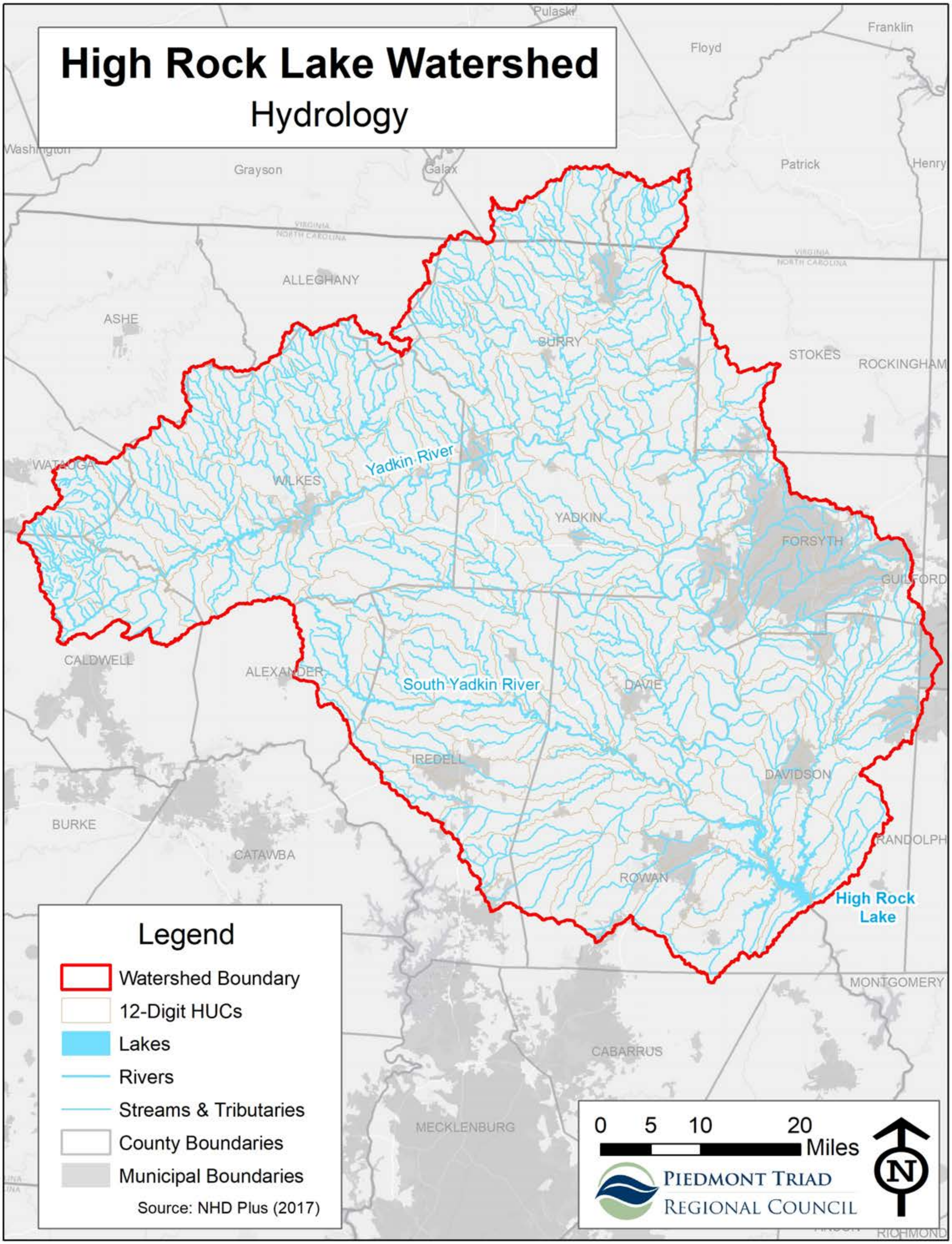
High Rock Lake is a man-made lake located in the western piedmont of North Carolina. High Rock Lake and High Rock Lake Dam were originally constructed in 1927 as part of the Yadkin Project, which is a series of four hydroelectric stations, dams, and reservoirs along the Yadkin River that are currently owned and operated by Eagle Creek Renewable Energy, a wholly owned subsidiary of Ontario Power Generation. The lake is 15,180 acres in size and has a normal pool elevation of 624 feet, which corresponds to a volume of approximately 239,672 acre-feet of water. However, water levels fluctuate daily based on power generation.

High Rock Lake receives water from a large land area that stretches from the foothills of the Appalachian Mountains to the southern piedmont. The entire drainage area or watershed is 3,974 square miles in size and includes 5,394 miles of streams and rivers that serve as the headwaters of the Yadkin Pee-Dee River Basin. 15 North Carolina counties (Alexander, Alleghany, Caldwell, Davie, Davidson, Forsyth, Guilford, Iredell, Randolph, Rowan, Stokes, Surry, Yadkin, Watauga, Wilkes) are, at least partially, included within the watershed, as well as a small section of Carroll and Patrick Counties in Virginia. Several urban centers are also located throughout the watershed, including Winston-Salem, High Point, Salisbury, Lexington, and Thomasville.

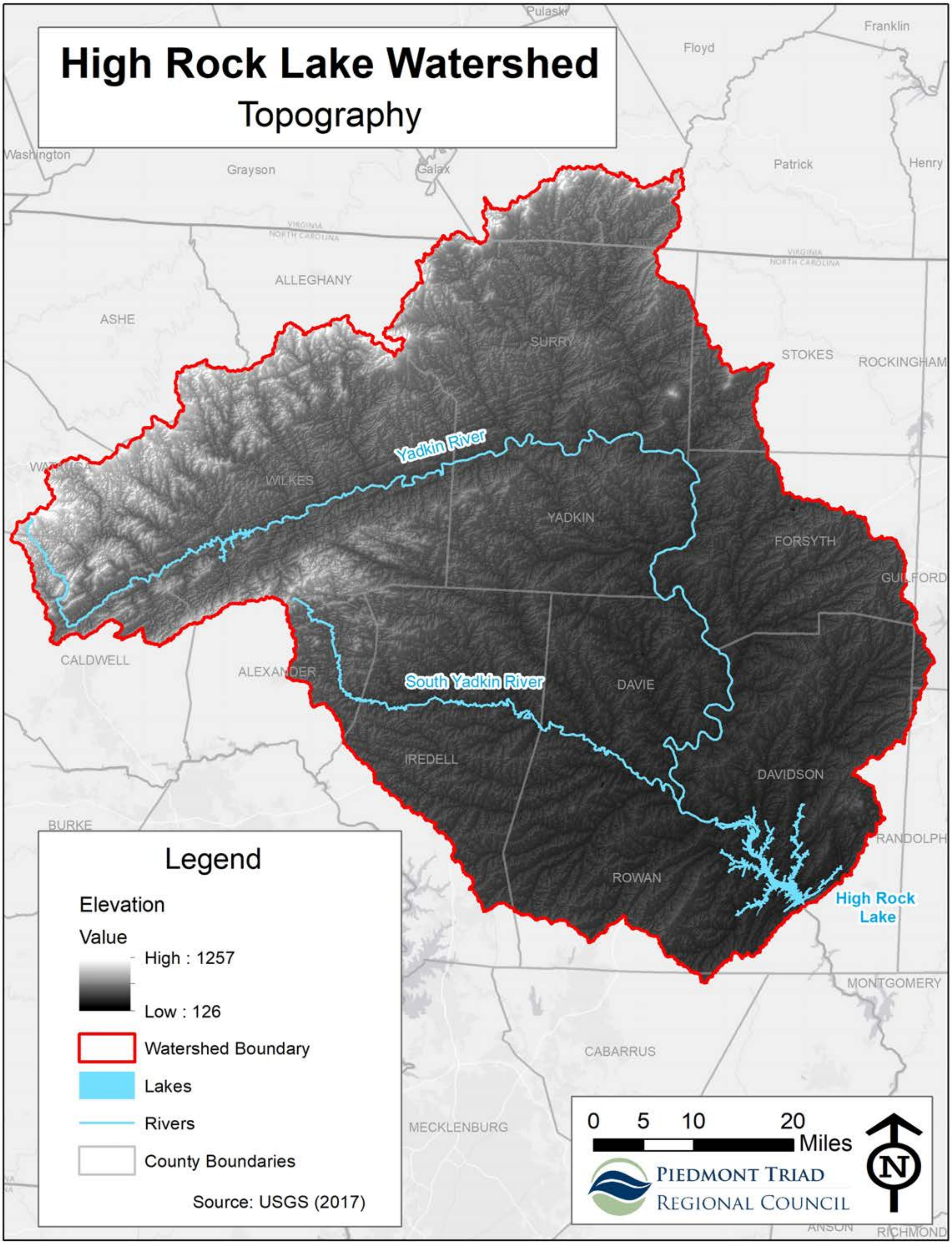
High Rock Lake Dam

Yadkin River, Rowan County

Photo Credit: Jon C. Lakey, Salisbury Post



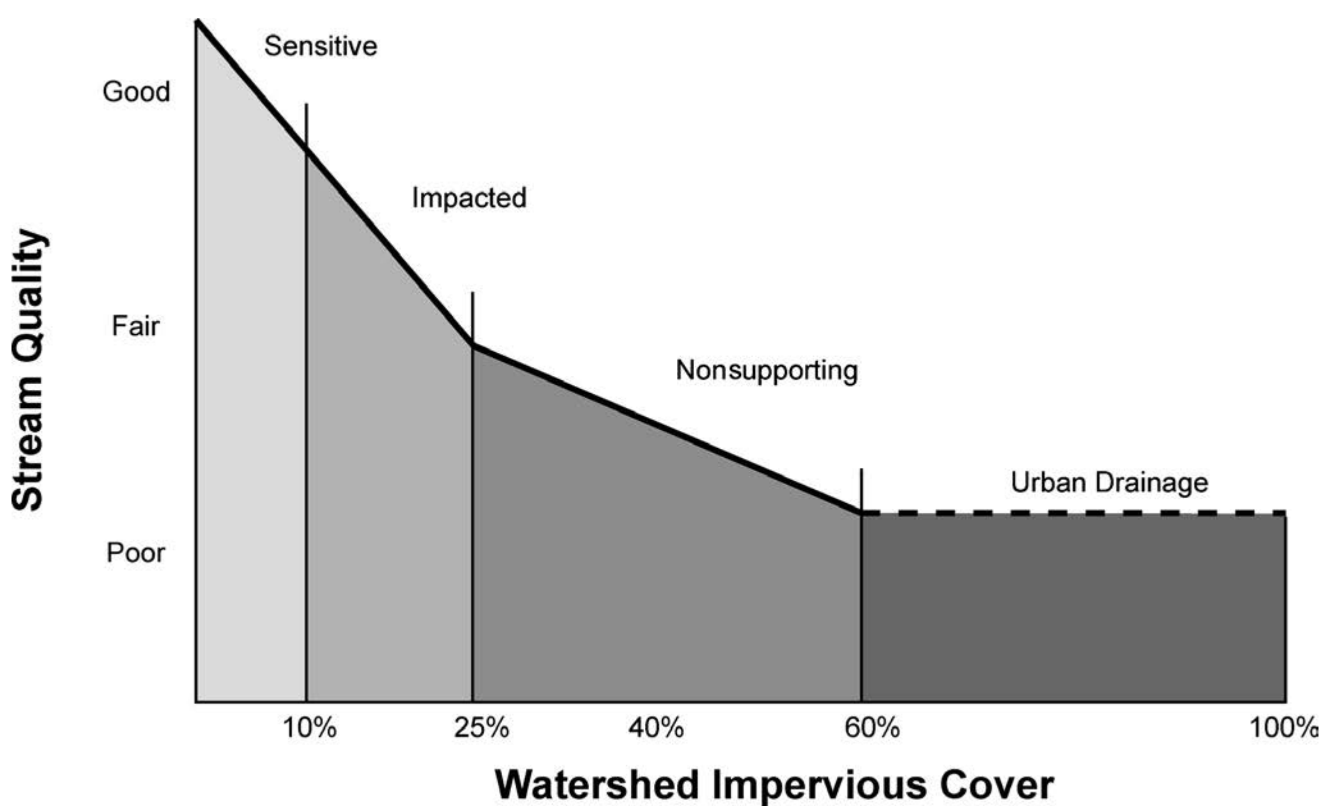
High Rock Lake Watershed
Hydrology
Pulaski
Franklin
Floyd
Washington
Grayson
Galax
Patrick
Henry
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WATAUGA
Yadkin River
WILKES
YADKIN
FORSYTH
GUILFORD
CALDWELL
ALEXANDER
South Yadkin River
DAVIE
IREDELL
DAVIDSON
BURKE
CATAWBA
RANDOLPH
ROWAN
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
RICHMOND
Legend
Watershed Boundary
12-Digit HUCs
Lakes
Rivers
Streams & Tributaries
County Boundaries
Municipal Boundaries
Source: NHD Plus (2017)
0 5 10 20
Miles
N
Piedmont Triad
Regional Council

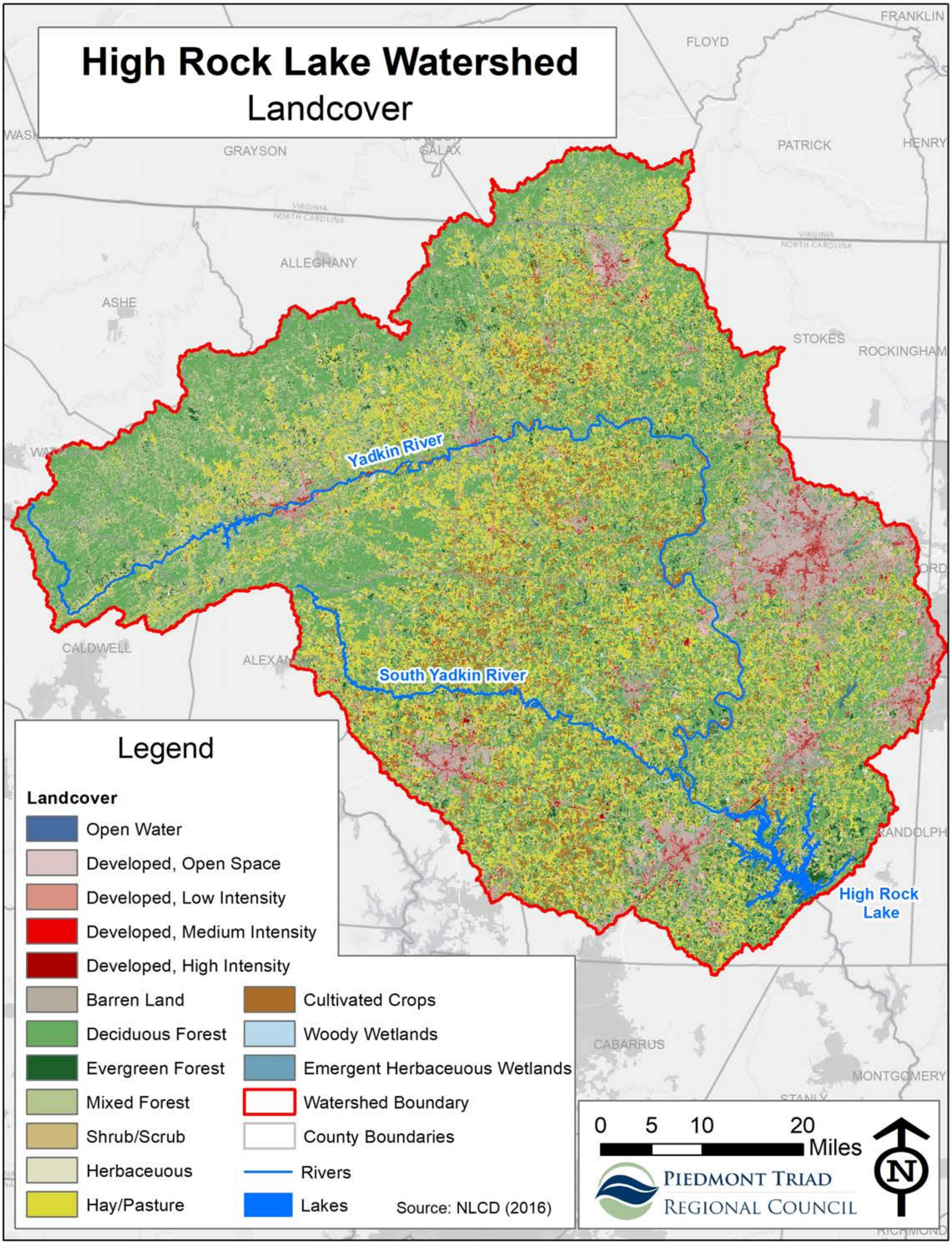

High Rock Lake Watershed
Topography
Pulaski
Franklin
Floyd
Washington
Grayson
Galax
Patrick
Henry
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
Yadkin River
WILKES
YADKIN
FORSYTH
GUILFORD
CALDWELL
ALEXANDER
South Yadkin River
DAVIE
IREDELL
DAVIDSON
BURKE
RANDOLPH
ROWAN
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
ANSON
RICHMOND
Legend
Elevation
Value
High : 1257
Low : 126
Watershed Boundary
Lakes
Rivers
County Boundaries
Source: USGS (2017)
0 5 10 20
Miles
N
Piedmont Triad
Regional Council

Development Patterns

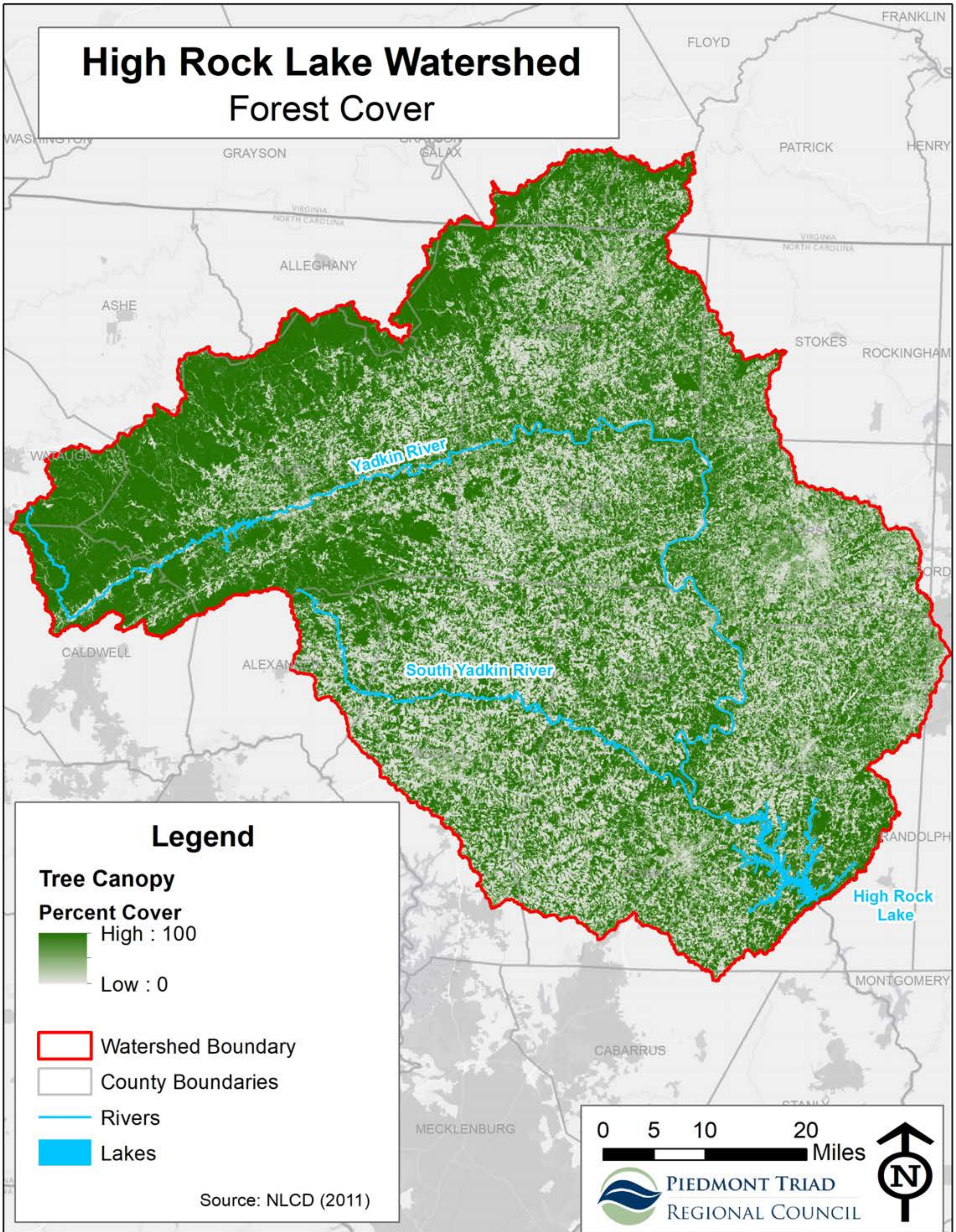
Historically, the High Rock Lake watershed has been predominantly rural and agriculture has played a large economic role in the region. Over the past few decades, the region has experienced a decline in agriculture and forestland and an increase in urban development. Despite these changes, deciduous forests and pasture/hay remain the two most prominent land cover types within the watershed, making up 44% and 25% of overall land respectively, while 13.3% of land is considered developed (MRLC, 2016). The Center for Watershed Protection has found that impervious cover exceeding 10% within a watershed can negatively impact stream ecosystems and aquatic life due to increases in stormwater runoff (Schueler et al., 2009). Impervious surfaces, such as roads, parking lots, and roofs prevent water from soaking into the ground and increase the volume of stormwater that runs off the land. Stormwater runoff can transport various pollutants into nearby waterways, including excess nutrients from fertilizers and pet and yard waste, and increase streambank erosion (U.S. EPA, 2019). While urban development and increases in stormwater runoff is one of the greatest water quality concerns, it is a broad mix of land uses throughout the watershed (both urban and rural) that are contributing to the high sediment and nutrient loads and resulting algal blooms in High Rock Lake.

Impact of Impervious Cover on Stream Quality Graph (Schueler et al, 2009)

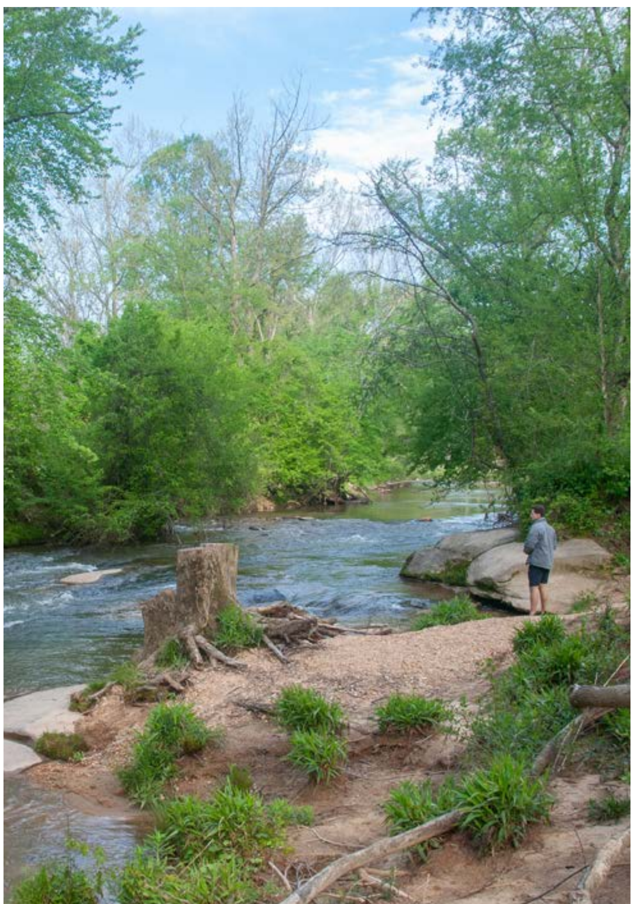




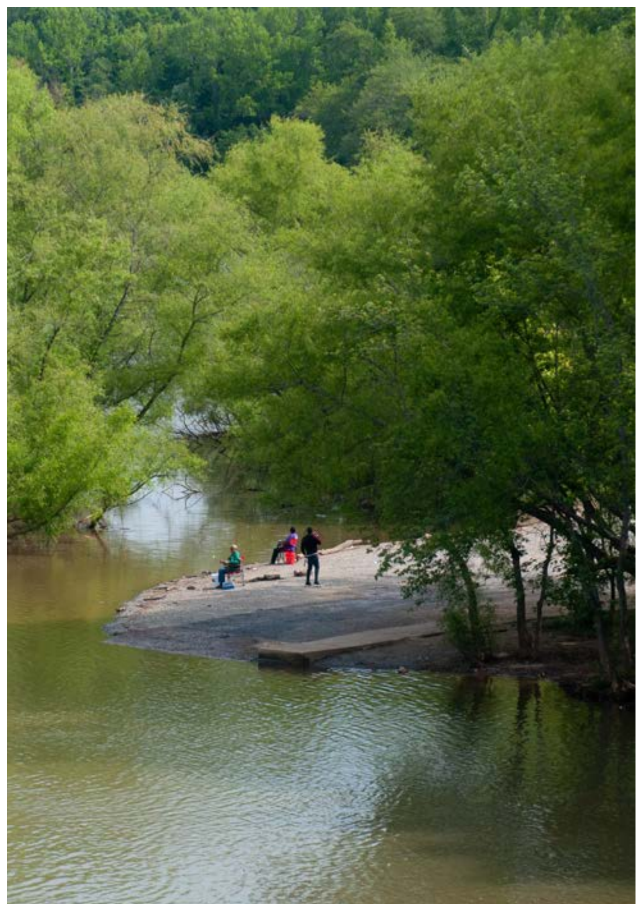
High Rock Lake Watershed
Landcover
FLOYD
FRANKLIN
GRAYSON
GALAX
PATRICK
HENRY
ALLEGHANY
ASHE
STOKES
ROCKINGHAM
Yadkin River
South Yadkin River
CALDWELL
RANDOLPH
High Rock Lake
CABARRUS
MONTGOMERY
Legend
Landcover
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Herbaceuous
Hay/Pasture
Cultivated Crops
Woody Wetlands
Emergent Herbaceuous Wetlands
Watershed Boundary
County Boundaries
Rivers
Lakes
Source: NLCD (2016)
0 5 10 20
Miles
N
PIEDMONT TRIAD
REGIONAL COUNCIL


High Rock Lake Watershed
Forest Cover
FRANKLIN
FLOYD
GRAYSON
GALAX
PATRICK
HENRY
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
STOKES
ROCKINGHAM
Yadkin River
South Yadkin River
CALDWELL
RANDOLPH
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
RICHMOND
Legend
Tree Canopy
Percent Cover
High : 100
Low : 0
Watershed Boundary
County Boundaries
Rivers
Lakes
Source: NLCD (2011)
0 5 10 20
Miles
N
Piedmont Triad Regional Council

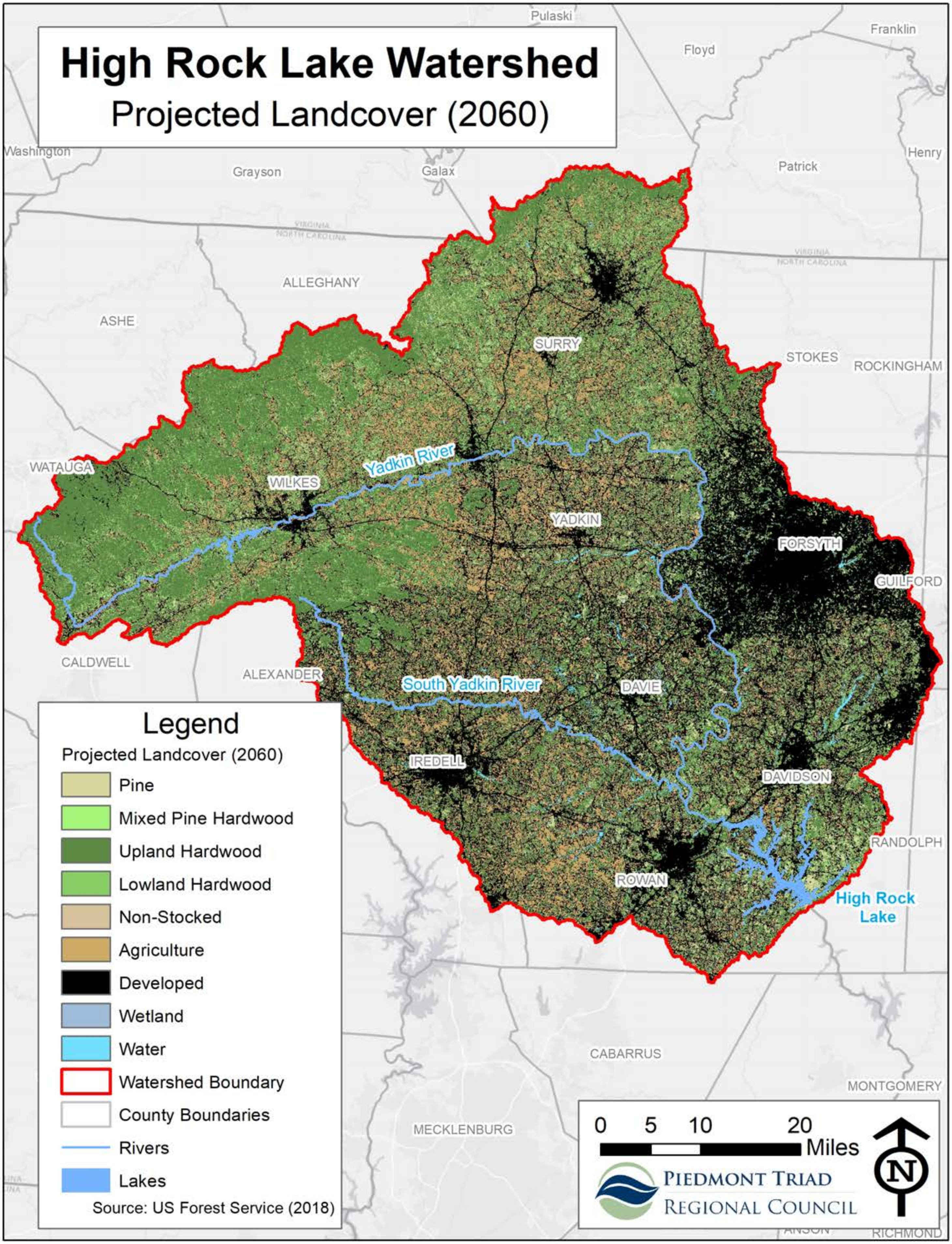
Based on research by the U.S. Forest Service, recent development trends are projected to continue throughout the 21st century. The amount of developed land within the High Rock Lake watershed is anticipated to more than double from 13.3% to 32.2% by the year 2060, while forests and agricultural land continues to decrease. This shift in land use throughout the watershed will only exacerbate water quality issues in High Rock Lake and its many tributaries, due to the enormous water quality benefits that trees and other natural vegetation provide. Trees and other natural vegetation help absorb stormwater runoff and nutrients, reduce sediment transport, and filter other harmful pollutants before they reach nearby waterbodies. Communities throughout the High Rock Lake watershed will need to have plans and policies in place that minimize sprawl and conserve open space in order to ensure that water resources are adequately protected.



Fisher River Park
Fisher River, Surry County



Yadkin River Park
Yadkin River, Davidson County


High Rock Lake Watershed
Projected Landcover (2060)
Pulaski
Franklin
Floyd
Washington
Grayson
Galax
Patrick
Henry
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WATAUGA
Yadkin River
WILKES
YADKIN
FORSYTH
GUILFORD
CALDWELL
ALEXANDER
South Yadkin River
DAVIE
IREDELL
DAVIDSON
RANDOLPH
ROWAN
High Rock Lake
CABARRUS
MONTGOMERY
MECKLENBURG
RICHMOND
Legend
Projected Landcover (2060)
Pine
Mixed Pine Hardwood
Upland Hardwood
Lowland Hardwood
Non-Stocked
Agriculture
Developed
Wetland
Water
Watershed Boundary
County Boundaries
Rivers
Lakes
Source: US Forest Service (2018)
0 5 10 20
Miles
N
Piedmont Triad Regional Council

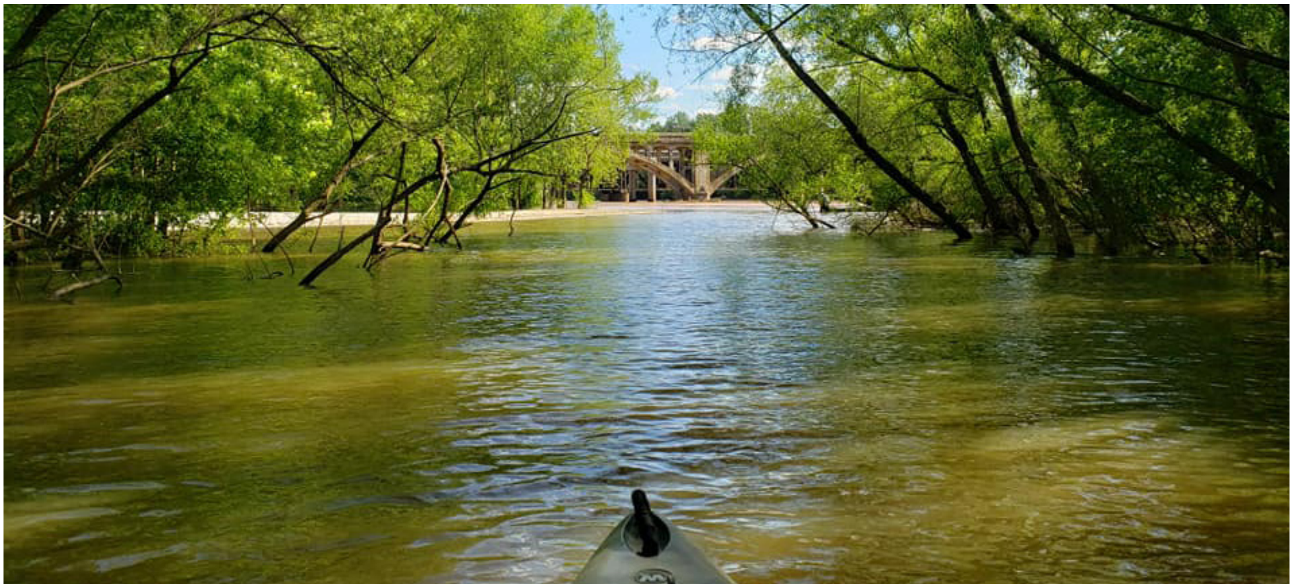


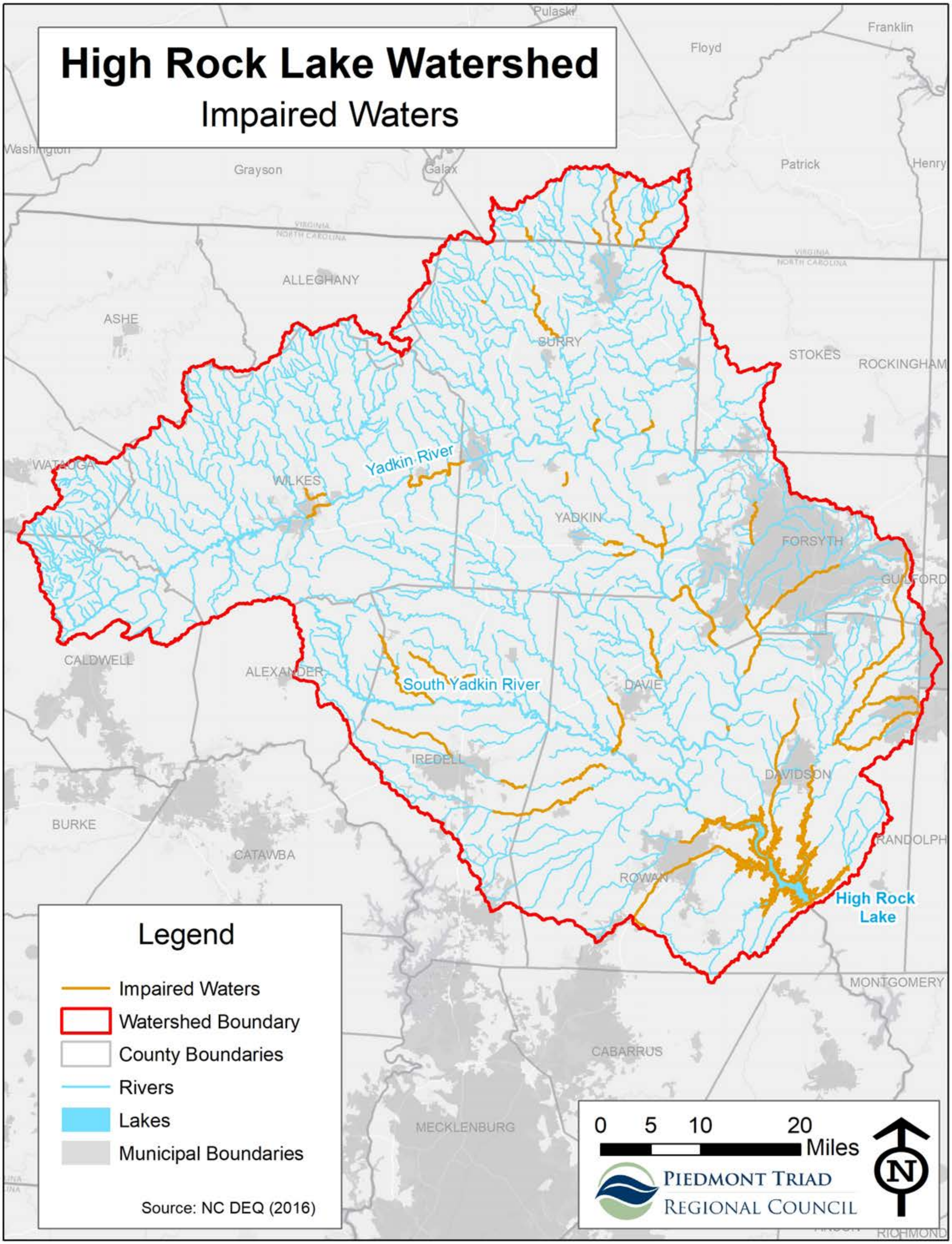
Photo Credit: Edgar Miller, Yadkin Riverkeeper

Upper High Rock Lake
Yadkin River, Davidson County

Water Quality

High Rock Lake is currently listed as an impaired waterbody due to elevated levels of turbidity, chlorophyll-a, and pH (NCDWR, 2018). These water quality impairments impede the lake's ability to support aquatic life and recreation and increase the number of harmful algal blooms (HABs) (NCDWR, 2018 & Tetra Tech, 2012). Depending on the type of algae and size of the bloom, HABs can pose significant risks to aquatic life and human health and cause negative economic impacts, such as a loss in revenue from water recreation activities. Chlorophyll-a and pH impairments within the lake are primarily associated with excessive algal growth, which is caused by elevated nutrient loads (nitrogen and phosphorus), high summer temperatures, and light availability, while turbidity violations are primarily due to fine sediment loads (Tetra Tech, 2016). While there are no water intakes in High Rock Lake, the Yadkin River is used as a regional source of drinking water.

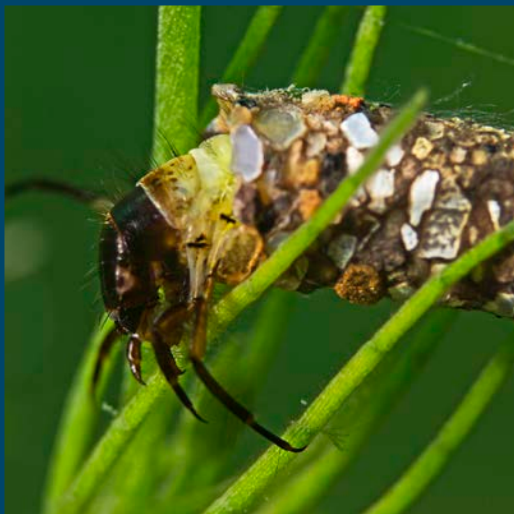
There is a high degree of spatial variability in water quality in High Rock Lake. A majority of sediment and nutrients enter the lake through the main stem of the Yadkin River. As a result, turbidity, total nitrogen, and total phosphorus concentrations are highest in the most upstream portion of the lake and decrease the closer you get to the dam downstream. The Yadkin River still carries a substantial legacy sediment load resulting from past uses. This pre-existing condition makes the control of current sediment inputs a higher priority than it might otherwise be,



High Rock Lake Watershed
Impaired Waters
Pulaski
Franklin
Floyd
Washington
Grayson
Galax
Patrick
Henry
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WATAUGA
WILKES
Yadkin River
YADKIN
FORSYTH
GUILFORD
CALDWELL
ALEXANDER
South Yadkin River
DAVIE
IREDELL
DAVIDSON
BURKE
CATAWBA
ROWAN
RANDOLPH
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
RICHMOND
Legend
Impaired Waters
Watershed Boundary
County Boundaries
Rivers
Lakes
Municipal Boundaries
Source: NC DEQ (2016)
0 5 10 20
Miles
N
Piedmont Triad Regional Council

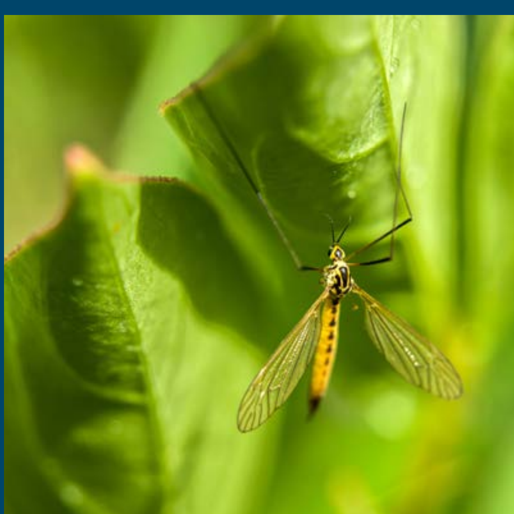
in an attempt to avoid exacerbating the problems already in existence. Sedimentation has also created a delta in the headwaters of High Rock Lake that is suspected to increase flooding and sediment deposition upstream (Bales, 2007). The highest concentrations of chlorophyll-a are found in the middle of the lake, which is attributed to decreasing turbidity and increasing light availability for photosynthesis (Rudd, 2018).

Macroinvertebrates



Caddisfly

Mayfly



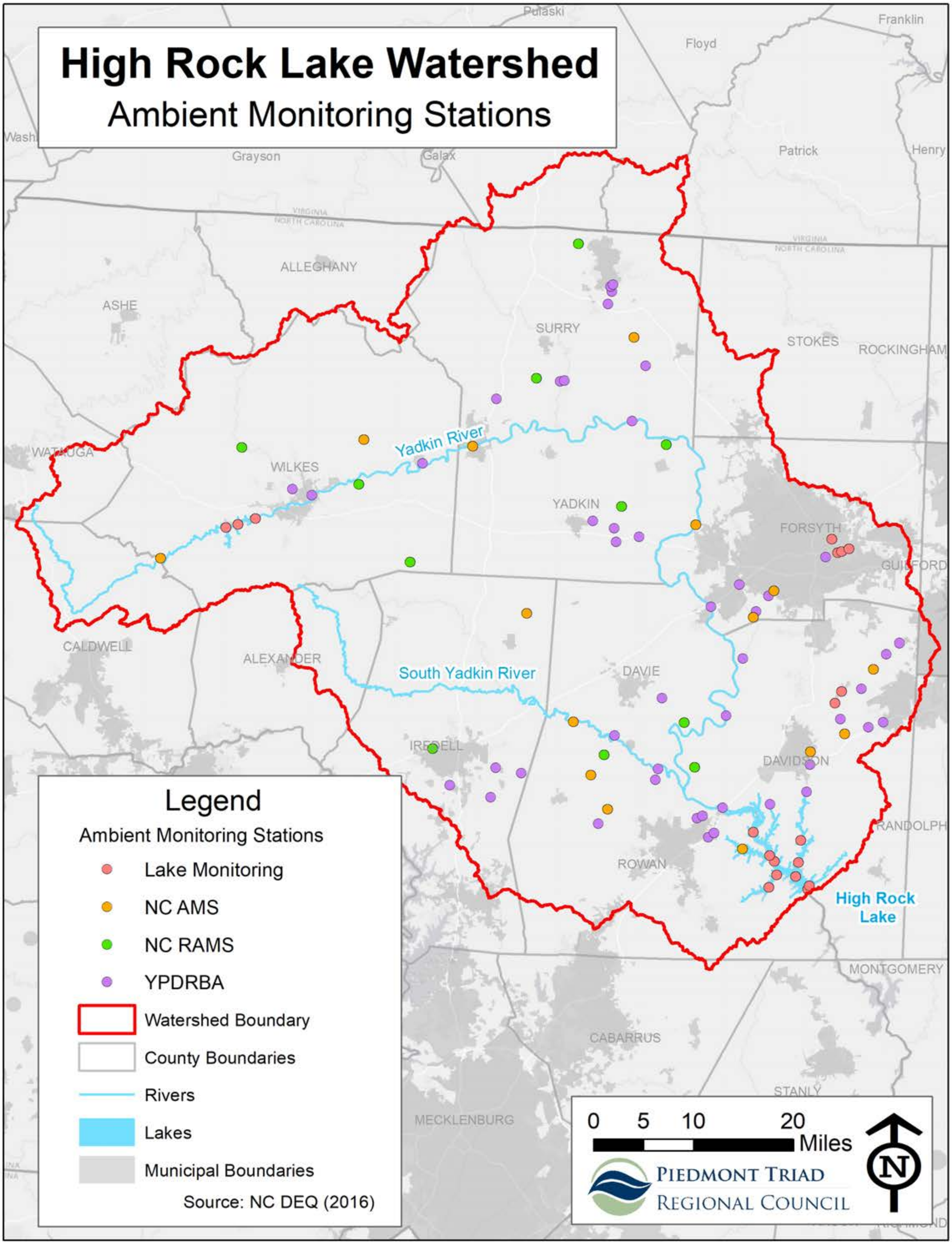
Crane fly

Impaired Streams

There are 833 miles of impaired streams, rivers, and other waterbodies within the High Rock Lake watershed that contribute to High Rock Lake's poor water quality. This correlates to 55 individual stream segments, 51 in NC and 4 in VA. Tributaries within the watershed are impaired for a variety of water quality parameters, including elevated levels of arsenic, chlorophyll a, copper, fecal coliform, pH, turbidity, zinc, and a lack of benthic or fish communities (NCDWR, 2018).

Biological Sampling

Biological indicators are regularly monitored by the North Carolina Division of Water Resources' (NCDWR) Bioassessment Branch. Out of the 55 impaired stream segments within the watershed, 16 are failing to adequately support benthic macroinvertebrates, which are small aquatic insects. 13 stream segments have fair benthic communities, while 3 are categorized as having poor benthic communities. The NCDWR Bioassessment Branch also monitors fish community data throughout the watershed. There are 6 stream segments that have fair fish community ratings, while 3 are listed as poor (NCDWR, 2018).


High Rock Lake Watershed
Ambient Monitoring Stations
Pulaski
Floyd
Franklin
Grayson
Galax
Patrick
Henry
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WATAUGA
WILKES
Yadkin River
YADKIN
FORSYTH
GUILFORD
CALDWELL
ALEXANDER
South Yadkin River
DAVIE
IREDELL
DAVIDSON
RANDOLPH
ROWAN
High Rock Lake
MONTGOMERY
CABARRUS
STANLY
MECKLENBURG
Legend
Ambient Monitoring Stations
Lake Monitoring
NC AMS
NC RAMS
YPDRBA
Watershed Boundary
County Boundaries
Rivers
Lakes
Municipal Boundaries
Source: NC DEQ (2016)
0 5 10 20 Miles
N
Piedmont Triad Regional Council

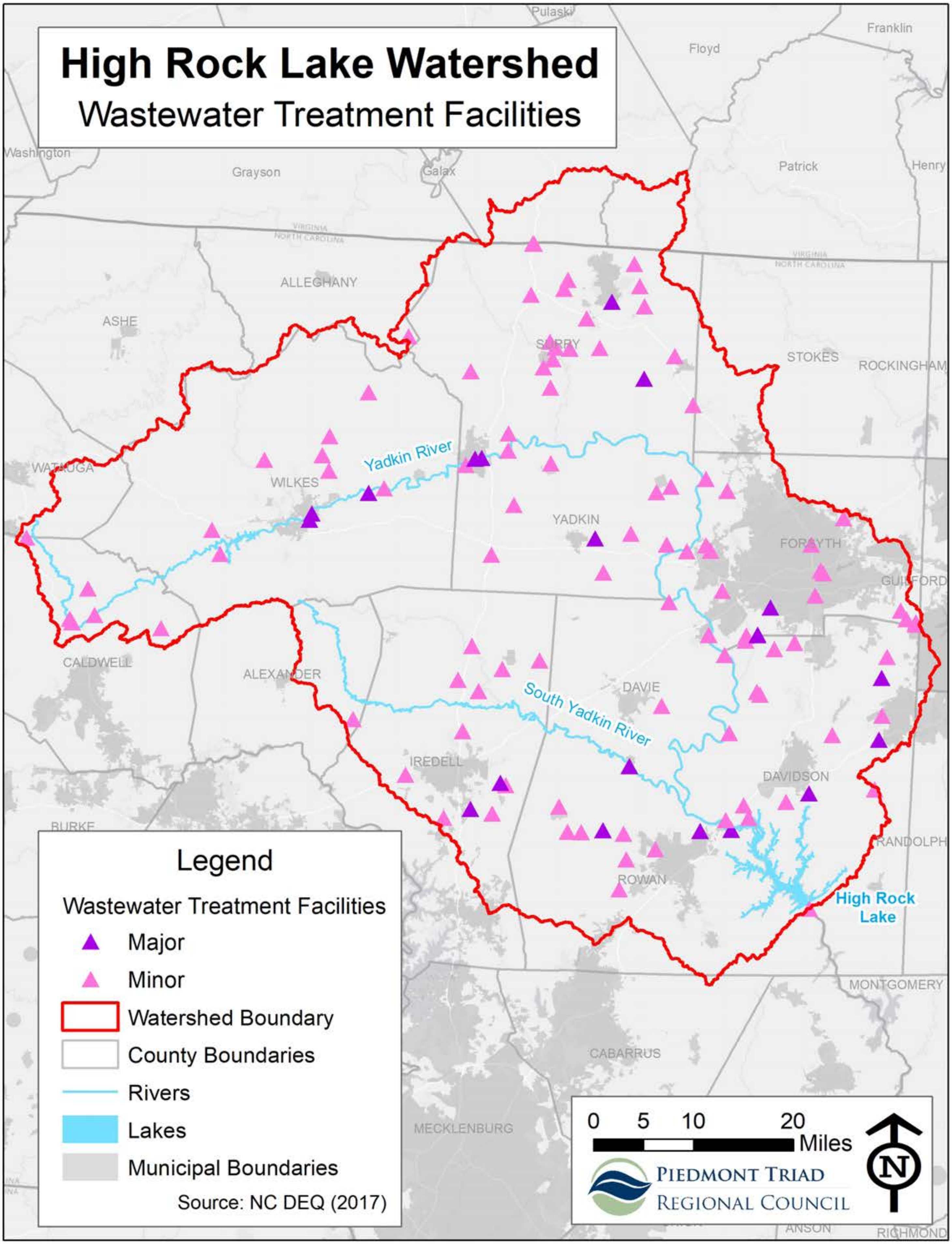
Ambient Monitoring Stations

Chemical water quality data is collected at over 130 locations throughout the High Rock Lake watershed. NCDWR maintains several stations through its Ambient Monitoring System (AMS), Random Ambient Monitoring System (RAMS), and Ambient Lake Monitoring. The AMS consists of a network of stations established to provide site-specific, long-term water quality information on significant rivers, streams, and estuaries throughout the state, while RAMS sites are selected randomly, sampled once per month for two years, and then retired. The Yadkin Pee-Dee River Basin Association (YPDRBA) also maintains 88 sampling stations throughout the watershed. This group is made up of local government and industrial dischargers who collectively monitor water quality in order to meet NPDES permit requirements.

Donnaha River Access
Yadkin River, Yadkin County
Photo Credit: Brian Fannon, Yadkin Riverkeeper

Permitted Facilities

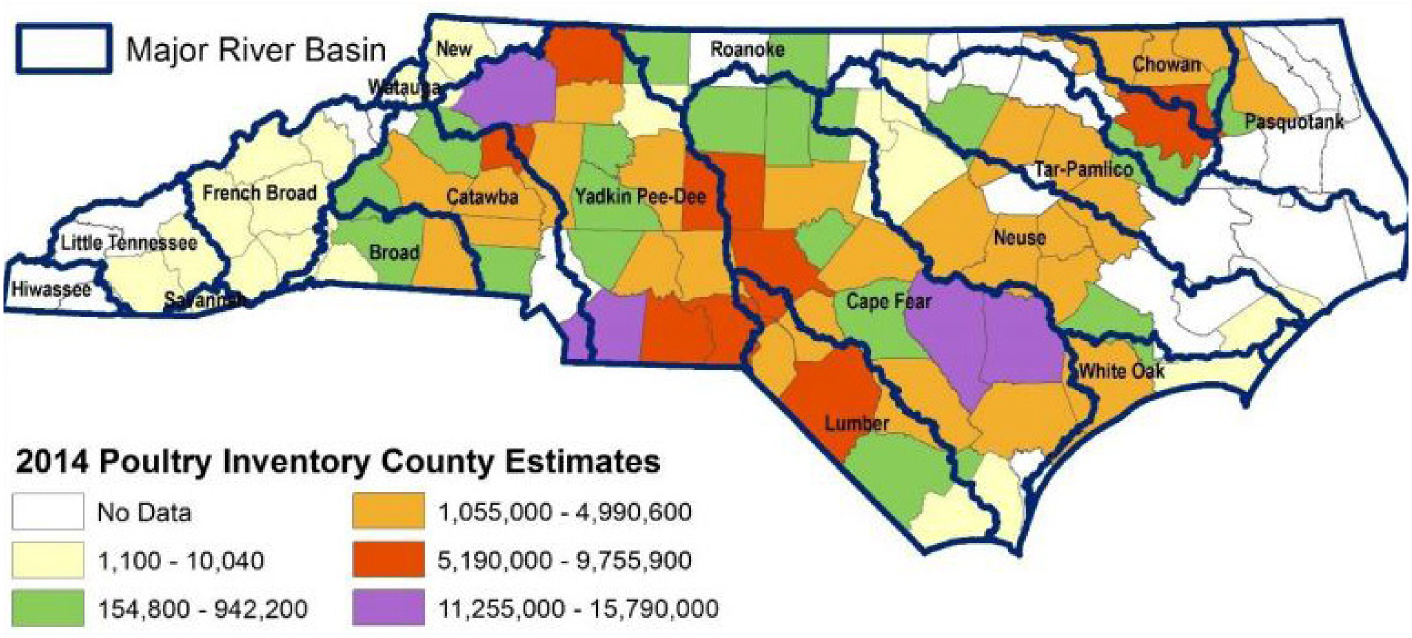
There are 103 active wastewater treatment facilities in the High Rock Lake watershed (NCDWR, 2019a). These facilities include municipal wastewater treatment plants, as well as industrial, state, and individual dischargers. Wastewater facility permits are categorized as minor or major depending on how much wastewater is produced and treated. Discharges from treatment systems treating domestic waste with a design flow greater than 1.0 million gallons per day (MGD) or with a pre-treatment program are classified as major discharges. Industrial and commercial discharges are classified based on several factors including flow, waste characteristics and water quality and health impacts.

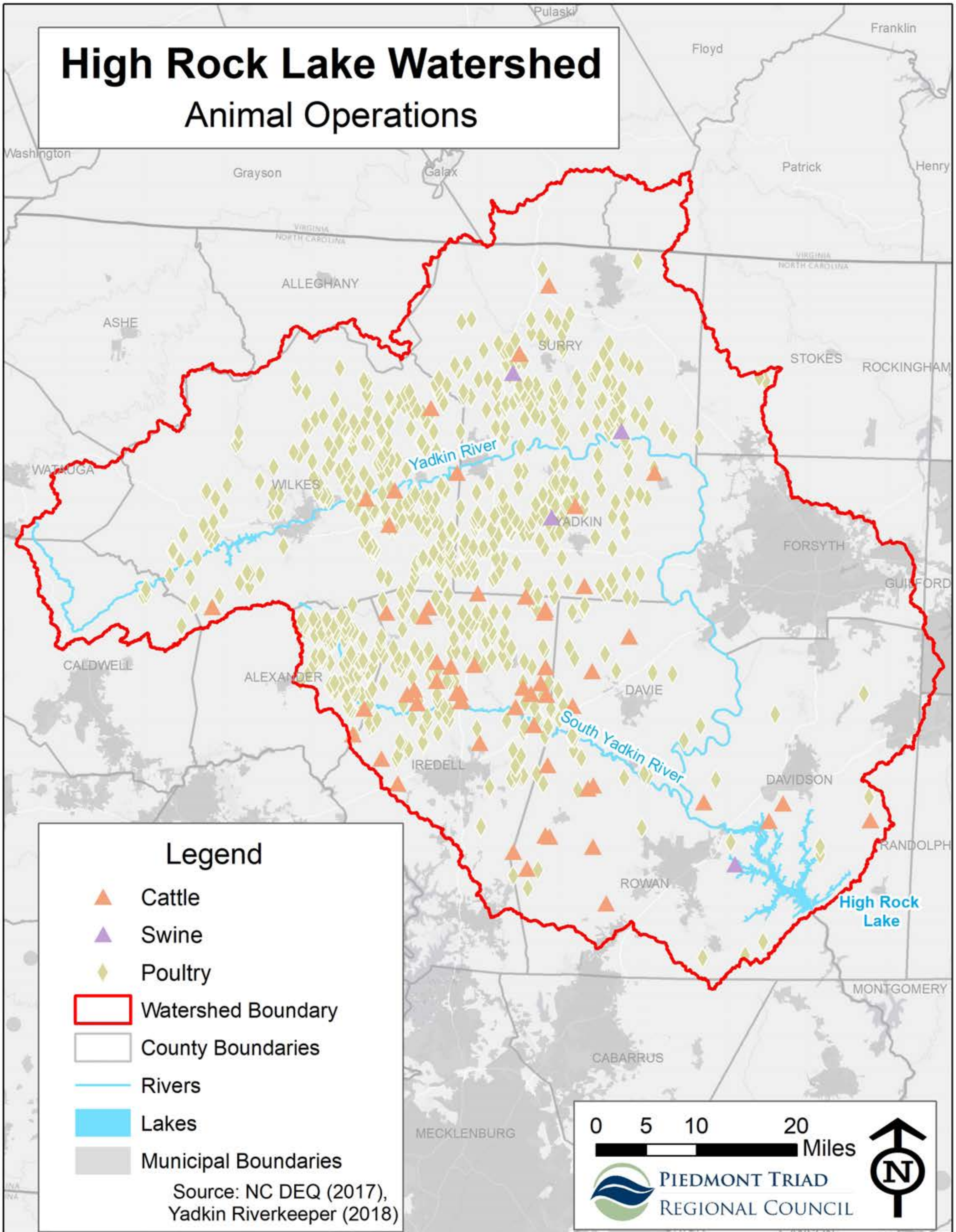

High Rock Lake Watershed
Wastewater Treatment Facilities
Pulaski
Franklin
Floyd
Washington
Grayson
Galax
Patrick
Henry
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WATAUGA
WILKES
Yadkin River
YADKIN
FORSYTH
GUILFORD
CALDWELL
ALEXANDER
DAVIE
South Yadkin River
IREDELL
DAVIDSON
BURKE
RANDOLPH
ROWAN
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
ANSON
RICHMOND
Legend
Wastewater Treatment Facilities
Major
Minor
Watershed Boundary
County Boundaries
Rivers
Lakes
Municipal Boundaries
Source: NC DEQ (2017)
0 5 10 20
Miles
N
Piedmont Triad Regional Council

Animal Operations

There are 63 permitted animal operations within the High Rock Lake watershed, including 57 cattle farms and 6 hog farms (NCDWR, 2019b). Waste from cattle and hog farms is typically stored in lagoons where it is held until it can be applied onto nearby fields based on an approved Certified Animal Waste Management Plan. Depending on soil composition, weather, and application rates, these practices can sometimes be a source of excess nutrients if not properly managed. In 1997, the North Carolina legislature placed a moratorium on all new hog facilities in the state and ordered the Department of Agriculture and Consumer Affairs to develop a plan to phase out anaerobic lagoons and spray fields as the primary methods of disposing of swine waste. Since that time, there has been an increase in poultry operations in the watershed and across the state. Between 1997 and 2017, the number of egg-laying and broiler chickens and turkeys sold in North Carolina increased from 660 million to 891 million (USDA NASS, 1997 & 2017). Poultry are now estimated to be a larger source of nutrients than cattle in the basin and, according to research by NCDWR, generate approximately 6 times more plant-available nitrogen and phosphorus (Patt, 2017). Dry-litter poultry operations are not required to apply for permits from the state, but must follow general requirements regarding storage, land application, soil testing, and record keeping. According to research by the Yadkin Riverkeeper, there are currently an estimated 741 poultry operations in the High Rock Lake watershed.

2014 Poultry Inventory County Estimates (Patt, 2014)





High Rock Lake Watershed
Animal Operations
Pulaski
Floyd
Franklin
Washington
Grayson
Galax
Patrick
Henry
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WATAUGA
WILKES
Yadkin River
YADKIN
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GUILFORD
CALDWELL
ALEXANDER
DAVIE
South Yadkin River
IREDELL
DAVIDSON
RANDOLPH
ROWAN
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
ANSON
RICHMOND
Legend
Cattle
Swine
Poultry
Watershed Boundary
County Boundaries
Rivers
Lakes
Municipal Boundaries
Source: NC DEQ (2017), Yadkin Riverkeeper (2018)
0 5 10 20 Miles
N
Piedmont Triad Regional Council

Previous Modeling Efforts

Since 2005, High Rock Lake has been the subject of several special studies, including the development of a lake and watershed model and intensive water quality monitoring to support these two efforts. The watershed model, which was completed in 2012, estimates land use contributions to nutrient and sediment loads, while the lake model, which was completed in 2013 and revised in 2016, helps users interpret and predict hydrodynamic and water quality responses to natural phenomena or man-made pollution. These two models work together to simulate conditions within High Rock Lake. Both models were developed by Tetra Tech and NCDWR with the support of a Technical Advisory Committee (TAC) comprised of members of state agencies and local governments, as well as the Yadkin Riverkeeper and Alcoa Power Generating, who was the owner of the Yadkin Project prior to Cube Hydro and Eagle Creek Renewable Energy. High Rock Lake is presently the focus of a plan to revisit North Carolina's nutrient-related water quality criteria. Nutrient strategy development is anticipated to commence upon the completion of that effort and in consultation with stakeholders in the watershed.

High Rock Lake Watershed Model

The High Rock Lake Watershed Model was developed in 2012 by Tetra Tech using the Hydrologic Simulation Program – FORTRAN (HSPF), which is a comprehensive, EPA-supported watershed modeling package that can simulate water quantity and quality for a wide range of pollutants. This model is used to estimate flow, suspended solids, phosphorus, and nitrogen loads delivered to the lake from both point and nonpoint sources. Based on Tetra Tech's review of model performance, it does a good" to "very good" job of predicting hydrologic conditions. There is more variability in water quality simulations, but they meet a majority of the calibration targets and successfully explain most of the spatial and temporal variability observed in gaging and monitoring data. Based on model predictions of average annual loading for the simulation period of 2000-2009, a majority of flow and pollutant loads reach High Rock Lake via the main stem of the Yadkin River, which accounts for about 70% of the flow, 62% of the sediment, 71% of the phosphorus, and 68% of the nitrogen reaching the lake (Tetra Tech, 2012). Estimated flow and pollutant loads for each major stream have been provided in Table 1 on the following page.

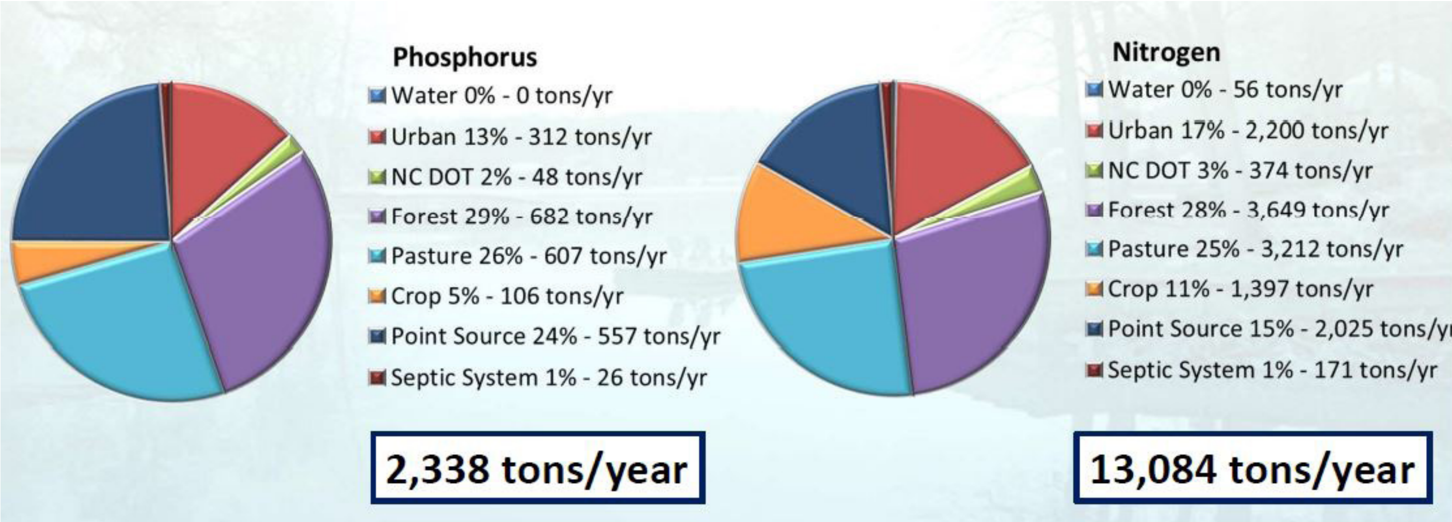
Table 1: Annual Average Watershed Flow and Pollutant Loads Delivered to High Rock Lake (Tetra Tech, 2012)

Watershed	Flow (AF/yr)	TSS (t/yr)	TP (t/yr)	TN (t/yr)
Yadkin River	1,951,767 (69.5%)	326,964 (62.5%)	685 (71.3%)	4,092 (67.5%)
South Yadkin River	558,544 (19.9%)	151,858 (29.0%)	178 (18.5%)	1,286 (21.2%)
Grants Creek	38,740 (1.4%)	8,284 (1.6%)	14 (1.4%)	101 (1.7%)
Abbotts Creek	148,500 (5.3%)	18,624 (3.6%)	49 (5.1%)	347 (5.7%)
Flat Swamp Creek	21,671 (0.8%)	3,625 (0.7%)	9 (0.9%)	53 (0.9%)
Dutch Second Creek	18,409 (0.7%)	3,452 (0.7%)	7 (0.8%)	52 (0.9%)
Town/Crane Creek	26,001 (0.9%)	4,576 (0.9%)	9 (0.9%)	65(1.1%)
Swearing Creek	27,808 (1.0%)	5,916 (1.1%)	9 (1.0%)	70 (1.1%)
North and South Potts Creek	18,605 (0.7%)	3,856 (0.7%)	8 (0.8%)	53 (0.9%)
Total	2,810,045	523,299	960	6,066

Algal Bloom at High Rock Lake

High Rock Lake, Davidson & Rowan County

Photo Credit: Yadkin Riverkeeper



The delivered loads shown in Table 1 result from a variety of point and nonpoint sources. Sources of suspended solids and nutrients considered within the watershed model include urban stormwater, forest, pasture and cropland, roads, and point sources. Loading from septic systems and atmospheric deposition are also represented within the model, however, the model's ability to predict pollutant loads from septic systems is greatly constrained by a lack of available data regarding septic system location, numbers, flow quantity, flow quality, and failure rates.

According to Tetra Tech's watershed model, the total nutrient budget for the High Rock Lake watershed is around 13,084 tons per year of nitrogen and 2,338 tons per year of phosphorus. Forests and pasture make up the highest percentage of nitrogen and phosphorus, followed by point sources and urban land. This is largely due to the fact that forests and pasture are the two most prominent land cover types within the watershed, as discussed on pg. 7 of this report. Although it may not be intuitive, forests do contribute to nutrient loads, primarily through organic matter (including leaf litter, other debris, and dissolved organic compounds, such as humic acids), while other sources typically export nutrients in inorganic forms (Tetra Tech, 2012). High Rock Lake Nutrient Management Strategy discussions are currently focused on reducing total phosphorus and inorganic nitrogen. Table 2 provides a more detailed analysis of nutrient sources and their contribution by each sub-watershed.

Table 2: Largest Sources of Pollutant Load by Constituent and Location (Tetra Tech, 2012)

Constituent	Location	Largest Contributor	Second Largest Contributor	Third Largest Contributor
Total Suspended Solids	Yadkin River at Yadkin College	Urban (non-MS4)	Crop	Pasture
	South Yadkin River near Mocksville	Pasture	Urban (non-MS4)	Crop
	Abbotts Creek at Lexington	Urban MS4	Pasture	Urban (non-MS4)
	Second Creek near Barber	Crop	Pasture	Urban (non-MS4)
	Muddy Creek near Muddy Creek	Urban MS4	Urban (non-MS4)	NC DOT
Total Phosphorus	Yadkin River at Yadkin College	Point Source	Forest	Pasture
	South Yadkin River near Mocksville	Pasture	Forest	Urban (non-MS4)
	Abbotts Creek at Lexington	Pasture	Point Source	Forest
	Second Creek near Barber	Pasture	Forest	Urban (non-MS4)
	Muddy Creek near Muddy Creek	Point Source	Urban MS4	Forest
Total Nitrogen	Yadkin River near Yadkin College	Forest	Pasture	Point Source
	South Yadkin River near Mocksville	Pasture	Forest	Urban (non-MS4)
	Abbotts Creek at Lexington	Point Source	Pasture	Forest
	Second Creek near Barber	Pasture	Crop	Urban (non-MS4)
	Muddy Creek near Muddy Creek	Point Source	Urban MS4	Urban (non-MS4)

High Rock Lake Hydrodynamic & Nutrient Response Models

The High Rock Lake Hydrodynamic & Nutrient Response Models were developed in 2012 by Tetra Tech using a combination of Environmental Fluid Dynamics Code (EFDC) and the Water Quality Analysis Simulation Program (WASP). The primary purpose of these two models is to simulate water flow, temperature, and water quality responses within the lake depending on natural conditions or pollutant loads. The nutrient response model has since been updated twice by the U.S. Environmental Protection Agency (EPA) to address comments received from the High Rock Lake TAC. NCDWR further revised the model in October 2016 to correct errors in the WASP model input files and updated the draft report to incorporate results of the final model.

The resulting nutrient model appears to perform well and meets most targets for a "good" quality simulation in terms of relative error and coefficient of variation. However, the correlation between observed and simulated concentrations of nutrients and chlorophyll a is generally low, suggesting a limited ability to predict individual algal blooms in this dynamic water body. Inputs that determine chlorophyll a response in the lake are primarily flow, nutrient load (nitrogen and phosphorus), and light availability, which is strongly affected by fine sediment load.

High Rock Lake Technical Advisory Committee & Model Review

The watershed and nutrient response models were both deeply informed by a Technical Advisory Committee, which NCDWR assembled in August 2005 to assist with development of monitoring and mathematical tools for the management of nutrients, algae (chlorophyll a) and turbidity in High Rock Lake. The High Rock Lake TAC was primarily comprised of members of state agencies and local governments, as well as the Yadkin Riverkeeper and Alcoa Power Generating. Over the course of model development, the TAC met 18 times to provide recommendations for monitoring, model development, and performance criteria. The TAC provided additional comments and feedback following each iteration of the watershed and nutrient response models. Some of the watershed model's remaining limitations include:

- Insufficient data available regarding the location, number, flow quantity, flow quality, and failure rates of septic systems within the watershed to accurately predict their contribution to water quality conditions. To address this issue, septic systems were modeled as point sources with an assumed failure rate of 10%. Septic loads were assigned based on a conceptual model developed by Tetra Tech in consultation with the NC Department of Public Health.

- Insufficient data to explicitly represent the impact of animal operations in the watershed model. Instead, loading associated with animal operations was incorporated into the general pasture land use classification.

- Additional information on channel morphology and sediment processes within the watershed could also improve the model.

All model review comments and responses can be found on NCDWR's website at https://deq.nc.gov/about/divisions/water-resources/planning/modeling-assessment/special-studies#HRL.

High Rock Lake Nutrient Management Strategy

Following the completion of model development in 2016, NCDWR began to meet with stakeholders throughout the High Rock Lake watershed to develop a nutrient management strategy. However, this effort has been postponed, as North Carolina is revisiting their nutrient related water quality criteria. It is unclear at this time when nutrient-related criteria will be finalized. Nutrient strategy development for High Rock Lake will recommence upon the completion of that effort.

Boone's Cave Park

Yadkin River, Davidson County

Total Maximum Daily Loads (TMDLs)

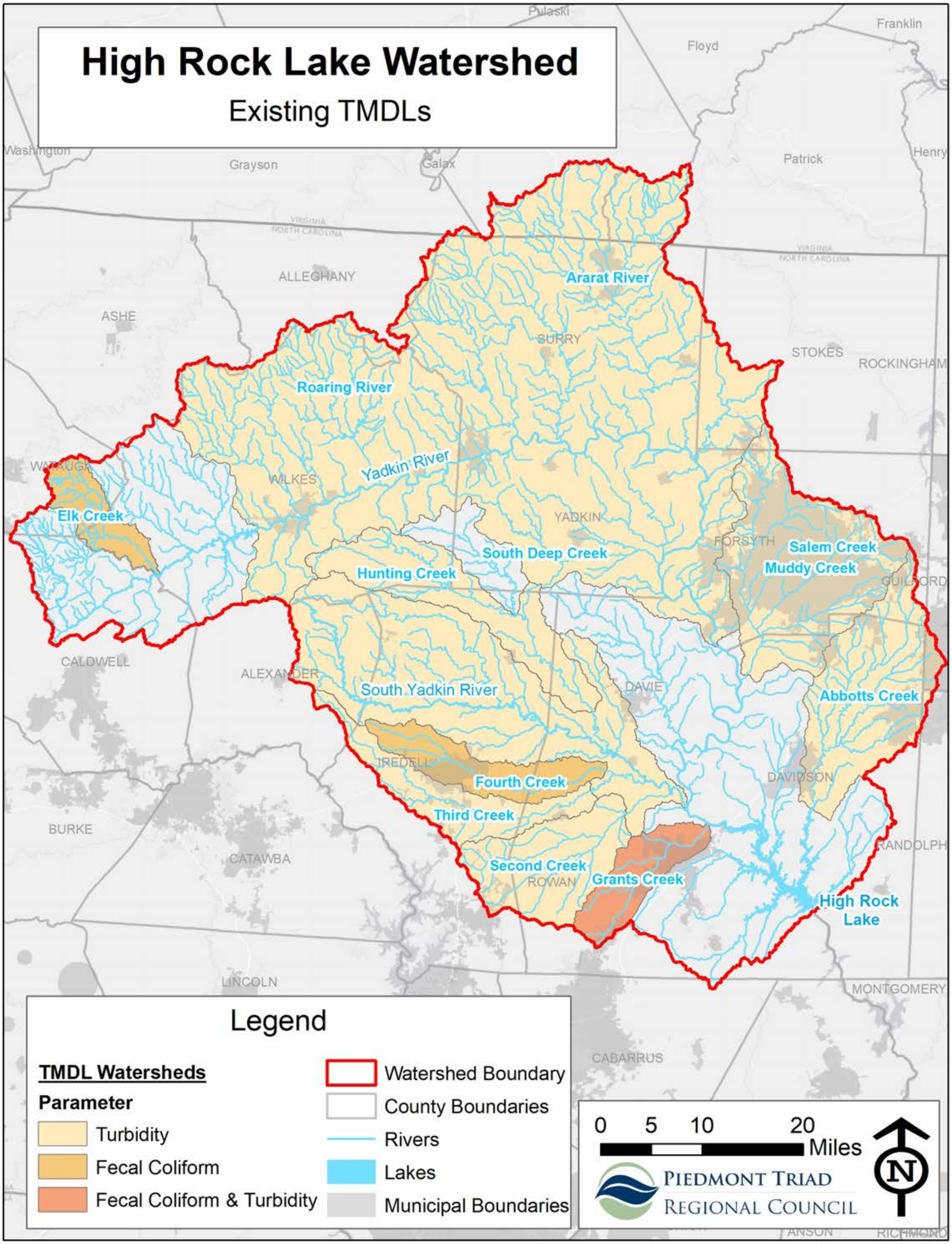
A total maximum daily load (TMDL) is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. All states are required by Section 303(d) of the 1972 Federal Clean Water Act (CWA) to develop TMDLs for water bodies that are impaired (too polluted to maintain their beneficial uses). The TMDL is then used to establish limits on sources of the pollutant which are classified as either point sources (waste load allocation) or non-point sources (load allocation). The TMDL must account for seasonal variation in water quality and include a margin of safety to ensure that the TMDL allocations will adequate to protect the body of water. TMDLs have been developed for 11 major tributaries within the High Rock Lake watershed to address total suspended solids, while 6 have been established to address fecal coliform bacteria.

Table 3: Total Suspended Solids (tons/day) TMDLs

Watershed	Existing Load	WLA	LA	MOS	TMDL
Abbotts Creek	21.30	0.064	9.236	10%	9.30
Ararat River	28.20	0.170	12.830	10%	13.00
Fourth Creek	9.85	0.515	4.745	10%	5.26
Grants Creek	8.03	0.683	4.17	10%	5.54
Hunting Creek	23.40	0.000	11.200	10%	11.20
Muddy Creek	44.30	5.462	16.14	10%	21.60
Second Creek	5.20	0.170	2.977	10%	3.10
South Deep Creek	16.40	0.003	8.497	10%	8.50
South Yadkin River	50.20	0.179	25.221	10%	25.40
Third Creek	13.30	0.489	6.4111	10%	6.90
Yadkin River	361.50	4.014	146.986	10%	151.00

Table 4: Fecal Coliform (cfu/day) TMDLs

Watershed	Existing Load	WLA	LA	MOS	TMDL
Elk Creek	1.08E+12	0	5.58E+11	6.20E+10	6.20E+11
Fourth Creek	-	9.09E+11	4.59E+13	25 cfu/100ml	200 cfu/100ml
Grants Creek	-	1.75E+11	2.18E+13	3.14E+12	2.51E+13
Hamby Creek	-	9.39E+10	3.21E+10	Implicit & Explicit (10%)	1.26E+11
Rich Fork	-	6.06E+10	5.70E+9	Implicit & Explicit (10%)	6.63E+10
Salem Creek	5.74E+12	7.49E+11	7.37E+10	9.14E+10	9.14E+11


High Rock Lake Watershed
Existing TMDLs
Pulaski
Floyd
Franklin
Washington
Grayson
Galax
Patrick
Henry
ALLEGHANY
ASHE
Ararat River
SURRY
STOKES
ROCKINGHAM
Roaring River
Yadkin River
WATAUGA
WILKES
YADKIN
Elk Creek
FORSYTH
Salem Creek
Muddy Creek
GUILFORD
South Deep Creek
Hunting Creek
CALDWELL
ALEXANDER
DAVIE
South Yadkin River
Abbotts Creek
IREDELL
Fourth Creek
DAVIDSON
Third Creek
BURKE
CATAWBA
RANDOLPH
Second Creek
ROWAN
Grants Creek
High Rock Lake
LINCOLN
MONTGOMERY
CABARRUS
ANSON
RICHMOND
Legend
TMDL Watersheds
Parameter
Turbidity
Fecal Coliform
Fecal Coliform & Turbidity
Watershed Boundary
County Boundaries
Rivers
Lakes
Municipal Boundaries
0 5 10 20
Miles
N
PIEDMONT TRIAD
REGIONAL COUNCIL

Carter Falls
Elkin Creek, Surry County

Local Watershed Plans

Local watershed plans will play a crucial role in restoring water quality throughout the High Rock Lake watershed. These plans identify potential point and nonpoint sources of pollution at a smaller, more detailed scale (typically 12-digit HUC or smaller) and develop restoration goals and strategies to improve water quality. Once an approved watershed plan is in place for an impaired stream or waterbody, local government or non-profit agencies can apply for 319 funding to support watershed restoration projects, such as stormwater and agricultural best management practices. Although there are over 90 individual stream segments and waterbodies within the High Rock Lake watershed that are impaired, only 5 local watershed plans have been developed thus far. These streams include Lower Abbotts Creek, Rich Fork Creek, Salem Creek, Second Creek, and Swearing Creek. The PTRC also developed a water supply protection plan for Big Elkin Creek and sections of the Yadkin River near Elkin and Jonesville in 2015.

Table 5: Approved Local Watershed Plans

Watershed	Year Completed	Lead Planning Agency	Document Link
Lower Abbotts Creek	2011	PTRC	https://files.nc.gov/ncdeq/Water%20Quality/Planning/NPU/319/WatershedMGTPlans_9element/LowerAbbotsCreekWRPrevised092011.pdf
Rich Fork Creek	2008	PTRC	https://www.ptrc.org/home/showdocument?id=1272
Salem Creek	2010	HDR Engineering, Inc	https://files.nc.gov/ncdeq/Water%20Quality/Planning/NPU/319/WatershedMGTPlans_9element/SalemCreek9ElelmentChecklist_and_SupportingDocuments.pdf
Second Creek	2008	Land of Lakes, RC & D	http://portal.ncdenr.org/c/document_library/get_file?uuid=66a7694e-b2e0-45b6-92d4-ec51dadb77c9&groupId=38364
Swearing Creek	2018	PTRC	https://www.ptrc.org/services/regional-planning/water-resources/ongoing-projects/swearing-creek-watershed-restoration-plan

Table 6: Other Watershed Protection Plans

Watershed	Year Completed	Lead Planning Agency	Document Link
Big Ekin Creek & Yadkin River	2015	PTRC	https://files.nc.gov/ncdeq/Water%20Resources/files/swap/SWPP%20Elkin.pdf

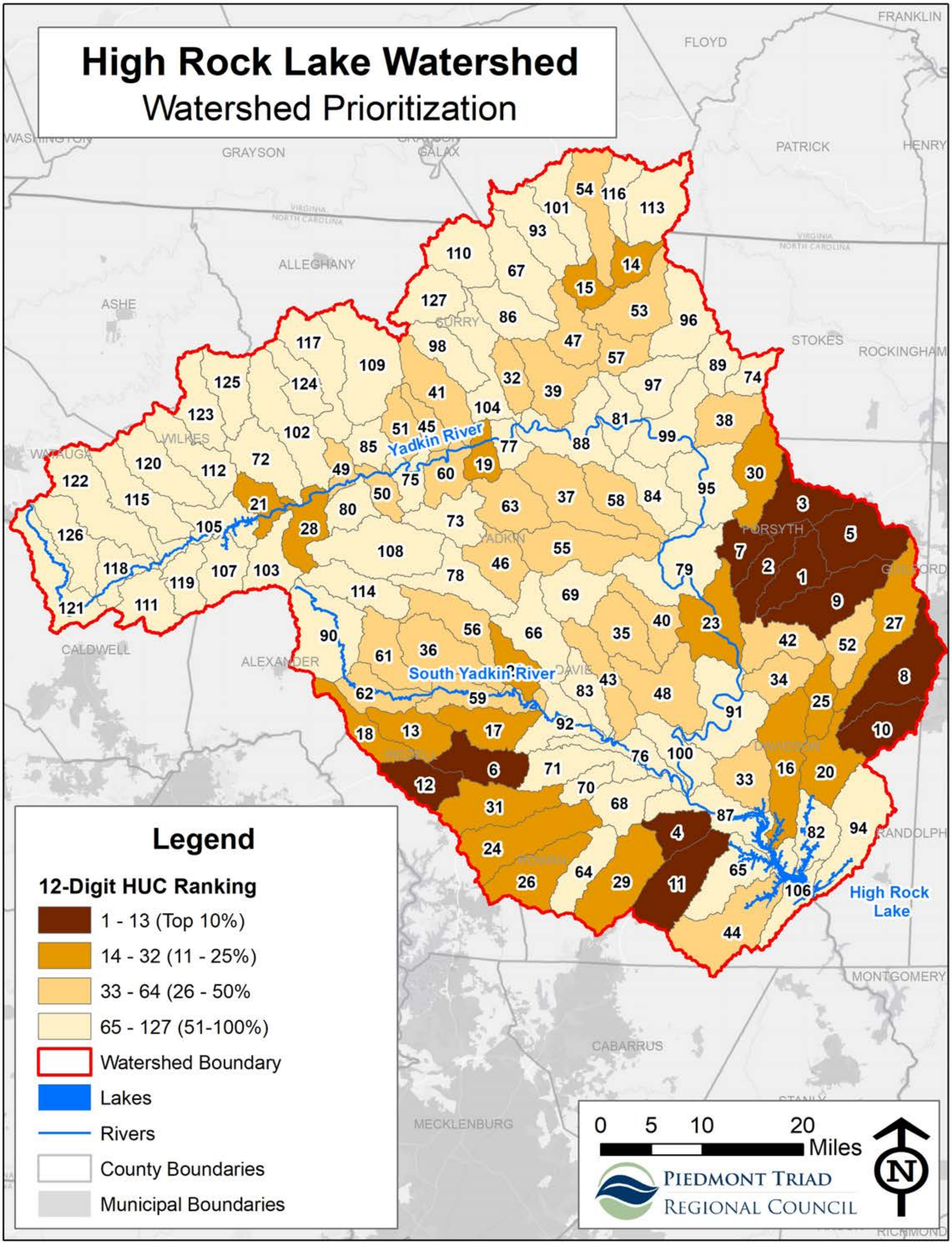
Watershed Prioritization Tool

In order to determine where best to target and prioritize restoration efforts, the project team developed a watershed prioritization tool using GIS modeling technology. This tool compares demographic, land use, and environmental characteristics across the High Rock Lake watershed in order to predict where water resources are under the greatest stress from pollutant sources (primarily those that contribute to sediment and nutrient loads). In total, fourteen data layers were included within the model and overlaid, including impervious surface cover, animal operations, soil characteristics, impact sites, roads, forest cover, population density, elevation, parcel size, zoning, and floodplain data. Local watersheds (12-digit HUCs) were then scored and ranked based on the combination of input data and environmental conditions. Watersheds with higher concentrations of pollutant sources received a higher score and rank, while those in relatively pristine condition received lower scores and priority. The watershed prioritization tool is not meant to be prescriptive, but rather enable stakeholders to make better informed decisions and investments in the watershed, based on our current knowledge of High Rock Lake, to achieve meaningful water quality benefits.

The top 10% of watersheds with the highest stress values are primarily located near urban centers, such as Winston-Salem, High Point, Statesville, Salisbury, and Thomasville. This reflects the high concentrations and weight given to impervious surface cover in the model. However, other factors may be contributing to water quality impairments in these areas when examined in more detail at a local scale. Efforts to improve water quality conditions throughout the High Rock Lake watershed should prioritize watersheds with the highest stress values, which are listed in order below.

Table 7: Priority Watersheds

RANK	HUC	Location
1	Lower Salem Creek (030401011305)	Winston-Salem
2	Middle Muddy Creek (030401011306)	Winston-Salem
3	Mill Creek (030401011301)	Winston-Salem
4	Lower Gants Creek (030401030102)	Salisbury/Spencer
5	Upper Salem Creek (030401011304)	Winston-Salem
6	Middle Fourth Creek (030401020402)	Statesville
7	Upper Muddy Creek (030401011303)	Winston-Salem/Lewisville
8	Rich Fork (030401030203)	High Point
9	South Fork Muddy Creek (030401011307)	Winston-Salem
10	Hamby Creek (030401030204)	Thomasville
11	Town of Spencer-Headwaters Cane Creek (030401030301)	Salisbury/Spencer
12	Upper Third Creek (030401020302)	Statesville
13	Upper Fourth Creek (030401020402)	Statesville


High Rock Lake Watershed
Watershed Prioritization
Legend
12-Digit HUC Ranking
1 - 13 (Top 10%)
14 - 32 (11 - 25%)
33 - 64 (26 - 50%
65 - 127 (51-100%)
Watershed Boundary
Lakes
Rivers
County Boundaries
Municipal Boundaries
0 5 10 20
Miles
N
Piedmont Triad Regional Council
Yadkin River
South Yadkin River
High Rock Lake
FRANKLIN
FLOYD
PATRICK
HENRY
GRAYSON
GALAX
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
WILKES
WATAUGA
FORSYTH
YADKIN
GUILFORD
CALDWELL
ALEXANDER
DAVIE
DAVIDSON
RANDOLPH
ROWAN
MONTGOMERY
CABARRUS
MECKLENBURG
RICHMOND
VIRGINIA
NORTH CAROLINA

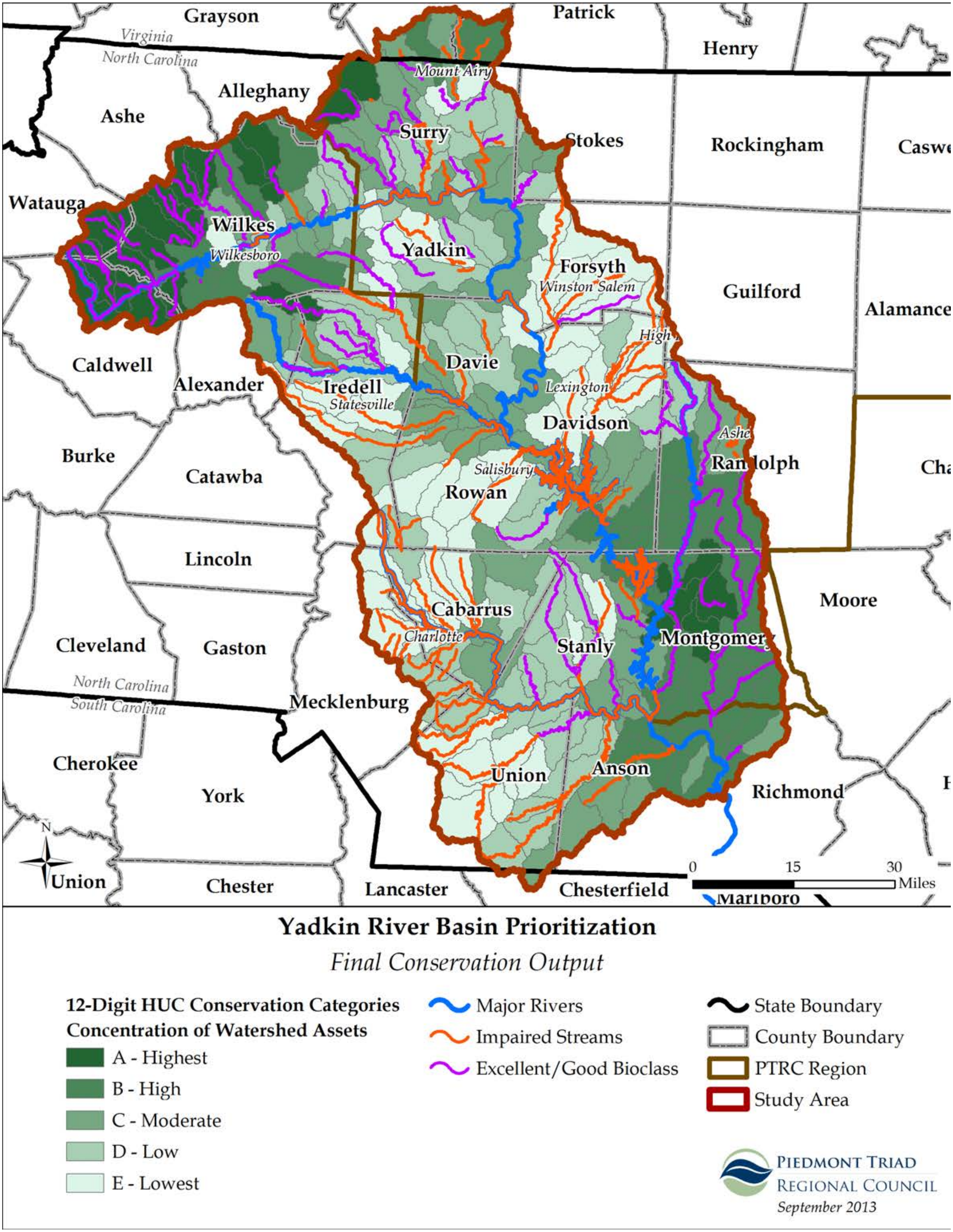
Conservation Priorities

Although restoration projects, such as stormwater control measures and best management practices, are critical tools to improve water quality, it is often far more cost effective to prevent degradation before it happens. Land conservation helps protect water quality by capturing stormwater, filtering pollutants, preventing erosion and flooding, and recharging groundwater. It also protects critical wildlife habitat, agricultural lands, and provides opportunities for outdoor recreation and tourism. By strategically conserving undeveloped land local stakeholders can help protect High Rock Lake and its tributaries from further impacts associated with development.

In 2013, the Piedmont Triad Regional Council developed a GIS-based model to help prioritize land for conservation within all three of the piedmont triad's major river basins (Cape Fear, Dan, and Yadkin-Pee Dee river basins). The model compares biodiversity/wildlife habitat, impervious surface cover, canopy cover, hydric soils, soil erodibility, floodplain, public land, population density, steep slopes, parcel size, and zoning data to identify areas that provide the most ecological benefits. In general, undeveloped areas near streams that provide critical wildlife habitat received the highest scores. Each HUC was ranked based on its mean conservation value. Map 12 shows the watersheds within the Yadkin-Pee Dee River Basin that have the highest concentration of ecologically significant land. Conservation efforts should target parcels within these watersheds to most effectively improve water quality and protect natural resources.

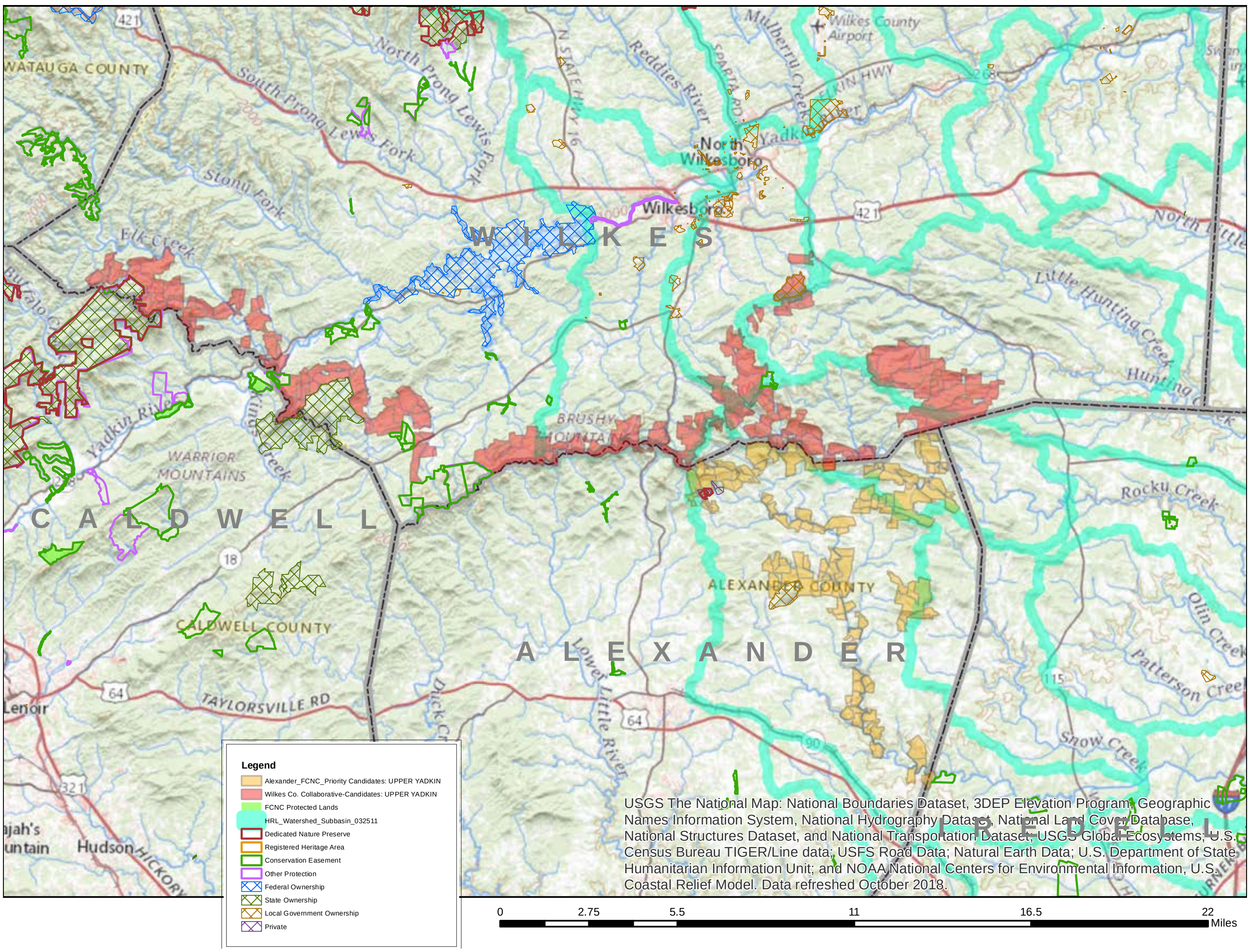
Environmental conservation efforts are often most effective when they are coordinated with other local and regional priorities, such as farmland preservation, outdoor recreation, or flood prevention. Local stakeholders should partner with Soil and Water Conservation Districts and local Parks and Recreation and Planning departments to identify specific properties that align with agricultural, recreation, and environmental goals. Land trusts, such as the Piedmont Land Conservancy, Three Rivers Land Trust, Foothills Conservancy, and Blue Ridge Conservancy can provide technical assistance when specific parcels or projects are identified.

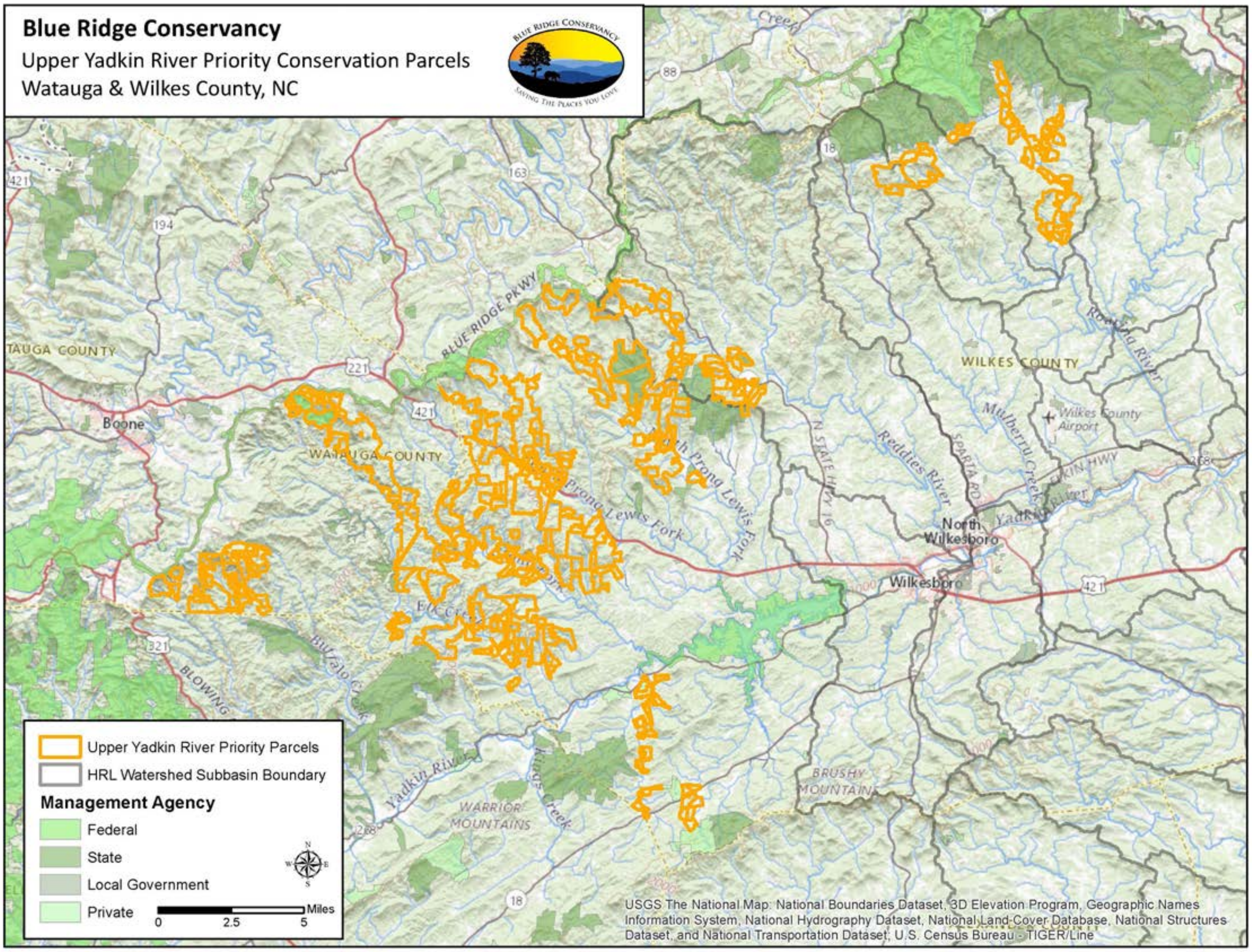
Several federal programs provide funding for voluntary floodplain buyouts. This funding can be used to purchase flood-damaged property and maintain it as open space to prevent future flood damage. Local governments can also help conserve natural resources by encouraging or mandating land use practices such as cluster development, open space requirements, built upon area limits, or stormwater control measures to protect High Rock Lake, the Yadkin River, and its tributaries.


Grayson
Patrick
Virginia
North Carolina
Henry
Mount Airy
Alleghany
Ashe
Surry
Stokes
Rockingham
Wataugа
Wilkes
Wilkesboro
Yadkin
Forsyth
Winston Salem
Guilford
Alamance
Caldwell
Alexander
Davie
High
Iredell
Statesville
Lexington
Burke
Catawba
Davidson
Asheboro
Randolph
Salisbury
Rowan
Lincoln
Moore
Cabarrus
Charlotte
Cleveland
Gaston
Stanly
Montgomery
North Carolina
South Carolina
Mecklenburg
Cherokee
Union
Anson
Richmond
York
Union
Chester
Lancaster
Chesterfield
Marlboro
0
15
30
Miles
N
Yadkin River Basin Prioritization
Final Conservation Output
12-Digit HUC Conservation Categories
Concentration of Watershed Assets
A - Highest
B - High
C - Moderate
D - Low
E - Lowest
Major Rivers
Impaired Streams
Excellent/Good Bioclass
State Boundary
County Boundary
PTRC Region
Study Area
Piedmont Triad Regional Council
September 2013

In addition to the regional conservation model that was developed by PTRC, the Blue Ridge Conservancy and Foothills Conservancy of NC have taken steps to identify conservation priorities in Wilkes and Alexander County. Most of the parcels that have been identified as conservation priorities are located along the headwaters of the Reddies and Roaring River and the main stem of the Yadkin River and South Yadkin River. These parcels would provide valuable riparian buffers for the river basin's headwater streams and help filter and capture nutrients before they enter the river.

UPPER YADKIN BASIN: FOOTHILLS CONSERVANCY AND COLLABORATING PARTNERS:
PARCEL CANDIDATES - CONSERVATION PRIORITIES

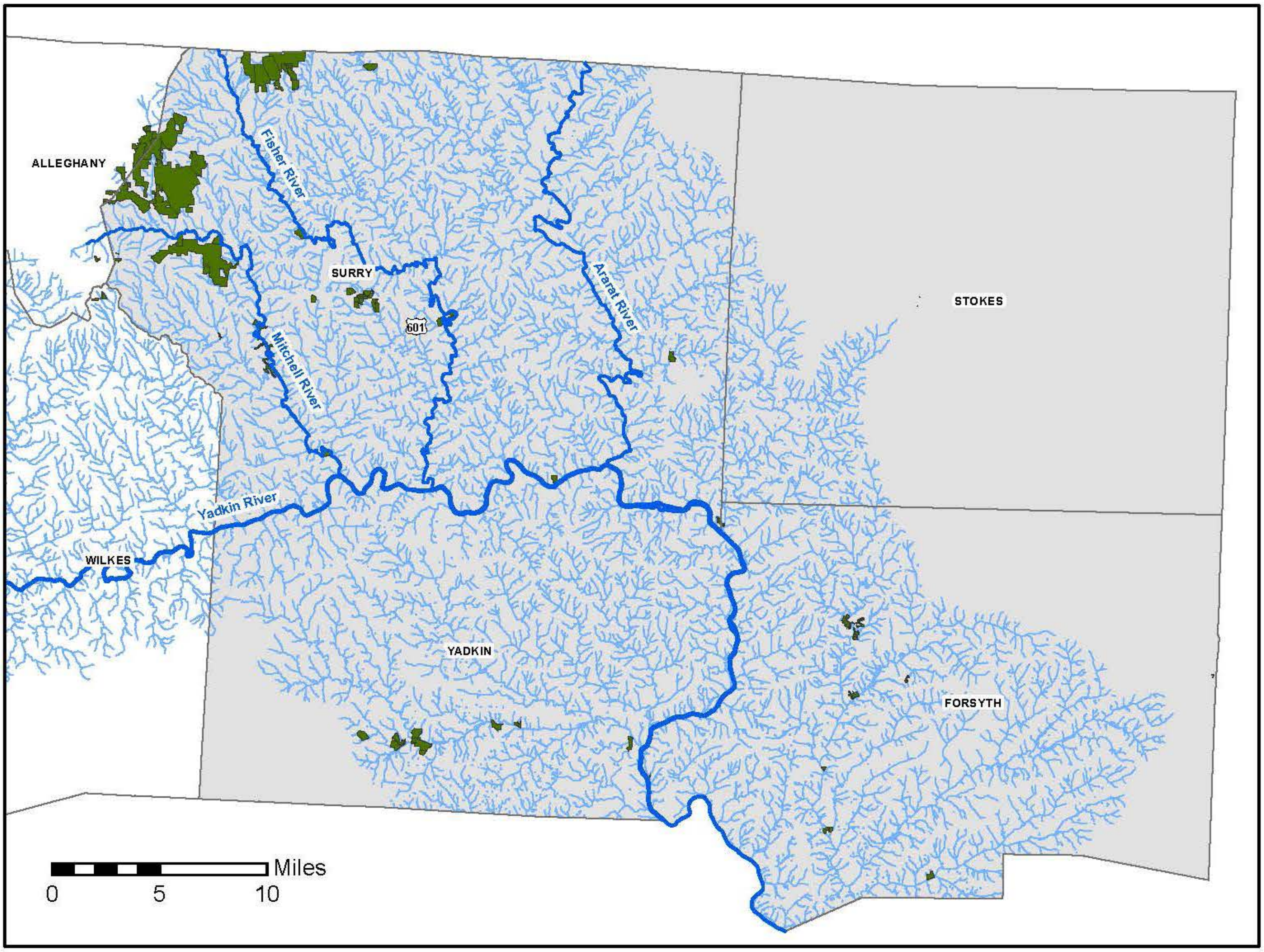




The Piedmont Land Conservancy (PLC) currently manages several properties in Surry, Stokes, Yadkin, and Forsyth County that have been placed under conservation easements. The largest protected areas are predominantly located in Surry County along the Mitchell and Fisher River. PLC also recently acquired 241 acres on US Highway 21 near Stone Mountain State Park to conserve steep, forested slopes and the headwaters of Elkin Creek. This tract, combined with an adjacent, 56-acre tract donated to PLC by the Chatham Family in 1999, creates a 297-acre preserve that will be transferred to the Town of Elkin for permanent ownership.

PLC Protected Sites in the Yadkin River Watershed (within the PLC Service Area)

as of December 31, 2019



PLC Protected Sites in the Yadkin River watershed within PLC's service area

PLC Service Area Counties*

Yadkin River Watershed in counties PLC has protected sites

* Note: Alleghany and Wilkes are not in PLC's service area; however, PLC works in Alleghany County within the Mitchell River watershed, as well as in Wilkes County in areas within the Yadkin River watershed that are not covered by another land trust.

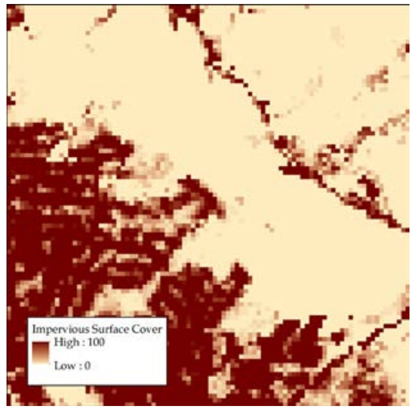
PIEDMONT LAND CONSERVANCY

P.O. Box 4025
Greensboro, NC 27404-4025
(336) 691-0088
www.piedmontland.org

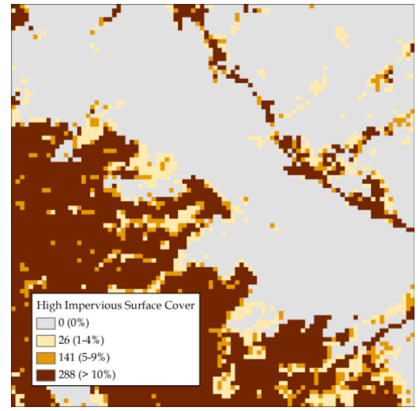
Map created May 6, 2020 by Mindy Mock

Methodology

a) Aerial - Ground Cover



b) Impervious Surface Cover Raster



c) Reclassified Raster

The methods in this analysis were based on those established in the Piedmont Triad Regional Watershed Assessment (2013), during which the Piedmont Triad Regional Council analyzed all three river basins within its service area, including the Upper Cape Fear, Yadkin Pee-Dee, and Dan River Basins. Subwatersheds throughout each river basin were then ranked based on their restoration and conservation needs using publicly-available data that was weighted according to a stakeholder driven voting process that included representatives from federal, state, and local government organizations, as well as private, non-profit, and academic sectors. Over the course of this project, the model was updated using the most recent publicly available data and modified slightly to reflect new knowledge and data sources in the basin. The Yadkin Riverkeeper shared the preliminary report and its findings and recommendations with members of the Yadkin Pee Dee River Basin Association, the Yadkin Pee Dee Water Management Group and several county soil and water conservation districts for input and feedback on the model.

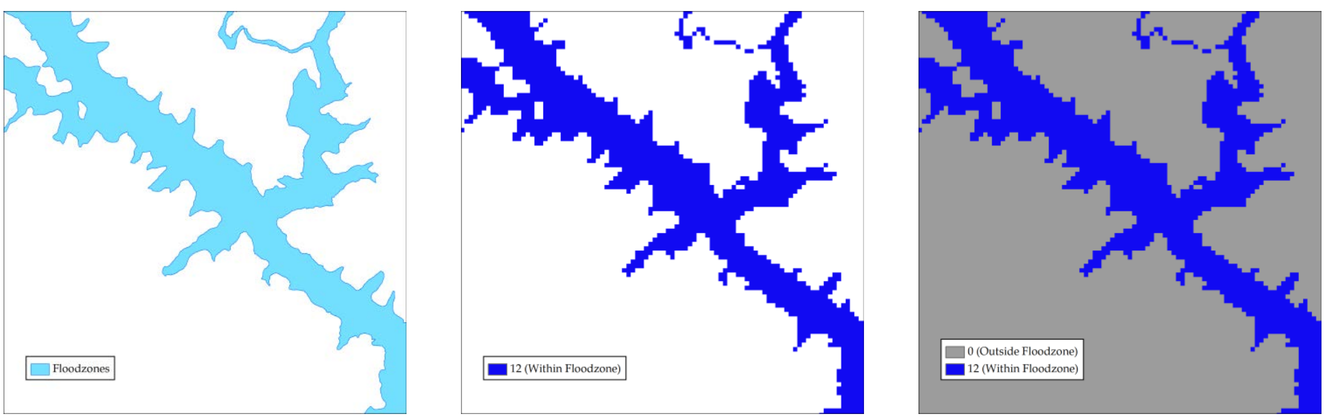
In order to uniformly assess data from as many as fourteen sources for the purposes of this project, each data layer had to be converted to raster format with a resolution of 30 meters to create a consistent data format for all of the input layers. Impervious Surface Cover and Forest Cover were obtained from the National Land Cover Database (NLCD) already in this format. Slope data was obtained from the U.S. Geological Survey in raster format with a 1 arc-second resolution (about 30 meters). These three raster layers were then reclassified and assigned integer values similar to those established during the Piedmont Triad Regional Watershed Assessment. Higher integer values were associated with a higher impact on water quality. For

Table 7: Watershed Stress Model Criteria & Weighting

Stress Layers				
Criteria	**Data Source**	**Factors**	**Integer Values**	**Layer Percentage**
High Impervious Surface Cover	NLCD 2016 Percent Developed Imperviousness	1 - 4%	26	29.3%
		5 - 9%	143	
		> 10%	293	
Cropland within 5 miles of poultry operations	Riverkeeper Alliance; NLCD 2016 landcover	Within 5 mile buffer where landcover = pasture/hay or cultivated crops	108	10.8%
Highly Erodible Soils	SSURGO (K factor)	0 - 0.23	0	8.7%
		0.24 - 0.39	34	
		0.40 - 0.49	87	
High Density of Impact Sites	NCDWR & VA DEQ	Low (1-7 per sq. mile)	41	8.1%
		High (8-48 per sq. mi)	81	
High Road Density	NCDOT & VDOT	Low	0	7.6%
		Med	0	
		High	76	
Low Forest Cover	NLCD 2011 update	< 50%	66	6.6%
High Population Density Change (2000 to 2010)	U.S. Census Bureau	1 - 9%	4	5.9%
		10 - 24%	7	
		25 - 49%	11	
		> 50%	59	
Cropland within 1 mile of cattle operations	Riverkeeper Alliance; NLCD 2016 landcover	Within 1 mile buffer where landcover = pasture/hay or cultivated crops	54	5.4%
High Population Density (2010)	U.S. Census Bureau	Low (1 -49)	12	5.2%
		Med (50-249)	37	
		High (250 +)	52	
Small Streams with Less than 50% Canopy Cover	NHD unnamed streams; NLCD 2011 canopy cover	Within 100 ft. buffer where forest cover <50%	45	4.5%
Steep Slopes	USGS NED (1 arc second)	> 15%	37	3.7%
Small Parcel Size	Counties	< 10 Acres	16	1.6%
Zoning (High Impact)	Counties/Municipalities	Commercial, Industrial, High Density Residential, Multi-family & Office	14	1.4%
Floodplain	NC Floodplain Mapping Program & VA DCR	Within 500 Year Floodplain	12	1.2%

example, the original impervious surface cover raster consisted of a cell matrix with values ranging from 0 to 100, representing the percentage of impervious surface cover within each cell. In the reclassification process, cell values ranging from 1 to 4 percent were given a new value of 26; values ranging from 5 to 9 percent were given a new value of 143; values ranging from 10 to 100 percent were given a new value of 293 to signify the high impact that impervious surfaces have on watershed conditions; and values of 0 percent were left at a value of 0 to signify no impact (see figure below). The same concept was applied to each input raster data layer.

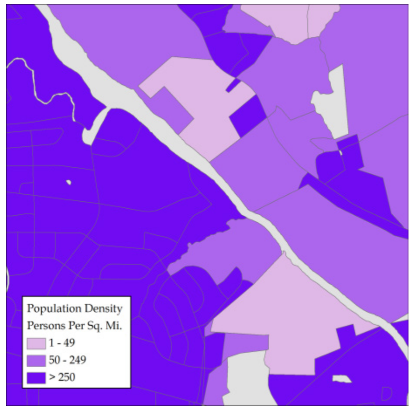
The eleven other data layers were received in vector format. Features in these layers were grouped by the factors in Table 7 and assigned integer values based on the level of anticipated impact on water quality. Each layer was then rasterized to a 30 meter cell size using the "Polygon to Raster" tool in ArcGIS. Even though the output rasters already contained the correct integer values, the "Reclassify" tool was then used on each layer to assign a value of zero to null areas in the watershed. For example, polygon features in the floodzone data layer were given values of 12. This polygon layer was then converted to a 30 meter resolution raster preserving the integer values. Because this raster contained null values for areas outside the floodzone, this raster was then reclassified so that cells within the floodzone areas maintained a value of 12 and cells outside the floodzone areas were given a value of 0 (see figure below). Each cell within the watershed boundary must be represented in the raster dataset for input in the next step, as null values would not be accepted.



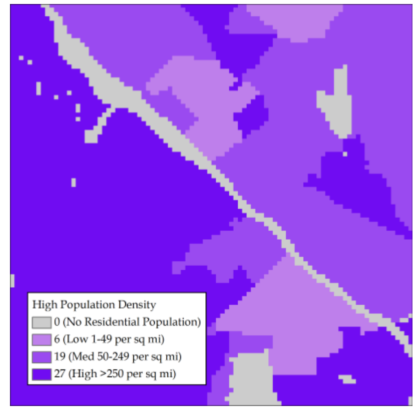
a) Original Vector Data **b) Conversion to Raster** **c) Reclassified Raster**

The figure below details another vector input example for population density. Total population values by census block were obtained from the 2010 Decennial Census. These population values were grouped by the factors in Table 7, assigned integer values similar to those established in the Piedmont Triad Regional Watershed Assessment, converted to a raster data layer, and then reclassified.

a) Aerial - Ground Cover

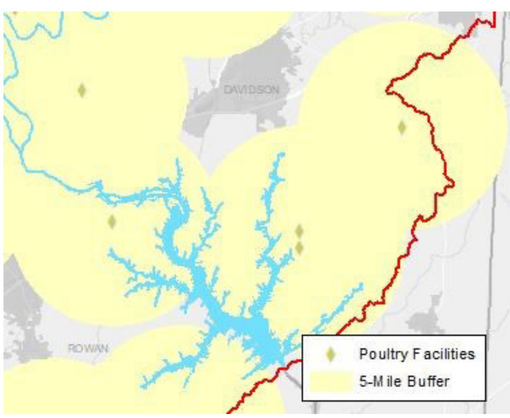


b) Original Census Blocks

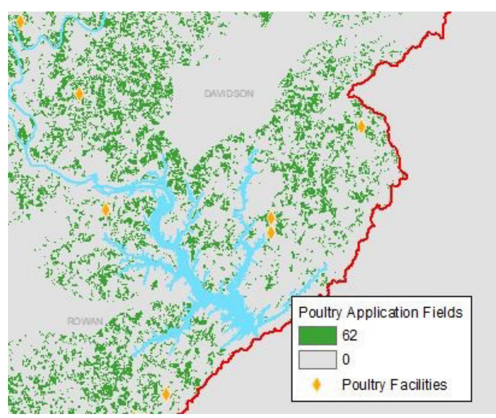


c) Reclassified Raster

Nutrient load impacts associated with cattle, swine, and poultry operations were given careful consideration in the development of the watershed prioritization tool. Most animal operations typically store animal waste onsite until it can be applied onto nearby fields based on an approved Waste Management Plan. Due to a lack of publically available manure hauler and land application data, some assumptions had to be made to estimate where waste is applied. It is estimated that most poultry waste (over 50%) is applied within a 5-mile radius of poultry facilities, while cattle waste is often applied much closer to its source (Cory-Watson 2012 & Christensen 2017). In order to more accurately reflect this transfer of nutrients, poultry and cattle facilities were assigned a 5 and 1-mile buffer respectively. The “Extract by Mask” tool was then used to select land within these buffers that is classified as “Pasture/Hay” or “Cultivated Crops”, according to the NLCD, in order to represent fields on which waste might be applied. Pasture and cropland within a 5-mile radius of poultry facilities was then reclassified and assigned a value of 108. Null areas within the poultry facility buffer that are not pasture or cultivated crops, as well as those outside the 5-mile buffer, were given a value of 0.



a) Poultry Facilities Buffer



b) Fields within 5 Miles of Poultry Facilities

Pasture and cropland within a 1-mile buffer of cattle facilities was given a lower overall weight based on animal counts and nutrient production estimates generated during development of the High Rock Lake Watershed Model (Tetra Tech, 2012). In general, cattle were estimated to generate about half of the amount of nutrients as poultry within the High Rock Lake watershed.

Table 9: Animal Counts and Nutrients Production by Water Quality Station

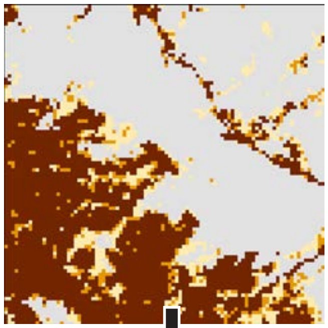
Station	Cattle Count (beef)	Cattle Count (dairy)	Chicken Count (excluding broilers)	Broiler Count	Total TN (lb-N/day)	Total TP (lb-P/day)
Yadkin River at Yadkin College (02116500)	34,146	3,248	2,372,213	15,098,819	50,104	12,453
Yadkin River at Enon (02115360)	25,260	1,773	1,447,074	14,431,179	41,094	10,058
Yadkin River at Elkin (02112250)	9,728	807	450,047	9,907,102	23,032	5,499
South Yadkin River (02118000)	6,777	4,858	792,615	1,448,014	12,416	2,929
Abbotts Creek (02121500)	1,756	334	0	248,287	1,490	325
Second Creek (02120780)	2,758	1,046	60,959	22,167	2,408	521

All 14 reclassified rasters were then input into the ArcGIS Weighted Sum Tool. This tool overlaid the input rasters on top of one another and summed the respective cells into one output stress value raster. Since we already provided weight to the input rasters by adjusting their integer values, no additional weighting was needed in this step.

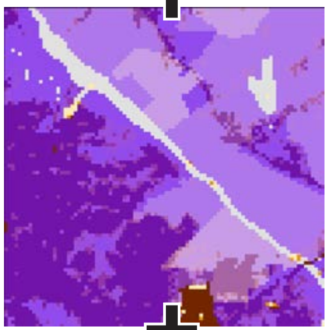
The resulting raster represents the stress vulnerability of the landscape in the High Rock Lake watershed on a continuous array of values, ranging from 0 to 773. The maximum possible stress value that a cell could attain was 1000 if that point in space possessed the highest factors for each input data layer, but no cells within the watersheds obtained this high of a stress value. This process attempted to identify areas throughout the watershed that have the greatest concentration of watershed stressors or pollutants and that likely require targeted strategies to reduce water quality impacts.

Raster Reclassification and Weighted Sum Process

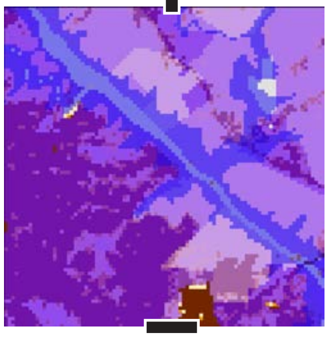
a) Reclassified Impervious Surface Cover Raster



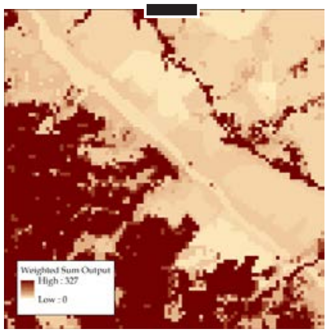
b) Reclassified Impervious Surface Cover Raster
Overlaid With Reclassified Population Density Raster

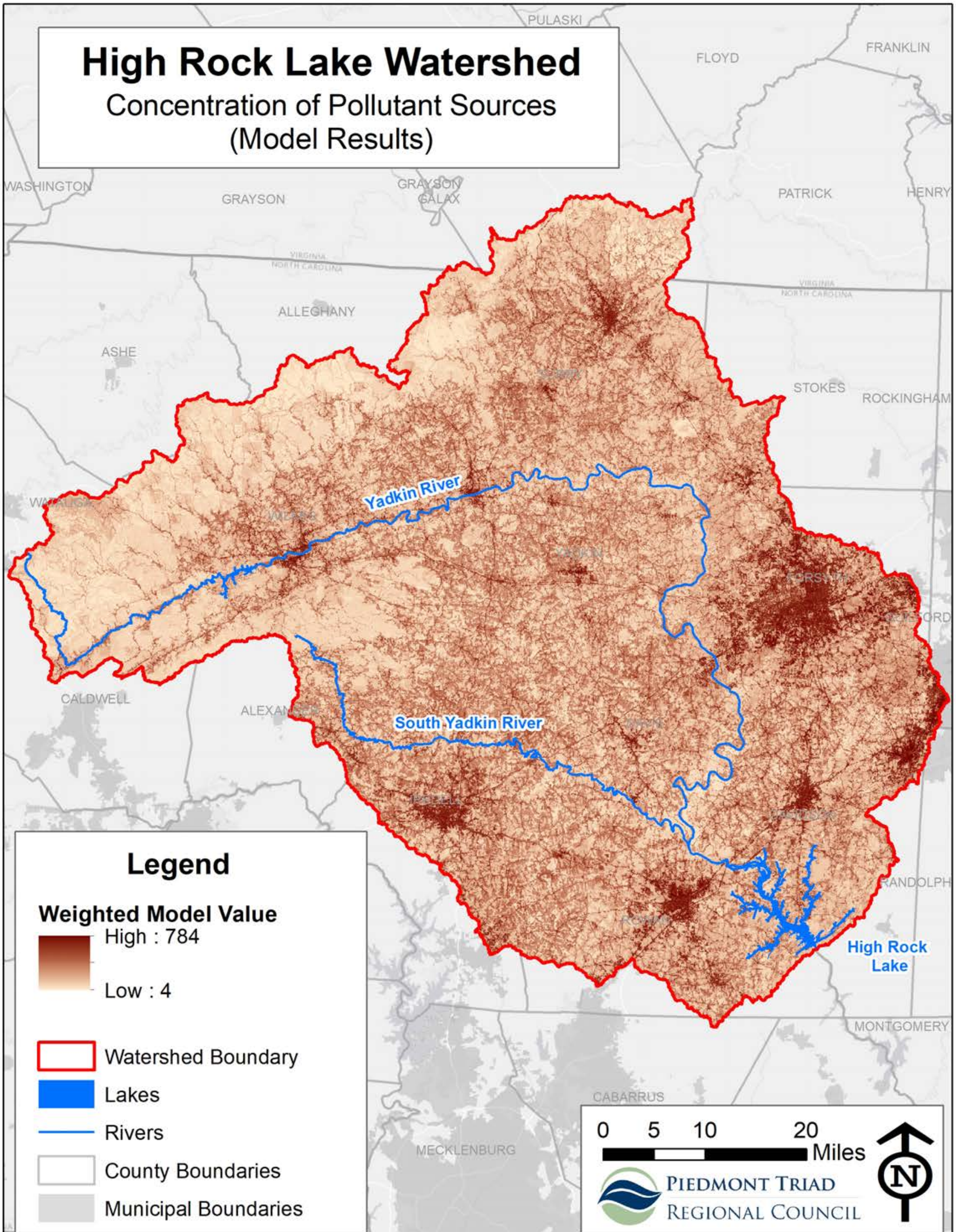


c) Reclassified Impervious Surface Cover Raster
Overlaid With Reclassified Population Density Raster
and then overlaid With Reclassified Floodzone Raster



d) Product of Weighted Sum Tool
(Output Stress Value Raster)




High Rock Lake Watershed
Concentration of Pollutant Sources
(Model Results)
PULASKI
FLOYD
FRANKLIN
WASHINGTON
GRAYSON
GRAYSON
GALAX
PATRICK
HENRY
VIRGINIA
NORTH CAROLINA
ALLEGHANY
ASHE
STOKES
ROCKINGHAM
Yadkin River
CALDWELL
ALEXANDER
South Yadkin River
RANDOLPH
High Rock Lake
MONTGOMERY
CABARRUS
MECKLENBURG
UNION
ANSON
Legend
Weighted Model Value
High : 784
Low : 4
Watershed Boundary
Lakes
Rivers
County Boundaries
Municipal Boundaries
0 5 10 20
Miles
N
Piedmont Triad
Regional Council

In the final step, the 12-digit HUC boundaries were overlaid on top of the output stress raster to determine the stress vulnerability of each local watershed. The ArcGIS "Zonal Statistics as Table" tool was used to calculate stress cell statistics (mean, minimum, maximum, range, etc.) for each 12-digit HUC boundary. Local watersheds were then ranked based on their mean stress value, which ranged from 77 to 456. The resulting watershed prioritization map groups local watersheds that have the highest mean stress values (top 10%, 25%, & 50%).

The conservation priorities model followed an identical process, but only included 10 data layers (3 raster and 7 vector). This conservation value raster represents the conservation potential of the Yadkin River Basins' landscape on a continuous array of values, ranging from 0 to 650 (see Map 15). The maximum possible stress value that a cell could attain was 680 if that point in space possessed the highest factors for each input data layer, but no cells within the watersheds obtained this high of a conservation value. The HUCs were grouped based on mean conservation value (see Map 12). The mean values ranged from 101 to 422. This process attempted to identify areas within the watersheds with the highest conservation value for watershed health and function, so that these areas can continue to be preserved.

Conservation Layers				
Criteria	**Data Source**	**Factors**	**Integer Values**	**Total Layer Value**
Biodiversity/ Wildlife Habitat Assessment	NC NHP & VA Natural Landscape Network	4-Jan	65	31.90%
		6-May	65	
		8-Jul	79	
		10-Sep	110	
Low Impervious Surface Cover	NLCD 2006 Percent Developed Imperviousness	> 10%	0	22.90%
		5 - 9%	54	
		0 - 4%	174	
High Forest Cover	NLCD 2001 update	> 50%	134	13.40%
Hydric Soils	SSURGO	Partially Hydric	22	7.80%
		All Hydric	56	
Highly Erodible Soils	SSURGO (K factor)	0 - 0.23	0	7.10%
		0.24 - 0.39	14	
		0.40 - 0.49	57	
Floodplain	NC Floodplain Mapping Program; VA DCR	Within 500 Year Floodplain	65	6.50%
Low Population Density (Persons Per Square Mile)	Census Bureau, 2010	High (250 +)	0	4.90%
		Med (50-249)	20	
		Low (1 -49)	29	
Steep Slopes	USGS NED (1 arc second)	> 15%	37	3.70%
Large Parcel Size	Counties	> 50 Acres	12	1.20%
Zoning (Low Impact)	Counties/Municipalities	Planned Unit Development, Low Density Residential, Conservation, VAD	5	0.50%


Grayson
Patrick
Virginia
North Carolina
Henry
Mount Airy
Alleghany
Ashe
Surry
Stokes
Rockingham
Watauga
Wilkes
Wilkesboro
Yadkin
Forsyth
Winston Salem
Guilford
Alamance
High Point
Caldwell
Alexander
Davie
Iredell
Statesville
Lexington
Davidson
Asheboro
Burke
Catawba
Salisbury
Randolph
Rowan
Lincoln
Moore
Cabarrus
Cleveland
Gaston
Charlotte
Stanly
North Carolina
South Carolina
Mecklenburg
Cherokee
York
Union
Anson
Richmond
Union
Chester
Lancaster
Chesterfield
Scotland
Marlboro
Yadkin River Basin Prioritization
Final Conservation Output
Conservation Value
High : 650
Low : 0
Major Rivers
State Boundary
County Boundary
PTRC Region
Study Area
N
0
15
30
Miles
Piedmont Triad Regional Council
September 2013

Findings

The highest ranking stressed watersheds are primarily located in urbanized areas (Winston-Salem, Salisbury, Statesville, and Thomasville), while the third tier of high-ranking stressed watersheds are in more rural, agricultural areas.

The highest conservation priorities are primarily located in the upper parts of the basin.

There are more than 90 impaired stream segments in the High Rock Lake watershed, but only 5 watershed protection plans have been developed.

The main stem of the Yadkin River accounts for about 70% of the flow, 62% of the sediment, 71% of the phosphorus, and 68% of the nitrogen reaching High Rock Lake.

TMDLs have been developed for 11 major tributaries within the High Rock Lake watershed to address total suspended solids, while 6 have been established to address fecal coliform bacteria.

The primary factors influencing chlorophyll-a responses and harmful algal blooms in High Rock Lake are primarily flow, nutrient load (nitrogen and phosphorus), and light availability, which is strongly affected by fine sediment load.

Water quality issues in High Rock Lake are a multi-source problem (urban, agriculture, wastewater) with no single solution.

The nutrient issues in High Rock Lake are similar to those in Falls Lake, Jordan Lake, Lower Neuse River, Tar-Pamlico River, and even the Chesapeake Bay.

Developed land in the watershed is anticipated to nearly double from 13% to 32 percent by 2060, which will only exacerbate water quality issues related to nutrients and sediments.

There are 103 active wastewater discharge permits and 63 animal operation permits in the High Rock Lake watershed.

There are an estimated 741 poultry operations, which are not required to apply for permits from the state, but must follow general requirements regarding storage, land application, soil testing, and record keeping.

Currently, there is a lack of available data to determine the impacts of septic systems and animal operations on nutrient loads and additional information is needed on channel morphology and sedimentation processes.

Yadkin Memorial Park

South Deep Creek, Yadkin County

Recommendations

1. Continue the work of Yadkin Riverkeeper Watershed Protection Task Force to build partnerships and develop joint projects to reduce nonpoint source nutrient and sediment pollution in the Yadkin River/High Rock Lake watershed.

2. Identify and assess similar nutrient management situations, plans, and lessons learned from Falls Lake, Jordan Lake, Lower Neuse River, Tar-Pamlico River, and Chesapeake Bay.

3. Assess current activities/actions being taken to address these concerns, including:

- Reviewing and commenting on EPA guidance on setting numeric nutrient criteria for freshwater lakes.
- Reviewing report of the Science Advisory Council on recommended chlorophyll-a levels for HRL.
- Participate in the NC Environmental Management's Triennial Review and advocate for new water quality standards for phosphorus, nitrogen, and bacteria.

4. Identify possible short, medium, and long-range goals and actions and evaluate feasibility of the following:

- Revisit High Rock Lake (HRL) nutrient management strategy based on approaches taken elsewhere (Jordan and Falls Lake, if appropriate) and ongoing work of the Yadkin Pee Dee River Basin Association
- Address ongoing concerns with Harmful Algal Blooms (HABs) in High Rock Lake and develop monitoring plan.
- Advocate for more transparency on the siting of large-scale poultry operations and the transport and land application of dry litter poultry waste.
- Increase funding for agricultural cost share programs, technical assistance, and farmland preservation and establish goals for reduction of nutrient runoff.
- Develop local watershed plans for each impaired tributary (12-digit or smaller) that target impaired parameters and nutrients.
- Enforce TMDLs upstream to support nutrient management strategy.

5. Identify key river/tributary buffers for conservation and restoration. Target areas should include:

- Roaring River (Wilkes) – Support ongoing stream restoration and BMP efforts.
- South Yadkin and its tributaries (Caldwell, Wilkes, Alexander, Iredell) – Develop watershed assessment and restoration plans.
- Ararat River (Surry) – Develop stream restoration plans/projects.
- Abbotts Creek (Davidson) – Assess compliance with existing TMDLs and implement existing watershed restoration plan.
- Swearing Creek (Davidson) – Implement existing watershed restoration plan.
- Grants Creek (Rowan) – Assess compliance with existing TMDLs and develop watershed assessment study to address flooding and related stormwater issues.
- Big Elkin Creek (Wilkes & Surry) - Implement existing water supply plan and support local stream restoration and stormwater management efforts by WatershedNOW

6. Develop collaborative grant proposals and partnerships to target and reduce non-point source pollution through:

- Implementation of agricultural best management practices (BMPs).
  - Advocate for increased state and federal funding for BMPs and technical assistance.
  - Partner with NRCS and local soil and water conservation districts to assist small sustainable farmers in acquiring cost share funding.
  - Research innovative financing options to pay farmers for installing BMPs and other “ecosystem services” they provide (i.e. buffers, reductions in nonpoint source pollution). Potential resource: “Paying for Nutrient Reduction and Management in Jordan Lake” by UNC Environmental Finance Center.
- Development of watershed protection plans and stream restoration projects on targeted areas.
  - In partnership with PTRC and other regional councils, seek funding through 205(j) water quality grants for watershed assessment and restoration projects
  - Apply for planning grants through the Clean Water Management Trust Fund for watershed restoration plans.
  - Work with the NC Division of Water Resources’ Nonpoint Source Planning Branch and Division of Mitigation Services to potentially direct planning and mitigation projects to the HRL watershed in ways that assist in meeting watershed and larger basin improvement efforts.

- Expansion of innovative stormwater management programs.
  - Assess the status of stormwater management programs in targeted watersheds and make recommendations on needed improvements.
  - Work with local governments in targeted sub-basins to develop and implement effective stormwater management programs.
- Increased funding for riparian buffer conservation and farmland preservation projects.
  - Partner with land trusts in the watershed to develop detailed conservation plans for riparian buffers in targeted sub-basins.
  - Work with the land trusts and soil and water conservation districts to place conservation easements on farmland adjacent to the river and its tributaries.
  - Promote the Conservation Reserve Enhancement Program (CREP), which was recently expanded to include the Yadkin River Basin, to increase buffers on agricultural land
- Increased public awareness.
  - Develop outreach materials on key recommendations to reduce nonpoint source pollution in the watershed.
  - Document success stories and other examples of projects that reduce nonpoint source pollution.
  - Focus social media outreach on the need to reduce nonpoint source pollution throughout the watershed.

The "Bull Hole" at River Park
South Yadkin River, Davie County

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