Watershed Assessment Report FINAL

October 2020

New Hope Creek and Little Creek Watershed Assessment Report

Durham, North Carolina

PREPARED FOR:

City of Durham
Public Works Department
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AECOM

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Acronyms and Abbreviations

µg	Micrograms
AMPA	Aminomethylphosphonic Acid
BANCS	Bank Assessment for Non-point Source Consequences of Sediment
BEHI	Bank Erosion Hazard Index
BLM	Biotic Ligand Model
BOD	Biochemical Oxygen Demand
CAPP	Critical Area Protection Plan
CCC	Criterion Continuous Concentration
cfu	Colony Forming Unit
City	City of Durham
CRS	Community Rating System
Cu	Copper
DO	Dissolved Oxygen
EI	Enhancement I
EII	Enhancement II
FC	Fecal Coliform
FEMA	Federal Emergency Management Agency
ft3/s	Cubic Feet Per Second
GIS	Geographic Information Systems
L	Liter
MCPA	2-Methyl-4-Chlorophenoxyacetic Acid
mg	Milligrams
ml	Milliliter
mpn	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NBS	Near Bank Stress
NCDEQ	North Carolina Department of Environmental Quality
NCDOT	North Carolina Department of Transportation
NCDWR	North Carolina Division of Water Resources
NCFRIS	North Carolina Flood Risk Information System
NCGS	North Carolina Geological Survey
NCIPC	North Carolina Invasive Plant Council
NCWRC	North Carolina Wildlife Resources Commission
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSW	Nutrient Sensitive Water
NTU	Nephelometric Turbidity Units
PAH	Polycyclic Aromatic Hydrocarbon
PCSWMM	Personal Computer Storm Water Management Model
PSA	Pilot Study Area
PTI	Pesticide Toxicity to Invertebrates
RAMP	Riparian Area Management Plan
RSAT	Rapid Stream Assessment Technique
RSC	Regenerative Stormwater Conveyance
SESQA	Southeast Stream Quality Assessment
SCM	Stormwater Control Measure
SNAP	Stormwater Nitrogen and Phosphorus (Tool)
TN	Total Nitrogen
TP	Total Phosphorus
UCFRBA	Upper Cape Fear River Basin Association
UDO	Unified Development Ordinance
UNRBA	Upper Neuse River Basin Association
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WIP	Watershed Improvement Plan
WQI	Water Quality Index
WS	Water Supply
WSW	Water Supply Watershed

1 Introduction

The City of Durham (City) is located in central North Carolina on a natural divide that drains to two water supply reservoirs, Falls Lake and B. Everett Jordan (Jordan) Lake. The City develops Watershed Improvement Plans (WIPs) in an effort to understand the unique conditions present in each of the City's watersheds and to develop projects and programs that target improvements in water quality and watershed health. Since 2007, the City has developed WIPs for three watersheds in the Falls Lake watershed (Ellerbe Creek [City of Durham, 2010], Little Lick Creek [City of Durham, 2016], and Eno River [City of Durham, 2018a]) and three watersheds in the Jordan Lake watershed (Third Fork Creek [City of Durham, 2012], Northeast Creek [City of Durham, 2013a], and Crooked Creek [City of Durham, 2013a]). This Watershed Assessment Report was prepared to support the development of a similar WIP for New Hope Creek and Little Creek, which drain to Jordan Lake (classified as Water Supply IV, Critical Area, Nutrient Sensitive Waters [NSW]).

The New Hope Creek and Little Creek watersheds encompass approximately 80 square miles within Durham and Orange Counties (Exhibit 1; based on analysis of provided GIS data). While most of the New Hope Creek watershed lies within Orange County, approximately 45%, or 36 square miles of the watershed, is located within the City of Durham. Major tributaries to New Hope Creek include Sandy Creek, Mud Creek, and Third Fork Creek. The City completed a WIP for Third Fork Creek watershed in 2012 (City of Durham, 2012). For this reason, Third Fork Creek is not included in this project. Little Creek watershed includes portions of Chapel Hill and the City of Durham in Orange and Durham Counties. Little Creek forms at the confluence of Bolin Creek and Booker Creek and flows southeast, joining New Hope Creek directly upstream Jordan Lake.

1.1 Purpose

The purpose of this Watershed Assessment Report is to provide a summary of the existing watershed conditions in the New Hope Creek and Little Creek watersheds. This summary includes the following key elements:

- Evaluation of watershed characteristics such as hydrology, geology, and soils that influence stormwater quantity and quality
- Analysis of instream water quality data
- Assessment of existing and future land use within the watershed
- Field evaluations of existing stormwater control measures (SCMs) for retrofits and preliminary assessment of potential new sites to treat runoff from developed areas that are currently not receiving treatment
- Field inventory and evaluation of stream channels and habitat quality of New Hope Creek, Little Creek, and their tributaries
- Identification of potential water quality improvement projects as part of the field efforts listed above
- Description of representative Pilot Study Areas (PSAs) where water quality improvement measures will be analyzed in detail
- Outline of the next steps in the development of the WIP

1.2 Documentation of Durham's Watershed Improvement Plans

The City of Durham's approach in developing comprehensive WIPs relies on several key elements that inform the process. The New Hope Creek and Little Creek WIP will be developed in a similar format as previous WIPs. The main elements of this WIP will be as follows:

1. Watershed Assessment Report (this document). This report serves as the foundation to develop the WIP and includes an analysis of current and future land use, water quality data, field identification of potential water quality improvement projects, and description of representative PSAs.
2. Watershed Improvement Plan Volume I (Executive Summary). This is a brief document that describes project goals, watershed analysis methods, and watershed improvement scenarios; includes a list of prioritized watershed improvement projects; and concludes with next steps for implementing the WIP.
3. Watershed Improvement Plan Volume II (Main Report). This report expands on Volume I, providing more details on the overall approach used to develop the WIP, including the watershed model development, watershed improvement scenario analysis, prioritization criteria for watershed improvement projects, a summary of public outreach events, and final WIP recommendations with key milestones and a proposed implementation schedule.
4. Watershed Improvement Plan Volume III (Technical Appendices). The technical memoranda and reports developed throughout the project to support the WIP are included as appendices in this section. This volume includes project factsheets for all feasible watershed improvement projects.
5. Critical Area Protection Plan (CAPP). This report identifies privately owned parcels with high-quality riparian buffers that are prioritized for conservation or protection in each watershed. If preserved, these areas may contribute to improved water quality of the streams and ecological health of the watershed. The plan is a single document with appendices for each watershed for which a WIP has been completed. The New Hope Creek and Little Creek watershed-specific CAPP will be included as an appendix to the WIP.
6. Riparian Area Management Plan (RAMP). The RAMP addresses the protection and maintenance of riparian buffers on City-owned or maintained property, utility easements, and greenway corridors. The plan examines existing maintenance practices in these areas for opportunities to protect, expand, or enhance riparian buffers to improve stream and watershed health. The plan provides strategic guidance for the City departments routinely involved in working within riparian areas.

1.3 Federal, State, and Local Regulations

The City of Durham watersheds, including New Hope Creek and Little Creek, are regulated under federal, state, and local water quality rules. The 2018 North Carolina 303(d) list identified New Hope Creek in Durham County along State Route (SR) 2220 (Old Chapel Hill Road) and a 4-mile segment from SR 2220 to Interstate 40 (assessment units 16-41-1-(11.5) a, b) as impaired for benthos with a fair rating. Little Creek from its source at the confluence of Booker and Bolin Creeks to 0.7 miles downstream of SR 1110 (Farrington Rd) is also listed in the 303(d) list for poor benthos conditions. A 2-mile segment of Third Fork Creek (assessment unit 16-41-1-12-(1)) that discharges into New Hope Creek is also identified as impaired upstream of NC Highway 54 based on copper violations.

New Hope Creek ultimately discharges into Jordan Lake, which is impaired for nutrients (total nitrogen [TN], total phosphorus [TP]), pH, and turbidity. A total maximum daily load (TMDL) was approved for nutrients in 2007, and for pH and turbidity in 2014. These TMDLs require the upstream jurisdictions (including the City of Durham) to manage their pollutant loads.

1.3.1 National Pollutant Discharge Elimination System Requirements

The City of Durham holds a Phase I National Pollution Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit (Permit No. NCS000249). To maintain compliance with the permit, the City provides an annual report indicating how it is meeting the minimum control measures required by the NPDES permit: public education and outreach, public participation and involvement, illicit discharge detection and elimination, post-construction runoff, municipal pollution prevention, and good housekeeping.

1.3.2 Jordan Lake Nutrient Management Strategy

In response to the impairments, the Jordan Lake Water Supply Watershed Nutrient Management Strategy (Jordan Lake Rules) was approved by the State of North Carolina legislature in 2009 (15A NCAC 02B.0262). The rules were developed to restore and maintain nutrient-related water quality standards and protect classified uses of Jordan Lake. The Jordan Lake Rules cover a variety of topics such as agriculture, urban stormwater management, riparian buffer preservation and mitigation, wastewater discharges, fertilizer management, and other options for offsetting nutrient loads. Portions of the Jordan Lake Rules are effective while other portions of the rules are delayed. NCDWR has partnered with the Triangle J Council of Governments and Jordan Lake One Water to develop a recommended One Water/Integrated Water Management framework for the Jordan Lake watershed as part of the Jordan Lake Nutrient Management Strategy Rules readoption.

Jordan reservoir is divided into three arms and the Jordan watershed into three tributary subwatersheds, namely the Haw River arm, Upper New Hope arm, and Lower New Hope arm. Each arm and subwatershed has its own reduction goals, allowable pollutant loads, and point and nonpoint source load allocations. As part of the adaptive management under the Jordan Lake Rules, the North Carolina Department of Environmental Quality (NCDEQ) is required to evaluate the effectiveness of these rules.

The North Carolina General Assembly chartered the University of North Carolina in 2016 to conduct a multiyear study and analysis of nutrient management strategies of Jordan Lake (UNC, 2019). The study was designed to provide empirically-based trend analysis of the factors contributing to Jordan Lake's impairment by using a set of fully integrated research projects and numerical models, which also provide a platform to project future conditions in Jordan Lake under a range of management scenarios. Results from the study provided insights into strategies for increasing revenues for management interventions, strengthening local government collaboration around Jordan Lake management, and addressing nutrient loading to Jordan Lake.

1.3.3 City of Durham Watershed Protection Ordinances

The City's Unified Development Ordinance (UDO) contains several natural and water resources protection provisions and sections that are listed below:

- Floodplain protection standards (Section 8.4)
- Riparian buffer protection standards (Section 8.5)
- Water supply reservoir buffer standards (Section 8.6)
- Watershed protection overlay standards (Section 8.7)
- Slope protection standards (Section 8.8)
- Wetland protection standards (Section 8.9)
- Sediment and erosion control standards for infrastructure and public improvements (Section 12.10)

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2 Characterization

2.1 Overview

The New Hope Creek and Little Creek watersheds are located within the Central Piedmont Region of North Carolina in the Upper Cape Fear River Basin (Exhibit 1). New Hope Creek discharges to Jordan Lake and the Cape Fear River before ultimately reaching the Atlantic Ocean. Most of the New Hope Creek watershed lies within Orange County, including the Town of Chapel Hill. New Hope Creek flows southeast from south of Hillsborough in Orange County through Durham County to its confluence with Jordan Lake in Chatham County. The New Hope Creek watershed (USGS 12-digit Hydrologic Unit Codes: 030300020601 and 030300020604) is approximately 80 square miles, and approximately 45% or 36 square miles of the watershed is within the City of Durham limits. A portion of the Duke University campus and commercial areas such as South Square and US 15-501 corridor are important areas in the New Hope Creek watershed within the City of Durham. Little Creek begins at the confluence of Bolin and Booker Creeks in the Town of Chapel Hill, Orange County, and flows through Durham County to its confluence with New Hope Creek north of Jordan Lake. The Little Creek watershed (USGS 12-digit Hydrologic Unit Code: 030300020603) is approximately 25.2 square miles, and approximately 5.6% or 1.4 square miles of the watershed is within the City of Durham limits.

Sandy Creek, Mud Creek, and Third Fork Creek are major tributaries to New Hope Creek. The Mud Creek watershed is approximately 5.9 square miles and is mostly located outside the City of Durham jurisdictional limits; the small areas within the City are fairly discontiguous. In contrast, Sandy Creek originates close to the Durham Freeway (NC 147), and the watershed is located entirely within the City of Durham. The Sandy Creek watershed is bound by Chapel Hill Road and Old Chapel Hill Road (SR 2220) on the eastern side and US Highway 15-501 and Garrett Road on the western side of the watershed. The Sandy Creek watershed is approximately 6.9 square miles. The Third Fork Creek watershed covers an area of 16.6 square miles. The northern boundary of the Third Fork Creek watershed lies in downtown Durham, north of the Durham Freeway, and the southern boundary is close to Interstate 40. The City completed a WIP for Third Fork Creek watershed in 2012 (City of Durham, 2012). For this reason, Third Fork Creek is not included in this project.

Given the large size of the watershed with multiple jurisdictions and tributaries, a study area was selected to help focus on identifying water quality problems and formulate recommendations, specifically, in the New Hope Creek and Little Creek watersheds within the city limits. The study area includes the portion of the New Hope Creek watershed that extends from the Durham County boundary to Stagecoach Road (SR 1107) along New Hope Creek and Farrington Road (SR 1110) along Little Creek (Exhibit 2). Third Fork Creek watershed is not included in the study area because the City completed a WIP for that watershed in 2012. The study area is 19,322 acres in total. Within the study area, approximately 12,499 acres (65% of study area) of the New Hope Creek watershed and approximately 900 acres (4.7% of study area) of the Little Creek watershed fall within the Durham City limits. The following sections describe watershed characteristics of the study area. Key datasets used in the preparation of this report are summarized in Appendix B.

2.2 Hydrology

Two U.S. Geological Survey (USGS) gages with daily stage and discharge data are located within the study area. USGS gage 0209722970 is located on Sandy Creek at West Cornwallis Road (SR 1308), and USGS gage 02097314 is located on New Hope Creek near Blands, North Carolina, at Stagecoach Road (SR 1107), south of the City of

Durham (Figure 2-1). As described in Section 2.5.3 of this document, several waterfowl impoundments are present within the project study area, upstream of USGS gage 02097314. The station at Stagecoach Road has been in operation since 1982, and has a drainage area of 76 square miles, or about 95% of the total New Hope Creek drainage area. The average daily streamflow is 112 cubic feet per second (ft^3/s) and median daily streamflow is 37 ft^3/s. The average monthly streamflow at this location ranges from a high of 195 ft^3/s in March to a low of 57 ft^3/s in August. While outside the study area, data from a third USGS gage 02097280 located on Third Fork Creek at West Woodcroft Parkway may be used to help understand the impact of the Third Fork Creek watershed on conditions in New Hope Creek.

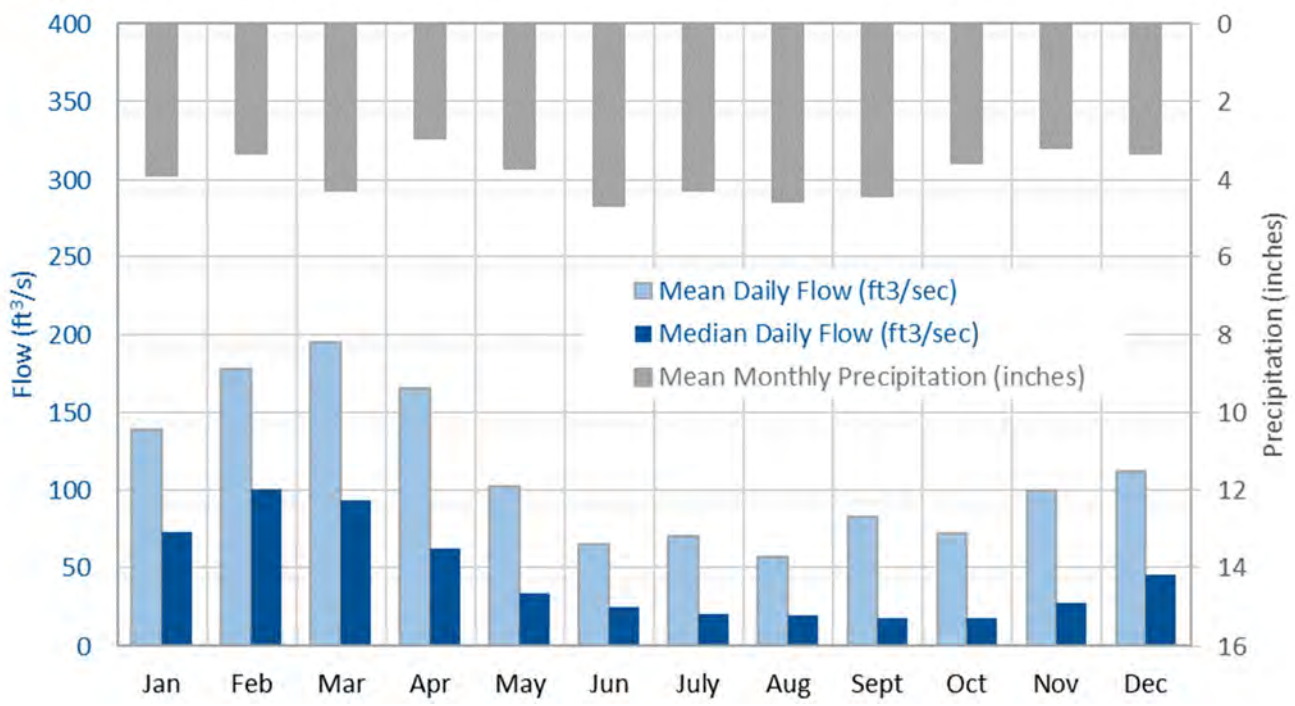

Figure 2-1. Daily flow (mean and median) at USGS gage 02097314 (New Hope Creek near Blands, NC) located on Stagecoach Road and mean monthly precipitation at Raleigh-Durham

2.3 Geology and Soils

The north-western portion of the study area is underlain by the resistant metamorphic rock of the Carolina Slate Belt, while the rest of the study area falls within the Triassic Basin, which comprises mostly sedimentary geology (Exhibit 3). Inside the study area, approximately 7% (1.8 square miles) of the New Hope Creek watershed falls within the Carolina Slate Belt and 93% (24.4 square miles) falls within the Triassic Basin. Within the study area, the entire Little Creek watershed falls within the Triassic Basin.

The Triassic Basin is composed of a mixture of conglomerates, sandstones, and mudstones, as well as igneous dikes of Jurassic origin. The differences in these underlying geologic materials, which serve as the parent material to surficial soils, produce soils with very different hydraulic properties. The Triassic Basin soils are poorly drained in nature and exhibit a low hydraulic conductivity. Additionally, the Triassic Basin soils have a high shrink-swell potential because of their clay composition. Because of their properties, the Triassic Basin soils control both surface water and groundwater hydrology in the area. The low infiltration rates result in flashy streams with relatively high peak flows during storm events, but low base flows due to poor groundwater recharge. Carolina Slate Belt soils typically have a moderate hydraulic conductivity but are shallow or thin. This allows for minimal

water storage in the surficial aquifer. As a result, streams draining areas of Carolina Slate Belt soils will often have no baseflow during extended dry periods.

The Natural Resources Conservation Service (NRCS) classifies soils into hydrologic soil groups based on infiltration rates and water storage capacities. The four major hydrologic soil groups are described as follows:

- Group A soils have high infiltration rates and low runoff potential and are primarily well-drained sandy soils. Less than 1% of the study area comprises Group A soils.
- Group B soils have moderate infiltration rates and runoff potential. They consist primarily of moderate to well-drained soils such as loams. Approximately 16% of the study area consists of Group B soils.
- Group C soils have low infiltration rates and moderately high runoff potential. These soils are typically sandy clays or clay loams. Approximately 2% of the study area consists of Group C soils.
- Group D soils have low infiltration rates and have high runoff potential. Most D soils are clays, contain a confining layer near the surface, or consist of shallow soils over bedrock. Urban complex and gullied soils are also typically classified as Group D soils. Approximately 55% of the study area consists of Group D soils (including undrained soils).

Group A soils have the highest infiltration rates and thus lowest runoff potential, while Group D soils have the lowest infiltration rates and highest runoff potential. Additionally, some soils are classified as a combination of two hydrologic soil groups (A/D, B/D, or C/D) with the first letter representing drained areas and the second letter representing undrained areas.

The north-western portion of the study area, within the Carolina Slate Belt, is dominated by well-drained Group B soils (~74%), while the portion of the watershed within the Triassic Basin is predominantly poorly drained Group D soils (~58%). The hydrologic soil groups within the study area are presented in Table 2-1 and Exhibit 4.

Table 2-1. Hydrologic soil groups within the study area by watershed

Hydrologic Soil Group	Mud Creek		Sandy Creek		Lower New Hope Creek		Little Creek		Study Area	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
A	28	<1%	0	0%	0	0%	31	1%	60	<1%
B	1,562	42%	845	19%	505	6%	66	3%	2,978	16%
C	37	1%	8	<1%	278	3%	26	1%	349	2%
D	1,303	35%	2,669	61%	5,093	60%	1,427	64%	10,492	55%
A/D	70	2%	133	3%	127	2%	51	2%	382	2%
B/D	191	5%	265	6%	1,862	22%	515	23%	2,833	15%
C/D	542	14%	143	3%	475	6%	80	4%	1,240	7%
Gullied Land (D soils)	9	<1%	17	<1%	83	1%	7	<1%	115	<1%
Urban Complex (D soils)	0	0%	320	7%	93	1%	0	0%	412	2%
Water	17	<1%	13	<1%	45	<1%	20	1%	94	<1%

2.4 Floodplains

Functioning natural floodplain systems offer many benefits, including flood risk reduction, water quality maintenance, groundwater recharge, and recreational opportunities such as fishing and hiking. Floodplains reduce flood risk by providing excess flood storage, reducing flood flow rates, reducing shoreline erosion, reducing runoff rates through ponding and infiltration, and regulating nonflood flow rates through groundwater recharge. Floodplain ecosystems offer habitat for a variety of plants and wildlife, which provide natural erosion control, filtration of pollutants entering streams, and improvement of water quality.

In 1968, the U.S. Congress created the National Flood Insurance Program (NFIP) to reduce risks associated with flooding, such as loss of human life and destruction of property, and to provide cost-effective flood insurance. The NFIP is administered by the Federal Emergency Management Agency (FEMA), part of the Department of Homeland Security. FEMA produces and updates Flood Insurance Rate Maps to demarcate Special Flood Hazard Areas. In April 2015, FEMA published preliminary flood maps for roughly half of the City of Durham and Durham County. The City Council adopted these updated maps for use in September 2018. The two primary hazard areas are the 1% Annual Chance Floodplain and the Floodway. The 1% Annual Chance Floodplain, commonly referred to as the "100-year floodplain," is the area in which flooding is predicted to have a 1% chance of occurring in any given year. The Floodway is the area within a floodplain where most of the flow and highest velocities occur during a flood. The 100-year floodplain and Floodway within the New Hope Creek and Little Creek watersheds are presented in Exhibit 5.

The City participates in the NFIP in part by enforcing minimum floodplain regulations on development. By participating in the NFIP, Durham residents are eligible for federally backed flood insurance policies, regardless of whether their property is located in a FEMA-mapped floodplain. Flood insurance is required for all buildings financed with federally backed loans if the buildings are located within the 1% Annual Chance Floodplain. Development activities within mapped FEMA floodplains are strictly regulated regarding fill placement, building standards, elevations, and flood protection. Development within the FEMA floodway is strongly discouraged by regulation and is usually limited to utility and street crossings. In addition, any development within the floodway generally requires flood studies by professional engineers to determine and map impacts of the development on floodplains.

Two primary goals of NFIP floodplain regulations are to prevent the construction of new buildings in mapped floodplains and reduce the impacts of new development on flood elevations. The City/County floodplain standards, codified in the UDO, are more stringent than minimum NFIP standards. For instance, the City/County requires that all new buildings be constructed or flood-proofed to elevations at least 2 feet above the 1% future conditions annual chance flood elevations (not shown on Exhibit 5). One of the benefits of stronger floodplain standards is that the City is rated in FEMA's Community Rating System (CRS). The City's current status as a CRS community saves Durham property owners with buildings in the 1% Annual Chance Floodplain 10% on flood insurance rates.

Within the study area, the City manages a flood warning gage monitoring system on Sandy Creek at Cornwallis Road in coordination with USGS. USGS also manages a monitoring gage at Stagecoach Road on New Hope Creek that is a part of the North Carolina Inundation Mapping and Alert Network. Public Works Stormwater & GIS Services staff and Durham County Emergency Management receive alerts when certain gage depths are reached. Emergency Management then arranges for the closure of several sections of roads leading to impacted areas. Stormwater & GIS services also monitors flood warning systems for flooding in areas outside of the study area, such as central Durham and at the City's Public Works Operation Center.

The City and Durham County Emergency Management participate in and help maintain the Eno-Haw Regional Hazard Mitigation Plan. One of the benefits of maintaining a hazard mitigation plan and participating in the NFIP is eligibility for FEMA hazard mitigation grants. The City applies for hazard mitigation grants for mitigation actions that include acquisition, open space creation, and raising residential building elevation for high-risk structures within FEMA floodplains.

2.5 Water Quality

The New Hope Creek and Little Creek WIP is aimed at (i) protecting areas of the watersheds with high-quality and healthy surface waters and (ii) identifying and providing recommendations for improving watershed areas with water quality concerns. This section describes the applicable surface water classifications and water quality standards, provides a brief overview of previous studies conducted in the watersheds, and characterizes the existing water quality conditions within these watersheds.

2.5.1 Surface Water Classifications

The North Carolina Division of Water Resources (NCDWR) assigns surface water classifications to all surface waters within North Carolina. These classifications are assigned to protect designated uses and special waterbody characteristics, such as swimming, fishing, or drinking water supply. Surface waters are subjected to a set of water quality standards that protect their designated use(s). Within the New Hope Creek and Little Creek watershed study area, three primary classifications and one supplemental classification apply to surface waters (Exhibit 6):

1. Class C (Primary): All surface waters within the state of North Carolina are subject to standards associated with Class C uses. These uses include secondary recreation (wading, boating, and other activities that involve infrequent human contact with water), fishing, wildlife, fish consumption, and aquatic life propagation.
2. Water Supply IV (WS-IV; Primary): Waters used as water supply for drinking, culinary, or food processing purposes that cannot feasibly meet the standards of WS-I through WS-III, which are the most stringent. WS-IV waters are generally located in a watershed with moderate to high-density development. These waters allow for development densities of one dwelling unit per one-half acre. The WS-IV classification includes a portion of New Hope Creek from 0.3 miles upstream of Durham County SR 2220 to Jordan Lake, Gum Creek from source to its confluence with New Hope Creek, and all of Little Creek within the study area. The WS-IV classification includes a critical area within one-half mile of the Jordan Lake normal pool and a protected area within 5 miles of the Jordan Lake normal pool. The City and County of Durham have developed a UDO that extends the State's critical area to a distance of one mile from the Jordan Lake normal pool. This UDO limits development density within both the critical area and protected area and requires stream buffers extend 100 feet to 150 feet for perennial streams and 50 feet for intermittent streams.
3. Water Supply V (WS-V; Primary): Waters protected as water supplies which are generally upstream and draining to Class WS-IV waters or waters used by industry to supply their employees with drinking water or as waters formerly used as water supply. There are no development density restrictions for these waters. The WS-V classification includes a portion of New Hope Creek from its source to 0.3 miles north of Durham County SR 2220 and all of Sandy Creek and Mud Creek.
4. Nutrient Sensitive Waters (NWS; Supplemental): A supplemental classification for waters that require additional nutrient management because of excessive aquatic vegetation (both microscopic and macroscopic). The entire Jordan Lake watershed is classified as NSW.

2.5.2 Water Quality Standards and Benchmarks

Water quality standards serve to protect waters based on their designated uses. The following water quality standards are important when measuring the overall health of the New Hope Creek and Little Creek watersheds study area:

- Benthic: Benthic classification assigned to each water body sampled consists of five categories: Excellent, Good, Good-Fair, Fair, and Poor. Classification is based on threshold numbers of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa present in a sample. Waters with Excellent or Good benthic classifications will contain diverse, stable, and pollution-sensitive communities of aquatic macroinvertebrates.
- Copper: The standard for dissolved copper is defined using the Criterion Continuous Concentration (CCC), which is defined as the highest concentration of a chemical in water that aquatic organisms can be exposed to indefinitely without resulting in an adverse effect (Chronic in NC 15A NCA 02B Surface Water Standards Table). The bioavailability, and therefore toxicity, of metals depends on various characteristics of a body of water. Because of this, the criterion for copper is site-specific and can vary throughout the year. The U.S. Environmental Protection Agency (USEPA) criteria are based on the Biotic Ligand Model (BLM) and require input data for temperature, pH, dissolved organic carbon, major cations (Ca, Mg, Na, and K), major anions (SO_4 and Cl), alkalinity, and sulfide (USEPA, 2007). The average CCC standards for the protection of aquatic life for copper are 4.7 micrograms per liter (µg/L) in New Hope Creek, 7.6 µg/L in Sandy Creek, 4.8 µg/L in Mud Creek, and 4.0 µg/L in Little Creek.
- Dissolved Oxygen (DO): The standard for the protection of freshwater aquatic life is a daily average not less than 5 milligrams per liter (mg/L) and an instantaneous value not less than 4 mg/L.
- Fecal Coliform Bacteria: The standard for the protection of human health and freshwater aquatic life requires that the geometric mean is less than 200 colony forming units per 100 ml (200 cfu/100 ml) based upon five consecutive samples during a 30-day period, and does not exceed 400 cfu/100 ml in more than 20% of the sample collected during the same period. Note that violations of the fecal coliform standard are expected during rain events.
- Nitrate: The standard for the protection of freshwater aquatic life is not to exceed 10mg/L for Water Supply Watershed (WSW).
- Turbidity: The standard for the protection of freshwater aquatic life is not to exceed 50 Nephelometric Turbidity Units (NTUs) for streams.
- Zinc: The USEPA has not yet approved the BLM for determining zinc criteria in freshwater systems, though it is in the planning phases. The current criterion is defined as a function of hardness (USEPA, 1996). The average CCC standards for the protection of aquatic life for zinc is 66 µg/L in New Hope Creek, 106 µg/L in Sandy Creek, 66 µg/L in Mud Creek, and 63 µg/L in Little Creek
- Total Nitrogen (TN), Total Phosphorus (TP), and Biochemical Oxygen Demand (BOD): There are no numeric standards for nutrients (TN or TP) or BOD that are established or enforced by the State of North Carolina, though the City applies the following local water quality benchmarks as part of its Water Quality Index (WQI):
  - BOD greater than 2 mg/L but less than 4 mg/L
  - TN greater than 0.8 mg/L but less than 1.0 mg/L
  - TP less than 0.08 mg/L
- Chlorophyll-a: The North Carolina water quality standard for chlorophyll-a is not to exceed 40 µg/L. In 2006, Jordan Lake was placed on the 303(d) list for elevated chlorophyll-a concentrations. Chlorophyll-a is

photosynthetic pigment found in algae and other plants. Harmful algal blooms, which cause elevated levels of chlorophyll-a, are often caused by excessive nutrient loading to slow-moving water bodies.

Three stream segments within the study area are listed as impaired under the 2018 North Carolina 303(d) list of impaired waterbodies, two segments of New Hope Creek and one segment of Little Creek, all impaired for benthos. Upstream of the study area, in Orange County, two segments of Bolin Creek and three segments of Booker Creek, both tributaries to Little Creek, are listed as impaired waterbodies. The location, length, and impairment status of impaired stream segments relevant to the study area are listed in Table 2-2.

Table 2-2. Waterbodies within the New Hope Creek and Little Creek watersheds identified as impaired on the 2018 North Carolina 303(d) list

Stream	Location	Length (miles)	Criteria Status	Rating	Parameter
New Hope Creek	0.3 miles upstream of Durham County SR 2220 to SR 2220	0.3	Exceeding	Fair	Benthos
New Hope Creek	From SR 2220 to I-40	4	Exceeding	Fair	Benthos
Little Creek	From source to a point 0.7 mile downstream of Durham County SR 1110	5	Exceeding	Poor	Benthos
Bolin Creek(1)	From Pathway Drive to US Highway 501 Business	3	Exceeding	Fair	Benthos
Bolin Creek(1)	US Highway 501 Business to Little Creek	1	Exceeding	Fair	Benthos
Booker Creek(1)	From source to dam at Eastwood Lake	4	Exceeding	>10% and >90% conf (2)	Dissolved Oxygen
Booker Creek(1)	From dam at Eastwood Lake to US Highway 15	1	Exceeding	Fair	Benthos
Booker Creek(1)	From US Highway 15 to Little Creek	1	Exceeding	Fair	Benthos

(1) Stream segments are located outside the study area in Orange County. Both Bolin Creek and Booker Creek are tributaries to Little Creek.
(2) Greater than 10% exceedance with greater than or equal to 90% confidence.

2.5.3 Summary of Previous Studies

Given the location of New Hope Creek in the Jordan Lake watershed, multiple stakeholders have been involved for several decades in conducting pertinent studies examining water quality in the lake and contributing waterbodies. This includes the City of Durham, Upper Cape Fear River Basin Association, New Hope Creek Advisory Committee, research universities (University of North Carolina and North Carolina State University), and state and federal agencies. A list of key studies investigating water quality and conservation efforts in the New Hope Creek and Little Creek are briefly discussed below:

- Landscape Plan for Wildlife Habitat Connectivity (2019). The Partners for Green Growth Program of the North Carolina Wildlife Resources Commission (NCWRC) and Orange County funded this study with the goal of developing an action plan to ensure wildlife habitat connectivity across the landscape of Eno River and New Hope Creek/Jordan Lake watersheds (Tuttle et al., 2019). Together, Eno River (in Neuse River Basin) and the New Hope Creek/Jordan Lake watersheds (in Cape Fear River Basin) contain over 65 Natural Heritage Natural Areas, defined as “terrestrial or aquatic sites of special biodiversity due to the presence of rare species, unique natural communities, important animal assemblages, and other ecological features.” In order to maintain the connectivity of wildlife habitats that is critical to their survival, the landscape conservation plan was developed, with anticipated additional benefits to water quality, native vegetation, local economy, and public health (Tuttle et al., 2019). The landscape conservation plan provides

recommendations and strategies for best practices to minimize the impacts of changing land use on wildlife habitat connectivity.

- Jordan Lake Study (2019). In 2019, the University of North Carolina completed a study on Jordan Lake as directed under 2016 legislation, for submission to the North Carolina General Assembly (UNC, 2019). This report is a compilation of several studies related to Jordan Lake performed by multiple agencies and researchers. Specifically, the report documents the following studies:
  - Jordan Lake Watershed and Reservoir Models
  - Paying for Nutrient Reduction and Management
  - Policy Principles and Possibilities for the Jordan Lake Watershed
  - Water Quality Monitoring and Water Circulation in Jordan Lake
  - Evaluation of Controls of Algal Blooms
  - Stream Monitoring and Nutrient Loading
  - Sediment Dynamics
  - Stormwater Control Measures
  - Agriculture in the Jordan Lake Watershed
  - Stakeholder Engagement in the Jordan Lake Watershed

  Based on the research presented, management recommendations are provided in three categories:
  - Increasing revenue for Jordan Lake management and water quality improvement
  - Increased local government collaboration for Jordan Lake management
  - Addressing nutrient loading to Jordan Lake

  Miller et al. (2019) conducted a complementary Jordan Lake and watershed modeling study for the North Carolina Policy Collaboratory. The modeling approach included both point and nonpoint sources of nutrients, and Upper Falls Lake was also considered in addition to Jordan Lake. The study found that anthropogenic activities are a primary cause of increased nutrient levels in the watershed. Urban land contributes the greatest TN and TP loads to Jordan Lake. The New Hope Creek watershed was found to contribute 19% of the total TN load and 20% of the total TP load to Jordan Lake. Within all watersheds point sources were found to contribute 48% of the total TN and 24% of the total TP loads to Jordan Lake, suggesting that loads from wastewater treatment plants remain substantial in comparison to the nonpoint sources (Miller et al., 2019; UNC, 2019).

  The study noted that up to 60% greater TN load and up to an 82% greater TP load was produced during wet years than dry years emphasizing the key role of hydroclimatological variability in formulating nutrient management strategies. Finally, the report provides several nutrient loading reduction scenarios from different sources and their benefit to the water quality improvement in Jordan Lake. Reducing nutrient loads to the New Hope arm of Jordan Lake is expected to provide greater water quality improvement benefits than reducing nutrient loading in the Haw River arm of the lake. A second model of Jordan Lake was created in Environmental Fluid Dynamics Code (EFDC) for this study and identified lake sediments as a considerable source of phosphate and ammonia.

- Sandy Creek Special Study (2019). The City of Durham conducted a special study in Sandy Creek watershed to support the New Hope Creek WIP project (City of Durham SW, 2019). The objectives of this study were to (i) characterize nutrient sources and loads, (ii) evaluate the impacts of stream physical and chemical conditions on aquatic life uses, and (iii) identify potential sources of pesticides within the Sandy

Creek watershed. The study focused on the mainstem of Sandy Creek and two main tributaries (Tributary A and D). Twenty-one sites were monitored with different types of monitoring conducted at each site, including hydrology, channel morphology, sediment quality, ambient water quality, pesticides, midge deformity, and synoptic nutrients. Analytical results for pesticides from the first sampling event were reported as non-detects, and thus pesticide monitoring was discontinued. A lack of sufficient samples of the correct genus prevented the midge deformity analysis from being completed. All other results are discussed in detail in the final report.

- Trends in Water Quality of Select Streams and Reservoirs used for Water Supply in the Triangle Area of North Carolina (2018). The USGS, in partnership with the Triangle Area Water Supply Monitoring Project, conducted a study in 2018 in which temporal trends in water quality were examined for 13 streams and 8 reservoir sites, including USGS site 02097314 on New Hope Creek. The investigation identified considerable changes in population, land cover, streamflow, and selected water-quality characteristics in the study area over the 25-year period data analyzed (1989-2013).
- Duke Law Stream Litter Study (2018). In 2018, Duke Environmental Law and Policy Clinic conducted litter sampling and surveys as a supplemental study to assess the health of the Sandy Creek watershed and its stream network (Gerbode et al., 2018). Three sampling locations were identified adjacent to City's ambient monitoring stations, and both dry period (baseline) and post-rainfall samples were collected to determine the influence of stormwater runoff in litter loads. North Carolina water quality standards and assessment methods do not exist for evaluating litter so the researchers chose to classify litter into seven different categories, namely hard plastic, soft plastic, styrofoam, glass, metal, sports equipment, and other, and then subcategorized as floatable (easily transported with flow) or sinkable (likely to settle out of the water column) litter. The Duke study observed litter present in all stream segments investigated during both dry and post-rainfall sampling events. Soft plastic was the most common litter item, followed by glass and hard plastic.
- City of Durham Comprehensive Plan (2017). The Durham Comprehensive Plan outlines the City's long-term vision for how the community would like to grow and develop (City of Durham, 2017). Chapter 7 (amended November 2017) of the Comprehensive Plan describes the City's goals and vision with respect to conservation and environment plans. This portion of the Plan describes the protection and restoration of Durham County's green infrastructure by focusing on water quality, air quality, floodplain protection, energy conservation, important habitats and rare species, open space planning, and farmland preservation, among other topics. Policies listed in Chapter 7 of the Comprehensive Plan that are supported by the New Hope Creek and Little Creek WIP are listed below:
  - Enforcement of sediment and erosion control measures that protect water quality and sensitive mussel species habitat (Chapter 7.1.2a)
  - Stream buffer protection through the UDO (Chapter 7.1.2c)
  - Low-impact development (Chapter 7.1.2d)
  - Permanent buffer protection through external funding sources (Chapter 7.1.2e)
  - Wetland restoration (Chapter 7.1.2f)
  - Stream restoration (Chapter 7.1.2g)
  - Streamflow restoration (Chapter 7.1.2j)
  - Protection of habitat for sensitive species identified by the NC Natural Heritage Inventory (Chapter 7.1.6)
  - Open Space Master Plans (Chapter 7.2.2d)

Chapter 9 (amended in June 2014) of the Comprehensive Plan focuses on actions needed to ensure that the City's water, wastewater, and stormwater facilities are well-maintained and adequate to support future new development. The New Hope Creek and Little Creek WIP supports the objectives of Durham's Comprehensive Plan by identifying stream, buffer, and SCM projects that benefit water quality and aquatic health.

- The Southeast Stream Quality Assessment (2014). In 2014, the USGS conducted a study of stream quality across the Piedmont and the southern Appalachian Mountains, which included sites on Sandy Creek and New Hope Creek. The goal of the study was to characterize multiple water quality factors (contaminants, nutrients, sediment, and streamflow alteration) that are stressors to aquatic life and the relation of these stressors to ecological conditions in streams throughout the study region. Benthic, water quality, sediment, and pesticide samples were collected as part of the study.
- Metformin and Other Pharmaceuticals Widespread in Wadeable Streams of the Southeastern United States (2014). In 2014, the USGS conducted a study to assess pharmaceutical contaminant concentrations in wadeable headwater streams in the Piedmont ecoregion of the southeastern United States. Primary objectives included addressing the current lack of information about fluvial pharmaceutical contamination in wadeable streams throughout the ecoregion and assessing the relative importance of non-WWTF sources of pharmaceutical contamination in these aquatic systems. The study involved monitoring at USGS site 0209722970 (Sandy Creek at Cornwallis Rd) within the New Hope Creek watershed.
- Durham Parks and Recreation Master Plan (2013). The City's Parks and Recreation Master Plan identifies three primary goals: making and maintaining connections, improving sustainability and accessibility, and optimizing current facilities (City of Durham, 2013b). In conjunction with this Plan, the Durham Trails and Greenway Masterplan (2011) addresses these goals by outlining a comprehensive trail system through the City, including seven proposed greenway trails totaling 16.5 miles in the New Hope Creek watershed and roughly 32 miles of existing greenway trails within the overall study area. Identification of riparian properties for restoration and preservation through the New Hope Creek and Little Creek WIP will provide opportunities to build upon existing conservation plans, increasing benefits to water quality and improving the connectivity of wildlife habitat corridors.
- Patterns of Watershed Urbanization and Impacts on Water Quality (2007). Carle et al. conducted a study in 2007 of six urban watersheds in Durham, North Carolina, including New Hope Creek, to examine how urbanization contributes to nonpoint source pollution. Multiple linear regression models were developed to relate indicators, including type and density of urbanization and access to municipal services, to total phosphorus, total Kjeldahl nitrogen, total suspended solids, and fecal coliforms within streams. Results indicate that development density was correlated to decreased water quality. Indicators of urbanization type such as the house age, amount of contiguous impervious surface, access to city services, and stormwater connectivity were correlated with water quality as well.
- U.S. Fish and Wildlife Service Wetland Study (1992). The New Hope Creek corridor spanning through Durham and Chapel Hill was designated as an "Important Regional Wetland" by the U.S. Fish and Wildlife Service in 1992 (USFWS, 1992). The report identifies approximately 1,500 acres with both Riverine (unconsolidated bottom) and Palustrine (forested and scrub-shrub) wetland types. The report describes the wetlands in the corridor as a rare area of Piedmont forest, which includes habitat for several species of special concern.
- New Hope Creek Corridor Open Space Master Plan (1991). The master plan was developed as a multijurisdictional plan (City of Durham, Town of Chapel Hill, Durham County, and Orange County) and adopted by the City of Durham in 1991 (City of Durham, 1991). The master plan identified critical areas of

environmental significance for protection and preservation of the New Hope Creek corridor that links the Eno River State Park, the New Hope Creek, and U.S. Army Corps of Engineers (USACE) land to the rapidly growing communities of Durham and Chapel Hill.

Some notable projects have positively impacted the adjacent floodplains in the New Hope Creek and Little Creek watersheds. In 1990, members of the Duke University Wetland Center with personnel from Duke Forest and the Pratt School of Engineering began planning the Stream and Wetland Assessment Management Park (SWAMP) restoration project in the Upper Sandy Creek watershed (Duke University Wetland Center, 2020). The original three-phase project was completed in 2007 and included stream recontouring, floodplain re-establishment, dam and impoundment construction, and construction of a stormwater treatment wetland. In 2009, in collaboration with the Durham Soil and Water Conservation District, construction began on a fourth phase which involved reconnecting a portion of Upper Sandy Creek to its original floodplain and to SWAMP's three earlier phases. This portion of the project was designed to improve water quality across 210 acres of the watershed through improved stream flow, hydrologic water retention, and sedimentation prevention. A fifth phase of the SWAMP project, a collaboration between Duke University and the Durham County Soil and Water Conservation District, included construction of 0.4-acre extended detention stormwater wetland and restoration of 734 linear feet of an unnamed Upper Sandy Creek tributary adjacent to the stormwater wetland (Duke University Wetland Center, 2020).

The NCWRC manages five impoundments within the project study area. These impoundments were constructed to mitigate impacts to wetlands and streams caused by the lake construction. Impoundments provide habitat for wildlife such as overwintering and migrating birds. Each impoundment in the Jordan Game Lands is managed such that flooding occurs every other year. While rainfall and stream flow impact the scheduling of flooding events, in general, the impoundment management regime involves slowly raising the water level in an impoundment beginning in early fall to promote flooding during late fall or early winter. In early spring, water is released from the impoundment so that the stream and wetlands return to base levels. Of the 46,768 acres of land protected around Jordan Lake, approximately 2,507 acres of managed land are located within the study area.

2.5.4 Water Quality Monitoring

The City of Durham has collected environmental monitoring data since 1998[1] (City of Durham, 2020a). The City operates and maintains ambient water quality monitoring stations throughout the City, with the data available for download from the City-maintained Water Quality Data Web Portal (http://www.durhamwaterquality.org/). Eleven ambient water quality stations are located within the study area of the New Hope Creek and Little Creek watersheds. Included in this list is one station located on the mainstem of New Hope Creek (NH0.0NHC) and 10 stations located on tributaries to New Hope Creek (LITC1.5LITC, NH1.0SC, NH1.7SCTA, NH2.3MC, NH3.0NHC, NH3.3SC, NH4.3SC, NH4.4SCTD, NH4.8SCTDT, and NH5.0SCTD). For each monitoring station, the first two letters denote the watershed (NH = New Hope), the number denotes the upstream distance from New Hope Creek in river miles, and the last two to four letters denote the stream name (LITC = Little Creek, MC = Mud Creek, NHC = New Hope Creek, SC = Sandy Creek, SCTA = Sandy Creek Tributary A, SCTD = Sandy Creek Tributary D). In addition to the City's monitoring stations, water quality data has been collected by the NCDWR and Upper Cape Fear River Basin Association (UCFRBA) in New Hope Creek at Stagecoach Road near Blands and in New Hope Creek at NC54 near Durham. The ambient water quality monitoring stations within the New Hope Creek and Little Creeks watersheds are presented in Exhibit 7.

The City of Durham conducts monitoring and assessing of benthic macroinvertebrate communities at two ambient water quality stations within the study area: NH2.3MC on Mud Creek and NH1.0SC on Sandy Creek. The water

[1] Although data collection began in 1998, the City's Water Quality Data Web Portal includes data collected since 2004.

quality ratings for NH2.3MC and NH1.0SC are mostly Fair and Poor. The City also conducted a comprehensive water quality study in the Sandy Creek watershed in 2018–2019 to support the WIP. The water quality stations that were a part of the Sandy Creek watershed study are shown in Exhibit 7.

All water quality monitoring stations within the New Hope Creek and Little Creek watersheds are described in Table 2-3.

Table 2-3. Water quality stations within the study area and available water quality data by year collected

Station ID	Stream	Agency	Watershed	Location	Drainage Area (sq. mile)	Project
LITC1.5LITC	Little Creek	City	Little Creek	Farrington Road	23.8	Ambient
NH0.0NHC	New Hope Creek	City	New Hope Creek	Chapel Hill Road	52.3	Ambient
NH1.0SC	Sandy Creek	City	Sandy Creek	Garrett Road	6.9	Ambient
NH1.6SC	Sandy Creek	City	Sandy Creek	Sandy Creek at Larchmont Rd.	6.6	SCWS
NH1.7SCTA	Sandy Creek Trib. A	City	Sandy Creek	Ivy Creek Boulevard	1.4	Ambient
NH1.8SCTA	Sandy Creek Trib. A	City	Sandy Creek	MLK Pkwy	0.06	SCWS
NH2.3MC	Mud Creek	City	Mud Creek	Pickett Road	5.4	Ambient/ Benthic
NH3.0NHC(1)	New Hope Creek	City	New Hope Creek	Erwin Road	31.3	Ambient/ Sediment
NH3.3SC	Sandy Creek	City	Sandy Creek	Cornwallis Road	4.8	Ambient/ Sediment/ SESQA
NH3.4SC	Sandy Creek	City	Sandy Creek	Upstream of confluence with Sandy Creek Trib. D	2.05	SCWS
NH3.4SCTD	Sandy Creek Trib. D	City	Sandy Creek	Upstream of confluence with Sandy Creek	2.65	SCWS
NH4.3SC	Sandy Creek	City	Sandy Creek	Erwin Rd at Duke Center for Living	1.39	Ambient
NH4.4SCTD	Sandy Creek Trib. D	City	Sandy Creek	Academy Road	1.59	Ambient / SCWS
NH4.7SC	Sandy Creek	City	Sandy Creek	Sandy Creek at Morrene Rd.	0.92	SCWS
NH4.8SCTDT	Sandy Creek Trib. D	City	Sandy Creek	Duke University Road	0.34	Ambient
NH5.0SCTD	Sandy Creek Trib. D	City	Sandy Creek	Anderson Road	0.96	Ambient
SCSN 1	Sandy Creek	City	Sandy Creek	Near Waterbury St.	0.99	SCWS

(1) Station is located outside of the project study area.
(2) Stations BB090 and BF057 are located at the same site.
NCDWR = North Carolina Division of Water Resources
SESQA = Southeast Stream Quality Assessment
SCWS = Sandy Creek Watershed Study
UCFRBA = Upper Cape Fear River Basin Association

Table 2-3. Water quality stations within the study area and available water quality data by year collected (continued)

Station ID	Stream	Agency	Watershed	Location	Drainage Area (sq. mile)	Project
SCSN 3	Sandy Creek	City	Sandy Creek	Welcome Dr. and Tryon Rd.	0.08	SCWS
SCSN 4	Sandy Creek	City	Sandy Creek	Near Evans St.	0.09	SCWS
SCSN 6	Sandy Creek	City	Sandy Creek	Off Kangaroo Dr. behind post office	0.06	SCWS
SCSN 7	Sandy Creek	City	Sandy Creek	Downstream of NC147 in Duke Manor Apartments off LaSalle St.	0.17	SCWS
SCSN 10	Sandy Creek	City	Sandy Creek	Near Circuit Dr.	0.08	SCWS
SCSN 11	Sandy Creek	City	Sandy Creek	Near parking lot on Fuqua Dr.	0.07	SCWS
SCSN 13	Sandy Creek	City	Sandy Creek	Near Nasher Museum parking lot off Campus Dr.	0.08	SCWS
SCSN 14	Sandy Creek	City	Sandy Creek	Near end of Hull Ave.	0.04	SCWS
SCSN 15	Sandy Creek	City	Sandy Creek	Near Campus Dr. downstream of NC147	0.03	SCWS
SCSN 17	Sandy Creek	City	Sandy Creek	Upstream of Morehead Dr.	0.09	SCWS
SCSN 18	Sandy Creek	City	Sandy Creek	Off Brooks-Pascal Dr. below stadium	0.08	SCWS
SCSN 21	Sandy Creek	City	Sandy Creek	Near Pierce St. and Prince St.	0.13	SCWS
B3040000	New Hope Creek	UCFRBA	Lower New Hope Creek	Stagecoach Road (SR 1107) near Blands	74.4	Ambient
B3020000	New Hope Creek	UCFRBA	Lower New Hope Creek	NC 54 near Durham	56.1	Ambient / Benthic
BB085	New Hope Creek	NCDWR	Lower New Hope Creek	I-40	57.9	Benthic
BB238	New Hope Creek	NCDWR	Lower New Hope Creek	Stagecoach Road (SR 1107) near Blands	74.4	Benthic
BB090, BF057[2]	New Hope Creek	NCDWR	Lower New Hope Creek	SR 2220	52.3	Benthic

(1) Station is located outside of the project study area.
(2) Stations BB090 and BF057 are located at the same site.
NCDWR = North Carolina Division of Water Resources
SESQA = Southeast Stream Quality Assessment
SCWS = Sandy Creek Watershed Study
UCFRBA = Upper Cape Fear River Basin Association

2.5.5 Water Quality Index

The City determines a WQI value for ambient water quality stations based on threshold values of dissolved oxygen, BOD, bacteria, nutrients, turbidity, and metals for a given sample date. A WQI is a numerical "grade" that ranges from 0 (poor) to 100 (excellent) and indicates the overall health of the stream. The WQI numerical value is assigned a letter grade (A, B, C, D, and F), where a value lower than 60 is considered an "F" and a value higher than 90 an "A". Average WQI values across all sample years for stations within the study area are presented in Table 2-4 and annual average values are presented in Appendix C.

At one station in the Little Creek watershed, LITC1.5LITC, water quality data are only available for calendar year 2015. The average WQI for 2015 was 72, which can be compared to a "C".

Two stations in the Lower New Hope Creek watershed were assigned WQI values, NH0.0NHC at Chapel Hill Road and NH3.0NHC at Erwin Road. The average value for NH0.0NHC is 82 and for NH3.0NHC is 91.

WQI values are available for seven stations in the Sandy Creek watershed. The average WQI for Sandy Creek (three stations) is 81.5. The average WQI for Sandy Creek Tributary A (one station) is 64. The average WQI for Sandy Creek Tributary D (two stations) is 81.5. The average WQI for Sandy Creek Tributary D (one station) is 78.

The one station in the Mud Creek watershed, NH2.3MC at Pickett Road, has an average WQI value of 85 (B).

Table 2-4. Average Annual WQI at stations within the study area

Station ID	Watershed	Stream Name	Location	Average Annual WQI	Years
LITC1.5LITC	Little Creek	Little Creek	Farrington Road	72	2015
NH0.0NHC	Lower New Hope Creek	New Hope Creek	Chapel Hill Road	82	2004-2011, 2013, 2015, 2017, 2019
NH3.0NHC	Lower New Hope Creek	New Hope Creek	Erwin Road	91	2009-2011, 2013, 2015, 2017, 2019
NH2.3MC	Mud Creek	Mud Creek	Pickett Road	85	2004-2011, 2013, 2015, 2017, 2019
NH1.0SC	Sandy Creek	Sandy Creek	Garrett Road	83	2004-2011, 2013, 2015, 2017, 2019
NH1.7SCTA	Sandy Creek	Sandy Creek Tributary A	Ivy Creek Boulevard	64	2010-2011, 2013, 2015, 2017, 2019
NH3.3SC	Sandy Creek	Sandy Creek	Cornwallis Road	80	2008-2020
NH4.3SC	Sandy Creek	Sandy Creek	Erwin Road	-	-
NH4.4SCTD	Sandy Creek	Sandy Creek Tributary D	Academy Road	77	2019
NH4.8SCTDT	Sandy Creek	Sandy Creek Tributary D	Duke University Road	78	2011, 2013, 2015, 2017
NH5.0SCTD	Sandy Creek	Sandy Creek Tributary D	Anderson Road	86	2011, 2013

WQI = Water Quality Index

2.5.6 Pesticides

A study conducted by USGS from April to June in 2014, the Southeast Stream Quality Assessment (SESQA), sampled 121 different sites across five states to assess stream quality, including station NH3.3SC at Cornwallis Road on Sandy Creek (USGS, 2014). The goal of this assessment was to determine how ecological conditions in streams were affected by chemical and physical stressors. Water samples were collected weekly for up to 10 weeks and analyzed for various parameters, including roughly 240 dissolved pesticides and pesticide degradates (compounds that result when pesticides break-down or degrade). USGS categorizes pesticides into four major groups: herbicides, insecticides, fungicides, and a mixed group of pesticides, including fumigants, nematicides, and other miscellaneous pesticides. The Sandy Creek station (NH3.3SC) scored a value of 0.76 normalized toxicity units, categorized as "Medium", for Predicted Pesticide Toxicity to Invertebrates (PTI). PTI scoring was based on comparisons of measured pesticide concentrations and published toxic concentrations for each taxonomic group. Acute toxicity is predicted above a PTI value of 1 normalized toxicity units, which is the theoretical threshold for an additive toxicity model; chronic (or a low degree of acute) effects are predicted above a PTI value of 0.1 normalized toxicity units.

Pesticide sampling was also conducted as part of the Sandy Creek Watershed Study (City of Durham, 2019) at four stations in the Sandy Creek watershed: NH3.4SCTD, NH3.4SC, NH4.4SCTD, and NH4.7SC. The 22 pesticides analyzed in this study were selected based on the frequency of detection and detection of concentrations above published toxicity limits in the 2014 SESQA study, as well as the testing ability of the contract laboratory. Pesticide samples were collected in June of 2018; however, the sampling efforts were suspended after the first event because all results were non-detects. The USGS study (USGS, 2014) measured these pesticides at the nanogram per liter range through the use of specialized analytical methods, whereas most commercial laboratories are only capable of reporting in the µg/L range. In the Sandy Creek Watershed Study, non-detect results may have been due to the pesticides not being present at the time, or due to the commercial lab being unable to detect concentrations of these chemicals below certain levels (City of Durham, 2019). A list of pesticides analyzed during the Sandy Creek Watershed Study is provided in Table 2-5.

Table 2-5. Pesticides analyzed in 2018 Sandy Creek watershed study at stations NH3.4SC, NH3.4SCTD, NH4.7SC, and NH4.4SCTD

Pesticide Name		
2,4-D	Diuron	Propiconazole
Acephate	Fipronil	Simazine
Aminomethylphosphonic Acid (AMPA)	Glyphosate	Sulfometuron-methyl
Atrazine	Imidacloprid	Tebuconazole
Azoxystrobin	2-Methyl-4-Chlorophenoxyacetic Acid (MCPA)	Tebuthiuron
Carbaryl	Metolachlor	Triclopyr
Carbendazim	Myclobutanil	
Dimethenamid-P	Prometon	

2.5.7 Observed Water Quality Conditions

Water Quality within the study area was assessed using data collected at one station along the mainstem of New Hope Creek (NH0.0NHC), one station on Little Creek (LITC1.5LITC), seven stations on Sandy Creek (NH1.0SC,

NH1.7SCTA, NH3.3SC, NH4.3SC, NH4.4SCTD, NH4.8SCTDT, and NH5.0SCTD), and one station on Mud Creek (NH2.3MC). Data from the special study in the Sandy Creek watershed in 2018–2019 are also included. New Hope Creek at Turkey Farm Road (City of Durham monitoring station NH 8.8NHC), located in Orange County, was used as a reference station by the City because of its good water quality. Sandy Creek has historically been found to have poor water quality for bacteria and aquatic life.

The City of Durham conducts monitoring and assessing of benthic macroinvertebrate communities at two ambient water quality stations within the study area: NH2.3MC on Mud Creek and NH1.0SC on Sandy Creek. The water quality ratings for NH2.3MC are mostly Fair and water quality ratings for NH1.0SC are mostly Poor. Existing water quality data are included in Appendix C and existing benthic data are presented in Table 2-6. Values presented in bold in Appendix C indicate that either a) the average concentration or b) a considerable number of individual samples for the year exceed the water quality standard or criteria. A summary of water quality within each subwatershed is presented below based on the downstream-most station in each subwatershed. A summary of water quality data by year and station is presented in Appendix C.

Little Creek (LITC1.5LITC)

Samples at LITC1.5LITC were only collected for 2013 and 2015, and only fecal coliform, DO, and turbidity samples were collected in 2013. The average annual WQI at LITC1.5LITC is 72. Parameters of concern that did not meet the standards within the timeframe samples were collected include BOD, fecal coliform, TN, TP, and copper as described below:

- The average BOD is 3.5 mg/L, higher than the 2 mg/L threshold.
- The geometric mean fecal coliform concentration is 58 cfu/100 ml in 2013 and 372 cfu/100 ml in 2015, higher than the 200 cfu/100 ml geometric mean standard. Concentrations exceeded the standard 12 out of the 24 months samples were collected.
- The average annual TN concentration is 0.87 mg/L, higher than the 0.80 mg/L benchmark.
- The average annual TP concentration is 0.09 mg/L, higher than the 0.08 mg/L benchmark.
- The CCC for copper was exceeded in 4 of the 12 samples collected.

Parameters that have acceptable concentrations within the timeframe samples were collected include DO, zinc, and turbidity as described below:

- The average DO concentration is 6.5 mg/L, higher than the 4.0 mg/L minimum standard. Concentrations were above the standard 19 of the 23 days samples were collected.
- The CCC for zinc was never exceeded.
- The average turbidity is 24 NTUs, which is below the maximum standard of 50 NTUs. Only one sample exceeded the standard.

New Hope Creek (NH0.0NHC)

Samples at NH0.0NHC were collected from 2004 to 2011, 2013, 2015, 2017, and 2019. The average annual WQI at NH0.0NHC is 82. BOD and fecal coliforms were the only parameters of concern that did not meet the standards within the timeframe samples were collected as described below:

- The average BOD is 2.3 mg/L for all years, which is slightly higher than the 2 mg/L benchmark.
- The geometric mean fecal coliform concentration for all years is 268 cfu/100 ml, which is above the 200 cfu/100 ml geometric mean standard. Concentrations exceeded the standard for 45% of samples taken.

Parameters that have acceptable concentrations within the timeframe samples were collected include DO, TN, TP, copper, zinc, and turbidity as described below:

- The average DO concentration is 7.2 mg/L which is well above the minimum standard of 4.0 mg/L. DO levels are above the standard 82% of days samples were taken.
- The average TN concentration is 0.68 mg/L which is below the 0.8 mg/L benchmark. The average annual TN concentration never exceeded the benchmark during the 12 years data were collected.
- The average TP concentration is 0.078 mg/L, which is slightly below the 0.08 mg/L benchmark. The average annual TP concentration exceeded the benchmark only 3 of the 12 years data were collected.
- The CCC for copper was exceeded in only 4% of samples taken.
- The CCC for zinc was never exceeded.
- The average annual turbidity value was below the standard of 50 NTUs for all years. Turbidity exceeded the standard in only 12% of samples taken.

Sandy Creek (NH1.0SC)

Samples at NH1.0SC were collected from 2004 to 2011, 2013, 2015, 2017, and 2019. The average annual WQI at NH1.0SC is 83. Parameters of concern that exceeded standards within the timeframe samples were taken include BOD, fecal coliforms, TN, and TP as described below:

- The average BOD is 2.4 mg/L, which is slightly higher than the 2 mg/L benchmark.
- The geometric mean fecal coliform concentration for all years was 333 cfu/100 ml, which is above the 200 cfu/100 ml geometric mean standard. Concentrations exceeded the standard for 55% of samples taken.
- The average TN concentration is 0.88 mg/L, which is above the 0.80 mg/L benchmark. The average annual TN concentration exceeded the benchmark 5 out of the 12 years samples were taken.
- The average TP concentration is 0.088 mg/L, which is above the 0.08 mg/L benchmark. The average annual TP concentration exceeded the benchmark 8 out of the 12 years samples were taken.
- The benthic bioclassification rating was Fair for 3 years and Poor for 8 years of the 11 years data were collected at NH1.0SC.

Parameters that have acceptable concentrations within the timeframe samples were collected include DO, copper, zinc, and turbidity as described below:

- The average DO concentration is 8.4 mg/L for all years, which is well above the minimum standard of 4.0 mg/L. DO concentrations were above the standard for 95% of samples taken.
- The CCC for copper was exceeded in only 13% of samples.
- The CCC for zinc was never exceeded during the 12 years samples were taken.
- The average turbidity value is 28 NTUs, which is below the standard of 50 NTUs. The average annual turbidity exceeded the standard only 1 year, in 2006. Only 15% of samples taken exceeded the standard.

Mud Creek (NH2.3MC)

Samples at NH2.3MC were collected from 2004 to 2011, 2013, 2015, 2017, and 2019. The average annual WQI at NH2.3MC is 84. Parameters of concern, that exceeded standards within the timeframe samples were taken include BOD, fecal coliform, and TN as described below:

- The average BOD is 2.4 mg/L for all years, which is higher than the 2 mg/L benchmark.

- The geometric mean fecal coliform concentration is 259 cfu/100 ml, which is above the 200 cfu/100 ml geometric mean standard. Fecal coliform values exceeded the standard in 48% of samples. Annual geometric mean values exceeded the standard in 8 of the 12 years samples were collected.
- The average TN concentration is 0.86 mg/L, which exceeds the benchmark of 0.80 mg/L. TN concentrations exceeded the benchmark for 41% of samples.
- The benthic bioclassification rating was Poor or Fair for 5 years and Good or Good-Fair for only 2 of the 7 years data were collected at NH2.3MC.

Parameters that have acceptable concentrations within the timeframe samples were collected include DO, TP, copper, zinc, and turbidity as described below:

- The average TP concentration is 0.067 mg/L, which is below the benchmark of 0.08 mg/L. TP concentrations exceeded the benchmark for only 16% of samples.
- The average DO concentration is 8.4 mg/L for all years, which is well above the 4.0 mg/L minimum threshold. DO concentrations were above the threshold for 92% of samples.
- The CCC for copper was exceeded in only 6% of samples.
- The CCC for zinc was never exceeded during the 12 years samples were taken.
- The average turbidity is 36 NTUs, which is below the standard of 50 NTUs. Turbidity values exceeded the standard for only 15% of samples.

Table 2-6. Benthic macroinvertebrate community sampling results

Collection Date	Total # Taxa	Total # Individuals	Total # EPT Taxa	Total # EPT Individuals	Biotic Index	Rating
BB085 – Lower New Hope Creek						
10/09/1985	48	-	4	-	-	Fair
BB090 – Lower New Hope Creek						
03/12/1987	50	-	2	-	-	Fair
BB238 – Lower New Hope Creek						
10/09/1985	32	-	3	-	-	Poor
07/07/1998	38	-	3	-	-	Fair
07/07/2003	32	-	3	-	-	Fair
07/22/2008	38	-	2	-	-	Fair
NH1.0SC – Sandy Creek						
09/18/2006	29	104	3	12	7.29	Fair
07/09/2007	30	98	5	22	7.09	Poor
09/18/2009	35	137	4	13	7.62	Poor
03/10/2009	43	192	5	17	7.62	Poor
04/29/2010	53	235	4	24	7.75	Poor
08/16/2010	49	-	6	21	7.61	Poor

EPT = Ephemeroptera, Plecoptera, and Trichoptera orders of aquatic insects.

Table 2-6. Benthic macroinvertebrate community sampling results (continued)

Collection Date	Total # Taxa	Total # Individuals	Total # EPT Taxa	Total # EPT Individuals	Biotic Index	Rating
NH1.0SC – Sandy Creek (continued)						
04/14/2011	23	-	4	-	7.52	Poor
04/25/2013	48	-	5	-	7.4	Poor
04/07/2015	16	55	2	-	6.85	Fair
03/30/2017	41	95	4	-	7.27	Poor
2019	29	-	5	25	6.89	Fair
NH2.3MC – Mud Creek						
03/09/2009	55	207	6	24	7.61	Poor
04/28/2010	59	215	9	51	6.35	Fair
04/15/2011	28	-	10	32	6.34	Fair
04/25/2013	53	-	7	-	6.8	Fair
04/07/2015	26	75	5	-	5.17	Good
03/30/2017	64	194	12	-	6.61	Good-Fair
2019	57	-	9	37	6.66	Fair

EPT = Ephemeroptera, Plecoptera, and Trichoptera orders of aquatic insects.

2.5.8 Sediment Sampling

A study was conducted on sediment bacteria from 2009 to 2010 at three ambient stations: NH2.3MC in Mud Creek, NH3.3SC in Sandy Creek, and NH3.0NHC in New Hope Creek. Samples were analyzed for physical characteristics (bulk density and soil components), organic carbon, fecal coliforms, and E. Coli. At all three sites fecal coliform concentrations were found to be elevated, where average values for NH2.3MC were 5,078 cfu/100 ml, for NH3.0NHC were 1,686 cfu/100 ml, and for NH3.3SC were 4,973 cfu/100 ml. Concentrations for E. Coli were elevated as well, where average values for NH2.3MC were 478 mpn, for NH3.0NHC were 75 mpn, and for NH3.3SC were 96 mpn.

Sediment sampling data is also available from the 2018 Sandy Creek Watershed Study for four sample stations (NH1.8SCTA, NH1.6SC, NH4.4SCTD, and NH4.7SC) within the Sandy Creek watershed (City of Durham, 2019a). Samples were analyzed for both physical (dry weight, particle size distribution) and chemical characteristics, including organic carbon, 10 metals, and 11 polycyclic aromatic hydrocarbons (PAHs).

Particle size analysis of sediment samples indicated that the NH1.8SCTA and NH1.6SC stations had predominantly medium to coarser sand, while both headwater stations (NH4.4SCTD and NH4.7SC) were characterized by fine-medium sand. Comparison of PAHs with historic observations from City-wide sampling sites could not be made since the reporting limit used in the Sandy Creek Watershed Study was higher than the historic mean. However, fluoranthene, pyrene, and phenanthrene were measured higher than the City-wide historic mean at NH1.8SCTA. Results also indicated that seven out of 10 PAHs were well above historical mean values at NH4.7SC. While comparisons to historic means could not be made for cadmium, all other metals were reported to be below historical mean values with the exception of zinc at stations NH1.6SC, NH4.4SCTD, and NH4.7SC, and lead at stations NH4.4SCTD and NH4.7SC. The incidence of toxicity, or the percent of samples that would likely cause

toxicity in one or more aquatic test species, ranged from 1.4% to 3.5% for all stations, suggesting the potential for toxicity from the combination of metals and PAHs is very low. The study concluded that given the low incidence of toxicity values observed, Sandy Creek watershed is a low-priority watershed for conducting future stream sediment toxicity studies. The study also suggested that there is a low likelihood that toxicity due to sediment chemistry would negatively impact benthic communities in Sandy Creek.

Sediment sampling was conducted by USGS at two stations: USGS-02097314 on New Hope Creek at Stagecoach Road (SR 1107) and 0209722970 on Sandy Creek at Cornwallis Road. Sampling at both stations was conducted in 2014 as part of the USGS Southeast Stream Quality Assessment (SESQA) study. Results from the SESQA study indicate medium toxicity of benchmark quotient contaminants (BQ5; PAHs, organochlorine compounds, PCBs, metals, and pesticides) and medium toxicity of Pyrethroid pesticides at both stations. Sampling at Stagecoach road was also conducted in May 2009, where mercury concentrations were found to be 0.11 mg/kg

2.6 Land Use

Durham County and the City of Durham actively maintain parcel land use data for areas within the county. In addition to the existing land use, future land use data, based on forecasted build-out by 2025, are also available for Durham County. While the future land use data used in this analysis is the most recent data available, it is expected to change as part of the City's Comprehensive Plan currently being updated. The existing and future land use data were grouped into 10 categories using a methodology similar to what was used in previous WIPs completed by the City of Durham in the Eno River, Little Lick Creek, Third Fork Creek, Ellerbe Creek, Northeast Creek, and Crooked Creek watersheds (Table 2-7). This simplification allows for a direct comparison between existing and future land uses within and across WIPs.

Table 2-7. Simplified land use categories based on the Durham City/County land use classification

Land Use Description	Land Use Code
Agriculture	AGR
Very Low Density Residential	VLR
Low Density Residential	LDR
Medium Density Residential	MDR
High Density Residential	HDR
Commercial	COM
Institutional	INT
Industrial	IND
Parks and Open Space	POS

2.6.1 Existing Land Use

To characterize existing land use data within the study area, the data were reclassified like previous WIPs as follows:

- Offices were classified as Commercial
- Utilities were classified as Commercial
- Public areas were classified based on impervious area and type:

  - Parcels with less than 10% impervious area were classified as Parks and Open Space
  - Churches, schools, and government buildings were classified as Institutional
- Recreation and open space areas were classified based on the location in respect to the FEMA 100-year floodplain boundaries and type:
  - Parcels on public or private land within a FEMA 100-year floodplain boundary were classified as Parks and Open Space
  - Parcels on private land outside of a FEMA 100-year floodplain boundary were classified as the adjacent existing land use
  - Parcels on public land outside of a FEMA 100-year floodplain boundary were classified as Parks and Open Space
- Vacant areas were classified based on impervious area and size:
  - Parcels with greater than 10% impervious area were classified as their future land use
  - Parcels less than 5 acres in size and with less than 10% impervious area were classified as Medium Density Residential
  - Parcels greater than 5 acres in size and with less than 10% impervious area were classified as Parks and Open Space
- Residential parcels were classified based on parcel acreage:
  - Parcels less than 0.125 acres: High Density Residential
  - Parcels between 0.125 and 0.33 acres: Medium Density Residential
  - Parcels between 0.33 and 1.0 acres: Low Density Residential
  - Parcels greater than 1.0 acres: Very Low Density Residential
- Durham City/County does not have an existing land use classification for transportation. Transportation rights-of-way were generated using available parcel data to identify parcels without an existing land use attribute. The “Erase” ArcGIS geoprocessing tool was used to create a polygon from these unclassified parcels. The resulting area was classified as “Roadways.”

The following land uses were reclassified in a manner consistent with previous WIPs:

- 411 (Com/Apartment-Garden) – classified as High Density Residential
- 413 (Com/Apartment-Dwg Conv) – classified as Low Density Residential
- 633 (Comm Svc/Home for the Aged) – classified as Medium Density Residential
- 643 (Comm Svc/Assisted Lvg) – classified as Medium Density Residential
- 697 (Comm Svc/ABC Stores) – classified as Commercial

Table 2-8 and Exhibit 8 present the reclassified existing land use within the study area. The study area within the city limits is 40% Residential, 24% Parks and Open Space, and 21% Commercial/Institutional.

Table 2-8. Existing land use within the study area

Land Use Description	Study Area		Within City Limits of Study Area	
	Acres	Percent(1)	Acres	Percent(1)
Agriculture	717	4%	103	1%
Very Low Density Residential	1,426	7%	563	4%
Low Density Residential	2,537	13%	2,097	16%
Medium Density Residential	1,941	10%	1,487	11%
High Density Residential	1,291	7%	1,252	9%
Commercial	1,522	8%	1,423	11%
Institutional	1,469	8%	1,335	10%
Industrial	26	<1%	26	<1%
Parks and Open Space	6,123	32%	3,180	24%
Roadways	2,261	12%	1,903	14%
Total	19,314	100%	13,369	100%

(1) Individual totals and percentages may not sum to column totals due to rounding.

2.6.2 Future Land Use

Similar to existing land use, future land use data provided by Durham City/County were also reclassified. This allows for a direct comparison between existing land use and future land use and an evaluation of development trends throughout the study area. The same Roadways land use polygon created for the existing land use was used to characterize roadway land use in the future land use condition because a Transportation future land use does not exist.

The current future land uses were amended by the Durham City/County Planning Department in the 2015 Durham City/County Comprehensive Plan (City of Durham, 2015). The future land use data are less granular compared to existing land use data. Existing land use data are parcel specific, whereas future land use data combine multiple parcels expected to contain similar land uses. Durham City/County are currently in the process of updating the Comprehensive Plan, which will result in changes to future land use designations. Future watershed assessments should reference the most updated data available.

In some areas throughout the study area, the existing degree of development density was found to be higher in the existing land use condition than in the projected future land use condition. For instance, many areas that are currently Medium Density or High Density Residential in the existing land use were projected to be Very Low or Low Density Residential in the future land use. To address this concern, the future land use condition was revised such that the future residential land use categories did not change to a lesser degree of development density. For example, existing High Density Residential areas remained as High Density Residential areas in the future land use rather than changing to a lower density (Medium, Low, or Very Low Density Residential) in the future. However, a lower density residential area was allowed to increase in development density if projected to do so in the future land use. Additionally, the following adjustments were made to the future land use for consistency with the existing land use:

- Low-Medium Density Residential areas were classified as Low Density Residential
- Medium-High Density Residential areas were classified as Medium Density Residential

- Rural Density Residential areas were classified as Very Low Density Residential
- Offices were classified as Commercial
- Design District areas were classified as High Density Residential

Specific parcel reclassifications were based on a desktop review of aerial imagery.

Table 2-9 and Exhibit 9 present the reclassified future land use condition within the study area. Future land use within the study area is projected to be primarily Parks and Open Space and Residential with an increase in Low- and High-Density Residential areas.

Table 2-9. Future land use within the study area

	Study Area		Within City Limits of Study Area	
Land Use Description	Acres	Percent(1)	Acres	Percent(1)
Agriculture	0	0%	0	0%
Very Low Density Residential	1,334	7%	115	1%
Low Density Residential	3,545	18%	2,623	20%
Medium Density Residential	1,840	10%	1,442	11%
High Density Residential	1,767	9%	1,479	11%
Commercial	1,639	8%	1,538	11%
Institutional	1,496	8%	1,362	10%
Industrial	153	1%	153	1%
Parks and Open Space	5,279	27%	2,769	21%
Roadways	2,261	12%	1,902	14%
Total	19,314	100%	13,369	100%

(1) Individual totals and percentages may not sum to column totals due to rounding.

2.6.3 Land Use Development Trends

Based on the current 2025 future land use projection, the primary development trend is the transition of both Agricultural, Very Low Density Residential, and Open Space land to Low Density and High Density Residential lands. There is no significant projected change in Commercial areas and a marginal increase in Industrial areas within the study area. Projected land use changes from existing to future land use for the study area are presented in Table 2-10 and for each subwatershed in Appendix D.

Table 2-10. Projected land use changes within the study area from existing to future conditions

Land Use Description	Existing Land Use (acres)			Future Land Use (acres)			Projected Change[1]					
							Study Area		City		County	
	Study Area	City	County	Study Area	City	County	Acres	Percent Change	Acres	Percent Change	Acres	Percent Change
Agriculture	717	103	614	0	0	0	-717	-100%	-103	-100%	-614	-100%
Very Low Density Residential	1,426	576	850	1,334	115	1,219	-92	-6%	-461	-80%	369	43%
Low Density Residential	2,537	2,096	441	3,545	2,623	922	1,008	40%	527	25%	481	109%
Medium Density Residential	1,941	1,493	448	1,840	1,442	398	-101	-5%	-51	-3%	-50	-11%
High Density Residential	1,291	1,252	39	1,767	1,479	288	476	37%	228	18%	248	631%
Commercial	1,522	1,422	100	1,639	1,538	101	117	8%	116	8%	1	1%
Institutional	1,469	1,335	134	1,496	1,362	134	27	2%	27	2%	0	0%
Industrial	26	26	0	153	153	0	127	488%	127	481%	0	-19%
Parks and Open Space	6,123	3,178	2,945	5,279	2,769	2,510	-844	-14%	-410	-13%	-434	-15%
Roadways	2,261	1,902	359	2,261	1,902	359	-	0%	0	0%	0	0%

(1) Individual totals and percentages may not sum to column totals due to rounding.

2.6.4 Impervious Cover

Impervious area greatly affects both the hydrologic response of a watershed and the water quality of surface waters. As the impervious area increases, streams often exhibit higher peak flows and total volumes in response to storm events and will also exhibit lower base flows. Pollutants, such as nutrients, bacteria, and heavy metals, deposited on impervious surfaces are transported to streams through stormwater runoff leading to water quality degradation. Additionally, these high peak flows result in increases in shear stress, which results in accelerations in bank erosion and stream scour, which are often a significant source of sediment.

The impervious cover for the study area was determined by merging City planimetric data (2016), County building footprint data (2015), and road centerline data (2016). The planimetric data include “footprints” for buildings, homes, driveways, and parking lots within Durham city limits. Outside of city limits, only buildings footprints were available. The impervious area associated with roadways was determined by applying a buffer to road centerline data maintained by the City and Durham County, where the width of each road was specified in the roads dataset. The final composite impervious coverage for the study area was produced by merging all three datasets. This approach is consistent with previous watershed plans developed for the City.

The impervious area within the study area is approximately 19% and the impervious area within the city limits is approximately 25% as shown in Table 2-11. A map displaying impervious cover within the study area is included as Exhibit 10. Appendix D provides additional detail on the impervious area for each subwatershed. Most of the

impervious cover occurs in the Lower New Hope Creek watershed (1,699 acres; 20% impervious) while the greatest percent impervious coverage is in the Sandy Creek watershed (27%). Little Creek and Mud Creek have the lowest impervious coverage at only 10% impervious area.

Table 2-11. Impervious area within the study area(1)

Watershed	Total Area acres)	Area within City Limits (acres)	Total Impervious Area (acres)	Impervious Area within City Limits (acres)	Total % Impervious(2)	% Impervious within City Limits(2)
Little Creek	2,223	899	228	154	10	17
Mud Creek	3,761	1,720	383	339	10	20
Lower New Hope Creek	8,562	6,345	1,699	1,613	20	25
Sandy Creek	4,413	4,413	1,188	1,188	27	27
Total	18,959	13,377	3,498	3,294	19	25

(1) All columns refer to areas within the study area.
(2) Individual totals and percentages may not sum to column totals due to rounding.

Table 2-12 provides a summary of impervious area and percent impervious area associated with each of the City's ambient monitoring stations and the two UCFRBA stations within the New Hope Creek and Little Creek watersheds. The drainage areas for stations on Sandy Creek have the largest impervious percentages, ranging from 27% to 46%, while the stations on Mud Creek and Little Creek have the lowest impervious percentages at 10% each. The NH3.0NHC watershed, receiving water west of the County line, is only 3% impervious, while the watersheds for the other three New Hope Creek stations have approximately 20% impervious surface.

Table 2-12. Water quality monitoring station drainage areas and associated impervious cover within study area(1)

Station	Watershed	Total Area (acres)	Area Within Study Area (acres)	Impervious Area Within Study Area (acres)	% Impervious Within Study Area(2)
LCTC1.5LITC	Little Creek	15,232	2,221	227	10
B3020000	Lower New Hope Creek	35,915	13,422	2,704	20
B3040000	Lower New Hope Creek	48,759	15,657	2,936	19
NH0.0NHC	Lower New Hope Creek	33,442	11,045	2,312	21
NH3.0NHC	Lower New Hope Creek	20,035	0	0	NA
NH2.3MC	Mud Creek	3,388	3,388	323	10
NH1.0SC	Sandy Creek	4,321	4,321	1,148	27
NH1.6SC	Sandy Creek	4,196	4,196	1,104	26
NH1.7SCTA	Sandy Creek	893	893	414	46
NH1.8SCTA	Sandy Creek	706	706	320	45
NH3.3SC	Sandy Creek	2,979	2,979	865	29

(1) With the exception of "Total Area (acres)", all columns refer to areas or percentage of area within the study area
(2) "NA" = not applicable

Table 2-12. Water quality monitoring station drainage areas and associated impervious cover within study area[1] (continued)

Station	Watershed	Total Area (acres)	Area Within Study Area (acres)	Impervious Area Within Study Area (acres)	% Impervious Within Study Area[2]
NH3.4SC	Sandy Creek	1,271	1,271	441	35
NH3.4SCTD	Sandy Creek	1,674	1,674	418	25
NH4.3SC	Sandy Creek	942	942	411	44
NH4.4SCTD	Sandy Creek	999	999	297	30
NH4.7SC	Sandy Creek	546	546	251	46
NH4.8SCTDT	Sandy Creek	220	220	89	40
NH5.0SCTD	Sandy Creek	596	596	176	30

(1) With the exception of "Total Area (acres)", all columns refer to areas or percentage of area within the study area
(2) "NA" = not applicable

2.7 Field Assessments

Watershed health and water quality are dependent on the streams that flow through them. Characterization of New Hope Creek, Little Creek, and their main tributaries is an integral part of the WIP development process. Field assessments were performed to evaluate existing conditions of streams and riparian buffers, identify water quality concerns, and identify potential stream and water quality improvement projects. A desktop Geographic Information System (GIS) analysis was conducted prior to the field visits to identify and prioritize the streams that would undergo a rapid (Level 1) or comprehensive (Level 2) assessment (City of Durham, 2020b).

Existing SCMs were also evaluated in the field for improper function, due to design or maintenance issues, and their potential to be retrofitted. Any existing areas where runoff treatment mechanisms do not exist were also evaluated for the feasibility of constructing a new SCM. A desktop prescreening was conducted prior to the field work for selecting new sites with a higher likelihood of feasibility for constructing new SCMs to capture untreated runoff.

Drainage density, the measure of stream length per unit area of drainage basin, is one indicator of drainage efficiency within a watershed. A higher drainage density can indicate less permeability in soils which produces higher flood rates. Drainage density for the subwatersheds and ambient monitoring stations within the study area is presented in Appendix E.

2.7.1 Stream Assessment Methods

The purpose of the stream assessments was to characterize existing stream conditions within the watershed and identify potential projects to improve the overall water quality and health of the watershed. Methods used during the stream assessment were consistent with previous watershed plans completed by the City of Durham. The field stream inventory and assessment was performed by field teams consisting of an Environmental Scientist with experience in stream ecology and an engineering professional with experience in stream restoration design from Wildlands and City Staff when available. The stream inventory included the following tasks:

1. Collect data on the physical condition of the streams and riparian buffers within the watershed
2. Identify stream reaches and riparian buffers in need of restoration, enhancement, or preservation

3. Identify potential sources of pollution along the stream corridors within the watershed
4. Identify issues with public utilities that cross or are adjacent to the streams
5. Collect information needed for the watershed improvement scenarios
6. Collect more detailed information such as streambank erosion rate on Level 2 stream reaches that can help to prioritize restoration and enhancement projects

Data were collected in the field using Survey123 for ArcGIS with a GPS-enabled tablet. After the field assessment was completed, the data was compiled into a geodatabase. In February 2020, field teams performed assessments along approximately 34 miles of stream, which included 115 individual stream reaches. Stream reach break points were determined in the field based on changes in stream and/or riparian buffer conditions, such as cross-sectional dimensions, degree of erosion, width and density of buffers, or obvious changes in stream type. Two levels of field assessment were performed. Level 1 stream assessments involved a higher-level survey to collect more general data on a large percentage of streams throughout the watershed. Level 2 stream assessments were more detailed and performed on a subset of Level 1 streams. Both Level 1 and Level 2 stream assessment methodologies are described below, and more detailed information on each assessment method can be found in the Stream Assessment Field Plan in Volume III – Technical Appendices of the Watershed Improvement Plan (City of Durham, 2020b).

2.7.1.1 Level 1 Stream Assessments

Most perennial and larger intermittent streams within the study area, except for those outside of the City limits or on federal land, were assessed during the Level 1 stream assessment. Streams with drainage areas greater than 50-acres were identified, using GIS analysis, to be evaluated during field assessment. The final selection of streams assessed is presented in the Stream Assessment Field Plan in Volume III - Technical Appendices of the Watershed Improvement Plan (City of Durham, 2020b). The Level 1 assessments included collection of the following data:

Basic Stream Reach Data

Basic information about each stream reach was collected, including stream reach ID, field team number, subwatershed, surrounding land use, and priority level of the assessment reach (Level 1 or Level 2).

Physical Measurements

A representative riffle cross-section was selected for each reach and channel cross-sectional dimensions were measured with a tape measure. An estimate of sinuosity and dominant bed material were also noted.

Rapid Stream Assessment Technique Evaluation

Field teams also performed a semi-quantitative evaluation of several stream characteristics using the Rapid Stream Assessment Technique (RSAT; Galli, 1996). This method includes an evaluation of the following riparian and in-stream features:

1. Channel Stability
2. Channel Scouring/Deposition
3. Physical Instream Habitat
4. Water Quality Indicators
5. Riparian Habitat Condition
6. Biological Indicators

For each stream reach assessed, field teams assigned a numeric score to each of the six metrics listed above. Adjective ratings of Excellent, Good, Fair, or Poor also correspond to a range of numeric scores. The component metric scores were then tabulated, and an overall score and corresponding overall rating was determined for each reach. Details regarding the RSAT method are presented in the Stream Assessment Field Plan in Volume III–Technical Appendices of the Watershed Improvement Plan (City of Durham, 2020b).

Stream Restoration, Enhancement, and Preservation Opportunities

Field teams evaluated potential project opportunities for each reach based on the condition of the reach and the feasibility of implementing different types of projects. A potential opportunity for each reach was selected from the following options: Restoration, Enhancement Level I (E1), Enhancement Level II (E2), Bank Stabilization, Buffer Restoration, or Preservation based on the definitions developed by USACE in its stream mitigation guidelines for North Carolina (USACE, 2003).

Water Quality Concerns

When potential water quality concerns were identified in the field, details were noted, and the location was recorded with the field tablet Global Positioning System (GPS). Potential water quality issues included visual evidence of discharge, leaking infrastructure, suspect odor, suspect water appearance, erosion and sediment control concern, or other. Water quality concerns were immediately reported to the City of Durham's Water Quality and Treatment department.

Litter Observed

A new metric intended to characterize litter observed in the watershed was included as part of the stream field assessments. Previous watershed improvement plans included a metric to capture observations of "dumping in channel". The updated metric was intended to provide consistent responses by assigning set categories, instead of open-ended comments, to characterize the relative abundance and apparent source of the dumping.

Initially, the categories used to capture relative abundance of litter during the field assessments were based on six groups described in a 2018 Duke Environmental Law and Policy Clinic study examining litter (Gerbode et al., 2018). Methods from the Duke study were referenced to revise the litter metric to articulate the approximate amount of litter and apparent source of the litter while remaining comparable with the metric used for 'dumping' in previous watershed improvement plans.

Analysis of the field data revealed that observations made with the six categories were subjective, overly qualitative, and prone to interpretation based on each field crew member's previous experience working in urban streams. Observations were also likely affected by unmeasured factors such as recent weather and stream flows. In a post-processing step, the categories used to capture relative abundance of litter were consolidated into four broader groups based North Carolina Department of Environmental Quality's Stream Watch program online stream assessment tool (NC DEQ, 2020), which characterizes trash density into four groups: none/sparse, light, moderate, heavy.

The five categories for apparent source of dumping were: Instream: likely from upstream source, Instream: likely from dumping, In buffer/along bank: likely from flooding event or upstream source, In buffer/along bank: likely from dumping and, Source unclear.

Utilities Condition

Field teams observed existing utilities that crossed or paralleled assessed streams. Field teams noted the type of utility present (sanitary sewer, gas, water, or other), the condition of the utility (stable or unstable), and any observed issue with the utility (leaking, exposed, stability threatened, or broken). The GPS was used to locate the

existing utilities. The City of Durham's Water Management department was notified of unstable or leaking utilities when they were observed by field teams.

Stormwater Control Measure Opportunities

Opportunities to implement SCMs along stream corridors were also noted by field teams. The teams identified the most appropriate SCM type and used the GPS to locate the potential SCM. Emphasis was placed on selecting feasible SCM locations.

Headcuts and Low-Head Dams

Locations of existing headcuts and low-head dams were recorded and located with the tablet GPS. A headcut as defined by Methodology for Identification of Intermittent and Perennial Streams and Their Origins (NC Division of Water Quality, 2010) is an abrupt vertical drop in the bed of a stream that is an active erosional feature. For the purposes of the field assessment, low-head dams were considered any man-made or natural structures (e.g. beaver dams) greater than three feet in height from the channel bed that were observed to significantly impede streamflow.

Vegetative Composition

A new parameter to assess the vegetative composition of the surrounding land was included in the field work performed for this watershed plan. Classifications of vegetative composition was adapted from the NC Stream Assessment Method or SAM (SFAT, 2013). The vegetation composition was classified into one of three categories based on qualitative observations of how levels of habitat disturbance are reflected in the composition of invasive species and native species: undisturbed, moderately disturbed, very disturbed. Dominant invasive species were noted where observed.

Photographs

Photographs taken at each reach included a shot from the upstream end of each reach looking downstream and at the downstream end of each reach looking upstream. Additional photographs captured habitat features such as deep pools, woody debris, areas of streambank erosion, and other noteworthy features of concern.

2.7.1.2 Level 2 Stream Assessments

Level 2 stream assessments were conducted on certain Level 1 reaches that were either selected during the planning of field work or selected in the field based on the judgement of field teams during Level 1 assessments. The prioritization of Level 2 reaches is described in the Stream Assessment Field Plan in Volume III– Technical Appendices of the Watershed Improvement Plan (City of Durham, 2020b). Level 2 assessments included Bank Erosion Hazard Index (BEHI), Near Bank Stress (NBS) analyses, and counts of large woody debris.

Bank Erosion Hazard Index

Field teams performed the BEHI assessment (Rosgen, 2006) on all Level 2 reaches. BEHI is an assessment of stream bank erosion potential and was performed on subreaches with similar streambank characteristics.

Near Bank Stress

An NBS assessment was performed for every subreach assessed for BEHI. The NBS assessment evaluates the potential shear stress on the streambank and results in an adjective rating of very low, low, moderate, high, very high, or extreme. These ratings are used with the BEHI ratings to develop estimates of sediment loads from bank erosion along a reach.

Large Woody Debris Counts

Field teams also counted large woody debris along each reach. Large woody debris was defined as any dead woody material over one meter in length and ten centimeters in diameter (Harman. et al, 2017).

2.7.1.3 Results of Stream Assessments

The results of the assessments indicate that the majority of streams assessed in the watershed are in fair to good overall health, but that some stream reaches are in poor overall condition. A total of 34.44 miles (Table 2-13) of streams were assessed by two field crews.

Table 2-13. Length of stream assessed by priority level

Priority Level	Length (miles)
Level 1	23.71
Level 2	10.73
Total	34.44

RSAT Results

Level 1 stream assessments occurred on approximately 34 miles of stream, divided into 115 individual stream reaches based on the current condition of the stream channel and the riparian corridor. The majority of stream reaches were rated Fair on the overall RSAT score (Table 2-14 and Exhibit 11). Of the overall stream miles assessed, none were rated Excellent, 18% were rated Good, 70% were rated Fair, 9% were rated Poor and 3% were not rated due to the presence of a beaver impoundment or other environmental factor. Figures shown below display characteristics of reaches in Good (Figures 2-2), Fair, (Figure 2-3), and Poor (Figure 2-4) conditions. Table 2-14 shows the miles of streams rated in each subwatershed and the overall percentage in each stream category. Table 2-15 provides additional characteristics for each individual stream reach assessed during field work.

Figure 2-2. Stream (MC1008) with Good overall RSAT score located in Duke Forest in NHC54_MC

Figure 2-3. Stream (SC2020) with Fair overall RSAT score located behind Lenox Baker Hospital in NHC12_LNHC

Figure 2-4. Stream (SC2015) with Poor overall RSAT score located parallel to Chapel Tower in NHC46_SC

Table 2-14. Rapid Stream Assessment Technique (RSAT) results by subwatershed

Subwatershed[1]	Watershed	Length of Stream Assessed (miles)	Percentage of Stream Channel within Each Stream RSAT Quality Category			
			Excellent	Good	Fair	Poor
NHC04_LC	Little Creek	0.88	0%	42%	58%	0%
NHC09_LNHC	New Hope Creek	0.76	0%	81%	19%	0%
NHC11_LNHC	New Hope Creek	0.42	0%	0%	100%	0%
NHC12_LNHC	New Hope Creek	0.91	0%	68%	32%	0%
NHC15_LNHC	New Hope Creek	0.33	0%	100%	0%	0%
NHC17_LNHC	New Hope Creek	0.32	0%	0%	100%	0%
NHC22_LNHC	New Hope Creek	0.33	0%	0%	68%	32%
NHC24_LNHC	New Hope Creek	0.81	0%	52%	48%	0%
NHC25_LNHC	New Hope Creek	0.46	0%	0%	100%	0%
NHC26_LNHC	New Hope Creek	1.28	0%	0%	77%	23%
NHC27_LNHC	New Hope Creek	0.83	0%	0%	100%	0%
NHC28_LNHC	New Hope Creek	1.1	0%	0%	43%	57%
NHC29_LNHC	New Hope Creek	1.94	0%	30%	70%	0%
NHC30_LNHC	New Hope Creek	1.29	0%	0%	79%	21%
NHC31_LNHC	New Hope Creek	0.51	0%	0%	50%	50%
NHC32_LNHC	New Hope Creek	0.72	0%	0%	80%	20%
NHC33_SC	Sandy Creek	0.98	0%	0%	100%	0%
NHC34_SC	Sandy Creek	0.18	0%	0%	100%	0%
NHC35_SC	Sandy Creek	2.11	0%	34%	66%	0%
NHC36_SC	Sandy Creek	1.92	0%	35%	65%	0%
NHC37_SC	Sandy Creek	0.59	0%	0%	100%	0%
NHC38_SC	Sandy Creek	0.24	0%	0%	100%	0%
NHC40_SC	Sandy Creek	2.19	0%	12%	80%	8%
NHC41_SC	Sandy Creek	0.43	0%	0%	100%	0%
NHC42_SC	Sandy Creek	0.53	0%	64%	0%	36%
NHC45_SC	Sandy Creek	1.78	0%	36%	64%	0%
NHC46_SC	Sandy Creek	1.32	0%	0%	70%	30%
NHC47_MC	Mud Creek	1.58	0%	0%	100%	0%
NHC48_MC	Mud Creek	1.64	0%	0%	100%	0%
NHC49_MC	Mud Creek	1.11	0%	0%	100%	0%
NHC51_MC	Mud Creek	1.035	0%	0%	100%	0%

(1) Out of the 56 subwatersheds in New Hope Creek and Little Creek Watersheds, 35 were assessed.
(2) Three percent stream miles assessed were not rated due to the presence of a beaver impoundment or other environmental factor.

Table 2-14. Rapid Stream Assessment Technique (RSAT) results by subwatershed (continued)

Subwatershed[1]	Watershed	Length of Stream Assessed (miles)	Percentage of Stream Channel within Each Stream RSAT Quality Category			
			Excellent	Good	Fair	Poor
NHC52_MC	Mud Creek	0.48	0%	0%	0%	0%
NHC54_MC	Mud Creek	0.99	0%	54%	46%	0%
NHC55_MC	Mud Creek	0.87	0%	21%	79%	0%
NHC56_MC	Mud Creek	1.56	0%	0%	62%	38%
Total[2]		34.44	0%	18%	70%	9%

(1) Out of the 56 subwatersheds in New Hope Creek and Little Creek Watersheds, 35 were assessed.
(2) Three percent stream miles assessed were not rated due to the presence of a beaver impoundment or other environmental factor.

Streams in 35 of the 56 subwatersheds in the study area were assessed by field crews. Subwatersheds within the City limits and those with primarily lotic systems were prioritized. Thirteen subwatersheds contained streams with an overall RSAT rating of Good. While 10 of the subwatersheds had some rated Poor, only 2 subwatersheds had greater than half of their assessed stream length rated Poor. Additionally, three subwatersheds had reaches that could not be rated because of a beaver impoundment or other environmental factors. The distribution of RSAT rating throughout the study area shows that the overall stream condition is Fair, but that localized areas are in Poor condition. The streams surveyed in the New Hope Creek and Little Creek Watersheds are located mostly in the Triassic Basin. Streams in this area tend to score lower on biological assessments due to relative lack of benthic macroinvertebrates which affects the biological indicators used in RSAT. Triassic Basin streams are not rated in the North Carolina Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates (NC DEQ, 2016) due to lack of habitat and flow cessation. The data collected for this assessment are comparable to data collected during previous City of Durham watershed assessments completed in the Triassic Basin.

Table 2-15. Characteristics of field assessed stream reaches

Reach ID	Stream[1]	Watershed	Length (feet)	Bankfull Width (feet)	Bankfull Depth (feet)	Priority Level	RSAT Rating[2,3]	Preliminary Project Recommendation
LC2001	UT to Little Creek	Little Creek	1,190	5.6	0.7	1	Good	Restoration
LC2002	UT to Little Creek	Little Creek	785	6.8	0.9	1	Fair	E2
LC2003	UT to Little Creek	Little Creek	761	7.2	1.0	1	Good	Preservation
LC2004	UT to Little Creek	Little Creek	1,897	4.8	0.4	1	Fair	Restoration
LNHC1001	New Hope Creek	New Hope Creek	3,043	30.1	1.4	1	Good	E2
LNHC1002	New Hope Creek	New Hope Creek	7,219	31.0	1.5	1	Fair	Restoration
LNHC1003	New Hope Creek	New Hope Creek	2,251	41.2	2.0	1	Fair	Bank Stabilization
LNHC1004	New Hope Creek	New Hope Creek	1,543	30.5	4.1	1	Fair	Bank Stabilization
LNHC1005	New Hope Creek	New Hope Creek	574	40.8	2.2	1	Fair	E2
LNHC1006	UT to New Hope Creek	New Hope Creek	1,446	11.7	2.0	1	Fair	Restoration
LNHC1007	UT to New Hope Creek	New Hope Creek	3,278	0.0	0.0	1	Poor	Restoration
LNHC1008	UT to New Hope Creek	New Hope Creek	1,066	13.5	2.8	1	Fair	E2
LNHC1009	UT to New Hope Creek	New Hope Creek	964	4.5	1.3	1	Fair	E2
LNHC1012	UT to New Hope Creek	New Hope Creek	761	4.6	1.1	1	Fair	Preservation
LNHC1013	UT to New Hope Creek	New Hope Creek	1,340	7.7	1.5	1	Poor	E1
LNHC1014	Sandy Creek Trib. A	Sandy Creek	1,395	23.1	2.8	2	Poor	Restoration
LNHC1015	Sandy Creek Trib. A	Sandy Creek	3,926	9.7	1.8	2	Fair	Restoration
LNHC1016	UT to New Hope Creek	New Hope Creek	1,467	4.5	1.4	2	Fair	Bank Stabilization
LNHC1018	UT to New Hope Creek	New Hope Creek	1,351	6.3	1.5	2	Fair	Bank Stabilization
LNHC1019	UT to New Hope Creek	New Hope Creek	1,346	8.3	1.1	2	Poor	E1
LNHC1020	UT to New Hope Creek	New Hope Creek	701	3.0	1.5	1	Fair	E2
LNHC1021	UT to New Hope Creek	New Hope Creek	1,879	7.9	1.0	1	Fair	Bank Stabilization
LNHC1022	UT to New Hope Creek	New Hope Creek	609	6.8	2.1	1	Poor	Restoration
LNHC1023	UT to New Hope Creek	New Hope Creek	880	5.9	1.1	1	Fair	E1
LNHC1024	UT to New Hope Creek	New Hope Creek	949	12.5	1.8	1	Poor	Restoration
LNHC1025	UT to New Hope Creek	New Hope Creek	789	10.2	2.0	1	Fair	E1
LNHC1026	UT to New Hope Creek	New Hope Creek	1,629	12.0	2.1	1	Fair	E1

(1) "UT" indicates Unnamed Tributary
(2) RSAT Ratings are as follows: Excellent Condition (42–50), Good Condition (30–41), Fair Condition (16–29), and Poor Condition (<16)
(3) Three streams that were assessed were not evaluated for RSAT due to site conditions (e.g. backwater from beaver dam)

Table 2-15. Characteristics of field assessed stream reaches (continued)

Reach ID	Stream[1]	Watershed	Length (feet)	Bankfull Width (feet)	Bankfull Depth (feet)	Priority Level	RSAT Rating[2,3]	Preliminary Project Recommendation
LNHC2001	UT to New Hope Creek	New Hope Creek	303	1.4	0.8	1	Poor	Restoration
LNHC2002	UT to New Hope Creek	New Hope Creek	450	2.9	0.9	1	Poor	E2
LNHC2003	UT to New Hope Creek	New Hope Creek	1,727	6.1	1.0	1	Fair	Bank Stabilization
LNHC2004	UT to New Hope Creek	New Hope Creek	552	13.4	1.2	2	Poor	E1
LNHC2005	UT to New Hope Creek	New Hope Creek	1,180	11.7	1.4	1	Fair	Restoration
LNHC2007	UT to New Hope Creek	New Hope Creek	1,461	4.1	0.9	1	Fair	Bank Stabilization
LNHC2008	UT to New Hope Creek	New Hope Creek	183	4.1	1.1	1	Fair	Bank Stabilization
LNHC2009	UT to New Hope Creek	New Hope Creek	2,232	12.0	1.9	1	Good	E2
LNHC2010	UT to New Hope Creek	New Hope Creek	409	16.9	1.9	1	Fair	Bank Stabilization
LNHC2013	UT to New Hope Creek	New Hope Creek	901	2.7	0.7	1	Fair	Bank Stabilization
LNHC2014	UT to New Hope Creek	New Hope Creek	768	3.7	1.0	1	Fair	Bank Stabilization
LNHC2015	UT to New Hope Creek	New Hope Creek	1,253	3.9	0.7	1	Good	Restoration
LNHC2016	UT to New Hope Creek	New Hope Creek	496	6.1	0.4	1	Good	Restoration
LNHC2017	UT to New Hope Creek	New Hope Creek	2,222	4.0	0.8	1	Fair	E1
LNHC2018	UT to New Hope Creek	New Hope Creek	1,644	5.1	1.2	1	Good	Restoration
LNHC2019	UT to New Hope Creek	New Hope Creek	1,117	12.0	1.0	1	Good	Bank Stabilization
LNHC2020	UT to New Hope Creek	New Hope Creek	1,068	8.8	1.4	1	Fair	E1
LNHC2021	UT to New Hope Creek	New Hope Creek	481	8.5	1.2	1	Fair	E2
LNHC2022	UT to New Hope Creek	New Hope Creek	514	1.5	0.7	1	Good	Bank Stabilization
LNHC2023	UT to New Hope Creek	New Hope Creek	466	3.4	0.9	1	Fair	Restoration
LNHC2024	UT to New Hope Creek	New Hope Creek	1,614	6.1	1.2	1	N/A	Restoration
LNHC2025	UT to New Hope Creek	New Hope Creek	1,344	4.4	0.9	1	Good	Restoration
LNHC2026	UT to New Hope Creek	New Hope Creek	586	3.8	0.6	1	Good	Bank Stabilization
MC1003	UT to Mud Creek	Mud Creek	213	7.1	0.8	1	Fair	E1
MC1004	UT to Mud Creek	Mud Creek	789	6.9	1.2	1	Fair	E2
MC1005	UT to Mud Creek	Mud Creek	468	8.4	1.7	1	Fair	E1
MC1006	UT to Mud Creek	Mud Creek	3,121	12.2	2.2	1	Poor	E1

(1) "UT" indicates Unnamed Tributary
(2) RSAT Ratings are as follows: Excellent Condition (42–50), Good Condition (30–41), Fair Condition (16–29), and Poor Condition (<16)
(3) Three streams that were assessed were not evaluated for RSAT due to site conditions (e.g. backwater from beaver dam)

Table 2-15. Characteristics of field assessed stream reaches (continued)

Reach ID	Stream[1]	Watershed	Length (feet)	Bankfull Width (feet)	Bankfull Depth (feet)	Priority Level	RSAT Rating[2,3]	Preliminary Project Recommendation
MC1007	UT to Mud Creek	Mud Creek	1,882	13.6	1.5	1	Fair	Restoration
MC1008	UT to Mud Creek	Mud Creek	2,830	14.7	1.1	1	Good	Preservation
MC1009	UT to Mud Creek	Mud Creek	2,538	N/A	N/A	1	N/A	Restoration
MC1010	UT to Mud Creek	Mud Creek	729	10.7	2.7	1	N/A	Restoration
MC1011	UT to Mud Creek	Mud Creek	99	18.4	2.6	1	Fair	Restoration
MC1012	Mud Creek	Mud Creek	3,779	15.6	2.5	1	Fair	Bank Stabilization
MC1013	Mud Creek	Mud Creek	2,079	14.7	2.7	1	Fair	Restoration
MC1014	Mud Creek	Mud Creek	2,047	16.0	1.8	2	Fair	Restoration
MC1015	Mud Creek	Mud Creek	6,313	15.7	1.9	2	Fair	Restoration
MC1016	UT to Mud Creek	Mud Creek	935	3.7	0.9	1	Fair	Bank Stabilization
MC1017	UT to Mud Creek	Mud Creek	2,692	6.8	1.1	1	Fair	Bank Stabilization
MC1018	UT to Mud Creek	Mud Creek	2,605	3.9	0.9	1	Fair	Bank Stabilization
MC1019	UT to Mud Creek	Mud Creek	951	7.3	1.4	1	Good	E2
MC1020	UT to Mud Creek	Mud Creek	1,033	14.3	0.7	1	Fair	E2
MC1021	UT to Mud Creek	Mud Creek	538	7.7	1.8	1	Fair	E1
MC1023	UT to Mud Creek	Mud Creek	1,342	6.4	1.3	1	Fair	Restoration
MC1024	UT to Mud Creek	Mud Creek	3,396	7.1	2.0	1	Fair	Preservation
MC1025	UT to Mud Creek	Mud Creek	2,185	9.5	1.4	2	Fair	Bank Stabilization
MC1026	UT to Mud Creek	Mud Creek	2,523	11.1	1.7	2	Fair	Restoration
MC1027	UT to Mud Creek	Mud Creek	2,466	6.3	1.4	2	Fair	E1
MC1028	UT to Mud Creek	Mud Creek	1,487	3.8	0.5	2	Fair	Bank Stabilization
SC1001	UT to Sandy Creek	Sandy Creek	957	6.2	0.7	1	Fair	Bank Stabilization
SC1003	UT to Sandy Creek	Sandy Creek	2,593	3.8	0.7	1	Fair	Bank Stabilization
SC2001	Sandy Creek Trib. D	Sandy Creek	3,355	12.5	1.5	1	Good	Preservation
SC2002	UT to Sandy Creek Trib. D	Sandy Creek	1,256	9.0	1.2	2	Fair	Restoration
SC2003	UT to Sandy Creek Trib. D	Sandy Creek	354	7.6	1.4	1	Fair	Restoration
SC2004	UT to Sandy Creek Trib. D	Sandy Creek	2,151	7.1	0.7	1	Fair	E1

(1) "UT" indicates Unnamed Tributary
(2) RSAT Ratings are as follows: Excellent Condition (42–50), Good Condition (30–41), Fair Condition (16–29), and Poor Condition (<16)
(3) Three streams that were assessed were not evaluated for RSAT due to site conditions (e.g. backwater from beaver dam)

Table 2-15. Characteristics of field assessed stream reaches (continued)

Reach ID	Stream[1]	Watershed	Length (feet)	Bankfull Width (feet)	Bankfull Depth (feet)	Priority Level	RSAT Rating[2,3]	Preliminary Project Recommendation
SC2005	Sandy Creek Trib. D	Sandy Creek	2,269	11.4	1.9	2	Fair	Restoration
SC2006	Sandy Creek Trib. D	Sandy Creek	1,797	13.5	1.6	2	Good	Bank Stabilization
SC2007	Sandy Creek Trib. D	Sandy Creek	1,006	5.4	2.3	1	Poor	Bank Stabilization
SC2008	UT to Sandy Creek	Sandy Creek	2,253	6.7	1.7	1	Fair	E1
SC2009	UT to Sandy Creek	Sandy Creek	780	13.1	1.7	2	Poor	E2
SC2010	UT to Sandy Creek	Sandy Creek	671	7.4	1.5	2	Fair	Bank Stabilization
SC2011	UT to Sandy Creek	Sandy Creek	640	11.8	2.1	2	Fair	Bank Stabilization
SC2012	UT to Sandy Creek	Sandy Creek	1,322	10.7	1.0	2	Fair	E2
SC2013	Sandy Creek	Sandy Creek	1,210	12.8	2.2	2	Fair	Bank Stabilization
SC2014	Sandy Creek	Sandy Creek	1,037	13.1	1.1	2	Fair	Bank Stabilization
SC2015	Sandy Creek	Sandy Creek	453	13.7	1.3	2	Poor	Bank Stabilization
SC2016	Sandy Creek	Sandy Creek	857	13.8	3.1	2	Poor	Bank Stabilization
SC2017	Sandy Creek	Sandy Creek	1,344	20.1	1.3	2	Fair	Restoration
SC2018	Sandy Creek	Sandy Creek	1,333	24.5	1.8	1	Good	Restoration
SC2019	UT to Sandy Creek	Sandy Creek	365	5.1	0.6	1	Fair	E2
SC2020	UT to Sandy Creek	Sandy Creek	39	4.7	1.1	1	Good	Bank Stabilization
SC2021	UT to Sandy Creek	Sandy Creek	360	4.8	1.2	1	Fair	Restoration
SC2022	UT to Sandy Creek	Sandy Creek	443	5.1	1.5	1	Fair	Restoration
SC2023	UT to Sandy Creek	Sandy Creek	810	7.2	1.1	1	Fair	E2
SC2024	UT to Sandy Creek	Sandy Creek	974	0.9	6.7	1	Poor	Restoration
SC2025	Sandy Creek	Sandy Creek	3,693	28.4	1.2	1	Fair	Restoration
SC2026	Sandy Creek	Sandy Creek	2,205	21.8	1.3	1	Fair	Restoration
SC2027	Sandy Creek	Sandy Creek	3,139	25.9	1.7	2	Fair	E2
SC2028	UT to Sandy Creek	Sandy Creek	1,219	5.8	0.8	1	Good	Bank Stabilization
SC2029	UT to Sandy Creek	Sandy Creek	1,267	9.6	1.4	1	Fair	Bank Stabilization
SC2030	UT to Sandy Creek	Sandy Creek	1,334	3.4	1.0	1	Good	E1
SC2031	UT to Sandy Creek	Sandy Creek	1,004	3.2	0.7	1	Good	Preservation

(1) "UT" indicates Unnamed Tributary
(2) RSAT Ratings are as follows: Excellent Condition (42–50), Good Condition (30–41), Fair Condition (16–29), and Poor Condition (<16)
(3) Three streams that were assessed were not evaluated for RSAT due to site conditions (e.g. backwater from beaver dam)

Table 2-15. Characteristics of field assessed stream reaches (continued)

Reach ID	Stream[1]	Watershed	Length (feet)	Bankfull Width (feet)	Bankfull Depth (feet)	Priority Level	RSAT Rating[2,3]	Preliminary Project Recommendation
SC2032	Sandy Creek	Sandy Creek	5,319	28.6	1.1	2	Fair	Restoration
SC2033	UT to Sandy Creek	Sandy Creek	2,068	7.1	0.9	1	Fair	Bank Stabilization
SC2034	UT to Sandy Creek	Sandy Creek	952	13.0	1.3	1	Good	Restoration
SC2035	UT to Sandy Creek	Sandy Creek	3,228	6.9	0.8	1	Good	Bank Stabilization
SC2036	UT to Sandy Creek	Sandy Creek	2,316	9.8	1.3	2	Fair	Bank Stabilization
SC2037	UT to Sandy Creek	Sandy Creek	1,272	34.0	0.5	1	Fair	Bank Stabilization
SC2038	Sandy Creek	Sandy Creek	5,186	25.3	1.8	2	Fair	Restoration

(1) "UT" indicates Unnamed Tributary
(2) RSAT Ratings are as follows: Excellent Condition (42–50), Good Condition (30–41), Fair Condition (16–29), and Poor Condition (<16)
(3) Three streams that were assessed were not evaluated for RSAT due to site conditions (e.g. backwater from beaver dam)

2.7.1.4 Potential Water Quality Concerns

Field teams noted potential water quality concerns as part of the field surveys. The most common water quality concerns observed were headcuts (see definition in Section 2.7.1.1) and exposed or threatened utilities. Headcuts can be ongoing sources of sediment as they migrate upstream and continue lowering the channel bed. Exposed or threatened utilities have the potential to discharge pollutants into streams. Field teams reported potential water quality concerns to the appropriate City department for follow-up. Table 2-16 includes a summary of potential water quality concerns identified during the 2020 stream evaluations. The data is also presented in Exhibit 12.

Table 2-16. Potential water quality concerns identified during stream assessments

Potential Water Quality Concern	Number of Observations
Potential sources of excess sediment	14
Suspect water appearance	9
Suspect odor	2
Sewer leak	0
Exposed or threatened utility(1)	56
Headcut	55

(1) Most exposed or threatened utilities were not deemed immediately hazardous. One instance of threatened or exposed utility was reported to the City staff for follow up.

Field teams noted low-head dams during field observations. No man-made dams were assessed; however, three beaver dams and four debris jams were noted as low-head dams.

Field teams noted litter present during field observations. These observations were characterized by the relative amount of litter and the apparent source of the litter based on judgement as described in Section 2.7.1.1. Sixty-one reaches were observed to have litter present, and Moderate was the most common rating. Table 2-17 includes a summary of litter observed during the 2020 field evaluations. As described, this is a new metric for City of Durham watershed assessments that has not been evaluated for its effectiveness. These results are subjective and can be affected by factors such as recent weather and stream flow conditions.

Table 2-17. Litter observed during stream assessments

Observed Litter	Number of Reaches by Observed Litter Category
Heavy	9
Moderate	30
Light	12
None/Sparse	10

2.7.1.5 Vegetative Composition Observed

Field teams assessed the riparian vegetation communities along the stream reaches. The community composition was characterized by the degree of vegetation disturbance based on the abundance of invasive vegetation present. Invasive plants are typically opportunistic and will flourish in response to habitat disturbance. Over time, with no intervening action, invasive vegetation will continue to expand through the surrounding landscape.

Invasive vegetation reduces the biological diversity of a riparian buffer and impairs its ability to provide ecosystem services, such as water quality benefits. The type and density of invasive vegetation also provides insight into the extent and timeframe of disturbance that occurred. Twenty-two reaches were observed to have a riparian vegetative composition close to undisturbed and 23 were considered very disturbed. Fifty-three reaches were observed to have riparian communities that were moderately disturbed but still composed of predominately native species. Table 2-18 includes a summary of the vegetation composition identified during the 2020 field evaluations. This is a new metric for City of Durham watershed assessments that has not been evaluated for its effectiveness in characterizing and prioritizing stream corridor condition and prioritizing potential projects. This data may be useful for identifying low disturbance riparian areas for preservation or high disturbance areas to focus restoration efforts.

Table 2-18. Vegetative composition observed during stream assessment

Vegetative Composition Observed	Criteria	Number of Observations
Undisturbed	Vegetation is close to undisturbed in species present and their proportions	22
Moderately disturbed	Vegetation indicated disturbance in terms of species diversity or proportions but is still largely composed of native species	53
Very disturbed	Vegetation is severely disturbed in terms of species diversity or proportion	23

2.7.1.6 Bank Erosion Hazard Index and Near Bank Stress

The Level 2 stream assessments included the BEHI and NBS evaluations to estimate erosion potential and shear stress on the stream banks. The results of these assessments can be used to estimate annual bank erosion rate and annual sediment yields using the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) method (Rosgen, 2001; Schueler and Stack, 2013). Level 2 assessments were conducted on 28 stream reaches, which totaled approximately 10 stream miles. Of these reaches, 11 (6.7 stream miles) were found to have estimated sediment yields of more than 20 tons/year. Table 2-19 provides the estimated erosion rate and sediment yield for Level 2 reaches, also presented in Exhibit 13. Erosion rates were estimated from the North Carolina Streambank Erodibility curves (Doll et al., 2003).

Table 2-19. Sediment yields based on Level 2 BEHI/NBS assessments

Reach ID	Stream	Watershed	RSAT Rating	Length (feet)	Estimated Erosion Rate (tons/feet/year)	Estimated Sediment Yield (tons/year)
LNHC1014	Sandy Creek Trib. A	Sandy Creek	Poor	1,395	0.082	115
LNHC1015	Sandy Creek Trib. A	Sandy Creek	Fair	3,926	0.009	35.8
LNHC1016	UT to New Hope Creek	New Hope Creek	Fair	1,467	0.003	4.9
LNHC1018	UT to New Hope Creek	New Hope Creek	Fair	1,351	0.009	11.6
LNHC1019	UT to New Hope Creek	New Hope Creek	Poor	1,346	0.006	8.5
LNHC2004	UT to New Hope Creek	New Hope Creek	Poor	552	0.007	3.7
MC1014	Mud Creek	Mud Creek	Fair	2,047	0.007	13.8
MC1015	Mud Creek	Mud Creek	Fair	6,313	0.01	64.9

Table 2-19. Sediment yields based on Level 2 BEHI/NBS assessments (continued)

Reach ID	Stream	Watershed	RSAT Rating	Length (feet)	Estimated Erosion Rate (tons/feet/year)	Estimated Sediment Yield (tons/year)
MC1025	UT to Mud Creek	Mud Creek	Fair	2,185	0.002	5.2
MC1026	UT to Mud Creek	Mud Creek	Fair	2,523	0.009	23.4
MC1027	UT to Mud Creek	Mud Creek	Fair	2,466	0.044	108.2
MC1028	UT to Mud Creek	Mud Creek	Fair	1,487	0.004	5.4
SC2002	UT to Sandy Creek Trib. D	Sandy Creek	Fair	1,256	0.033	41.8
SC2005	Sandy Creek Trib. D	Sandy Creek	Fair	2,269	0.067	151.6
SC2006	Sandy Creek Trib. D	Sandy Creek	Good	1,797	0.012	21.3
SC2009	UT to Sandy Creek	Sandy Creek	Poor	780	0.001	0.9
SC2010	UT to Sandy Creek	Sandy Creek	Fair	671	0.006	3.7
SC2011	UT to Sandy Creek	Sandy Creek	Fair	640	0.012	7.5
SC2012	UT to Sandy Creek	Sandy Creek	Fair	1,322	0.007	9.8
SC2013	Sandy Creek	Sandy Creek	Fair	1,210	0.016	19.7
SC2014	Sandy Creek	Sandy Creek	Fair	1,037	0.006	6.3
SC2015	Sandy Creek	Sandy Creek	Poor	453	0.036	16.3
SC2016	Sandy Creek	Sandy Creek	Poor	857	0.005	4.4
SC2017	Sandy Creek	Sandy Creek	Fair	1,344	0.007	9.7
SC2027	Sandy Creek	Sandy Creek	Fair	3,139	0.009	29.6
SC2032	Sandy Creek	Sandy Creek	Fair	5,319	0.006	32.5
SC2036	UT to Sandy Creek	Sandy Creek	Fair	2,316	0.005	11.6
SC2038	Sandy Creek	Sandy Creek	Fair	5,186	0.063	328.3
Total				56,655		1,095.4

2.7.1.7 Large Woody Debris

Large woody debris (defined in Section 2.7.1.2 above) was counted along each Level 2 reach. Plentiful large woody debris has multiple benefits to streams including slowing the velocity of water, creating shade, trapping organic material, and creating diverse aquatic habitat. Numbers of large woody debris in the streams assessed ranged from 0 to 50, though stream reach SC2015 was an outlier with 300 pieces of debris (Table 2-20).

Table 2-20. Large Woody Debris based on Level 2 assessments

Reach ID	Stream	Watershed	Length (feet)	RSAT Rating	Large Woody Debris
SC2009	UT to Sandy Creek	Sandy Creek	780	Poor	0
SC2005	Sandy Creek Trib. D	Sandy Creek	2,269	Fair	3
MC1025	UT to Mud Creek	Mud Creek	2,185	Fair	4
MC1027	UT to Mud Creek	Mud Creek	2,466	Fair	5
MC1014	Mud Creek	Mud Creek	2,047	Fair	5
MC1015	Mud Creek	Mud Creek	6,313	Fair	6
LNHC1015	Sandy Creek Trib. A	Sandy Creek	3,926	Fair	7
LNHC1016	UT to New Hope Creek	New Hope Creek	1,467	Fair	7
SC2032	Sandy Creek	Sandy Creek	5,319	Fair	8
SC2038	Sandy Creek	Sandy Creek	5,186	Fair	8
SC2027	Sandy Creek	Sandy Creek	3,139	Fair	9
SC2006	Sandy Creek Trib. D	Sandy Creek	1,797	Good	10
SC2013	Sandy Creek	Sandy Creek	1,210	Fair	10
SC2016	Sandy Creek	Sandy Creek	857	Poor	10
SC2017	Sandy Creek	Sandy Creek	1,344	Fair	12
LNHC2004	UT to New Hope Creek	New Hope Creek	552	Poor	14
MC1026	UT to Mud Creek	Mud Creek	2,523	Fair	18
LNHC1018	UT to New Hope Creek	New Hope Creek	1,351	Fair	20
LNHC1019	UT to New Hope Creek	New Hope Creek	1,346	Poor	20
LNHC1014	Sandy Creek Trib. A.	Sandy Creek	1,395	Poor	20
SC2002	UT to Sandy Creek Trib. D	Sandy Creek	1,256	Fair	23
SC2036	UT to Sandy Creek	Sandy Creek	2,316	Fair	25
SC2011	UT to Sandy Creek	Sandy Creek	640	Fair	32
SC2012	UT to Sandy Creek	Sandy Creek	1,322	Fair	45
SC2014	Sandy Creek	Sandy Creek	1,037	Fair	50
SC2015	Sandy Creek	Sandy Creek	453	Poor	300

2.7.2 Stormwater Control Measure Assessment Methods

The SCM assessment included a desktop review and field evaluation of existing SCMs (Section 2.1.2.1) as well as prescreening and field evaluation of potential new SCM locations (Section 2.1.2.2).

2.7.2.1 Existing SCMs

Evaluation Methods

Desktop Evaluation

The City provided a geodatabase containing information on the 264 existing SCMs within the New Hope Creek and Little Creek watersheds. These SCMs were evaluated during a desktop review to select sites for field evaluation. A total of 205 existing SCMs were omitted during this prescreening from further evaluation in the field. SCMs were omitted based on the following conditions:

- Recently constructed devices (around 5 years old or newer) with limited potential to route impervious area
- SCMs that had not been built at the time of the screening (SCM status was "Construction Drawing Approved" or that appeared to be under construction in aerial photography)
- SCMs with limited room for expansion due to apparent topography, development, use, or utility conflicts
- SCMs with inherently limited opportunity for retrofitting including bioretention with internal water storage (IWS), proprietary systems (such as Filterra), and underground facilities because these SCMs either already achieve significant water quality treatment and/or are difficult and expensive to access.

Field Evaluation

Fifty-nine SCMs of the 264 SCMs were evaluated by field teams (Exhibit 14). Field work procedures and protocols are outlined in the SCM Inventory and Assessment Field Plan in Volume III – Technical Appendices in the New Hope Creek and Little Creek Watershed Improvement Plan (City of Durham, 2019b). Field teams used tablets and forms developed in ArcGIS Online to collect the following information for each SCM:

- The SCM ID, subwatershed code, date, surrounding land use, the hydrologic soil group, receiving waterbody, and type of SCM
- Photographs of each component of the SCM and an overview of each SCM
- Physical measurements and information pertaining to specific components of the SCM, such as inlets, outlets, riser structures, emergency spillways, etc.

Field forms based on the Eno River WIP were used to evaluate the SCMs in this watershed plan with the following updates:

- Recharacterizing land uses to correspond to the Stormwater Nitrogen and Phosphorus (SNAP) version 4.1 Tool.
  - "Industrial" and "Institutional" were added as land use types and "Open Space" was updated to "Parks & Open Space."
- Additional existing SCM options were included to accommodate the range of SCM types that exist within this watershed.
  - Sand Filter, Level Spreader, Bioretention, Bioretention without IWS, Erosion Control Device, and Existing Water Retention Feature (i.e., farm pond) were added to the list of Existing SCM Types.
  - Contributing Drainage Area Additions were revised to provide clarity for field crews. Devices that would be more appropriate as a stand-alone new SCM, including Bioretention, Constructed Wetland, and Sand Filter were excluded as additions. Treatment swales were distinguished between Treatment Swale – Wet and Treatment Swale – Dry, to differentiate from the non-specific term, Grassed Swale, that was previously used. Permeable Pavement and Green Stormwater Infrastructure were added as options for Contributing Drainage Area Additions.

- Add-on Retrofit Recommendations were revised to better reflect feasible projects that would provide nutrient credits. Options intended to primarily address maintenance concerns only were excluded as were projects that would be considered Contributing Drainage Area Additions.
  - Options removed from the list include Build/Replace Filtering Device, Add Riprap to Stabilize Inlet, Plant Vegetation to Stabilize/Uptake Nutrients, Add Permeable Pavement, Add Bioretention Cell, Add Upflow Filter to Pond, and Add Sand Filter Trench to Pond.
- Updating Site Constraints to be consistent with previous field work experience and simplify characterization.
  - Site Constraint options were added to include all types of utilities, including Sanitary Sewer Lines, Gas Lines, Power Lines, Telecom, and Water Lines. Other options added to site constraints include Houses/Structures, Driveway/Road/Parking Lot, Inadequate Area, and Accessibility.
- Reducing the number of Site Constraints from three options to two options and Add-on Retrofit Recommendations from five options to two options. This is intended to capture the most relevant and useful information.
- Updating retrofit recommendation options to be consistent with the cost estimation tool.
  - Volume Retrofit Recommendations were modified to match the cost estimation tool.
- Rewording SCM Structural Retrofits Recommendation options for clarity. For example, from “Redesign Wet Pond” to “Redesign to Wet Pond.”

The SCM Inventory and Assessment was completed during December 2019 and January 2020 by field teams comprising staff from Kimley-Horn, Three Oaks Engineering, and the City. The key components of this field effort included assessing the surrounding area of existing SCMs, evaluating retrofit opportunities, and identifying SCMs with impaired functionality due to design or maintenance issues.

Characterization of Stormwater Treatment

The existing SCMs located within the New Hope Creek and Little Creek watersheds that were evaluated by field teams consisted of dry ponds (19), wet ponds (36), bioretention cells (2), sand filters (1), and stormwater wetlands (1) (Table 2-21). Table 2-22 lists the number of SCMs located in each surrounding land use type. Table 2-23 presents a further breakdown of SCM number based on the surrounding land use types and subwatershed. Figure 2-5 through Figure 2-8 provide examples of SCMs visited in this study. Several of the SCMs selected for field evaluation were located in residential areas. A general trend observed was that neighborhoods in the northern part of the study area tended to have fewer existing SCMs and those present were generally older or outdated designs. The areas nearer to Duke University had newer apartment complexes. The SCMs in this area were much newer and appeared to sufficiently treat runoff from the development.

Table 2-21. Existing SCMs visited in the field

Subwatershed	Existing SCM Type					
	Dry Pond	Wet Pond	Bioretention	Sand Filter	Stormwater Wetland	Total
Little Creek (NHC01_LC-NHC07_LC)	5	5	-	-	-	10
Lower New Hope (NHC08_LNHC-NHC32_LNHC)	5	30	1	1	-	37
Sandy Creek (NHC33_SC-NHC46_SC)	7	1	1	-	1	10
Mud Creek (NHC47_MC-NHC56_MC)	2	-	-	-	-	2
Total	19	36	2	1	1	59

Table 2-22. Existing SCMs visited by surrounding land use

Surrounding Land Use	Number of SCMs
Residential	38
Commercial	12
Institutional (schools, churches, etc.)	8
Parks & Open Space	1
Total	59

Table 2-23. Existing SCMs visited by surrounding land use and subwatershed

Surrounding Land Use	Number of SCMs			
	Little Creek(1)	Sandy Creek(2)	Mud Creek(3)	Lower New Hope Creek(4)
Residential	9	4	1	24
Commercial	1	1	-	10
Institutional (schools, churches, etc.)	-	4	1	3
Parks & Open Space	-	1	-	-
Total	10	10	2	37

(1) Subwatersheds NHC01-NHC07
(2) Subwatersheds NHC33-NHC46
(3) Subwatersheds NHC47-NHC56
(4) Subwatersheds NHC08-NHC32

Figure 2-5. Example of a wet pond (SCM 13124) at Realm at Patterson Place Apartments (3767 SW Durham Drive)

Figure 2-6. Example of a dry pond (SCM 00267) near the intersection of Keohane Drive and Alman Drive

Figure 2-7. Example of a bioretention area (SCM 00289) at the intersection of Old Chapel Hill Road and Everwood Court

Figure 2-8. Example of a construction wetland (SCM 13345) at Lakewood Elementary School at 2520 Vesson Avenue

SCMs Requiring Maintenance

Nutrient and sediment loads can be effectively removed using structural SCMs. However, SCM performance can be significantly reduced by poor design, construction, or maintenance. SCMs designed under older design guidelines can have reduced stormwater treatment performance compared to current minimum design criteria. During the SCM Inventory and Assessment, each SCM's general maintenance condition was evaluated to assess the impact on its performance. Field teams identified 11 SCMs with potential maintenance needs to function properly in Table 2-24. Examples of SCMs requiring maintenance are provided in Figure 2-9 and Figure 2-10. These SCMs were reported to the City Stormwater Control Measure Inspection team for follow-up to ensure compliance with appropriate operations and maintenance requirements.

Table 2-24. Existing SCMs with potential maintenance needs

Subwatershed	SCM ID	Surrounding Land Use	SCM Type	Maintenance Concerns
NHC32_LNHC	00497	COM	Dry Pond	Riser clogged and impounded with trash and sediment. Pond not constructed under current design guidelines
NHC25_LNHC	00316	HDR	Wet Pond	Spillway has settled or was installed incorrectly and is preventing the pond from properly draining the water quality volume
NHC14_LNHC	00387	HDR	Wet Pond	Pond has converted to a wetland with vegetation growing in the bottom
NHC14_LNHC	00464	COM	Wet Pond	Forebay deteriorated, has converted to wetland
NHC14_LNHC	00230	HDR	Wet Pond	Emergency drain is open lowering permanent pool, fence at the outlet is partially blocking the channel
NHC13_LNHC	00255	COM	Dry Pond	Unclear how SCM is intended to function, pipe between old dry pond and newer SCM appears blocked, couldn't find outfall pipe
NHC09_LNHC	00276	LDR	Wet Pond	SCM appears to need to be dredged back to original volume, has converted to a wetland, excessive algae growth
NHC12_LNHC	00103	HDR	Wet Pond	Water level appears to be below intended permanent pool

COM = Commercial
HDR = High Density Residential
LDR = Low Density Residential

The majority of SCMs flagged as potentially needing maintenance were experiencing overgrown vegetation. Improper vegetation maintenance can impact an SCM's storage capacity and reduce overall performance. SCMs that have converted to a wetland may experience greater water quality treatment than originally intended, such as a dry pond that has converted to a wetland; however, the SCM should be evaluated if any necessary water storage volume has been compromised by the overgrown vegetation that was not part of the original design.

Figure 2-9. Example of SCM with heavy algae growth (SCM 00503) near Maplewood Park at Whitcomb Street and Chapel Hill Road

Figure 2-10. Example of SCM with trash impounded at the outlet (SCM 00497) at Michael Jordan Nissan (3930 Durham-Chapel Hill Boulevard)

Other Existing Features

During prescreening, several features were identified on the aerial map that appeared to be existing water retention features, but these features were not present in the City's database. Twelve such features, listed in Table 2-25 were documented as having potential retrofit opportunities and visited in the field. For each of these features, field teams recorded the same information that was recorded for existing SCMs. The 12 features included dry ponds (4), wet ponds (6), and existing water retention features such as farm ponds (2). These features were labeled as NHC0019 – NHC0025 and NHCMC0067 – NHCMC0071. Most of the features appear to have been constructed for purposes other than stormwater benefits.

Table 2-25. SCMs and Existing Features identified that have potential retrofit opportunities

SCM ID	Surrounding Land Use	Existing SCM Type
NHC0019	LDR	Dry Pond
NHC0020	LDR	Existing Water Retention Feature (e.g. farm pond)
NHC0021	HDR	Wet Pond
NHC0022	HDR	Wet Pond
NHC0023	IND	Dry Pond
NHC0024	HDR	Wet Pond
NHC0025	COM	Wet Pond
NHCMC0067	HDR	Wet Pond
NHCMC0068	HDR	Wet Pond
NHCMC0069	HDR	Existing Water Retention Feature (i.e., farm pond)
NHCMC0070	HDR	Dry Pond
NHCMC0071	LDR	Dry Pond

LDR = Low Density Residential, HDR = High Density Residential, IND = Industrial, COM = Commercial

Water Quality Performance of Existing SCMs

A computer simulation model is being developed for the watershed to evaluate the benefit of existing SCMs. Field-evaluated SCMs will be assigned removal efficiencies for sediment and nutrient removal. Performance of a SCM is variable as it depends on multiple factors such as presence of forebay, overgrowth, and general maintenance. Field data and observations by field crews will be used to develop water quality multipliers for each SCM. These water quality multipliers will be applied to sediment and nutrient reduction rates to obtain a pollutant removal efficiency of each SCM. In future condition modeling scenarios, a 1.0 water quality multiplier will be used based on the assumption that design and maintenance issues will be corrected. The water quality multiplier for existing SCMs will be applied as follows:

- 1.0 for optimal SCM performance
- 0.25 if the SCM was not functioning

The water quality multiplier may be adjusted as follows:

- 0.20 will be subtracted from the water quality multiplier if the SCM function was impeded by overgrown vegetation and sedimentation
- 0.20 will be subtracted from the water quality multiplier if the SCM lacked a forebay. For SCMs not required to have a forebay, no reductions will be made

2.7.2.2 New SCMs

Sites for potential new SCMs were identified prior to field work through a GIS prescreening analysis. The intent of these sites is to provide stormwater treatment to developed areas that are not currently being treated. Typically, these are areas where development occurred under historic regulations that did not require stormwater treatment. Field teams visited 59 potential sites for new SCMs. During the field visit at each potential new SCM site, field teams recorded the following:

1. Characteristics of the site – surrounding land use, suitability
2. Potential new SCM type – primary and secondary SCM options, length, and width of available area, and a completed sketch of the potential SCM
3. Contributing drainage area additions – primary and secondary options for small-scale (parcel-level) SCMs that can be implemented to create a treatment train (series of SCMs)
4. Site accessibility and other constraints not identified during the GIS prescreening
5. Characteristics of receiving waters – the type of receiving waterway or waterbody

These field observations were evaluated along with other site constraints to recommend a site for constructing a new SCM as described in Section 3.2.2.

The field form used to evaluate the new SCMs was revised similarly to the existing SCM form as described previously, with one additional revision.

- Recharacterizing land uses to correspond to the SNAP Tool, version 4.1.
  - The options for the land use in the area of the proposed SCM were updated to Roof, Roadway, Parking/Driveway/Sidewalk, Protected Forest, and Other Pervious/Landscaping.

2.8 Summary

Water Quality

Various water quality concerns are prevalent throughout the study area. Three segments of New Hope and Little Creek within the study area are impaired for benthos, according to the 2018 North Carolina 303(d) list of impaired waterbodies. Elevated levels of fecal coliforms, TN, TP, turbidity, and copper have been documented at monitoring stations throughout New Hope Creek and Little Creek watersheds. Zinc does not appear to be a problem pollutant in the New Hope Creek and Little Creek watersheds. Water quality issues throughout the study area include:

- City benthic sampling resulted in mostly fair ratings for New Hope Creek, mostly poor ratings for Sandy Creek, and a mixture of poor to good ratings for Mud Creek.
- Elevated fecal coliform was found to be present in all waterbodies throughout the sampled period. Fecal coliform thresholds were exceeded in 36% of samples at New Hope Creek, 46% samples in Little Creek, 70% of samples in Sandy Creek, and 49% of samples in Mud Creek. Because only 19% of fecal coliform samples at the station upstream of the study area (NH3.0NHC) exceed the threshold, the larger exceedance rate (45%) at the furthest downstream station (NH0.0NHC) on New Hope Creek indicates the presence of fecal coliform sources within the study area.

- Average annual TN values exceeded the threshold in Little, Sandy, Mud Creeks in most of the years for which samples were collected, while only about 8% of annual average TN values in New Hope Creek exceeded the threshold. Average annual TP values exceeded the threshold in 42% of years sampled in New Hope Creek, 100% of years sampled in Little Creek, 25% of years sampled in Mud Creek, and 71% of years sampled in Sandy Creek. Similar to fecal coliform, elevated nutrients in New Hope Creek appear to be associated with sources within study area as evidenced by increased TN and TP concentrations and annual averages between the upstream station (NH3.0NHC) and downstream station.
- Copper exceeded the CCC at least 1 month out of the year for stations in all subwatersheds. Copper concentrations were elevated in Sandy Creek where 10% of samples exceeded the CCC for copper, and in Little Creek watersheds 17% of samples exceeded the CCC for copper.
- Turbidity in Sandy Creek was a moderate concern, with 5.7% of annual average values exceeding the standard. Turbidity appears to be a larger concern in Mud Creek where 16.7% of average annual values were found to exceed the 50 NTU threshold. Turbidity was not a concern for New Hope and Little Creeks where the average annual turbidity value was below the standard of 50 NTU for all years.

Land Use

The existing land use for the study area is mostly Residential (37%), located primarily within City limits, with Parks and Open Space the second-largest land use (32%), consisting primarily of USACE and Duke Forest land. Most residential land use is Low Density Residential, encompassing 13% of the study area. Medium Density Residential encompasses approximately 10% of the study area, while Very Low Density Residential encompasses approximately 7% of the study area and High Density Residential land use encompasses approximately 7% of the study area. Based on future land use projects, the primary development trend is the conversion of Agriculture and Open Space into Residential development. There is a projected 100% decrease in Agricultural land and 14% decrease in Parks and Open Space, while High Density Residential land use is projected to increase by 37% and Low Density Residential land use is projected to increase by 40%. Most of the change to residential land use is anticipated to occur in the region south of Highway NC 751 and northwest of Highway NC 15-501.

Field Assessments

The most common water quality concerns observed during stream evaluations were headcuts and exposed or threatened utilities. The results of the assessments indicate that the majority of streams assessed in the watershed are in Fair to Good overall health, but that some stream reaches are Poor. Of the overall stream miles assessed, 18% were rated Good, 70% were rated Fair, and 9% were rated Poor. A total of 39 reaches were recommended for restoration, 33 for enhancement, 37 for bank stabilization, and six for preservation.

Of the 59 SCMs that were evaluated by field teams, 11 SCMs were identified as having potential maintenance concerns to ensure proper function. The main concern for the majority of the SCMs was overgrown vegetation, which can impact their storage capacity and diminish their ability to retain stormwater. These SCMs were reported to the City Stormwater Control Measure Inspection team for follow-up to ensure they are in compliance with Operations and Maintenance requirements. During prescreening of the SCMs, 12 additional features were identified as existing water retention features with retrofit potential.

3 Preliminary Project Opportunities

Results from field assessments were used to identify potential water quality improvement projects throughout the watershed. These projects included new SCMs, retrofits to existing SCMs, and stream restoration, enhancement, and preservation. The potential project opportunities discussed here have passed the initial feasibility criteria described by a desktop and field assessment. These potential water quality improvement projects will be further evaluated using computer simulation models and then scored and prioritized based on additional criteria and implementation costs to develop a list of recommended projects as part of the New Hope Creek and Little Creek WIP.

3.1 Stream Corridor Improvements

One of the goals of the stream inventory assessment was to identify stream reaches in need of restoration, enhancement, or preservation. Opportunities to improve stream health through these types of projects were identified during the field assessments. During February 2020, field teams assessed approximately 35 miles of streams, split into 115 individual reaches (Exhibit 15; Table 3-1) (City of Durham, 2020b). Of the assessed streams, approximately 31 miles were within City limits, 3 miles were outside City limits, and 1 mile bordered City limits. Potential stream project opportunities considered for each reach included: Restoration, Level I Enhancement, Level II Enhancement, Bank Stabilization, and Preservation.

These project opportunities are defined by the USACE as follows (USACE, 2003):

- Stream Restoration: Convert an unstable, altered, or degraded stream corridor, including adjacent riparian buffers and floodplain, to a natural, stable condition. Includes restoring a naturally stable channel planform pattern, longitudinal profile (riffle/pool sequence), and channel cross-section dimensions as well as improving biological and water quality functions.
- Enhancement I (EI): Improvements to the stream channel and riparian zone that restore channel stability, water quality, and stream ecology. Re-establish channel cross-section dimensions and longitudinal profile, but restoration of channel pattern is not feasible or warranted. May also include other practices that provide improved water quality and ecological benefits.
- Enhancement II (EII): Activities that improve channel stability, water quality, and stream ecology but do not include re-establishing the channel profile or pattern. May include re-establishment of the channel cross-section as well as practices to improve water quality and ecological benefits.
- Bank Stabilization: In-place stabilization of an eroding streambank. Techniques include sloping streambanks to a less vertical and more stable angle, installing streambank revetments with natural materials such as root wads or brush toe, and revegetating banks and riparian buffers without restoring cross-section dimensions.
- Preservation: Establishing protection of ecologically important streams (generally considered for high-quality streams) in perpetuity through the implementation of protective mechanisms. Preservation may include the protection of upland buffer areas adjacent to the stream necessary to ensure protection or enhancement of the overall stream.

All stream reaches assessed were assigned one of the potential project types described above. Reaches with constraints, such as utility conflicts, existing infrastructure, and no opportunity to raise the stream bed without increasing flood risks, were designated as Enhancement II or Bank Stabilization regardless of stream condition.

Full Stream Restoration was proposed for stream reaches in need of modifications to cross-sectional dimensions, stream bed profile, and channel realignment in order to create a stable, functioning stream (Figure 3-1).

Figure 3-1. Example of a potential Stream Restoration reach (SC2025) that starts downstream of Cameron Blvd and flows through the Duke University Golf Club in NHC40_SC

Reaches found to need improvements but not require complete channel reconstruction were categorized as potential enhancement reaches (Figure 3-2 and Figure 3-3). The techniques used in stream enhancement depend on the level of intervention needed to return the channel to a highly functioning stream. These can include raising the stream bed and adjusting cross-sectional dimensions (Enhancement I) to minimal activities such as bank stabilization and replanting riparian vegetation (Enhancement II).

Figure 3-2. Example of a potential Enhancement I reach (SC2008) that flows between Anderson St and Cranford Rd in NHC41_SC

Figure 3-3. Example of a potential Enhancement II reach (MC1020) that flows through Colonial Village at Deerfield in NHC55_MC

Stream Preservation was recommended to protect stream reaches that have a high-quality riparian buffer and minimal bank erosion and incision (Figure 3-4). All stream reaches recommended for preservation received a Good overall RSAT score except for two reaches that received a Fair score. These Fair reaches had high-quality buffer and minimal erosion.

Figure 3-4. Example of a potential preservation reach (Reach 1004) located upstream of Cornwallis Road in Duke Forest in NHC56_MC

All 115 reaches assessed in the field are reflected in Table 3-1 below with the project opportunities type (Exhibit 15). Approximately 32 miles of stream corridor improvement projects were recommended based on the assessments. These results are based on a preliminary evaluation of conditions observed in the field. Potential projects will be evaluated and prioritized for implementation in a later phase of the watershed planning process. For potential project types for each reach, refer to Table 2-15.

Table 3-1. Potential stream project opportunities

Project Type	Number of Reaches	Project Length (linear feet)
Restoration	39	75,446
Enhancement I	16	22,366
Enhancement II	17	19,483
Bank Stabilization	37	52,467
Preservation	6	12,102
Total	115	181,864

3.2 Stormwater Control Measures

The SCM inventory and field assessment identified opportunities to improve the current level of stormwater and water quality treatment within the New Hope Creek and Little Creek watershed study area. These opportunities (Exhibits 16 and 17) include retrofits or modifications to existing SCMs to improve their function and water quality treatment performance, as well as developed areas that are not currently receiving treatment but are suitable for new SCMs. Undeveloped areas of the watershed were not evaluated because future development will require on-site stormwater controls that comply with the UDO administered by both the City and Durham County.

3.2.1 Existing SCM Retrofits

Field teams visited 71 existing features during the SCM inventory and field assessment, which included 59 existing SCMs within the City's SCM database and 12 features located during the field work but not within the City's database. All these existing features were visited to further evaluate them for potential retrofits or modifications. Field teams noted constraints, such as nearby utilities or proximity to streams or wetlands, that could prevent installation or required maintenance activities for potential retrofits.

SCMs were evaluated for different types of retrofits: structural, volume, and add-on retrofits. Structural retrofits focus on modifications to the SCM's outlet structure. Structural retrofits can be simple, such as adding additional weirs or orifices on the outlet structure to treat the water quality volume or reduce peak flows for a particular storm event (simple control structure modification), or more complex, such as redesigning an entire SCM to convert it to another type of SCM (e.g., converting a dry pond to a pocket wetland). Volume retrofits involve increasing the storage volume of an existing SCM so that it can treat a larger volume of stormwater runoff or provide a longer retention time. Volume retrofits typically require expanding the existing SCM's footprint or excavating/dredging within the current footprint. Add-on retrofits can be implemented without changing the storage volume or SCM footprint. These retrofits focus on enhancing the current water quality treatment capability by adding components, such as a forebay, level spreader, or floating wetlands, to existing SCMs.

Of the 71 existing features visited, 29 were determined to be candidates for retrofits and recommended for further evaluation (Table 3-2 and Exhibit 16). Of these 29 recommended sites, three are in the Little Creek watershed, 13 are in the Lower New Hope Creek watershed, eight are in the Sandy Creek watershed, and five are in the Mud Creek watershed. The primary recommendations were to redesign the existing SCMs as constructed or pocket wetlands or wet ponds. In most cases, this recommendation would involve a relatively minor redesign of an outlet structure and vegetation with increased water quality credit.

Little Creek

SCM retrofit recommendations in the Little Creek watershed include redesigning the existing dry ponds to constructed wetlands. Recommended add-on retrofits include adding level spreaders with filter strips and building sediment forebays.

Lower New Hope Creek

Retrofits in the Lower New Hope Creek watershed include redesigning SCMs to wetlands and increasing storage (by lowering permanent pool or increasing the footprint). Recommended add-on retrofits include building sediment forebays, adding level spreaders, adding floating wetlands, and building a littoral shelf.

Sandy Creek

SCM retrofit recommendations in the Sandy Creek watershed include redesigning SCMs as a wetland or wet pond and implementing a simple control structure modifications. A rainwater harvesting system is recommended at one of the sites as a contributing drainage area addition.

Mud Creek

SCM retrofit recommendations in the Mud Creek watershed include redesigning SCMs as a wetland or wet pond and implementing simple control structure modifications. One site was recommended for dredging to increase storage volume. Recommended add-on retrofits at two sites include adding internal berms or baffles and building a sediment forebay. Internal berms or baffles are recommended in situations where an SCM may be short-circuiting because it wasn't designed with a high enough length to width ratio. A contributing drainage area addition for riparian buffer restoration is recommended for one site.

Table 3-2. Primary retrofit recommendations and potential add-on retrofits for existing SCMs and features evaluated by field teams

Existing SCM/Existing Water Retention Feature	Subwatershed	SCM Type	Primary Retrofit Recommendation	Build Sediment Forebay	Add Internal Berms or Baffle	Add Floating Wetlands	Build Littoral Shelf	Add Level Spreader-filter Strip per MDC
00054	NHC33_SC	Dry Pond	Redesign Constructed Wetland					
00072	NHC36_SC	Dry Pond	Redesign Constructed Wetland					
00100	NHC18_LHNC	Wet Pond	Redesign Constructed Wetland			✓		
00103	NHC12_LHNC	Wet Pond	Redesign Constructed Wetland				✓	
00111	NHC09_LHNC	Wet Pond	Redesign Constructed Wetland	✓				
00255	NHC13_LHNC	Dry Pond	Redesign Constructed Wetland	✓				
00267	NHC47_MC	Dry Pond	Redesign Pocket Wetland		✓			
00276	NHC09_LHNC	Wet Pond	Redesign Constructed Wetland					✓
00287	NHC26_LNHC	Wet Pond	Redesign Wet Pond			✓		
00289	NHC26_LNHC	Bioretention w/o IWS	Add upturn pipe for internal water storage					
00303	NHC36_SC	Dry Pond	Redesign Pocket Wetland					
00316	NHC25_LNHC	Wet Pond	Lower Water Level to Gain Storage			✓		
00325	NHC30_LNHC	Dry Pond	Redesign Constructed Wetland					
00359	NHC36_SC	Dry Pond	Redesign Pocket Wetland					
00360	NHC36_SC	Dry Pond	Redesign Pocket Wetland					
00439	NHC06_LC	Dry Pond	Redesign Constructed Wetland	✓				✓
00446	NHC06_LC	Dry Pond	Redesign Constructed Wetland					✓
00447	NHC06_LC	Dry Pond	Redesign Constructed Wetland	✓				✓
00464	NHC14_LNHC	Wet Pond	Redesign Constructed Wetland					

Table 3-2. Primary retrofit recommendations and potential add-on retrofits for existing SCMs and features evaluated by field teams (continued)

Existing SCM/Existing Water Retention Feature	Subwatershed	SCM Type	Primary Retrofit Recommendation	Build Sediment Forebay	Add Internal Berms or Baffle	Add Floating Wetlands	Build Littoral Shelf	Add Level Spreader-filter Strip per MDC
00497	NHC32_LNHC	Dry Pond	Redesign Constructed Wetland					
00503	NHC42_SC	Dry Pond	Redesign Pocket Wetland					
00511	NHC31_LNHC	Dry Pond	Redesign Constructed Wetland					
00674	NHC34_SC	Bioretention w/o IWS	Simple Control Structure Modification					
NHC0024	NHC26_LNHC	Other	Redesign Wet Pond					
NHCMC0067	NHC46_MC	Wet Pond	Redesign Wet Pond					
NHCMC0068	NHC47_MC	Wet Pond	Simple Control Structure Modification	✓				
NHCMC0069	NHC56_MC	Existing Water Retention Feature (i.e. farm pond)	Riparian Buffer Restoration					
NHCMC0070	NHC56_MC	Dry Pond	Redesign Wet Pond					
NHCMC0071	NHC56_MC	Dry Pond	Redesign Constructed Wetland					

3.2.2 New SCMs

Based on the field review, 36 of the 59 potential new SCM sites were recommended for further evaluation as a new SCM (Table 3-3 and Exhibit 17). The main considerations for evaluating site suitability are identifying inlet and outlet locations and determining whether significant impervious area runoff can be routed to the SCM. Potential site constraints considered include topography, insufficient space, structures (e.g. retaining walls not readily visible during desktop evaluation), existing utilities, or conflicts with current land use (e.g. discerning a dedicated recreational field from an unused grassed area). Similar to the existing SCMs, new SCM sites were also evaluated for contributing drainage area additions. Figure 3-4 lists the 36 potential new SCM types by subwatershed.

Twenty of the 36 recommended new SCMs are bioretention devices. Bioretention devices are generally smaller devices but can provide efficient stormwater treatment and nutrient reduction. They can accommodate various installation configurations (e.g. existing inlet structures) as they do not require a high ground water table to maintain a wetted footprint (in contrast to constructed wetlands); however, they do require 3-4 feet of depth for soil media, which can be a limiting factor.

Three of the 59 SCMs visited in the field are located in the Little Creek watershed. During desktop exercises, engineers determined that most of the high-density development in this watershed is being treated by existing SCMs but that field evaluations would be needed to assess opportunities at other residential and commercial development in the watershed. During field evaluations, the field teams determined these sites to be infeasible for new SCM construction. For this reason, SCM opportunities in the Little Creek watershed are predominately green stormwater infrastructure practices, devices that would treat smaller-scale drainage areas, or future developments that could provide increased treatment. The limited potential for new stormwater control measures outside of existing residential and commercial areas is largely a result of land use and development patterns in this watershed. Areas of the watershed that are currently developed have SCMs that were installed under previous stormwater standards that provide some degree of treatment. As described in Section 2.7.2.1, these existing SCMs were evaluated for modifications to provide additional stormwater treatment. New development that occurs in the watershed would be subject to City/County development ordinances and required to meet stormwater performance standards. Much of the undeveloped area of the watershed is protected as part of the Jordan Lake Game Lands.

The area of Little Creek evaluated for this project was representative of the type of existing land use in the watershed within the Durham city limits. Land use is concentrated around major transportation corridors as Low to Medium Density Residential Development. Little Creek's headwaters lie within Orange County with Bolin Creek and Booker Creek, two major tributaries of Little Creek, receiving drainage from the towns of Carrboro and Chapel Hill (Town of Carrboro, 2012 and N.C Division of Water Quality, 2012). Within Durham County and the City of Durham limits, the Little Creek watershed is characterized as having a large amount of undeveloped floodplain area dominated by bottomland hardwood forest wetlands of the National Wetland Inventory Classification: Palustrine, Forested, Broad-Leaved Deciduous, and Temporarily/Seasonally Flooded (Federal Geographic Data Committee, 2013). Approximately 1% of the Little Creek watershed within the project study area is categorized as Commercial. 3% is categorized as Institutional, 3% is categorized as High Density Residential, 4% is categorized as Agricultural, 8% is categorized as Roadway, 12% is categorized as Low Density Residential, 13% is categorized as Medium Density Residential, 14% is categorized as Very Low Density Residential, and 42% is categorized as Parks and Open Space. Much of the area categorized as Parks and Open Space is owned by the US Army Corps of Engineers for the purpose of protecting water quality in Jordan Lake. As previously described in Section 2.5.4 of this document, several NCWRC Waterfowl Impoundments located in the Jordan Lake Game Lands are managed in a manner to mimic natural wetlands, which provides treatment for stormwater entering the lake.

Of the existing sites visited, 36 were recommended for new SCMs (Table 3-4). Of these 36 sites, there are none in the Little Creek watershed, 13 are in the New Hope Creek watershed, 16 are in the Sandy Creek watershed, and 7 are in the Mud Creek watershed. The primary recommendation was to construct bioretention basins.

Table 3-3. Potential new SCMs recommended for further evaluation

Subwatershed	New SCM ID	SCM Type	Predominant Land Use Type
NHC09_LHNC	NHC0002	Treatment Swale - Dry	Other Pervious/Landscaping
NHC09_LHNC	NHC0003	Bioretention	Other Pervious/Landscaping
NHC09_LHNC	NHC0005	Treatment Swale - Dry	Other
NHC14_LNHC	NHC0006	Treatment Swale - Wet	Other Pervious/Landscaping
NHC23_LNHC	NHC0008	Regenerative Stormwater Conveyance	Other Pervious/Landscaping
NHC26_LNHC	NHC0009	Bioretention	Other Pervious/Landscaping
NHC26_LNHC	NHC0010	Treatment Swale - Dry	Other Pervious/Landscaping
NHC26_LNHC	NHC0012	Bioretention	Other Pervious/Landscaping
NHC26_LNHC	NHC0013	Bioretention	Parking/Driveway/Sidewalk
NHC27_LNHC	NHC0014	Treatment Swale - Wet	Other Pervious/Landscaping
NHC27_LNHC	NHC0015	Constructed Wetland	Other Pervious/Landscaping
NHC27_LNHC	NHC0016	Treatment Swale - Wet	Other Pervious/Landscaping
NHC27_LNHC	NHC0018	Constructed Wetland	Other Pervious/Landscaping
NHC34_SC	NHCSC0026	Stream Restoration	Other Pervious/Landscaping
NHC35_SC	NHCSC0027	Constructed Wetland	Other Pervious/Landscaping
NHC40_SC	NHCSC0029	Bioretention	Other Pervious/Landscaping
NHC40_SC	NHCSC0031	Bioretention	Other Pervious/Landscaping
NHC40_SC	NHCSC0032	Bioretention	Other Pervious/Landscaping
NHC43_SC	NHCSC0034	Bioretention	Other Pervious/Landscaping
NHC45_SC	NHCSC0035	Constructed Wetland	Protected Forest
NHC46_SC	NHCSC0036	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0037	Proprietary	Other Pervious/Landscaping
NHC46_SC	NHCSC0039	Constructed Wetland	Other Pervious/Landscaping
NHC46_SC	NHCSC0040	Regenerative Stormwater Conveyance	Other Pervious/Landscaping
NHC46_SC	NHCSC0043	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0044	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0046	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0047	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0049	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0047	Bioretention	Other Pervious/Landscaping
NHC46_SC	NHCSC0049	Bioretention	Other Pervious/Landscaping

Table 3-3. Potential new SCMs recommended for further evaluation (continued)

Subwatershed	New SCM ID	SCM Type	Predominant Land Use Type
NHC51_MC	NHCMC0052	Bioretention	Other Pervious/Landscaping
NHC51_MC	NHCMC0054	Constructed Wetland	Protected Forest
NHC51_MC	NHCMC0055	Bioretention	Other Pervious/Landscaping
NHC51_MC	NHCMC0056	Bioretention	Other Pervious/Landscaping
NHC51_MC	NHCMC0057	Bioretention	Other Pervious/Landscaping
NHC51_MC	NHCMC0058	Bioretention	Other Pervious/Landscaping
NHC56_MC	NHCMC0062	Bioretention	Other Pervious/Landscaping

Table 3-4. Potential new SCMs by subwatershed

Subwatershed	Bioretention	Constructed Wetland	Regenerative Stormwater Conveyance	Treatment Swale (Dry)	Treatment Swale (Wet)	Other	Total
Little Creek (NHC01-NHC07)	-	-	-	-	-	-	-
New Hope (NHC09-NHC32)	4	2	1	3	3	-	13
Sandy Creek (NHC33-NHC46)	10	3	1	-	-	2 (Stream Restoration and proprietary)	16
Mud Creek (NHC47-NHC56)	6	1	-	-	-	-	7
Total	20	6	2	3	3	2	36

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4 Pilot Study Areas

4.1 Selection Criteria

PSAs were evaluated through field investigation and modeling to determine water quality benefits associated with implementing various SCMs and practices. Results of PSA modeling and SCM evaluations will be used to inform watershed-wide modeling scenarios. With these goals in mind, the study area was divided into 56 subwatersheds. The 56 subwatersheds were then categorized into seven groups based on similar characteristics, including land use, imperviousness, soil type, projected development trends, location relative to city limits, and presence of existing SCMs (Exhibit 18).

Ten candidate PSAs were selected from the 56 subwatersheds by first categorizing subwatersheds based on the following features:

- Existing land use
- Projected development trends
- Percentage of impervious area
- Predominant hydrologic soil group
- Number and type of existing SCMs

4.2 Pilot Study Area Descriptions

Based on the selection criteria outlined in Section 4.1, the 56 subwatersheds were grouped into one of seven categories as described below:

Parks and Open Space – Poorly Drained: Subwatersheds include NHC02_LC, NHC03_LC, NHC05_LC, NHC11_LNHC, NHC14_LNHC, NHC15_LNHC, NHC28_LNHC, NHC37_SC, NHC39_SC, NHC40_SC, and NHC51_MC.

- Existing land use is primarily Parks and Open Space, Agricultural, and/or Very Low Density Residential
- Existing development includes areas with a low number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- Low percent impervious

Parks and Open Space – Well Drained: Subwatersheds include NHC08_LNHC, NHC10_LNHC, NHC13_LNHC, NHC16_LNHC, NHC19_LNHC, NHC23_LNHC, NHC27_LNHC, NHC53_MC, NHC54_MC, and NHC55_MC.

- Existing land use is primarily Parks and Open Space, Agricultural, and/or Very Low Density Residential
- Existing development includes areas with a low number of SCMs
- Predominantly well-drained hydrologic soil group B soils
- Predominantly low percent impervious

Low Density – Poorly Drained: Subwatersheds include NHC06_LC, NHC20_LNHC, NHC22_LNHC, NHC24_LNHC, NHC26_LNHC, NHC29_LNHC, NHC36_SC, and NHC38_SC.

- Existing land use is primarily Low or Very Low Density Residential

- Existing development includes areas with a low to medium number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- Predominantly low to medium percent impervious

Low and Medium Density Residential – Poorly Drained: Subwatersheds include NHC04_LC, NHC09_LNHC, NHC18_LNHC, NHC21_LNHC, NHC35_SC, NHC47_MC, and NHC56_MC.

- Existing land use is primarily Low and Medium Density Residential
- Existing development includes areas with a low to high number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- Low to medium percent impervious

High Density Residential and Commercial: Subwatersheds include NHC25_LNHC, NHC30_LNHC, NHC31_LNHC, NHC33_SC, and NHC46_SC.

- Existing land use is primarily High Density Residential and Commercial
- Existing development includes areas with a low to high number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- Low to high percent impervious

Commercial: Subwatersheds include NHC12_LNHC, and NHC32_LNHC.

- Existing land use is primarily Commercial
- Existing development includes areas with a high number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- High percent impervious

New Development – Poorly Drained: Subwatersheds include NHC01_LC, NHC07_LC, and NHC34_SC.

- Existing land use is primarily Parks and Open Space and Very Low Density Residential
- Future land use projections show a significant change in land use from lower to higher density
- Existing development includes areas with a low number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- Low to medium percent impervious

New Development – Well Drained: Subwatersheds include NHC48_MC, NHC49_MC, NHC50_MC, and NHC52_MC.

- Existing land use is primarily Parks and Open Space and Very Low Density Residential
- Future land use projections show a significant change in land use from lower to higher density
- Existing development includes areas with a low number of SCMs
- Predominantly well-drained hydrologic soil group B

- Low percent impervious

Institutional: Subwatersheds include NHC17_LNHC, NHC41_SC, NHC42_SC, NHC43_SC, NHC44_SC, and NHC45_SC.

- Existing land use is primarily Institutional
- Existing development includes primarily areas with a low number of SCMs
- Predominantly poorly drained hydrologic soil group D soils, which limits the types of SCMs that can be successfully implemented
- Medium to high percent impervious
- Consists predominantly of areas belonging to Duke University, Duke Forest, or Duke University Medical Center. Subwatershed NHC17-LNHC includes B. Everette Jordan High School.

Ten candidate PSAs were identified based on the above analysis. Key factors in the selection of these PSAs include the opportunity to intentionally engage and involve historically-underserved communities as described in the project Equitable Community Engagement Plan (City of Durham, 2020c), the watershed location within the City, water quality concerns, soil type, and predominant land ownership (Exhibit 19):

- Parks and Open Space – Poorly Drained: NHC40_SC
- Low Density – Poorly Drained: NHC24_LNHC
- Low and Medium Density Residential – Poorly Drained: NHC04_LC, NHC47_MC
- High Density Residential and Commercial: NHC30_LNHC, NHC25_LNHC, NHC46_SC
- New Development – Well Drained: NHC48_MC
- Commercial: NHC32_LNHC
- Institutional: NHC45_SC

The 10 candidate PSAs identified in the preceding section were discussed with the City on November 21, 2019. Seven final PSAs were selected based on location within City limits and overall representativeness within the study area. The final PSAs recommended for detailed field evaluation and modeling are provided below by representative land use category:

- Parks and Open Space – Poorly Drained: NHC40_SC
- Low Density – Poorly Drained: NHC24_LNHC
- Low Medium Density Residential – Poorly Drained: NHC04_LC, NHC47_MC
- High Density Residential and Commercial: NHC30_LNHC
- Commercial: NHC32_LNHC
- Institutional: NHC45_SC

4.3 Future Monitoring and Modeling

A computer model application, PCSWMM (Personal Computer Storm Water Management Model), is being developed for the study area to prioritize the potential water quality improvement projects identified in Section 3. This model is being used to simulate the hydrology, channel hydraulics, and water quality to evaluate water quality benefits associated with potential watershed improvement projects. Field assessments have been completed, and the data collected by field teams are being used to support model development. Detailed data

collected within each of the seven final PSAs is being used to model these areas in high resolution. The results of this model will then be extrapolated to other subwatersheds with similar characteristics.

5 Next Steps

The New Hope Creek and Little Creek watershed assessment describes existing watershed conditions, provides a list of potential project opportunities to improve watershed conditions, and identifies PSAs for detailed modeling and SCM evaluation. The watershed assessment suggests that the New Hope Creek and Little Creek watersheds are in Fair to Good health overall, but potential water quality improvement opportunities do exist within the watershed. These projects include new SCMs to treat areas not currently receiving treatment, retrofits to existing SCMs, in addition to Stream Restoration, Enhancement, and Preservation. Results of the watershed assessment will be used to inform future monitoring and modeling of PSAs. These results will also be incorporated into the WIP to help prioritize management strategies and recommend water quality improvement projects.

The next steps in the development of the New Hope Creek and Little Creek WIP include:

1. Develop the PCWMM model for characterizing existing pollutant loads and evaluating future scenarios for load reductions using a variety of pollution control measures.
2. Conduct a cost-benefit analysis of potential SCM projects using the City's cost estimation tool.
3. Prioritize the potential water quality improvement projects. Criteria used in the prioritization process include water quality treatment and cost-effectiveness, habitat and biological integrity, stream bank protection, community enhancement, implementation constraints, public safety and public property considerations, and project location. Prioritization criteria are being reviewed as part of this project.
4. Update the Riparian Area Management Plan (RAMP) and Critical Area Protection Plan (CAPP) to identify parcels in the watershed with high-quality stream and stream buffer area on public and private land that, if preserved, may help contribute to sustaining watershed health.
5. Conduct public information sessions in-person or reach stakeholders via social media outlets to provide updates on field assessments, potential projects, and watershed characterization and seek input for developing the WIP recommendations. Public outreach opportunities will be contingent on social distancing requirements due to the COVID-19 outbreak.
6. Develop the final WIP, describing watershed goals and characterization, watershed modeling and scenario analysis results, and recommended water quality improvement projects with factsheets for the top 30 high-priority projects.

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6 References

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Appendix A:

Exhibits

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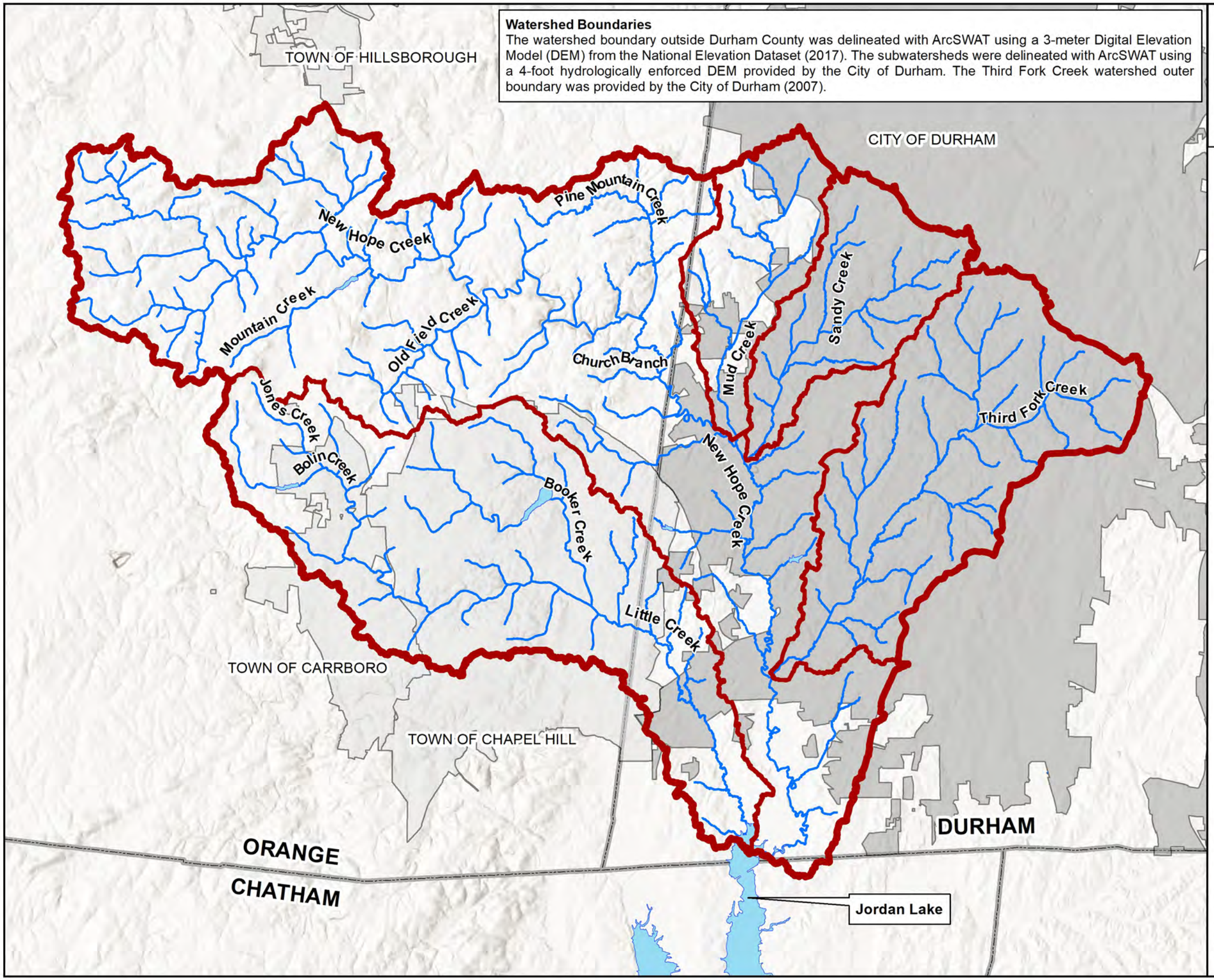

Watershed Boundaries
The watershed boundary outside Durham County was delineated with ArcSWAT using a 3-meter Digital Elevation Model (DEM) from the National Elevation Dataset (2017). The subwatersheds were delineated with ArcSWAT using a 4-foot hydrologically enforced DEM provided by the City of Durham. The Third Fork Creek watershed outer boundary was provided by the City of Durham (2007).

Exhibit 1
Watershed Overview Map

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN

- Streams
- Lakes and Reservoirs
- New Hope and Little Creek Watersheds
- Subwatersheds
- Durham City Limits - 2019
- Other Municipal Limits
- County Boundary

0 1 2 Miles

N

CITY OF DURHAM
AECOM

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Exhibit 2
Study Area

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN

The study area was delineated with ArcSWAT using a 4-foot hydrologically enforced DEM provided by the City of Durham.

Durham Public Libraries
Durham Public Schools
Major Roads
Roads
Streams
Ponds and Lakes
Parks
Jordan Game Lands
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
Durham City Limits - 2019
County Boundary

ORANGE
DURHAM
CHATHAM
Sandy Creek
Mud Creek
New Hope Creek
Little Creek
Jordan Lake
Sandy Creek Park
Lakewood Middle
Lakewood Elementary
Southwest Library
Creekside Elementary
Sherwood Githens Middle
C E Jordan High
Leigh Farm Park

N
0 0.5 1 Miles

CITY OF DURHAM
AECOM

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DURHAM
0 5 10 Miles

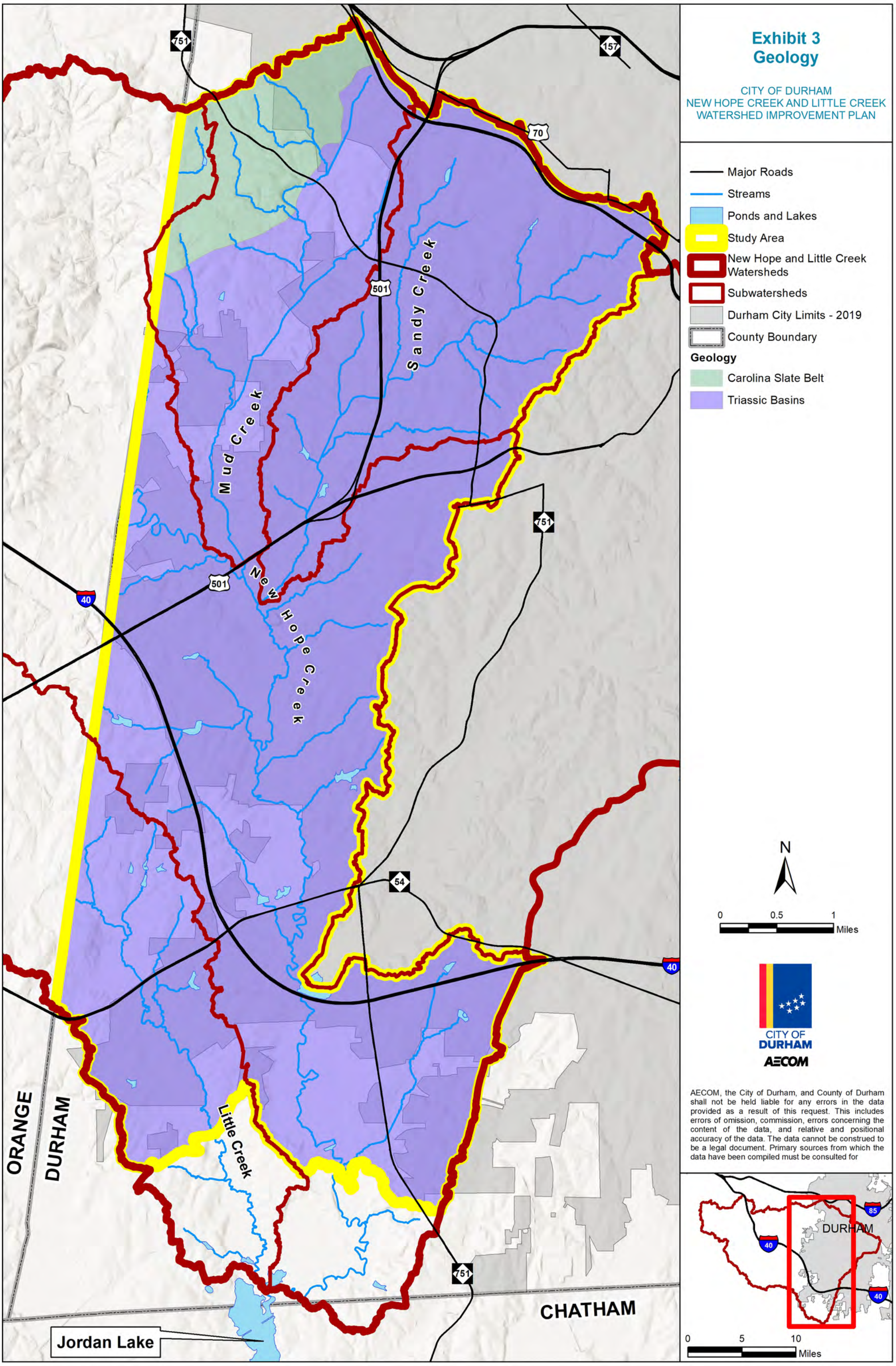
Exhibit 3
Geology
CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN
Major Roads
Streams
Ponds and Lakes
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
Durham City Limits - 2019
County Boundary
Geology
Carolina Slate Belt
Triassic Basins
N
0
0.5
1
Miles
CITY OF DURHAM
AECOM
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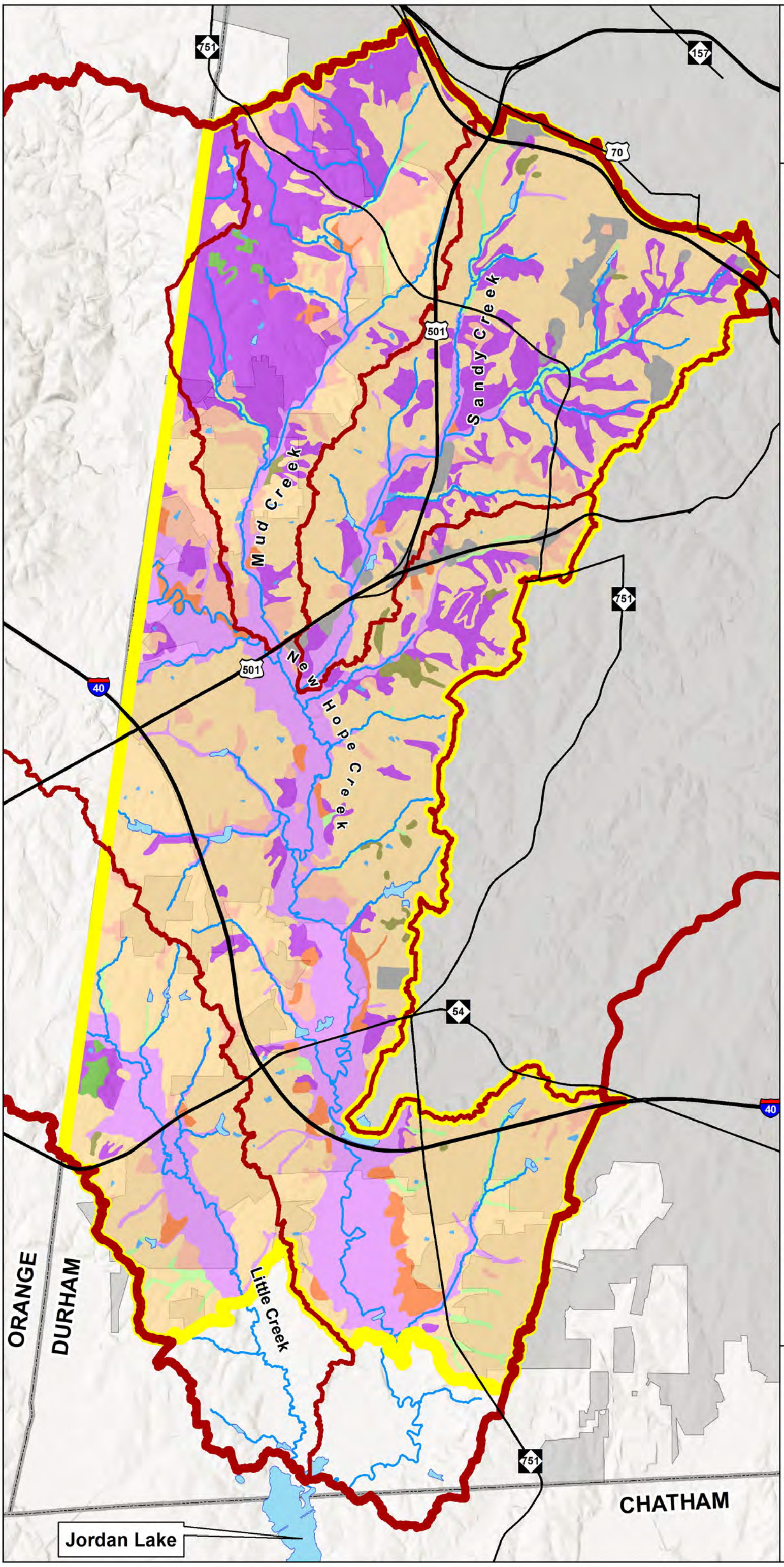
DURHAM
0
5
10
Miles
Sandy Creek
Mud Creek
New Hope Creek
Little Creek
ORANGE
DURHAM
CHATHAM
Jordan Lake
751
157
70
501
40
54
85

Exhibit 4
Hydrologic Soil Groups

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



Major Roads
Streams
Ponds and Lakes
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
Durham City Limits - 2019
County Boundary

Hydrologic Soil Group

A - Rapid Infiltration (<1%)
A/D - (Drained/Undrained Areas) (2%)
B - Medium Infiltration (16%)
B/D - (Drained/Undrained Areas) (15%)
C - Slow Infiltration (2%)
C/D - (Drained/Undrained Areas) (7%)
D - Very Slow Infiltration (55%)
Gullied Land (<1%)
Urban Land (2%)
Water (<1%)

N

0 0.5 1 Miles

CITY OF DURHAM
AECOM

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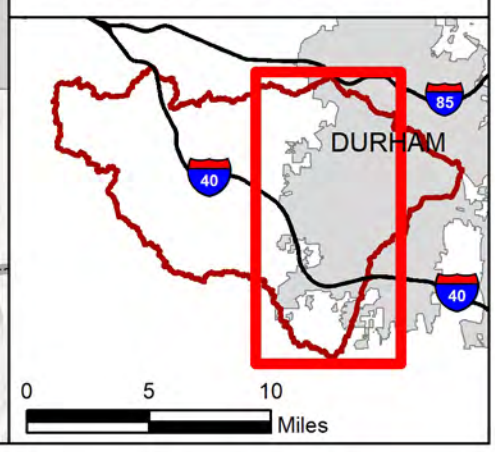
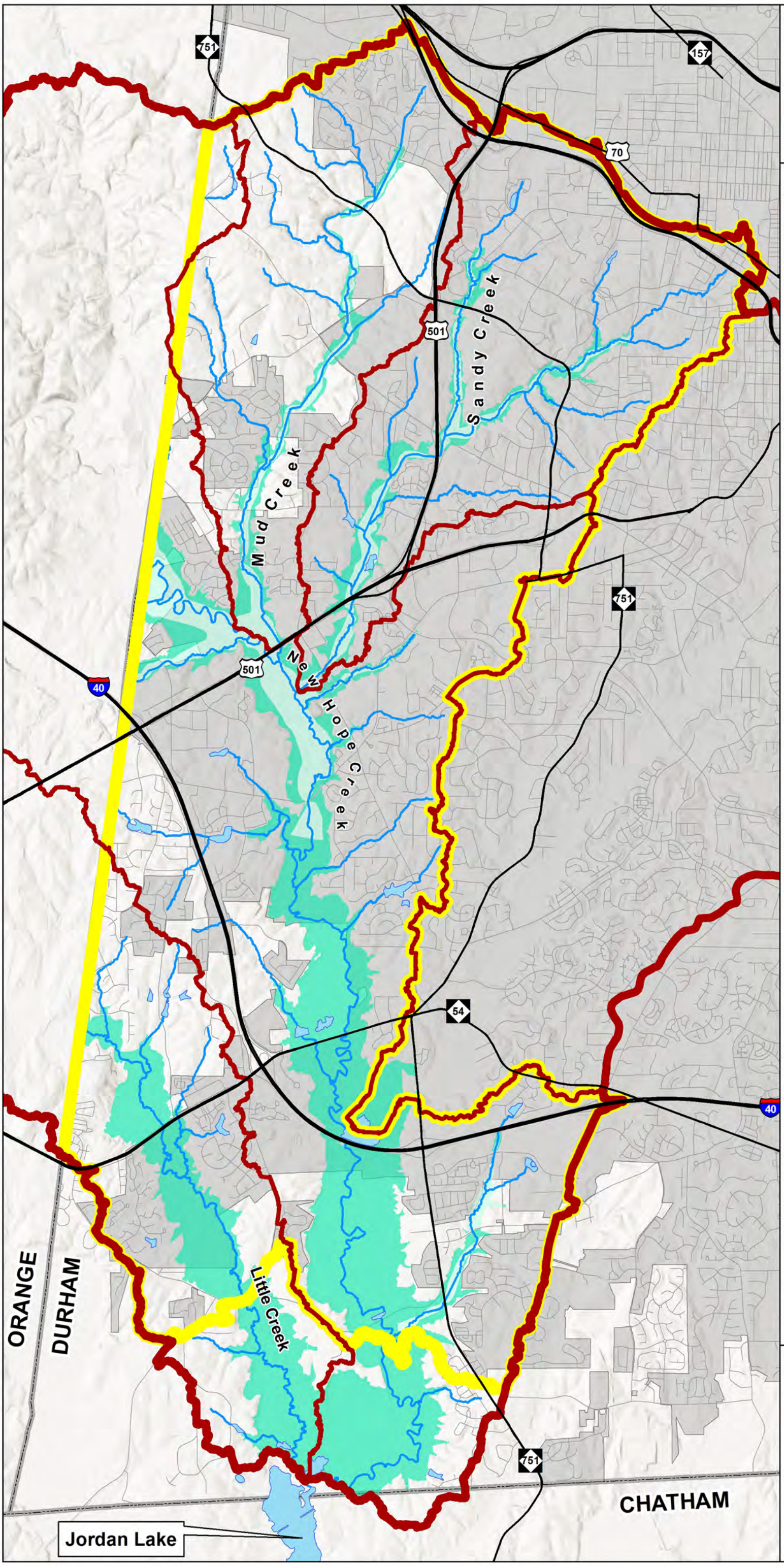


Exhibit 5
FEMA Floodplains

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



- Major Roads
- Roads
- Streams
- Ponds and Lakes
- Study Area
- New Hope and Little Creek Watersheds
- Subwatersheds
- Durham City Limits - 2019
- County Boundary

Flood Zones

- FEMA 100-yr Floodplain (effective 2019)
- FEMA Floodway (effective 2019)

N

0 0.5 1 Miles

CITY OF DURHAM
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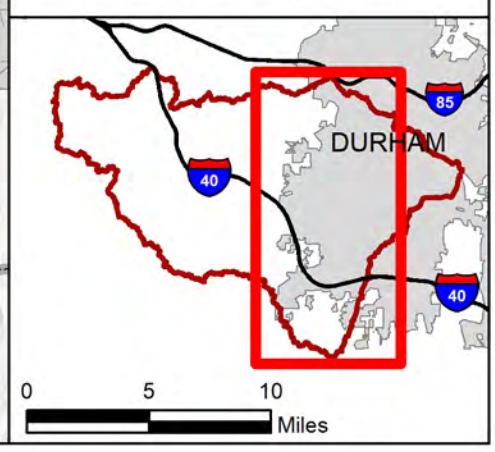

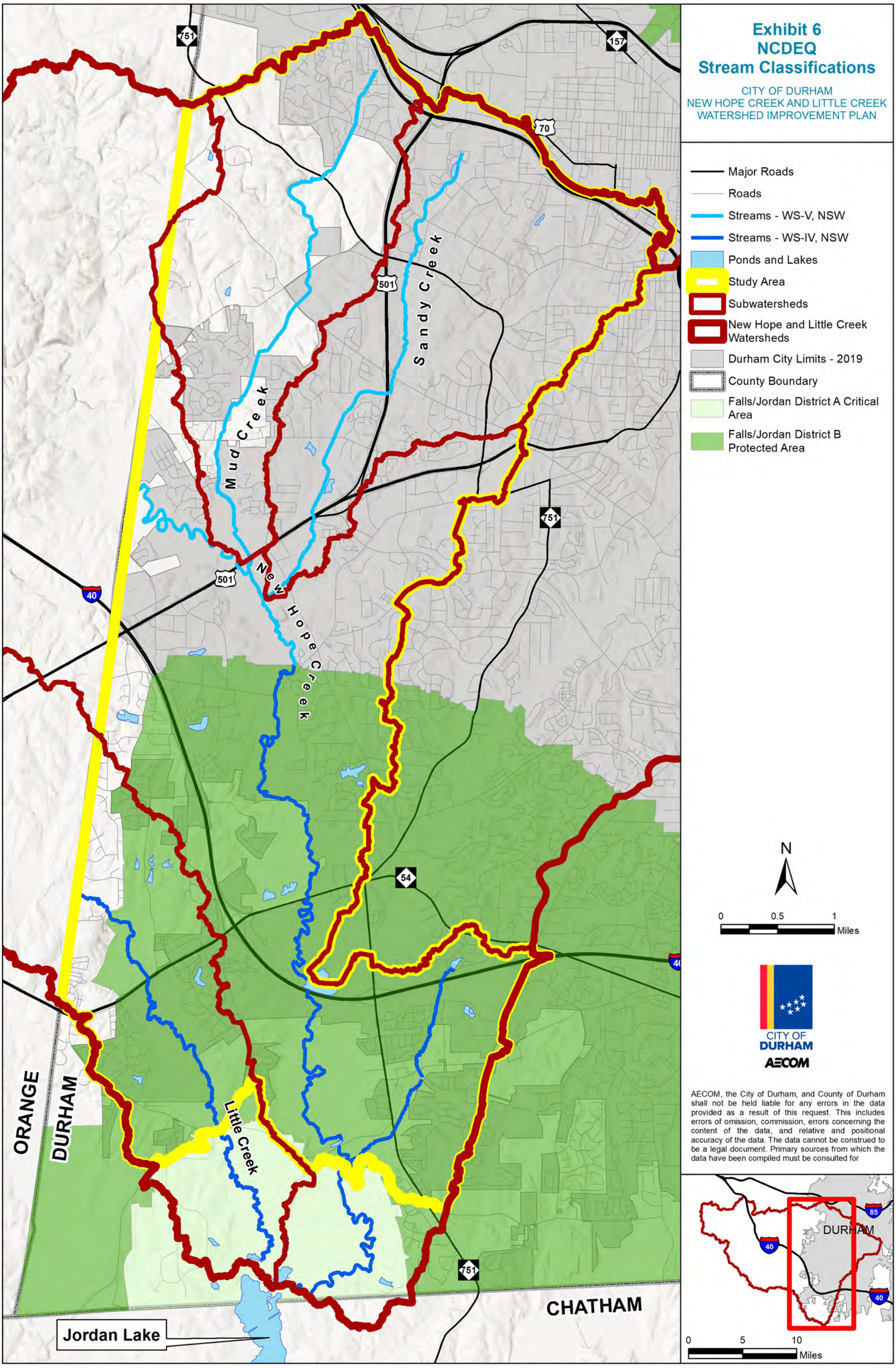
Exhibit 6
NCDEQ
Stream Classifications
CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN
Major Roads
Roads
Streams - WS-V, NSW
Streams - WS-IV, NSW
Ponds and Lakes
Study Area
Subwatersheds
New Hope and Little Creek Watersheds
Durham City Limits - 2019
County Boundary
Falls/Jordan District A Critical Area
Falls/Jordan District B Protected Area
N
0
0.5
1
Miles
CITY OF DURHAM
AECOM
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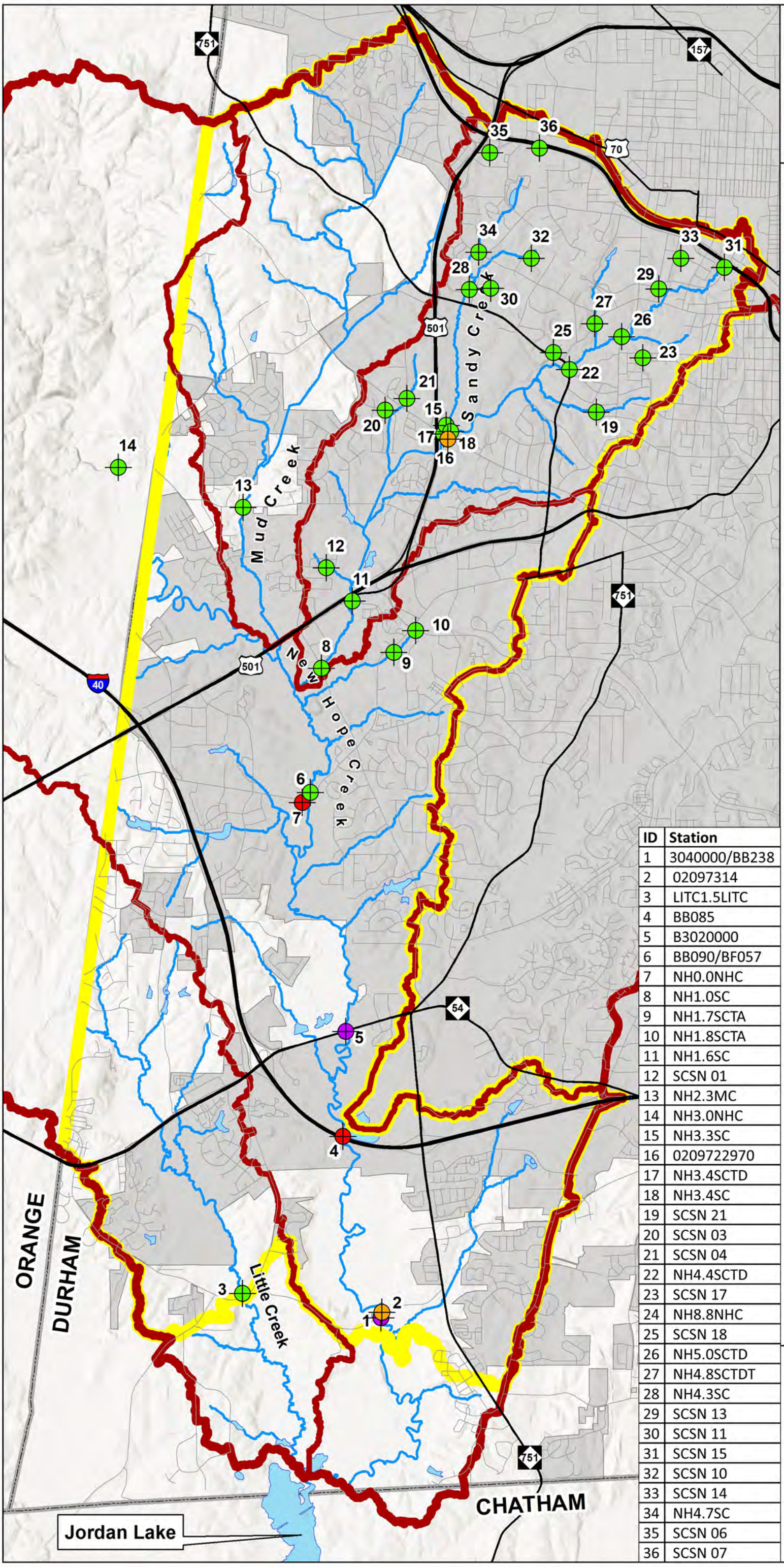
DURHAM
0
5
10
Miles
Sandy Creek
Mud Creek
New Hope Creek
Little Creek
ORANGE
DURHAM
CHATHAM
Jordan Lake
751
157
70
501
40
54

Exhibit 7
Monitoring Stations

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



ID	Station
1	3040000/BB238
2	02097314
3	LITC1.5LITC
4	BB085
5	B3020000
6	BB090/BF057
7	NH0.0NHC
8	NH1.0SC
9	NH1.7SCTA
10	NH1.8SCTA
11	NH1.6SC
12	SCSN 01
13	NH2.3MC
14	NH3.0NHC
15	NH3.3SC
16	0209722970
17	NH3.4SCTD
18	NH3.4SC
19	SCSN 21
20	SCSN 03
21	SCSN 04
22	NH4.4SCTD
23	SCSN 17
24	NH8.8NHC
25	SCSN 18
26	NH5.0SCTD
27	NH4.8SCTDT
28	NH4.3SC
29	SCSN 13
30	SCSN 11
31	SCSN 15
32	SCSN 10
33	SCSN 14
34	NH4.7SC
35	SCSN 06
36	SCSN 07

Major Roads
Roads
Streams
Ponds and Lakes
Study Area
Subwatersheds
New Hope and Little Creek Watersheds
Durham City Limits - 2019
County Boundary

Stations

City of Durham
North Carolina Department of Water Resrouces
Upper Cape Fear River Basin Association
USGS

N

0 0.5 1 Miles

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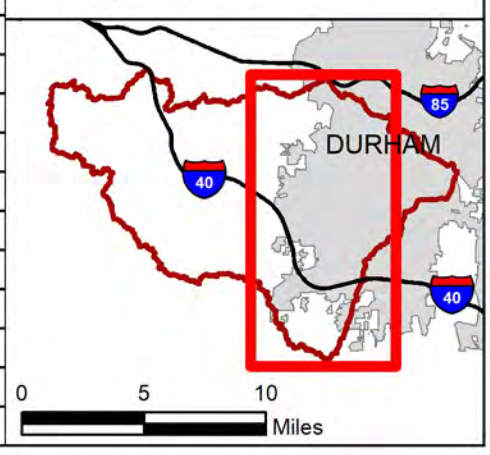
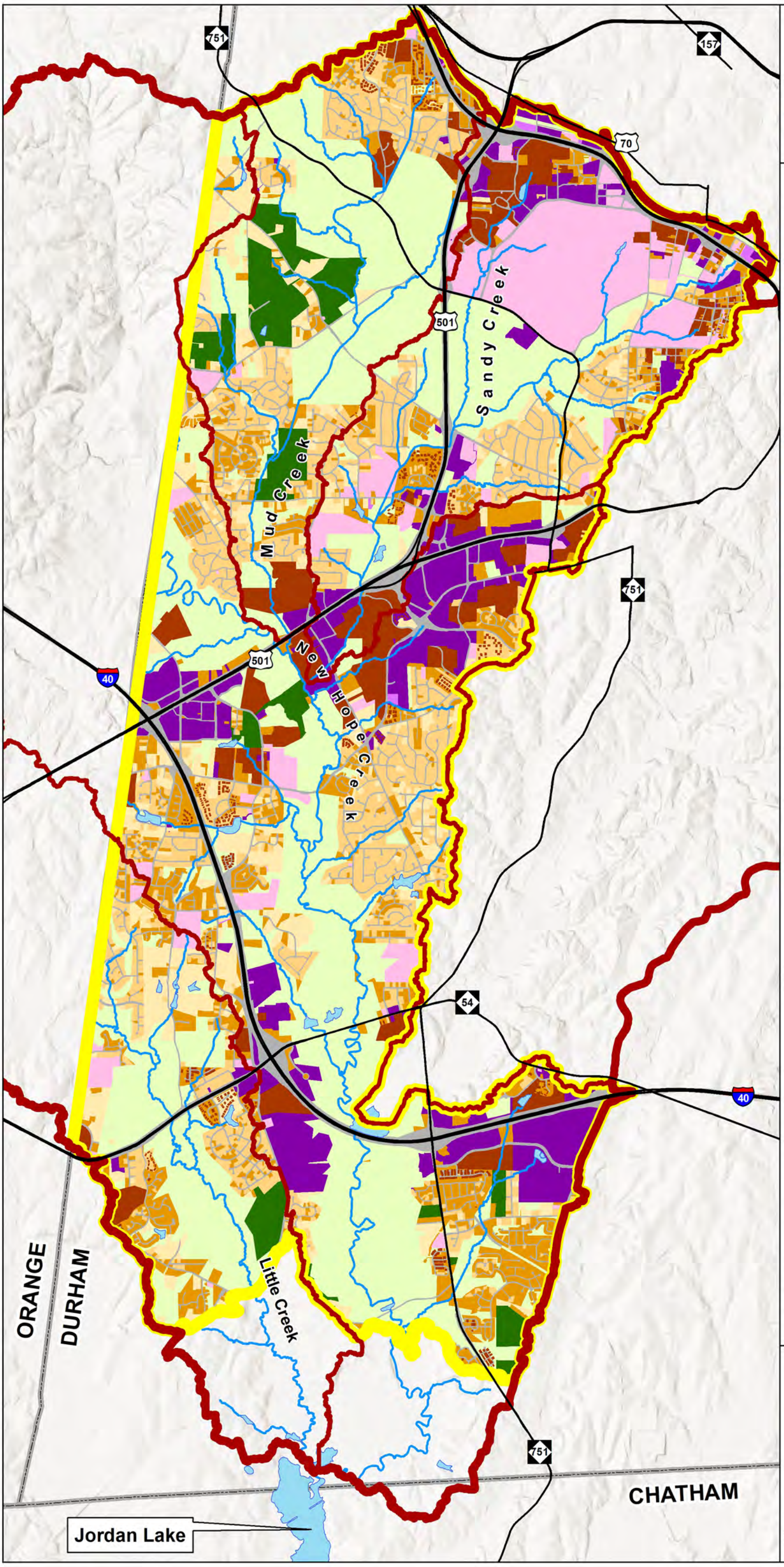


Exhibit 8
Existing Land Use

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



- Major Roads
- Roads
- Streams
- Ponds and Lakes
- Study Area
- New Hope and Little Creek Watersheds
- Subwatersheds
- County Boundary

Land Use

- Very Low Density Residential
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Institutional
- Industrial
- Commercial
- Parks and Open Space
- Agriculture
- Roadway

N

0 0.5 1 Miles

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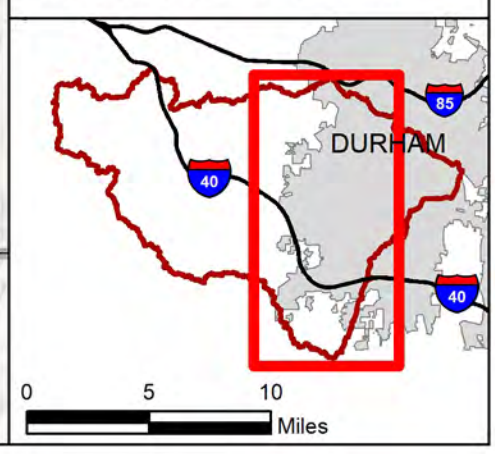

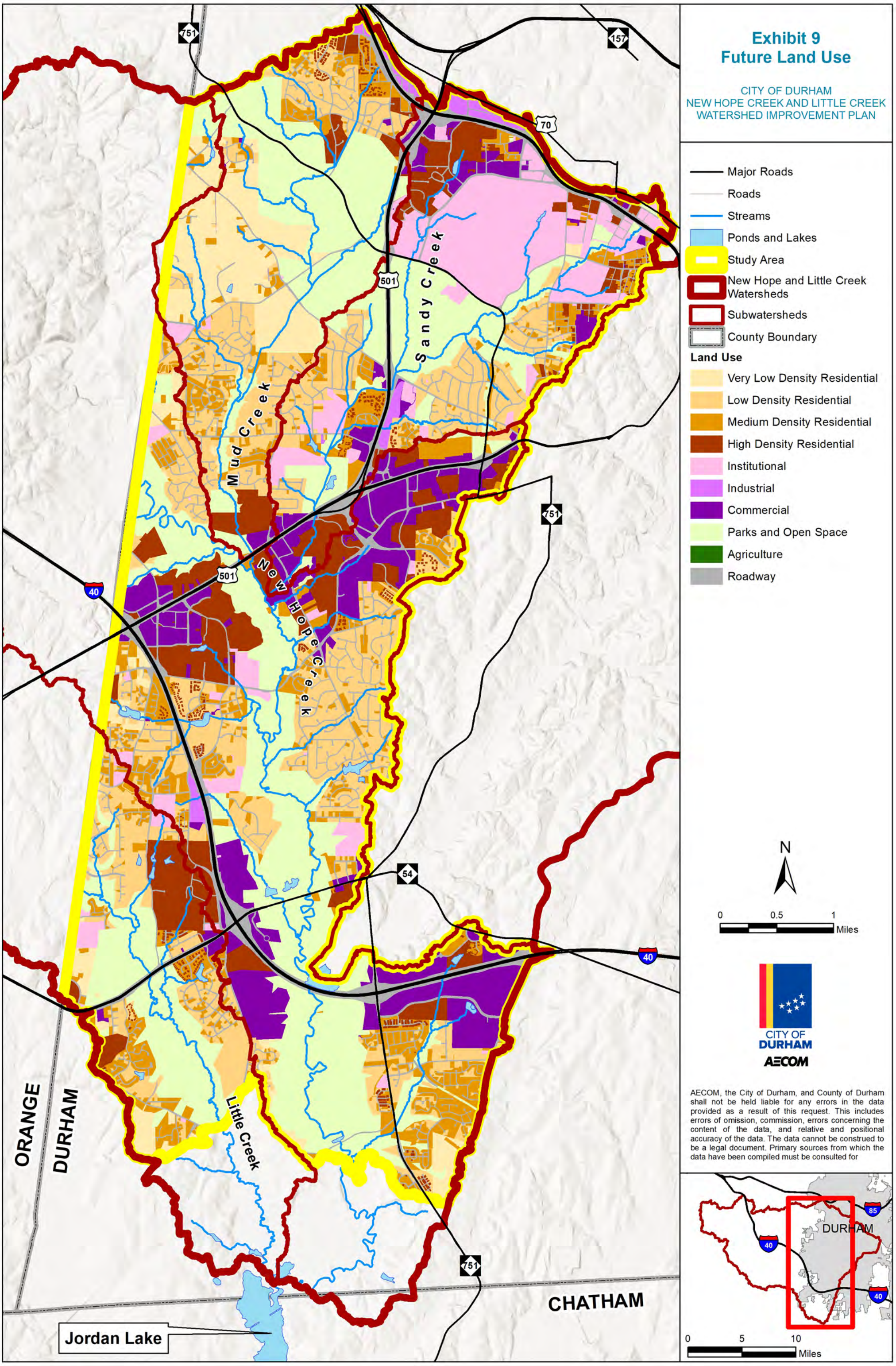
Exhibit 9
Future Land Use
CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN
Major Roads
Roads
Streams
Ponds and Lakes
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
County Boundary
Land Use
Very Low Density Residential
Low Density Residential
Medium Density Residential
High Density Residential
Institutional
Industrial
Commercial
Parks and Open Space
Agriculture
Roadway
N
0
0.5
1
Miles
CITY OF DURHAM
AECOM
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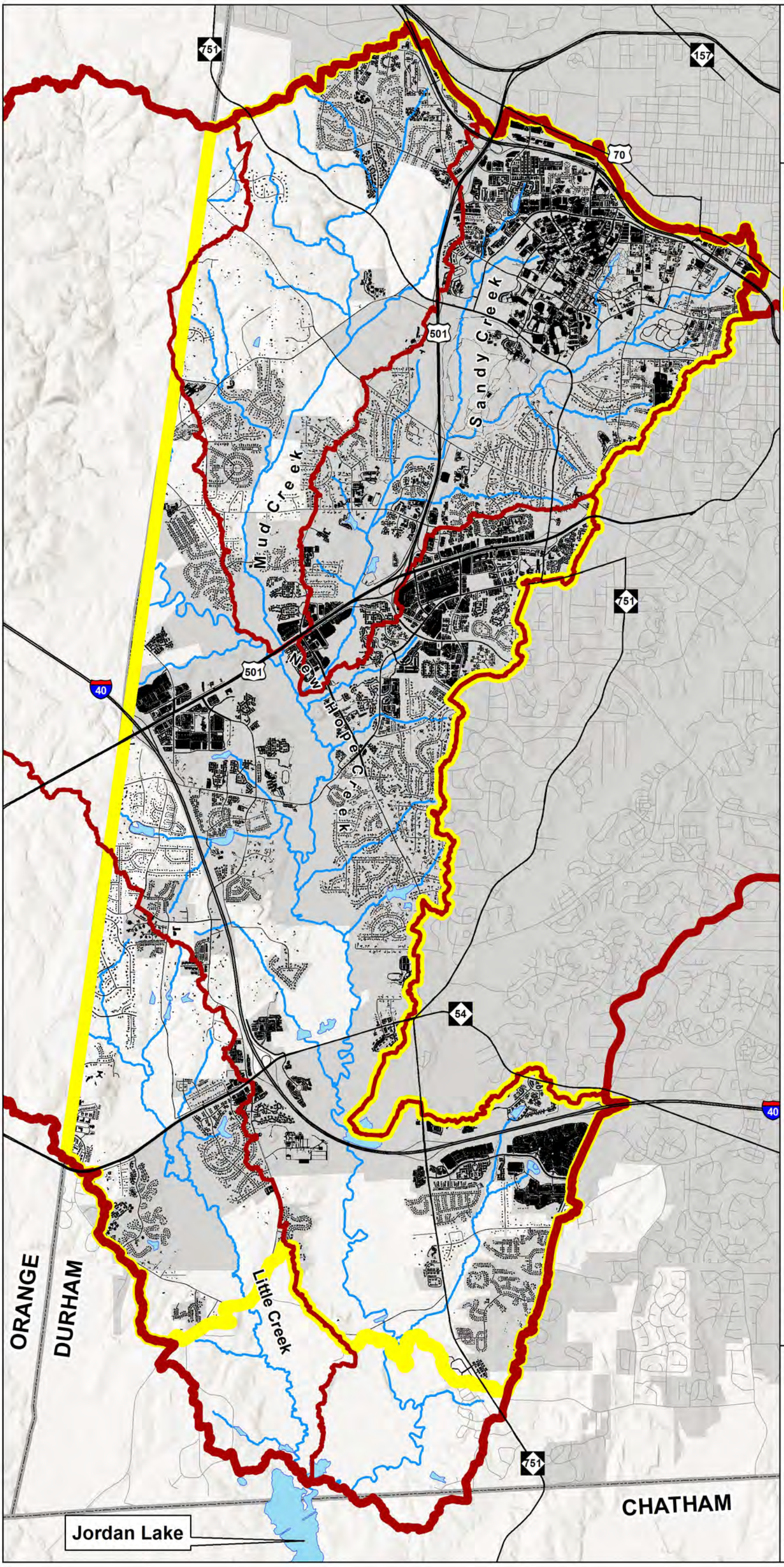
DURHAM
0
5
10
Miles
Sandy Creek
Mud Creek
New Hope Creek
Little Creek
ORANGE
DURHAM
CHATHAM
Jordan Lake
751
157
70
501
40
54
85

Exhibit 10
Impervious Area

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



- Major Roads
- Roads
- Streams
- Ponds and Lakes
- Study Area
- New Hope and Little Creek Watersheds
- Subwatersheds
- Durham City Limits - 2019
- County Boundary
- Impervious Area

Impervious area in study area: 18%
Impervious area in city limits: 25%

N

0 0.5 1 Miles

CITY OF DURHAM

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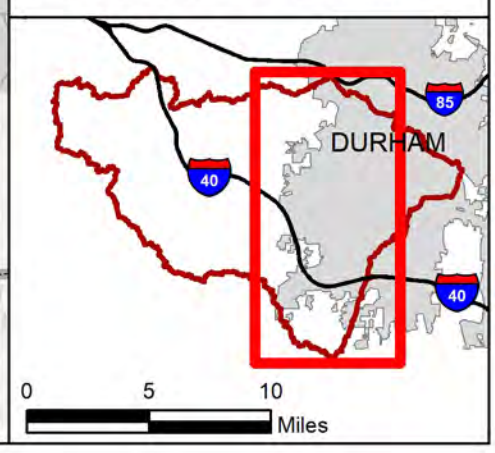
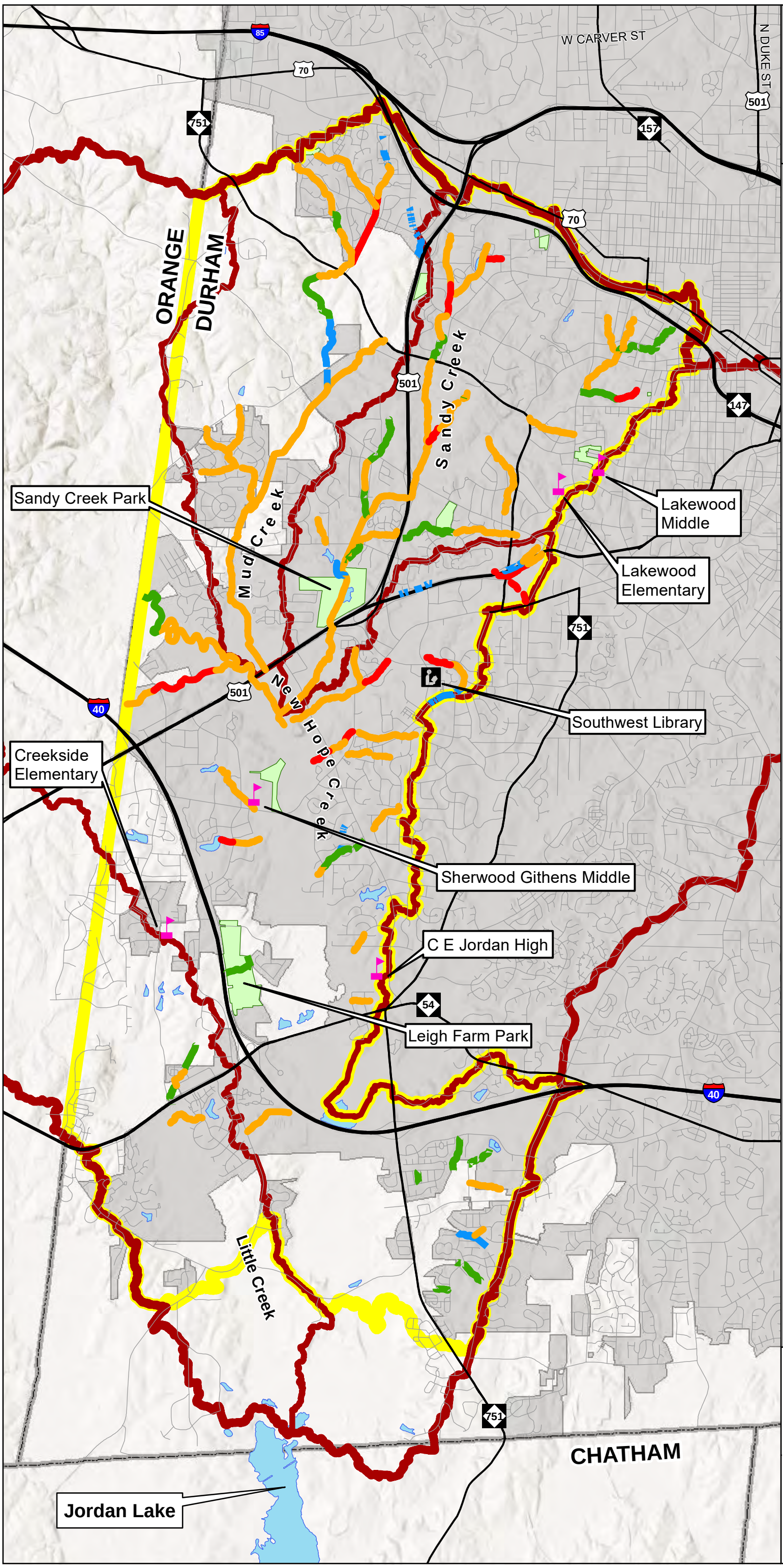


Exhibit 11
Stream Quailty Rating (RSAT)

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



Durham Public Libraries
Durham Public Schools
Major Roads
Roads
Ponds and Lakes
Parks
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
Durham City Limits - 2019
County Boundary

RSAT Rating

Good Condition (30-41)
Fair Condition (16-29)
Poor Condition (< 16)
Streams (Assessed but no RSAT)

N

0 0.5 1 Miles

CITY OF DURHAM
AECOM

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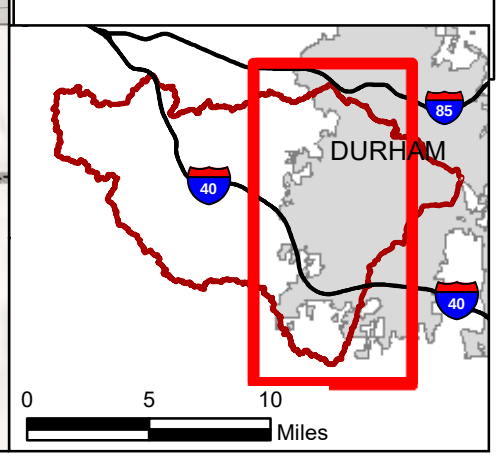
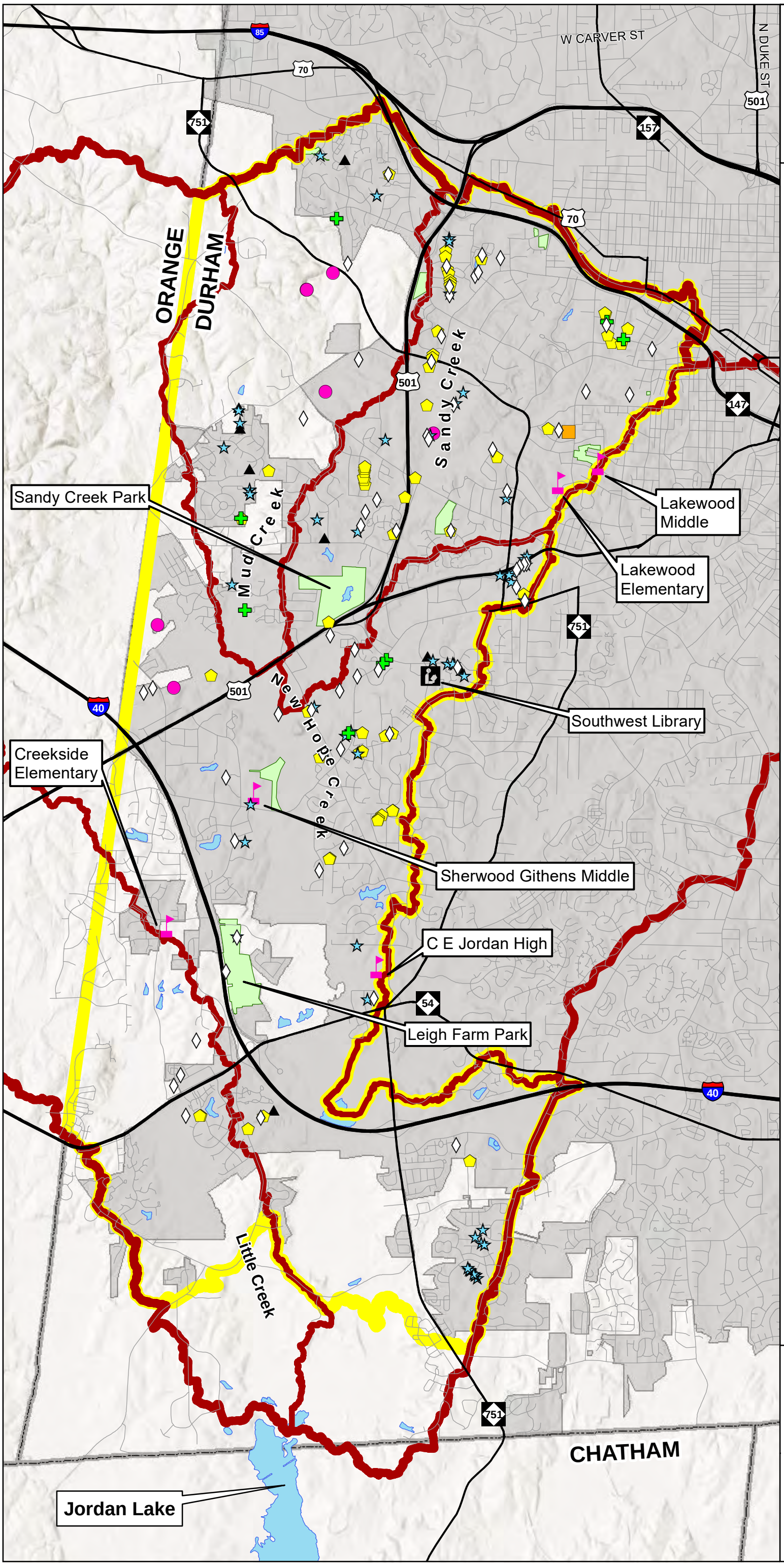


Exhibit 12
Observed Water Quality Concerns

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



- Durham Public Libraries
- Durham Public Schools
- Major Roads
- Roads
- Ponds and Lakes
- Parks
- Study Area
- New Hope and Little Creek Watersheds
- Subwatersheds
- Durham City Limits - 2019
- County Boundary
- Potential sources of excess sediment
- Suspect water appearance
- Suspect odor
- Low-head dam
- Exposed or threatened utility
- Headcut
- Litter Observed

N

0 0.5 1 Miles

CITY OF DURHAM

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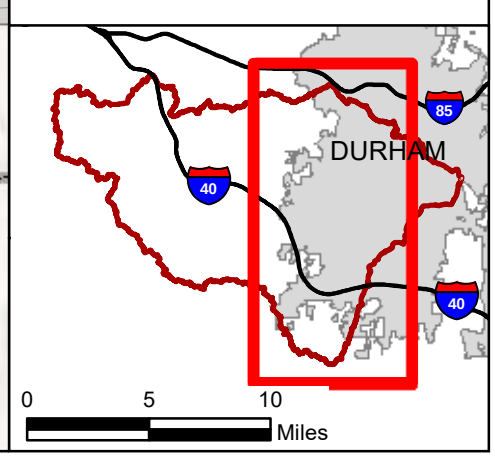
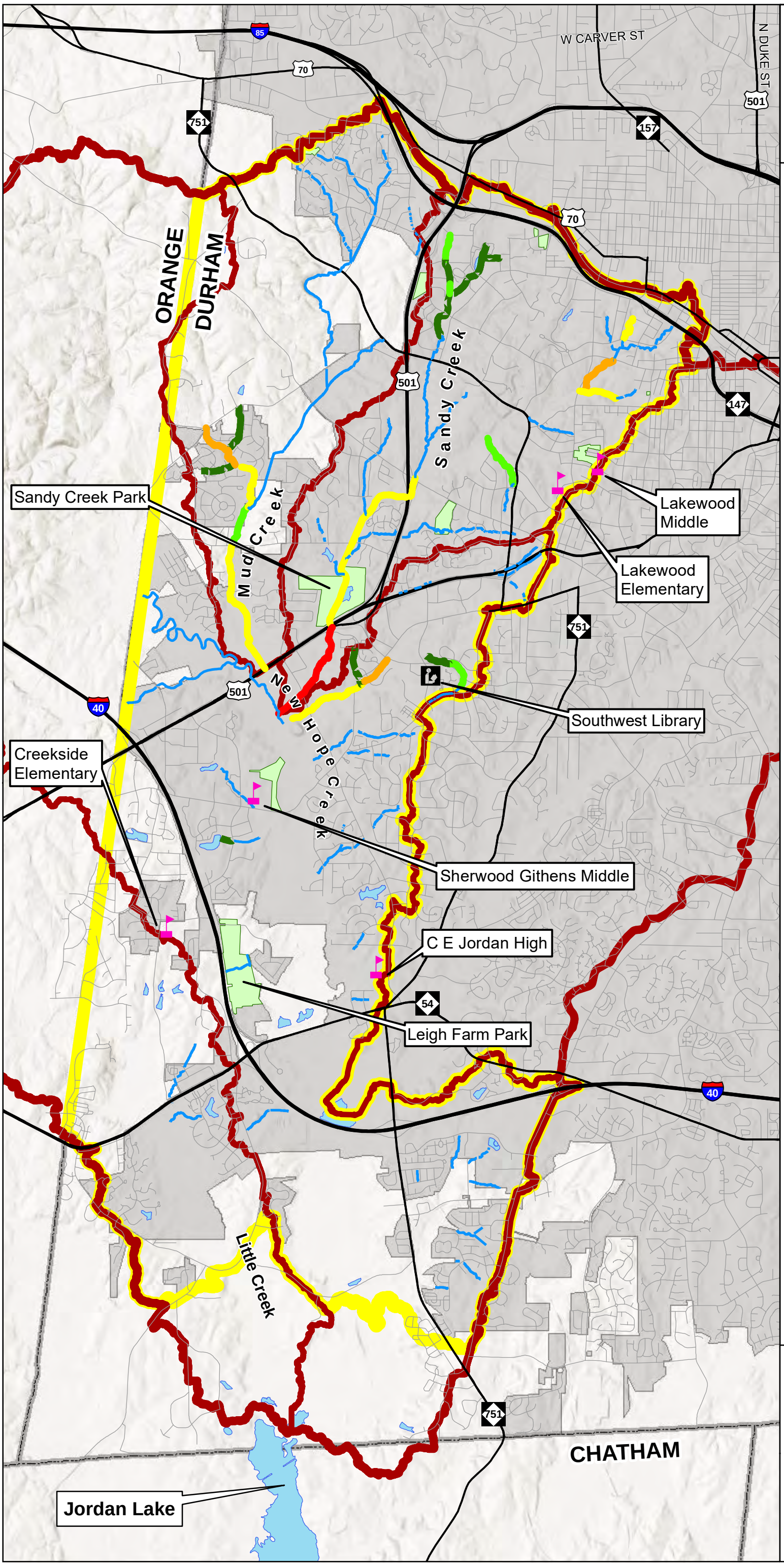


Exhibit 13
Stream Bank Erosion

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



- Durham Public Libraries
- Durham Public Schools
- Major Roads
- Roads
- Streams (Not Assessed for Bank Erosion)
- Ponds and Lakes
- Parks
- Study Area
- New Hope and Little Creek Watersheds
- Subwatersheds
- Durham City Limits - 2019
- County Boundary

Sediment Yield (tons/year)

- 1-10 (tons/year)
- 10-20 (tons/year)
- 20-100 (tons/year)
- 100-300 (tons/year)
- >300 (tons/year)

N

0 0.5 1 Miles

CITY OF DURHAM

AECOM

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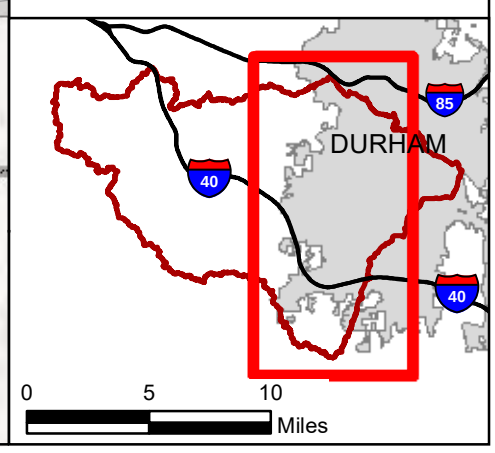


Exhibit 14
Existing Stormwater Control Measures Evaluated

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN

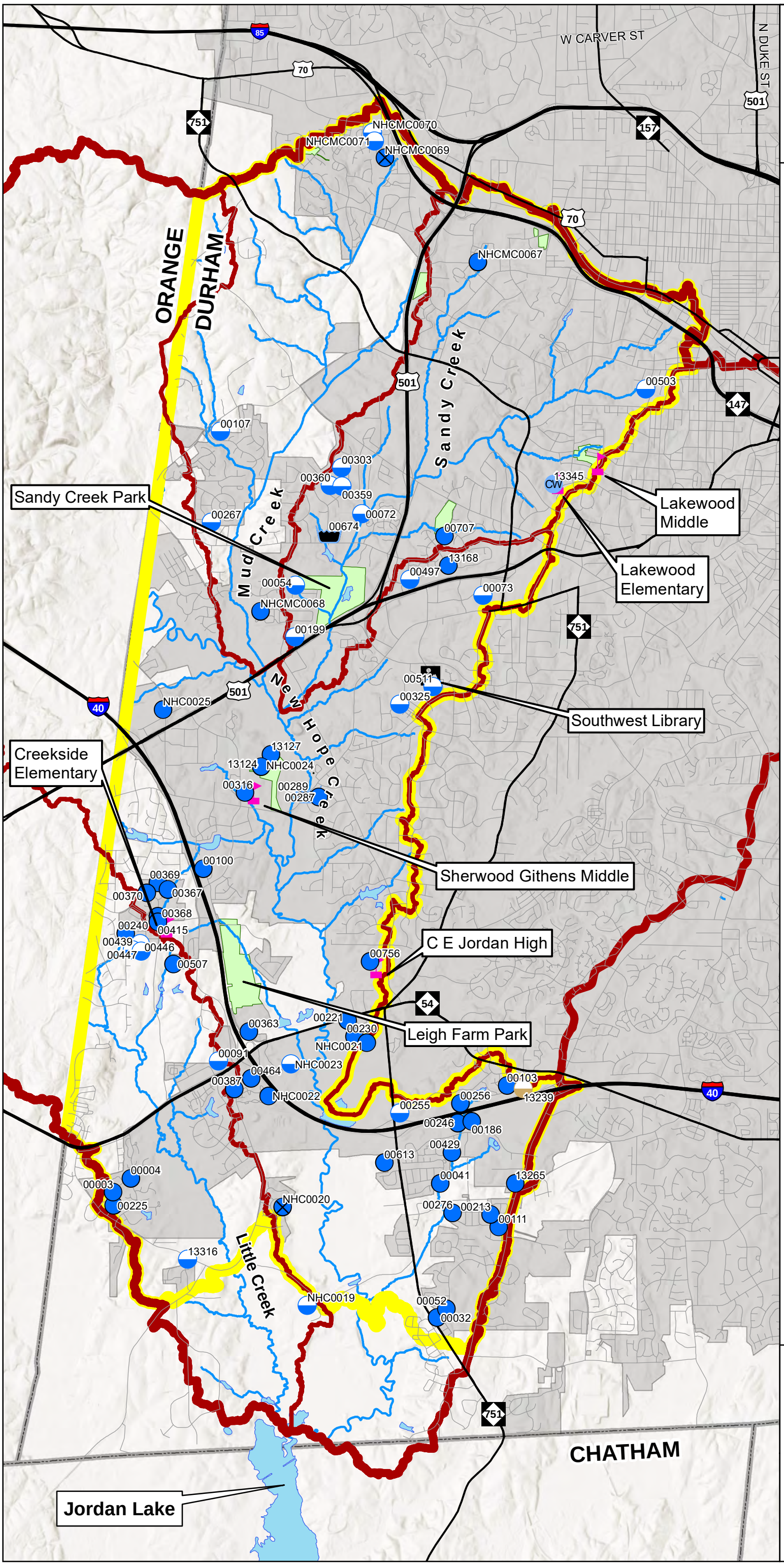
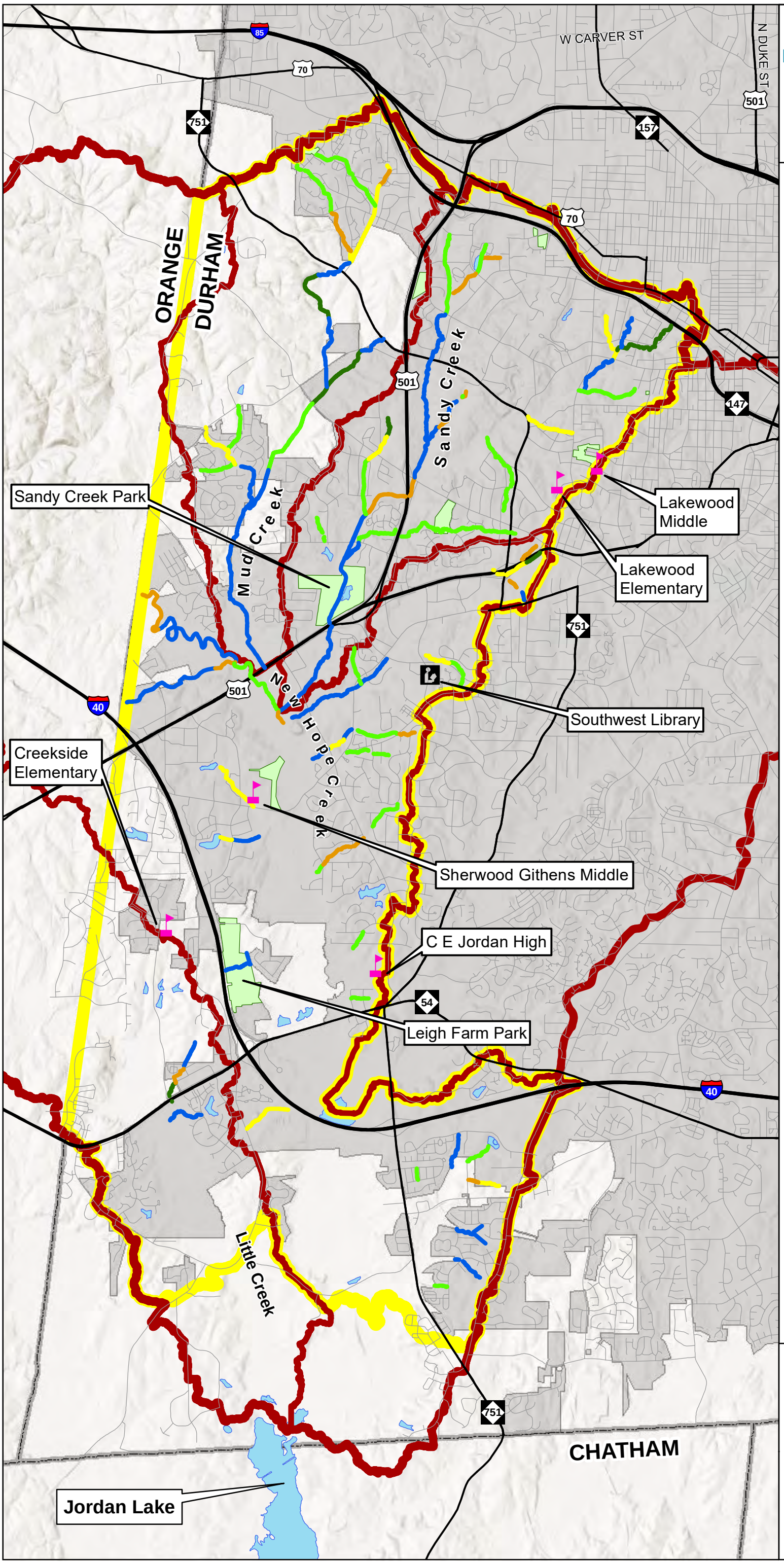


Exhibit 15
Potential Stream Projects

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



- Durham Public Libraries
- Durham Public Schools
- Major Roads
- Roads
- Ponds and Lakes
- Parks
- Study Area
- New Hope and Little Creek Watersheds
- Subwatersheds
- Durham City Limits - 2019
- County Boundary

Stream Project Potential (Number of Reaches)

- Restoration (39)
- Stream Enhancement I (16)
- Stream Enhancement II (17)
- Bank Stabilization (37)
- Preservation (6)

N

0 0.5 1 Miles

CITY OF DURHAM

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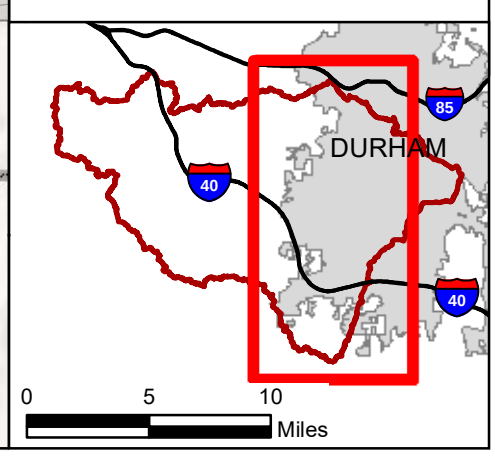
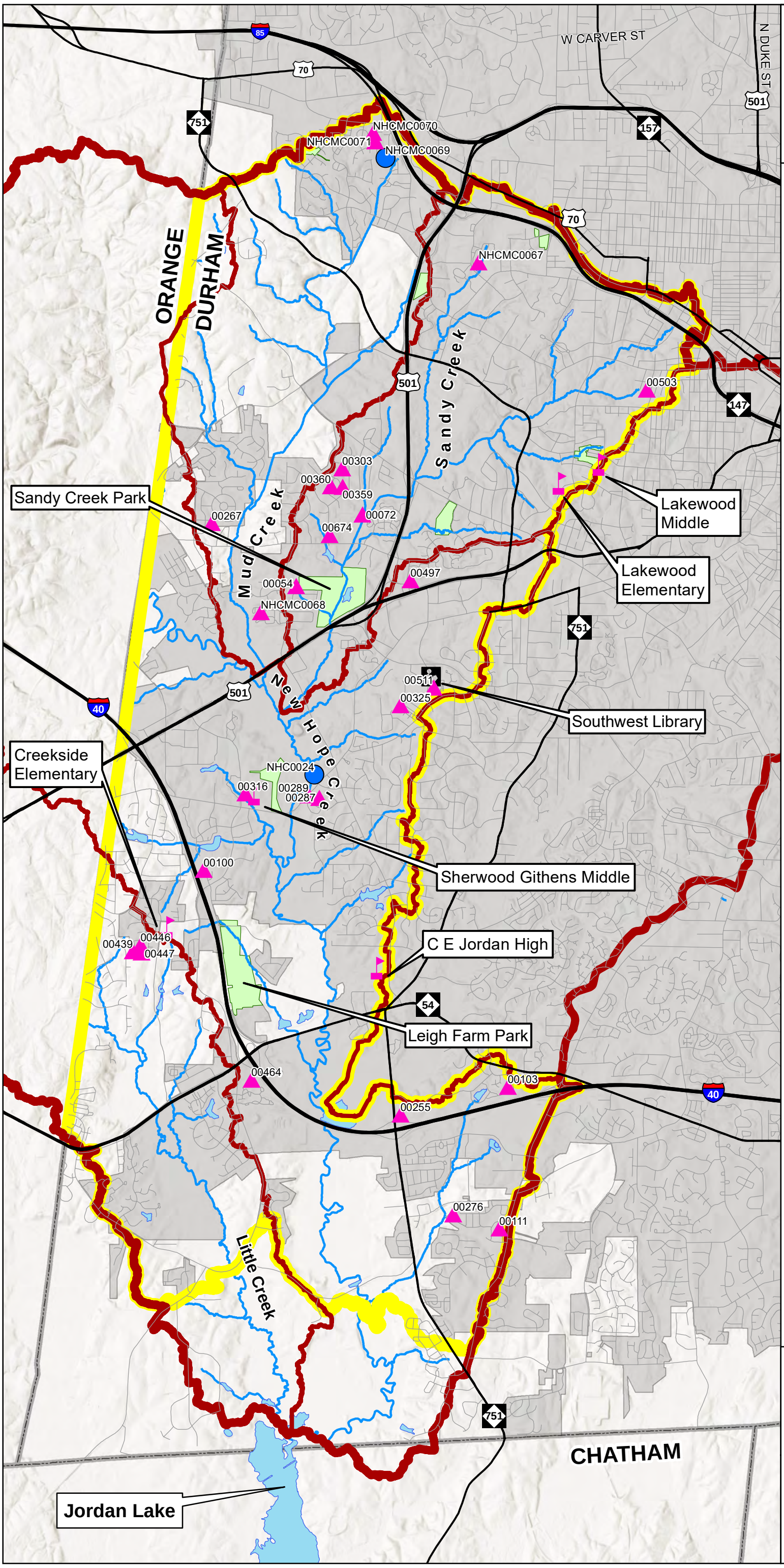


Exhibit 16
Potential Retrofits to Existing Stormwater Control Measures

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



Durham Public Libraries
Durham Public Schools
Major Roads
Roads
Streams
Ponds and Lakes
Parks
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
Durham City Limits - 2019
County Boundary

Existing SCM Type

Existing Water Retention Features
Existing SCMs (SCM ID)

N

0 0.5 1 Miles

CITY OF DURHAM
AECOM
Kimley»Horn

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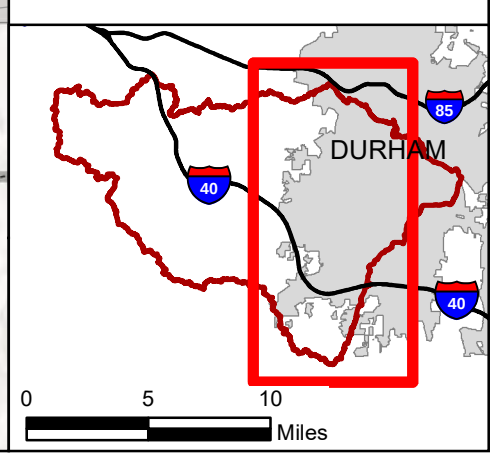
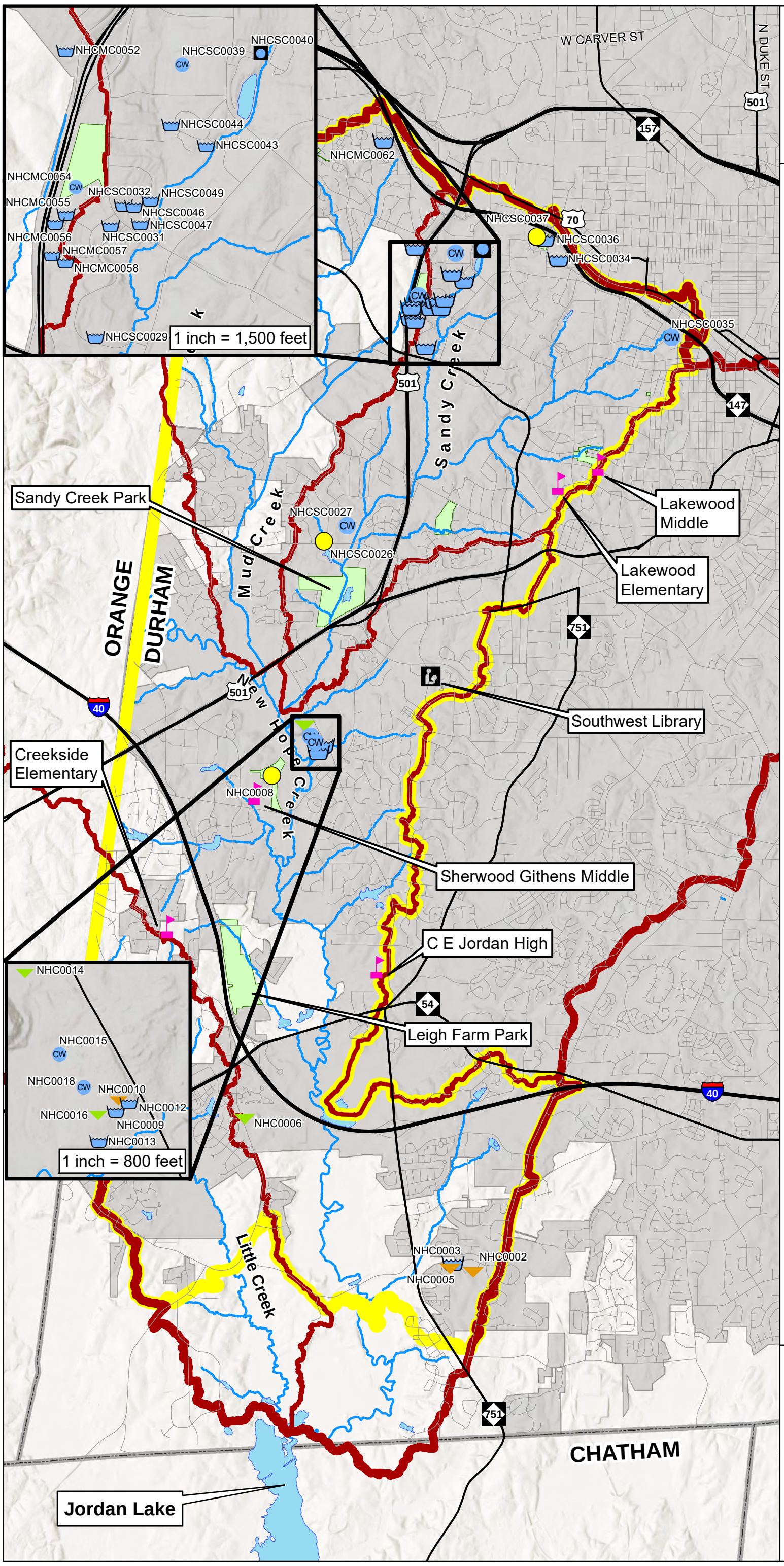


Exhibit 17
Potential New Stormwater Control Measures

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



Durham Public Libraries
Durham Public Schools
Major Roads
Roads
Streams
Ponds and Lakes
Parks
Study
New Hope and Little Creek Watersheds
Subwatersheds
Durham City Limits - 2019
County Boundary

Potential New SCM Type

Bioretention
Constructed Wetland
Regenerative Stormwater Conveyance
Treatment Swale - Dry
Treatment Swale - Wet
Wet Pond
Other

N

0 0.5 1 Miles

CITY OF DURHAM
AECOM
Kimley»Horn

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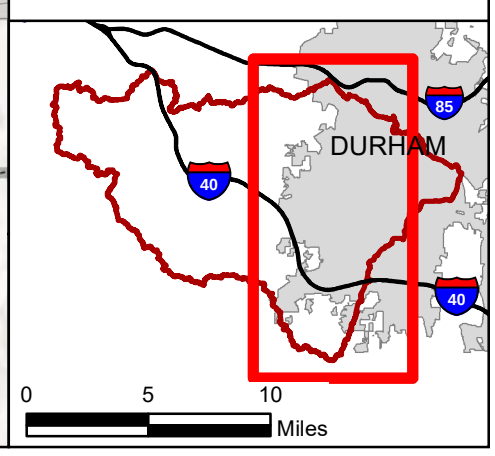
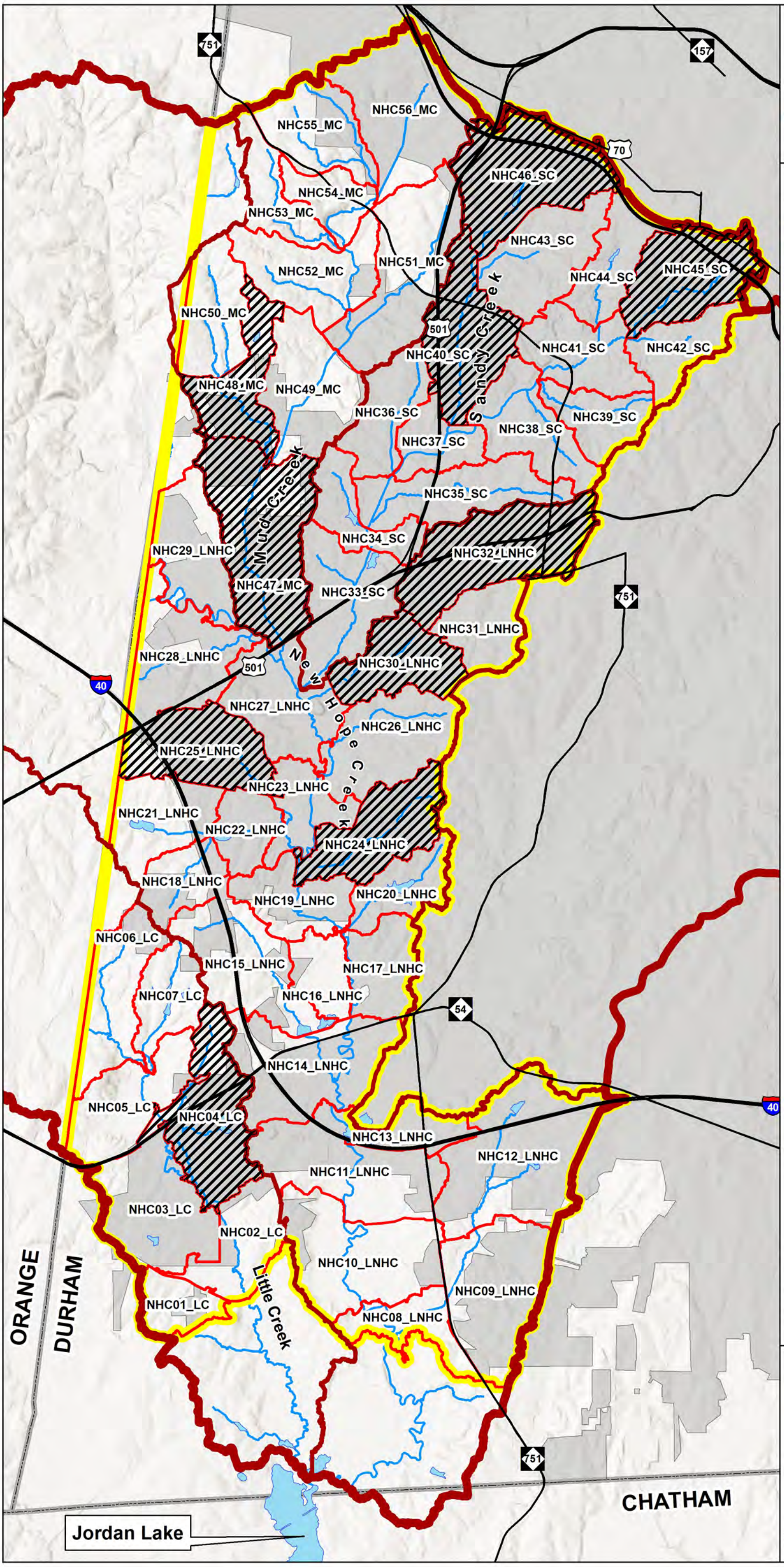


Exhibit 18
PSA Subwatersheds

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



Major Roads
Streams
Ponds and Lakes
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
PSA Subwatersheds
Candidate PSAs
County Boundary
Durham City Limits - 2019

N

0 0.5 1 Miles

CITY OF DURHAM
AECOM

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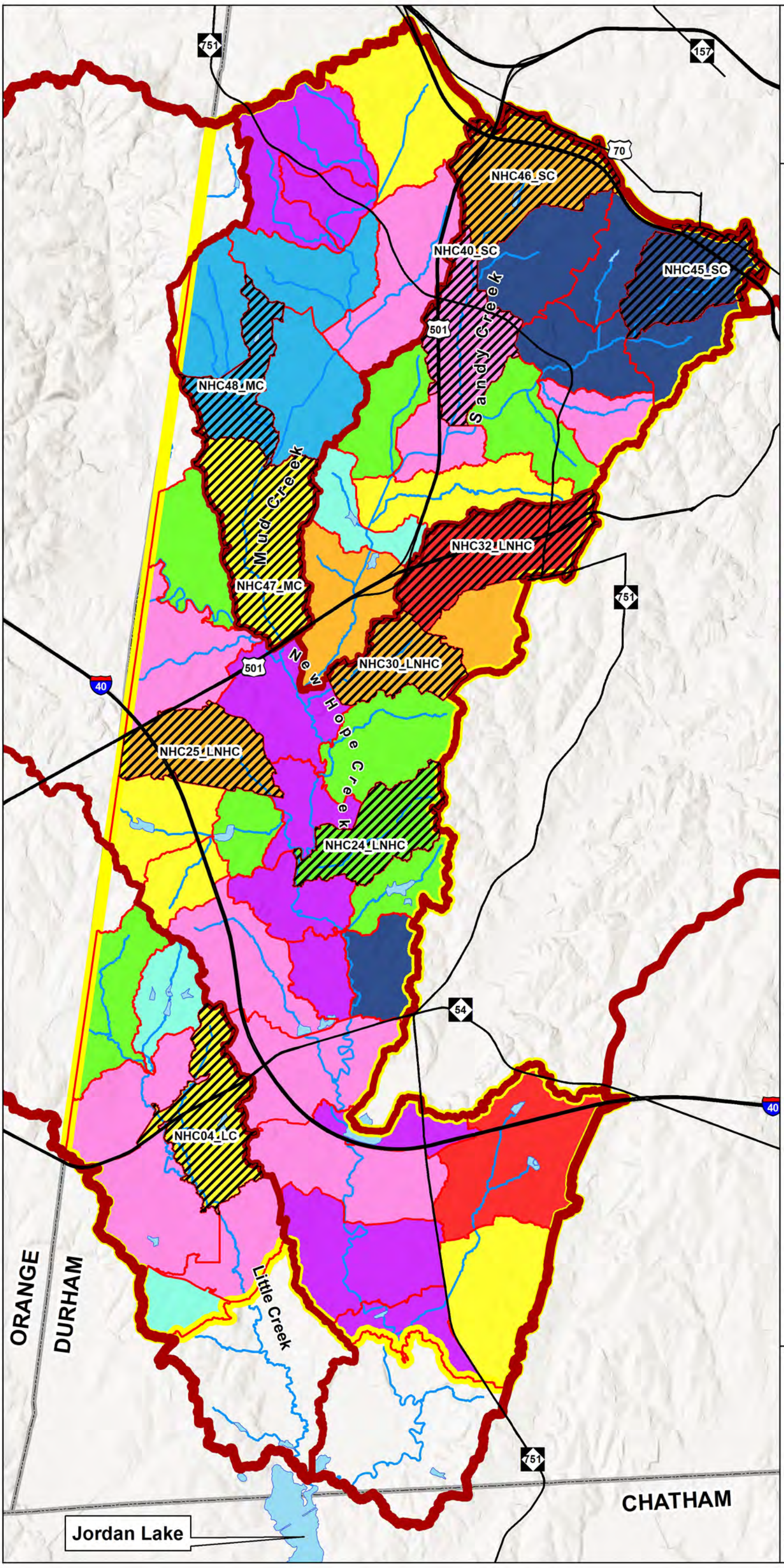
Exhibit 19
PSA Subwatershed Categories

CITY OF DURHAM
NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN



Major Roads
Streams
Ponds and Lakes
Study Area
New Hope and Little Creek Watersheds
Subwatersheds
PSA Subwatersheds
Candidate PSAs
County Boundary
Durham City Limits - 2019

PSA Subwatershed Categories

Parks and Open Space - Poorly Drained
Parks and Open Space - Well Drained
Low Density - Poorly Drained
Low and Medium Density Residential - Poorly Drained
High Density Residential and Commercial
Commercial
New Development - Poorly Drained
New Development - Well Drained
Institutional

N

0 0.5 1 Miles

CITY OF DURHAM
AECOM

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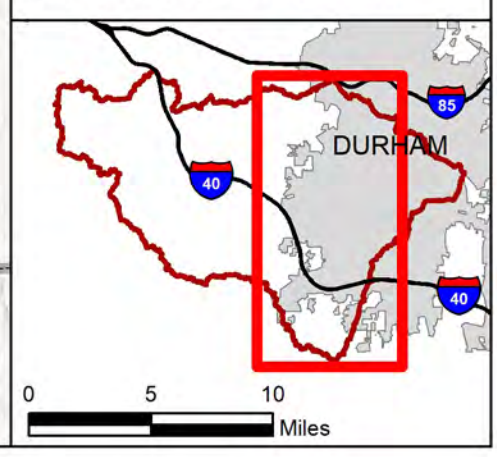

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Appendix B:

Data Catalog

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Table B-1. New Hope Creek and Little Creek WIP data catalog

Description	Date[1]	Source
Boundaries		
Durham City Limits	8/12/2019	City
North Carolina Counties	8/12/2019	NC One Map
Existing Land Use	8/12/2019	City/AECOM
Future Land Use	8/12/2019	City/AECOM
Durham Parcels	9/9/2019	City
Impervious Area	8/12/2019	City
New Hope Creek Watershed Boundary	11/1/2019	AECOM
New Hope Creek Watersheds	12/4/2019	AECOM
New Hope Creek WIP Subwatersheds	12/4/2019	AECOM
Durham Public Libraries	8/12/2019	City
Durham Public Schools	5/19/2016	City
Durham Parks	8/12/2019	City
Durham County Buildings	8/12/2019	Durham County
Environmental		
Geology	8/12/2019	NCGS
Soils	8/12/2019	City
Jordan Game Lands	02/03/2020	NCWRC
City of Durham Water Quality Monitoring Stations	3/15/2020	City
NCDEQ Ambient Water Quality Monitoring Stations	3/15/2020	NCDEQ
UNRBA Water Quality Monitoring Stations	3/15/2020	UNRBA
USGS Stream Gages	3/15/2020	USGS
Sanitary Sewer Overflows	3/21/2019	City
Hydrology		
Streams	7/012019	USDA/NRCS
Durham Streams	8/12/2019	City

(1) "8/12/2019" indicates the date received from the City and for which the last update is unavailable.
FEMA = Federal Emergency Management Agency
NCDEQ = North Carolina Department of Environmental Quality
NCDOT = North Carolina Department of Transportation
NC FRIS = North Carolina Flood Risk Information System
NCGS = North Carolina Geological Survey
NCWRC = North Carolina Wildlife Resources Commission
NRCA = Neuse River Compliance Association
UNRBA = Upper Neuse River Basin Association
USDA = United States Department of Agriculture
USGS = United States Geological Survey

Table B-1. New Hope Creek and Little Creek WIP data catalog (continued)

Description	Date[1]	Source
Hydrology (continued)		
Ponds and Lakes	7/01/2019	USDA/NRCS
Floodplains	12/6/2019	NC FRIS/FEMA
NCDEQ Stream Classifications	8/12/2019	NCDEQ
Stormwater Infrastructure		
Stormwater Pipes	5/19/2016	City
Stormwater Channels	5/19/2016	City
Stormwater Nodes	5/19/2016	City
Existing Stormwater Control Measures	9/9/2019	City
Topography		
2-foot Contours	8/12/2019	City
10-foot Contours	8/12/2019	City
3-meter DEM	1/1/2017	USGS
Hydro-Enforced DEM	8/12/2019	City
Transportation		
Major Roads	8/12/2019	City
Roads	3/1/2019	NCDOT
Durham Streets	8/12/2019	City
Water/Wastewater Infrastructure		
Septic Systems	1/4/2013	Durham County
Sand Filters	1/4/2013	City
Water Main	8/12/2019	City
Water Lateral	8/12/2019	City
Sewer Gravity Main	8/12/2019	City
Sewer Force Main	8/12/2019	City

(1) "8/12/2019" indicates the date received from the City and for which the last update is unavailable.
FEMA = Federal Emergency Management Agency
NCDEQ = North Carolina Department of Environmental Quality
NCDOT = North Carolina Department of Transportation
NC FRIS = North Carolina Flood Risk Information System
NCGS = North Carolina Geological Survey
NCWRC = North Carolina Wildlife Resources Commission
NRCA = Neuse River Compliance Association
UNRBA = Upper Neuse River Basin Association
USDA = United States Department of Agriculture
USGS = United States Geological Survey

Appendix C:

Summary of Existing Water Quality Data

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Table C-1. Summary of existing water quality data

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
LITC1.5LITC – Little Creek at Farrington Road														
2013	12	-	58	17%	6.7	25%	-	-	-	-	-	19	0%	156
2015	12	72	372	33%	6.3	9%	3.5	0.87	0.09	33%	0%	29	8%	143
NH0.0NHC – Lower New Hope Creek at Chapel Hill Road														
2004	13	85	259	25%	7.7	0%	2.1	0.82	0.07	8%	0%	23	9%	158
2005	12	82	189	17%	6.9	17%	2.6	0.77	0.07	0%	0%	35	8%	182
2006	13	86	306	36%	8.1	8%	2.2	0.74	0.07	8%	0%	38	23%	154
2007	11	67	214	40%	4.2	64%	2.8	0.73	0.08	0%	0%	30	18%	194
2008	12	79	302	25%	7.2	17%	2.2	0.62	0.08	0%	0%	23	0%	155
2009	12	87	121	8%	7.3	17%	2.1	0.62	0.04	8%	0%	22	8%	182
2010	12	85	205	25%	7.3	25%	2.7	0.66	0.08	0%	0%	22	0%	166
2011	12	79	271	33%	6.2	42%	2.7	0.75	0.11	0%	0%	31	25%	198
2013	12	92	103	17%	8.3	0%	2.3	0.55	0.05	8%	0%	20	17%	143
2015	12	80	477	50%	8.1	18%	2.0	0.64	0.06	0%	0%	17	8%	202
2017	13	79	568	50%	7.4	17%	2.2	0.60	0.10	8%	0%	21	8%	174
2019	12	79	737	67%	8.0	0%	2.2	0.73	0.17	8%	0%	44	17%	147

(1) The fecal coliform standard for the protection of human health and freshwater aquatic life requires that the geometric mean is less than 200 colony forming units per 100 ml (200 cfu/100 ml) based upon 5 consecutive samples during a 30-day period, and does not exceed 400 cfu/100 ml in more than 20% of the sample collected during the same period. Values presented in bold the table are the geometric mean of all samples collected in each year. Thus, exceedances of the standards presented in bold are not true standard violations, but can still be useful for assessing the impacts of fecal coliform bacteria within the watershed.

(2) WQI = Water Quality Index (unitless)

(3) BOD = Biochemical Oxygen Demand

Values shown in bold indicate that either the average concentration or a considerable number of individual samples for the year exceed the water quality standard or criteria.

Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH1.0SC – Sandy Creek at Garrett Road														
2004	12	80	564	50%	9.2	0%	2.1	1.22	0.13	25%	0%	27	18%	300
2005	12	82	377	50%	8.2	0%	2.8	1.24	0.09	0%	0%	38	17%	248
2006	13	79	486	42%	8.9	0%	2.6	0.96	0.08	17%	0%	56	31%	220
2007	11	79	224	30%	6.6	27%	3.0	0.79	0.09	10%	0%	26	18%	237
2008	12	84	234	25%	7.8	8%	2.0	0.68	0.08	8%	0%	17	8%	225
2009	12	89	104	8%	8.2	17%	2.0	0.64	0.05	8%	0%	41	17%	243
2010	11	85	309	27%	8.8	0%	2.4	0.79	0.08	9%	0%	16	0%	254
2011	12	83	267	42%	8.2	8%	2.8	0.76	0.10	8%	0%	26	17%	286
2013	12	88	104	17%	9.3	0%	2.2	0.82	0.07	25%	0%	21	25%	228
2015	12	82	770	62%	8.9	0%	2.3	0.67	0.06	25%	0%	16	8%	289
2017	12	86	419	36%	8.2	0%	2.1	0.62	0.10	17%	0%	18	8%	258
2019	12	71	1201	64%	8.5	0%	2.8	1.36	0.12	8%	0%	28	8%	207
NH1.6SC – Sandy Creek at Larchmont Road														
2018	7	-	-	-	8.2	0%	-	1.23	0.12	-	-	7	0%	240

(1) The fecal coliform standard for the protection of human health and freshwater aquatic life requires that the geometric mean is less than 200 colony forming units per 100 ml (200 cfu/100 ml) based upon 5 consecutive samples during a 30-day period, and does not exceed 400 cfu/100 ml in more than 20% of the sample collected during the same period. Values presented in bold the table are the geometric mean of all samples collected in each year. Thus, exceedances of the standards presented in bold are not true standard violations, but can still be useful for assessing the impacts of fecal coliform bacteria within the watershed.

(2) WQI = Water Quality Index (unitless)

(3) BOD = Biochemical Oxygen Demand

Values shown in bold indicate that either the average concentration or a considerable number of individual samples for the year exceed the water quality standard or criteria.

Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH1.7SCTA – Sandy Creek Tributary A at Ivy Creek Boulevard														
2009	12	-	1107	67%	6.8	17%	-	-	-	-	-	24	17%	343
2010	12	67	1082	75%	6.0	33%	3.4	1.07	0.06	8%	0%	15	0%	384
2011	12	70	710	67%	5.5	42%	2.6	1.09	0.10	0%	0%	14	0%	408
2013	12	70	434	42%	6.2	33%	2.9	1.01	0.09	8%	0%	18	0%	330
2015	12	65	2455	100%	5.9	36%	2.8	1.07	0.07	17%	0%	22	8%	381
2017	12	54	3518	85%	5.3	42%	3.7	1.19	0.15	33%	0%	21	0%	355
2018	4	-	-	-	6.7	0%	-	-	-	-	-	20	0%	391
2019	12	62	1787	85%	5.7	33%	2.3	1.17	0.11	8%	0%	25	8%	331
NH1.8SCTA – Sandy Creek Tributary A at MLK Parkway														
2018	8	-	-	-	8.6	0%	-	1.25	0.10	-	-	19	0%	429

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(2) WQI = Water Quality Index (unitless)

(3) BOD = Biochemical Oxygen Demand

Values shown in bold indicate that either the average concentration or a considerable number of individual samples for the year exceed the water quality standard or criteria.

Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH2.3MC – Mud Creek at Pickett Road														
2004	12	88	248	25%	9.1	0%	2.0	0.86	0.07	8%	0%	20	9%	138
2005	11	89	152	9%	8.1	9%	2.1	1.06	0.05	0%	0%	38	18%	154
2006	13	88	174	27%	9.2	0%	2.3	1.18	0.07	0%	0%	54	31%	142
2007	7	65	511	50%	7.6	43%	4.5	0.92	0.07	0%	0%	116	50%	126
2008	10	86	253	30%	9.0	0%	2.0	0.66	0.08	10%	0%	34	20%	127
2009	12	84	373	33%	8.8	0%	2.3	1.16	0.08	10%	0%	47	20%	146
2010	12	89	293	40%	9.3	0%	2.2	0.80	0.05	0%	0%	22	0%	146
2011	11	84	152	36%	6.7	18%	2.4	0.82	0.07	0%	0%	17	0%	166
2013	12	89	129	25%	7.6	8%	2.1	0.70	0.04	8%	0%	22	8%	145
2015	10	81	462	67%	8.4	11%	2.0	0.76	0.04	0%	0%	23	10%	162
2017	10	80	343	18%	7.8	10%	2.1	0.65	0.08	20%	0%	34	20%	158
2019	11	82	360	38%	8.8	9%	2.2	0.67	0.10	9%	0%	41	9%	124

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Values shown in bold indicate that either the average concentration or a considerable number of individual samples for the year exceed the water quality standard or criteria.

Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH3.0NHC – New Hope Creek at Erwin Road														
2004	12	-	51	8%	9.2	8%	-	-	-	-	-	12	9%	121
2005	12	-	30	0%	7.7	8%	-	-	-	-	-	8	0%	131
2006	13	-	37	18%	9.4	0%	-	-	-	-	-	9	0%	117
2007	10	-	54	11%	6.0	30%	-	-	-	-	-	14	10%	136
2008	12	-	57	8%	8.6	8%	-	-	-	-	-	10	0%	124
2009	14	92	64	7%	8.2	14%	2.0	0.52	0.04	17%	0%	13	7%	124
2010	13	96	33	0%	9.4	8%	2.0	0.56	0.04	18%	0%	6	0%	121
2011	12	94	28	8%	7.2	17%	2.1	0.62	0.03	0%	0%	7	0%	133
2013	12	94	58	17%	9.8	0%	2.0	0.43	0.03	0%	0%	13	0%	122
2015	12	86	213	29%	8.8	18%	2.3	0.43	0.03	8%	0%	8	0%	128
2017	12	88	141	13%	8.0	0%	2.1	0.43	0.07	8%	0%	20	8%	130
2019	12	88	169	29%	8.0	17%	2.1	0.47	0.05	0%	0%	17	0%	116

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH3.3SC – Sandy Creek at Cornwallis Road														
2008	12	85	379	33%	8.2	0%	2.0	0.77	0.08	17%	0%	15	0%	269
2009	14	87	325	31%	8.1	0%	2.3	0.83	0.04	8%	0%	31	7%	270
2010	34	84	262	36%	8.4	3%	2.4	0.90	0.08	8%	0%	22	9%	262
2011	23	84	388	42%	8.5	0%	2.8	1.16	0.10	25%	0%	20	9%	398
2012	12	88	186	25%	8.0	0%	2.3	0.74	0.09	8%	0%	16	8%	255
2013	12	83	167	33%	8.3	0%	2.3	0.91	0.10	8%	0%	21	25%	264
2014	12	78	769	58%	8.2	0%	2.7	0.85	0.11	42%	0%	58	33%	243
2015	12	75	1665	69%	8.3	0%	2.6	0.97	0.14	25%	0%	64	17%	305
2016	12	80	521	69%	8.1	0%	2.3	1.04	0.09	8%	0%	22	17%	264
2017	12	79	688	54%	7.7	0%	2.4	1.12	0.10	17%	0%	16	8%	279
2018	13	70	1060	69%	8.1	0%	2.6	1.37	0.16	17%	0%	42	25%	240
2019	12	73	1300	64%	7.1	0%	2.1	0.99	0.12	8%	0%	19	8%	224
2020	1	81	252	0%	12.1	0%	2.0	0.99	0.11	0%	0%	12	0%	255
NH3.4SC – Sandy Creek upstream of confluence with Sandy Creek Tributary D														
2018	1	-	-	-	6.4	0%	-	-	-	-	-	-	-	291

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH3.4SCTD – Sandy Creek Tributary D upstream of confluence with Sandy Creek														
2018	1	-	-	-	5.4	0%	-	-	-	-	-	-	-	220
NH4.3SC – Sandy Creek at Erwin Road at Duke Center for Living														
2008	12	-	422	58%	8.4	0%	-	-	-	-	-	13	8%	347
NH4.4SCTD – Sandy Creek Tributary D at Academy Road														
2004	12	-	562	67%	8.9	0%	-	-	-	-	-	20	9%	266
2005	12	-	688	83%	7.7	8%	-	-	-	-	-	14	8%	230
2018	7	-	-	-	8.3	0%	-	1.48	0.09	-	-	17	0%	314
2019	12	77	425	64%	7.2	17%	2.0	0.99	0.10	17%	0%	20	8%	243
NH4.7SC – Sandy Creek at Morrene Road														
2018	8	-	-	-	7.6	0%	-	1.27	0.12	-	-	15	0%	350
NH4.8SCTDT – Sandy Creek Tributary D at Duke University Road														
2006	13	-	758	58%	8.2	0%	-	-	-	-	-	14	0%	253
2007	10	-	733	56%	6.5	0%	-	-	-	-	-	9	0%	268
2008	12	-	523	67%	6.8	8%	-	-	-	-	-	11	0%	251
2009	12	-	1020	67%	7.3	0%	-	-	-	-	-	16	17%	232
2010	12	-	607	75%	6.2	33%	-	-	-	-	-	12	0%	355

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
NH4.8SCTDT – Sandy Creek Tributary D at Duke University Road (continued)														
2011	12	75	647	42%	7.3	0%	4.1	1.20	0.12	17%	0%	11	9%	364
2013	12	84	136	25%	7.6	0%	2.6	0.93	0.10	8%	0%	8	0%	300
2015	12	77	812	71%	7.4	9%	2.3	1.00	0.10	8%	0%	8	0%	384
2017	12	73	865	71%	6.8	8%	2.1	0.84	0.15	8%	0%	14	8%	364
NH5.0SCTD – Sandy Creek Tributary D at Anderson Road														
2006	13	-	1037	50%	8.9	0%	-	-	-	-	-	10	0%	224
2007	8	-	537	57%	8.4	0%	-	-	-	-	-	10	0%	209
2008	11	-	702	45%	8.7	0%	-	-	-	-	-	7	0%	258
2009	10	-	816	70%	9.5	0%	-	-	-	-	-	62	20%	230
2010	11	-	1437	64%	8.2	9%	-	-	-	-	-	11	0%	395
2011	11	82	537	55%	8.1	0%	2.6	0.79	0.09	18%	0%	12	0%	307
2013	12	89	159	25%	9.5	0%	2.1	0.68	0.07	8%	0%	14	0%	302
SCSN 1 – Sandy Creek near Waterbury Street														
2018	1	-	-	-	2.8	100%	-	1.63	0.07	-	-	22	0%	128
SCSN 3 – Sandy Creek at Welcome Drive and Tryon Road														
2018	1	-	-	-	2.7	100%	-	1.42	0.21	-	-	49	0%	239

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
SCSN 4 – Sandy Creek near Evans Street														
2018	1	-	-	-	2.5	100%	-	1.85	0.02	-	-	14	0%	207
SCSN 6 – Sandy Creek off Kangaroo Drive Behind Post Office														
2018	1	-	-	-	2.2	100%	-	0.70	0.22	-	-	24	0%	625
SCSN 7 – Sandy Creek downstream of NC-147 in Duke Manor Apartments off LaSalle Street														
2018	1	-	-	-	6.1	0%	-	2.23	0.10	-	-	12	0%	496
SCSN 10 – Sandy Creek near Circuit Drive														
2018	1	-	-	-	7.8	0%	-	1.11	0.05	-	-	1	0%	222
SCSN 11 – Sandy Creek near Parking Lot on Fuqua Drive														
2018	1	-	-	-	6.8	0%	-	0.92	0.04	-	-	3	0%	388
SCSN 13 – Sandy Creek near Nasher Museum Parking Lot off Campus Drive														
2018	1	-	-	-	4.6	0%	-	1.28	0.06	-	-	6	0%	267
SCSN 14 – Sandy Creek near end of Hull Avenue														
2018	1	-	-	-	7.8	0%	-	1.70	0.36	-	-	5	0%	381
SCSN 15 – Sandy Creek near Campus Drive downstream of NC-147														
2018	1	-	-	-	5.5	0%	-	1.24	0.07	-	-	3	0%	613

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
SCSN 17 – Sandy Creek upstream of Morehead Drive														
2018	1	-	-	-	1.7	100%	-	7.84	0.33	-	-	7	0%	635
SCSN 18 – Sandy Creek off Brooks-Pascal Drive below Stadium														
2018	1	-	-	-	7.0	0%	-	4.24	0.17	-	-	23	0%	458
SCSN 21 – Sandy Creek near Pierce Street and Prince Street														
2018	1	-	-	-	3.1	100%	-	1.43	0.16	-	-	5	0%	246
B3020000 – Lower New Hope Creek at NC-54														
2000	14	-	206	33%	5.9	7%	-	0.29	0.07	-	-	20	11%	145
2001	19	-	110	25%	5.8	11%	-	1.14	0.15	-	-	26	8%	160
2002	17	-	123	33%	5.8	24%	-	0.76	0.08	-	-	23	8%	170
2003	17	-	139	33%	6.2	18%	-	1.03	0.08	-	-	33	25%	135
2004	17	-	440	50%	7.3	12%	-	1.16	0.10	-	-	50	8%	179
2005	17	-	100	0%	6.0	35%	-	0.79	0.09	-	-	26	8%	168
2006	17	-	110	25%	6.5	12%	-	0.60	0.10	-	-	28	17%	147
2007	17	-	128	25%	5.2	53%	-	0.57	0.11	-	-	22	8%	159
2008	17	-	334	50%	5.9	35%	-	0.78	0.09	-	-	29	8%	144
2009	17	-	130	17%	5.9	24%	-	0.54	0.04	-	-	20	0%	131

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
B3020000 – Lower New Hope Creek at NC-54 (continued)														
2010	17	-	526	42%	5.8	29%	-	0.58	0.18	-	-	32	17%	133
2011	17	-	76	17%	4.6	53%	-	0.79	0.10	-	-	25	8%	158
2012	17	-	103	33%	4.9	35%	-	0.87	0.10	-	-	22	0%	139
2013	17	-	190	25%	5.8	18%	-	0.72	0.08	-	-	22	0%	141
2014	9	-	164	20%	6.4	12%	-	0.39	0.06	-	-	17	0	142
2015	17	-	101	12%	6.2	35%	-	0.61	0.06	-	-	16	6	160
2016	17	-	123	12%	6.4	6%	-	0.52	0.04	-	-	15	6	132
2017	17	-	59	6%	5.7	24%	-	0.43	0.04	-	-	15	6	156
2018	17	-	523	35%	5.8	12%	-	0.94	0.04	-	-	29	24	114
B3040000 – Lower New Hope Creek at Stagecoach Road (SR 1107)														
2000	28	-	282	33%	7.1	0%	-	2.24	0.22	-	-	33	14%	-
2001	28	-	162	24%	7.0	0%	-	4.71	0.37	-	-	22	5%	-
2002	31	-	129	26%	7.8	0%	-	4.45	0.30	-	-	26	8%	-
2003	29	-	146	17%	7.5	0%	-	3.13	0.30	-	-	32	21%	-
2004	29	-	293	46%	7.4	0%	-	3.10	0.35	-	-	30	13%	-

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Table C-1. Summary of existing water quality data (continued)

Year	# of Samples	Avg WQI[2]	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD[3] (mg/L)	Nutrients		Dissolved Metals – USEPA Criterion Continuous Concentration (CCC)		Turbidity		Average Conductivity (µs/cm)
			GeoMean FC (cfu/100 ml)	Percent of FC Samples > 400 cfu/100 ml[1]	Avg DO (mg/L)	Percent of DO Samples < 4 mg/L		Avg TN (mg/L)	Avg TP (mg/L)	Percent of Cu samples > USEPA CCC for Cu	Percent of Zn samples > USEPA CCC for Zn	Average Turbidity (NTU)	Percent of Samples Exceeding 50 NTU	
B3040000 – Lower New Hope Creek at Stagecoach Road (SR 1107) (continued)														
2005	25	-	117	12%	8.1	0%	-	3.88	0.39	-	-	17	0%	-
2006	43	-	98	17%	7.6	2%	-	4.78	0.54	-	-	25	13%	-
2007	42	-	102	13%	7.2	3%	-	5.25	0.48	-	-	21	8%	-
2008	44	-	143	13%	7.4	0%	-	4.22	0.49	-	-	27	13%	-
2009	43	-	121	14%	7.5	0%	-	4.96	0.22	-	-	19	6%	314
2010	43	-	180	25%	7.4	2%	-	4.36	0.19	-	-	22	4%	-
2011	43	-	131	13%	7.2	2%	-	5.12	0.20	-	-	22	8%	-
2012	42	-	206	26%	7.1	0%	-	6.15	0.32	-	-	28	8%	-
2013	43	-	134	13%	7.3	0%	-	3.72	0.17	-	-	27	13%	-
2014	33	-	160	8%	7.5	0%	-	3.84	0.27	-	-	20	0%	-
2015	20	-	181	27%	7.9	0%	-	4.44	0.41	-	-	24	0%	-
2016	25	-	193	25%	7.1	4%	-	2.93	0.16	-	-	28	8%	-
2017	18	-	255	31%	7.3	0%	-	3.38	0.17	-	-	45	21%	-
2018	12	-	390	44%	7.5	10%	-	2.62	0.13	-	-	28	0%	-

(1) The fecal coliform standard for the protection of human health and freshwater aquatic life requires that the geometric mean is less than 200 colony forming units per 100 ml (200 cfu/100 ml) based upon 5 consecutive samples during a 30-day period, and does not exceed 400 cfu/100 ml in more than 20% of the sample collected during the same period. Values presented in bold the table are the geometric mean of all samples collected in each year. Thus, exceedances of the standards presented in bold are not true standard violations, but can still be useful for assessing the impacts of fecal coliform bacteria within the watershed.

(2) WQI = Water Quality Index (unitless)

(3) BOD = Biochemical Oxygen Demand

Values shown in bold indicate that either the average concentration or a considerable number of individual samples for the year exceed the water quality standard or criteria.

Appendix D:

Land Use and Impervious Area by Subwatershed

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Table D-1. Existing, future, and projected land use change by subwatershed

	Existing Land Use (acres)										Future Land Use (acres)										Land Use Change (acres)								
Subwatershed	AGR	COM	HDR	IND	INT	LDR	MDR	POS	ROAD	VLR	AGR	COM	HDR	IND	INT	LDR	MDR	POS	ROAD	VLR	AGR	COM	HDR	IND	INT	LDR	MDR	POS	VLR
NHC01_LC	0	0	0	0	2	1	44	66	11	31	0	0	0	0	2	7	44	8	11	84	n/a	n/a	n/a	n/a	0	6	0	-58	53
NHC02_LC	78	0	0	0	0	24	18	134	16	3	0	0	0	0	0	103	18	134	16	2	-78	n/a	n/a	n/a	n/a	79	0	0	-1
NHC03_LC	0	6	42	0	3	33	82	210	39	32	0	6	42	0	3	66	82	196	39	14	n/a	0	0	n/a	0	33	0	-15	-18
NHC04_LC	0	17	10	0	3	96	62	158	63	32	0	17	95	0	3	86	59	117	63	0	n/a	0	85	n/a	0	-10	-2	-41	-32
NHC05_LC	0	0	19	0	15	3	20	228	21	42	0	0	53	0	15	6	15	200	21	38	n/a	n/a	34	n/a	0	3	-5	-28	-4
NHC06_LC	0	0	0	0	25	104	33	98	30	47	0	0	0	0	25	136	33	92	30	21	n/a	n/a	0	n/a	0	32	0	-6	-26
NHC07_LC	0	0	0	0	13	10	20	33	8	137	0	0	87	0	13	86	8	19	8	0	n/a	n/a	87	n/a	0	76	-12	-13	-137
NHC08_LNHC	0	0	2	0	0	0	31	145	18	7	0	0	2	0	0	11	31	132	18	9	n/a	n/a	0	n/a	n/a	11	0	-13	2
NHC09_LNHC	58	0	5	0	0	33	192	117	66	19	0	0	5	0	0	82	192	71	66	75	-58	n/a	0	n/a	0	49	0	-47	55
NHC10_LNHC	19	14	6	0	5	29	23	382	18	41	0	14	6	0	5	62	23	372	18	38	-19	0	0	n/a	0	33	0	-10	-3
NHC11_LNHC	6	143	4	0	2	17	26	246	40	0	0	155	4	0	0	23	23	239	40	0	-6	12	0	n/a	-2	6	-4	-7	0
NHC12_LNHC	22	278	84	0	8	36	92	35	121	13	0	314	78	0	7	61	86	23	121	0	-22	36	-6	n/a	-1	25	-7	-12	-13
NHC13_LNHC	0	24	0	0	0	0	13	84	62	0	0	37	0	0	0	0	0	84	62	0	n/a	13	n/a	n/a	0	n/a	-13	0	n/a
NHC14_LNHC	0	61	73	0	4	1	32	234	97	6	0	79	80	0	2	1	18	231	97	0	n/a	18	7	n/a	-1	0	-14	-2	-6
NHC15_LNHC	0	52	1	1	35	29	48	142	65	65	0	64	39	23	35	66	36	110	65	0	n/a	12	38	22	0	37	-12	-33	-65
NHC16_LNHC	0	0	0	0	0	12	2	143	2	7	0	0	0	0	0	27	2	134	2	0	n/a	n/a	n/a	n/a	n/a	15	0	-8	-7
NHC17_LNHC	0	6	0	0	53	52	40	69	15	4	0	16	0	0	52	56	32	69	15	0	n/a	10	n/a	n/a	-1	4	-8	0	-4
NHC18_LNHC	0	0	4	0	0	41	52	33	42	14	0	0	4	1	0	88	51	0	42	0	n/a	0	0	1	0	47	-1	-33	-14
NHC19_LNHC	0	0	0	0	16	19	23	152	9	34	0	0	0	0	16	61	23	144	9	0	n/a	n/a	n/a	n/a	0	42	0	-9	-34
NHC20_LNHC	0	0	0	0	0	100	22	33	22	31	0	0	0	0	0	149	22	15	22	0	n/a	n/a	n/a	n/a	n/a	49	0	-17	-31
NHC21_LNHC	0	1	28	0	12	88	67	12	55	42	0	1	28	0	12	100	67	10	55	31	n/a	0	0	n/a	0	12	0	-2	-10
NHC22_LNHC	0	1	5	0	6	39	35	20	17	44	0	1	6	0	6	95	34	5	17	3	n/a	0	1	n/a	0	57	0	-16	-41
NHC23_LNHC	0	0	0	0	26	22	14	119	9	11	0	0	0	0	26	32	14	119	9	1	n/a	n/a	n/a	n/a	0	10	0	0	-10
NHC24_LNHC	0	0	0	0	0	181	22	60	40	51	0	0	0	0	0	240	22	52	40	0	n/a	n/a	n/a	n/a	0	59	0	-8	-51
NHC25_LNHC	25	88	49	0	18	11	47	23	71	42	0	88	152	0	18	2	24	0	71	18	-25	0	103	n/a	0	-9	-23	-23	-24
NHC26_LNHC	0	17	25	4	7	173	54	31	58	43	0	39	24	0	7	206	56	17	58	5	n/a	21	-1	-4	0	33	2	-14	-37
NHC27_LNHC	39	28	86	0	3	0	16	177	22	2	0	29	136	0	3	0	16	168	22	0	-39	1	49	n/a	0	0	-1	-9	-2
NHC28_LNHC	0	78	32	0	0	0	16	227	48	14	0	79	83	0	0	20	2	180	48	2	n/a	0	51	n/a	n/a	20	-14	-47	-12
NHC29_LNHC	0	0	1	0	18	113	31	117	32	21	0	0	1	0	18	120	31	108	32	23	n/a	n/a	0	n/a	0	7	0	-9	2
NHC30_LNHC	0	89	104	0	3	11	24	15	29	11	0	110	112	0	2	11	19	3	29	0	n/a	21	8	n/a	-1	0	-5	-12	-11
NHC31_LNHC	0	42	65	0	6	51	39	0	25	3	0	43	70	0	5	52	36	0	25	0	n/a	1	5	n/a	-1	1	-3	n/a	-3
NHC32_LNHC	0	210	72	0	25	13	66	32	99	7	0	249	80	0	0	10	60	25	99	0	n/a	39	8	n/a	-25	-3	-5	-7	-7
NHC33_SC	0	74	90	0	30	43	4	88	79	2	0	82	88	0	30	43	6	82	79	0	n/a	8	-2	n/a	0	0	2	-6	-2
NHC34_SC	0	4	0	0	38	35	25	47	31	33	0	10	3	0	37	74	29	29	31	0	n/a	5	3	n/a	-1	39	5	-17	-33
NHC35_SC	0	28	13	1	55	111	58	46	52	10	0	26	11	22	49	118	58	38	52	0	n/a	-1	-2	20	-6	8	0	-8	-10
NHC36_SC	0	0	0	0	17	106	20	67	29	20	0	0	0	0	17	122	20	66	29	5	n/a	n/a	0	n/a	0	16	0	-1	-16
NHC37_SC	0	12	6	0	11	14	35	60	36	6	0	11	6	9	11	16	36	55	36	1	n/a	-1	0	9	0	2	1	-6	-5
NHC38_SC	0	0	0	0	5	125	10	125	29	28	0	0	0	0	5	154	10	125	29	0	n/a	0	n/a	n/a	0	28	0	0	-28
NHC39_SC	0	1	7	0	16	47	27	83	19	8	0	1	7	0	16	52	30	83	19	0	n/a	0	0	n/a	0	5	3	0	-7
NHC40_SC	0	9	13	0	70	0	0	263	40	0	0	0	13	0	78	0	0	263	40	0	n/a	-9	0	n/a	9	n/a	n/a	0	0

"n/a" indicates that the land use type was not present in the existing or future land use coverage.
All values rounded to the nearest acre. Individual totals and percentages may not sum to column totals due to rounding.
AGR = Agriculture, COM = Commercial, HDR = High Density Residential, IND = Industrial, INT = Institutional, LDR = Low Density Residential, MDR = Medium Density Residential, POS = Parks and Open Space, VLR = Very Low Density Residential
NHC = New Hope Creek, LC = Little Creek, LNHC = Lower New Hope Creek, SC = Sandy, and MC = Mud Creek

Table D-1. Existing, future, and projected land use change by subwatershed (continued)

	Existing Land Use (acres)										Future Land Use (acres)										Projected Land Use Change (acres)								
Subwatershed	AGR	COM	HDR	IND	INT	LDR	MDR	POS	ROAD	VLR	AGR	COM	HDR	IND	INT	LDR	MDR	POS	ROAD	VLR	AGR	COM	HDR	IND	INT	LDR	MDR	POS	VLR
NHC41_SC	0	9	2	0	90	39	23	97	26	20	0	0	2	0	99	55	25	97	26	1	n/a	-9	0	n/a	9	17	2	0	-19
NHC42_SC	0	30	39	0	84	5	27	6	26	0	0	39	36	0	79	0	36	1	26	0	n/a	9	-3	n/a	-5	-5	10	-6	n/a
NHC43_SC	0	10	0	0	348	0	0	0	19	0	0	5	0	0	353	0	0	0	19	0	n/a	-5	0	n/a	5	n/a	0	n/a	n/a
NHC44_SC	0	1	10	0	188	0	0	8	35	0	0	0	10	0	189	0	0	8	35	0	n/a	-1	0	n/a	2	n/a	0	0	n/a
NHC45_SC	0	38	29	8	122	15	41	55	61	13	0	10	33	0	177	7	33	54	61	9	n/a	-29	4	-8	54	-8	-8	-1	-4
NHC46_SC	0	121	154	9	32	8	36	18	138	3	0	92	169	60	29	5	22	4	138	0	n/a	-30	15	52	-3	-3	-14	-14	-3
NHC47_MC	67	17	93	0	0	133	96	108	64	49	0	17	93	0	0	242	96	100	64	15	-67	0	0	n/a	n/a	108	0	-8	-33
NHC48_MC	75	0	0	0	24	91	18	23	30	23	0	0	0	0	24	128	18	11	30	72	-75	n/a	n/a	n/a	0	38	0	-12	49
NHC49_MC	46	0	0	0	1	81	32	171	30	40	0	0	0	0	1	118	32	21	30	200	-46	n/a	0	n/a	0	37	0	-151	160
NHC50_MC	80	0	0	0	0	22	14	82	9	84	0	0	0	0	0	22	14	0	9	246	-80	n/a	n/a	n/a	n/a	0	0	-82	162
NHC51_MC	0	3	11	0	15	0	2	453	52	0	0	3	11	0	15	0	2	453	52	0	n/a	0	0	n/a	0	0	0	0	0
NHC52_MC	171	0	0	0	0	1	7	123	10	60	0	0	0	0	0	1	7	141	10	213	-171	n/a	n/a	n/a	0	0	0	18	153
NHC53_MC	31	2	0	0	0	16	12	123	9	18	0	2	0	0	0	16	12	106	9	67	-31	0	n/a	n/a	n/a	0	0	-17	49
NHC54_MC	0	0	4	0	0	2	0	148	7	6	0	0	4	0	0	2	0	148	7	6	n/a	n/a	0	n/a	n/a	0	0	0	0
NHC55_MC	0	0	12	0	0	75	14	190	21	0	0	0	12	0	0	60	36	183	21	0	n/a	n/a	0	n/a	n/a	-15	22	-7	n/a
NHC56_MC	0	7	89	4	3	182	88	57	110	16	0	2	80	39	0	183	91	50	110	0	n/a	-5	-8	36	-3	0	3	-7	-16

"n/a" indicates that the land use type was not present in the existing or future land use coverage.
All values rounded to the nearest acre. Individual totals and percentages may not sum to column totals due to rounding.
AGR = Agriculture, COM = Commercial, HDR = High Density Residential, IND = Industrial, INT = Institutional, LDR = Low Density Residential, MDR = Medium Density Residential, POS = Parks and Open Space, VLR = Very Low Density Residential
NHC = New Hope Creek, LC = Little Creek, LNHC = Lower New Hope Creek, SC = Sandy, and MC = Mud Creek

Table D-2. Existing impervious area by subwatershed

Subwatershed	Total Area (acres)	Impervious Area (acres)	Percent Impervious	Subwatershed	Total Area (acres)	Impervious Area (acres)	Percent Impervious
NHC01_LC	156	10	7%	NHC29_LNHC	333	48	15%
NHC02_LC	273	12	4%	NHC30_LNHC	286	107	37%
NHC03_LC	448	53	12%	NHC31_LNHC	231	84	36%
NHC04_LC	439	70	16%	NHC32_LNHC	524	269	51%
NHC05_LC	348	29	8%	NHC33_SC	409	117	28%
NHC06_LC	337	44	13%	NHC34_SC	212	35	17%
NHC07_LC	221	9	4%	NHC35_SC	375	92	25%
NHC08_LNHC	203	7	4%	NHC36_SC	259	38	15%
NHC09_LNHC	491	66	13%	NHC37_SC	180	25	14%
NHC10_LNHC	537	23	4%	NHC38_SC	323	43	13%
NHC11_LNHC	484	46	9%	NHC39_SC	208	32	15%
NHC12_LNHC	689	265	39%	NHC40_SC	394	46	12%
NHC13_LNHC	183	26	14%	NHC41_SC	305	77	25%
NHC14_LNHC	508	96	19%	NHC42_SC	217	75	35%
NHC15_LNHC	437	43	10%	NHC43_SC	377	170	45%
NHC16_LNHC	165	3	2%	NHC44_SC	242	95	39%
NHC17_LNHC	240	33	14%	NHC45_SC	384	106	27%
NHC18_LNHC	187	30	16%	NHC46_SC	523	235	45%
NHC19_LNHC	254	13	5%	NHC47_MC	627	96	15%
NHC20_LNHC	209	34	16%	NHC48_MC	284	37	13%
NHC21_LNHC	305	47	15%	NHC49_MC	402	28	7%
NHC22_LNHC	167	27	16%	NHC50_MC	291	8	3%
NHC23_LNHC	201	15	8%	NHC51_MC	536	34	6%
NHC24_LNHC	354	62	17%	NHC52_MC	373	10	3%
NHC25_LNHC	373	117	31%	NHC53_MC	211	5	3%
NHC26_LNHC	410	99	24%	NHC54_MC	168	4	3%
NHC27_LNHC	373	50	13%	NHC55_MC	312	29	9%
NHC28_LNHC	415	86	21%	NHC56_MC	556	130	23%

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Appendix E:

Subwatershed and Ambient Monitoring Station Drainage Density

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Table E-1. Drainage density by subwatershed in study area

Subwatershed	Watershed	Total Stream Length (miles)	Subwatershed Area (square miles)	Drainage Density (miles/square miles)
NHC02_LC	Little Creek	0.82	0.43	1.9
NHC03_LC	Little Creek	0.78	0.70	1.1
NHC04_LC	Little Creek	0.65	0.69	1.0
NHC05_LC	Little Creek	0.40	0.54	0.7
NHC06_LC	Little Creek	0.74	0.53	1.4
NHC07_LC	Little Creek	0.00	0.35	0.0
NHC08_LNHC	Lower New Hope Creek	0.61	0.32	1.9
NHC10_LNHC	Lower New Hope Creek	1.09	0.84	1.3
NHC11_LNHC	Lower New Hope Creek	0.79	0.76	1.0
NHC13_LNHC	Lower New Hope Creek	0.39	0.29	1.4
NHC14_LNHC	Lower New Hope Creek	1.44	0.79	1.8
NHC16_LNHC	Lower New Hope Creek	0.00	0.26	0.0
NHC17_LNHC	Lower New Hope Creek	0.83	0.38	2.2
NHC19_LNHC	Lower New Hope Creek	0.74	0.40	1.9
NHC20_LNHC	Lower New Hope Creek	0.00	0.33	0.0
NHC23_LNHC	Lower New Hope Creek	0.90	0.31	2.9
NHC24_LNHC	Lower New Hope Creek	0.33	0.55	0.6
NHC26_LNHC	Lower New Hope Creek	0.40	0.64	0.6
NHC27_LNHC	Lower New Hope Creek	1.38	0.58	2.4
NHC28_LNHC	Lower New Hope Creek	0.33	0.65	0.5
NHC29_LNHC	Lower New Hope Creek	1.79	0.52	3.5
NHC33_SC	Sandy Creek	1.36	0.64	2.1
NHC34_SC	Sandy Creek	0.18	0.33	0.5
NHC35_SC	Sandy Creek	0.46	0.59	0.8
NHC36_SC	Sandy Creek	0.00	0.41	0.0
NHC37_SC	Sandy Creek	0.70	0.28	2.5
NHC38_SC	Sandy Creek	0.00	0.50	0.0
NHC40_SC	Sandy Creek	1.52	0.62	2.5
NHC43_SC	Sandy Creek	0.03	0.59	0.0
NHC46_SC	Sandy Creek	0.78	0.82	1.0
NHC47_MC	Mud Creek	1.60	0.98	1.6
NHC48_MC	Mud Creek	0.00	0.44	0.0

Table E-1. Drainage density by subwatershed in study area (continued)

Subwatershed	Watershed	Total Stream Length (miles)	Subwatershed Area (square miles)	Drainage Density (miles/square miles)
NHC49_MC	Mud Creek	1.14	0.63	1.8
NHC51_MC	Mud Creek	0.37	0.84	0.4
NHC52_MC	Mud Creek	0.58	0.58	1.0
NHC54_MC	Mud Creek	0.78	0.26	3.0
NHC56_MC	Mud Creek	1.01	0.87	1.2

Table E-2. Drainage density for each ambient water quality monitoring station

Station	Stream	Total Stream Length (miles)	Drainage Area (square miles)	Drainage Density (miles/square miles)
LCTC1.5LITC	Little Creek	4.2	23.8	0.2
NH2.3MC	Mud Creek	4.3	5.4	0.8
B3020000	New Hope Creek	23.9	56.1	0.4
B3040000	New Hope Creek	27.9	76.2	0.4
NH0.0NHC	New Hope Creek	21.2	52.3	0.4
NH3.0NHC	New Hope Creek	16.3	31.3	0.5
NH1.0SC	Sandy Creek	4.8	6.9	0.7
NH1.6SC	Sandy Creek	4.1	6.7	0.6
NH3.3SC	Sandy Creek	2.4	4.8	0.5
NH3.4SC	Sandy Creek	2.3	2.1	1.1
NH4.3SC	Sandy Creek	1.2	1.5	0.8
NH4.7SC	Sandy Creek	0.8	0.9	0.9
NH1.7SCTA	Sandy Creek Trib. A	1.3	1.4	0.9
NH1.8SCTA	Sandy Creek Trib. A	1.4	1.1	1.3
NH3.4SCTD	Sandy Creek Trib. D	2.3	2.7	0.9
NH4.4SCTD	Sandy Creek Trib. D	1.3	1.6	0.8
NH5.0SCTD	Sandy Creek Trib. D	0.7	1.0	0.7
NH4.8SCTDT	Sandy Creek Trib. D	0.6	0.3	2.0

Appendix F:

Pilot Study Area Factsheets

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New Hope Creek Subwatershed NHC04_LC

Overview

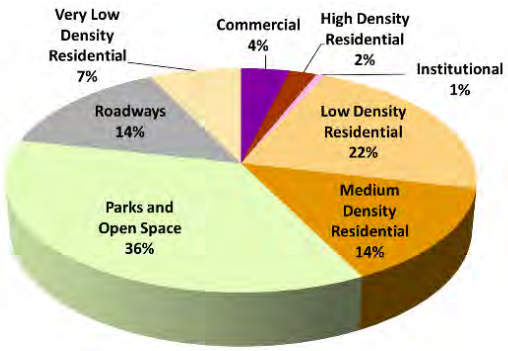
Subwatershed NHC04_LC is located in the southwest portion of Durham County in the Little Creek watershed. NHC04_LC has a drainage area of 440 acres (74% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 10% impervious cover.

Landmarks

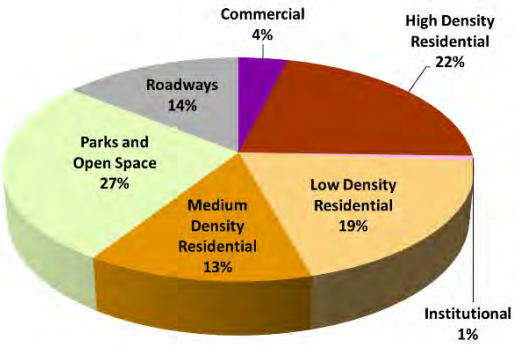
- Falconbridge Subdivision
- Woodland Acres
- North Carolina Highway 54

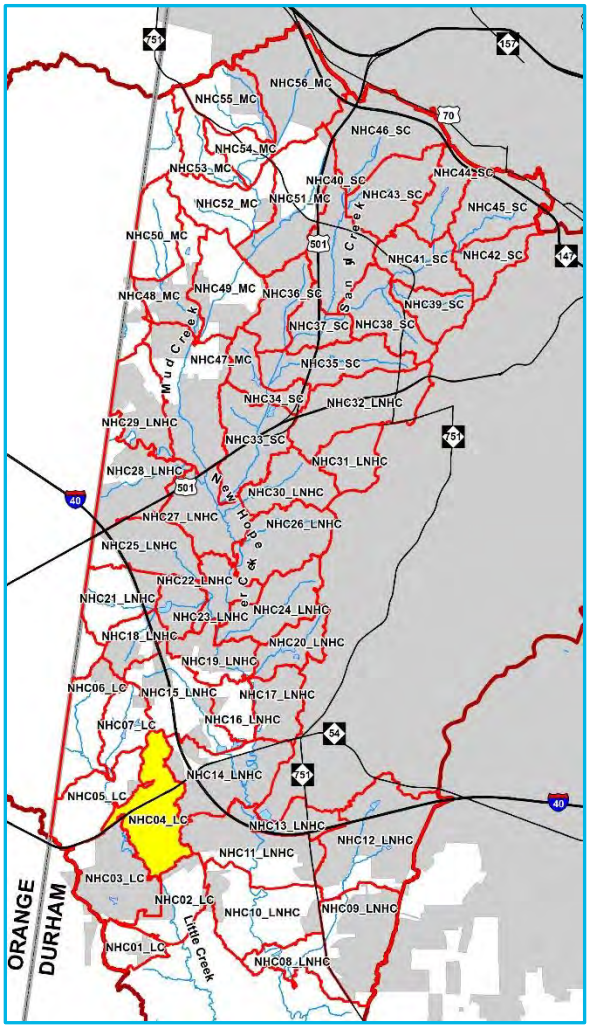
Land Use

Existing: The existing land use is predominately parks and open space and low density residential.



Future: The future land use is predominately residential with a decrease in parks and open space and a substantial increase in high density residential.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

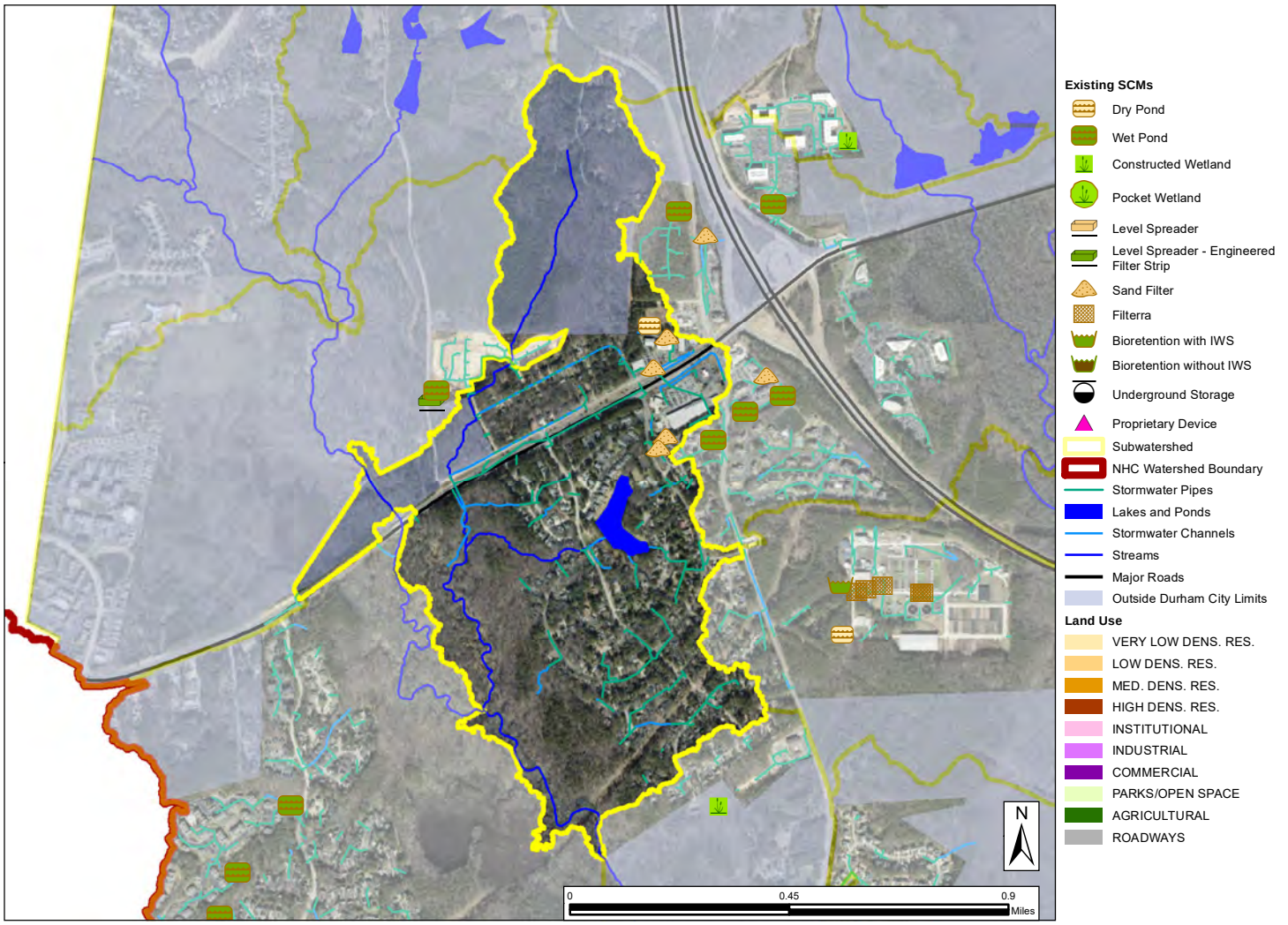
- Sand Filter (4): 00671, 00088, 00043, 00679
- Rain Harvesting System (1): 13748
- Dry Pond (1): 00091

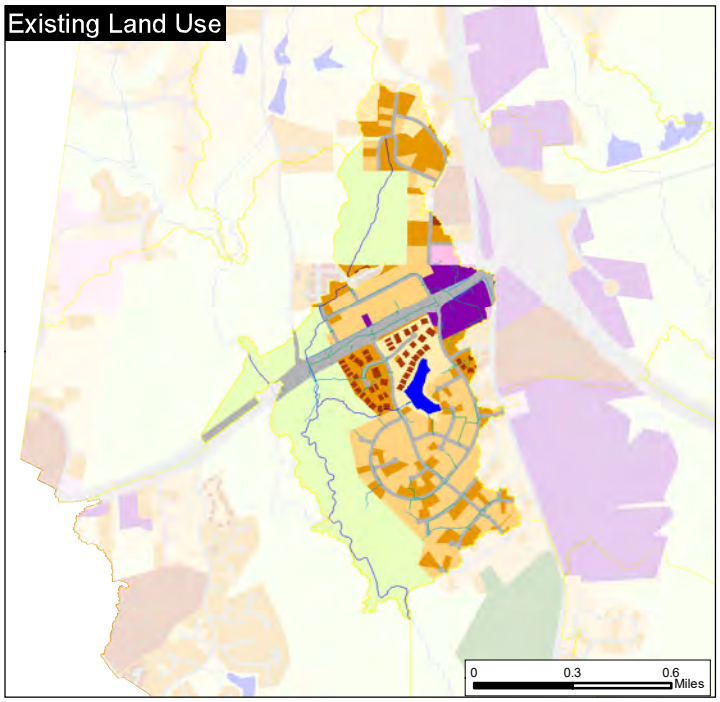
Potential SCM Locations

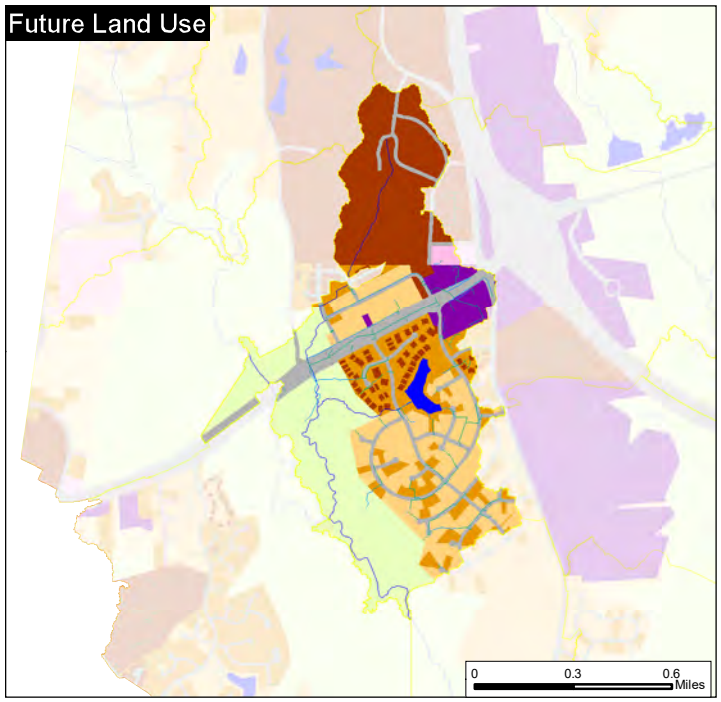
- Dry Swale (1): NHCLC0001

Stream Assessments

- Preservation (1): LC2003
- Restoration (2): LC2004, LC2001
- Stream Enhancement II (1): LC2002







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Subwatershed NHC04_LC Pilot Study Area Map

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New Hope Creek Subwatershed NHC24_LNHC

Overview

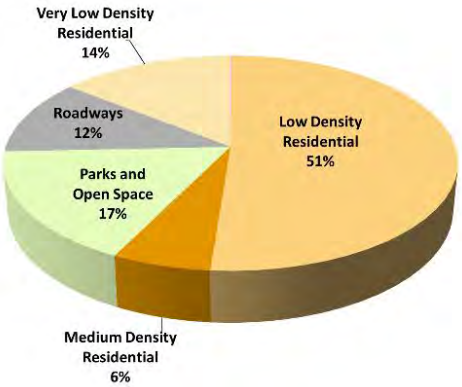
Subwatershed NHC24_LNHC is located entirely within City limits in the Lower New Hope Creek watershed. NHC24_LNHC has a drainage area of 355 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 12% impervious cover.

Landmarks

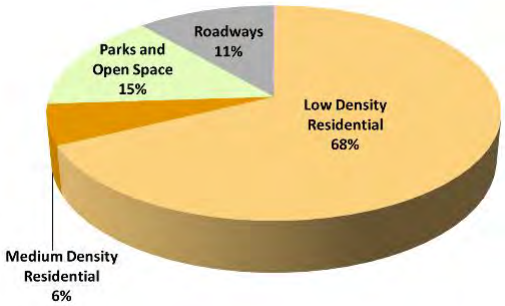
- Garrett Road
- Mary Dell Subdivision
- New Hope Creek

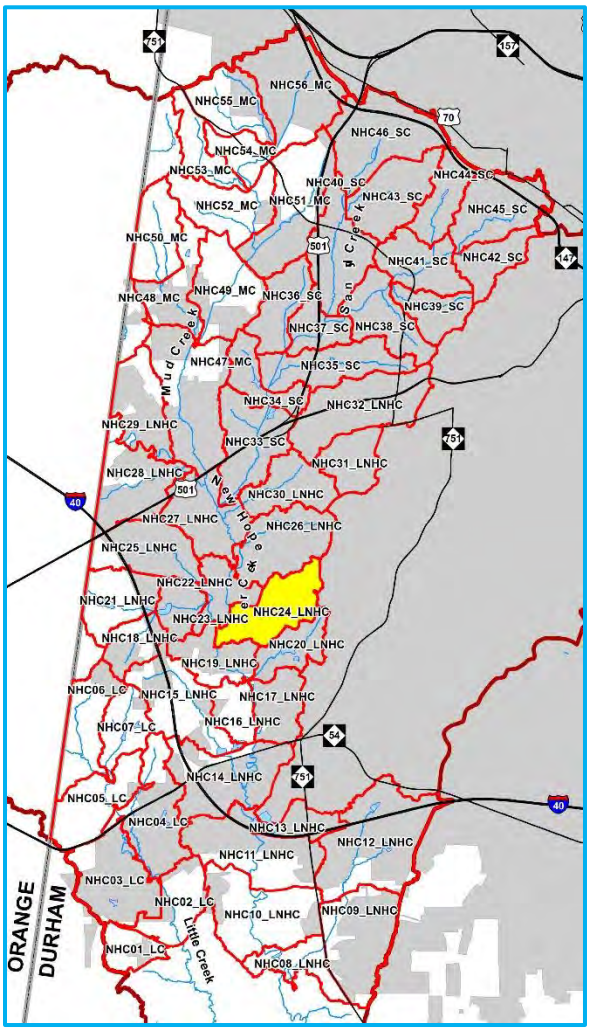
Land Use

Existing: The existing land use is predominately low density residential, followed by parks and open space.



Future: The future land use is predominately low density residential as well, with a conversion of very low density residential to low density residential and a slight decrease in parks and open space.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

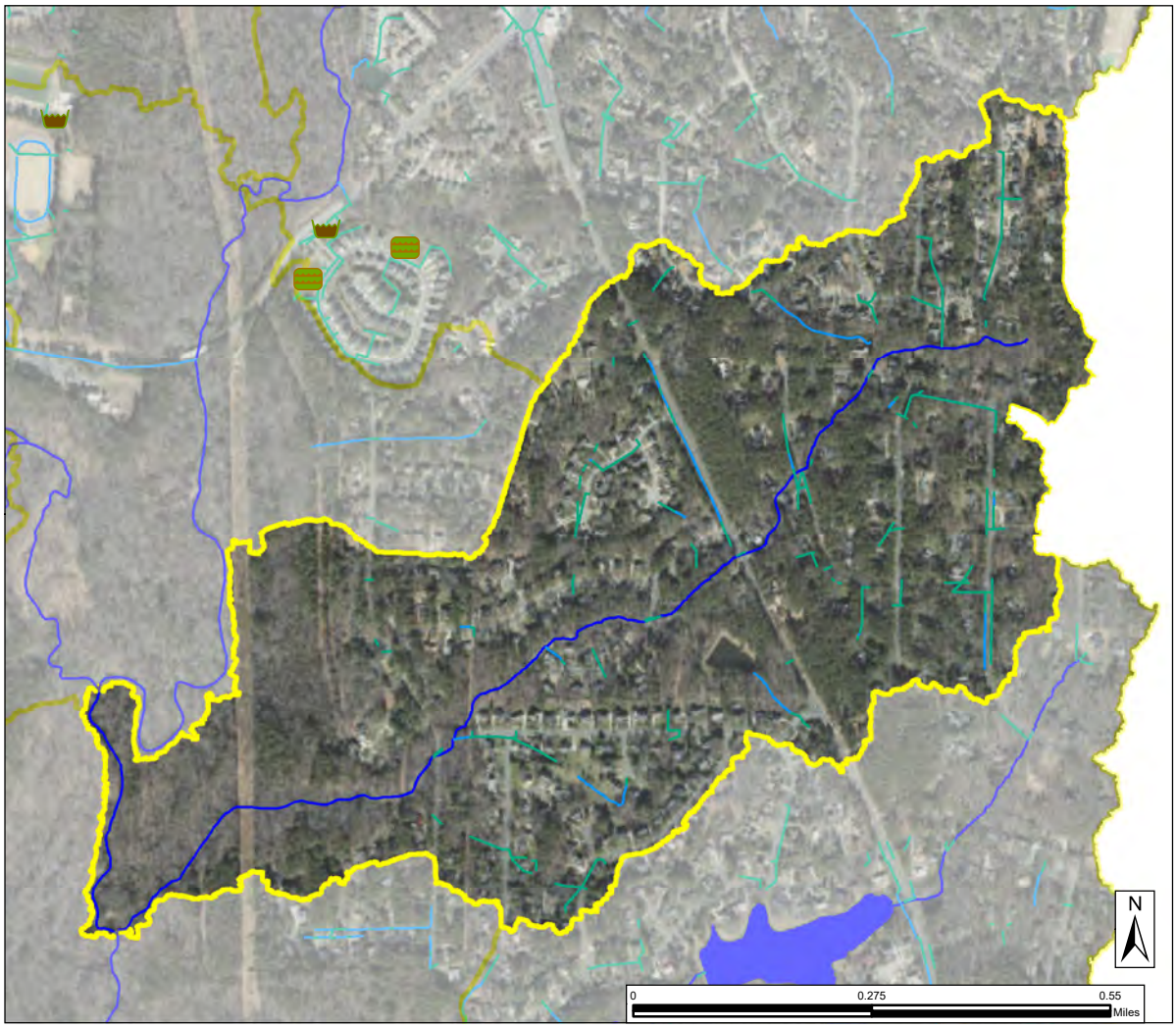
- None

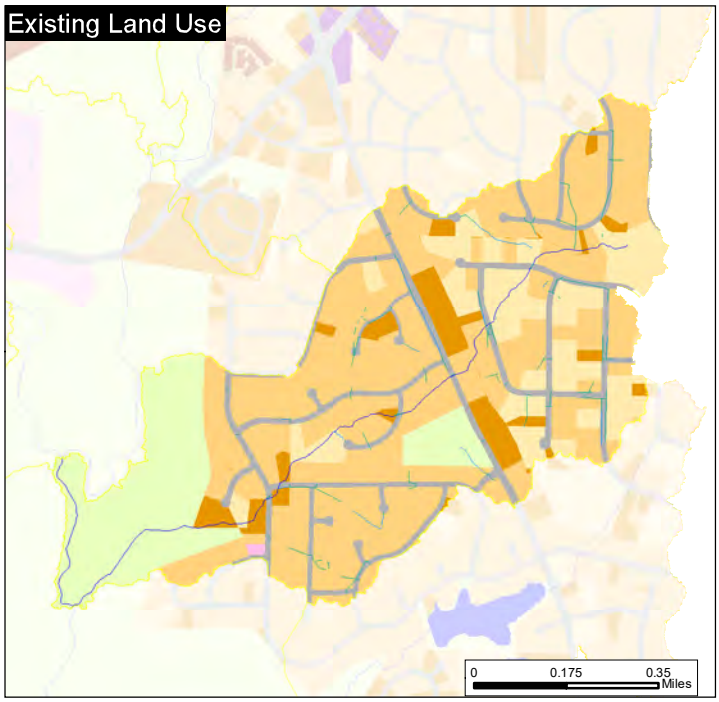
Potential SCM Locations

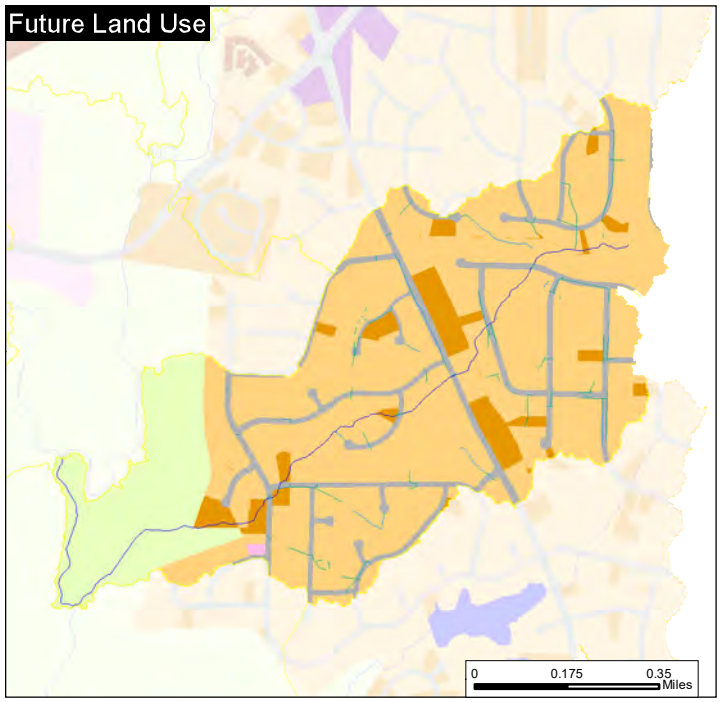
- None

Stream Assessments

- Bank Stabilization (3): LNHC2007, LNHC2008, LNHC2010
- Stream Enhancement II (1): LNHC2009







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Subwatershed NHC24_LNHC Pilot Study Area Map

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New Hope Creek Subwatershed NHC25_LNHC

Overview

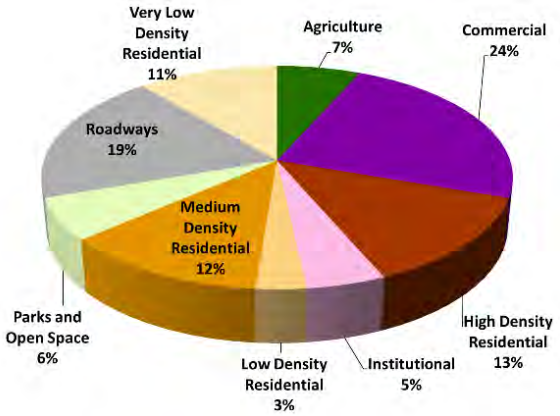
Subwatershed NHC25_LNHC is located in the central region of the study area along the Orange County border, within the Lower New Hope Creek watershed. NHC25_LNHC has a drainage area of 374 acres (85% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 24% impervious cover.

Landmarks

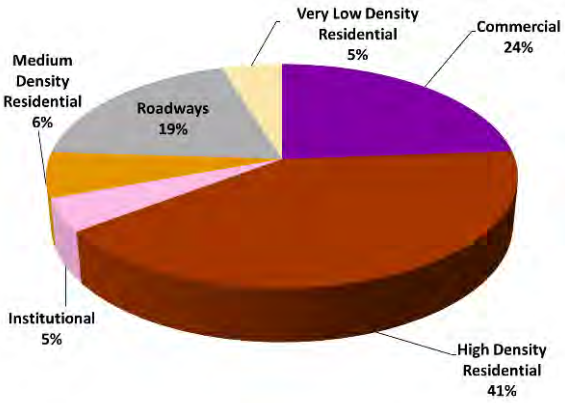
- Sayward Drive
- Interstate 40
- US Highway 15 501

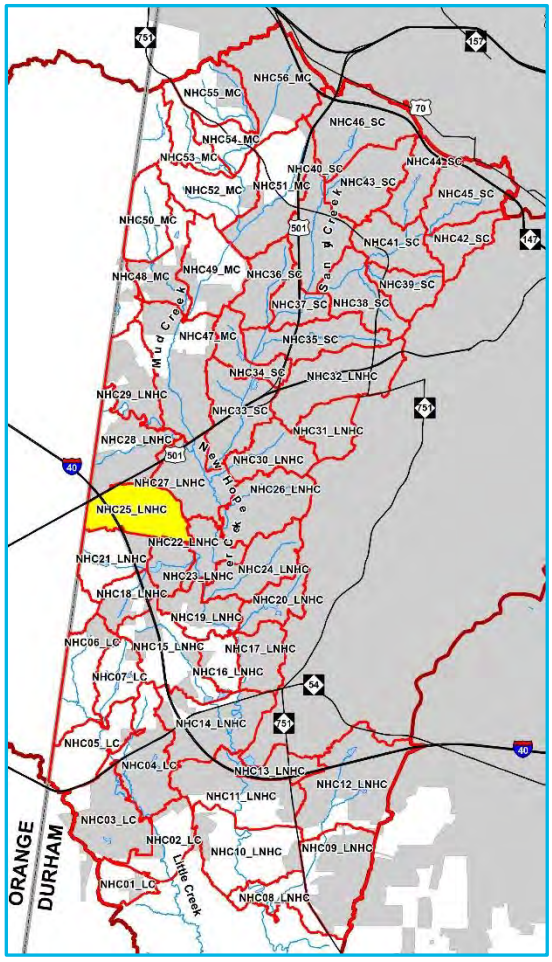
Land Use

Existing: The existing land use is predominately commercial and roadways.



Future: The future land use is predominately high density residential and commercial, with a projected increase in high density residential areas.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

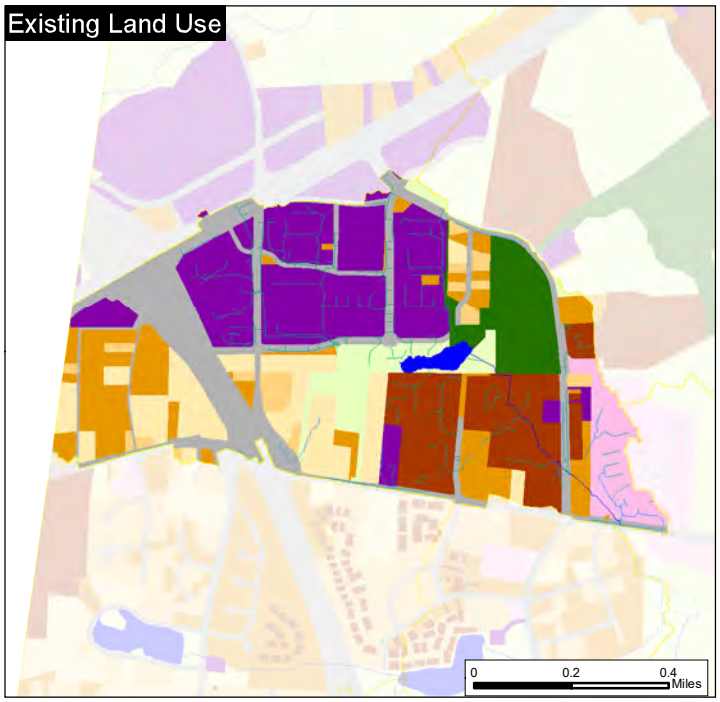
- Constructed Wetland (2): 00433, 000432
- Wet Pond (3): 00316, 00431, 13123
- Pocket Wetland (1): 00001
- Underground Storage (2): 13787, 13786
- Sand Filter – Underground (3): 13902, 13901, 13785

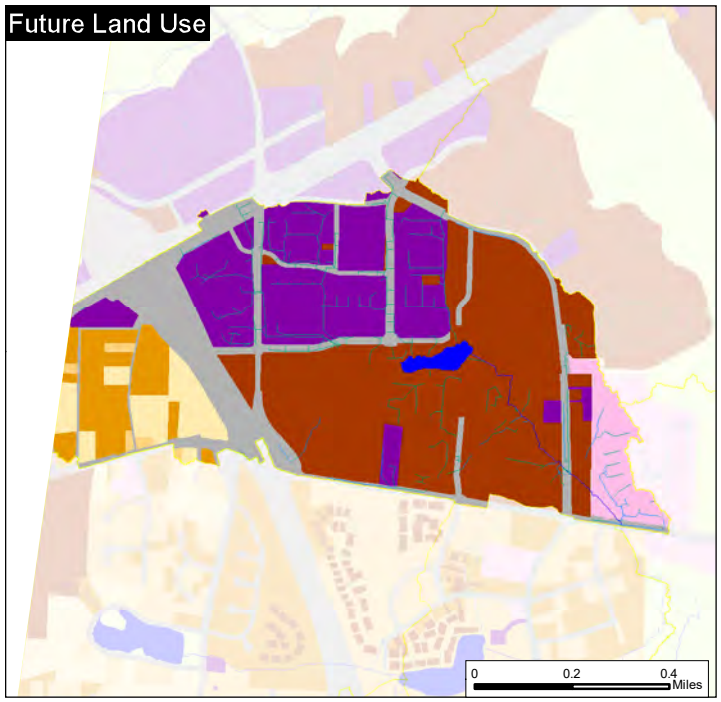
Potential SCM Locations

- None

Stream Assessments

- Stream Enhancement I (2): LNHC1025, LNHC1026





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Subwatershed NHC25_LNHC Pilot Study Area Map

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New Hope Creek Subwatershed NHC30_LNHC

Overview

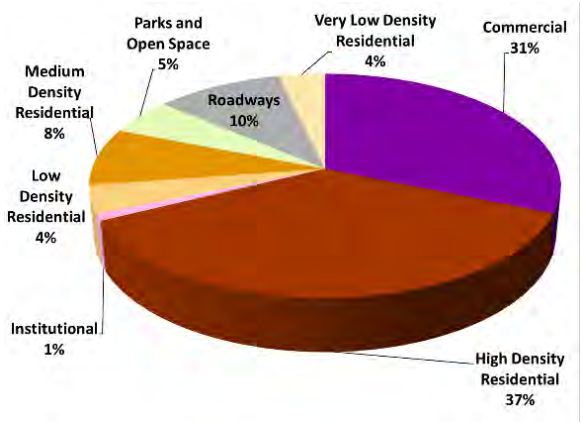
Subwatershed NHC30_LNHC is located completely in City limits in the Lower New Hope Creek Watershed. NHC30_LNHC has a drainage area of 286 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 33% impervious cover.

Landmarks

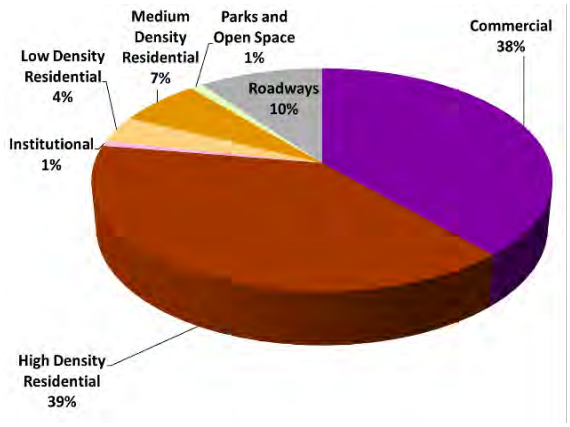
- University Drive
- Martin Luther King Jr. Parkway
- Blue Cross and Blue Shield of North Carolina

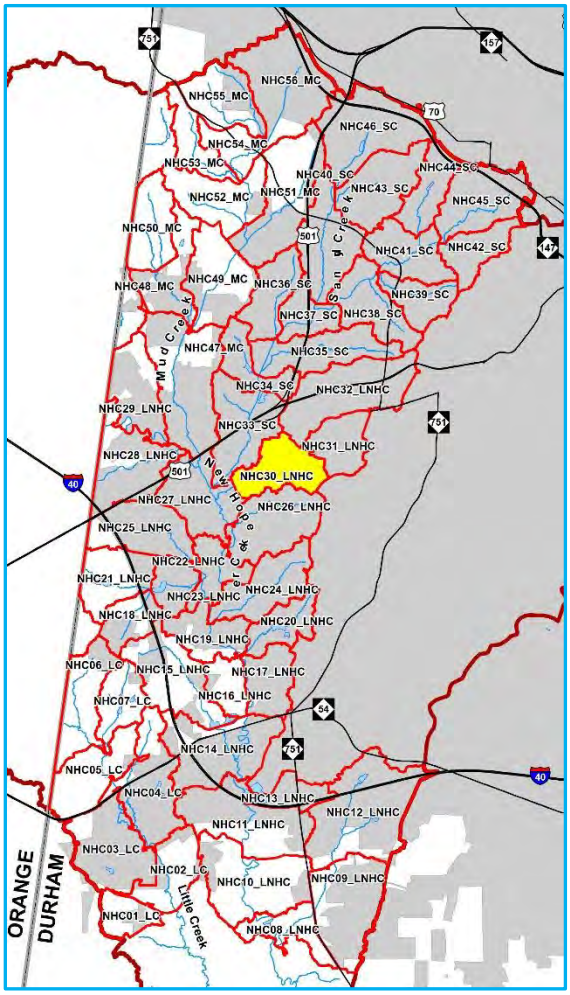
Land Use

Existing: The existing land use is predominately commercial and high density residential.



Future: The future land use is predominately high density residential and commercial.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

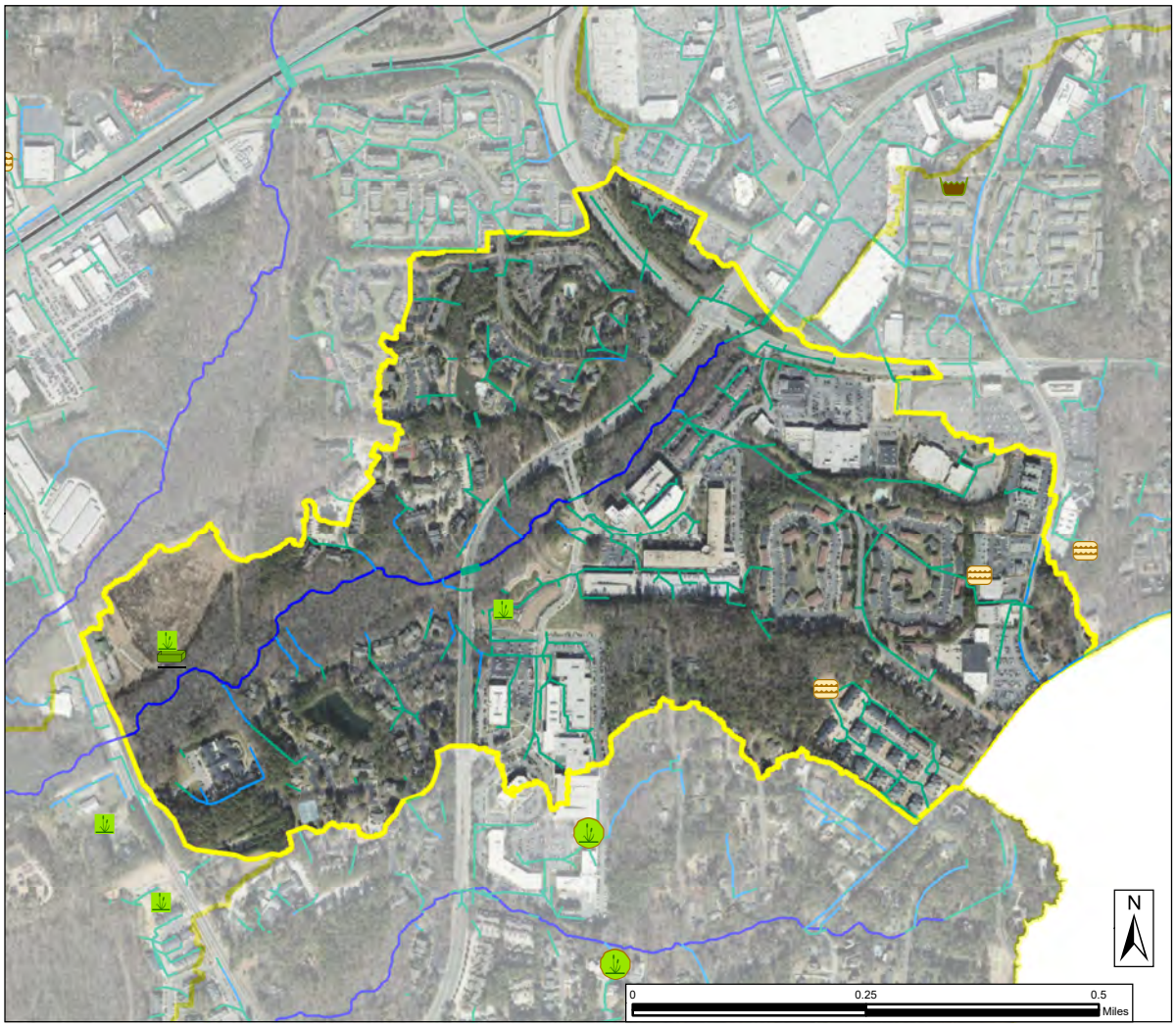
- Dry Pond (2): 00325, 00069
- Sand Filter – Underground (1): 13344
- Level Spreader (1): 13879
- Constructed Wetland (2): 13878, 13430
- Permeable Pavement (1): 13612

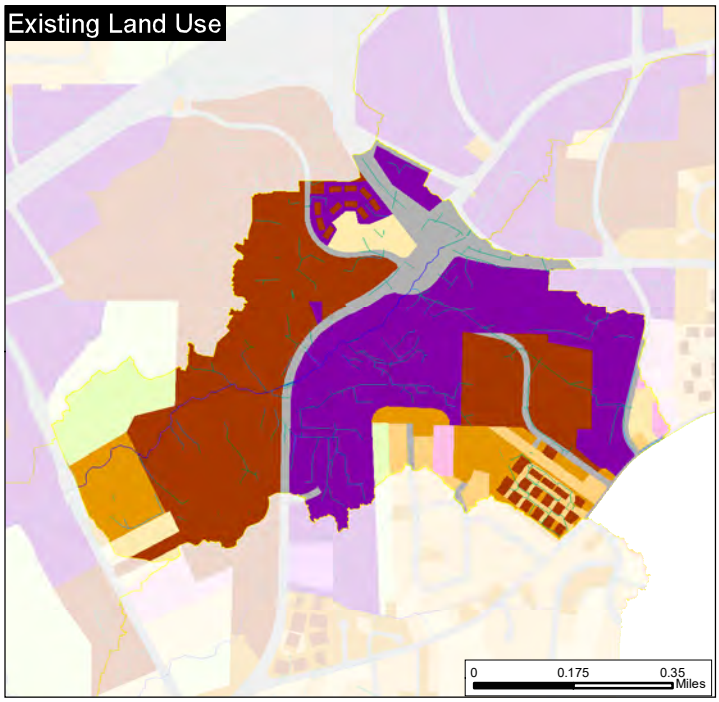
Potential SCM Locations

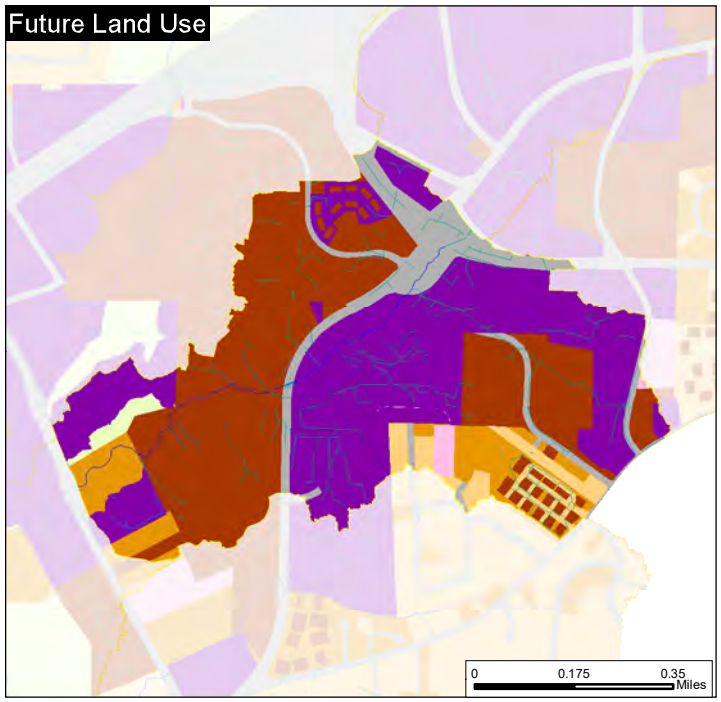
- None

Stream Assessments

- Bank Stabilization (1): LNHC1016
- Restoration (2): LNHC1014, LNHC1015







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Subwatershed NHC30_LNHC Pilot Study Area Map

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New Hope Creek Subwatershed NHC32_LNHC

Overview

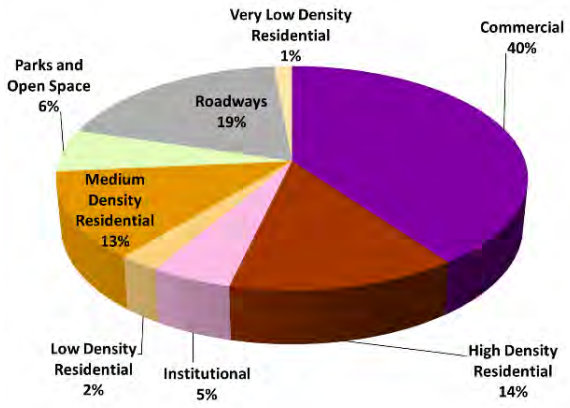
Subwatershed NHC32_LNHC is located completely in City limits in the central region of the study area within the Lower New Hope Creek Watershed. NHC32_LNHC has a drainage area of 525 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 43% impervious cover.

Landmarks

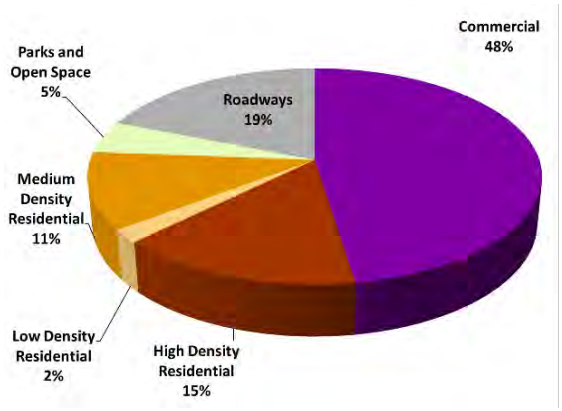
- Durham-Chapel Hill Boulevard
- University Drive
- Durham Academy Middle School

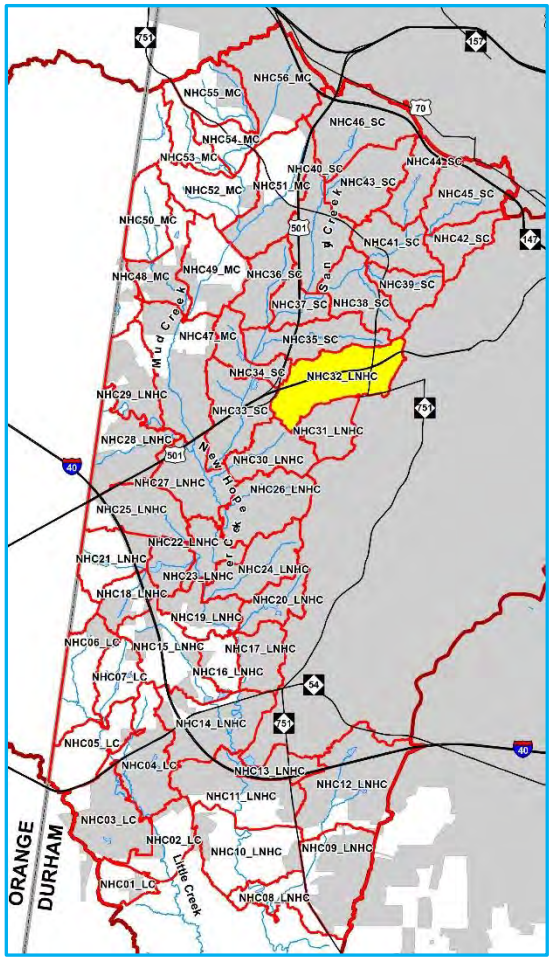
Land Use

Existing: The existing land use is predominately commercial and roadways.



Future: The future land use is predominately commercial and roadways, with a small projected increase in commercial areas.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

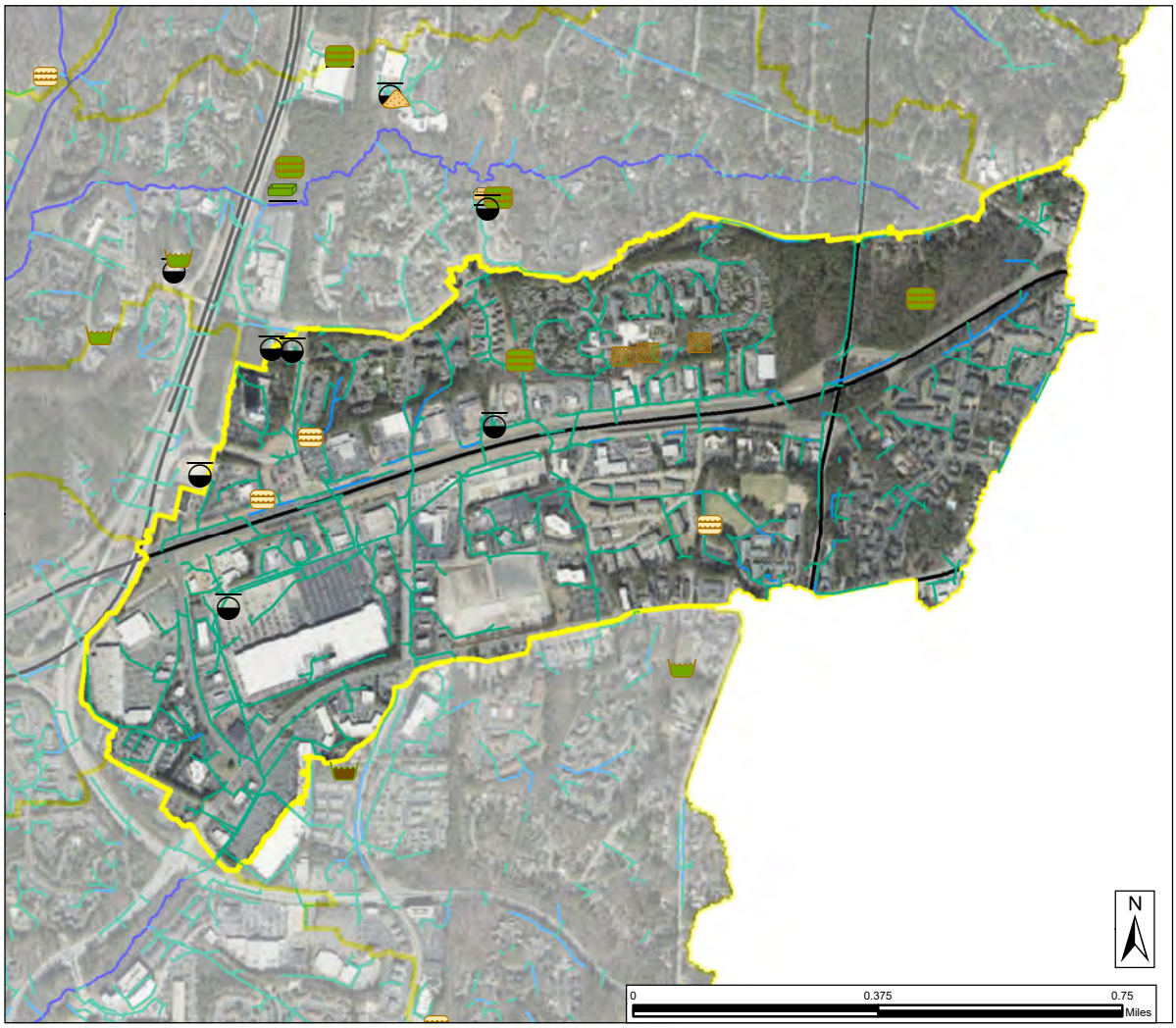
- Dry Pond (3): 00073, 13395, 00497
- Sand Filter – Underground (3): 13445, 13860, 13313
- Underground Storage (3): 00300, 00647, 00025
- Wet Pond (2): 13168, 13587
- Filterra (3): 13329, 13331, 13330

Potential SCM Locations

- None

Stream Assessments

- Stream Enhancement I (1): LNHC1013
- Stream Enhancement II (2): LNHC1009, LNHC2002
- Preservation (1): LNHC1012
- Restoration (1): LNHC2001



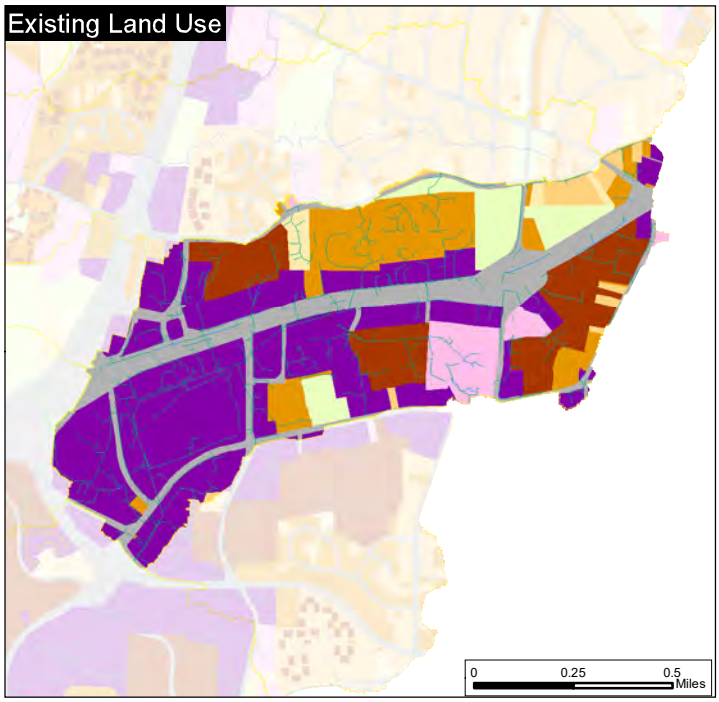
Existing SCMs

- Dry Pond
- Wet Pond
- Constructed Wetland
- Pocket Wetland
- Level Spreader
- Level Spreader - Engineered Filter Strip
- Sand Filter
- Filterra
- Bioretention with IWS
- Bioretention without IWS
- Underground Storage
- Proprietary Device
- Subwatershed
- NHC Watershed Boundary
- Stormwater Pipes
- Stormwater Channels
- Streams
- Major Roads
- Durham City Limits

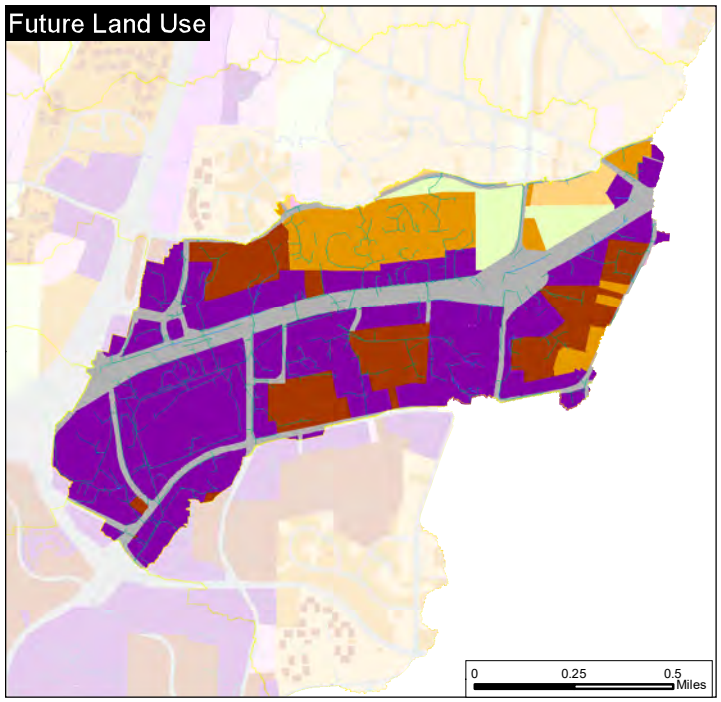
Land Use

- VERY LOW DENS. RES.
- LOW DENS. RES.
- MED. DENS. RES.
- HIGH DENS. RES.
- INSTITUTIONAL
- INDUSTRIAL
- COMMERCIAL
- PARKS/OPEN SPACE
- AGRICULTURAL
- ROADWAYS

Existing Land Use



Future Land Use



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Subwatershed NHC32_LNHC Pilot Study Area Map

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New Hope Creek Subwatershed NHC40_SC

Overview

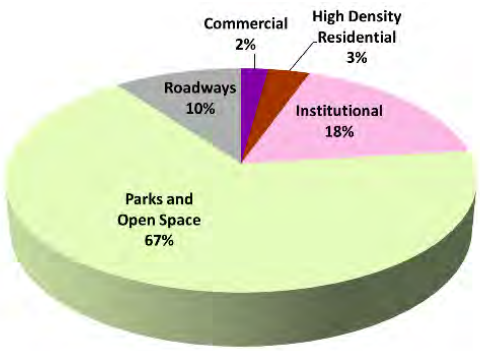
Subwatershed NHC40_SC is located completely in City limits in the northern region of the study area in the Sandy Creek watershed. NHC40_SC has a drainage area of 394 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 9% impervious cover.

Landmarks

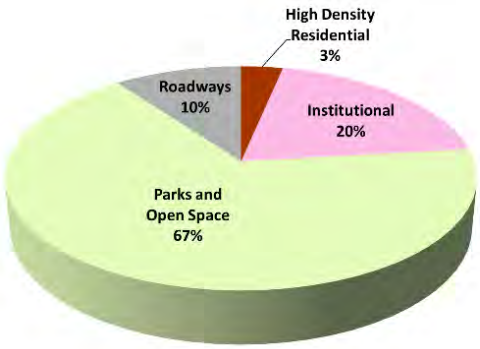
- Sandy Creek
- US Route 501
- Duke University Golf Club

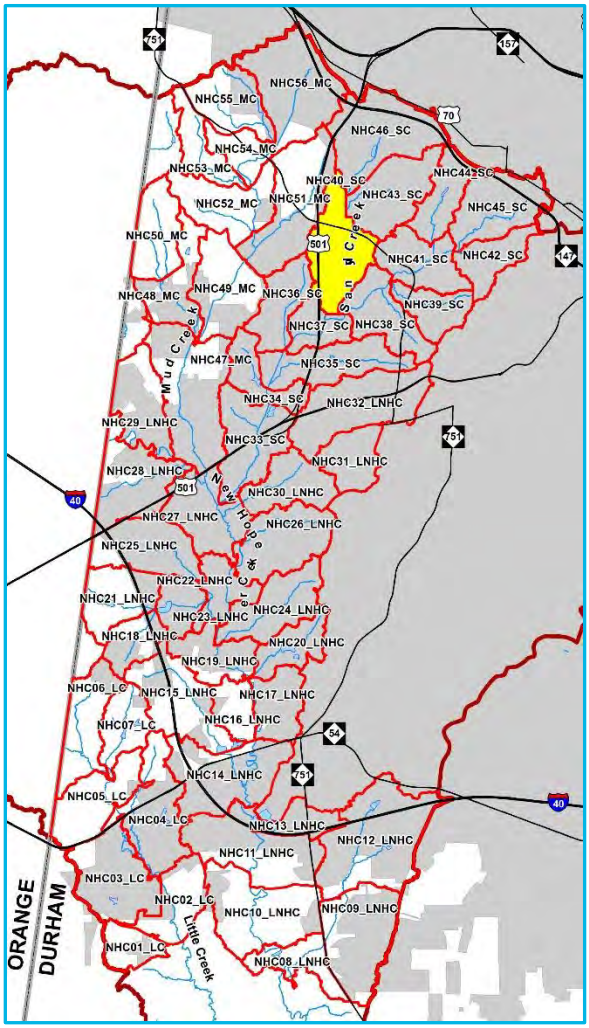
Land Use

Existing: The existing land use is predominately parks and open space.



Future: The future land use is predominately parks and open space.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

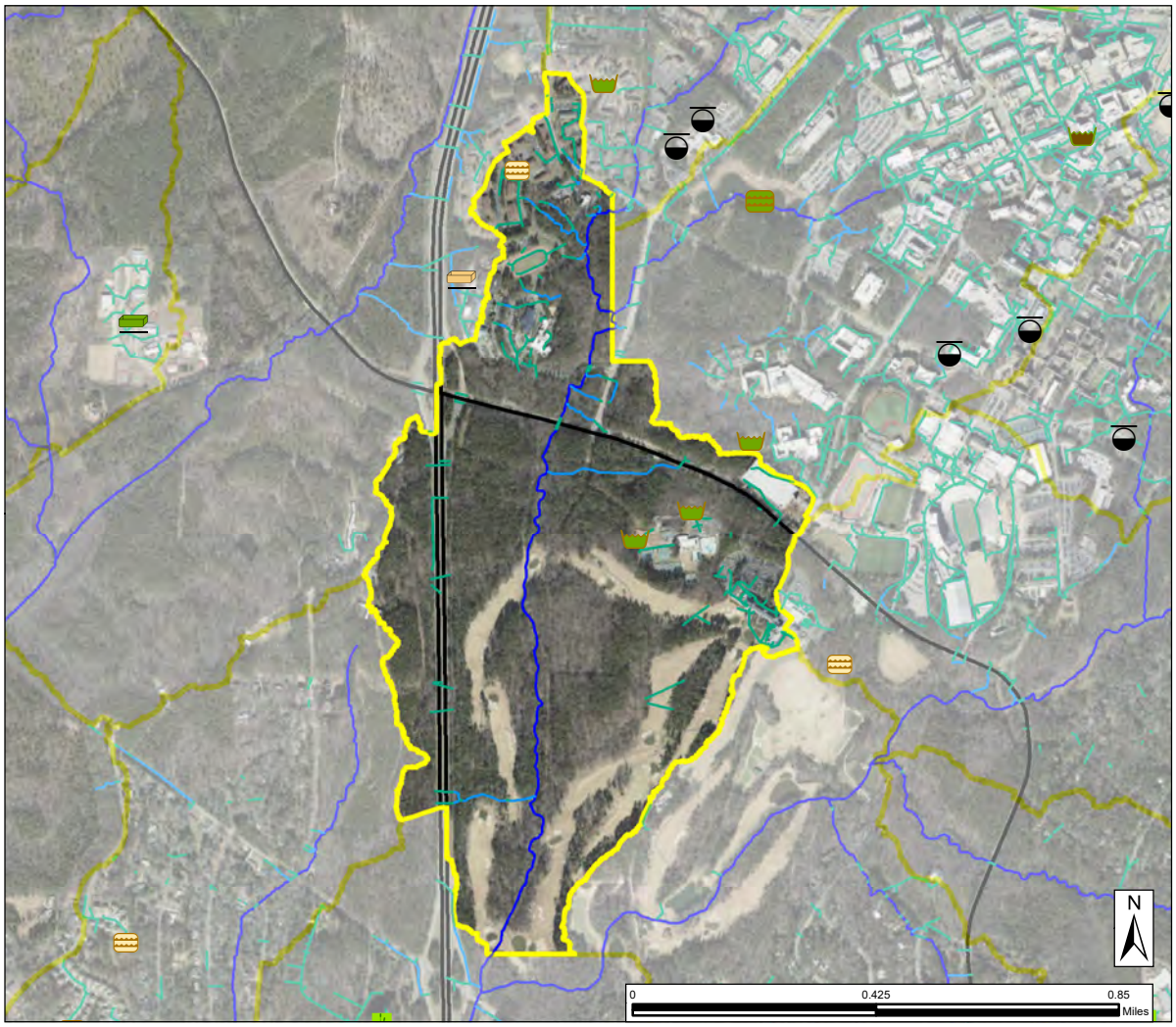
- Bioretention with IWS (2): 13167, 13166
- Rain Harvesting System (1): 13890
- Dry Pond (1): 13499

Potential SCM Locations

- Bioretention (3): NHCSC0029, NHCSC0031, NHCSC0032

Stream Assessments

- Bank Stabilization (1): SC2020
- Restoration (7): SC2017, SC2018, SC2021, SC2022, SC2024, SC2025, SC2026
- Stream Enhancement II (2): SC2019, SC2023

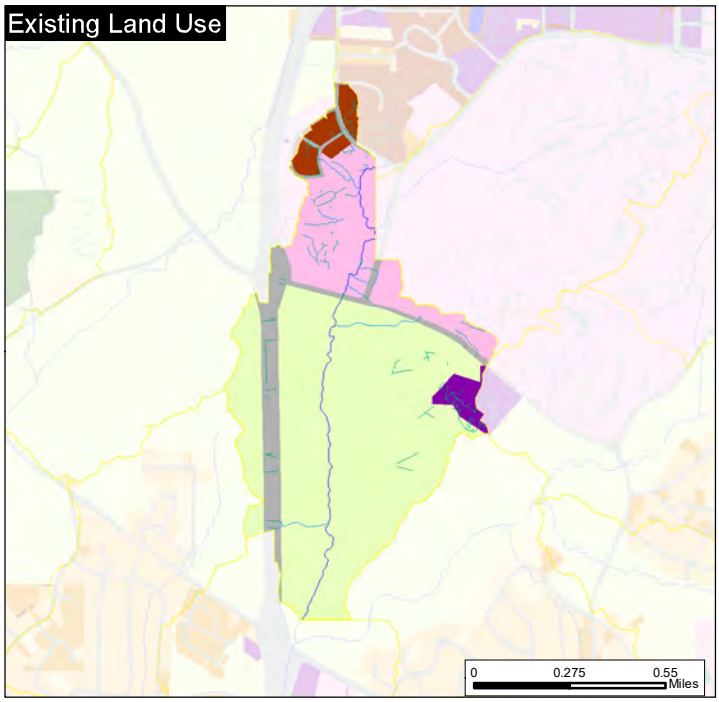


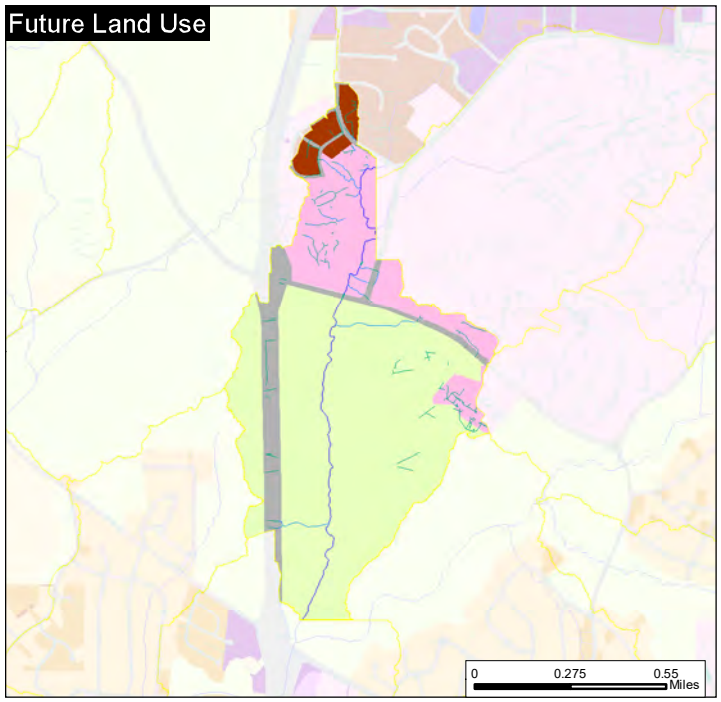
Existing SCMs

- Dry Pond
- Wet Pond
- Constructed Wetland
- Pocket Wetland
- Level Spreader
- Level Spreader - Engineered Filter Strip
- Sand Filter
- Filterra
- Bioretention with IWS
- Bioretention without IWS
- Underground Storage
- Proprietary Device
- Subwatershed
- NHC Watershed Boundary
- Stormwater Pipes
- Stormwater Channels
- Streams
- Major Roads
- Durham City Limits

Land Use

- VERY LOW DENS. RES.
- LOW DENS. RES.
- MED. DENS. RES.
- HIGH DENS. RES.
- INSTITUTIONAL
- INDUSTRIAL
- COMMERCIAL
- PARKS/OPEN SPACE
- AGRICULTURAL
- ROADWAYS





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Subwatershed NHC40_SC Pilot Study Area Map

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New Hope Creek Subwatershed NHC45_SC

Overview

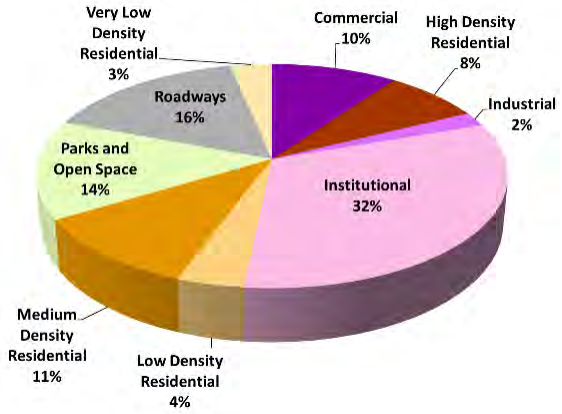
Subwatershed NHC45_SC is located completely in City limits in the northeastern region of the study area in the Sandy Creek Watershed. NHC45_SC has a drainage area of 385 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 20% impervious cover.

Landmarks

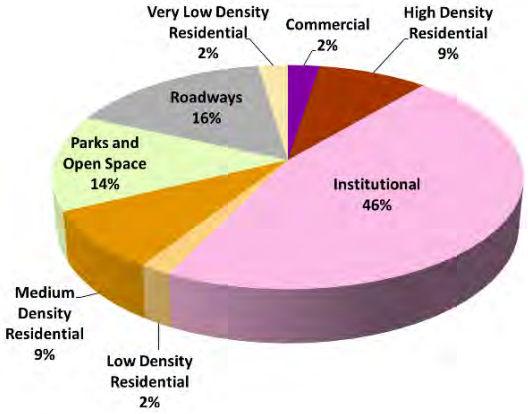
- Duke University – Main Campus
- Duke University – East Campus
- Durham Freeway

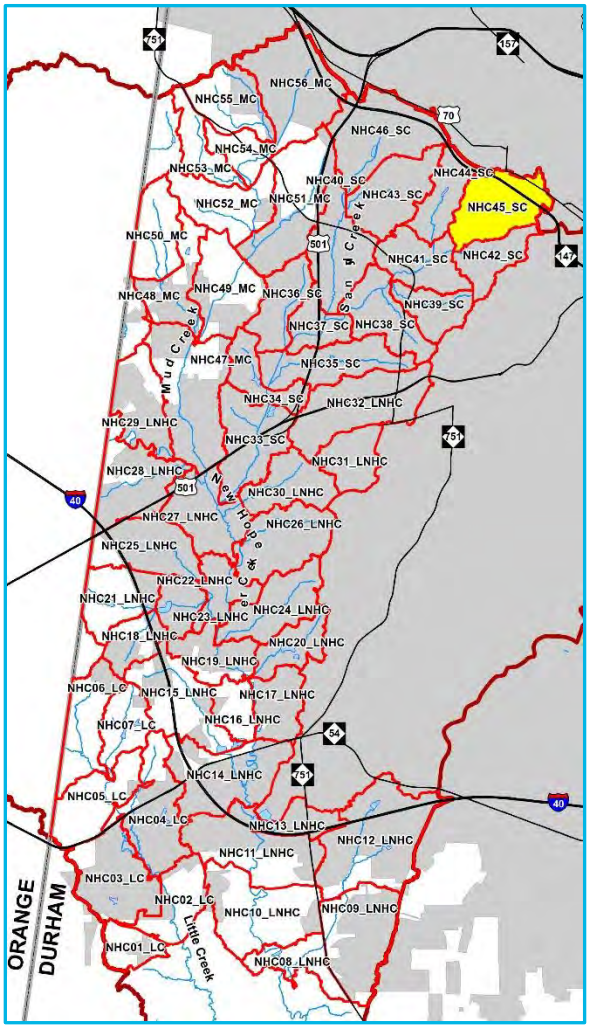
Land Use

Existing: The existing land use is predominately institutional.



Future: The future land use is predominately institutional.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

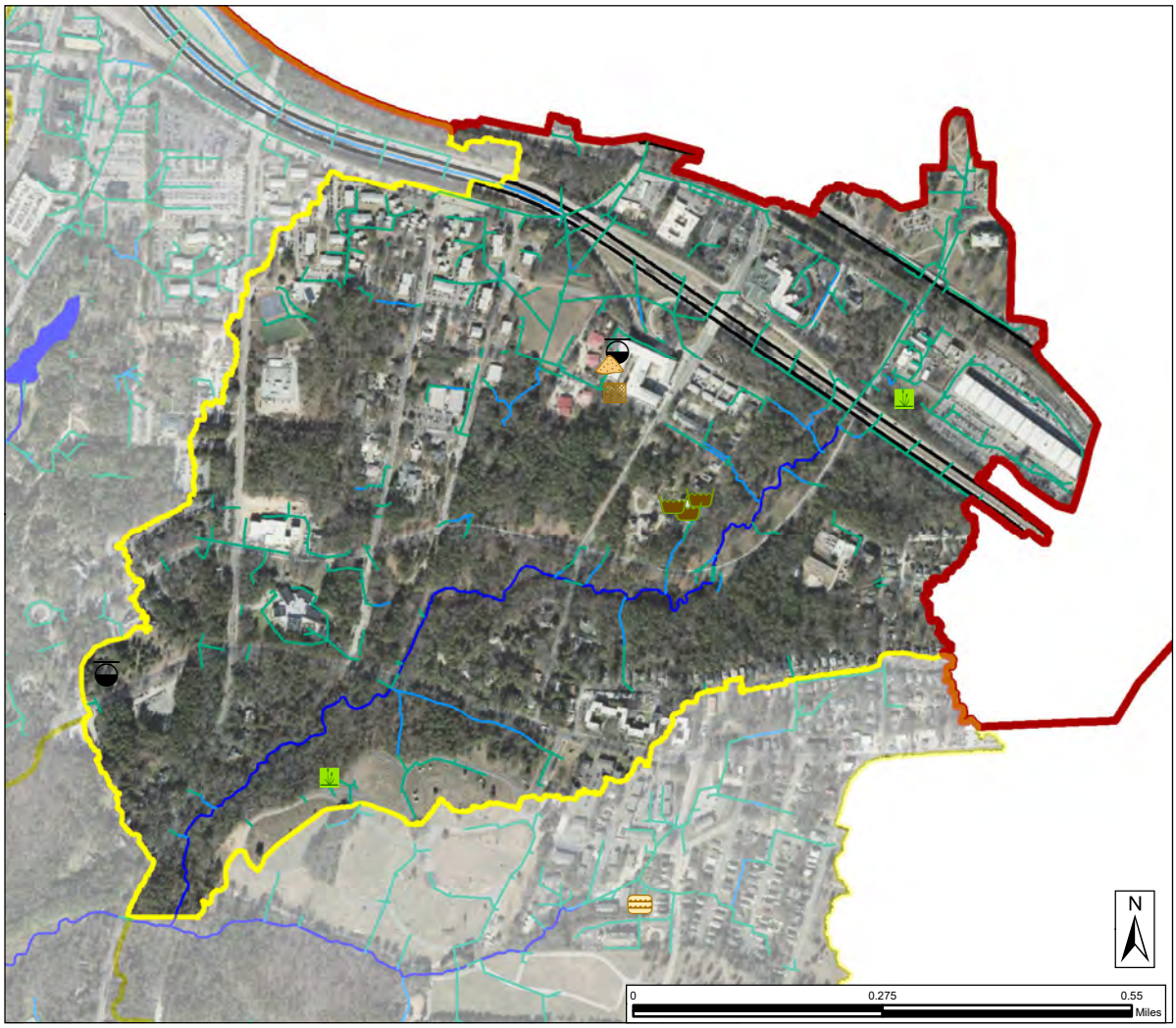
- Bioretention without IWS (3): 00384, 00660, 00661
- Constructed Wetland (2): 13438, 00537
- Filterra (1): 00833
- Sand Filter (1): 00832
- Underground Storage (2): 13569, 00831

Potential SCM Locations

- Constructed Wetland (1): NHCSC0035

Stream Assessments

- Preservation (1): SC2001
- Restoration (3): SC2002, SC2003, SC2005
- Stream Enhancement I (1): SC2004



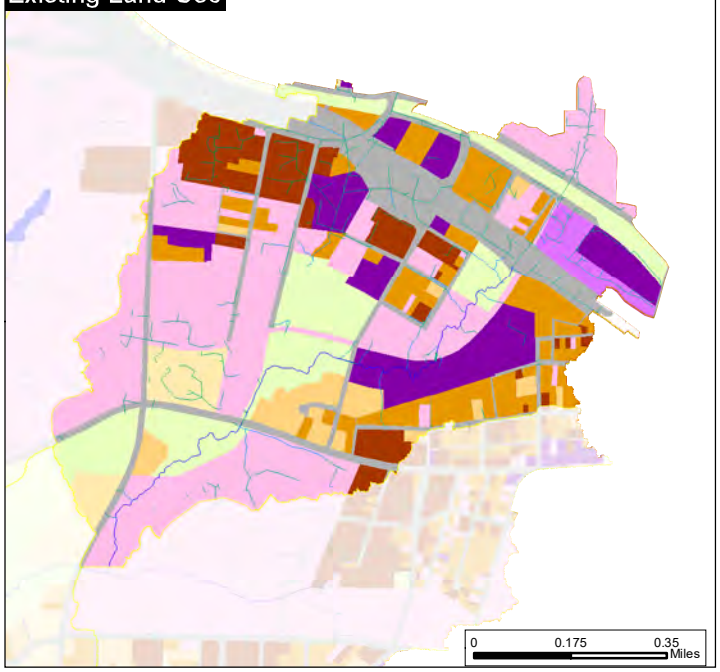
Existing SCMs

- Dry Pond
- Wet Pond
- Constructed Wetland
- Pocket Wetland
- Level Spreader
- Level Spreader - Engineered Filter Strip
- Sand Filter
- Filterra
- Bioretention with IWS
- Bioretention without IWS
- Underground Storage
- Proprietary Device
- Subwatershed
- NHC Watershed Boundary
- Stormwater Pipes
- Lakes and Ponds
- Stormwater Channels
- Streams
- Major Roads
- Durham City Limits

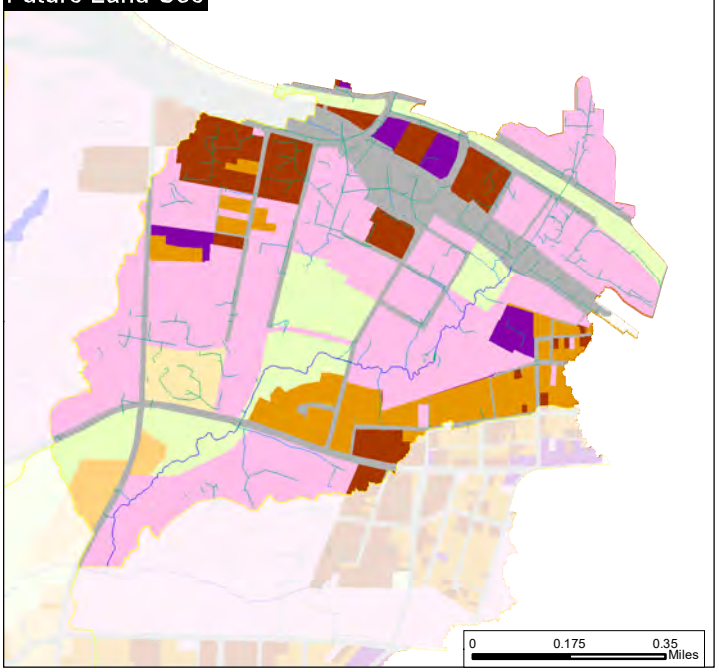
Land Use

- VERY LOW DENS. RES.
- LOW DENS. RES.
- MED. DENS. RES.
- HIGH DENS. RES.
- INSTITUTIONAL
- INDUSTRIAL
- COMMERCIAL
- PARKS/OPEN SPACE
- AGRICULTURAL
- ROADWAYS

Existing Land Use



Future Land Use



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Subwatershed NHC45_SC Pilot Study Area Map

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NEW HOPE CREEK AND LITTLE CREEK
WATERSHED IMPROVEMENT PLAN

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New Hope Creek Subwatershed NHC46_SC

Overview

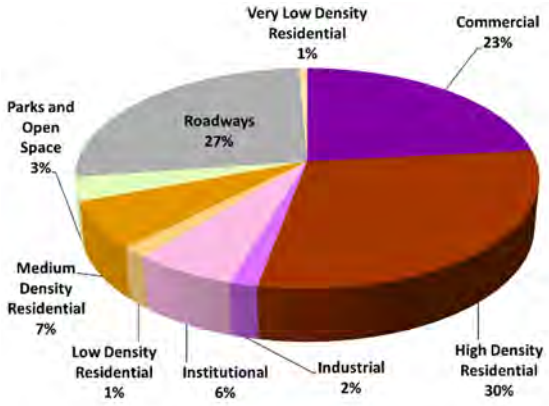
Subwatershed NHC46_SC is located completely in City limits in the northern region of the study area in the Sandy Creek Watershed. NHC46_SC has a drainage area of 523 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 36% impervious cover.

Landmarks

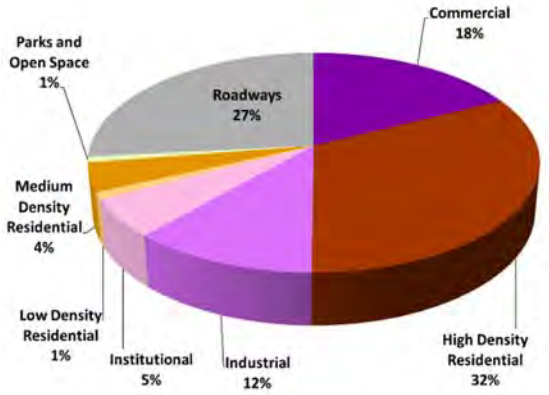
- Durham Freeway
- Duke University Hospital
- Crest Street

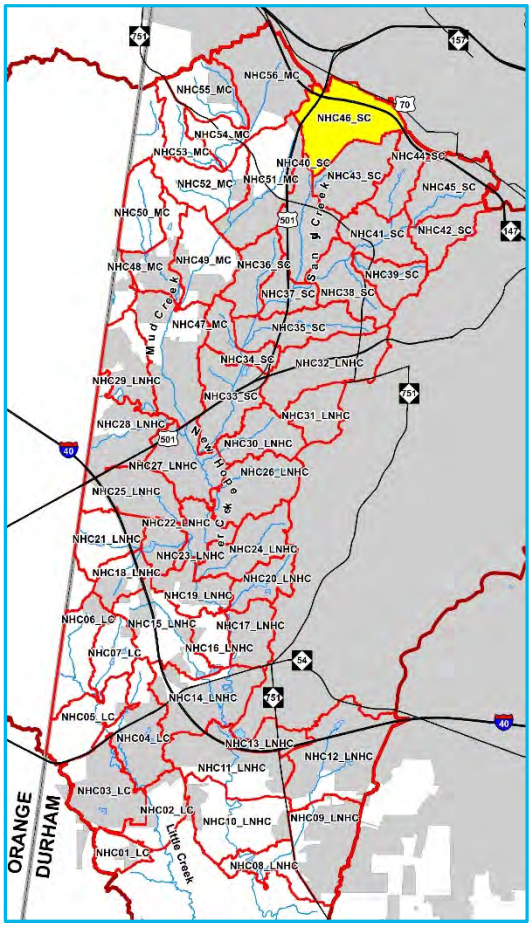
Land Use

Existing: The existing land use is predominately high density residential areas and roadways.



Future: The future land use is predominately high-density residential areas and roadways, with a projected increase in industrial areas.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

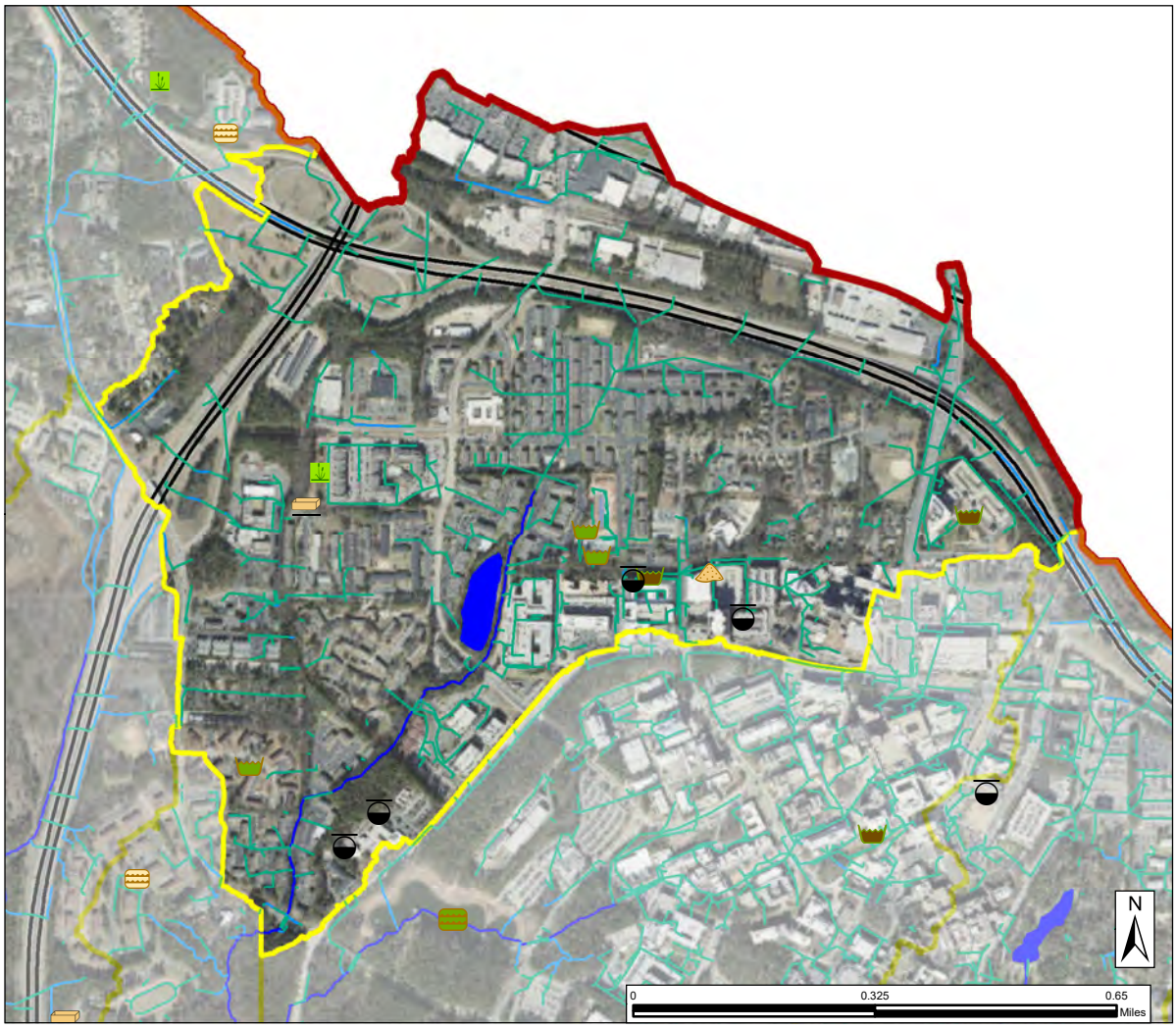
- Underground Storage (4): 13812, 13814, 00550, 00521
- Sand Filter – Underground (3): 13813, 13815, 13695
- Sand Filter (1): 00494
- Permeable Pavement (1): 13816
- Bioretention with IWS (3): 13520, 13559, 13558
- Bioretention without IWS (2): 00485, 13898
- Grassed Swale (1): 13568
- Level Spreader (1): 00664
- Constructed Wetland (1): 00665

Potential SCM Locations

- Bioretention (7): NHCSC0036, NHCSC0043, NHCSC0044, NHCSC0046, NHCSC0047, NHCSC0048, NHCSC0049
- Constructed Wetland (1): NHCSC0039
- Regenerative Stormwater Conveyance (1): NHCSC0040

Stream Assessments

- Bank Stabilization (6): SC2010, SC2011, SC2013, SC2014, SC2015, SC2016
- Restoration (1): SC2017
  Stream Enhancement II (2): SC2009, SC2012



Existing SCMs

- Dry Pond
- Wet Pond
- Constructed Wetland
- Pocket Wetland
- Level Spreader
- Level Spreader - Engineered Filter Strip
- Sand Filter
- Filterra
- Bioretention with IWS
- Bioretention without IWS
- Underground Storage
- Proprietary Device
- Subwatershed
- NHC Watershed Boundary
- Stormwater Pipes
- Lakes and Ponds
- Stormwater Channels
- Streams
- Major Roads
- Durham City Limits

Land Use

- VERY LOW DENS. RES.
- LOW DENS. RES.
- MED. DENS. RES.
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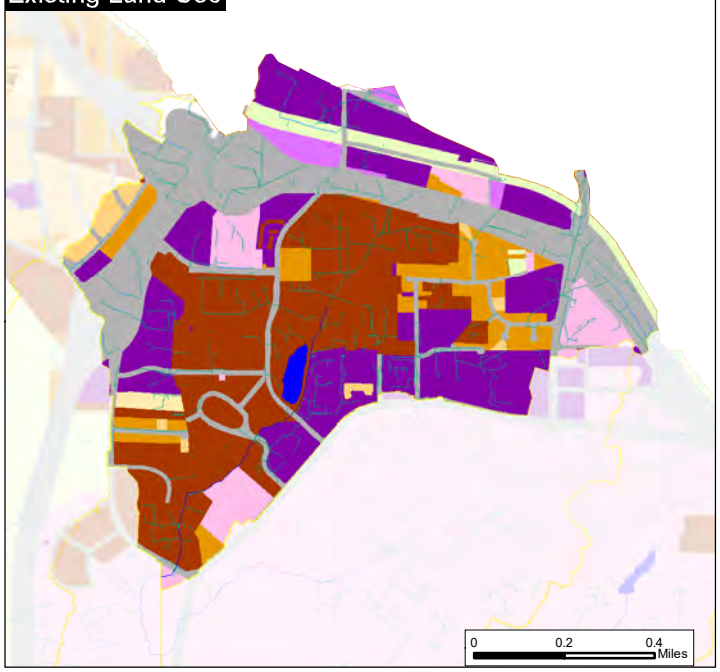
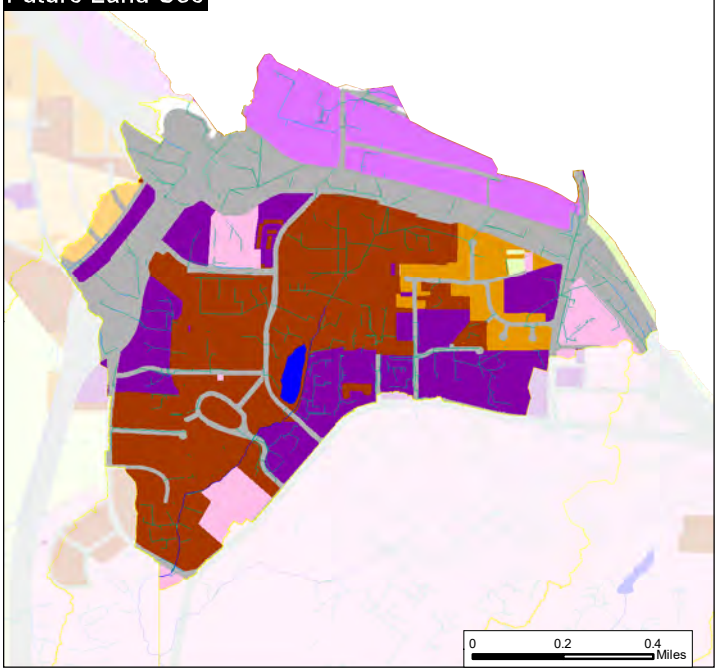
- AGRICULTURAL
- ROADWAYS

Existing Land Use



Future Land Use



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New Hope Creek Subwatershed NHC47_MC

Overview

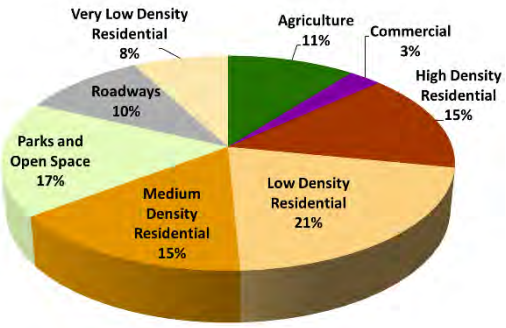
Subwatershed NHC47_MC is located in the central region of the study area in the Mud Creek watershed. NHC47_MC has a drainage area of 631 acres (72% within Durham City limits), is comprised primarily of hydrologic soil group D soils, and has 11% impervious cover.

Landmarks

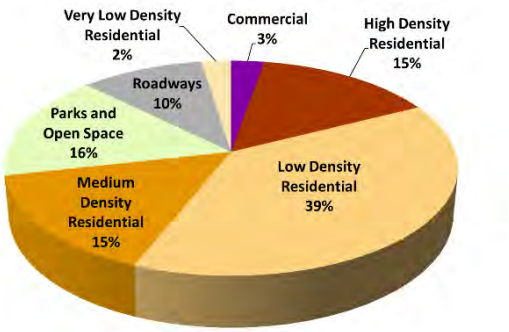
- Pickran Estates
- Pickett Road
- Mud Creek

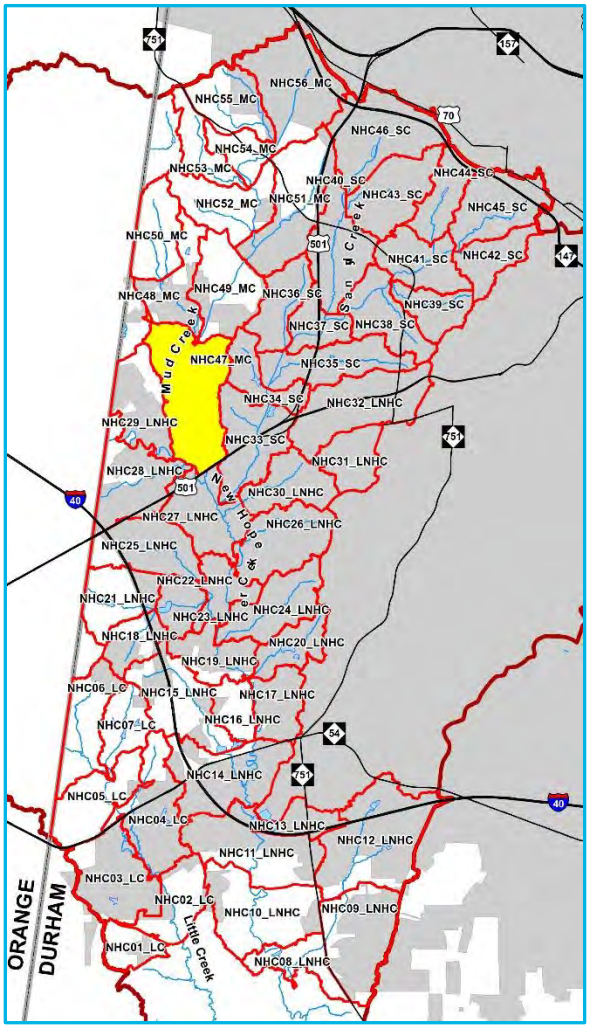
Land Use

Existing: The existing land use is predominately low to high density residential areas, followed by parks and open space.



Future: The future land use is predominately low to high density residential areas, with a projected increase in low density residential areas and decrease in agriculture.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

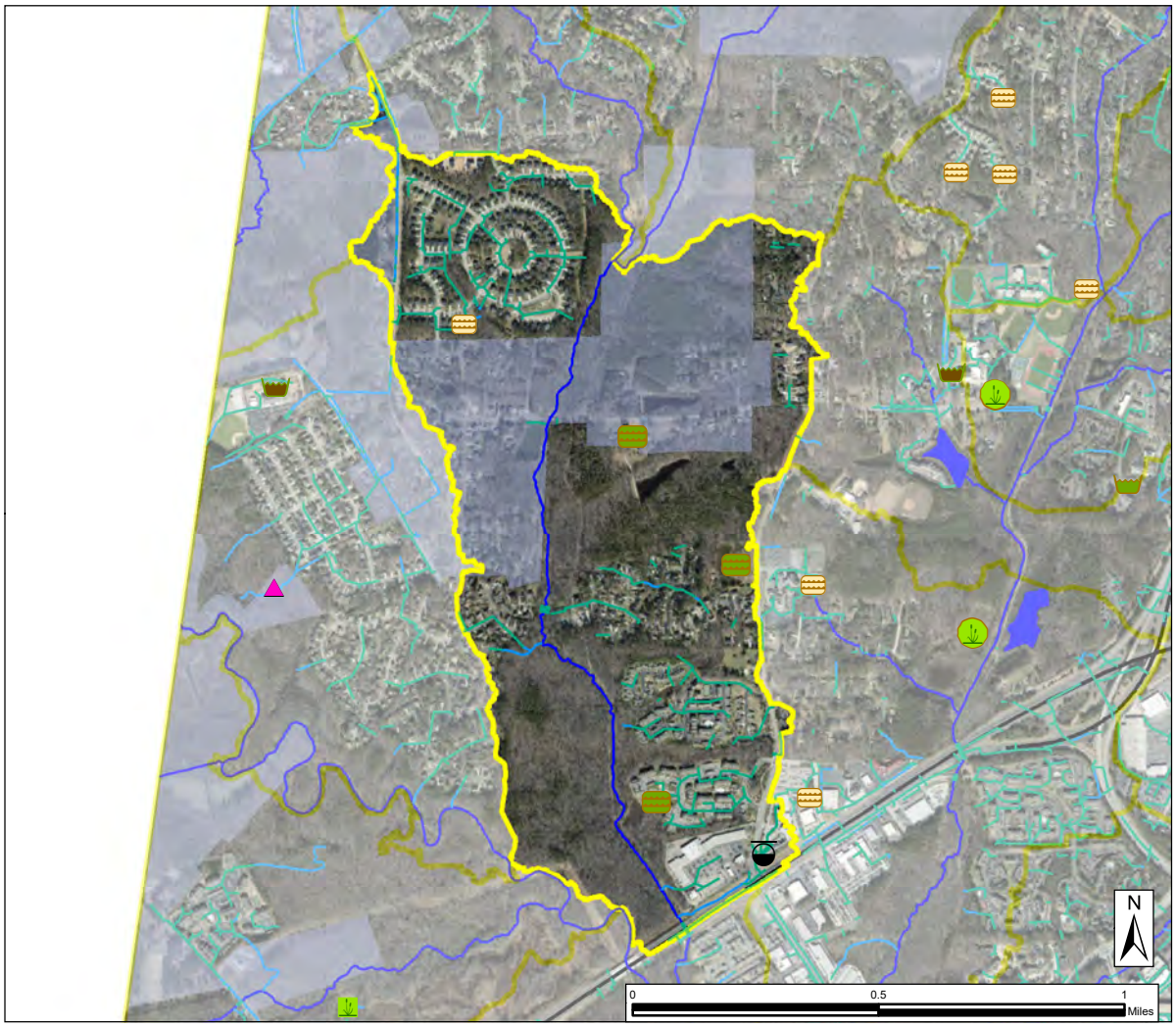
- Wet Pond (5): 00495, 13824, 13684, 13683, 13682
- Dry Pond (1): 00267
- Underground Storage (1): 00198

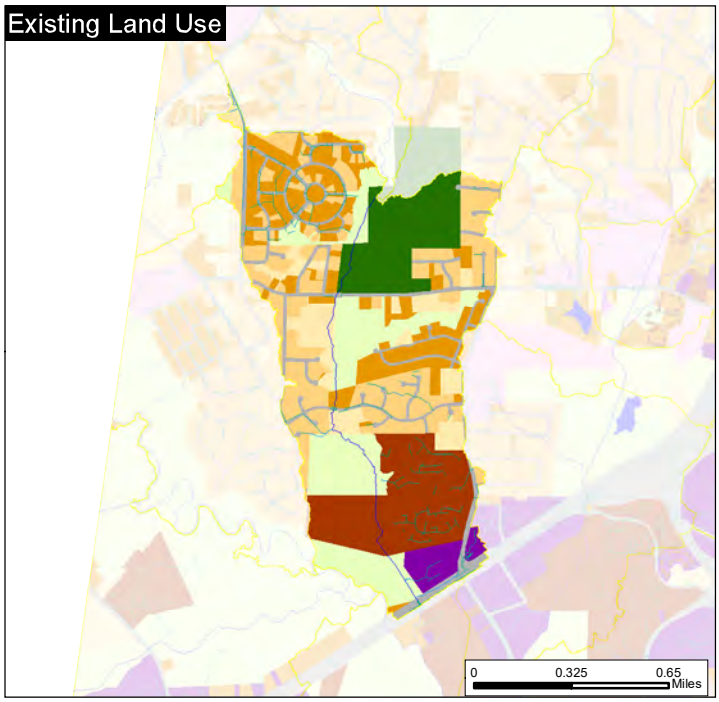
Potential SCM Locations

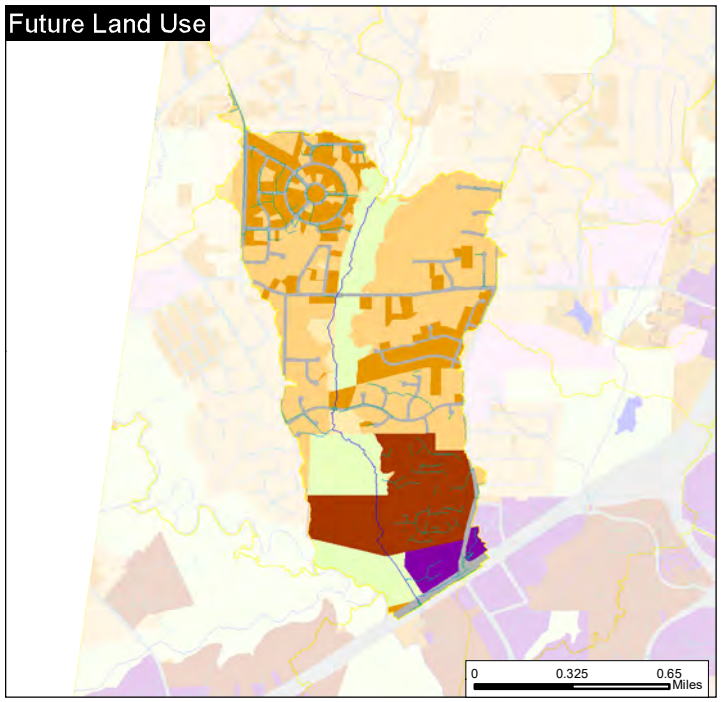
- None

Stream Assessments

- Restoration (2): MC1014, MC1015







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New Hope Creek Subwatershed NHC48_MC

Overview

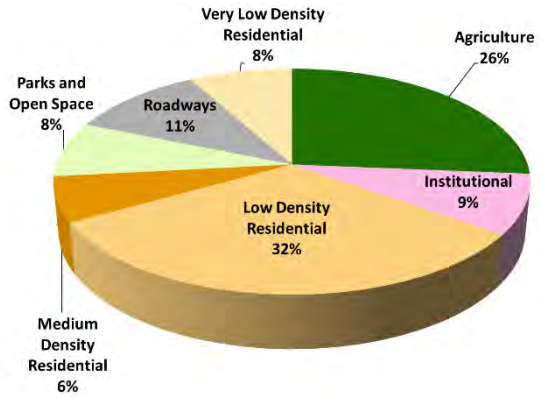
Subwatershed NHC48_MC is located in the north-eastern region of the study area in the Mud Creek watershed. NHC48_MC has a drainage area of 284 acres (100% within Durham City limits), is comprised primarily of hydrologic soil group B soils, and has 9% impervious cover.

Landmarks

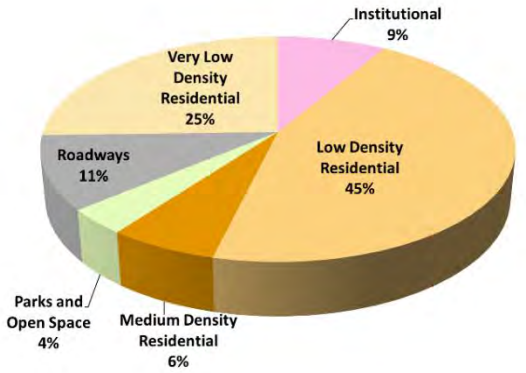
- Lochnora Subdivision
- Erwin Road
- Mt. Sinai Road

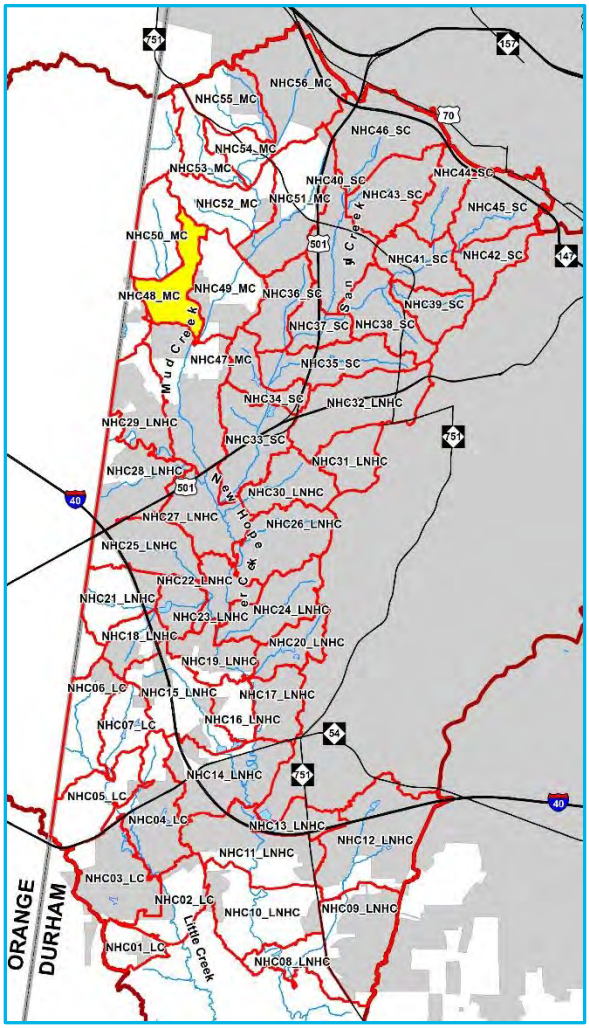
Land Use

Existing: The existing land use is predominately low density residential and agricultural areas.



Future: The future land use is predominately very low to low density residential areas, with a projected decrease in agricultural areas.





Subwatershed Location Map

Stormwater Features

Existing SCM Locations

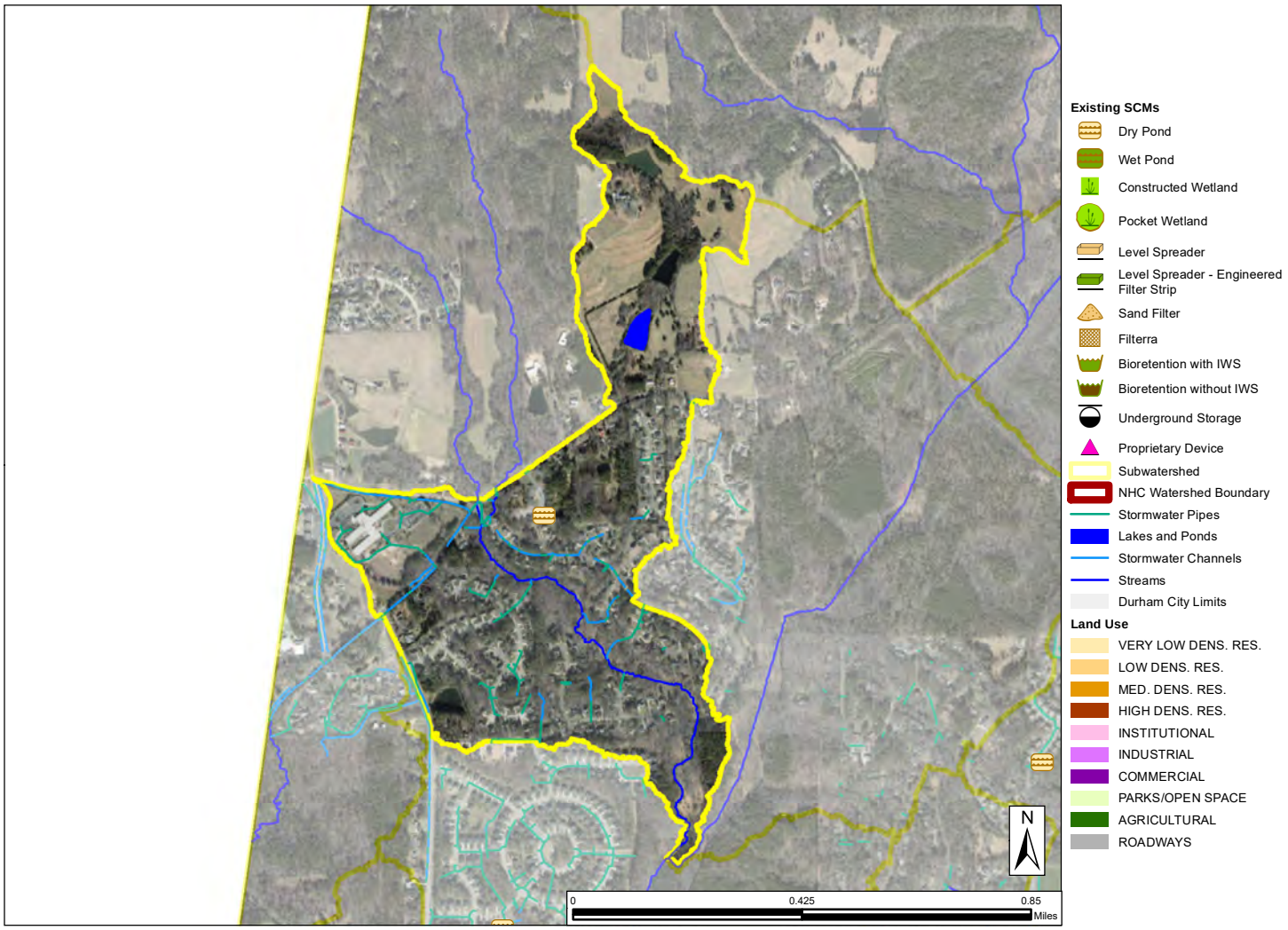
- Sand Filter – Underground (1): 13778
- Dry Pond (1): 00107

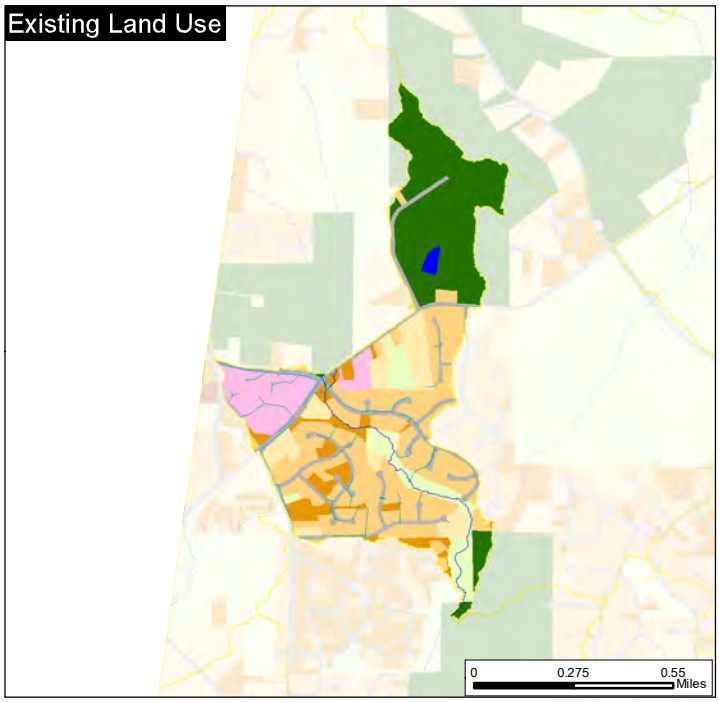
Potential SCM Locations

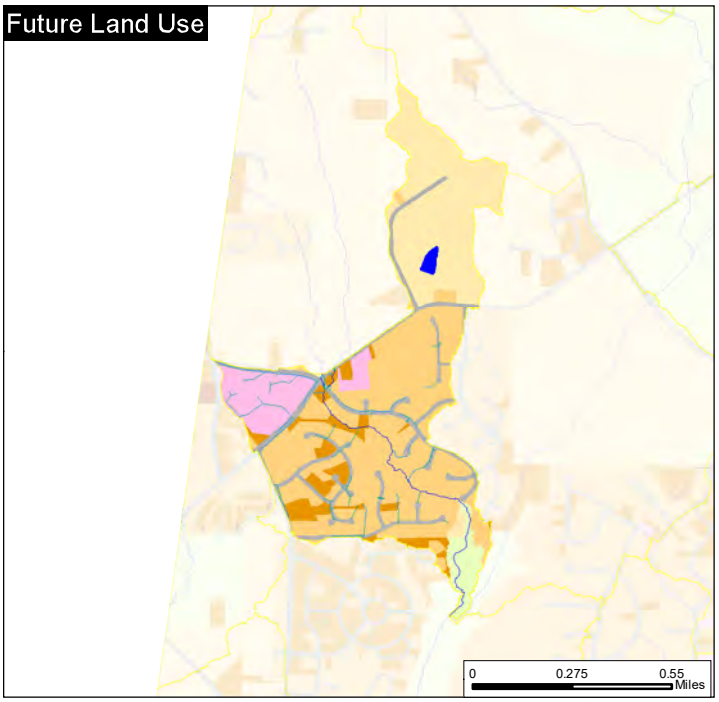
- None

Stream Assessments

- Bank Stabilization (2): MC1025, MC1028
- Restoration (2): MC1014, MC1026
- Stream Enhancement I (1): MC1027







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