Upper Middle Creek Watershed Action Plan

Wake County, NC
USGS HUC 030202010901

Prepared By: **Report Date: 7/8/22**

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

303(d)	List of Impaired Waterbodies
AU	Stream assessment unit used for 303(d) list
BO	Biological Opinion
CFU	colony forming units
CWEP	Clean Water Education Partnership
DMS	North Carolina Division of Mitigation Services
DOT	North Carolina Department of Transportation
DWR	North Carolina Division of Water Resources
EIS	Environmental Impact Statement
EPT	Pollutant-sensitive insects that live in streams
HSG	hydrologic soil group
HUC	hydrologic unit code
IBI	Index of biotic integrity
mg/L	milligrams per liter
mL	milliliters
NCDEQ	North Carolina Department of Environmental Quality
NCDWR	NC Division of Water Resources (falls within the above)
NCLWF	NC Land and Water Fund
NCNHP	North Carolina Natural Heritage Program
NCWRC	North Carolina Wildlife Resources Commission
NRCS	National Resource Conservation Service
NSW	Nutrient Sensitive Water
Plan	Upper Middle Creek Watershed Action Plan
SCM	Stormwater Control Measure
SR	State Route
TJCOG	Triangle J Council of Governments
TLC	Triangle Land Conservancy
ULC	Urban Land Complex
UNCSOG	UNC School of Government
USEPA	US Environmental Protection Agency
USGS	United States Geological Survey

Guide to Nine Minimum Elements

This table serves as a quick reference guide to where the Environmental Protection Agency (EPA) Nine Minimum Elements within this watershed management plan.

EPA Nine Minimum Elements		Location in Plan
1	Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.	• Plan goals defined: Section 5.0 • Stressors and sources of impairment mapped, and causes identified: Section 3.0 • Existing water quality data review: Section 0 • Identify the indicators to be measured: Table at beginning of Section 8.1 • More granular watershed analysis: See subwatersheds and impervious surface map/notes from partners in Section **Error! Reference source not found.** • Identify point vs. nonpoint sources: 3.3 • Initial field assessment at areas of greatest concern: 3.1.3.3 • Data sources, estimates and assumptions cited throughout • Data gaps: 3.2.1
2	An estimate of the load reductions expected from management measures.	• Loads from sources quantified: Section 4.1 • Load (peak flow) reduction targets identified: Section 4.3.1 • Peak flow reductions linked to causes/sources: Section 5.1 • Data to extrapolate practice types to load reductions and cost: - SCMs: Table in 6.3.2.1 - Ag BMPs: Table in 6.3.3.1 - Stream restoration: Table in 6.3.4.1 • Analysis to ensure water quality criteria or other goals will be achieved/load reduction needed to reach targets: - Flow reduction target: Section 4.3.1 - IC target: Section 4.3.2

		• Prioritize proposed activities/projects and identify critical areas that need management: - See subwatersheds and impervious surface map/notes from partners in Section **Error! Reference source not found.**. I had hoped to use USGS SPARROW modeling to further identify critical areas and target practices by NHD+ subcatchment, but the national-level input data that informed model output did not show any distinctions between subwatershed besides higher modeled nitrogen loads at the location of the South Cary WWTP. USGS staff I reached out to could not comment on why. • Describe current and future management measures within the watershed: - Current projects: 6.2.2.1 - Future projects: 6.3 • Document relevant authorities that may have a role in management plan: - Partners table at top of section 5.0 • Management activities address indicators: - Objectives tables in section 5.0 - Primary Goal Indicators table in Section 8.1
3	A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.	Considered satisfactory in prior review: • Prioritization criteria defined • Review of existing plans, policies, and projects Critical source areas and SCM project prioritization: • See subwatersheds and impervious surface map/notes from partners in Section 6.3.1.
4	Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.	(Considered fully satisfactory in prior review) Section 8.6
5	An information and education component used to enhance public understanding of the project and	(Considered fully satisfactory in prior review) Section 8.2

	encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	
6	Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	• Include projected dates for the development and implementation of short, mid- and long-term actions needed to meet the goals of the plan, with specifics on what entity will accomplish the actions, including monitoring: Section 7.4 • Implementation schedule must be measurable, attainable, and include completion dates to ensure continuous implementation of the plan: Sections 7.2 and 7.3 • Info on how implementation will be tracked: All of Section 7.0
7	A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	
8	A set of criteria that can be used to determine whether load reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.	• Give evaluation criteria/indicators as numeric targets, not abstract metrics. Include expected dates of achievement. Should include direct measurements (ie, bacterial counts) as well as indirect measurements (such as before/after photographs, etc.) that can indicate whether substantial progress is being made: Section 7.5 and 7.6 • Review process to determine if the pollutant load (flow) reductions are being met and how to proceed/modify strategies if interim goals are not being met: Section 7.5
9	A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the established criteria.	• Monitoring should be of the load reduction goals to measure progress towards water quality improvement: Section 7.5 and 8.1

Below is a list of 9 Elements required by the EPA and N.C. DEQ, as summarized in the NC Coastal Federation's Watershed Planning Handbook. All the criteria listed are addressed within this plan.

1. Identification of impairment, pollutant, causes, and sources of pollution that need to be controlled.

a. Include a map of the watershed
b. Identifies the major stressors and sources of impairment, spatial visualize the information in map
c. Identify point vs. nonpoint sources
d. Identify the indicators to be measured
e. Review existing water quality or biological data
f. Perform a field assessment, this can be initially conducted at areas of greatest concern.

2. Identify and detail reduction load and the measures necessary to meet water quality standards

a. Indicate the quantitative reduction load
b. Prioritize proposed activities/projects and identify critical areas that need management
c. Describe future and current management measures within the watershed
d. Document relevant authorities that may have a role in management plan
e. Management activities should address the indicators

3. Detailed management activities and the expected outcome

a. Describe what the indicators will be for each management measure
b. Establish what the expected potential pollutant load reductions by each project will be

4. Identification of technical and financial assistance needed to implement and long-term O&M

a. Estimate amount of technical assistance needed
b. Estimate amount of financial assistance needed, ideally using a detailed cost list
c. Identify federal, state, local, and private funds or resources that could potentially assist

5. Education and information plan for the watershed

a. Clearly identify stakeholders
b. Programs should have multifaceted involvement from local, state and federal programs and agencies; there should be a range of information and education options available

6. Plan implementation schedule

a. Identify timeline of implementation of actions with specifics on what entity will accomplish the actions, including monitoring
b. Schedule should address short-, mid- and long-term actions

7. Implementation and tracking of measurable milestones to ensure benchmarks of success

a. Milestones should be measurable and have a clear timeframe on when the milestone should be measured

8. Indicator to measure progress toward meeting watershed goals

a. Direct measurements (such as bacterial counts) and indirect measurements (such as number of beach closings, photographs, etc.) that can indicate whether substantial progress is being made
b. Should address how to proceed/modify strategies if interim goals are not being met

9. Monitoring component to evaluate effectiveness of plan

a. Monitoring should be of the load reduction goals to measure progress towards water quality improvement

EXECUTIVE SUMMARY

The Upper Middle Creek watershed is an important resource for species and habitats, outdoor recreation, flood mitigation, and protection of downstream water quality; however, various drivers and inputs, primarily those related to nonpoint source pollution from stormwater runoff, continuously degrade its water quality. Ongoing and increasing development in the urban areas within this watershed region will further this trend over time without intervention. This Watershed Action Plan outlines the current state of the watershed as well as steps that should be taken to mitigate the impacts of development on water quality, as organized by the EPA's Nine Minimum Elements of a Watershed Plan. Partnering organizations including Wake Soil and Water Conservation District and local governments in the watershed have identified specific prioritized projects to help minimize loading to the watershed from primary pollutants of concern including sediment, fecal coliform pollution, and other pollutants associated with runoff from urbanized areas. This Plan is intended to be a living document and a springboard for local government partners to begin implementing projects to improve and preserve surface water quality and habitat. Ongoing collaboration will be essential to meaningfully improve water quality and ecosystem health in this urbanizing watershed.

1.0 INTRODUCTION AND PURPOSE

The purpose of this watershed plan is to guide restoration efforts and improve water quality in the Upper Middle Creek watershed of Wake County, North Carolina. A major driver for the development of this plan was the 2018 designation of two stream segments in the watershed as “impaired” by the North Carolina Department of Environmental Quality (NCDEQ) due to benthic macroinvertebrate community being rated as “Fair”. Additionally, local government stakeholders cited the “Complete 540” expressway project construction as an important driver for assessing baseline watershed condition and restoration needs of this rapidly growing area. The overall goal of this document is to identify pollution sources which have degraded water quality and watershed habitat resulting in benthic community declines and provide a roadmap for project partners and other stakeholders to improve conditions, with the ultimate result of "impaired" stream segments removal from the impaired water list. (See more information on Plan goals, objectives, and actions in Section 5.0, Goals and Objectives.)

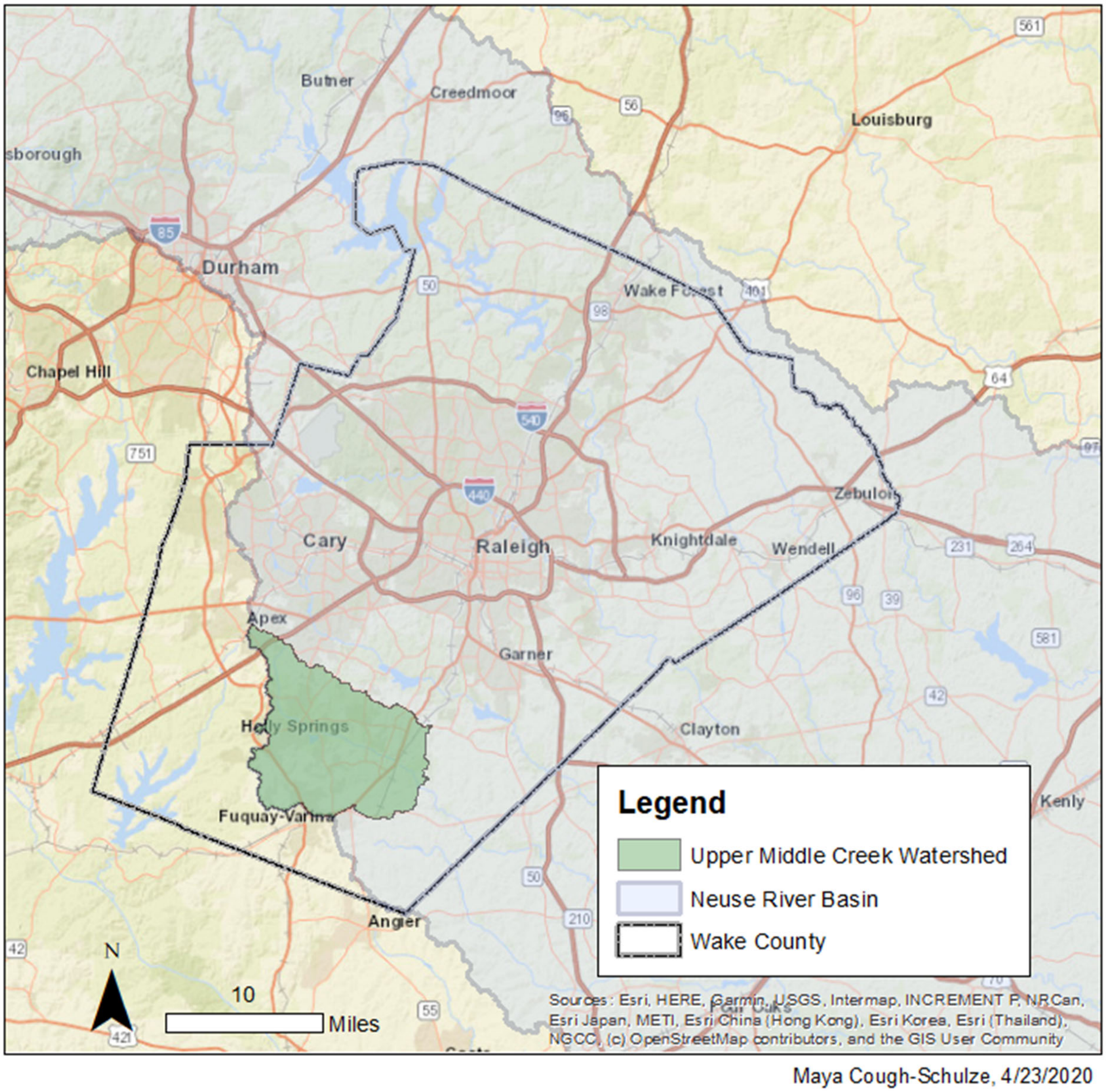
Per the United States Environmental Protection Agency (USEPA)’s Nine Minimum Elements of a Watershed Restoration Plan, this document outlines current watershed conditions, priorities for future conservation and restoration projects, benchmarks for measuring success, and recommendations for ongoing improvement. This plan is intended to be updateable as further information becomes available, so that it will continue to be useful to future stakeholders as the watershed changes over time.

2.0 WATERSHED DESCRIPTION

The Upper Middle Creek watershed is a rapidly developing, 57 square mile (147 square kilometer) watershed (USGS 12-digit HUC 030202010901) located in the south-central Wake County, NC. It is the upper-most watershed in a sequence of three sub-watersheds that combine to form the Middle Creek Watershed, located within the Neuse River Basin, as shown in Figure 1 below. The Upper Middle Creek watershed extends north from above Highway 1 in Apex, to below Highway 401 in Fuquay-Varina to the south. This area encompasses major portions of Fuquay-Varina and Holly Springs, moderate portions of Apex and Cary, and a large portion of unincorporated Wake County, as shown in Figure 2.

In 2014, Wildlands Engineering completed a regional watershed plan for the North Carolina Ecosystem Enhancement Program (now North Carolina Division of Mitigation Services) for the USGS 8-digit hydrologic unit 03020201 which encompasses the Triangle region and the Upper Middle Creek watershed. This plan was developed to "identify and prioritize potential mitigation projects to offset ecological impacts related to development throughout the Neuse 01 subbasin," (Wildlands Engineering, 2014). According to this report, agriculture has been a major land use in the region since the 18th century and continuing through recent times. In the 1700s, the region produced cotton and tobacco; through the early 1900s, major agricultural products included cattle, swine, timber, and turpentine. Current agricultural production in the watershed focuses on tobacco, soybeans, wheat, and cattle; there are also several horse boarding facilities in the watershed.

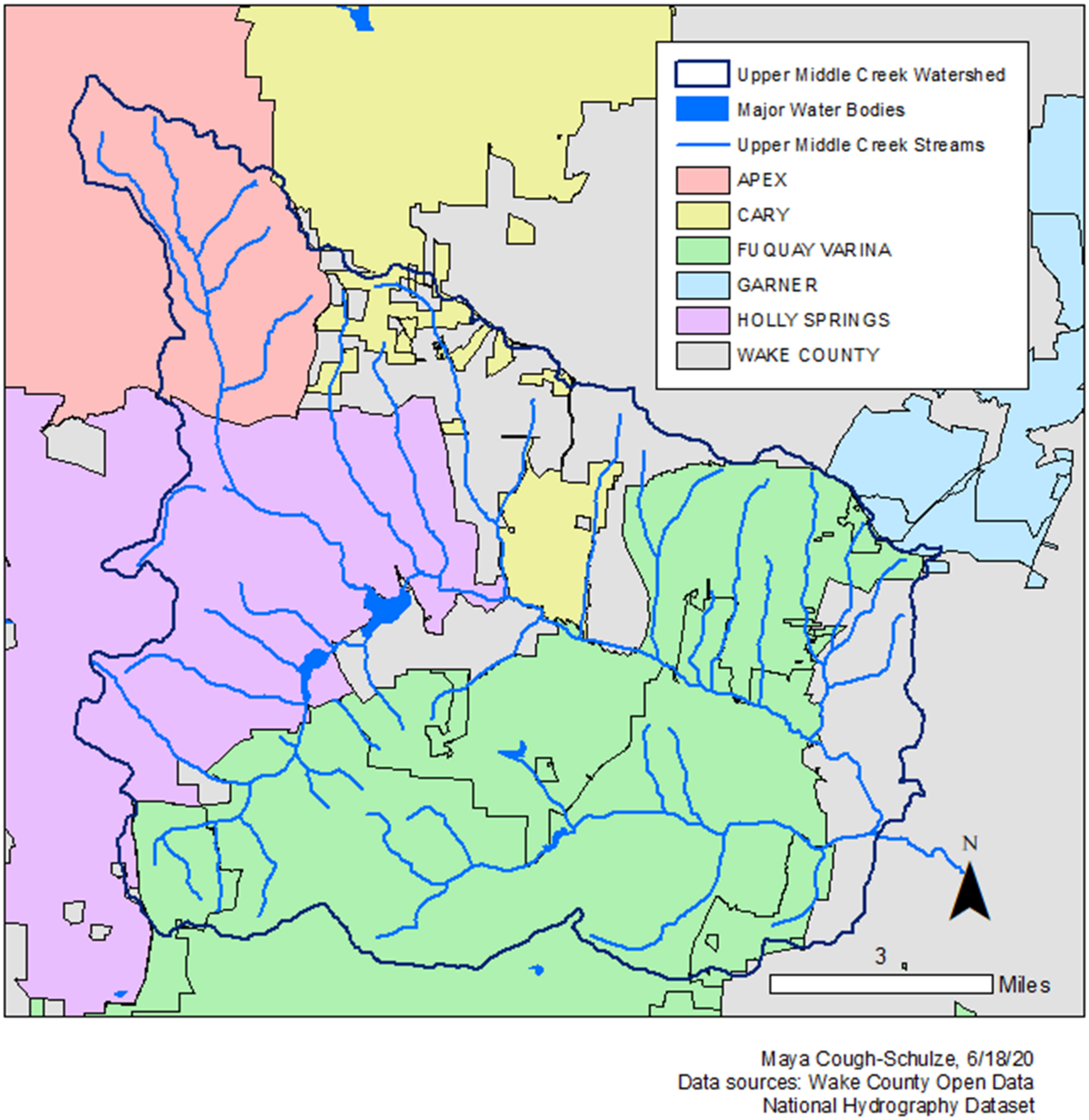
Figure 1: Overview Map



The construction of Research Triangle Park (RTP) in 1959 initiated job growth in the region, driving the expansion of Raleigh and Cary in the second half of the 20th century. Apex, Holly Springs, and Fuquay-Varina did not expand rapidly until the 1990s, when these towns grew by 250 to 300%. Between 2000 and 2015, these three towns continued to grow by over 100%. The completion of I-540 is expected to be a driver of continued development along its corridor (Wildlands 2014), detailed further in section 3.1.3.1.

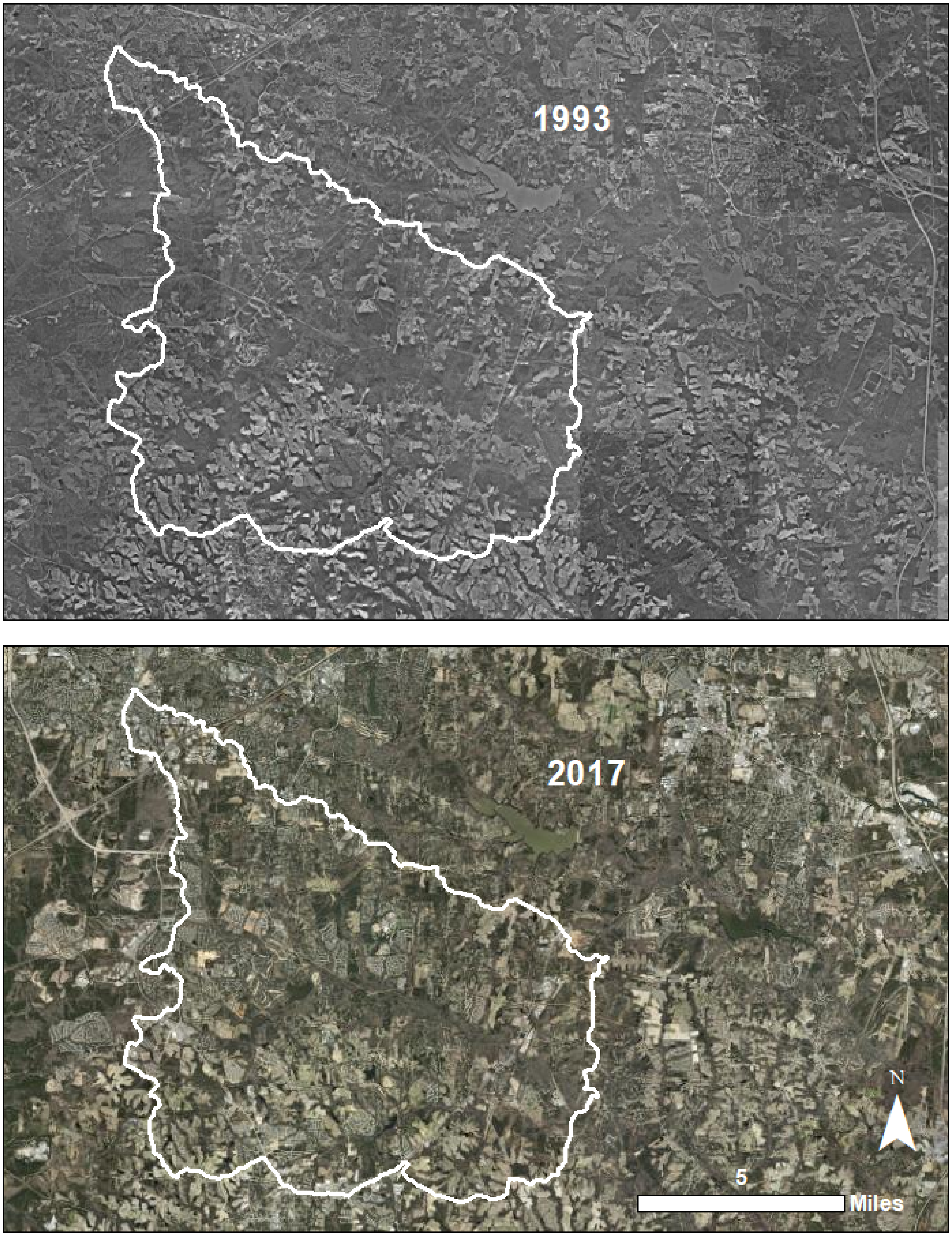
Realtor.com named the Town of Apex the fastest-growing suburb in the U.S in July 2018. Apex's interactive development map shows that there are multiple new multifamily subdivisions approved or under construction in the headwaters of the Upper Middle Creek watershed in southern Apex (Town of Apex, n.d.) Fuquay-Varina's ETJ expanded by over 9,000 acres in December 2020, reflecting the projected continuation of the development boom in this Raleigh bedroom community.

Figure 2: 2020 Planning Jurisdictions in the Upper Middle Creek Watershed



Given this growth, over the past few decades, agricultural and forestlands in the greater Raleigh area have increasingly been converted to low to medium density residential use (Wildlands 2014; see also historic aerial photograph in Figure 3). This includes suburban development, several golf courses, and other low-density landscaped residential/commercial uses. The Neuse 01 Regional Watershed Plan found the Upper Middle Creek watershed to have the highest increase in urban and impervious areas relative to its neighboring watersheds in the Neuse River Basin (Wildlands 2014). NCDEQ's Neuse River Basinwide Water Quality Plan for this subbasin stated that "the increased volume of stormwater runoff is contributing to instream habitat loss and sedimentation. With the projected increase in population growth for this area, this trend is likely to continue unless we take steps now to improve stormwater controls and preserve critical areas against further development," (NCDEQ 2009.)

Figure 3: Upper Middle Creek Watershed Circa 1993 and 2017



Maya Cough-Schulze, 6/26/20
Data sources: USGS

According to the National Land Cover Dataset (NLCD), between 2001 and 2016, developed areas increased by 14%, while forestlands decreased by 9% and agricultural lands decreased by 5% (NLCD 2019.) The following sections outline specific watershed characteristics that are important to understand to prioritize and implement water quality improvement projects in the Upper Middle Creek region.

2.1 Hydrology

The Neuse 01 Regional Watershed Plan (Wildlands 2014) prioritized compensatory mitigation sites within the Upper Neuse River basin Hydrologic Unit 03020201 of which Upper Middle Creek was one of twelve Target Local Watersheds. They characterized the hydrology of the Upper Neuse Basin and nested Upper Middle Creek watershed as follows:

> *"In general, soils in the Neuse 01 RWP area are highly erodible and are underlain by fractured rock formations that have limited water storage capacity. Streams in this area tend to have low summer flows and limited ability to assimilate oxygen-consuming wastes (WRC, 2005). The…Upper Middle Creek subwatershed…[is] near a transitional area between the poorly drained soils of the Triassic Basin and the moderately drained soils weathered from granitic rocks underlying most of the other subwatersheds. Therefore, streams in these subwatersheds are even more susceptible to periods of interrupted flow, particularly in the upper reaches…the natural susceptibility of these watersheds to experience periods of very low, to interrupted flow is further compounded by anthropogenic factors such as water withdrawals and urbanization."*

2.2 Water Classifications

All surface water segments within the Upper Middle Creek watershed described in this section are classified as C; Nutrient Sensitive Waters (NSW). Class C waters are defined by NCDEQ as those protected for secondary recreation purposes such as fishing, boating, and other uses where full-body contact with the water is deemed incidental (full definition: "Waters protected for uses such as secondary recreation, fishing, wildlife, fish consumption, aquatic life including propagation, survival and maintenance of biological integrity, and agriculture. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner" (NCDEQ Classifications, n.d.)

NSW is a "supplemental classification intended for waters needing additional nutrient management due to being subject to excessive growth of microscopic or macroscopic vegetation." Due to nutrient-related pollution, the Neuse Stormwater Rule (15A NCAC 02B .0235 and .0240, 1998) laid out a "nutrient strategy" which seeks to reduce nutrient levels delivered to the Neuse Estuary. As part of this rule and strategy, sectors are required to reduce their nitrogen loads including municipal stormwater dischargers over a given size threshold, agricultural producers and point source dischargers. The Neuse Rules required that Wake County and the Town of Cary prevented stormwater runoff for the 1-year, 24-hour storm from yielding a net increase in peak flow leaving a site as compared to predevelopment conditions, and required that they cap nitrogen loading in stormwater runoff to 3.6 pounds/acre/year, or meet a portion of this load reduction by funding nutrient management offsite through NC Division of Mitigation Services or another approved entity (15A NCAC 02B .0235, 1998). Agricultural operations in the basin were mandated to collectively reduce their nitrogen loading by 30% (15A NCAC 02B .0238 and .0239) by implementing nutrient management plans and fertilizing at rates recommended by the U.S. Department of Agriculture Natural Resource Conservation Service (USDA NRCS).

Updated Neuse New Development Stormwater Rules were adopted in April 2020, during the writing of this Plan. Per these rules, when local implementation begins, new development and redevelopment that Apex, Holly Springs and Fuquay-Varina approve will be required to adhere to nitrogen loading requirements. Local implementation of this rule for these new local governments likely will begin no earlier than January 2023 (Patricia D'Arconte, personal communication) though this timeline is subject to change. At the time of writing, local governments and TJCOG staff were participating in initial workgroup meetings to learn about next steps for implementation and implications for nutrient management in stormwater runoff.

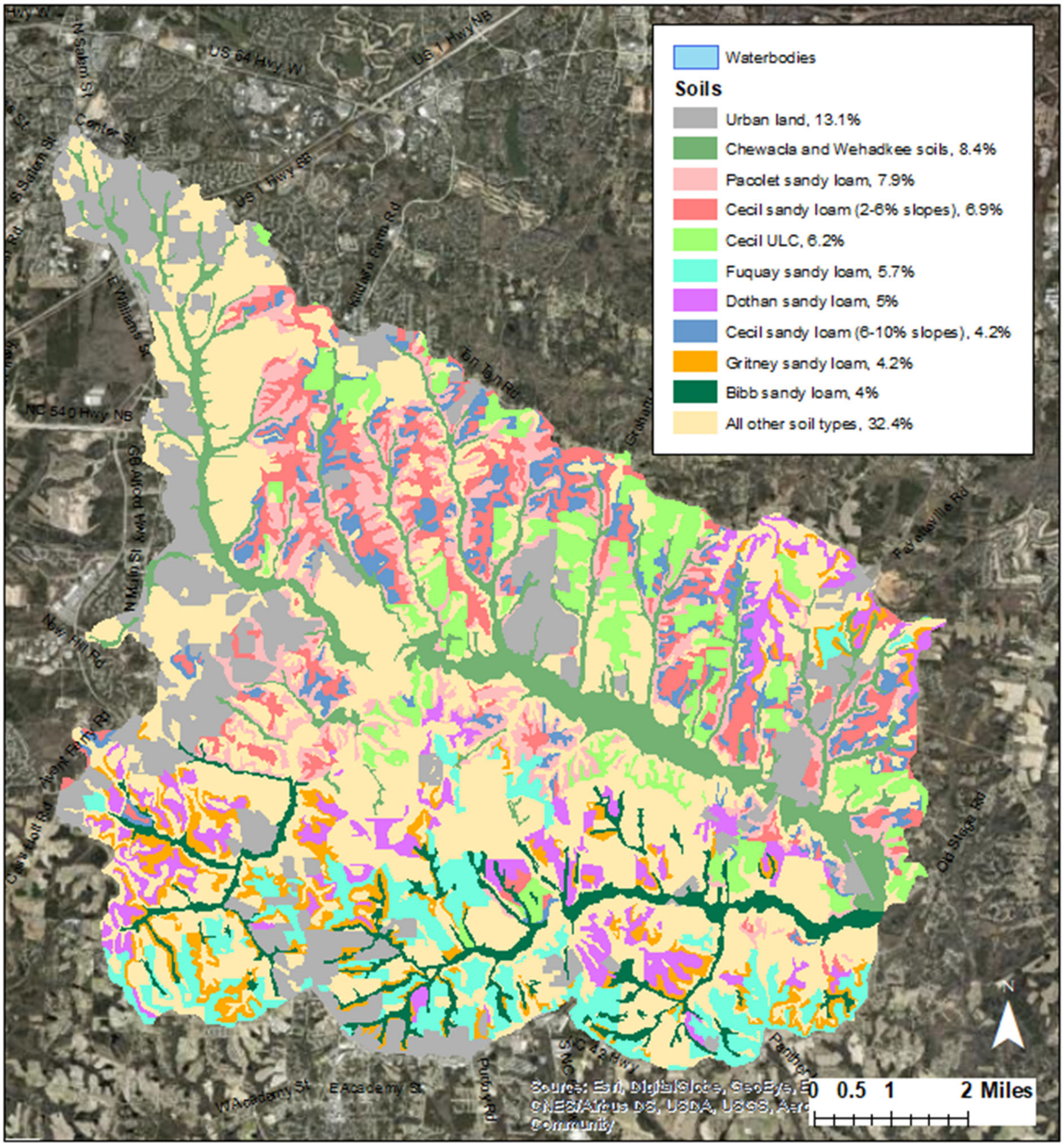
2.3 Soil Type

According to the USDA NRCS Web Soil Survey tool, the Upper Middle Creek watershed is comprised of 46 different soil types. Characteristics of the 10 soil types which make up a majority (>65%) of the land area are described in the table below. 50% of the soils in the watershed are considered prime farmland; 10%, prime farmland if drained; and 40% are not considered prime farmland. 67% of soils in the watershed are classified as well- or moderately-well drained, i.e., promoting higher infiltration rates and producing less runoff. The predominant hydrologic soil group in the watershed is A (sands, loamy sands, or sandy loams), which typically have high infiltration potential and low runoff. Soils in the floodplain are typically more poorly drained due to greater clay content or other layers that impede infiltration. Note also that the web soil survey classifies 13% of the watershed as urban, defined as "impervious layers over human-transported material," (NRCS 2019).

Table 1: Major Soil Types and Characteristics

Soil Type Name	Watershed area (%)	Slope (%)	Natural Drainage Class	Hydrologic Soil Group	Prime farmland?
Urban land	13.10%	NA	N/A	N/A	No
Chewacla and Wehadkee soils	8.40%	0-2	Somewhat poorly drained	B/D	If drained
Pacolet sandy loam	7.90%	10-15	Well drained	B	Yes
Cecil sandy loam	6.90%	2-6	Well drained	A	Yes
Cecil ULC	6.20%	2-10	Well drained	A	No
Fuquay loamy sand	5.70%	0-6	Well drained	A	Yes
Dothan loamy sand	5.00%	2-6	Well drained	C	Yes
Cecil sandy loam	4.20%	6-10	Well drained	A	Yes
Gritney sandy loam	4.20%	6-10	Moderately well drained	D	Yes
Bibb sandy loam	4.00%	0-2	Poorly drained	A/D	No
All other soil types (36 types)	34.4%				

Figure 4: Major Soil Types in the Upper Middle Creek Watershed



Maya Cough-Schulze 6/18/20
Data Source: NRCS Web Soil Survey

2.4 Significant Natural Heritage

The Upper Middle Creek watershed supports a range of threatened and endangered species, whose continued viability depends upon the presence of adequate water quality. Additionally, due to its position in the headwaters, protecting ecosystems and habitats in this watershed is important to ensure that downstream ecosystems are protected. The North Carolina Natural Heritage Program (NCNHP) has identified the Middle Creek Aquatic Habitat, Bluffs and Floodplain shown in Figure 5, below, as important natural areas which support rare species and ecosystems in *An Inventory of Significant Natural Areas in Wake County, NC* (2003) and subsequent documents.

2.4.1.1 Middle Creek Bluffs and Floodplain

The Middle Creek Bluffs and Floodplain Natural Area is identified by the NCNHP as supporting high-quality Piedmont Bottomland Forest (NCNHP 2003). Unimpacted Piedmont Bottomland Forests support various wetland canopy tree and plant species. This site, like most in Wake County, has been degraded by sewer lines and logging; however, it remains one of the best examples of this natural community in the area, supporting an "unusual mix of montane and coastal plain" species (NCNHP 2003).

The Middle Creek Bluffs and Floodplain support rare natural communities including Mesic Mixed Hardwood Forest (Slope variant), Dry Oak-Hickory Forest, Piedmont/Coastal Plain Heath Bluff, Piedmont/Low Mountain Alluvial Forest, Floodplain Pool, and Piedmont/Mountain Semipermanent Impoundment.

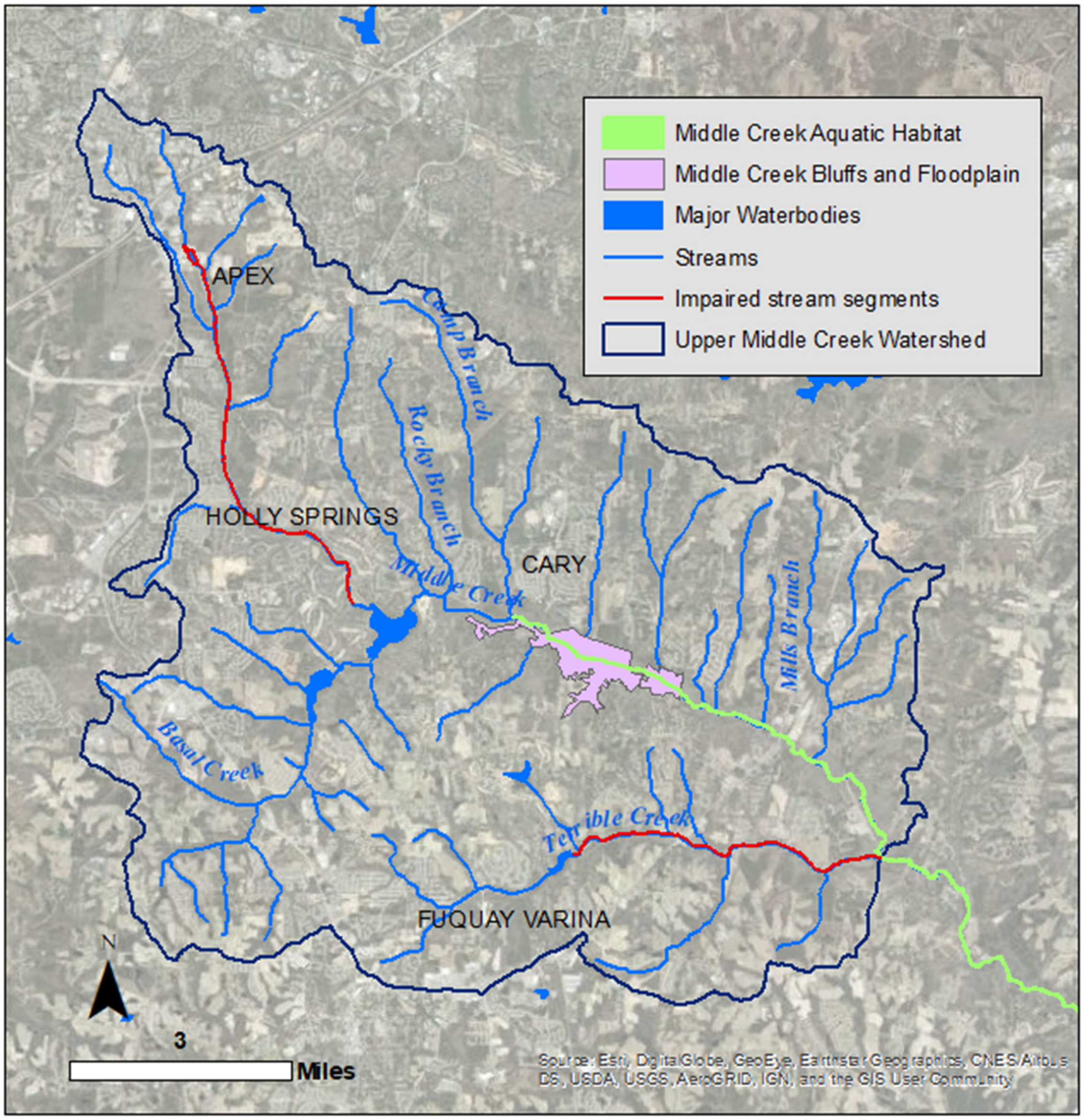
Protection of the forest and wetland communities in the Middle Creek Bluffs and Floodplain area is essential to maintain adequate habitat for both rare and common riparian species. Forest cover shades the stream, maintaining temperatures favorable for aquatic species, and contributes woody debris and organic matter to the in-stream habitat and food web. Conserving this forest community is important to protect both habitat and water quality from the impacts of stormwater runoff and pollutants it contains, as well as prevent streambank erosion and associated sedimentation in the creek. Conservation of the forest and wetland communities of the Middle Creek Bluffs and Floodplain Natural Area and adjacent floodplain and forestland will help to protect this high quality, rare natural community from impacts as the watershed continues to develop.

2.4.1.2 Middle Creek Aquatic Habitat

Another NCNHP-identified important area, the Middle Creek Aquatic Habitat, originates at the Sunset Lake Dam in the Upper Middle Creek watershed and extends into Johnson County 22 miles to its confluence with Swift Creek. The stream is particularly important for its diversity of freshwater mussels (2003, 2020), including the US Fish & Wildlife Service proposed Federal Threatened Atlantic Pigtoe, *Fusconaia masoni*. Other freshwater mussel species including the Triangle Floater (*Alasmidonta undulata)***,** Atlantic Pigtoe (*Fusconaia masoni),* Eastern Lampmussel (*Lampsilis radiata)* and Creeper (*Strophitus undulates)* have been documented from the Upper Middle Creek watershed (NCNHP 2020.) While maintaining adequate water quality is important for all aquatic species, it is particularly important for freshwater mussels which are particularly pollution intolerant (EPA 2008.) Freshwater mussel species typically require well-oxygenated stream habitat with minimal in-stream sedimentation (NatureServe Explorer, n.d.) NCNHP staff report that sedimentation and bank instability have compromised instream habitat for many freshwater mussel populations to the point that they are near-extirpated. Additionally, freshwater mussel larvae require specific host fish species, on whose gills they must live to progress to the juvenile stage; thus, ecosystems that supports host fish species are necessary to ensure these mussels' viability (USFWS 2019.)

Other rare species that have been found in Middle Creek include the North Carolina Spiny Crayfish (*Orconectes carolinensis*), last reported in 2001 (NCNHP 2020); this species endemic to the Neuse and Tar-Pamlico River Basins typically lives under rocks in clear, shallow, perennial streams with little visible flow (NCWRC 2020.) The Neuse River waterdog (*Necturus lewisi*), another species endemic to the Neuse and Tar-Pamlico River Basin, was historically found in the Upper Middle Creek watershed but has not been observed there in the last 20 years (NCNHP 2020). This species is proposed for federal listing as Threatened by the US Fish & Wildlife Service. Protecting water quality and instream and riparian habitat quality in the Upper Middle Creek watershed will help to protect rare aquatic species and habitats, preventing their continued decline or extirpation. (As the map below shows, Middle Creek Aquatic Habitat prioritized by NCNHP extends into the less-developed downstream portion of Middle Creek farther from the Triangle region.)

Figure 5: Important Natural Areas in the Upper Middle Creek Watershed



Maya Cough-Schulze 6/18/20
Data sources:
North Carolina Natural Heritage Program,
National Hydrography Dataset,
North Carolina Department of Environmental Quality

2.5 Land Cover and Land Use

The Upper Middle Creek watershed is significantly developed; considered together, low-, medium-, and high-density developed land comprises over 40% of the watershed. Most of the developed land lies in the headwaters, where the downtown areas of Apex and Holly Springs are located. All partners have reported that development is converting what was mostly farm or forested areas into residential land uses. The majority of currently forested and agricultural land lies in unincorporated Wake County. Local governments have taken steps to alleviate the impacts of development on water quality through implementing watershed protection overlays and making efforts to increase tree protection, outlined further in section 6.2.1.2.

Table 2: 2016 Land Cover in the Upper Middle Creek Watershed

2016 Land Cover Class	Area (acres)	Area (%)
Developed, Open Space	8,084	22.3
Mixed Forest	5,274	14.5
Developed, Low Intensity	4,702	12.9
Deciduous Forest	4,306	11.9
Evergreen Forest	3,324	9.2
Hay/Pasture	3,052	8.4
Cultivated Crops	1,744	4.8
Woody Wetlands	1,664	4.6
Developed, Medium Intensity	1,633	4.5
Herbaceous	1,151	3.2
Open Water	485	1.3
Developed, High Intensity	399	1.1
Shrub/Scrub	328	0.9
Emergent Herbaceous Wetlands	124	0.3
Barren Land	54	0.1

3.0 WATERSHED CONDITION, STRESSORS, AND SOURCES (ELEMENT 1)

3.1 Watershed Condition

Three impaired stream assessment units (AUs) in the Upper Middle Creek watershed were placed on NCDWR's 2018 303(d) list of impaired waters due to biological sampling that showed the reaches had only "fair" quality benthic macroinvertebrate communities. NCDWR conducts fish and benthic macroinvertebrate monitoring and uses this data to develop index of biological integrity scores which result in the assignment of AUs one of five categories: Excellent, Good, Good-Fair, Fair, and Poor. Biological monitoring showed benthic communities in the watershed to be impaired. Data collected at fish monitoring stations from 2004-2015 indicated that the fish communities met biological criteria as of the 2018 303(d) list; this data is summarized in section 3.1.2.

Table 3: Impaired Waters in the Upper Middle Creek Watershed Per 2022 303(d) List

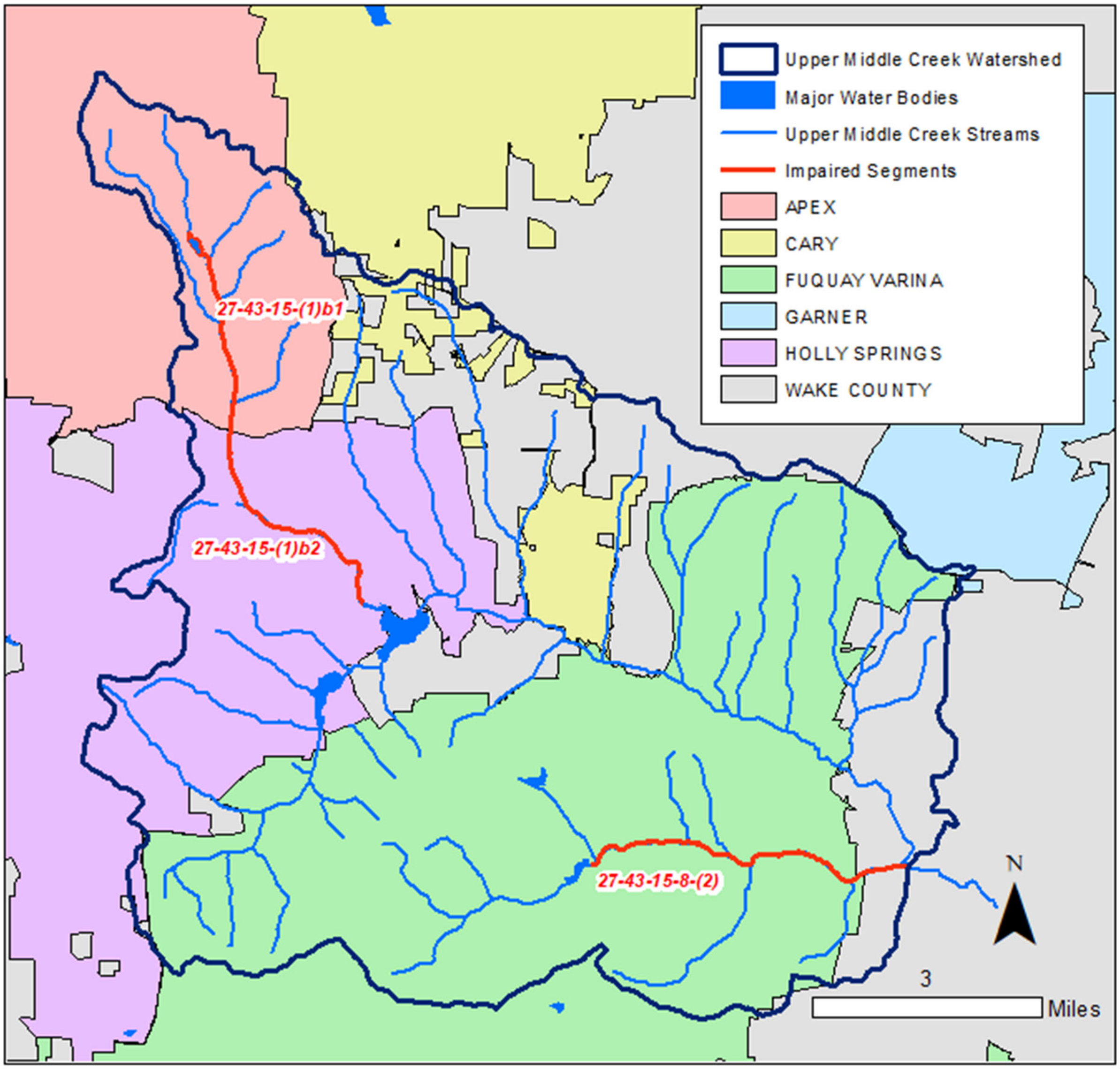
Assessment Unit	Creek Name	Description	Reason for Rating	Parameter	Year Listed
27-43-15-(1)b1	Upper Middle Creek	From 0.9 miles south of US 1 to UT on UT on west of creek 3.0 miles downstream	Fair Bioclassification	Benthic Community	2005
27-43-15-(1)b2	Upper Middle Creek	From UT on west side of creek 3.0 miles downstream to backwaters of Sunset Lake	Fair Bioclassification	Benthic Community	2010
27-43-15-8-(2)	Terrible Creek	From dam on Johnsons Pond to Middle Creek	Fair Bioclassification	Benthic Community	2010

As shown in

Figure 6, below, the first impaired stretch of Upper Middle Creek composed of directly connected AUs 27-43-15-(1)b1 and 27-43-15-(1)b2) begins at a pond adjacent to the Apex Wastewater Treatment Plant (WWTP) and extends 5.3 miles downstream to the backwaters of Sunset Lake. The second impaired stretch is on Terrible Creek; AU 27-43-15-8-(2) begins at Johnson's Pond Dam and extends 3.9 miles downstream to the confluence of Terrible Creek and Middle Creek (approximately 0.6 miles upstream of Old Stage Rd.)

Of note, Upper Middle Creek below the dam at Sunset Lake (AU 27-43-15-(4)a1) was listed as impaired for fish community as of the 2016 303(d) list, but was delisted in 2018.

Figure 6: Impaired Stream Segments in the Upper Middle Creek Watershed



3.1.1 Benthic Community Health

Benthic macroinvertebrates such as aquatic insects and crustaceans are used as indicators of stream water quality. Macroinvertebrate species in the orders Ephemeroptera, Plecoptera and Tricoptera ("EPT" species) require cleaner water to survive than less pollution-sensitive benthic macroinvertebrates like worms and snails. Thus, the presence of "EPT" species indicates higher water quality; the presence of more pollutant-tolerant taxa indicates lower water quality. Waterbodies with high water quality will also typically contain more diverse species assemblages that remain so over time.

Species diversity, presence of pollutant tolerant species, and a range of other metrics related to both species and habitat are incorporated into 'indices of biological integrity,' (IBIs.) NCDWR's Biological Assessment Branch uses these bioclassifications to assess point and nonpoint source impacts to the waterbody, document changes over time and space, and completement other water quality and habitat data. For each waterbody where data is collected, NCDWR uses IBI scores to assign bioclassifications of Excellent, Good, Good-Fair, Fair and Poor. Rating of Fair or Poor puts the waterbody on the 303(d) list of impaired waters. The waterbody will not be removed from this list until newer data collected on the given stream or waterbody assessment unit results in a bioclassification of Good-Fair or above. Thus, many waterbodies (or rather, assessment units) remain on the 303(d) list for an extended period.

The table below shows the results of indices and bioclassifications developed based on current and historic benthic macroinvertebrate data collected in the watershed. These stations are also shown in the map in Figure 7. Current data collection stations JB295 and JB330 on Middle Creek and station IB329 on Terrible Creek are shown in red because the most recent EPT biotic indices developed based on data collected at these stations reflected impaired benthic macroinvertebrate community health on that stream assessment unit. Current station JB68 is shown in black text because data collected at this station has resulted in this AU being classified as meeting criteria. Historic data indicated by bolded dates are discussed further below.

Table 4: Biological Assessment Results and Benthic Community Impairment

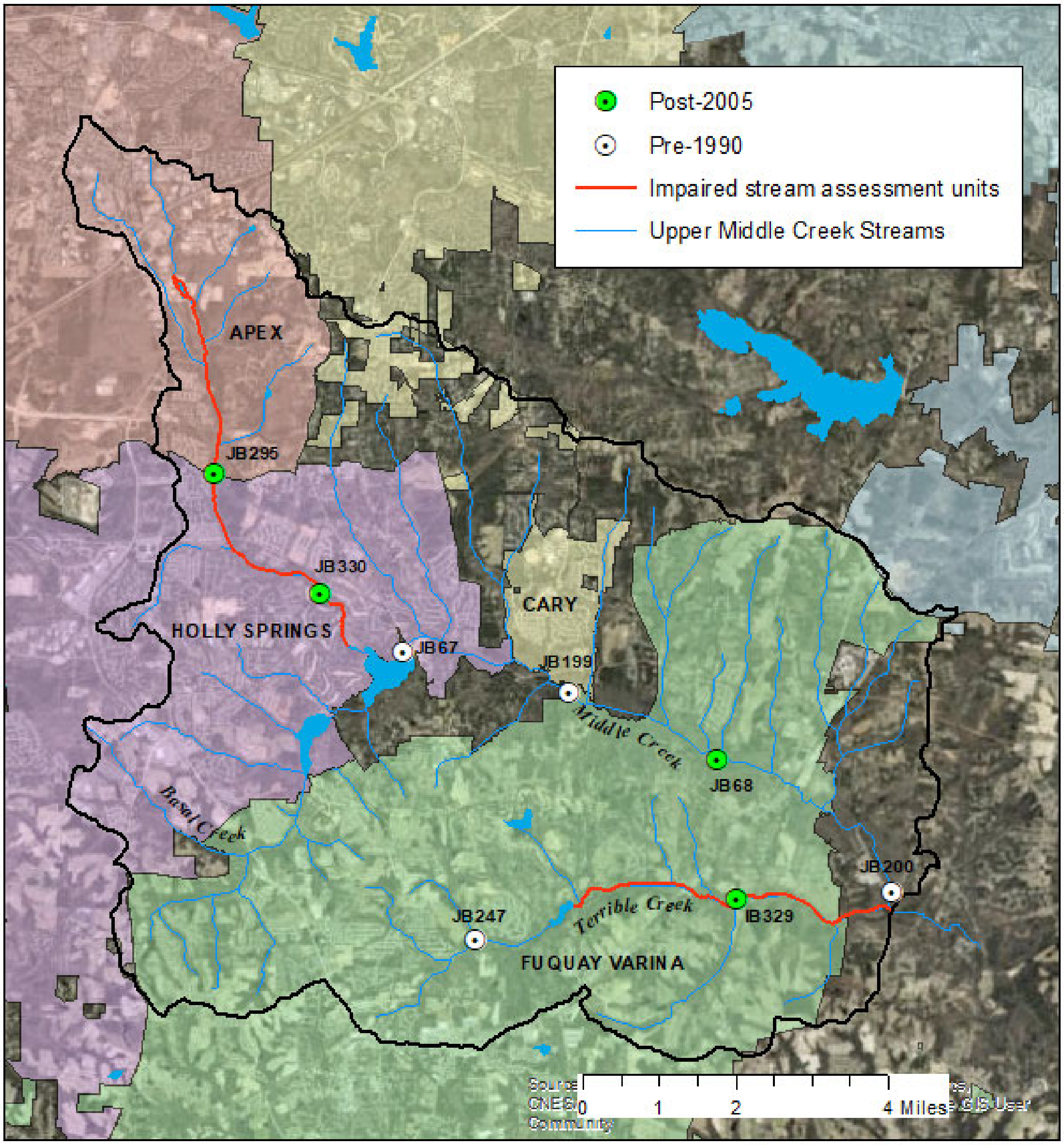
Station ID	Location Description	Most Recent Assessment Year	EPT Biotic Index	NC Biotic Index	Most Recent Bioclassification
JB295	Middle Creek at Sunset Lake Road	2005	5.85	6.44	Fair
JB330	Middle Creek at Holly Springs Road (SR 1152)	2010	6.03	--	Fair
IB329	Terrible Creek at Hilltop Road (SR 2751)	2010	5.64	--	Fair
JB068	Middle Creek at SR 1375	2015	4.96	6.08	Good-Fair
JB067	Middle Creek below Sunset Lake	**1986**	5.95	6.88	Fair*
JB199	Tallicud Road	**1986**	5.96	6.87	Fair*
JB247	Terrible Creek at SR 1301	**1990**	5.14	6.38	Good-Fair
JB200	Middle Creek at US 401	**1986**	4.87	6.17	Good

*Red text indicates impaired stream segments. * Upper Middle Creek below the Sunset Lake Dam is not 303(d) listed based on these historic data because more recent monitoring at JB68 on the same stream assessment unit reflects a Good-Fair bioclassification (and monitoring at stations JB067 and JB199 was discontinued.)*

EPT biotic indices suggest that water quality has varied over time and space rather than showing clear temporal or spatial trends. However, indices are an aggregated way of investigating water quality and benthic community health; data on species richness and abundance provides a more detailed picture, as discussed below. (EPT species richness is defined by the number of types of EPT species present at a site; abundance, by the overall number of species present that fall into these taxonomic groups.)

Identifying the cause of a benthic impairment is difficult because benthic community health can be affected by many factors, including sedimentation, habitat loss and chemical pollution. Pollution sensitive benthic macroinvertebrates also require high dissolved oxygen, neutral pH, and cold water. Much of the near-stream environment of the upstream impaired stretch of Middle Creek is forested; this intact canopy may be providing adequate shade to help keep stream temperatures cool and oxygenated and provide adequate organic matter inputs to support aquatic food web systems. Water quality data discussed in section 0 corroborates that dissolved oxygen and pH data fall within ranges supporting pollution-sensitive species. This suggests that high, flashy stormwater flows and associated sediment are likely causing the impairment by degrading benthic habitats.

Figure 7: Current and Historic Benthic Macroinvertebrate Monitoring Stations in the Watershed



3.1.1.1 Recent Benthic Data: Upper Middle Creek Mainstem

In 2005 at station JB295 in Apex, there were 12 types of EPT species, whereas in 2010, at JB330 in Holly Springs, there were 8 types of EPT species. This 33% decrease in EPT species richness between the two stations could be due to change over time or reflect some pollutant input between the upstream and downstream station that affected the EPT species. The total EPT abundance also declined between 2005 and 2010 between these two stations (see Appendix II for species data sheets.)

At JB330 in 2010, specific conductivity was measured at 482 µS/cm, while at JB295 in 2005, specific conductivity was measured at 319 µS/cm. Specific conductivity reflects the presence of "inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate," as measured by the ability of these ions to pass an electric current (EPA Web Archive, 2012.) The EPA does not place numeric limits on specific conductivity in wastewater discharges; however, "studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm [equivalent to µS/cm]," (2012), indicating that observed conductivity levels have approached the higher end of the range suitable for fish habitat.

Habitat data collected at the time of benthic sampling was also evaluated for its potential impact on benthic community health. 90% canopy cover was observed at JB330 in 2010, relative to 70% at JB295 in 2005. JB330 also showed a higher percentage of cobble and gravel substrate relative to sand and silt than JB295. Higher canopy cover and gravel substrate are more optimal habitat for pollution intolerant EPT species. Overall, total benthic habitat scores (as measured by ten habitat components including substrate and canopy cover) were better at JB330 than at JB295 (see Appendix III for habitat data sheets).

However, Upper Middle Creek's channel was wider and deeper at JB330 in 2010 than at JB295 in 2005. JB330 also had slightly worse channel modification and in-stream habitat scores than JB295 (see Appendix III for habitat data sheets). The habitat metrics observed at JB330 may be due to its watershed position (approximately 2 miles downstream from JB295), channel form evolution, or both. Potential drivers of channel form evolution could include stormwater runoff from impervious surface scouring out the streambed by bypassing buffers via concentrated overland flow or outfalls to the creek.

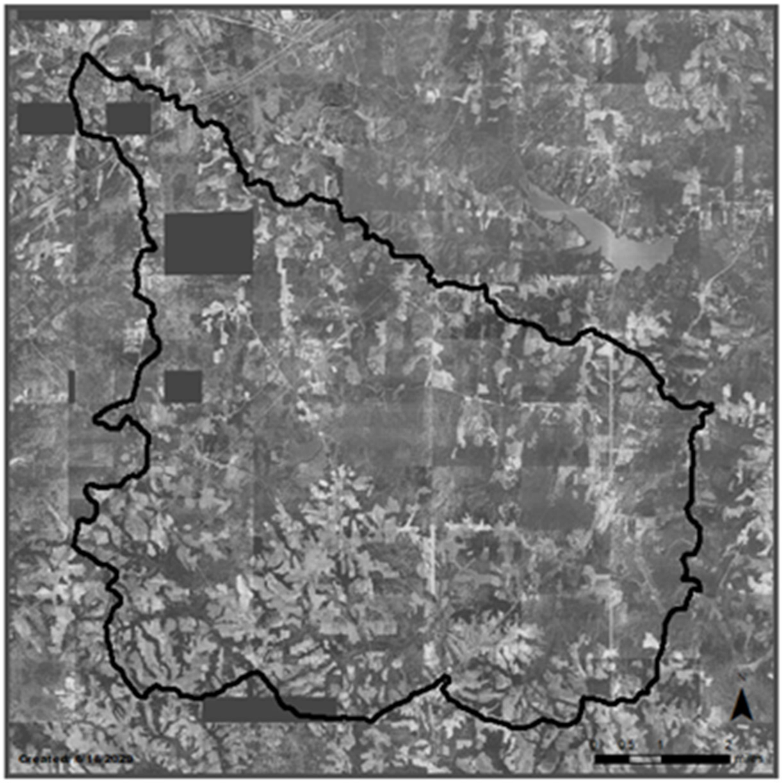
Within the unimpaired downstream portion of Upper Middle Creek shown in Figure 7, station JB068 has consistently shown higher EPT richness and abundance over the period of record (1986-2015) than at stations JB295 and JB330 on the impaired segments upstream. Specific conductivity measured at benthic sampling dates every five years from 2000 – 2015 ranged from 220 to 393 µS/cm at JB068. NCDEQ staff in August 2010 noted that this was likely indicative of upstream point and nonpoint source pollutants, including potentially the upstream Cary WWTP discharge (NCDEQ 2010.) Benthic habitat metrics at JB068 reflected less optimal bottom substrate and riffle habitat than upstream stations JB295 and JB330, as well as greater percent of silt as compared to station JB330 upstream.

3.1.1.2 Historic Benthic Data: Upper Middle Creek Mainstem

Historic (1986) benthic macroinvertebrate data were available for several stations where monitoring was later discontinued. In 1986, historic station JB200 at the watershed outlet had a bioclassification of "good" due to an EPTBI of 4.87. This sample yielded 26 total EPT taxa and an EPT abundance of 105, likely reflective of less-developed condition of the watershed at the time. Due to this station's location at the watershed outlet, it is not possible to discern any specific tributaries or upstream contributing areas that may have contributed to this bioclassification. However, the watershed as a whole was less impacted at the time. (Water quality parameters and habitat data were not available at historic NCDEQ benthic stations.)

1986 data were available both for historic station JB199 and current station JB068, two miles apart on the mainstem of Upper Middle Creek. Both stations showed similar EPT abundance; JB199 had slighty lower total EPT abundance and slightly higher EPTBI than JB068. This part of the watershed was largely forested and agricultural land in the 1980s and prior, as shown in the historic aerial photograph below:

Figure 8: 1974 Aerial Photograph of Upper Middle Creek Watershed (credit: Wake Soil and Water Conservation District)



Historic station JB067, just below Sunset Lake, is approximately 1.5 miles downstream of current station JB330, for which there only exists one sample collected in 2010. Despite the spatial distance and 32-year timespan, these stations had similar EPT richness and EPTBI. JB330 had higher EPT abundance in 2010. While ratings suggest benthic community health at current station JB330 in 2010 was similar to historic station JB067 in 1986, the presence of the Sunset Lake impoundment between these two stations makes it hard to draw conclusions about why, as impoundments affect benthic habitat by changing sediment and streamflow dynamics, nutrient cycling, water temperature, and aquatic organism passage (Poulos et al 2019).

3.1.1.3 Recent and Historic Benthic Data: Terrible Creek Tributary

The Terrible Creek tributary, which joins Upper Middle Creek just before the watershed outlet, is impaired based upon a single 2010 special study sample collected at IB329, which yielded a "fair" rating due to an EPTBI of 5.64. The most recently available Neuse Basinwide Water Quality Plan recommended in 2009 that this benthic monitoring be conducted due to upstream wastewater treatment plant discharge violations at the time yielding higher total ammonia and biochemical oxygen demand than permitted, as well as due to the presence of upstream development (NCDEQ 2009).

Historic station JB247 on Terrible Creek was last sampled in 1990, and receved a rating of "Good-Fair" due to an EPTBI of 5.14. This historic station is approximately 3.5 miles upstream of IB329 on Terrible Creek, and the Johnson Pond fishing impoundment lies between the two. The sample taken at this station in 1990 yielded 16 EPT taxa and an abundance of 75. The 2010 benthic macroinvertebrate survey at IB329 yielded 12 EPT taxa and an abundance of 54 individuals. This 25% decrease in EPT richness and 28% decrease in EPT abundance may be due to increasing development in the watershed, change in other conditions over time, reflect impacts of IB329's position downstream of an impoundment, or a combination of all the above.

3.1.2 Fish Community Data

Fish monitoring data indicated that all portions of Upper Middle Creek met biological criteria for fish community health per the 2018 303(d) list. However, the segment of Upper Middle Creek below Sunset Lake (AU 27-43-15-(4)a, currently meeting all criteria) was listed as impaired in 2016 due to a "Poor" fish community rating. The current determination that fish communities in the watershed are meeting biological criteria is based on 2015 fish data from Upper Middle Creek yielding a "Good" rating and from Terrible Creek yielding a "Good-Fair" rating. DEQ data summary sheets (in Appendix IV) show that fish species diversity and fish NCIBI scores (and thus bioclassifications) at these stations have fluctuated since 2004. The tables below show the changes over time of total species and NCIBI score/rating at the two recently sampled fish community stations, JF34 on Middle Creek and JF35 on Terrible Creek.

Table 5: Fish Community Trends at Station JF34 on Middle Creek

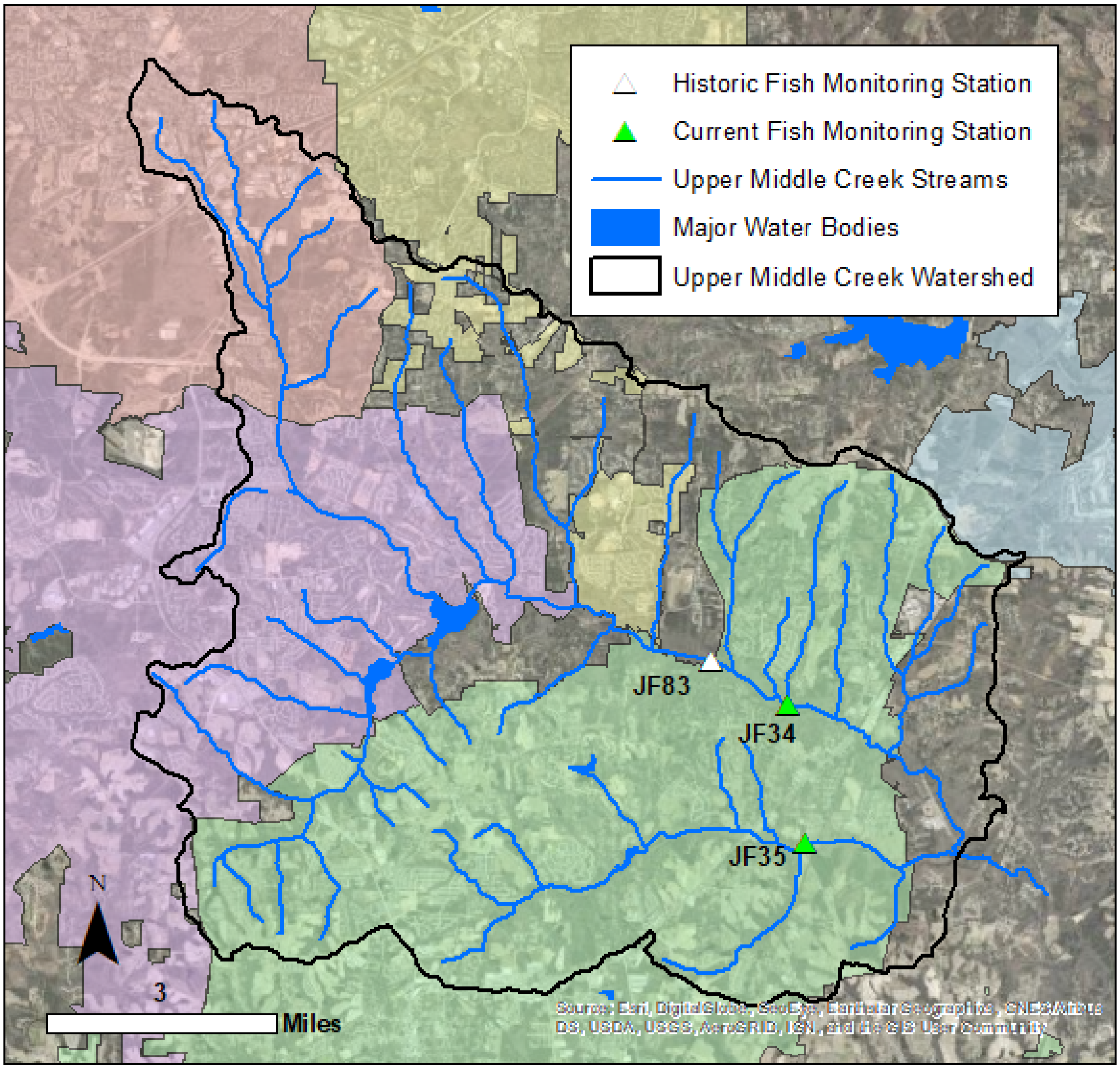
Sample Date	Species Total	NCIBI Score	NCIBI Rating
5/21/2015	20	48	Good
6/2/2011	21	40	Good-Fair
4/21/2010	20	44	Good-Fair
7/20/2004	27	54	Excellent

Table 6: Fish Community Trends at Station JF35 on Terrible Creek

Sample Date	Species Total	NCIBI Score	NCIBI Rating
3/30/2015	14	44	Good-Fair
4/21/2010	17	52	Good
4/8/2005	14	50	Good

Historic station JF83 on Middle Creek is included on the map in Figure 10, but no data sheet was available for this station. Its bioclassification of Excellent in 1995 was reported on NCDEQ's Wadeable Streams Fish Community Assessments webmap.

Figure 9: Current and Historic Fish Community Monitoring Stations



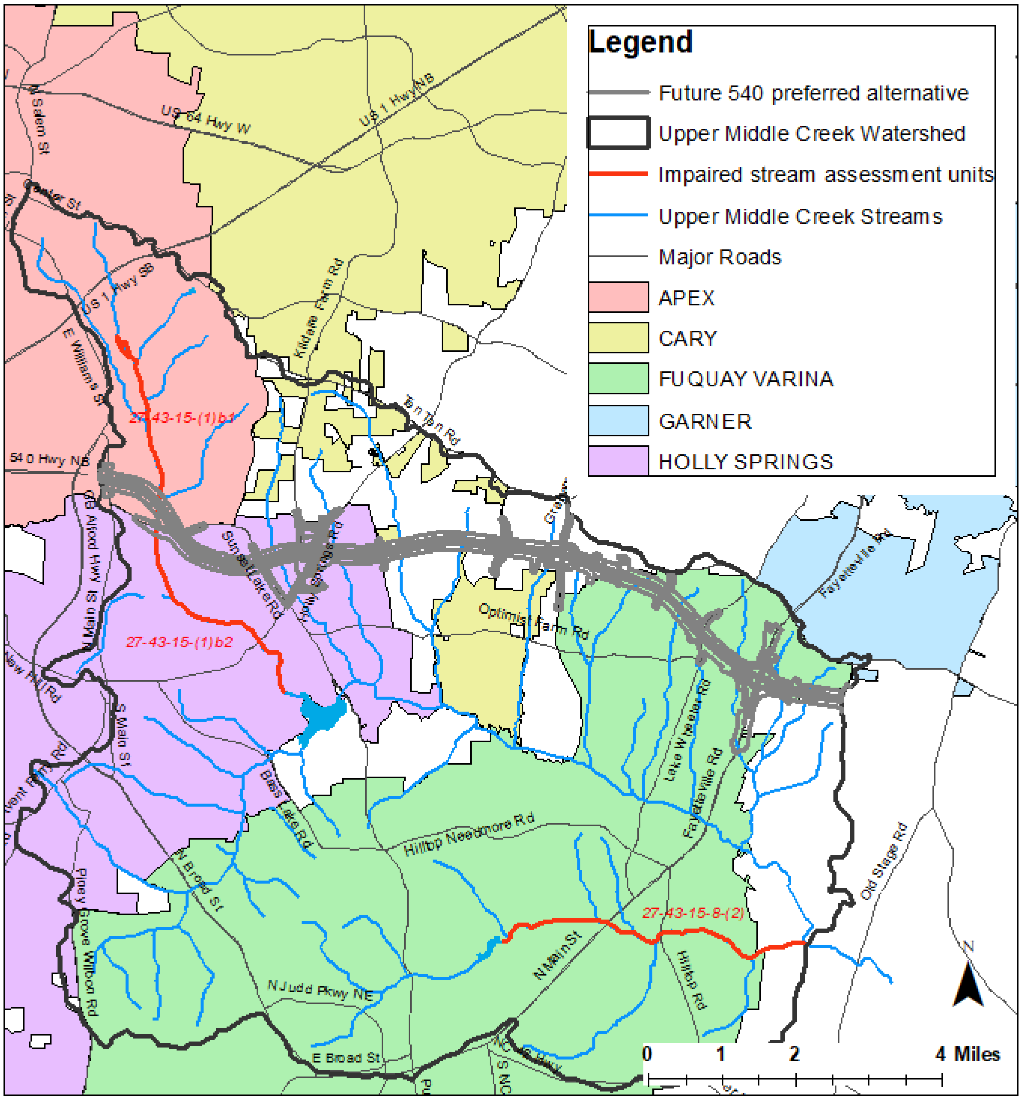
Maya Cough-Schulze, 6/18/20
Data sources: Wake County Open Data
National Hydrography Dataset
NCDEQ Open Data

3.1.3 Stakeholder Concerns Regarding Water Quality

3.1.3.1 "Complete 540" Expressway Impacts

Local government staff have expressed concern about potential impacts of the "Complete 540" route on water quality resulting from increased development which will impact the watershed. The selected route skirts municipal downtowns but cuts across Upper Middle Creek and many of its tributaries, as shown in the map below.

Figure 10: Proposed "Complete 540" Path through Wake County

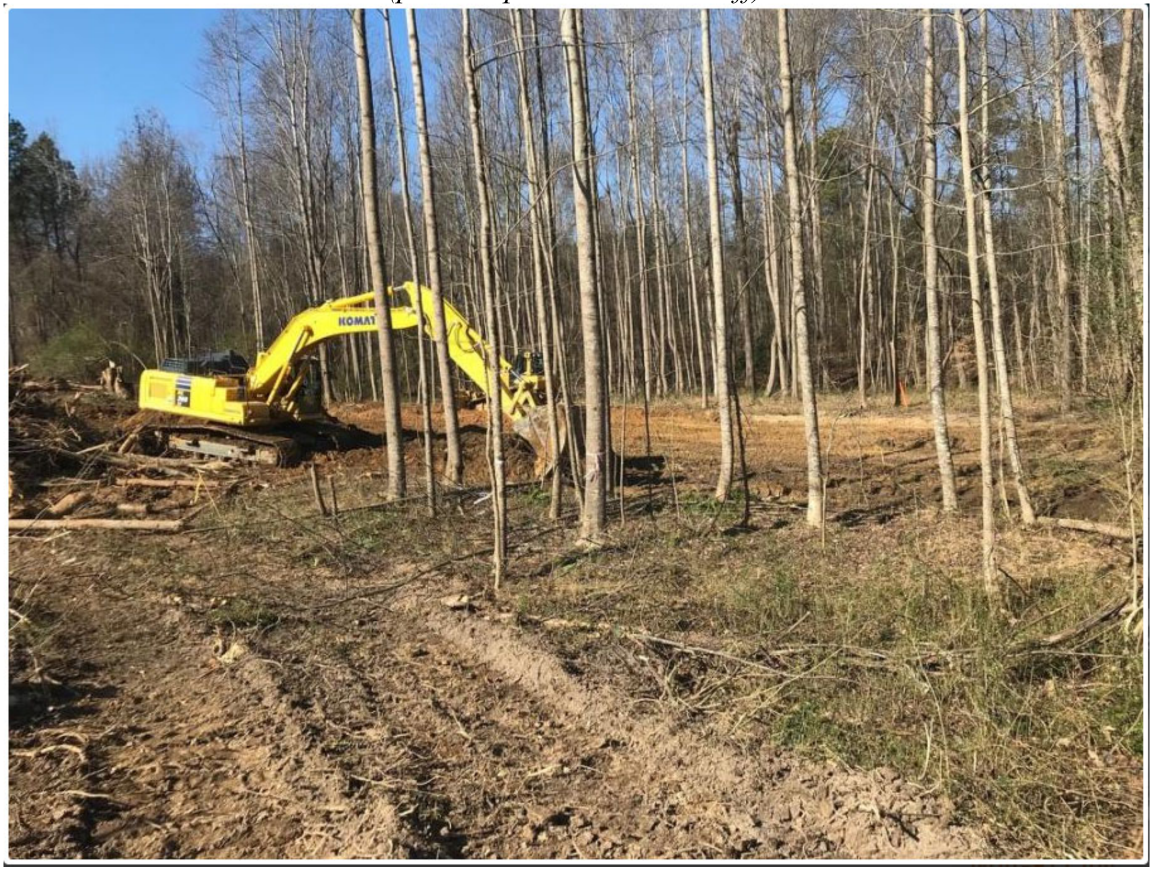


Maya Cough-Schulze, 2/7/2020

Michael Baker International's *Indirect and Cumulative Effects Memorandum* states that because growth is expected to be so rapid in this area, additional impervious surfaces created by the 540 extension are projected to increase greatly between the 2010 Baseline and 2040 No-Build scenarios regardless of whether the project happened (Michael Baker International, 2017). They modeled changes in water quality between 2040 Build and No-Build scenarios, finding >1% increase in impervious surface in the Upper Middle Creek watershed between the 2040 Build and No-Build scenarios. They also concluded that increased degradation of water quality was "likely to occur with or without construction of the Complete 540 project" (2017.)

This document further stated that the "ultimate impact of new development on water quality will be shaped by development and conservation practices [and] existing local stormwater regulations and specific best management practices (BMPs) that further limit impervious surfaces and/or encourage stormwater retention and treatment methods," (2017.)

Figure 11: Clearing land for bridge foundations near I-40 and U.S. 401, December 2019 (photo: Spectrum News Staff)



Groundbreaking for the first phase of this project began in December of 2019 (Spectrum News staff, 2019.) Several routes, shown below, were considered for the project, which has been in consideration in some form for 20 years (Sorg 2018.) The route that NCDOT ultimately selected is projected to have lesser impacts on rare species than some of the routes initially considered. The "Complete 540" expressway route that NCDOT ultimately selected did not cut across the important Middle Creek Bluff and Floodplain habitat, outlined in Section 2.4. The Blue-Purple-Lilac route shown in the map below, considered in 2013, would have cut through these sensitive habitats (H.W. Lochner, Inc, 2015). The route alternatives considered and the selected alternative are shown below (US Department of Transportation Federal Highway Administration, 2018).

Figure 12: "Complete 540" – Proposed Expressway Route Options, October 2013

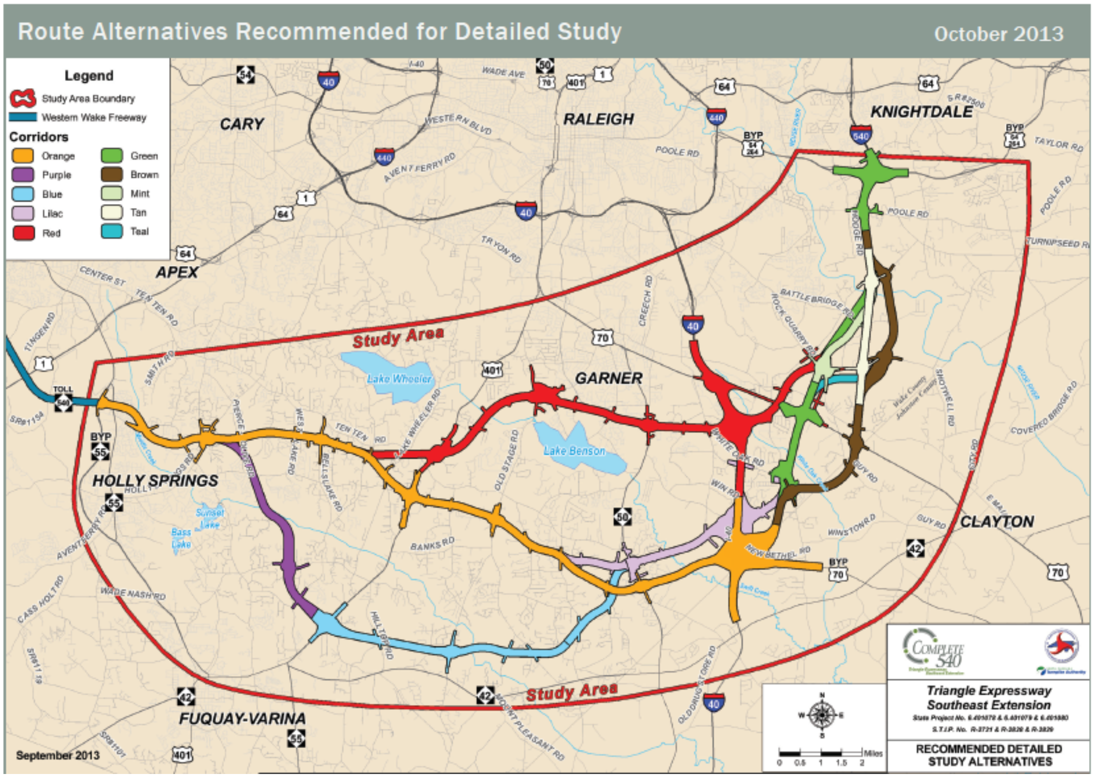


Figure 13: Selected "Complete 540" Expressway Route

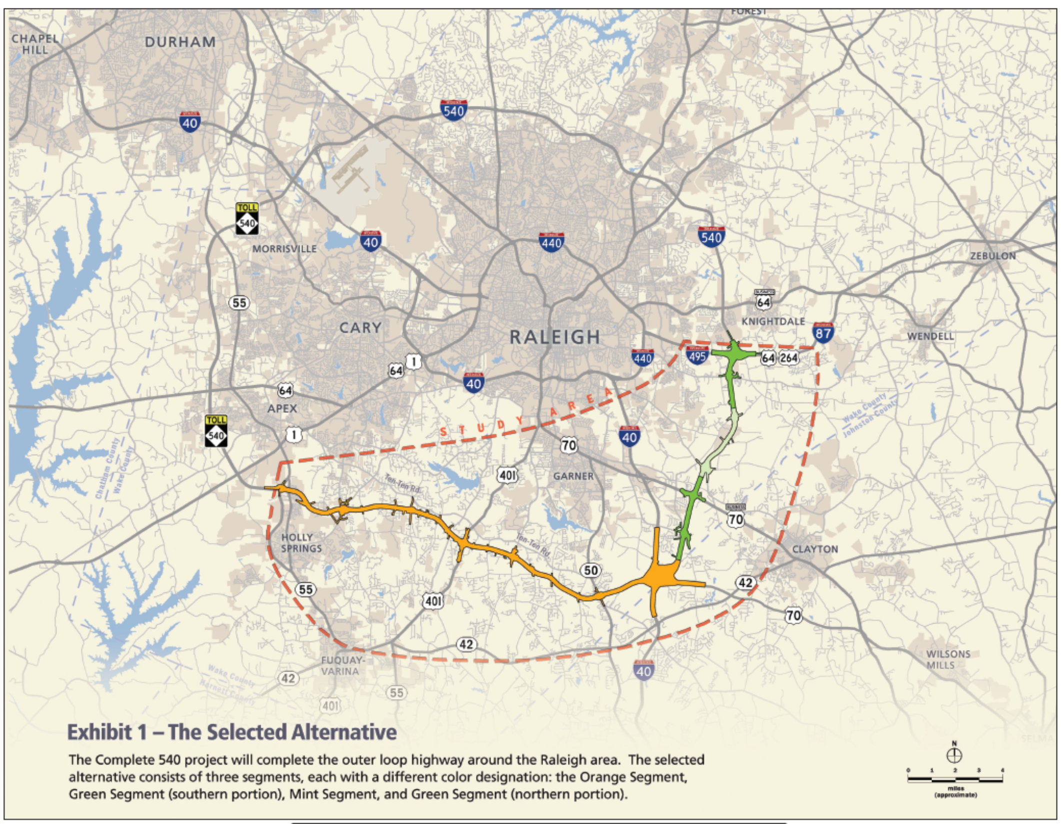
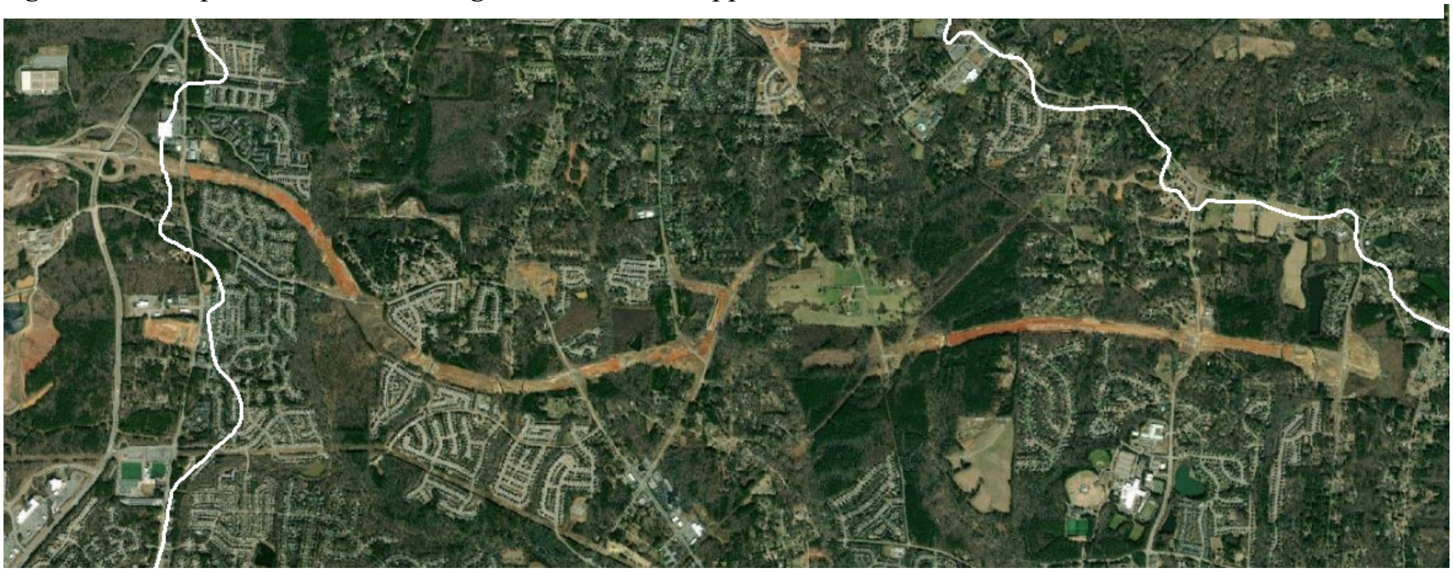


Figure 14: Complete 540 Route Being Constructed in Upper Middle Creek Headwaters



While the Expected Effects of the Preferred Alternative states that there will be no environmental justice impacts (NCDOT 2018), other sources have suggested this may not fully encompass the impacts of the expressway extension. Per a 2018 NC Policy Watch article, the selected route will displace residents of Blue Skies Mobile Home Park near Apex. Additionally, as the extension will be a toll road, those who cannot afford the toll are expected to use other roads, which could increase congestion there (Sorg 2018.)

3.1.3.2 Limited Public Land, Funding, and Incentive for Watershed Restoration

Local government staff have reported limited public land on which to complete watershed restoration projects due to the largely suburban residential nature of land use in their jurisdictions. Other barriers to more widespread implementation of watershed restoration projects include lack of funding or other incentives for private landowners or homeowners' associations to implement projects not required by regulation, or upgrade existing, older, privately owned SCMs that may not provide as many benefits as newer stormwater treatment practices.

Apex and Holly Springs staff cite as a challenge how significant area was developed prior to current stormwater or sediment and erosion control regulations, and these areas have thus been built out without SCMs. Given this and the reality of rapid development, stream restoration to prevent further streambank erosion and urban tree and buffer preservation to absorb stormwater and sediment before it reaches streams are more likely to be feasible than SCM implementation in the near term in the Upper Middle Creek watershed.

3.1.3.3 Specific Pollutant Concerns

Holly Springs staff have identified erosion and sedimentation as issues of concern in the watershed. As can be seen in the photo below, upstream sediment loads have created a delta at the mouth of Middle Creek as it flows into Sunset Lake. Carried by stormwater to the lake, this sediment likely originates from significant streambank erosion due to concentrated stormwater flow as well as copious new development in the watershed.

Holly Springs staff report that the Sunset Lake Homeowners' Association (HOA) has not expressed interest in SCM implementation and wants to dredge the sediment in Sunset Lake, forming a delta shown below in June 2019:

Figure 15: Sediment deposition from Middle Creek into Sunset Lake (photo: Maya Cough-Schulze, June 2019)

In addition to erosion and sedimentation, nonpoint source nutrient pollution may be a concern as Upper Middle Creek lies within the nutrient-sensitive Neuse River Basin. Municipal staff from multiple jurisdictions expressed concerns about the nutrient loads exported from their older developments given their regulation under the new Neuse Nutrient Strategy.

An NCSU study incorporating data from the upstream Falls and Jordan Lake watersheds found that land urbanized before 1980 exported more than double the total nitrogen and phosphorus of either agricultural land or urban land developed after 1980 (Miller 2019.) While this study and associated report did not evaluate data in the Upper Middle Creek watershed, characteristics of pre-1980 development including "legacy effects (e.g., older wastewater infrastructure, scoured or buried stream networks, lack of best management practices (BMPs)), or merely…increased imperviousness associated with high-density areas," (Miller 2019) may be reasons for increased export from older development in the Upper Middle Creek watershed as well.

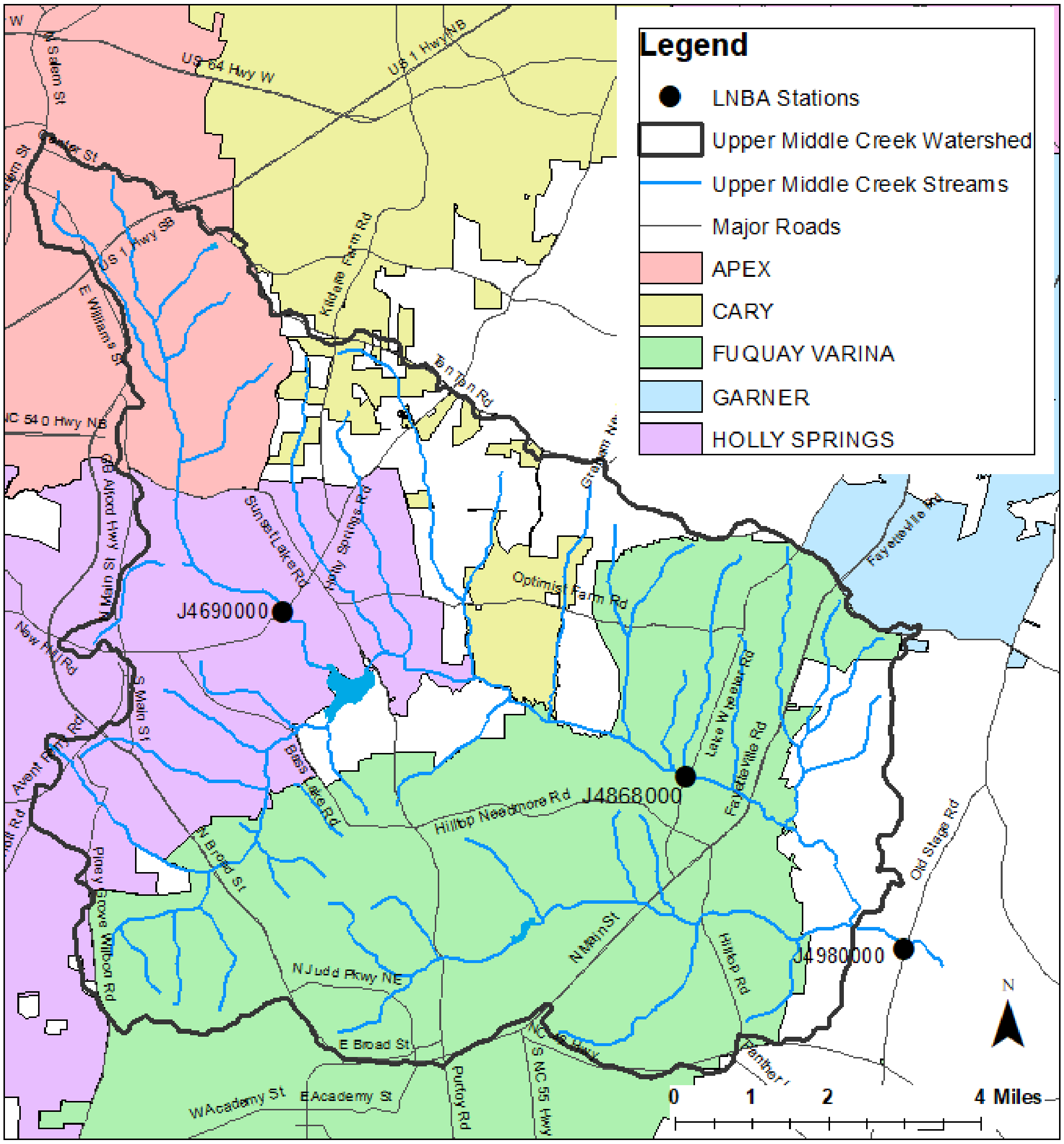
3.2 Water Quality Data and Potential Stressors

The goal of this section is to characterize data that may be related to or inform the benthic impairment described in previous sections, as well as to describe other pollutants of potential concern such as nutrients and fecal coliform bacteria. Physical, chemical and bacterial water quality data were reviewed at three stations with a recent multiyear record (2005-2018, as Station J4868000 has only been sampled since 2005.) Two stations lie within the Upper Middle Creek watershed, while one is at the outlet just outside the watershed, as shown in Figure 16 below. Parameters of interest are described below for these three stations for the period of record.

3.2.1 Data Gaps

NCDEQ does not currently perform regular ambient water quality monitoring at any stations in this 12-digit HUC. The data presented here were collected by the Lower Neuse Basin Association (LNBA), a coalition of wastewater dischargers who collect data on end-of-pipe and in-stream water quality as a component of compliance with their NPDES permits. NCDEQ uses this data to monitor potential discharge violations and indications of degradation of water resources. The wastewater dischargers that comprise the LNBA monitor water quality data on a monthly basis at the stations shown below.

Figure 16: Lower Neuse Basin Association Monitoring Stations



It is typical of this monitoring to collect samples during non-storm conditions, so the data presented represent primarily baseflow conditions rather than the impacts of large rain events. This suggests that monitoring coalition data may not fully represent the impact of nonpoint source pollutants (such as sediment) in this watershed, which may play a larger role in degrading benthic habitats during and immediately after large storms. Table 7, below, summarizes the water quality parameters evaluated from the available data.

Table 7: LNBA Water Quality Monitoring Data Summary, 2005-2018

Station	Parameter	DO	Temp	pH	SpC	TSS	Total Nitrogen	Total Phosphorus	Fecal Coliform
J4690000	**Median**	7.1	20	6.9	224	5.7	2.03	0.35	250
	Max	13	28.2	8	598	277	15.01	8.46	6000
	Min	4.4	3.1	6.3	80	1.5	0.82	0.05	17
J4868000	**Median**	7.1	21.6	7.1	156	8.7	1.47	0.23	170
	Max	12.8	28.6	7.6	519	245	4.6	2.98	6100
	Min	4.4	3.2	6.6	72	2	0.49	0.05	2
J4980000	**Median**	7.2	20.4	7	164	10.5	1.33	0.17	147
	Max	12.7	28.4	7.8	494	295	7.04	2.99	5200
	Min	4.8	1.2	6.3	69	1.7	0.48	0.04	2
	Recommendation or standard	>4 mg/L		6.0 - 9.0					<200cfu

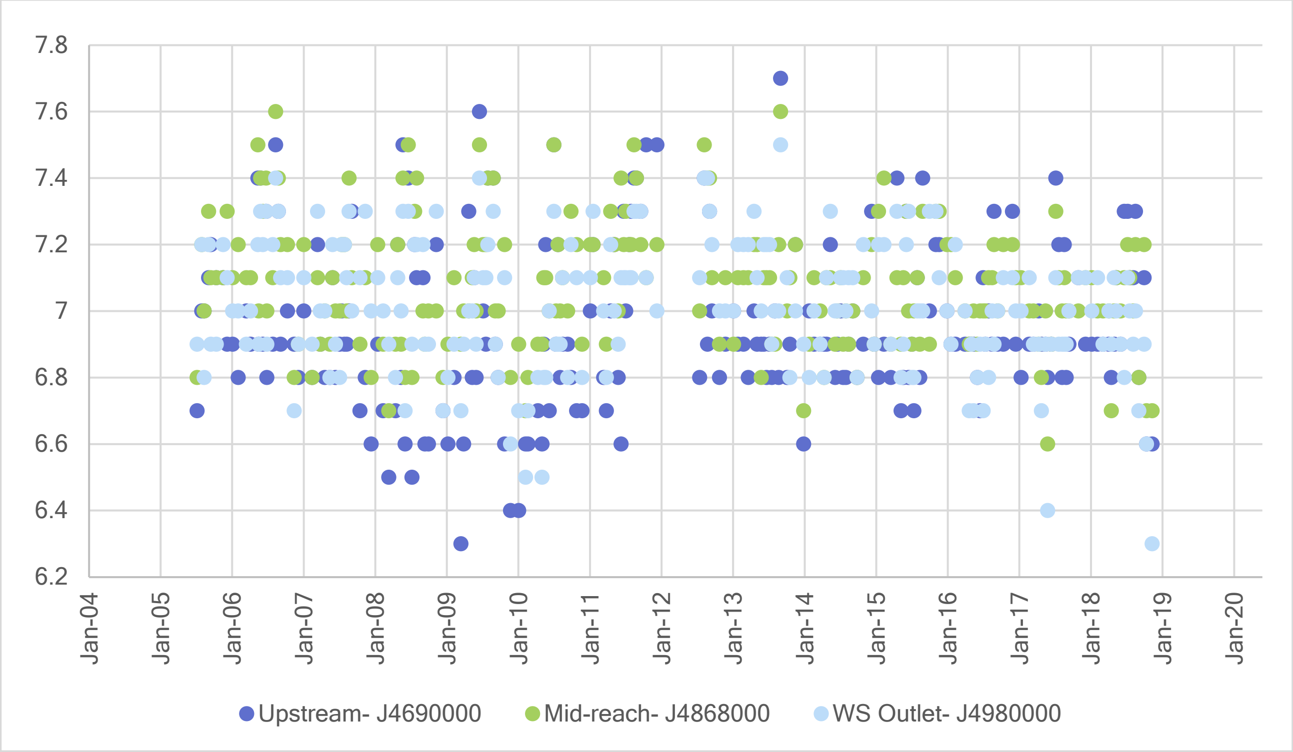
Red text indicates exceedance of EPA concern level of 200cfu/100mL for primary recreation (1976)

No clear overall increasing or decreasing trends were observed at these sites over the last 15 years; all parameters are discussed further below.

3.2.2 pH

Pollution-intolerant benthic macroinvertebrates (EPT species) require clear, cold, neutral pH water to thrive. pH values typically fell in the neutral range, indicating that pH is not a likely to be a current stressor of pollution intolerant benthic macroinvertebrates.

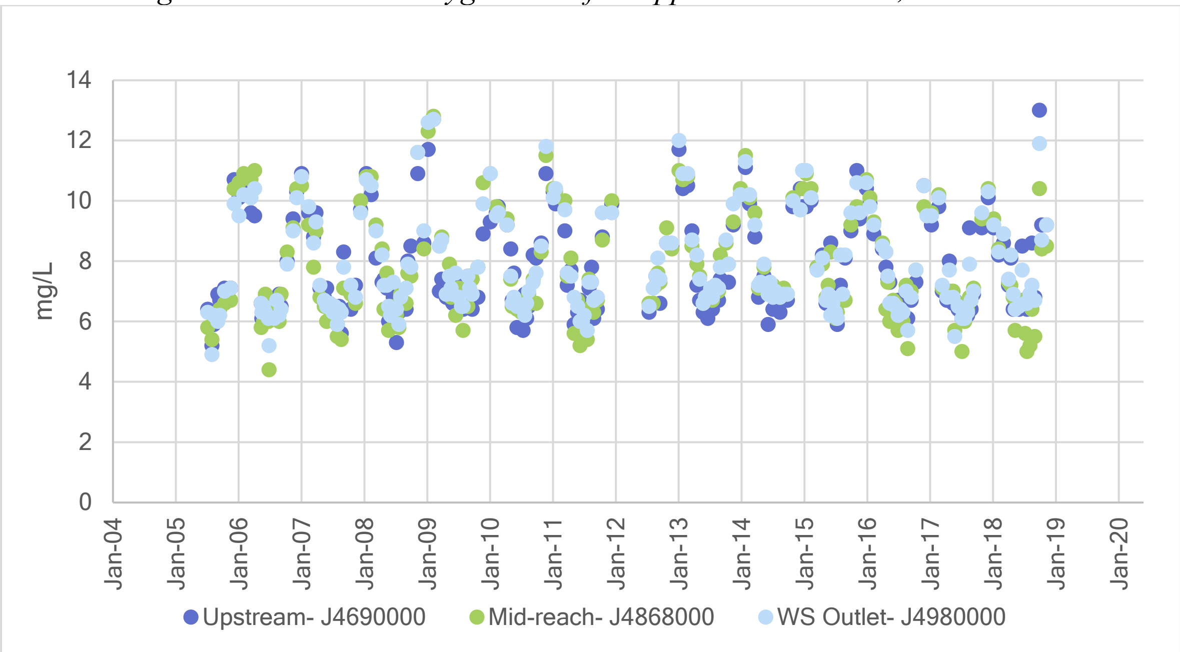
Figure 17: pH Data for Upper Middle Creek, 2005-2018



3.2.3 Dissolved Oxygen

As shown below, dissolved oxygen (DO) levels have occasionally fallen below the minimum water quality standard for aquatic life of 5mg/L, indicating that oxygen stress may be contributing to benthic community impairment, particularly in summer when oxygen levels are lower. As the watershed continues to develop, DO should continue to be assessed for the potential of future impacts on benthic macroinvertebrate health.

Figure 18: Dissolved Oxygen Data for Upper Middle Creek, 2005-2018



3.2.4 Nutrients

Upper Middle Creek lies within the Neuse River Basin, which is classified as a nutrient-sensitive water (NSW). Thus, nutrient data were evaluated to investigate whether this watershed could be contributing significant nutrient loading to NSW waters downstream, or if water quality trends could help explain benthic community impairment. Total nitrogen and phosphorus levels have fluctuated over the available 15-year data period in the watershed without showing a clear overall trend.

EPA Ecoregional nutrient criteria recommendations suggest 0.4 to 0.6 mg/L TN and 0.03 mg/L TP as reference values for good water quality (EPA, 2000.) As shown in the figure below, TN and TP values above these references indicate that nutrient sources may be impacting benthic life. Nutrients in surface water can come from a range of pollution sources present in the watershed, including fertilizer applied to farms, lawns and golf courses, leaking septic systems and other wastewater impacts, and livestock and pet waste, as well as atmospheric deposition and natural sources.

High nutrient levels are correlated with algae growth, organic matter, high suspended solids, and other conditions that do not provide optimal habitat for pollution-intolerant macroinvertebrates (EPA, n.d.) High algal biomass can also harm pollution-sensitive macroinvertebrates by physically blocking sunlight, compromising stratification in the water column, and potentially releasing cyanotoxins, depending on the species. NCDEQ's most recent Neuse Basinwide Water Quality Plan reported bluegreen algal mats in 2009 in the segment of Upper Middle Creek below Sunset Lake (currently meeting all criteria per the 2018 303(d) list) noting that these indicated high nutrient loads from NPDES dischargers and nonpoint source runoff at the time. Thus, nutrients associated with point and nonpoint source pollution should continue to be assessed to avoid any future concerns about eutrophication which could impact both aquatic ecosystems and drinking water.

No recent DEQ monitoring data reported algal mats in Upper Middle Creek. Monitoring data is typically collected during non-storm conditions, and thus may not fully reflect storm-event driven impacts of nutrients on water quality and benthic health. More frequent monitoring of conditions sooner after storms might help inform stakeholders as to the degree to which nutrients are affecting streams in the watershed.

Figure 19: Total Nitrogen Data for Upper Middle Creek, 2005-2018

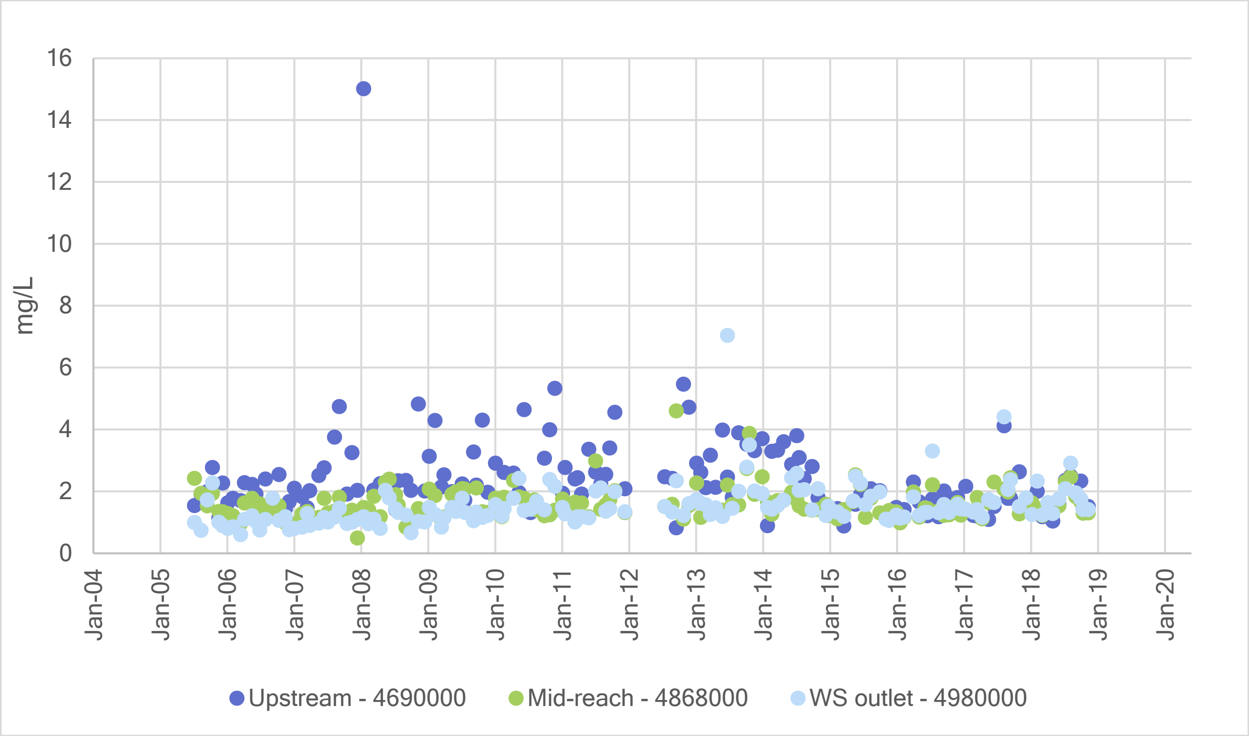
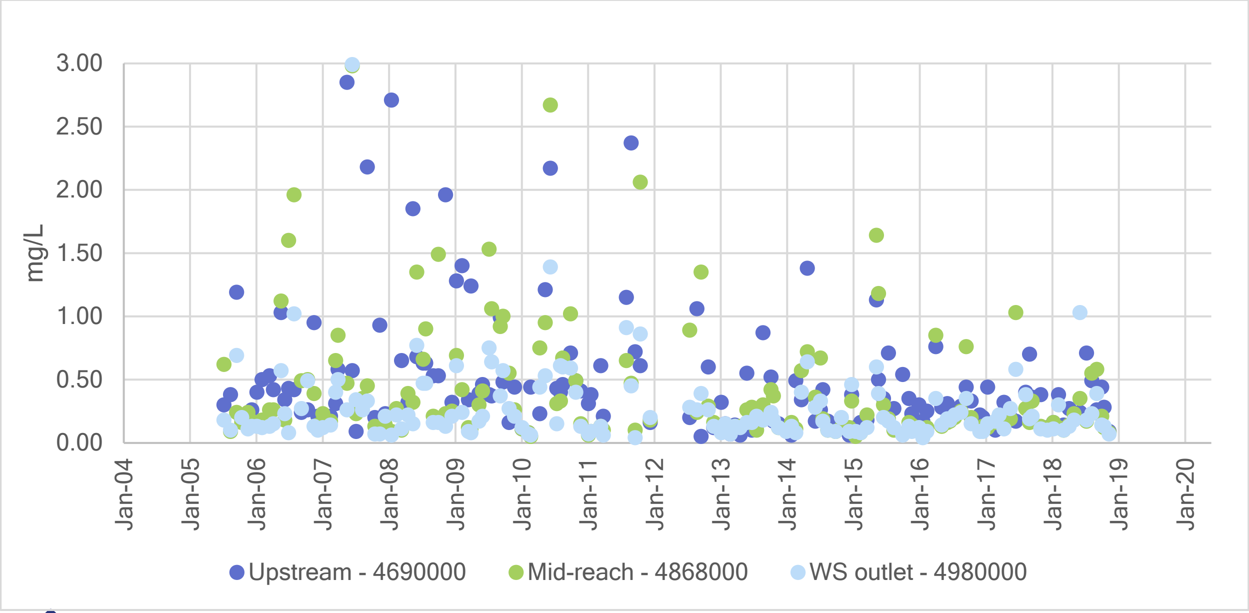


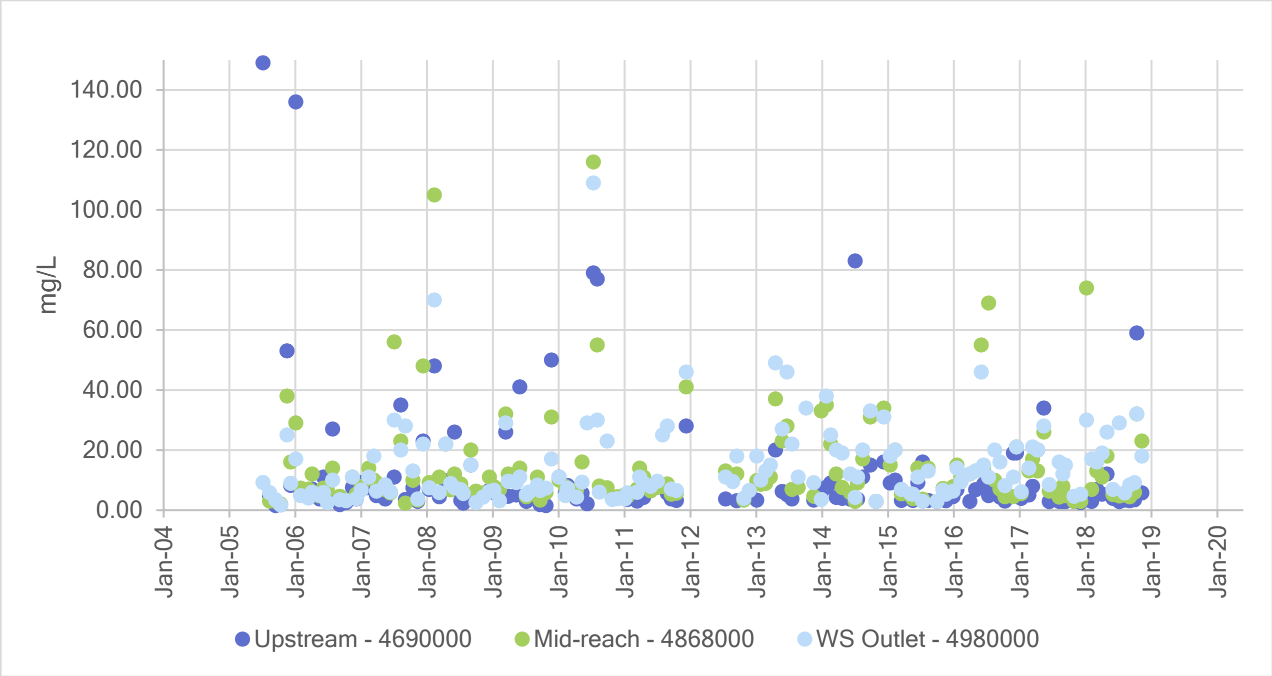
Figure 20: Total Phosphorus Data for Upper Middle Creek, 2005-2018



3.2.5 Total Suspended Solids

Total suspended solids (TSS) data were also evaluated as a potential stressor for benthic macroinvertebrates and because stakeholders identified sediment and erosion as concerns. As shown by the very high maxima in Table 7 above and Figure 21 below, occasional high total suspended solids (TSS) measurements indicate that sedimentation or other suspended pollutants may be impacting benthic life. Sources of TSS can include sediment, vehicle exhaust emissions and other vehicle-related debris, construction debris, road paint, leaf litter, and atmospherically deposited particles (Minnesota Stormwater Manual 2018.)

Figure 21: Total Suspended Solids Data in Upper Middle Creek, 2005-2018



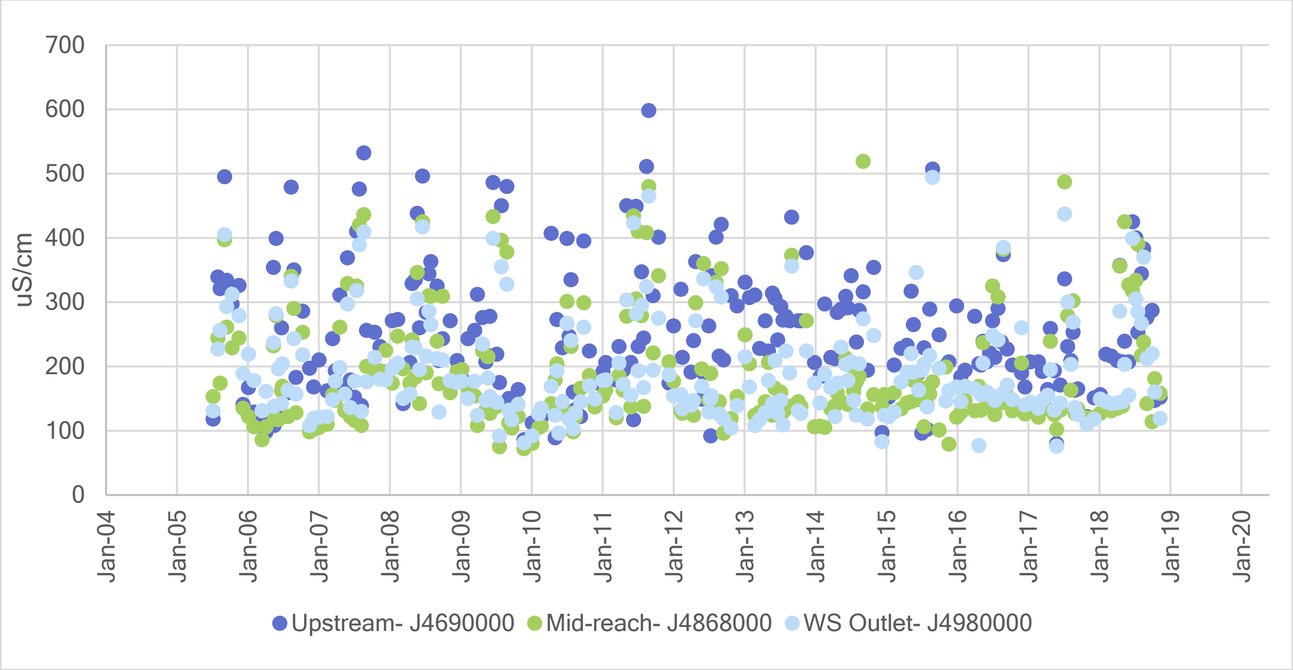
Monitoring data is typically collected during non-storm conditions, and thus may not fully reflect storm-event driven impacts of suspended solids on water quality and benthic health. More frequent monitoring of conditions sooner after storms might help inform stakeholders as to the degree to which sediment and other suspended solids are affecting streams in the watershed.

NCDEQ assigns impairment based on turbidity rather than TSS. None of the stream segments in question are currently impaired for turbidity, but Upper Middle Creek below Sunset Lake (currently unimpaired AU 27-43-15-(4)a1) was impaired for turbidity in 2008, 2010, and 2012. NCDEQ's most recent Neuse Basinwide Water Quality Plan indicated that elevated turbidity levels were likely due to the impacts of rapid growth upstream (NCDEQ 2009.) It can be inferred that sediment and other suspended solids may continue to be pollutants of concern as rapid growth continues.

3.2.6 Specific Conductivity

Specific conductivity data were evaluated as a general measure of stream water quality. Specific conductivity reflects the geology through which water flows as well as impacts of pollutant discharges to streams (EPA Web Archive 2012.) High specific conductivity levels (Figure 9) may reflect the presence of sediment from clay soils, wastewater discharges, metals, or other point or nonpoint source pollutants that could stress benthic communities.

Figure 22: Specific Conductivity Data, 2005-2018



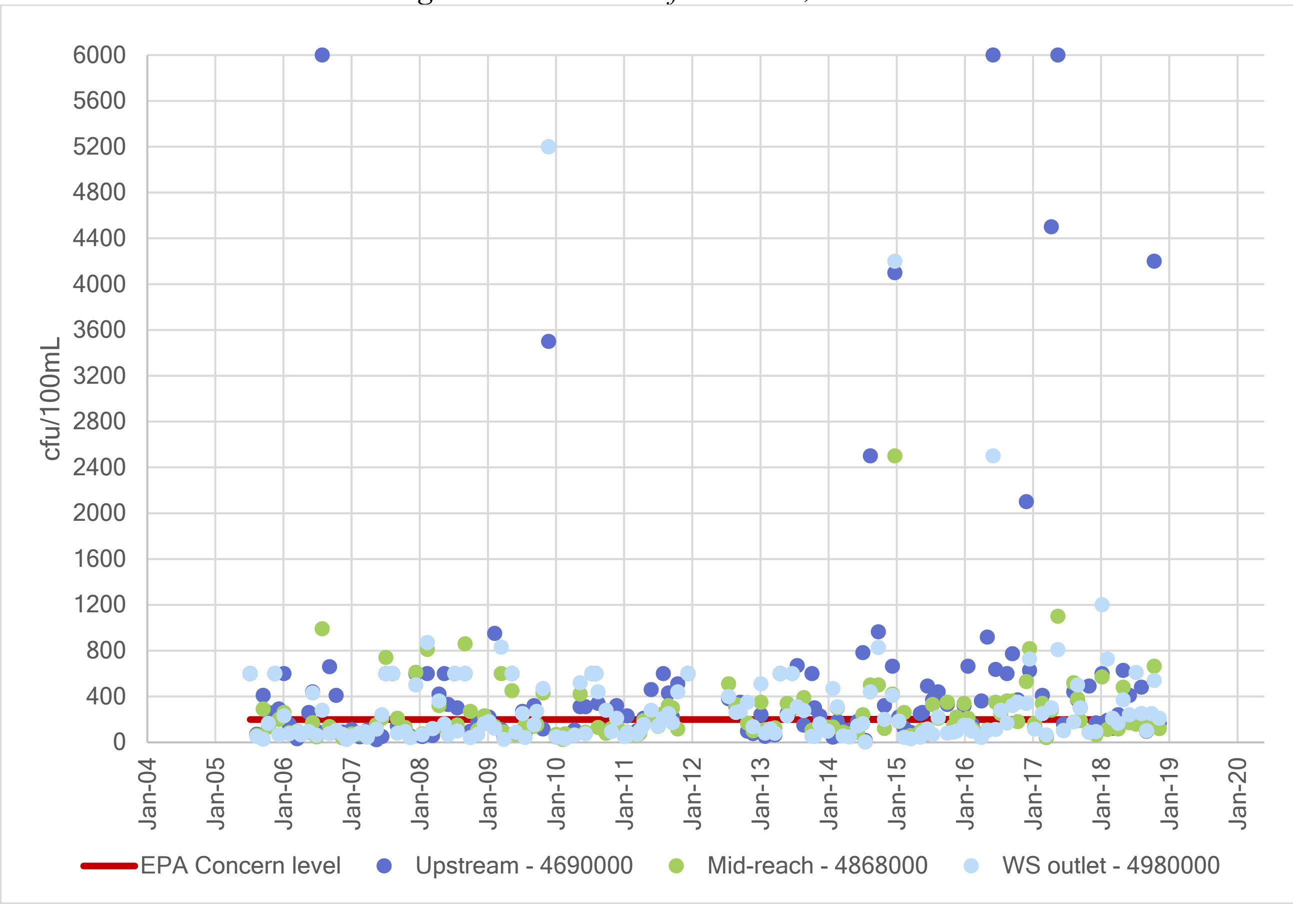
Section 3.1.1.1 outlines the NCDEQ observation of high specific conductivity at benthic site JB068 the time of benthic sampling, likely associated with an upstream WWTP outfall. Benthic station JB68 has not been impaired since 1990, suggesting that specific conductivity does not conclusively point toward a source of benthic impairment.

3.2.7 Fecal Coliform Bacteria

Fecal coliform data were evaluated as part of this plan because impaired AU 27-43-15-(1)b2 immediately upstream of Sunset Lake received a "data inconclusive" rating at the last sampling for this parameter in 2016. NCDEQ's 2018 Integrated Report Assessment Procedure manual states that this rating is assigned to fecal coliform monitoring results when "data do not meet the 5 samples in 30 days requirement needed to determine if this parameter is meeting or exceeding criteria," (NCDEQ n.d.) NCDEQ methods specify that five fecal coliform samples must exceed criteria within a consecutive 30-day period for a waterbody to be "impaired". In practice, NCDEQ staff capacity generally limits the ability to collect five samples in 30 days, so waters rated "inconclusive" could be impaired for fecal coliform. NCDEQ's most recent Neuse Basinwide Water Quality Plan confirms this, referencing "data inconclusive" fecal coliform ratings and elevated fecal coliform levels at several segments of Upper Middle Creek in the mid-early 2000s (NCDEQ 2009).

Recent LNBA fecal coliform data shown below frequently exceeded the EPA concern level of 200 cfu/100 mL for primary recreation (EPA 1976)—sometimes by orders of magnitude. This indicates that fecal coliform bacteria are a concern not just for water quality, but for recreation and human health in the watershed. This also suggests significant fecal coliform sources exist in the watershed that are not reflected by the current monitoring frequency and "inconclusive" impairment status. Sources could potentially include leaks from aging wastewater lines or septic systems, pet waste, or others.

Figure 23: Fecal Coliform Data, 2005-2018



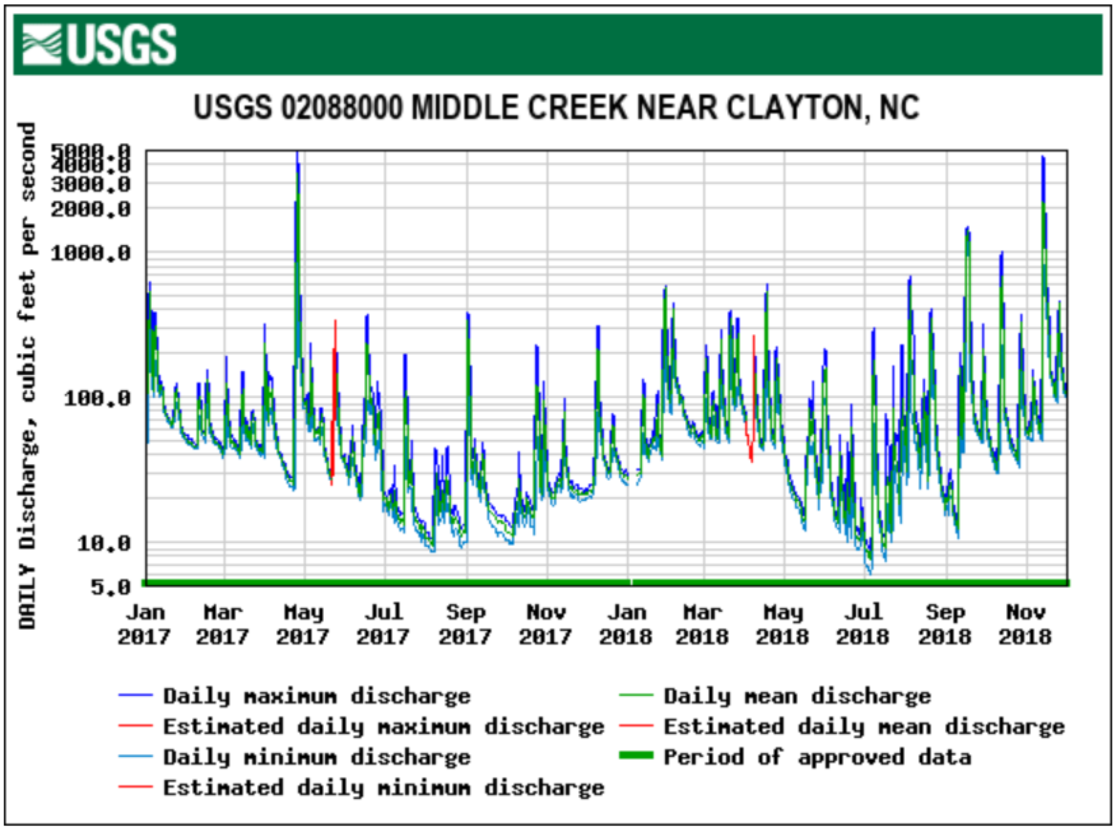
3.3 Sources Contributing to Watershed Impairment

3.3.1 Nonpoint Source Issues

3.3.1.1 Urban Stormwater Volume, Flashiness, and Associated Pollutants

Stormwater runoff volume in this increasingly developed watershed, as well as the pollutants carried by stormwater, appear to be a major pollutant source contributing to benthic community impairment. While there are no USGS flow gages within the Upper Middle Creek watershed, as shown in Figure 24, the nearest gage approximately 8 miles downstream on Middle Creek shows over an order of magnitude variation in daily discharge throughout the year. Flashy stormwater-driven hydrology is characteristic what Walsh et al. (2005) have called "Urban Stream Syndrome," in which increased stormwater volume running off from impervious areas carves out deep, canyon-like stream channels that become disconnected from their floodplains and deliver pollutants from impervious surface to streams. Low baseflows, too, affect pollutant concentrations and benthic habitat, contributing to less rich and diverse aquatic species assemblages. The interactions between streamflow, benthic habitat and pollutant concentrations was outside the scope of this project, but would be a useful area for further hydrologic study as relevant data allows.

Figure 24: Hydrograph at USGS Gage Downstream of Upper Middle Creek Watershed Outlet



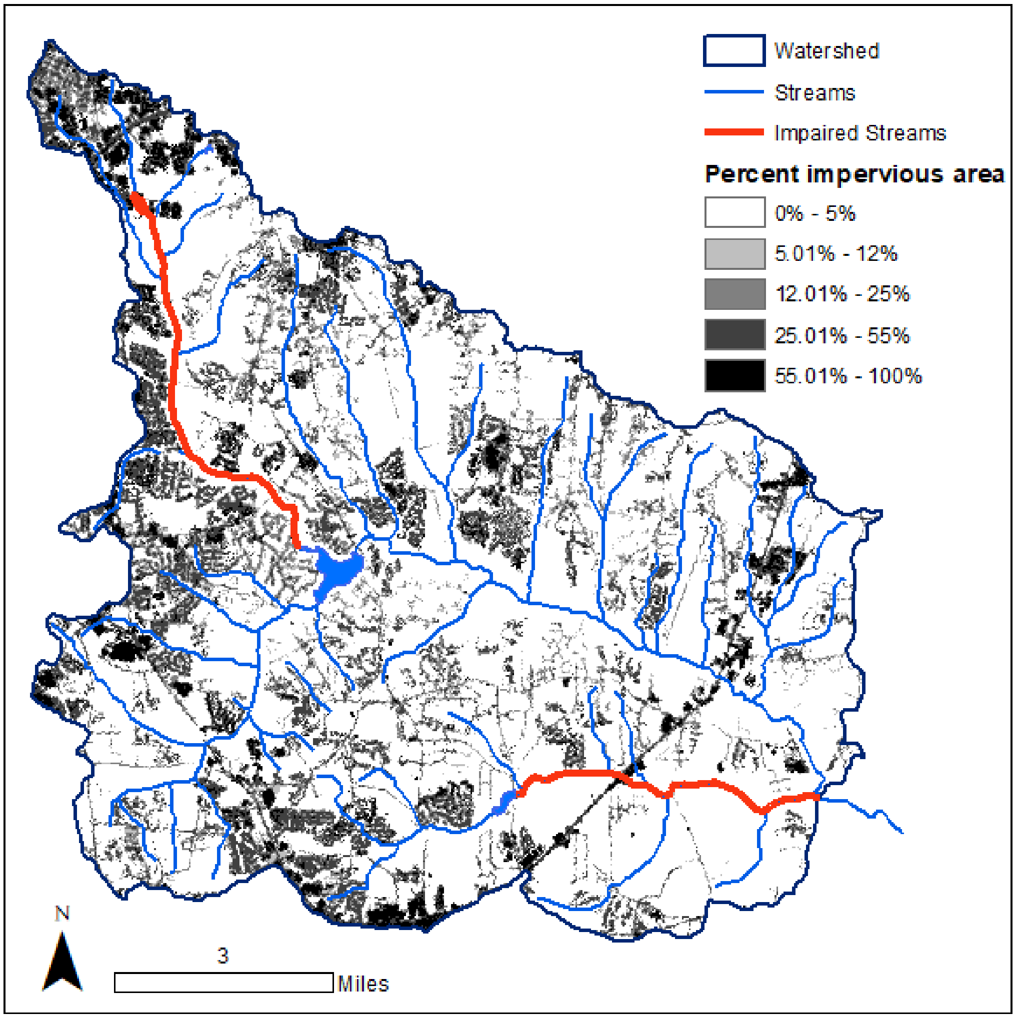
Development has greatly increased throughout the watershed over the last two decades, bringing with it increased stormwater runoff from impervious surfaces. According to the National Land Cover Dataset, between 2001 and 2016 the watershed lost over 3,000 acres of forest and 1,500 acres of agricultural land, while gaining 5,000 acres of developed land, a 13% increase. Increasing development in the watershed subsequently increases the amount of impervious surface in the watershed. This impervious surface associated with development in urban centers and along road corridors contributes significant stormwater runoff downstream, which picks up pollutants such as sediment, nutrients, and bacteria, scours prime aquatic habitat, and causes channel and bank erosion which contributes further sediment to the stream and can smother potential aquatic habitat.

Additionally, much of the developed land in the watershed is low-density or developed open space, which includes single-family residential lots and three golf courses: Knights Play Golf Center in Apex, Devils Ridge Golf Club in Holly Springs, and Bentwinds Golf and Country Club in Fuquay-Varina. These land use types typically contribute the pollutants mentioned above as well as excess pesticides and fertilizers used for lawn care and landscaping. During construction of any new developments, imperfect sediment and erosion control practices may also be contributing to the occasionally high observed total suspended solids data LNBA measured in Upper Middle Creek, outlined in section 3.2.5. As the pace of development continues to increase, these changes underscore the need for protection of existing forest and wetland areas, as well as projects to restore water quality. Municipalities in the watershed are using various policy and planning tools to try to mitigate the effects of rapid development on increased stormwater runoff and associated pollutants, further outlined in section 6.2.1.

Impervious surfaces such as roads, parking lots, and roofs prevent water from soaking into the ground. Instead, water remains on the surface when it rains, resulting in a significant increase in the volume of stormwater that runs off the land. This can cause additional flooding, erosion, higher stream temperatures, and transport pollutants that can affect aquatic species.

According to research from the Center for Watershed Protection, "at between 10 – 25% imperviousness within a watershed, major alterations in stream morphology occur that significantly impact water quality. At greater than 25% impervious cover, water quality can be significantly degraded," (2003). Figure 25, below, indicates that much of the upper portion of the watershed in Apex and Holly Springs is well over 25% impervious surface, increasing the risk of degraded water quality from associated stormwater runoff in Upper Middle Creek.

Figure 25: Distribution of Impervious Surface in the Upper Middle Creek Watershed



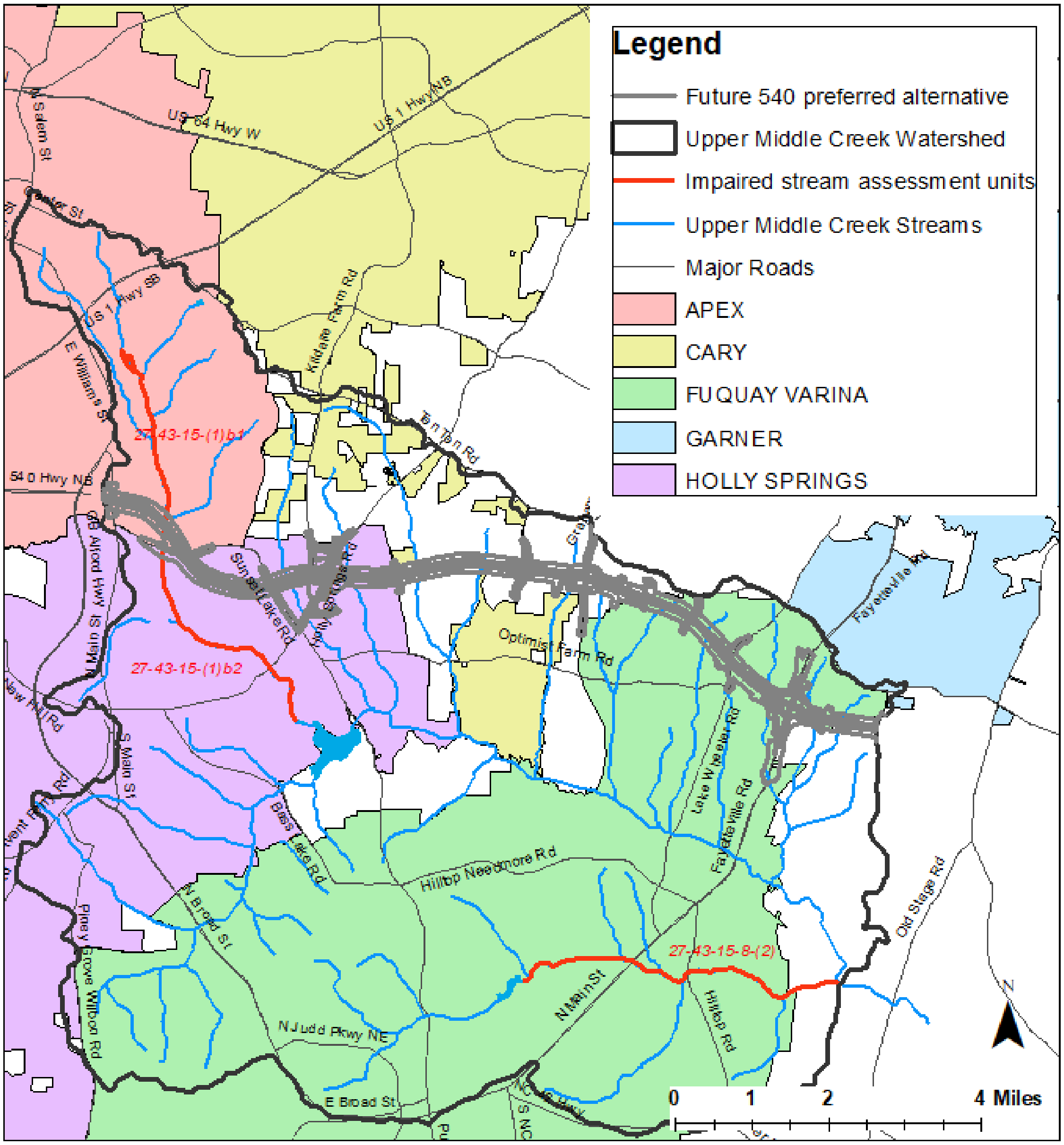
Sources: National Hydrography Dataset Flowlines Carolinas, USGS National Land Cover Database 2016 Percent Imperviousness

Created by Jannette Morris, 6/26/2019

The presence of buffers and other best management practices in Apex and Holly Springs which aim to "disconnect" impervious surface from the stream allow some stormwater flowing over impervious surfaces to infiltrate and be treated before it reaches the stream. However, concentrated, high-velocity surface flows and piped flow through a stormwater system may bypass the treatment effects of riparian buffers. Thus, in an increasingly impervious watershed such as Upper Middle Creek, any practices that might help slow, spread out, and encourage infiltration of water prior to discharge to the stream should be incentivized. This includes both large-scale stormwater control measures (SCMs) as well as many distributed smaller-scale SCMs (such as rain gardens) on public or private land. Section 7.0 details recommendations regarding SCM implementation to capture and treat runoff in the watershed.

Land clearing and construction for the "Complete 540" project will cross the northernmost impaired segment of Upper Middle Creek and add 10 miles of new highway to the watershed. Construction began in December of 2019; the first phase of this project will run 18 miles from NC Highway 55 Bypass in Apex to I-40 south of Raleigh (Olson 2020.) Impacts to Upper Middle Creek are likely as the expressway route will cross an already-impaired segment of Upper Middle Creek's headwaters. According to the USFWS Biological Conference Opinion developed as part of the Complete 540 project, "the most common contaminants in highway runoff are heavy metals, inorganic salts, hydrocarbons, and suspended solids that accumulate on the road surface as a result of regular highway operation and maintenance activities," (2019); these contaminants can reasonably be expected to increase with highway construction. Litter from roadway traffic may also increase. Additionally, over the longer term, this highway extension may incentivize development of current forested and agricultural land along the highway corridor.

Figure 26: Proposed "Complete 540" Path Through Upper Middle Creek Watershed



Maya Cough-Schulze, 2/7/2020

3.3.1.2 *Agricultural Runoff*

The total portion of agricultural land use in the watershed decreased by 4.5% between 2001 and 2016 and continues to decrease as agricultural lands are frequently converted to development. However, where cattle have access to streams on farms remaining in the watershed, they contribute to streambank erosion can deliver sediment, nutrients, and bacteria to streams. Runoff from current and historic agricultural lands may also be contributing pesticides to Upper Middle Creek. Wake Soil and Water Conservation District has identified many projects to address nonpoint source agricultural pollutants, outlined in Section 6.3.3. No land application of sludge or CAFOs were identified in the watershed.

Agricultural producers are currently satisfying the regulatory requirement outlined in the Neuse Nutrient Strategy of collectively reducing nitrogen loss from fields by at least 30% per State-approved nutrient reduction estimation methods. Despite targets being met, more information would be helpful to fully characterize the impact of current agricultural fields in production on nutrient, bacteria and sediment loads, as well as the impact of historical agricultural lands contributing legacy pollution.

3.3.1.3 Leaking Septic, Sewage, and Other Waste

The Upper Middle Creek watershed includes a high density of houses with septic systems, which when functioning improperly can yield nutrient and fecal coliform pollution to waterbodies. The Septic and Onsite Wastewater section of Wake County's Water Quality Division provides information and outreach to county residents about septic systems and their maintenance. Between 2011 and 2017, 191 out of 8979 permitted parcels in the Upper Middle Creek watershed were reported to have failing septic systems. This 2% failure rate suggests that leaking septic systems are unlikely to be a *major* cause of nonpoint fecal coliform pollution in the watershed. However, as these are only reported failures, the number of malfunctioning septic systems could be higher.

While any systems that are not well maintained have the potential to contribute contamination to the watershed, the actual contribution of septic systems to surface or groundwater in the watershed is more complicated. When septic systems malfunction and release nutrients to the environment, this does not always contribute nutrient loading to surface or ground water in the watershed. (Nutrient models to estimate the amount of loading associated with both functioning and malfunctioning septic systems do not always consider variables that affect loading rates to surface water.) Variables that affect nutrient loading associated with malfunctioning septic systems include soil type, distance to surface waters, vegetation, and type of failure (surface vs. subsurface effluent). Wake County has a required offset of 50 ft from streams, and vegetation/buffers along surface waters provide attenuation of nutrient loads prior to entering surface waters, which should be considered in any nutrient load calculations.

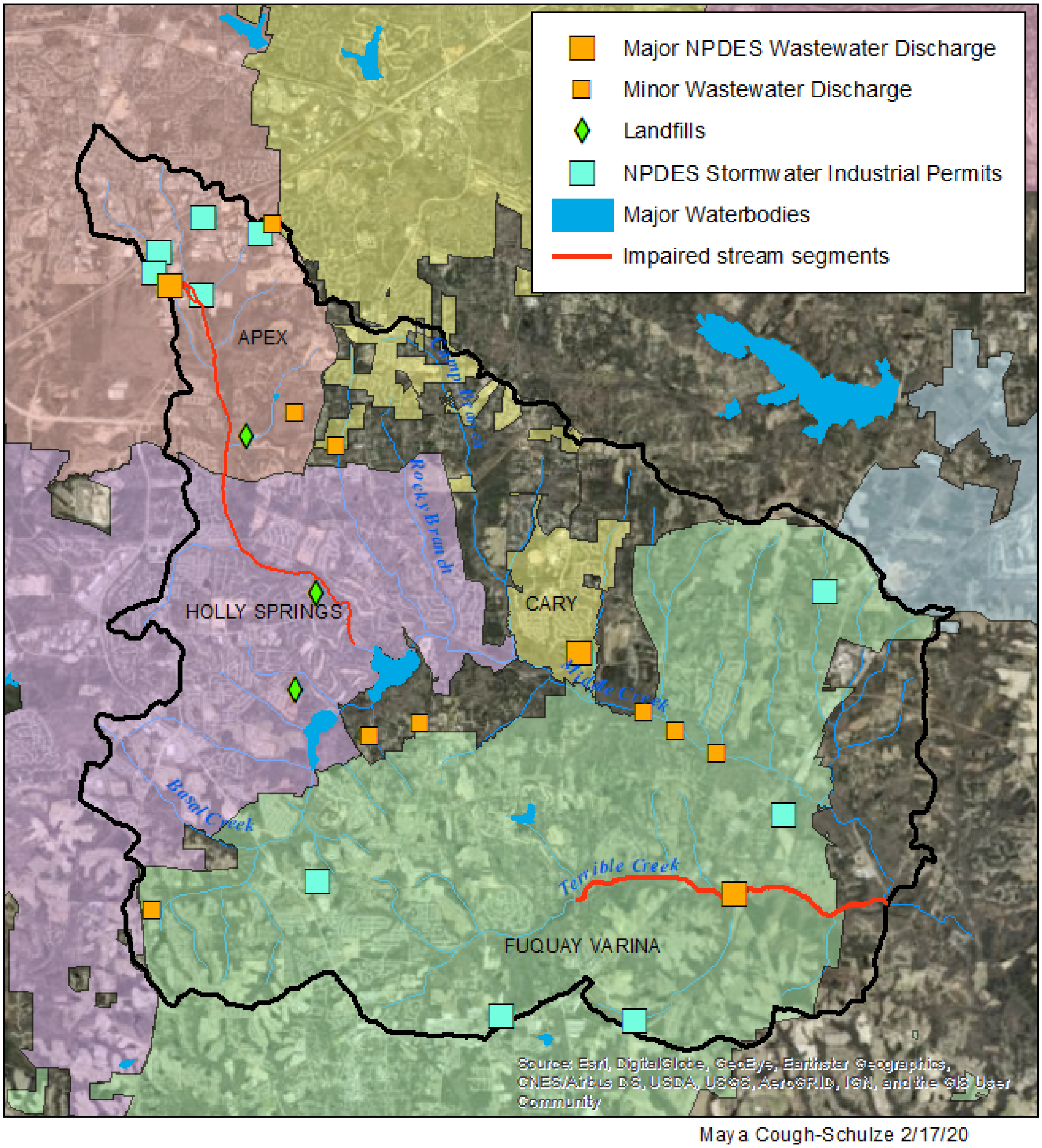
Other pollution sources that could be contributing to the elevated fecal coliform levels seen in LNBA data include illicit discharges, sanitary sewer overflows, and flashy stormwater flows carrying pet waste or naturally occurring bacterial sources to streams. The impacts of these potential fecal coliform pollution sources were not explored in detail due to a lack of available data or information.

3.3.2 Potential Point Sources

Figure 27 below depicts locations of regulated dischargers that may contribute point source pollution to the watershed (NPDES and landfill data from NCDEQ Open Data page.) As shown below, several industrial facilities have stormwater discharge permits upstream of the impaired segment in the headwaters of Upper Middle Creek, where they may contribute to high flows that alter benthic habitat. Two large municipal wastewater treatment plant (WWTP) discharges are also located along the impaired stream segments. Additionally, three pre-regulatory landfills are located near the upstream impaired segment of Upper Middle Creek and may contribute contaminants to the creek via surface or subsurface flow or leaching from groundwater if not properly managed.

Other potential point sources for which data were not available may include illicit discharges and sanitary sewer overflows, potentially abetted by stormwater entering any old, leaky sanitary sewer lines. Proper management of point source pollution cannot completely eliminate loading to the stream, and typically affords fewer opportunities for water quality improvement; therefore, recommendations in this report focus on viable nonpoint source pollution reduction or mitigation strategies.

Figure 27: Potential Point Sources of Pollution



3.3.3 Summary of Nonpoint Source Impacts

The land use and water quality information discussed in section 3 suggests that flashy stormwater flows and associated sediment are likely main contributors to the impairment of benthic communities in the watershed. Fecal coliform bacteria were also flagged as a potential pollutant of concern to water quality and potentially recreation or health. To that end, section 4 below outlines plans, policies, and projects to help restore and protect the watershed from impacts of stormwater and agricultural runoff.

4.0 POLLUTANT LOADS AND LOAD REDUCTIONS

4.1 Existing Pollutant Load Estimates

Included below are pollutant loads estimated by land uses included in EPA's STEPL tool for the full Upper Middle Creek watershed. Note that there is a degree of uncertainty inherent in estimating loads from pollution sources with minimal data, like septic systems. Because data do not exist on streambank erosion rates across the full watershed, the estimates below do not include this (likely significant) sediment source. Any sediment delivery due to streambank erosion would be additional to the below.

Table 8: Pollutant Load By Land Use Estimated Via EPA STEPL Tool

Sources	**N Load (lb/yr)**	**P Load (lb/yr)**	**Sediment Load (t/yr) (Not comprehensive)**
Urban	93,020.21	14,314.16	2,137.91
Cropland	16,356.76	4,042.99	2,012.53
Pastureland	30,202.50	3,060.88	802.40
Forest	3,225.18	1,551.37	166.36
Feedlots	1,348.07	269.61	0.00
Septic	529.43	207.36	0.00

The table above intentionally does not include a total row for N, P and TSS loads, because of the pollution sources that data does not exist to quantify, mentioned above.

Data availability in this watershed is a barrier to generating accurate estimates of existing loads as well as load reduction estimates for priority practices. Practically speaking, monitoring the benthic community will likely be used as the indicator of recovery rather than monitoring pollutant loads.

4.2 Sediment Delivery to Bass and Sunset Lakes

The EPA's Critical Source Area Identification and BMP Selection Supplement to the Watershed Planning Handbook notes that: "Biological monitoring or tracking of other indicators related to the pollutant load reduction targets may be helpful in demonstrating whether there is an impact on water quality. For example, the Long Creek Section 319 NNPSMP project in North Carolina accessed data from the local municipality on dredging at the water quality intake pool as an indicator of sediment load from eroding cropland (USEPA 2011). At the start of the project, the water supply intake pool had to be dredged quarterly to maintain adequate storage volume, but by the end of the project the frequency of dredging had been reduced to less than once per year," (2018).

If data were available when Sunset Lake was dredged, this model could be applied there (see section 3.1.3 photo of the accumulated a delta of sediment.) Data does not currently exist quantifying all sediment inputs to Sunset Lake. Consultants working for the Town of Holly Springs have assessed sediment loading rates from streambank erosion on a single tributary of Bass Lake (which feeds into Sunset Lake, shown in the map below.) They suggested that major assumptions could be made to extrapolate loading rates from this tributary to sediment delivery to the whole of Sunset Lake, with the caveat that resulting estimates could be orders of magnitude off. This exercise was undertaken resulting in the extremely high TSS estimates below but should NOT be used out of context or considered accurate. Per EPA recommendation, biological monitoring should be used to assess the impairment directly instead of using STEPL or these estimates to generate TSS load reduction targets.

Figure 28: Bass and Sunset Lake Relative to Planning Jurisdictions

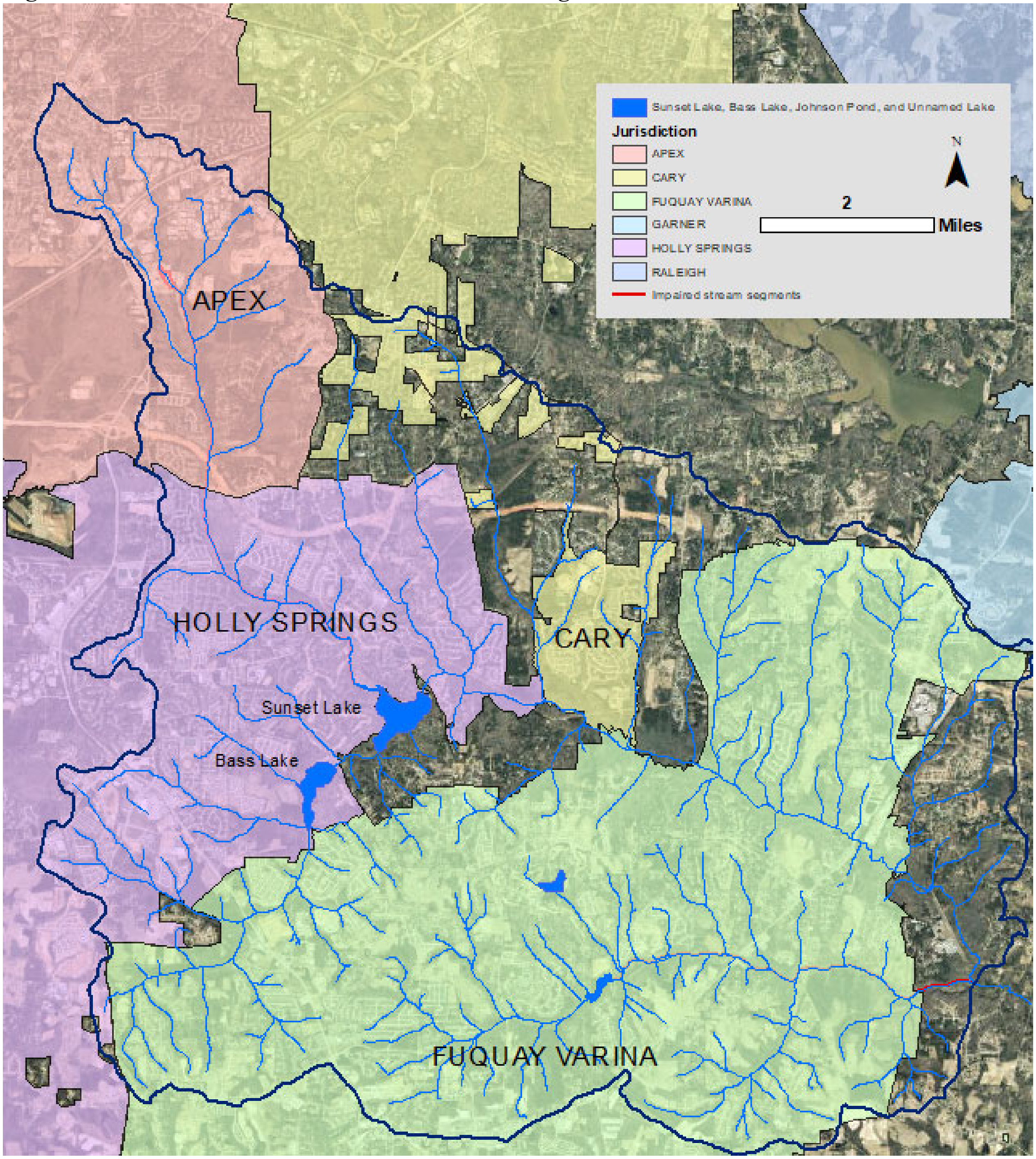
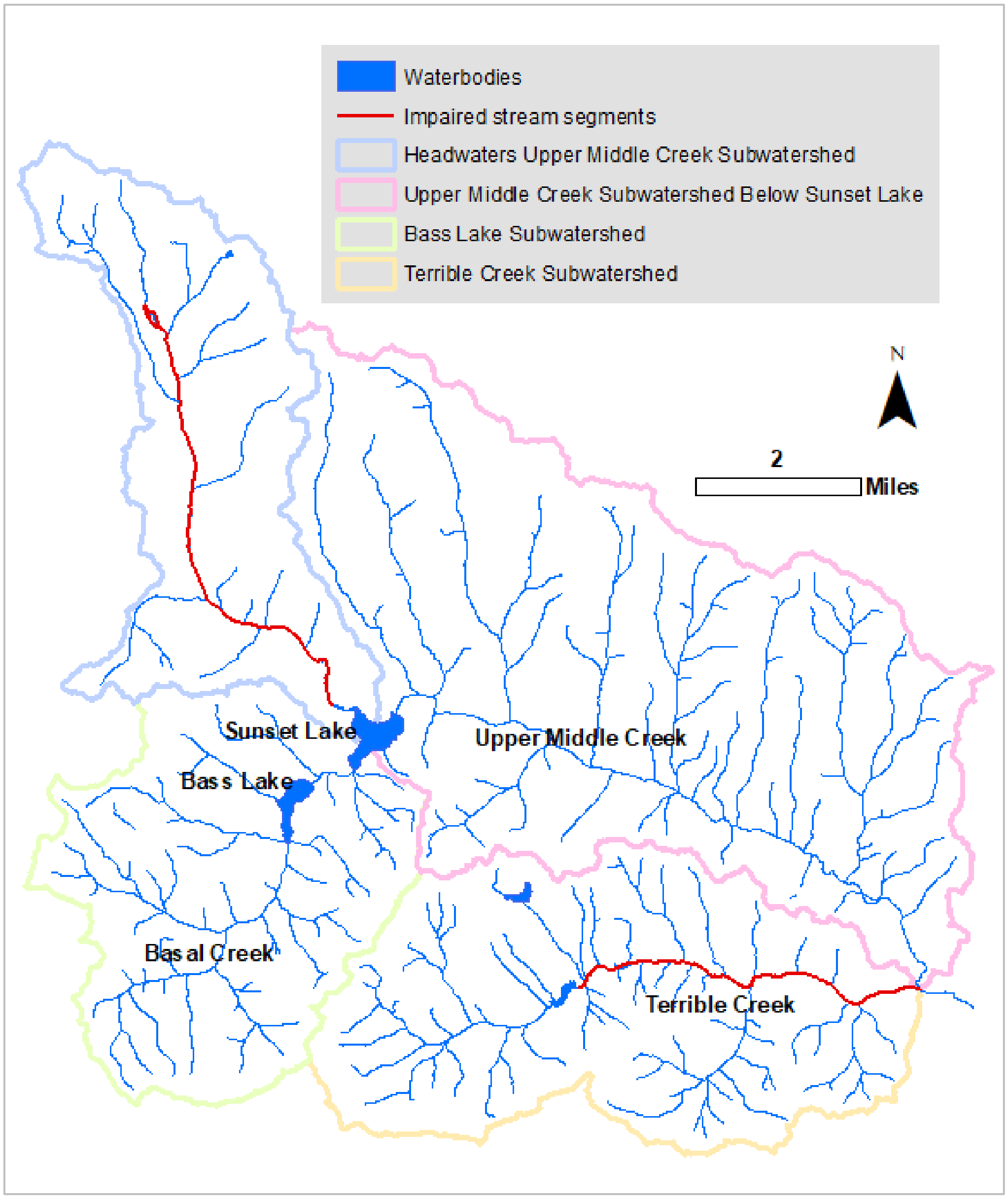


Figure 29: Bass and Sunset Lake Locations Relative to Major Subwatersheds



Given available data (reviewed in section 0) it was not possible to empirically assess sediment loading across the whole watershed. However, using the sediment loading rate from a pilot study on a tributary of Bass Lake, consultants Freese and Nichols estimated a rough annual sediment loading rate per square mile.

The one tributary that Freese and Nichols assessed had an annual sediment export rate of 726.3 tons per year in a 0.86 square mile watershed, and a sediment delivery rate of 844.5 tons/year/square mile of drainage area from streambank erosion along the pilot study reach. Applying that rate to the entire Bass Lake drainage area of 8.95 square miles yielded a sediment delivery of approximately 7,558 tons per year. Freese and Nichols staff noted from observation that the reach studied was fairly typical of the other tributaries of Bass Lake, so this could serve as a planning-level high estimate of sediment delivery into Bass Lake on annual basis. They also noted that the Town will continue to study additional streams and should be able to come up with a more accurate estimate in future.

However, actual sediment delivery into Bass Lake was probably significantly less due to sediment remaining in the riparian system, either deposited on the floodplain or stored in the channel, thus not being delivered to Bass Lake. Additionally, this estimate assumed that all the tributaries of Bass Lake had similar mixtures of erosion rates as the pilot study reach (UT to Bass Lake), while in reality some of the watersheds may have more length of stream in pipe or hard infrastructure that would have had no erosion.

Consultants suggested that very rough planning-level estimates of sediment loading into Sunset Lake could be made by assuming that the tributary of Bass Lake that they studied was representative of the stability condition of the inputs to Sunset Lake and generalizing a sediment yield per acre of watershed then multiplying by the total watershed area of Sunset Lake. But this estimate could be off by orders of magnitude.

The Bass Lake Subwatershed is approximately 10.8 square miles. The Upper Middle Creek Headwaters subwatershed approximately 9.47 square miles. If the tributary of Bass Lake that Freese and Nichols studied were representative of conditions in the entirety of the Bass Lake and Upper Middle Creek Headwaters subwatersheds, there could be a maximum of 7,558 tons per year x 2 = 15,116 tons per year of sediment delivered to Sunset Lake from these two watersheds. However, the Headwaters subwatershed has much denser stormwater infrastructure across Apex' downtown than does Holly Springs' low-density residential area in the Bass Lake watershed, which could make the Headwaters have less streambank erosion. Further, 7,558 tons was a high estimate of sediment delivery to Bass Lake. Thus, these should be considered proof of concept estimates ONLY.

Given more data on sediment delivery from streambank erosion on multiple reaches in the Upper Middle Creek Headwaters and Bass Lake subwatersheds, this method could be refined to generate more accurate estimates of sediment delivery to Sunset Lake.

4.3 Load Reduction Targets

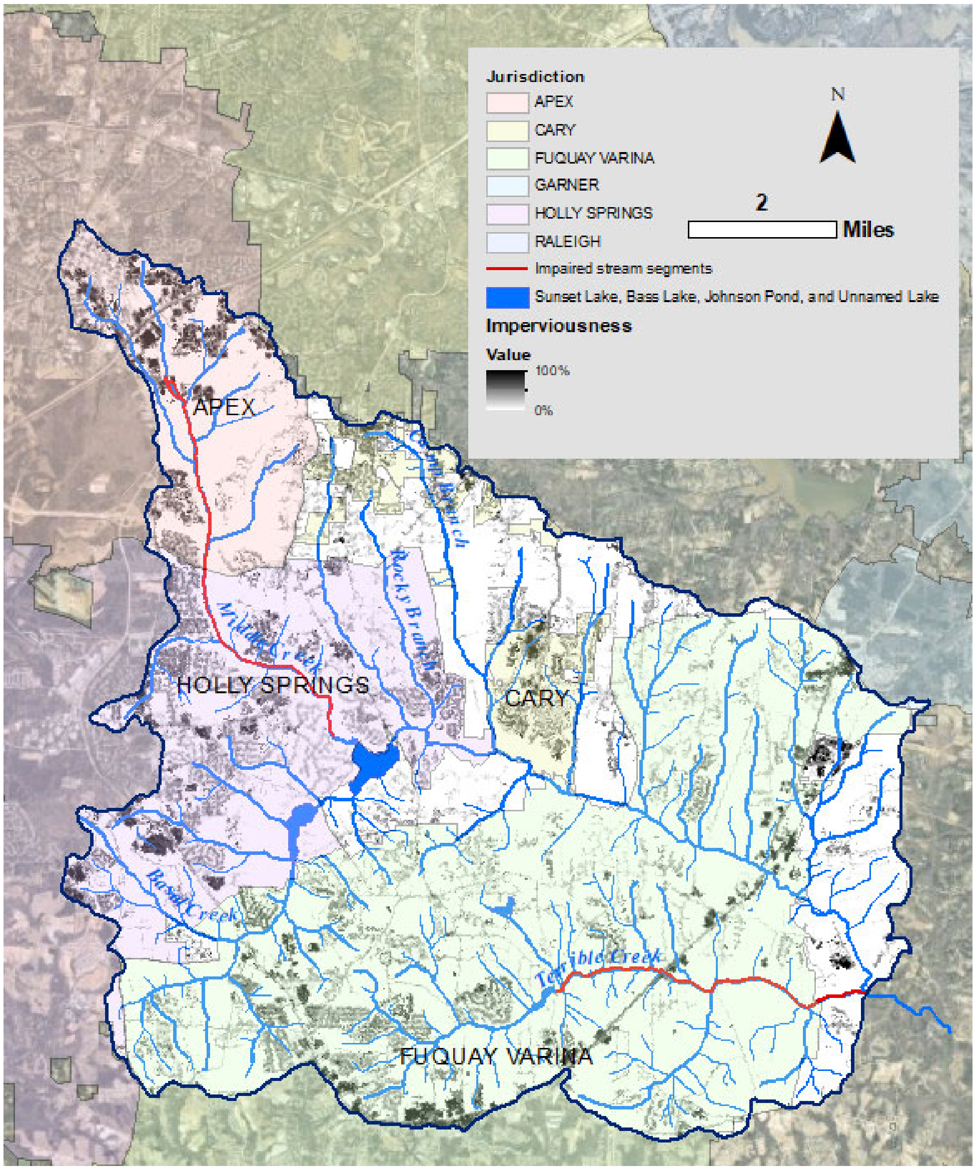
The EPA's Critical Source Area Identification and BMP Selection Supplement to the Watershed Planning Handbook notes that "While watershed models have been commonly used to estimate pollutant loads from alternative BMP treatment scenarios, they should not be used to estimate load reductions for direct comparison with pollutant load reduction targets. Nor should inadequate water quality monitoring (e.g., monthly grab samples and instantaneous flow measurements) be used to calculated measured pollutant loads. In cases where pollutant loads cannot be estimated with suitable confidence, projects should focus their monitoring efforts on BMP implementation…by tracking implementation against interim milestones, project managers will know if the plan is being executed properly even if they don't know the resulting pollutant load reductions. Biological monitoring or tracking of other indicators related to the pollutant load reduction targets may be helpful in demonstrating whether there is an impact on water quality," (EPA 2018).

Based on this recommendation, peak flow and impervious cover reduction targets have been outlined below. Per EPA above, load reductions estimated for BMPs recommended in this plan should not be directly compared with these pollutant load reduction targets.

4.3.1 Peak Flow Reduction Target

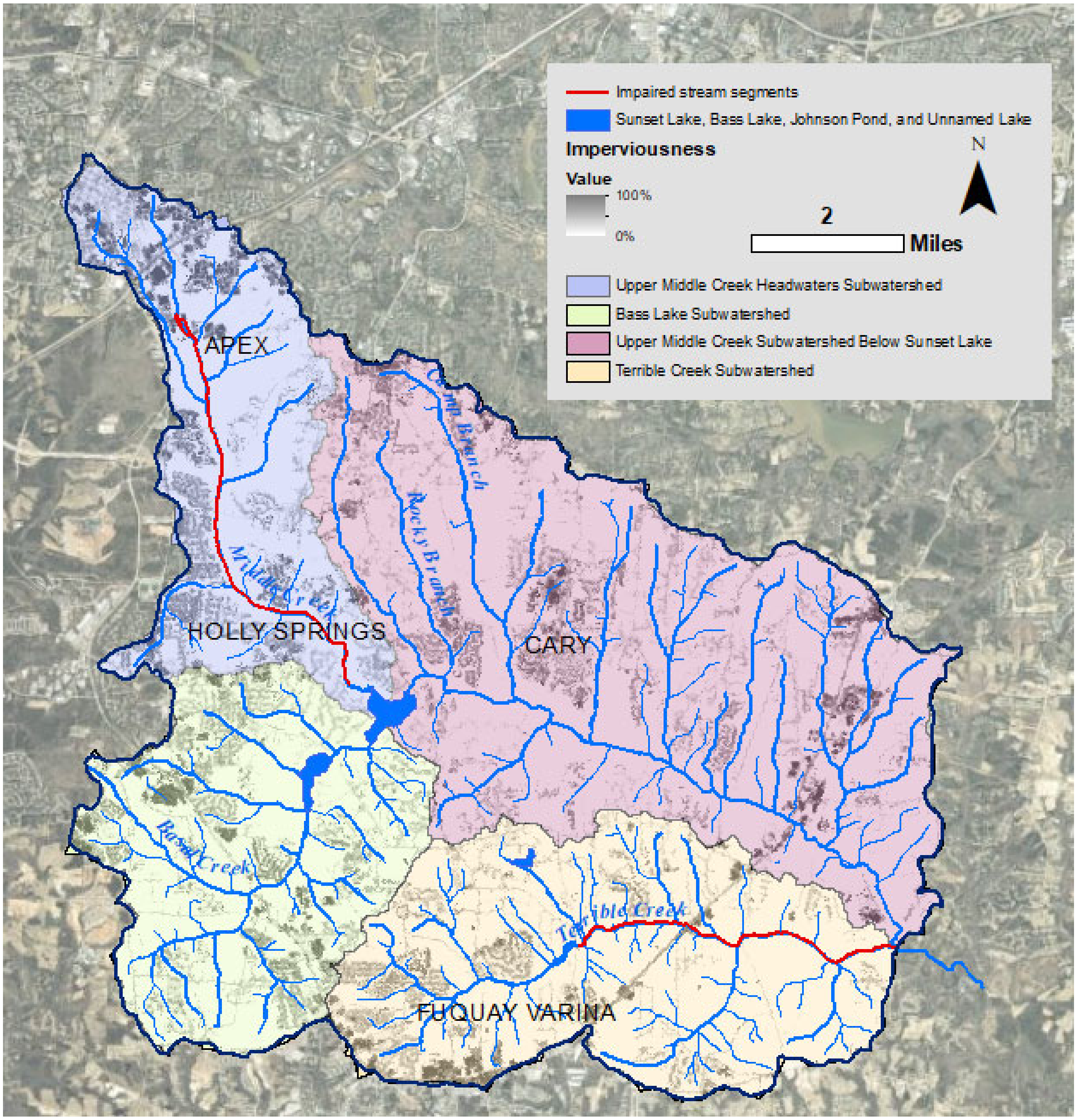
As you can see in the map below, the headwaters of Upper Middle Creek are highly impervious, but impervious surfaces are also distributed throughout the watershed in denser portions of Apex, Holly Springs, Fuquay-Varina and small outpouchings of Cary and unincorporated Wake County. As reviewed in section 3.3.1, this watershed contains a range of land uses ranging from urban to suburban to agricultural and forest, which produce a varying range of pollution sources. Because impervious surfaces are distributed throughout the subwatersheds, it makes sense to aim to reduce urban peak flows onsite adjacent to all impervious areas. (Further information about recommended spatial targeting of SCMs is included in **Error! Reference source not found.**.)

Figure 30: Impervious Surface Distribution and Planning Jurisdictions



To address stormwater runoff generated by impervious surfaces and determine what level of stormwater load reductions are needed to improve water quality conditions in the major subwatersheds below, the USGS Streamstats tool was used to estimate urban and average peak flows. StreamStats' map-based user interface can be used to delineate drainage areas for user-selected sites on streams, and then estimate basin characteristics and flow statistics for the selected sites using geospatial and local data. StreamStats uses available land cover, soil, and precipitation data to predict average and urban peak stormwater flow rates. These two rates were compared to determine how much more stormwater is being generated in urban areas.

Figure 31: Imperviousness in Major Subwatersheds (Used to Target Peak Flow/Volume Reductions)



The Upper Middle Creek Headwaters and Terrible Creek contain the two currently impaired stream segments; in both, urban peak stormwater flows are approximately 15% higher than average peak stormwater flows, despite variation in land use and impervious cover shown in the maps above and figures below. (While these subwatersheds contain the only two currently impaired assessment units, because the whole watershed is connected and developing rapidly it is essential to reduce stormwater peak flows in the other two subwatersheds as well, to maintain benthic community health in Upper Middle Creek.)

The management measures recommended in this plan have been prioritized based on their ability to help reduce stormwater peak flows, volume and pollutant loads in runoff, as well as on current feasibility. SCMs, agricultural BMPs and stream restorations all perform best at small to medium storm sizes and can be damaged by extreme weather events. They are typically constructed for these storm sizes at which they perform best. Engineers are also grappling with how to design practices to also be resilient to extreme events that are becoming more common. Reducing stormwater peak flows by approximately 15% in the Upper Middle Creek Headwaters and Terrible Creek subwatersheds would not necessarily address these extreme events but would be protective of practices constructed for median storm sizes. Reducing peak flows by 15% would help to address the benthic impairment by maintaining natural stream channel functions and habitat as well as reducing the delivery of peak urban stormwater flows from impervious surfaces that scour out and transport sediment to benthic habitats.

Figure 32: Average vs. Urban Peak Flow Estimates in the Upper Middle Creek Headwaters Subwatershed

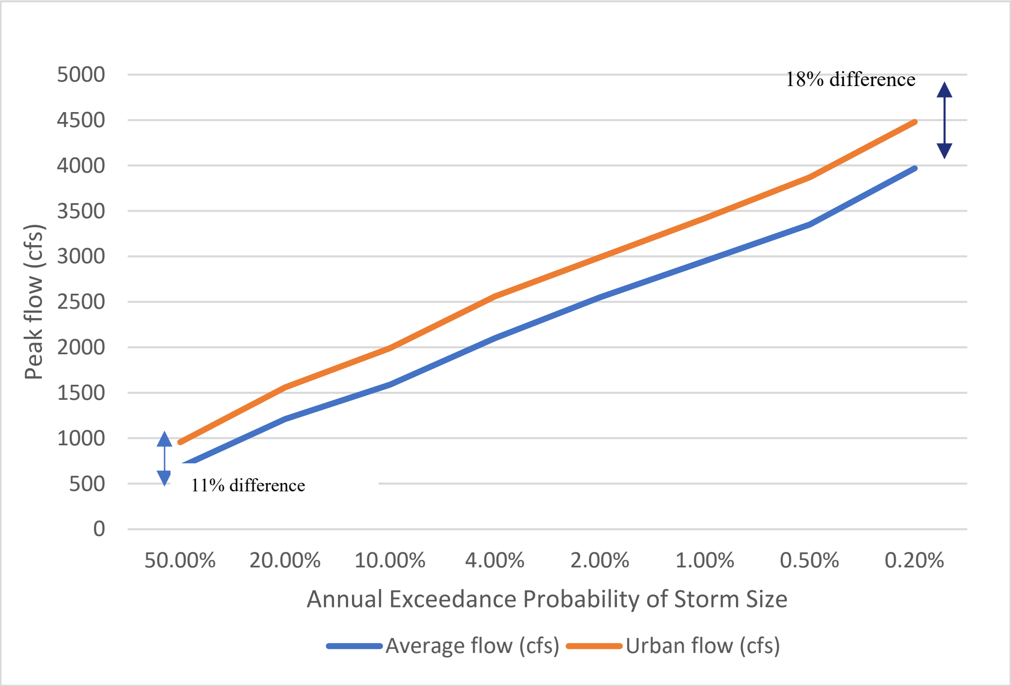
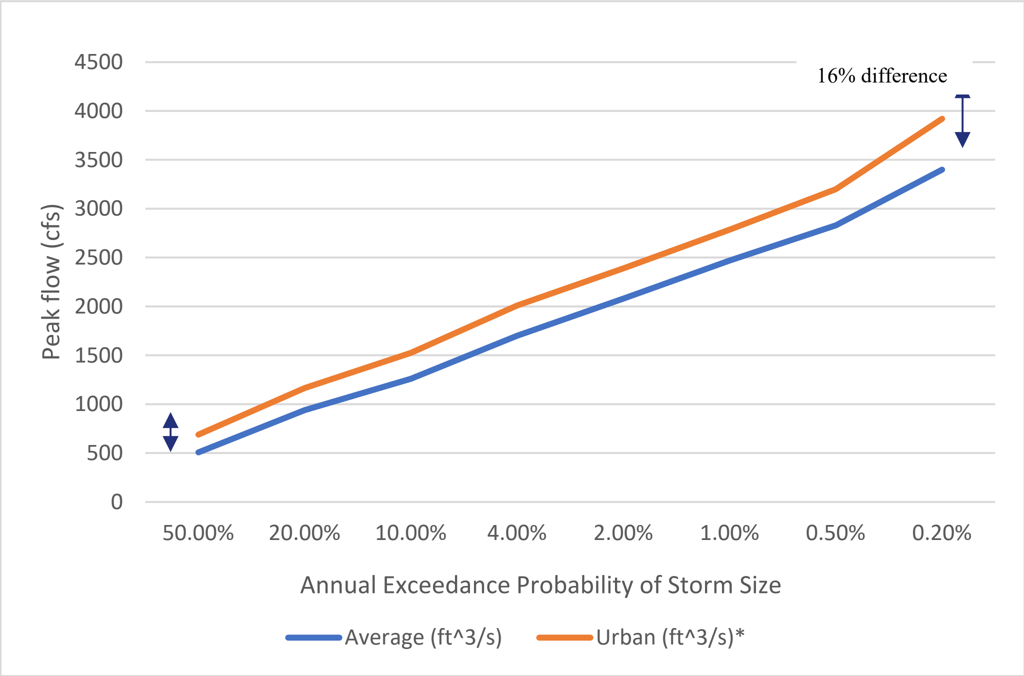


Figure 33: Average vs Urban Peak Flows in the Terrible Creek Subwatershed



Hopkins' 2017 study found that "distributed SCM networks can reduce runoff volumes and sediment and PP [particulate phosphorus] export compared to centralized SCMs, especially for small precipitation events. However, large, high-intensity precipitation events contribute substantially to overall export and these types of events were not adequately controlled by SCMs in either of the urban study watersheds. This result highlights the importance of both frequent small, low-intensity events and infrequent large, high-intensity events for SCM design and in the development of watershed management plans."

Land in the Upper Middle Creek watershed is not yet as highly urbanized as the Washington, DC metropolitan area, but growth projections suggest the Triangle region will need to plan for rapid increases in population, impervious surface and stormwater runoff.

4.3.2 Impervious Cover Reduction Target

The Swift Creek watershed can serve as a model as it is directly to the north of Upper Middle Creek and also impaired for benthos. The TMDL for Swift Creek sets an impervious cover target rather than a numeric pollutant reduction or stormwater reduction target. The TMDL notes that:

> *Degraded benthic community sites are evident as impervious cover increases. Specifically, from sites in North Carolina with a total impervious area greater than 10%, 62% were degraded. In contrast, 90% of sites with less than 10% IC were not degraded. The goal of this target is to achieve water quality standards, in this case, a benthic macroinvertebrate community classification of Good-Fair, Not Impaired or better.*
>
> *Based on the above findings, a total watershed impervious cover (IC) of 10% was used as the surrogate target for this TMDL, to be implemented through stormwater management…Because IC is a surrogate measure, eliminating IC is not necessary in reaching the TMDL target*

> *reductions.* ***Measuring the aquatic life (biological community) directly will be the method for assessing attainment of the TMDL goal (EPA 2009).***

Both the Swift Creek TMDL and EPA's supplemental guidance document, *Critical Source Area Identification and BMP Selection,* recommend measuring biological communities directly to assess their recovery (rather than measuring any proxy, like % IC.)

5.0 GOALS AND OBJECTIVES

Figure 34: Reproduced with permission from the Haskett Creek Watershed Plan

Watershed restoration work is recognized as a long-term undertaking that will take many years. The goal of a 9-element watershed restoration plan, as designated by the EPA, is to meet water quality standards. The water quality standard in question in this plan is the benthic macroinvertebrate impairment. The primary goal of this watershed plan is to restore benthic macroinvertebrate community health in the Upper Middle Creek watershed. The objectives and actions under this goal can serve as interim measures of success that will set the stage implementation.

Objectives and actions outlined in the Plan have primarily been prioritized for the purpose of improving the benthic community rating to good-fair or better, which would indicate a diverse benthic macroinvertebrate community. Objectives and actions have been targeted to address the identified stressors to the benthic community of stormwater runoff peak volume/peak flows and associated streambank erosion and sedimentation in Upper Middle Creek.

As outlined in the previous section, fecal coliform is an additional water quality concern. Using current data at the time of writing, it is difficult to determine whether there is a direct causal link between fecal coliform levels and benthic community health with the current available data. However, given the high identified fecal coliform levels, actions have also been identified to address fecal coliform.

Expected timeframe, partners, resources, and evaluation criteria needed to accomplish each action and ensure the plan's success are outlined in successive tables associated with each objective and its action steps. These tables should be updated as the needs of the watershed change, and action items are completed.

While this section outlines priorities, this watershed is developing so quickly that it requires an everything-at-once approach to solve. When considering the whole watershed, the objectives and actions should be implemented concurrently when possible. Links between ultimate and proximate causes of pollution and site-specific considerations have been outlined below as relates to prioritizing different types of implementation projects.

Table 9: Upper Middle Creek Watershed Plan Goals and Objectives

Primary Goal: Improve benthic community rating to good-fair or better, to ultimately meet biological water quality standards.
OBJECTIVES
1. Reduce peak stormwater flows and overall runoff volume to minimize impacts to the benthic community as the watershed continues to develop.
2. Preserve existing open space, forestland and farmland to prevent water quality and benthic community health from declining as the watershed develops.

3. Address identified animal and human fecal coliform pollution sources concurrently with reducing stormwater runoff.
4. Address sediment pollution stemming from streambank erosion (concurrently with reducing causes of erosion - stormwater runoff volume and velocity upgradient in the watershed.)
5. Continue and grow public outreach, education and involvement to promote community stewardship and appreciation of water quality and ecosystem health in the Upper Middle Creek watershed.
6. Maintain, strengthen, and develop new partnerships to implement this plan, evaluate its successes and modify it based upon results of implementation.

The objectives above and actions below were identified by TJCOG and local and regional stakeholders who will work together to implement this plan. Project team members and their roles are shown in the table below.

Table 10: Partnering Organizations and Their Roles in the Watershed Plan and its Implementation

Organization	Roles and Responsibilities
Triangle J Council of Governments	Project manager and plan writer. Implementation responsibilities: - Seek 319 funding to implement prioritized projects - Serve as technical advisor on plan implementation - Follow up with project partners about progress toward meeting implementation goals, objectives and actions - Convene partners every 5 years to update plan - Via TJCOG CWEP program staff, create educational materials and/or technical communications for public consumption and train interested stakeholders on community science tools - Facilitate interest meeting for watershed group to help implement plan
Wake County Soil & Water Conservation District	Input on agricultural best management practice priorities, soil science, initiator of original grant-funded project. Implementation responsibilities: - Provide agricultural BMP recommendations in unincorporated Wake County and lead agricultural BMP implementation
Town of Holly Springs	Input on stream restoration, water quality issues, stormwater management and planning solutions within Holly Springs' jurisdiction. Implementation responsibilities: - Provide SCM and stream restoration recommendations within jurisdiction and lead SCM project implementation - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation
Wake County	Input on watershed planning and restoration priorities and septic system issues in unincorporated Wake County. Implementation responsibilities: - Provide SCM recommendations within jurisdiction and lead SCM project implementation

	- Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation - Provide updates on malfunctioning septic system data
Town of Fuquay-Varina	Input on stormwater management and engineered or planning solutions within Fuquay-Varina's jurisdiction. Implementation responsibilities: - Provide SCM recommendations within jurisdiction and lead SCM project implementation - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation
Town of Apex	Input on stormwater management and engineered or planning solutions within Apex' jurisdiction. Implementation responsibilities: - Provide SCM recommendations within jurisdiction and lead SCM project implementation - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation
North Carolina Division of Water Resources	Project funders and technical experts on various water quality / nutrient management issues. Implementation responsibilities: - Provide updates about any 9-element planning or 319 grant implementation requirements to project team
Whole team	- Propose updates to goals, objectives and actions in plan, as necessary, as implementation progresses - Communicate updates to TJCOG project manager, other team members as they occur - Participate in annual meeting to update plan, assess progress toward meeting goals - Technical assistance and funding for prioritized projects within jurisdictions - Education and outreach within jurisdictions - Monitor effectiveness of implemented projects
Watershed Group (TBD)	- Engage stakeholders (local residents, schools, parks, etc) - Participate in annual team meetings

The implementation charts in the following sections are organized as follows:

Timeframe – The period of time in which each task is to be completed. Actions are grouped into four categories, based on local priorities and feasibility: Ongoing (continuous), Short (1-3 years), Mid (3-5 years), or Long (5-10 years). Although this plan is meant to be a living document, a 10-year planning horizon was assumed for the purposes of implementation.

Partners – The organizations that are responsible for implementing each task. Organizations in bold have been assigned to lead this particular initiative.

Resources Needed – Assets that will need to be secured in order to complete each task. Resources are grouped into six main categories: Funding, Staff Capacity, Technical Assistance, Training, Public or Elected Official Support, and Educational Materials.

Evaluation Criteria – Specific indicators that will be used to track the progress and success of each action. It is recommended that local stakeholders regularly maintain this information using spreadsheets or other resources discussed in this plan.

5.1 Objective 1: Reduce Stormwater Runoff Peak Flows

Available data indicate that stormwater runoff is the primary driver of water quality impairments in Upper Middle Creek. Increases in impervious surfaces and stormwater runoff and associated hydrologic alteration increase sedimentation and erosion and degrade benthic and other ecosystems and water quality. Restoration and management techniques should be prioritized to capture and treat stormwater onsite, promote infiltration, and reduce stormwater reduction volume and peak flows and with them also the many and varied pollutants in stormwater runoff.

Unfortunately given that much of the watershed is privately owned, local government partners have found that SCM son private property are typically poorly maintained and forgotten with change of ownership. Thus, recommendations below primarily refer to public property.

Objective 1: Reduce peak stormwater flows by approximately 15%					
Action #	**Specific Action**	**Timeframe**	**Partners Involved (Bold = responsible)**	**Resources Needed**	**Evaluation Criteria (Indicators)**
1-1	Identify areas to implement new SCMs to reduce peak flows within individual local government jurisdictions	Ongoing	**Holly Springs, Apex, Cary, Fuquay-Varina**, NCDWR, NCLWF, engineering firms	Funding, technical assistance, & staff time	# of SCMs installed, stormwater volume or peak flow reduced by the SCM, water quality data, value added ($/ft/yr)
Note: Apply for 319 or other grant funding to support.					
1-2	Identify and promote SCM retrofits as part of maintenance or redevelopment of publicly owned buildings, schools, parks, parking lots and drainage systems.	Ongoing	**Holly Springs,** other local governments as opportunities available (none noted at time of writing.) Wake County Public Schools, Wake Tech, Wake County Green Schools network, NC Cooperative	Technical assistance, staff time & training	# of SCMs installed, stormwater reduced, water quality data, value added ($/ft/yr)

			Extension, TJCOG, engineering firms		
Notes: Work with Wake County Public Schools (who manages own GSI on school campuses) and Wake County Green Schools Network to implement SCM retrofits on school grounds to promote youth understanding of the benefits of stormwater management. Explore possibilities to work with Wake Tech campus. Prioritize highly visible sites for SCM retrofits, add signage to promote education and work with WRRI, Extension to provide tours. Apply for 319 or other grant funds.					
1-3	Promote street tree programs and encourage stormwater reduction measures on streets in future capital improvement projects	Mid	**All local governments,** landscaping companies and nurseries recommended by practitioners for good tree installation practices	Funding, technical assistance, staff time, & training	# of street trees planted/SCMs, stormwater reduced, water quality data, value added ($/ft/yr)
Note: Identify streets that are wide enough to accommodate SCMs. Adjust ordinances using Code & Ordinance worksheet to accommodate.					
1-4	Work with Department of Transportation to incorporate retrofits into highway upgrades	Mid	NCDOT, RPOs, **Apex (at NC-55)**, other jurisdictions as opportunities allow	Staff time & technical assistance	# of SCMs installed, stormwater reduced, water quality data, value added ($/ft/yr)
Note: Coordinate with relevant RPOs.					
1-5	Enhance cost share/incentive program to encourage greater uptake of GSI on private property where best professional judgment deems appropriate	Mid	**Cary, Holly Springs,** possibly Apex in future with new stormwater utility, Cooperative Extension, businesses, & homeowners	Funding, technical assistance, educational materials, & staff time	# of SCMs installed, funding provided ($)
Note: This could include financial assistance, development incentives, or recognition programs for both structural or non-structural SCMs.					
1-6	Prioritize disconnection impervious surfaces from one another and from surface waters, on both public and private property. Ie, disconnect all	Mid	**Cary,** Apex, Holly Springs, Fuquay-Varina, Wake County, all coordinating internally between local government departments to	Staff time, funding, educational materials	Area where IC effectively reduced, # of roofs disconnected, volume of stormwater reduced

	roof drains on public property.		disconnect IC on govt property, CWEP, businesses, homeowners		
Note: Identify neighborhoods with direct roof drain connections. City could provide this service at no-cost to homeowners to incentivize.					
1-7	Consider establishing stronger recommendations or incentives to use LID in new development	Short	**Cary, Apex, Holly Springs, Fuquay-Varina, Wake County,** TJCOG, UNCSOG	Technical assistance, staff time, & elected official buy-in	N/A
Note: Use Code & Ordinance Worksheet tools.					
1-8	Incorporate watershed plan recommendations into other City/County plans	Short	**Apex, Holly Springs, Fuquay-Varina, Cary, Wake County,** TJCOG	Staff time	N/A

5.2 Objective 2. Preserve Existing Open Space, Forestland and Farmland

The transition of the remaining forestland and farmland in the watershed to subdivisions will likely hasten the decline of benthic communities in Upper Middle Creek. Following low-impact development recommendations above alone will not suffice unless combined with preserving forest and farmland where possible to help slow this decline. In addition, riparian buffers greater than required by regulation would help prevent declining watershed health.

Objective 2: Preserve Existing Open Space, Forestland and Farmland					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria (Indicators)**
2-1	Support Wake SWCD, Triangle Land Conservancy, recreation departments, and other partners to conserve land	Short-Mid	**All local governments,** TLC, Wake SWCD, NCLWF, Extension, private landowners	Technical assistance, staff time, & willing property owners	Acres of land conserved, stormwater reduced, water quality data, value added ($/ft/year)
Note: Prioritize land in critical areas that provides multiple benefits. Aim for ≤10% impervious cover in each catchment.					
2-2	Explore how subdivision	Short	**Wake County,** other local	Staff Time	# of strengthened policies

	regulations can encourage open space and better protect land and water resources		governments, TJCOG		
Note: This is currently at the staff level in Wake County. Fuquay-Varina already has low-density requirements.					
2-3	Identify potential incentives to encourage open space preservation	Short	Local Governments, NCDEQ, TJCOG	Technical assistance & staff time	Acres of land conserved, stormwater reduced, water quality data, value added ($/ft/year)
Note: Tools to evaluate Codes and Ordinances for open space protection exist from the Center for Watershed Protection and others, including NC Wildlife Resources Commission's Green Growth Toolbox.					
2-4	Use Code & Ordinance Tool to identify other opportunities to improve open space protections in City/County ordinances		Local Governments, NCDEQ, **TJCOG**		# of strengthened policies
See note above					
2-5	Align conservation goals with local governments' Future Land Development Plans, Wake County's Comprehensive Plan updated in 2021, and its associated Development Framework for identifying areas most suitable for preservation	Short	**Local governments,** TJCOG	Staff time	N/A
Note: PLANWake Comp Plan available at https://www.wakegov.com/departments-government/planning-development-inspections/planning/planwake-comprehensive-plan					

2-6	Explore floodplain protection and trail opportunities to meet conservation goals	Mid-Long	Local governments (including **parks and recreation departments**), TJCOG, TLC, NCLWF	Funding, technical assistance, & staff time	Acres of land conserved, miles of trail constructed

5.3 Objective 3. Address Fecal Coliform Pollution Sources

Another factor contributing to degraded water quality in Upper Middle Creek and its tributaries is the elevated levels of fecal coliform bacteria (see data summarized in section 3.2.7 above.) Specific actions to help reduce fecal coliform pollution sources are outlined in the table below. It is important to note that reducing both fecal coliform sources and transport to waterbodies is essential to address this water quality issue. In other words, animal and human fecal coliform pollution sources must be reduced concurrently with reducing stormwater runoff volume and velocity to improve instream impacts of fecal coliform bacteria.

Objective 3: Address identified animal and human fecal coliform pollution sources concurrently with reducing stormwater runoff.					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria (Indicators)**
3-1	Pursue agricultural BMPs that prevent animal waste from reaching streams	Short	**Wake SWCD,** all local governments' pet waste education campaigns, NCDEQ	Staff time, funding, technical assistance	# of BMPs installed, estimated fecal coliform reduction as calculated from references, or water quality data if available
Note: Pursue 319 grant funds to match Wake SWCD funds for agricultural BMP implementation					
3-2	Remediate any malfunctioning septic systems identified (continue to pursue data on identifying malfunctioning septic systems across the watershed)	Ongoing	**Wake County,** NCDEQ	Staff time, funding, technical assistance	# of septic systems repaired or replaced, estimated fecal coliform reduction as calculated from references, or water quality data if available
Note: If requested, pursue 319 grant funds to implement septic system repairs					

3-3	Local government stormwater and wastewater utility staff coordinate to address any wastewater-related fecal coliform pollution sources that may be identified from I/I or impacts of treated wastewater discharge to receiving streams	Mid-Long	**All local governments coordinating between internal departments**	Staff time, potentially funding for repair projects	# of repairs made, volume of I/I reduced
Note: TJCOG may be able to help facilitate intra-governmental department collaboration					
3-4	Implement and incentivize pet waste pickup and public education about its importance	Short	**All local governments,** TJCOG	Staff time, modest funding	# of pet waste pickup stations, estimated fecal coliform reduction as calculated from references if they exist
Note: Can use public education resources provided by TJCOG CWEP program, of which all local governments in watershed other than Wake County are members.					

5.4 Objective 4. Address Sediment Pollution Sources

Local government staff have observed moderate to significant streambank erosion on Upper Middle Creek and its tributaries which has contributed to instream and in-lake sediment pollution. In other words, streambank erosion is both a symptom of excessive stormwater runoff volume/velocity and a source of sediment pollution. Thus, improving benthic community health requires both causes of erosion - stormwater runoff volume and velocity upgradient in the watershed – and reducing the erosion of the streambanks themselves. When considering specific project sites for streambank stabilization or channel restoration, designers and engineers should ensure that ensure that upstream and upgradient stormwater runoff volume and velocity have been accounted for so that the streambank stabilization project will not be compromised by stormwater runoff. The table below identifies actions for reducing streambank erosion, as stormwater runoff reduction is covered in Objective 1.

Additionally, as this watershed continues to experience rapid growth, construction site runoff will be likely to be an ongoing source of sediment to Upper Middle Creek. It was outside of the scope of this project to assess the magnitude of this impact, and local government staff are best equipped to assess the relative contribution of runoff from construction sites relative to streambank erosion. Basic actions that are best practices independent of sediment source magnitude are included under objective 4b, below.

Objective 4a: Address sediment pollution stemming from streambank erosion					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria (Indicators)**
4-1	Identify and replant riparian buffer on any denuded streambanks stable enough to be suitable without bank regrading or stabilization. Consider widening stream buffer beyond required where possible.	Short	**Local governments, Wake SWCD,** Extension, NCDEQ, TJCOG	Staff time, technical assistance, funding	Linear feet or area of riparian area revegetated, riparian plant survival after 5 years (or other interval)
4-2	Identify unstable, eroding streambanks shedding sediment beyond the capacity of riparian buffer planting to address		**Local governments,** Wake SWCD, Extension	Staff time, technical assistance, funding	Linear feet of streambank that could benefit from unstable streambanks
4-3	Stabilize unstable streambanks that are actively shedding sediment using nature-based practices/ designs as approved by local government staff and contractors.		**Local governments,** Wake SWCD, Extension, NCDEQ, TJCOG	Staff time, technical assistance, funding	Linear feet of streambank stabilized, macroinvertebrate community rating 5-10-15 years in future
Note: Apply for 319 and/or NCLWF grants to conduct this work					
4-4	If needed, restore stream channels that are actively degrading using nature-based practices/ designs as approved by local government staff and contractors.		**Local governments,** Wake SWCD, Extension, NCDEQ, TJCOG		
Objective 4b: Address sediment pollution stemming from construction site runoff					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria (Indicators)**

4b-1	Partner with local governments to offer new methods of education on construction sites about appropriate stormwater/sediment runoff controls	Short	**Local governments, TJCOG CWEP program**	Staff time	# of construction sites given education materials that no longer have sediment/erosion violations
Note: Work across all local government departments responsible for sediment in construction site runoff					
4b-2	Use DEQ Barrier Evaluation Tool Check and check NC Dam Safety ratings of impoundments in watershed; share results with partners	Mid	**TJCOG with all partners**	Staff time	Barrier Evaluation Tool and dam safety ratings

5.5 Objective 5. Continue and Expand Public Outreach and Education

Local government staff from Apex, Holly Springs and Fuquay-Varina participate in the Clean Water Education Partnership (CWEP), which uses education and outreach to teach the public how our individual and collective behaviors can improve water quality. The table below identifies actions to accomplish Objective 5, to continue and expand public outreach and education to promote understanding and stewardship of the Upper Middle Creek watershed.

Objective 5: Continue and Expand Public Outreach and Education

Action #	Specific Action	Timeframe	Partners Involved	Resources Needed	Evaluation Criteria (Indicators)
5-1	Establish active Watershed Group to implement and update plan	Short	All; **TJCOG facilitate interest meeting**	Staff time & stakeholder buy-in	# of active participants; # of milestones met
Note: Determine organizational responsibilities and meeting frequency.					
5-2	Promote stewardship of Upper Middle Creek by seeking outdoor hands-on education options at CWEP direct education visits to Apex, Holly Springs and Fuquay-Varina (see ideas below)	Short	Apex, Holly Springs, Fuquay-Varina, **TJCOG CWEP program**	Staff time and willing teachers or other education settings	Learning outcomes based on pre/post education visit survey, formation of any student groups to clean up Middle or Terrible Creeks or other parks in

					watershed adjacent to schools
Note: Connect CWEP with any relevant education settings, ie scouts, afterschool or others					
5-2	Install education signage with any new, publicly-visible SCMs or stream restoration projects; promote tours for local residents	Mid	**All local governments** as they install SCMs	Technical assisstance and staff time	# of signs installed; # of tours about SCMs' purpose for local residents
Note: If SCMs installed using 319 funds, signage costs are also eligible					
5-4	Continue and expand direct education coordination with CWEP program, as interest allows, ie Stream Watch or Adopt-A-Stream volunteer groups, or via citizen science volunteer monitoring if volunteer interest/capacity allows	Short-Mid	**TJCOG CWEP program,** local government staff, local citizens to champion stream stewardship and education (teachers, students, others)	Technical assistance, staff time & willing volunteers	# of volunteers as proxy for level of interest in program, # of streams monitored, citizen science data
Note: CWEP always works directly with local government stormwater or parks saff					
5-5	Work with local government partners to reduce specific pollutants of concern – sediment, nutrients and fecal coliform – via developing and distributing educational materials about reducing construction site runoff, streambank erosion, lawn fertilization, septic system malfunctions and pet waste	Ongoing	**Local government staff,** TJCOG CWEP program, private citizens, golf courses	Technical assistance & staff time	Public buy-in to any incentive programs, estimated lbs of N/P reduced, fecal coliform data

Additional specific recommendations for place-based education and engagement are noted below. These would be good locations for TJCOG's Clean Water Education Partnership AmeriCorps to work with local government stormwater staff to deliver a lesson or stewardship activity, possibly in conjunction with the Wake County Green Schools network:

- Middle Creek High School and West Lake Middle School adjacent to the Camp Branch and Upper Middle Creek mainstem
- Lufkin Road Middle School in the headwaters in Apex
- Ballentine Elementary School adjacent to Terrible Creek

Universally, Parks Departments should be considered partners and local government stormwater staff should continue to coordinate with them in education and restoration efforts. This is already happening through local governments' internal education work and their education work with TJCOG's CWEP program, ie through Cary and Holly Springs' participation in CWEP's Regional Creek Week in 2021 and 2022. Bass Lake Park and Middle Creek Park and Disc Golf Course (in Holly Springs and Cary, respectively) could be good places to include signage about pet waste pickup, litter, and the purpose of riparian buffers. At the time of writing, Fuquay-Varina staff was also working with parks staff to assess streambank quality at Hilltop Needmore Town Park and Preserve where mowed lawn and paved trails appeared to be close to the creek.

Finally, if education and engagement efforts yielded community interest in citizen science, TJCOG could reach out to WRRI and the NC Aquatic Data Hub could serve as a resource.

6.0 MANAGEMENT STRATEGIES AND ASSOCIATED POLLUTANT LOAD REDUCTIONS

6.1 Overview of Watershed Restoration Needs

The mix of land uses and watershed impacts would benefit from broader implementation of stormwater control measures, agricultural best management practices and stream restoration projects. This is widely understood by watershed stakeholders; however, due to the pace of development, it is difficult to find public land on which to site stormwater control measures, as most of the developed land in the watershed is privately-owned residential developments. Additionally, because they are responsible to constituents, town councils and state regulators, local government staff have limited time to focus on implementing voluntary projects beyond those required by development review, stormwater permits and nutrient management strategies.

Section 6.2 below outlines existing plans, policies and projects which municipalities are already implementing to try to reduce the impacts of nonpoint source pollution within their jurisdictions. Section 6.3 outlines the management measures that local government staff prioritized to further reduce nonpoint source impacts on water quality.

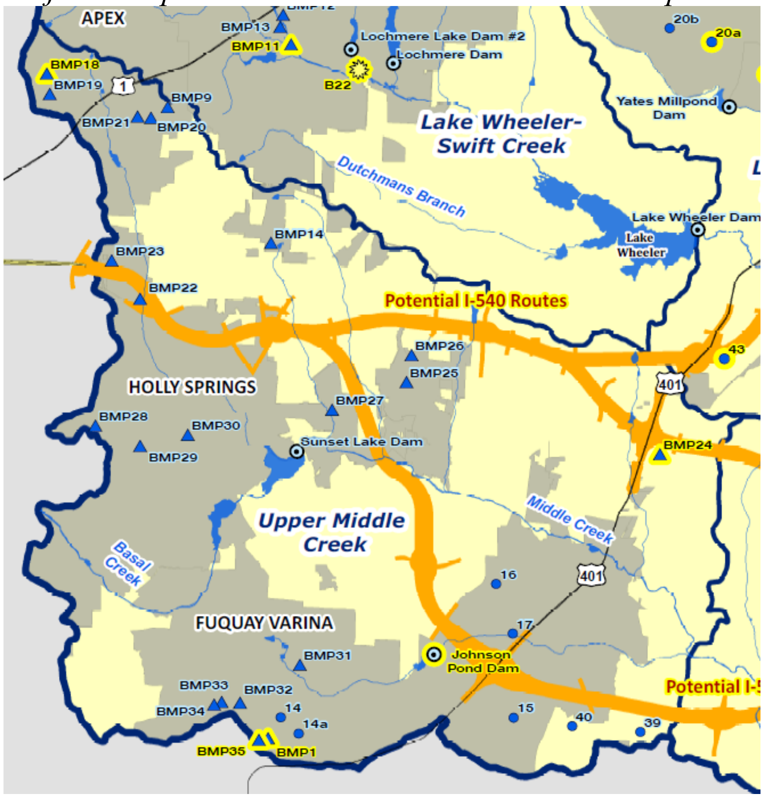
6.2 Existing Plans, Policies and Projects

6.2.1 Existing Plans and Policies

6.2.1.1 Neuse 01 Regional Watershed Plan

In 2014, Wildlands Engineering completed the Neuse 01 Regional Watershed plan for NC Division of Mitigation Services. Their GIS-based prioritization of potential compensatory mitigation sites yielded five high-priority project sites in the Upper Middle Creek watershed: BMPs 1, 18, 24, and 35, as well as removal of the Johnson Pond Dam.

Figure 35: Projects Proposed in 2014 Associated with the Complete I-540 Project



BMP18 cited in the Project Atlas would involve retrofitting an existing dry pond near Apex Middle School as a wet pond or wetland; Apex staff sounded intrigued by the possibility as it is difficult to find retrofit opportunities in older subdivisions. This site will lie near to the right of way for the widening of 55; staff indicated that this may pose a design challenge to implement, but it could still be a possibility.

Wake County staff noted no current plan to implement BMP24 and questioned whether the site was still suitable for SCM construction given its proximity to Highway 401/Fayetteville Rd. BMP1 and BMP35 are located at the site of the Town of Fuquay-Varina High School. In 2019, the Town approved demolition and rebuild of the Fuquay-Varina High School, currently under construction at the time of writing. Per Town stormwater regulations, the new school has constructed a bioretention facility that will treat stormwater in an area that previously had no treatment. The Town did not have any current plans for Johnson Pond.

Rapid growth and redevelopment pose challenges to implementation of some sites prioritized in the Neuse 01 plan five years after Wildlands identified them; however, others remain possibilities. This underscores the need to rapidly implement prioritized restoration projects ahead of new development in the watershed.

6.2.1.2 Apex Tree Canopy Study

In 2018, the Town of Apex contracted with the Green Infrastructure Center, Inc. to study Apex' canopy extent, determine possible planting areas, estimate impact of increasing tree canopy on decreasing stormwater runoff, review existing codes and ordinances, and provide recommendations. The study recommended creating a stormwater utility and fee to cover maintenance of stormwater infrastructure, which includes trees. Another recommendation relevant to stormwater management was to incorporate measures into Apex' Unified Development Ordinance (UDO) to set parking requirements as minimums and maximums, with the possibility of requiring developers who exceed parking maximums to plant trees. Many of these recommendations are being considered at the time of writing.

6.2.1.3 Stormwater Utilities

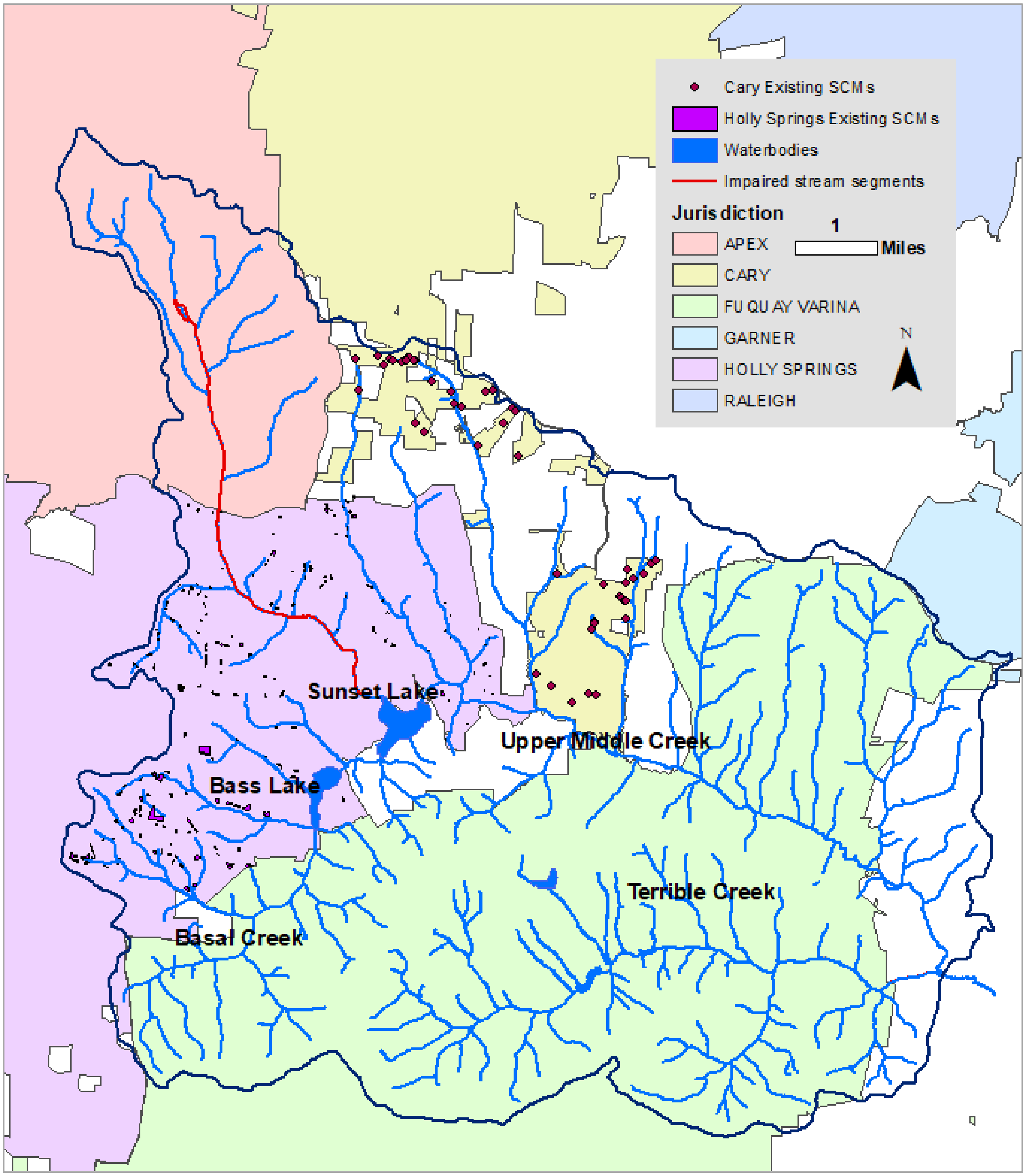
Stormwater utility fees provide revenue that a local government may be able to use for stormwater infrastructure maintenance or green stormwater infrastructure project implementation. Holly Springs has a Stormwater Program Management Fee, where fees may be used for watershed restoration projects. Apex recently (2021) approved a stormwater utility fee. At the time of writing the uses for Apex' stormwater utility fee were still being determined.

6.2.2 Existing Watershed Restoration and Conservation Projects

6.2.2.1 Existing Watershed Restoration Projects

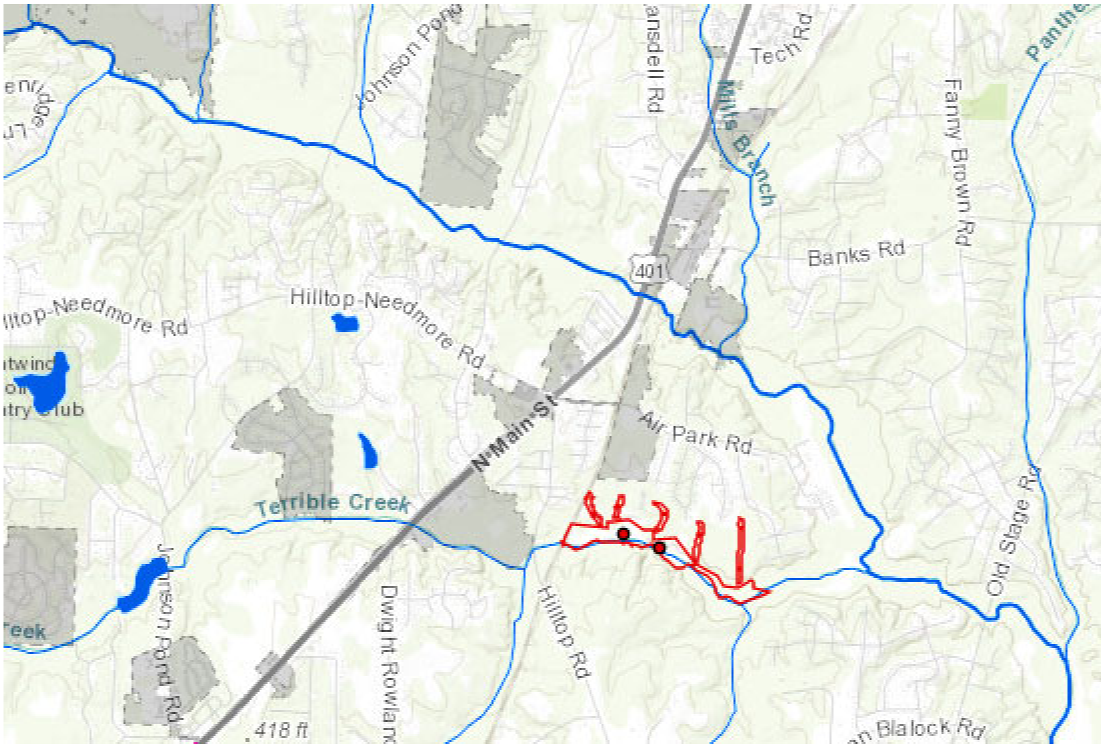
Local governments in the watershed install SCMs as part of their Phase II NPDES and/or Neuse Stormwater obligations. As you can see from the SCMs mapped below, local governments have already completed extensive SCM implementation in the watershed. Below includes only those that are mapped. Fuquay-Varina staff will bring existing SCM data into GIS as soon as summer 2022. Wake County does not regulate any SCMs in this watershed and does not currently have funds to construct new SCMs. Wake County staff noted that they try to coordinate with Wake County Public Schools, but the school system manages all SCMs on their property. Wake County regulates stormwater for County jurisdiction (as well as Rolesville, Wendell and Zebulon).

Figure 36: Mapped SCMs in the Upper Middle Creek Watershed (Other Jurisdiction Mapping Forthcoming)



Existing restoration efforts in the watershed are not only limited to engineered stormwater practices. Since 2013, the NC Division of Mitigation Services (DMS) has held a permanent conservation easement which protects five unnamed tributaries to Terrible Creek on the 12.6-acre Pepperwood Farm Riparian Buffer Mitigation Site (DMS 2018). The Year 5 (2018) Annual Monitoring Report for this site describes how prior to restoration, "riparian areas were cleared of native forest vegetation, heavily degraded by livestock grazing and hoof shear, maintained for hay production, and subject to raw manure fertilization. Streams were straightened, routinely cleared, and subject to storm water runoff from boarding facilities," (DMS 2018.) Riparian buffer restoration goals include eliminating agricultural activities and associated nonpoint source pollutants in riparian areas and establishing hardwood vegetated stream buffers. Water quality and habitat benefits of these practices include reduced erosion, filtering of any pollutants from the landscape, improved aquatic habitat due to increased shade and natural detritus, and a terrestrial wildlife corridor in a largely developed watershed. Per 2018 monitoring of species composition and density, vegetation at the site appeared to be establishing successfully (DMS 2018.)

Figure 37: Riparian Buffer Mitigation Site at Pepperwood Farm on Terrible Creek



This project is a good example of restoration at a strategic location (on an impaired stream, protecting several tributaries) protected in perpetuity by a conservation easement.

6.2.2.2 Existing Conserved Lands

Conservation, coupled with restoration, will help prevent waterways from being further impaired. Figure 38, below, shows in pink crosshatch eco- and hydrologically important areas identified by the NCNHP within the watershed. Note that the riparian corridor along Middle Creek is largely unprotected. NCNHP staff report that this land is too wet to develop but some parts of the area have been clear-cut in recent years. Mature bottomland floodplain forest in this area (pictured in Figure 39, and further discussed in section 2.4) should be protected in perpetuity.

When Wake SWCD learns of a landowner interested in pursuing conservation easements, they direct them to Triangle Land Conservancy (TLC). Wake SWCD has a strong partnership with TLC which involves things like TLC speaking about conservation options at Wake SWCD's annual Keeping the Farm Workshop. Wake SWCD is currently trying to create a Farmland Preservation Program in Wake, (pending County Commissioner approval in June 2022) which would include Enhanced Voluntary Agricultural Districts (EVAD) and conservation easement opportunities for Wake County landowners. This is part of their work updating their current Voluntary Agricultural District (VAD) Ordinance.

If approved this summer, the EVAD would involve a 10-yr irrevocable conservation agreement. Incentives for participating in EVAD include:

(1) the opportunity to receive up to 25% of gross sales from the sell of nonfarm products without losing zoning exemption under GS 153A-340(b)

(2) 90% cost share rate for state cost share program funds

(3) May receive priority consideration for grants

Additionally, if approved, Wake SWCD's new Farmland Preservation Program would support PLANWake (the growth and sustainability plan for development in Wake County) initiatives by:

(1) Sustaining natural resources and agricultural land by directing growth to community centers

(2) Help fulfil the goal of protecting more open spaces and working agricultural/forest land

(3) Increases preservation efforts in the rural areas and in the drinking water supply watersheds

When possible, these preservation programs should aim to protect the natural areas below:

Figure 38: Conservation Priorities Identified by NCNHP in the Upper Middle Creek Watershed

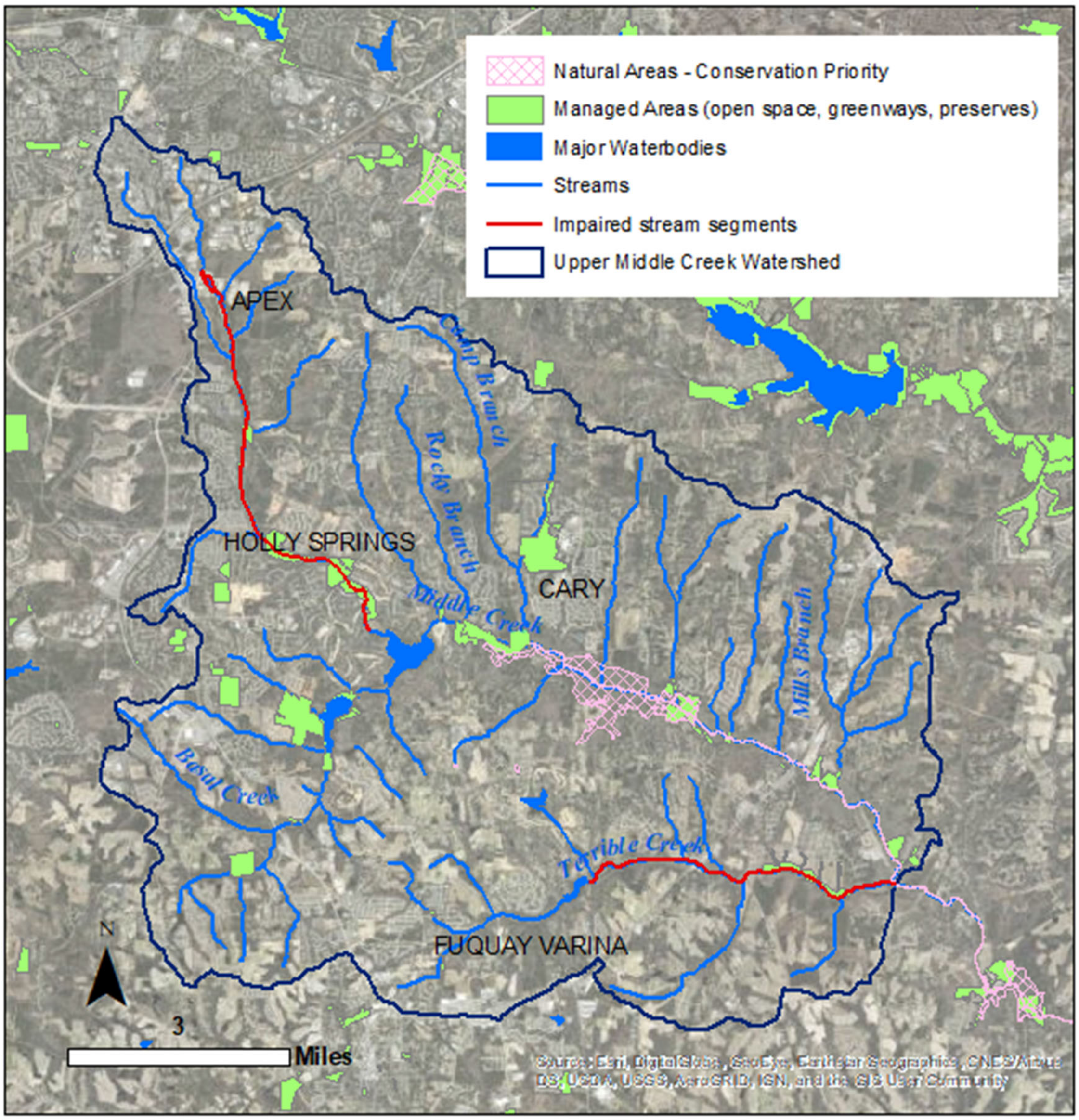


Figure 39: Bottomland Floodplain Forest Along Middle Creek (credit: Michael Schafale, NCNHP)

6.3 Prioritized Watershed Improvement Projects

This section identifies watershed improvement practices that will help address the following priority pollutants (sources):

- Stormwater volume/peak flows (due to development and impervious surfaces)
- Sediment (due to development, streambank erosion and natural sources)
- Fecal coliform (due to livestock access, wastewater and potentially leaking septic)
- Potentially nutrients (due to lawn and golf course fertilization, livestock access, and wastewater)

Priority practices defined by partners include:

- **SCMs** where feasible given available affordable land and suitable site for SCM implementation
- **Stream restoration projects** where bank erosion is actively shedding sediment into creek and local governments have the ability to alleviate peak flows via SCMs above in catchment
- **Agricultural BMPs** where near-stream agricultural activities are actively polluting the creek with sediment or animal waste or runoff from crop fields
- In addition, Wake County staff also expressed support for continuing to evaluate the need for septic system repair, replacement and education if leaking septic systems were discovered to be impacting water quality in future.

Specifically, the Town of Holly Springs and Wake County Soil and Water Conservation District staff proposed projects outlined in the following sections, all of which are short- to medium-term priorities. TJCOG staff visited two of the potential stream restoration project sites with Holly Springs staff; Wake Soil and Water and Holly Springs staff and consultants identified all projects based on field site condition assessments and communication with landowners. This "menu" of shovel-ready projects addresses both the benthic macroinvertebrate community impairment and other specific pollutant concerns outlined in previous sections. These include fecal coliform bacteria (per LNBA data and “inconclusive” DWR rating) and sedimentation issues as shown by prior turbidity impairments between 2008-2012 as referenced in NCDEQ's Neuse Basinwide Water Quality Plan and local government staff observation.

These projects are not comprehensive of all potential restoration needs to address all sources within the watershed. Rather, they are the prioritized, feasible projects identified by partners to address the benthic macroinvertebrate impairment and other observed pollutants of concern. Programmatic measures outlined in later sections should be taken as complementary to and pursued concurrently with the specific project recommendations below.

As section 4.3.1 outlines, stormwater peak flows should be reduced by approximately 15% watershed-wide to restore the benthic community. Implementing the specific practices outlined below additional practices recommended but not yet spatially prioritized will help reduce stormwater peak flows as well as other pollutants including sediment to help delist impaired segments of Middle and Terrible Creeks.

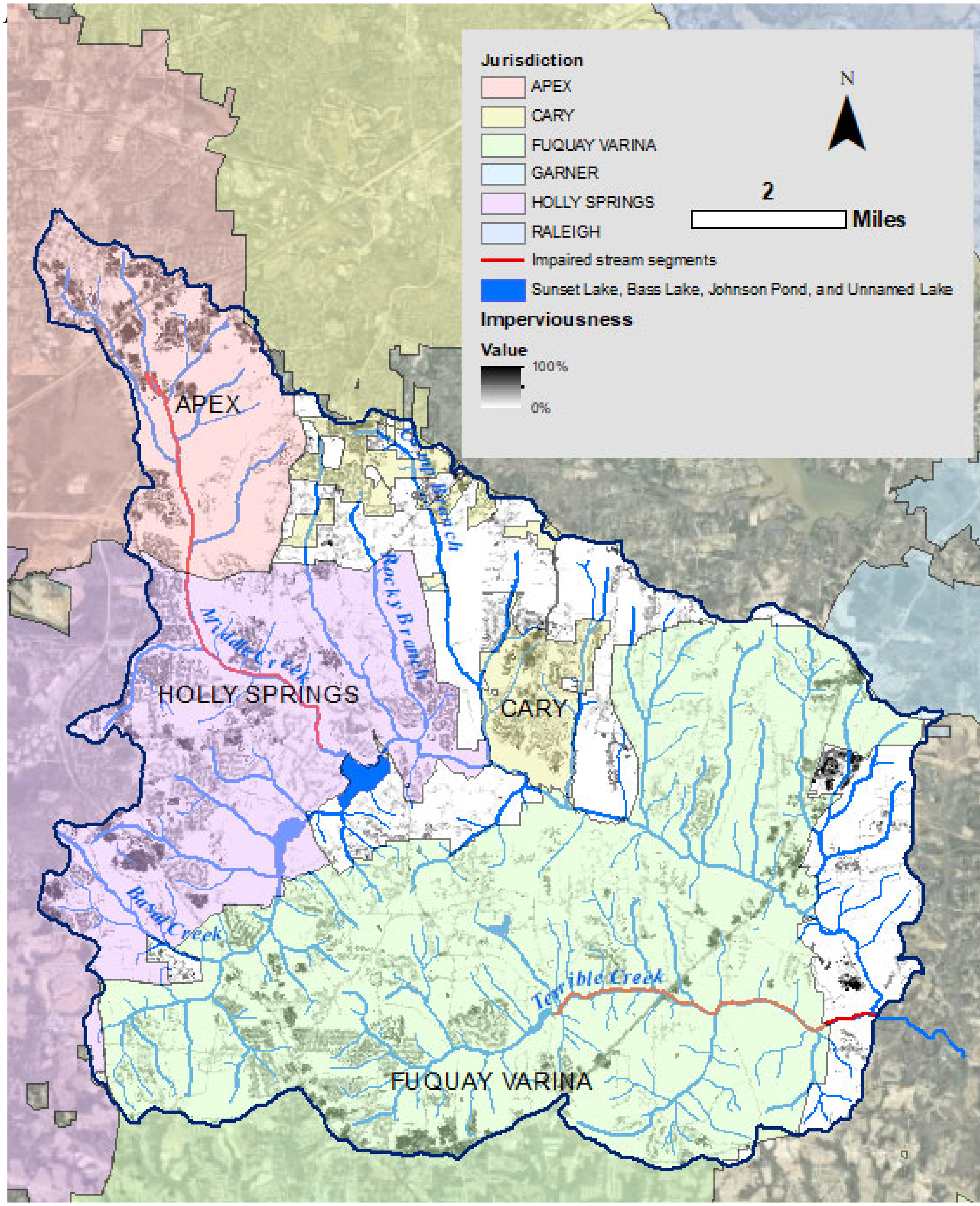
Costs of watershed restoration practices are included below and water in this section. They cannot be directly compared, because agricultural BMP and SCM costs include construction only, but stream restoration costs include permitting, engineering design, and more. However, below shows how the cost of implementing the prioritized projects outlined in this plan will be in the ballpark of $800,000.

- CONSTRUCTION-ONLY agricultural BMPs: $161,800
- CONSTRUCTION-ONLY SCM costs: $135,000 (Holly Springs staff reported that the cost of plants and topsoil alone came to nearly $50,000 at the time of writing)
- ALL Stream restoration costs (survey/easements, delineation/permitting, geotech, design (field data collection, modeling, TM, 90%, 100%, and bid documents @ $100/lf), construction, and construction administration for full stream channel restoration): $4,887,350

These costs are not comprehensive of full watershed restoration, which depends on many factors that are currently unknown. The Burnt Mill Creek watershed plan developed in Wilmington, NC noted that "only gross estimates of total cost [of watershed restoration] are possible. Claytor (1999) suggests that…a two square mile watershed that is 25% impervious has approximately 320 impervious acres…Assuming a total cost of $10,000 per impervious acre, it would take approximately $1.6 million to retrofit 160 impervious acres. This approaches $1 million per square mile of total watershed area. This estimate should be used only as a general indication of the likely scale of effort that may be necessary, assuming a sufficient number of viable retrofit projects can be identified. Actual total costs may be higher or lower depending on many factors, including the types of BMPs used and the scale of each project. Some cost reduction may be possible if retrofits are planned and implemented in conjunction with anticipated capital improvements and infrastructure enhancements," (2004).

6.3.1 Spatial Targeting of Watershed Improvement Practices

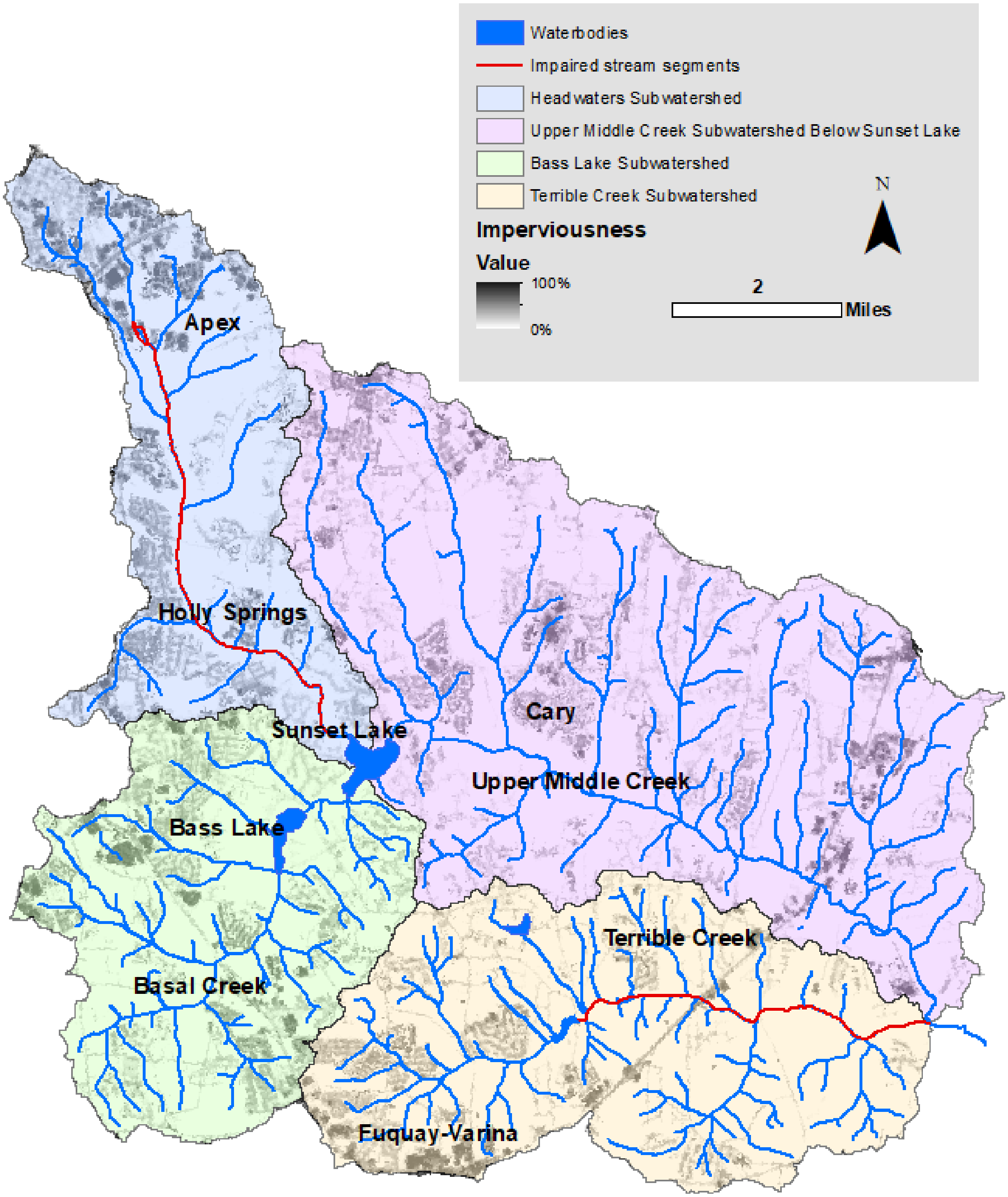
The two maps below show impervious surface distribution vs. jurisdictional and subwatershed boundaries. You can see that jurisdictions will have to collaborate to restore these impairments, since they span 3 of the 5 jurisdictional boundaries. And while only two subwatersheds contain currently impaired stream segments, the segment below Sunset Lake was previously impaired, and impervious surfaces (and therefore stormwater impacts) are distributed throughout the watershed. Thus, while it is important to target practices adjacent to impaired stream segments and at sites of highest observed stormwater runoff/pollutant loading, there is a case to be made for widespread implementation of distributed practices to address the widespread, distributed sources. Additionally, outsize pollutant loads can be contributed by sources farther from impaired segments (ie, if a construction site violated sediment and erosion control requirements during an extreme weather event.)



As you can see in the map below, the locations of impaired segments and subwatersheds do not exactly line up with jurisdictional boundaries. This shows the need to enable local governments to collaborate across jurisdictional boundaries using a One Water approach. Only collaborative efforts can solve cross-jurisdictional challenges such as watershed restoration.

The location of development within the watershed presents challenges for its restoration. The highest density of stormwater runoff-producing impervious surface is in the headwaters, composed of downtown Apex. The impaired segment of Upper Middle Creek lies directly downstream of this area, up to the backwaters of Sunset Lake.

Figure 41: Impairments, Subwatersheds and Impervious Surface Distribution



Below summarizes local government project partners' input about recommendations and challenges for siting SCMs, with TJCOG staff recommendations for targeting SCM locations.

The headwaters in **Apex** are largely built-out, and already have good buffers and tree protection policies. Apex staff cited the challenge of little available land in the headwaters where SCMs would be most useful. Further downstream where there is more available land, SCM implementation would be less helpful to address runoff volumes and pollutant loading. Staff mentioned that businesses in the built-out downtown area are implementing underground detention (for volume) coupled with proprietary nutrient reduction SCMs.

Recommendation: Continue to prioritize the current approach in Apex and continue to seek available land for other SCMs where appropriate.

Holly Springs is composed of extensive low-density development, including golf courses, private residential communities and public parks adjacent to Upper Middle Creek, Sunset Lake and Bass Lake and its tributaries. Extensive sediment is deposited into Sunset Lake.

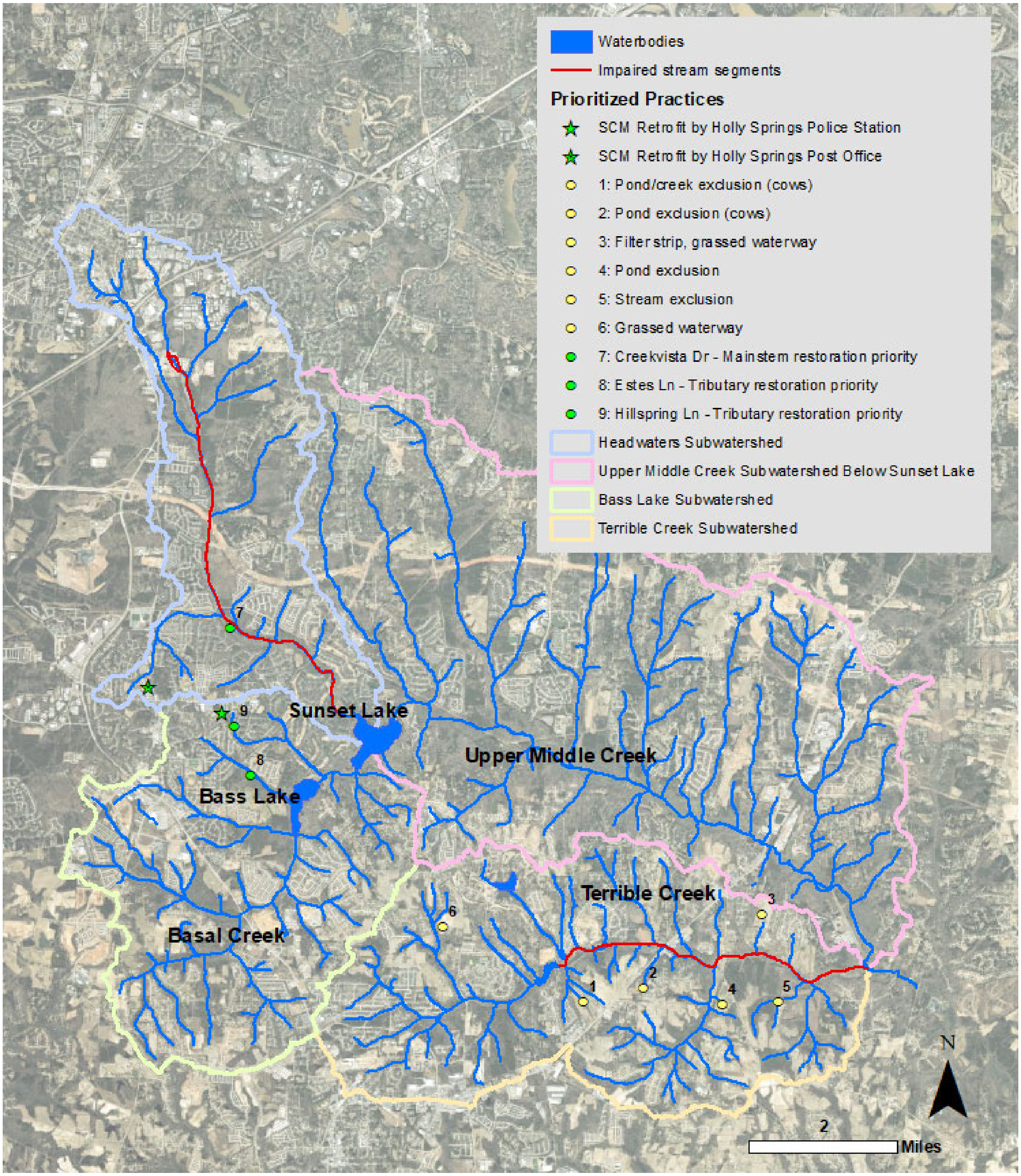
Recommendation: Implement identified SCMs and stream restoration projects and prioritize education to encourage additional SCM implementation that can address stormwater volume and sediment. (Reference section 6.2.2.1 to see widespread SCMs already constructed.)

Cary, Fuquay-Varina and portion of **unincorporated Wake County** in the watershed include higher-density pockets but are lower-density overall. This part of the watershed still contains more forest and farmland.

Recommendation: Proactively plan to protect greenspace and implement SCMs where possible. Work with Wake Soil and Water to implement agricultural BMPs and protect private forestland in this area

The specific watershed restoration projects identified by project partners are shown in the map below. They were identified based on local government staff's field-based observation of a impacts of priority pollutants (stormwater volume/peak flows, sediment and fecal coliform) causing a resource concern (ie, erosion, sedimentation); the potential to upfit low-performing SCMs; proximity to impaired segments; and public land ownership or interested/willing landowners.

Figure 42: Prioritized Near-Term Watershed Improvement Projects and Subwatersheds



6.3.2 Stormwater Control Measures

Project partners prioritized the SCM types below for implementation in the Upper Middle Creek watershed based on the following criteria:

- Stormwater peak flow and volume reduction capacity
- Land availability and cost

- Efficacy for nutrient removal
- O&M needs

NCSU BAE staff noted that "in general, detention-based practices (wetlands, wet ponds, dry ponds, infiltration basins, bioretention cells, rainwater harvesting, sand filters, and permeable pavement) will have the highest peak flow reductions for smaller storms (e.g, 1-yr, 24-hr). However, for larger storms (e.g., 10-yr, 24-hr), wetlands, wet ponds, dry ponds, and infiltration basins will provide the greatest peak flow reductions since they typically have more storage volume than bioretention cells, sand filters, rainwater harvesting systems, and permeable pavement" (Waickowski, personal communication, 2021.)

These SCM types should be prioritized where possible to help address stormwater peak flows and volume, the primary driver of the benthic impairment, and/or additional ecosystem service benefits.

Table 11: SCM Types and Efficiency Prioritized

SCM	% Annual Runoff Volume Eliminated via ET&I*	TN EMC of Effluent in mg/L	TP EMC of Effluent in mg/L
Bioretention per MDC	67%	0.58	0.12
Infiltration per MDC	84%	0	0
Wet Pond per MDC	17%	1.22	0.15
Stormwater Wetland per MDC	29%	1.12	0.15

*Calculated from references in DEMLR SCM Credit Document for predominant HSG B per communication with Rich Gannon, 2021

Project partners noted that much of the watershed is private residential land owned by HOAs which are more likely to implement wet ponds than stormwater wetlands or infiltration basins. Individual landowner and HOA track record of effectively maintaining SCMs was noted as a potential issue.

Bearing in mind these realistic constraints, project partners determined that the following SCMs should be implemented on different land uses:

- Public property: Bioretention, stormwater wetland or infiltration basins
- Business sites: Infiltration for flow, plus Storm Filter for nutrients
- Subdivisions/HOAs: Encourage use of stormwater wetlands or bioretention over wet ponds to protect creek
- Anywhere: Retrofit dry ponds as stormwater wetlands or infiltration basins

Larger storms due to climate change will mean that all tools will be necessary to prevent further degradation to streams in the Upper Middle Creek watershed and throughout the region. Hopkins et al's 2017 study in urban Maryland notes that "distributed SCMs can reduce runoff and sediment loads during small rain events compared to centralized SCMs, but these differences become less evident for large events when peak discharge likely leads to substantial bank erosion." They conclude that "meeting water quality goals requires the careful selection of an appropriate blend of infiltration- and/or detention-based SCMs and considerations for the optimal arrangement of SCMs on the landscape to possibly provide redundant treatment for large precipitation events."

6.3.2.1 Specific Prioritized SCM Projects

Specific SCM retrofits prioritized at the time of writing are mapped and described below. The Town of Holly Springs has identified 2 historic SCMs within the Middle Creek basin that are ideal candidates for retrofitting, in order to increase pollutant removal in the watershed. Both of these SCMs were installed as dry detention areas, primarily for flood detention. Staff has reviewed these devices and both appear that they could be converted to constructed wetlands in accordance with NCDEQ Minimum Design Criteria (MDC) for improved pollutant removal efficiency, while retaining the required Town flood reduction requirements. The required alterations would include, but not be limited to modification of the existing outlet structure, introduction of topsoil, regrading to create the required flow paths and pools and planting of the required water quality vegetation. These retrofits are not a requirement of any other NPDES Phase II or NSW requirements.

Load reduction estimates below were calculated by Holly Springs staff using loading rates based on current land use data and NCDEQ Minimum Design Criteria. Current dry detention basin performance to stormwater wetland performance, as STEPL does not address performance of this retrofit scenario. These estimates can be refined and estimates for TP and TSS load reductions estimates, potentially using DWR's Stormwater Nitrogen and Phosphorus Tool. SCM load reduction estimates should not be directly compared with agricultural BMPs load reduction estimates from STEPL in section 6.3.3.1 because of the difference in methods.

Cost estimates below are rough ballparks that Holly Springs staff could refine when allocated local government or other funding becomes available to do full engineering designs for these retrofits.
The Burnt Mill Creek Plan notes that "Stormwater retrofit costs are difficult to estimate until specific practices and locations have been selected. Unit costs vary greatly with the size of the area treated. Using data from the mid-1990s, Schueler (2000) reported that typical costs for stormwater ponds were about $5,000 per impervious acre treated for projects covering 100 impervious acres, but $10,000 per impervious acre treated for project treating 10 impervious acres. Treating a single acre costs an average of $25,000 or more," (2004). In other words: It's complicated, place-based, and varies widely.

Village Center Shoppes Dry Detention Area at PIN # 0649847045, Town Property Adjacent to the Post Office:

This dry detention basin was installed in 2009 and already shows signs of wetland vegetation, indicating that conversion would be successful. It has an existing bottom area of greater than 11,000 square ft that could be converted without any additional property acquirement need or modification to the embankment.

Estimated cost: $75,000
Estimated load reduction: 4.98 lbs/ac/yr TN

Figure 43: Existing Dry Detention Basin by Holly Springs Post Office, to Retrofit to Stormwater Wetland

Figure 44: Location of Holly Springs Post Office Retrofit Site

Shoppes at Bass Lake Dry Detention Area PIN #0659227849, by Law Enforcement Center:

This dry detention basin was installed in 2009 and rehabilitated in 2015. It is easily accessible and has an outlet structure that could be easily modified. It has an existing bottom area of greater than 5,000 square ft of that could be converted without any additional property acquirement need or modification to the embankment.

Estimated cost: $60,000
Estimated load reduction: 5.17 lbs/ac/yr TN

Figure 45: Existing Dry Detention Basin by Holly Springs Police Station,, to Retrofit to Stormwater Wetland

Figure 46: Location of Holly Springs Police Station Retrofit Site

Additionally, while lower priority than the above-mentioned practices, the SCM at Apex Middle School should be assessed for current relevance (this was BMP18 prioritized for retrofit in NC DMS' Neuse 01 Regional Watershed Plan). At the time of writing, Apex staff were unsure of whether this project's location would fall within the right-of-way of NC-55 road widening project, which has been delayed until 2028-29.

6.3.2.2 Recommendations and Next Steps for Implementing SCMs

It will continue to be difficult to find available land in suitable locations for additional SCMs that is not prohibitively expensive and immediately developed. Thus, retrofitting lower-functioning SCMs (such as dry detention basins) to improve pollutant reductions and better retain stormwater peak flows will continue to be one of the most cost-effective ways of implementing SCMs throughout the watershed. Where possible, new SCMs should also be prioritized to reduce runoff volume and associated pollutants at the lowest cost.

SCM Retrofit Recommendations:

- Local government staff inventory dry detention basins throughout the watershed and prioritize them for retrofit within their jurisdictions. NCSU BAE can be a resource, if needed.
- Apex can start by working with NCDOT to evaluate the feasibility of retrofitting the dry pond at Apex Middle School based on whether it will fall within the ROW.

New SCM Implementation Recommendations:

- Businesses (especially in the Headwaters subwatershed in Apex) should implement infiltration basins coupled with StormFilters or similar technologies to achieve the goal of reducing stormwater runoff volume while also meeting nutrient reduction goals. Businesses already implementing these practices can serve as a resource.
- Project partners should attempt to educate HOAs about the potential benefits of implementing wetlands instead of wet ponds due to their greater ecosystem service benefits. Partners could also explore opportunities to educate individual homeowners about implementing voluntary residential stormwater retrofits, although local government staff have noted that project permanence is less likely on private property when homeowners change.

6.3.3 Agricultural Best Management Practices

Terrible Creek is currently listed as impaired based on a single 2010 special study sample collected at IB329 (see section 3.1.1.3 and benthic station map, Figure 7.) Terrible Creek's impairment is technically an artifact of DEQ monitoring methods; it cannot be officially "unimpaired" until DEQ continues to collect data at this site.

The Terrible Creek subwatershed is relatively less developed than its upstream counterparts. The segment of Upper Middle Creek below Sunset Lake was removed from the 2016 303d list based on a benthic macroinvertebrate rating of Good-Fair at DEQ monitoring site JB068. With concerted effort to implement restoration projects and other recommended practices and policies to prevent pollution and stormwater runoff, Terrible Creek's benthic community can likewise recover.

There are relatively few animal operations in the county, but Wake SWCD offers technical assistance and financial assistance to the agricultural operations that remain, via state and federal cost share programs to install agricultural BMPs including:

- Exclusion fencing- to fence out cattle from streams and then install watering tanks or a well in the field(s)
- Dry stacks- proper waste storage for cattle and horse operations
- Nutrient management- of nutrient inputs and to utilize animal waste for crop needs
- Buffers- vegetative strips along field edges and streams to filter runoff
- Grazing management- to reduce erosion in fields

Agricultural best management practices outlined below have been prioritized by Wake SWCD to reduce crop and pastureland erosion and impacts of cattle access to streams. Implementing these projects will help alleviate sediment, nutrient and fecal coliform loading in the Terrible Creek subwatershed. Runoff volume and sediment from agricultural lands in the watershed impact benthic macroinvertebrates by scouring out and depositing fine silt into microhabitats. Additionally, as mentioned in section 3.2.7, inconclusive fecal coliform ratings suggest this may be a pollutant of concern.

6.3.3.1 Specific Prioritized Agricultural Projects

Wake SWCD staff prioritized the following agricultural BMPs based on the following criteria:

- Proximity to the impaired segment of Terrible Creek (all are ~0.5 miles from the AU)
- Need for specific BMPs associated with current crop rotation
- Feasibility, as defined by available parcels in production and long-term relationships with farmers

Wake SWCD staff have visited the sites outlined below and landowners have expressed interest in implementing the identified BMPs below, contingent on the availability of funding assistance.

Table 12: Agricultural Best Management Practice Timeline, Costs and Load Reductions

Site	BMP	Pollutant Practice Is Intended to Treat	When Project Could Be Implemented After Funding Available	Estimated Cost	Sediment Load Reduction* (tons/year)	Nitrogen Load Reduction* (lbs/year)	Phosphorus Load Reduction* (lbs/year)
1	Pond/ creek exclusion (cows), 3195 LF	Bank erosion, fecal coliform, N/P	2 years	$20,000	9.3	22.8	7.3
2	Pond exclusion (cows), 1891 LF	Bank erosion, fecal coliform, N/P	2 years	$18,200	3.4	12.0	3.2
3	Filter Strip (1,340 LF/ 0.5 ac), Grassed Waterway (500 LF/ 0.5 ac)	Sediment, N/P	1 year	$22,000	399.4	579.8	221.1
4	Pond Exclusion (2480 LF)	Bank erosion, fecal coliform, N/P	3 years	$6,800	167.0	317.5	119.1
5	Stream Exclusion (1831 LF)	Bank erosion, fecal coliform, N/P	3 years	$17,300	42.0	179.5	38.1
6	Grassed Waterway (700 LF / 0.65 ac)	Sediment, N/P	1 year	$2,500	47.0	77.2	28.9

**Estimated using EPA STEPL tool, 2019*

These BMPs identified are common in Wake County and have a high acceptance and success rate with producers. Implementation of livestock exclusion projects in the watershed are increasing as cattle access to streams affects surface water quality and animal health. Grassed waterways are common on tilled cropland and are increasingly needed due to increasing stormwater runoff in the county.

Sites 3 and 6 are conventionally tilled crop fields. Agronomic practices required include grassed waterways, filter strips, and cover crops to prevent headcuts and channelized water flow and reduce the nutrient and sediments loads to adjacent water bodies. These practices serve to slow the rate of water movement and collect sediment moving off crop fields. These projects are ready to implement in the short term given funding assistance.

Figure 47: Prioritized Site 3 For Grassed Waterway and Filter Strip

Pastureland BMPs (sites 1, 2, 4, 5) are focused on excluding cattle from ponds and streams. At the sites listed, cattle currently utilize surface waters as a drinking source, resulting in destabilization of banks and degraded water quality. Livestock exclusion systems involve installing fences to prevent cattle access to water bodies and reliable, clean water source to replace the surface water source. Bank stabilization measures may be required at some sites. When funding becomes available, these projects will be ready to implement within 2-3 years.

Figure 48: Prioritized Site 2 for Cattle Exclusion

Figure 49: Pond Exclusion Needed Due to Bank Destabilization at Site 4

6.3.3.2 Recommendations and Next Steps for Agricultural Best Management Practices

Agricultural BMPs should continue to be prioritized in the Terrible Creek Subwatershed to address observed sources of sediment runoff from farm fields and sources of animal waste to streams. Projects should be prioritized as near to impaired Terrible Creek as possible for greatest benefit. SWCD staff should use available tools to estimate load reductions that would result from any further projects.

6.3.4 Stream Restoration Projects

Prioritized stream restoration projects outlined below are intended to stabilize streambanks and reconnect stream and floodplain in areas where high stormwater flows from the (sub)urbanized headwaters are impacting benthic macroinvertebrates and water quality in Upper Middle Creek.

Current impacts of urban stormwater on this upper reach include bank erosion, channelization disconnecting the stream from its floodplain, and reduced sinuosity. Given the pace of development in Holly Springs, there exists a need to manage increasing stormwater runoff volume and its impacts to streambank erosion. Stream restoration projects outlined below have been prioritized by Town staff to reduce sediment loading stemming from streambank erosion (as referenced in section 3.1.3.3.), and to help slow and infiltrate stormwater before it reaches the stream, preventing it from scouring out and/or depositing fine silt in microhabitats which benthic macroinvertebrates need to survive.

6.3.4.1 Specific Prioritized Stream Restoration Projects

Holly Springs staff prioritized the following stream restoration sites based on locations with known bank erosion, distance to Upper Middle Creek (one is directly on Middle Creek, two are on tributaries), and feasibility as defined by land ownership and access. Holly Springs staff have visited the sites outlined below and landowners have expressed at least initial interest in implementing the projects depending on the availability of funding.

The three stream restoration sites prioritized are shown in the table and discussed below. Estimated costs include survey/easements, delineation/permitting, geotech, design (field data collection, modeling, TM, 90%, 100%, and bid documents @ $100/lf), construction, and construction administration for full stream channel restoration. Listed load reductions were estimated using BANCS methodology (Chesapeake Bay Program, n.d.) and NCSU erosion rate curves (unpublished) and confirmed by Freese and Nichols who conducted a bank erosion rate study for the Town of Holly Springs (Ian Jewell, personal communication, 2020.) These methods solely quantify the sediment load reduction due to avoided bank erosion, as Holly Springs staff identified bank erosion as a major sediment source and motivation for implementing stream restoration projects. Improved buffer and reconnection to the floodplain will also reduce nutrient and sediment loading from the larger watershed which have not been quantified due to lack of existing NC-based data/models or funding to collect field data at the time of writing. Field data collection as part of funded engineering design can be used to update load reduction estimates in future.

Table 13: Stream Restoration Project Timeline, Costs, and Load Reductions

Site	Location description	Land ownership	Estimated implementation timeline	Estimated cost	Sediment load reduction*	Nitrogen load reduction**	Phosphorus load reduction**
7	Creekvista Drive Outfall (1,600 LF)	HOA (may bequeath to town)	3-5 years	$1,647,100	119 tons/yr	271 lbs/yr N	125 lbs/yr P
8	Estes Lane Outfall (2,200 LF)	Public/utility easement	2-3 years	$2,251,600	273 tons/yr	622 lbs/yr N	286 lbs/yr P
9	Hillspring Lane Tributary (950 LF)	Private	3-5 years	$988,650	118 tons/yr	269 lbs/yr N	124 lbs/yr P

**4'-5' bank height x lengths listed above x 0.15 – 0.2 ft/yr erosion rate derived from NC Piedmont streambank erosion curves using BEHI/NBS per Freese and Nichols/Town of Holly Springs*
***Per Chesapeake Bay Protocol default concentration of 1.05 lb/ton P, 2.28 lb/ton N in soil volume above (Stantec, n.d.)*

TJCOG staff visited two of the proposed Upper Middle Creek stream restoration sites with Holly Springs staff on 6/26/19. Below, Upper Middle Creek near Creekvista Drive is a prioritized stream restoration site impacted by historical practices of water and sewer installation removing buffers, lack of buffer regulations during development, as well as upstream development occurring prior to current stormwater control regulations. The channel shows visible signs of degradation and bank instability. The channel length shown needs varying degree of rehabilitation and stabilization and the primary impediment to restoration is currently financing and full access for construction. Holly Springs staff have met with the homeowners' association at this site, and the HOA is amenable to the possibility of bequeathing the property to the Town as the land is not useable and is seen as a potential liability due to erosion and NSW designation.

Figure 50: Upper Middle Creek in Holly Springs near Creekvista Drive

The second site that Holly Springs staff have prioritized for stream restoration is on a tributary of Upper Middle Creek that flows to Bass Lake. This site off Estes Drive, pictured below, has been impacted by similar historic development, buffer and water/sewer line installation practices as the Creekvista Drive site. This tributary is on public property associated with a nearby park and is a priority site for stream restoration, possibly combined with a future greenway. The primary current impediment to restoration is financing and granting of increased access easement from private owners (it is necessary to walk across private property to access this reach.)

Figure 51: UT to Upper Middle Creek near Estes Drive (Looking Downstream)

Finally, Holly Springs staff have prioritized a stream restoration on another tributary which leads to Bass Lake, off Hillspring Lane. Conditions are very similar to the Estes Drive reach pictured above. The channel shows visible signs of degradation, loss of sinuosity and bank instability. Holly Springs staff have had preliminary conversations about this potential project with several homeowners along the Hillspring Lane reach; the current main impediment to restoration is financing, granting of increased easement from private owners and potential loss of "usable" property for affected owners.

6.3.4.2 Recommendations and Next Steps for Stream Restoration Projects

Stream restoration projects have been and should continue to be prioritized at sites where streambanks are unstable and eroding, via riparian buffer planting if possible, via nature-based stream restoration designs (as approved by local government staff and contractors) if not. Projects should be prioritized as near to impaired segments as possible for greatest benefit.

It will be challenging to restore benthic macroinvertebrate community health on this part of Upper Middle Creek given that the headwaters are already developed, ongoing development is proceeding rapidly, and most of the land is privately owned. However, this makes it all the more important to take the opportunity, in advance of further buildout, to implement stream restoration projects in conjunction with other recommended practices and policies outlined above. Section 7.0 outlines further watershed management recommendations including non-structural practices.

7.0 IMPLEMENTATION SCHEDULES

7.1 Roles and Responsibilities

Table 14: Roles and Responsibilities in Plan Implementation

Organization	Roles and Responsibilities
Triangle J Council of Governments	- Seek 319 funding to implement prioritized projects - Serve as technical advisor on plan implementation - Follow up with project partners about progress toward meeting implementation goals, objectives and actions - Convene partners every 5 years to reassess and update plan - Via TJCOG CWEP program staff, create educational materials and/or technical communications for public consumption and train interested stakeholders on community science tools
Wake County Soil & Water Conservation District	- Provide agricultural BMP recommendations in unincorporated Wake County and lead agricultural BMP implementation
Town of Holly Springs	- Provide SCM and stream restoration recommendations within jurisdiction and lead project implementation there - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation
Wake County	- Provide watershed restoration project recommendations within jurisdiction and lead implementation there - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation - Provide updates on malfunctioning septic system data
Town of Fuquay-Varina	- Provide watershed restoration project recommendations within jurisdiction and lead implementation there - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation
Town of Apex	- Provide watershed restoration project recommendations within jurisdiction and lead implementation there - Provide updates on any programmatic changes that enable more widespread restoration and conservation implementation
North Carolina Division of Water Resources	- Provide updates about any 9-element planning or 319 grant requirements to project team
Whole planning project team above	- Communicate updates to TJCOG project manager, other team members as they occur

	- Propose updates to goals, objectives and actions in plan, as necessary, as implementation progresses - Participate in meeting every 5 years to update plan, assess progress toward meeting goals - Provide technical assistance and funding for prioritized projects within jurisdictions - Provide education and outreach within own jurisdictions
Watershed Group (TBD, resident-led)	- Engage stakeholders (local residents, parks, etc) - Participate in annual team meetings

7.2 General Implementation Schedule

This plan is being developed for the next 20 years. It will be re-evaluated and updated every 5 years based on project partner input.

Table 15: General Implementation Schedule.

Action	Partner	Time
Seek and budget funds for watershed restoration projects in watershed.	Local governments/Wake SWCD with TJCOG assistance on grant applications (local governments to provide match)	Years 1-10
Investigate other cost-effective methods of retrofitting SCMs on public and private property beyond what is currently outlined in plan.	TJCOG with most interested partners	Years 1-5
Meet with partners to support efforts that are already in place and to determine best methods to incorporate additional stormwater education about Upper Middle Creek	TJCOG CWEP educator to reach out to all local government stormwater staff who already work with CWEP program	Annually
Catalyze development of watershed group and/or champion by doing at least one of the following (based on partner input): 1) Develop citizen/stakeholder capacity to lead watershed efforts a) Hold meeting for stakeholders to learn about the watershed plan, give input, and survey them on their values and priorities b) Based on interest, host follow-up meeting for interested residents of watershed to meet, organize, coalesce into watershed group, with TJCOG staff input and local government staff support	TJCOG to facilitate, local governments to support, residents of watershed to attend	Within 5 years

2) Develop local government staff capacity to lead watershed efforts. a) Present to Town/County Boards about the need for dedicated staff support for watershed restoration implementation b) If it is possible to create a funded position(s) they could serve as watershed coordinator/ champion to help implement this plan	TJCOG with local government support	Within 5 years
Review each Town and Wake County's current planning, zoning, new development and land management strategies and regulations to maximize stormwater reductions (ie, using Center for Watershed Protection Codes and Ordinances worksheet)	Local government staff lead within jurisdictions or TJCOG if funded time to complete	Within 5 years
As prioritized by partners, seek additional monitoring support from DEQ; incorporate as addendum to this Plan (see monitoring and recommendation 1: Expand Monitoring)	DEQ with most interested local governments	Years 1-10
Connect with Triangle Land Conservancy, Wake SWCD about conservation opportunities	TJCOG bring up NHP prioritized areas (TLC and Wake SWCD already collaborate)	Years 1-5 and ongoing
Mid-course Evaluation. Update the Watershed Management Plan with Addendums (see Evaluation section)	TJCOG	Year 10
Explore Education and Outreach opportunities, resource needs (such as for HOAs)	TJCOG with local government partners via CWEP	Year 1-5
Promote stormwater reduction retrofits within private developments once HOAs have been educated about the importance of stormwater management	Local government partners to lead within jurisdictions	Year 10
Annual review of Milestones and Evaluation to determine whether plan remains on track. Implement further evaluation to get back on track if necessary (see section 7.6)	TJCOG and/or local government watershed coordinator	Year 15
Renew plan. Update and write updated Watershed Management Plan. Additional funding should be sought during this time to support additional 10 years.	TJCOG and/or local government watershed coordinator	Year 17
Final Assessment. Review entire plan and implementation successes and failures, lessons learned and how future plans can improve	TJCOG and/or local government watershed coordinator	Year 20

7.3 Project Implementation Schedule

The estimated cost does not incorporate staff time of partners involved and strictly considers cost of materials and professional labor to install projects. Estimated Cost reflects total cost to install or execute all components of the Action and Indicator (it does not reflect each individual installation but the Action as a whole).

Table 16: Restoration Project Implementation Schedule

Action	Partner Responsible	Time	Maintenance Schedule	Estimated Cost	Indicator
Printing and distribution of stormwater management education materials to residents	TJCOG (via CWEP program distributing general and/or Upper Middle Creek-specific materials to local government staff)	Year 1-5	Annually provide additional prints to public buildings	$100/year	500 residents receive educational materials annually
Install dry detention retrofits at Holly Springs Police Station and Post Office, with signs	Holly Springs	Year 1-5	Annually, incorporate with regular landscape maintenance schedule	Approx. $135,000 for retrofit of two dry detention basins as stormwater wetlands	Construction of 2 retrofits with signs as appropriate
Install agricultural BMPs 1-6 in the Terrible Creek Watershed	Wake SWCD	Year 1-10	Contract between landowner and SWCD stipulates permanence for 10 years (SWCD conducts annual spot checks of 5% of open contracts)	$86,800	Construction of agricultural BMPs

Install 3 of 3 stream restoration projects	Holly Springs and Wake SWCD	Year 1-10	Holly Springs: annually, incorporate with regular lanscape maintenance schedule; Wake SWCD: Assessed at year 5 of contract with landowner	$4,887,350 (includes all costs*, not just construction)	3 of 3 stream restoration projects
(Other projects to be added here after year 10)					

*survey/easements, delineation/permitting, geotech, design (field data collection, modeling, TM, 90%, 100%, and bid documents @ $100/lf), construction, and construction administration for full stream channel restoration

7.4 Milestones for Project Implementation

Interim, measurable milestones that will be tracked include:

- Quantitative milestones like the number of SCM and agricultural BMP projects installed, linear feet of restored streambanks, acres riparian area revegetated and land conserved, amount of funding received to implement watershed restoration projects, the number of new local government FTEs dedicated to implementing targeted watershed restoration projects, the number of community members educated on stormwater pollution/reduction techniques, and ultimately, the number of stream miles no longer impaired
- Qualitative milestones like pre- and post-project photos, the existence of a watershed group, existence of contracts for planning/engineering SCMs and/or urban stream restoration projects prioritized in this plan, implementation of agricultural BMPs and project permanence for 10 years per contract between landowner and Wake Soil and Water Conservation District, and adoption of ordinance and programmatic changes that support, enforce, or enhance plan recommendations
- See also criteria/indicators in Section 7.5 below

7.4.1 Short Term (1-5 years)

- TJCOG/Holly Springs and/or Wake County secure at least one 319 grant to implement projects that could include:
  - Install Holly Springs' two proposed dry detention basin retrofits for stormwater reduction and 1 of 3 stream restoration projects (linear feet vary by project; see 6.3.2.1 and 6.3.4.1 for LF for specific projects)
  - Install 3 of 6 agricultural BMPs prioritized in plan (linear feet vary by project; see 6.3.3.1 for LF for specific projects)
- Local government stormwater staff and TJCOG CWEP program educate residents of watershed on stormwater runoff and stormwater reduction techniques

- TJCOG and/or local government staff present to the town board or stormwater advisory committee of at least one local government in the watershed to make the case for the importance of funding dedicated staff for watershed conservation and restoration (ideally, that can partner across jurisdictions to reduce stormwater impacts)
- Reduce average peak stormwater flows by 5% through the implementation of SCMs, disconnecting impervious surfaces, and other techniques

7.4.2 Mid-Term (5-10 years)

- Local governments (with TJCOG support if needed) secure at least one NCLWF, 319 or other grant to install projects that could include:
    - Additional retrofits of dry detention basins across the watershed to reduce stormwater volume and peak flows
    - Remaining 3 agricultural BMPs prioritized in plan, or substitute appropriate deliverable if these projects no longer remain relevant
    - 2nd and 3rd stream restoration projects prioritized in plan, or substitute appropriate deliverable if these projects no longer remain relevant
- Local government stormwater staff and TJCOG CWEP program educate residents on stormwater runoff and stormwater reduction techniques
- Reduce average peak stormwater flows by 5% through the implementation of SCMs, disconnecting impervious surfaces, and other techniques
- TLC and project partners work to conserve land to prevent degradation, specifically prioritizing land in headwaters as well as Upper Middle Creek Bluffs and Floodplain habitat prioritized by NCNHP for both species/ecosystem and flood storage
- At least one local government (or TJCOG) has hired a staff member with dedicated funding to focus on watershed protection and restoration planning, policies and projects within their jurisdiction (not primarily on regulatory compliance, development review, gray stormwater infrastructure inventory and maintenance, etc. as important as those may be.) This person would be the ‘champion’ of the plan and Upper Middle Creek restoration.

7.4.3 Long-Term (10-20 years)

- Continue to prioritize and install SCMs (new or retrofit), agricultural BMPs and stream restoration projects as appropriately prioritized using methods outlined in this plan or by project partners using new data/information about watershed
- Local government stormwater staff and TJCOG CWEP program educate residents on stormwater runoff and stormwater reduction techniques
- Reduce average peak stormwater flows by 5% through the implementation of SCMs, disconnecting impervious surfaces, and other techniques
- Ideally: Both Upper Middle and Terrible Creek AUs unimpaired
- Upper Middle Creek Bluffs and Floodplain permanently protected

7.5 Monitoring and Evaluation of Meeting Plan Goals

Progress toward meeting the primary plan goal of benthic recovery will be monitored using the following evaluation criteria in the table below. These will be used to determine whether stormwater peak flow and water quality reductions impacting sensitive benthic macroinvertebrates are being achieved over time, and therefore whether substantial progress is being made toward attaining water quality standards.

The definitions of short-, medium- and long-term below are the same as above:
Short term: 1-5 years; Medium-term: 5-10 years; Long-term: 10-20 years.

Primary Goal Indicators

	Indicator	Measured by	Collected by	Collection Cycle
1	Benthic community health	Medium term: Compare DEQ benthic community ratings in successive assessments with current ratings until Good-Fair or above is achieved and AUs are not impaired	NCDEQ	Every 3-4 years
		Long term: DEQ special benthic study in 20 years to verify if cumulative impact of restoration and protection efforts outlined below have improved benthic community	NCDEQ	Single instance
	Stormwater peak flows	Ongoing: Stormwater peak flow reduction is necessary for benthic community recovery and improved benthic community ratings would be an indicator of reduced stormwater peak flows. (I know this is circular logic, but the 2009 Swift Creek TMDL outlines benthic recovery as their metric of stormwater flow reduction, assessed via proxy target of reducing effective impervious cover to less than 9%.)	See above	
		Medium-term: Visual indicators of reduced stormwater conveyance to Upper Middle Creek and tributaries, as monitored using DEQ community science tools such as Source and Conveyance Information Tracking System	TJCOG CWEP educator initiating a Stream Watch group; then, independent	TBA depending on community interest

		(SCITS) tool (more info about community science tools here) Ongoing: Modeled change in peak flows based on impervious surface data to be generated by Wake County Long-Range Planning based on recent orthophotos (more granular than NLCD-based impervious cover used by StreamStats)	 Wake County Long-Range Planning and Water Quality Division	 TBA depending on frequency of orthophoto flights, but starting with 2021 data
2	Sedimentation issues	Short term: Rate of growth of delta in Sunset Lake Short term: Presence/absence of developer sediment/erosion control violations Medium term: BEHI scores for impaired assessment units Medium/Long term: Turbidity ≤ 50 NTU per state standard	LNBA TJCOG with info from local governments Consultant TBA (Freese and Nichols is already working on this on tributaries in Bass Lake sub-watershed in Holly Springs; if Apex and Fuquay prioritize, could contract to assess BEHI there too) No turbidity data is currently collected in watershed; if DEQ established an ambient station here or if a Stream Watch or future watershed group had an interest in citizen science, they could monitor turbidity	Monthly Could assess annually TBA TBA

3	Nutrient enrichment (due to golf courses, lawns and potentially wastewater)	Short term: Presence/absence of visible algae growth downslope of fertilized lawns, golf courses, leaking septic systems etc., observed as part of LNBA monitoring	LNBA	As observed
4	Fecal coliform issues (due to cows in stream, possible wastewater sources)	Short term: Fecal coliform continuing not to exceed state standard of ≤ 200 cfu/100 mL Medium term: New livestock exclusion fencing Medium term: Partners could prioritize DEQ do a 5 in 30 study to get a baseline and redo after implementing projects to reduce impacts of nutrient sources	LNBA Wake SWCD DEQ	Monthly After project implementation TBA depending on partner and DEQ priorities, capacity
5	Education to increase community stewardship	Short term: Conduct pre- and post-assessments at all CWEP educational visits in Apex, Holly Springs, Cary and Fuquay-Varina within the watershed to document student learning post-lesson Medium term: Establishment of a dedicated school group to collaborate on education, engagement with Upper Middle Creek by school campus and in public parks Medium term: Number of landowners that attended community meetings who implement new BMPs	TJCOG CWEP educator facilitate annual education visits with local government stormwater staff TJCOG CWEP educator facilitate initial education visits with local government stormwater staff, then self-led Wake SWCD and Water Resources	Annually TBA depending on interest 5+ years
6	Facilitate ongoing partnership of local governments to implement, update plan	Short term then ongoing: Project partner attendance at check-ins about status of watershed health, updates for plan every 5 years	TJCOG (facilitate); all partners (active participants)	Meet every 5 years

7.6 Evaluation of Plan Deliverables

To ensure that the Watershed Management Plan is meeting the needs of the watershed and the community, the watershed plan will be evaluated on a regular basis to determine its effectiveness. The table below outlines how this plan will be evaluated over its 20-year lifespan.

Note that the evaluation metrics below effectively will be evaluating the impacts of ongoing development as well as of implementing watershed restoration projects. Thus, the project team should re-evaluate metrics over the life of the plan and re-assess strategies to meet the plan goals, to ensure partners meet goals and that any failures to meet them do not reflect impacts to the watershed outside of partners' control.

Table 17: Evaluation of the Upper Middle Creek Watershed Management Plan

Evaluation	Partner	Indicator	Timeframe
Progress toward implementing projects prioritized in plan	Holly Springs, Wake SWCD	Have applied for and been awarded funds to implement SCM, stream restoration and agricultural BMP projects, with locally- committed funds as well	Years 1-10
Progress towards meeting peak flow reduction goals, estimated at watershed scale after installing stormwater reduction projects	Holly Springs or other local government staff implementing SCMs	*Storm EZ* at site of SCM retrofits; StreamStats or other method at watershed scale	Pre/Post implementation of projects
Progress towards meeting benthic standards	TJCOG based on DEQ data	Fair benthic rating should increase to Good-Fair or above at stations JB295, JB330 and IB329, and Good benthic rating at JB68 should be maintained	Assess at years 10, 15, 20 based on data collected every 3-4 years
Progress toward meeting impervious cover goal	Wake County (currently calculating more granular impervious cover data based on recent orthophotos)	Impervious cover remains or decreases to <=10% in all subwatersheds and the watershed as a whole	In 2022 and again in 10 years, pending funded time to complete follow-up impervious cover assessment
Mid-course evaluation	TJCOG with local government input	Conduct full assessment of plan with suggestions on ways to enhance or redirect the plan to meet goals	Year 10
Education and Outreach Evaluation	TJCOG CWEP program with local governments	Evaluation of Education and Outreach success: review stakeholder input garnered through info meeting, Watershed	Year 10

		Group, any Stream Watch or other education/ engagement groups that generate.	
Publicize and evaluate successes	Local governments implementing projects or education events	During/after project implementation and during education and outreach events update stakeholders on watershed successes	Throughout, as projects and education efforts are implemented

8.0 ADDITIONAL RECOMMENDATIONS FOR PLAN IMPLEMENTATION

8.1 Recommendation 1: Expand Monitoring of Watershed Condition

This plan recommends more frequent long-term monitoring of benthic macroinvertebrates and water quality parameters to provide a clearer baseline status and to show changes to water quality over time as the watershed urbanizes. Specifically, continuous benthic macroinvertebrate monitoring at the same stations would aid comparisons over time. In particular, Terrible Creek is currently listed as impaired based on a single 2010 special study sample collected at IB329 (see section 3.1.1.3 and benthic station map, Figure 7.) Because of this, the Terrible Creek subwatershed cannot be delisted until DEQ collects further benthic data collection on AU 27-43-15-8-(2). If Partners prioritized the expense, performing benthic bioassays throughout the creek could help identify where any sediments are toxic to or unable to support benthic life.

As sediment was identified as a pollutant of concern, monitoring of total suspended solids at more locations in the watershed would help better capture the impacts of high flows. LNBA, DWR, local governments or another entity could potentially complete this monitoring, depending on staff capacity and other concerns. Turbidity monitoring would also be useful given that impairments are designated based on turbidity.

Fecal coliform data characterized in section 3.2.7 suggests that more frequent fecal coliform monitoring at LNBA stations J4690000, J4868000, and J4980000 might show Upper Middle Creek to be impaired for fecal coliform bacteria levels. If Division of Water Resources staff completed a “5 in 30” study (five samples in 30 days) this could help elucidate whether the fecal coliform data observed to exceed EPA recommendations for primary recreation would also classify Upper Middle Creek as impaired using DWR methodology.

A microbial source tracking study may also be helpful to identify fecal coliform sources in the watershed. Identifying the relative contributions of wildlife, cows, pets, and humans’ leaking septic systems would be a helpful tool to inform fecal coliform management strategies.

8.2 Recommendation 2: Seek to Increase Public Education and Engagement

As mentioned under Objective 5 in section 5.5, effective education, outreach and public involvement is important to increase the public’s understanding of how they impact watersheds and how watersheds impact them, as well as to solicit input on potential restoration projects and to promote behaviors that protect water quality. As local governments in the watershed consider projects outlined above for implementation, local governments’ hosting “open house” / Q&A sessions would help increase public understanding of and interest in these projects. Open houses should follow best practices to ensure anyone who wants to can attend and listen closely to attendees’ concerns.

Additional local government public education staff to be involved in these efforts whose roles were not previously mentioned in this plan include:

- Matthew B. Poling, mpoling@fuquay-varina.org, Fuquay-Varina Engineering Director

- Nancy Daly, Nancy.Daly@wakegov.com, under auspices of Wake County One Water Partnership, leads education and outreach subcommittee

Apex, Holly Springs, Cary and Fuquay-Varina all participate in TJCOG's Clean Water Education Partnership (CWEP) program, which uses education and outreach to teach the public how our individual and collective behaviors can improve water quality. Wake County is not currently a member of CWEP; joining would help citizens who reside in unincorporated Wake County in the Upper Middle Creek watershed learn about how they can affect water quality.

CWEP's Education and Outreach Coordinator conducts in-depth education for children and adults at schools (virtual or in person), libraries, and festivals, as well as via social media and a dedicated website. Municipal staff participating in the development of this plan have taught school-aged children about stormwater alongside the Education and Outreach Coordinator, whose lessons teachers or stormwater staff can also use on their own and tailor for their needs. CWEP can also provide tools such as app-based citizen science efforts and by train youth to implement Stream Watch programs, which Scouts or other groups could do in the Upper Middle Creek watershed. CWEP conducts pre/post assessments at selected events to assess audience learning about behaviors that reduce personal impacts on stormwater pollution.

8.3 Recommendation 3: Collaborate Using a One Water Approach to Manage Stormwater at All Scales

Lack of available, affordable land is a challenge in this rapidly urbanizing watershed; thus, creative, collaborative solutions must be found to secure land, funding, and support for stormwater control measures to reduce peak stormwater flows that degrade Upper Middle Creek habitat. Stormwater utility fees are one important, sustained funding source for SCM implementation, and thus are an important tool for local governments in the watershed to implement whenever possible.

All partners cited limited available public land on which to site SCMs. Where possible, larger scale SCMs maintained by municipal staff would help to retain and treat the increasing volume of stormwater runoff that this rapidly urbanizing watershed generates. Additionally, local governments could expand efforts to incentivize more widespread implementation of small, distributed green infrastructure projects on private property, where project permanence can be assured. Wake and Durham Soil and Water Conservation District CCAP programs, Ellerbe Creek Watershed Association's Creek Smart program, and City of Durham's Rain Catchers program are all excellent local models of this type of program that municipalities in the Upper Middle Creek watershed could follow if capacity allowed.

A regional approach to stormwater management is currently somewhat limited by how local governments are prohibited from spending funds on stormwater management in other jurisdictions. If a "One Water" approach to stormwater management becomes possible, local governments could consider partnering to fund and implement SCMs in beneficial locations for the watershed across jurisdictional boundaries.

8.4 Recommendation 4: Preserve Critical Areas to Prevent Degradation

In addition to watershed restoration projects, preserving land to prevent future degradation is an important preventive action to take in designated critical areas, as well as wherever possible given the rapid pace of growth. The Neuse River Basin Water Quality Plan stated that "Local governments, land trusts and watershed groups need to work together to protect and preserve sensitive lands within this watershed," (NCDEQ 2009.)

Specifically, action should be taken to permanently protect the Significant Natural Areas shown in Figure 5 identified by NCNHP in the Upper Middle Creek watershed. Conserving Upper Middle Creek's floodplain and instream habitat will protect ecosystems composed of threatened, endangered or rare species, as well as species that may be declining which are not yet rare. Parts of important Middle Creek Bluffs, Floodplain and Aquatic habitat identified by NCNHP are privately owned. These sites could be prioritized for conservation acquisition by Triangle Land Conservancy or other conservation organizations. Protecting the Middle Creek Bluffs, Floodplain and Aquatic Habitat would not only protect high-quality habitats for rare species, but also serves to store and filter stormwater runoff before it enters the stream, helping to stabilize streambanks and preventing erosion. This is just one example of how riparian ecosystem conservation provides many benefits ranging from flood protection to improved habitat to improved water quality.

More broadly, jurisdictions in the Upper Middle Creek watershed could follow the model the Upper Neuse Clean Water Initiative (UNCWI) has taken to collaboratively invest in preserving land for watershed protection. While the majority of UNCWI protected sites are in the Falls Lake watershed, several sites are in the Swift Creek watershed adjacent to Upper Middle Creek and could serve as examples.

Additionally, continued tree canopy protection is recommended as the municipalities and the I-540 corridor develops. Apex could share its tree protection policy as a model for other municipalities. The USFWS' 2019 Biological Opinion put forth as part of the Complete 540 environmental impact assessment process recommends "protection of riparian corridors and leaving sufficient canopy cover along banks" to protect the endangered Atlantic Pigtoe mussel species. Continued riparian tree protection would help protect not only threatened mussel species but the whole watershed ecosystem by shading the stream to reduce temperatures, maintaining bank stability/decreasing bank erosion, and providing woody debris and habitat. Tree canopy throughout the watershed, beyond the riparian zone, should also be pursued whenever possible, as trees serve as green stormwater infrastructure.

USFWS' 2019 Biological Opinion recommends "moderation of surface and ground water withdrawals to maintain natural flow regimes; increased use of stormwater management and reduction of stormwater flows into the systems; and reduction of other watershed and floodplain disturbances that release sediments, pollutants, or nutrients into the water." This underscores how preventing further degradation of this watershed will require a holistic approach including strategic conservation, restoration and stormwater management; innovative local and regional policies, funding mechanisms, and adequate staffing to implement them; and consideration of the relationship of groundwater to streamflow and surface water quality.

8.5 Recommendation 5: Strengthen Planning and Policy Tools to Prevent Pollution

Planning tools can be used to make it easier to implement green infrastructure and to reduce stormwater runoff. The Center for Watershed Protection and Wisconsin Sea Grant have both developed tools that systematically score local governments on their current use of planning tools governing residential streets and parking lots, lot development, conservation and natural areas, and explicit stormwater codes, among others.

The Neuse 01 Preliminary Findings report recommended more stringent enforcement of erosion and sediment control programs (Wildlands 2014). Local programs are delegated by the State and the Sedimentation Control Commission and NC DEMLR has oversight. Local government staff in this rapidly growing region face the challenge of constantly having more and more potential pollution sources to oversee; further conversation with state government staff on appropriate staffing levels for local programs would be beneficial. Similarly, illicit discharge detection and elimination may fall under an NPDES Permit, another state rule such as a Nutrient Management strategy, or local ordinance and may likewise be challenging to comprehensively enforce given current staffing levels and the pace of development. In other words, policy tools are only as effective as their implementation. At the time of writing, local and state government were both having trouble keeping departments fully staffed, presenting a challenge for implementation/enforcement.

8.6 Recommendation 6: Secure Funding and Technical Assistance to Implement Plan Recommendations

The practices outlined in section 6.3 and recommendations in section 8.1 - 8.5 largely require funding and technical expertise to implement. Local government staff have expressed interest in pursuing 319 grants and other funding to implement projects prioritized in this plan or others that would address the identified pollutants of concern. This document is intended to be a resource for these ongoing efforts.

Potential funding and technical assistance sources are outlined below. These can be updated as time goes on.

Table 18: Sources of Financial Assistance for Plan Implementation

Funding Source	Deadline	Funding Purpose	Website
NCDWR 319 Program	May	Projects to restore watersheds impaired by nonpoint source pollution	www.deq.nc.gov/about/divisions/water-resources/planning/nonpoint-source-management/319-grant-program
NCDWR Water Resources Development Grant	June, December	Stream restoration, land acquisition	https://deq.nc.gov/about/divisions/water-resources/water-resources-grants/financial-assistance
National Fish and Wildlife Foundation Five Star and Urban Waters	January	Restoration, education and training to support stewardship and restoration of coastal, wetland and riparian ecosystems across the country	https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program?activeTab=tab-2

Restoration Grant Program			
NC Clean Water Management Trust Fund	February	Stream restoration, land acquisition, innovative stormwater projects	www.NCLWF.net
USEPA Environmental Education Grants	Variable	Promote environmental awareness and stewardship and help provide people with the skills to take responsible actions to protect the environment	www.epa.gov/education/environmental-education-ee-grant-solicitation-notice
NC Division of Soil and Water Community Conservation Assistance Program	Variable	Installation of various best management practices on urban, suburban and rural lands not directly involved with agriculture production	http://www.ncagr.gov/SWC/costshareprograms/CCAP/index.html
USDA NRCS Environmental Quality Incentives Program	March	Financial and technical assistance to implement structural and management conservation practices that optimize environmental benefits on working agricultural land	https://www.nrcs.usda.gov/wps/portal/nrcs/main/nc/programs/financial/eqip/
USDA NRCS Conservation Reserve Program	February	In exchange for a yearly rental payment, farmers enrolled in 10-15-year contracts through this program agree to remove environmentally sensitive land from agricultural production and plant species to improve water quality, prevent erosion, and reduce loss of wildlife habitat	https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/
Stormwater utility fees	N/A	Municipalities who have a stormwater utility in future can use fees collected by this utility to fund green infrastructure projects	N/A

Table 19: Sources of Technical Assistance for Plan Implementation

Name	Organization	Role	Expertise	Email
Maya Cough-Schulze	Triangle J Council of Governments	Project Manager	Watershed plan development	mcough-schulze@tjcog.org
Mikayla Renn, Abigail Haselton (previously: John Beck and Justin Hynicka)	Wake Soil and Water Conservation District	Project Partner	Agricultural best management practices, soil science	mikayla.renn@wakegov.com
Daniel Colavito and Zach Pitts	Town of Holly Springs	Project Partner	Stream restoration, stormwater management	daniel.colavito@hollyspringsnc.gov, zack.pitts@hollyspringsnc.gov
Nancy Daly	Wake County Environmental Services – Water Quality Division	Project Partner	Watershed restoration	nancy.daly@wakegov.com
Jennifer Mitchell	Town of Fuquay-Varina	Project Partner	Stormwater management/ engineering	jmitchell@fuquay-varina.org
Jessica Bolin and Stan Fortier	Town of Apex	Project Partner	Stormwater management/ engineering	jessica.bolin@apexnc.org, stan.fortier@apexnc.org

Additional technical assistance contacts to implement restoration projects include:

- Wake County Parks, Recreation and Open Space for project prioritization in Wake County (contact: Chris Snow)
- Triangle Land Conservancy for landscape-scale project prioritization, conservation priorities in in the watershed (contact: Leigh Ann Hammerbacher)
- Fuquay-Varina Parks, Recreation and Cultural Resources for specific project prioritization (contact: Director Jonathan Cox, jcox@fuquay-varina.org, 919-552-1431)
- Fuquay-Varina Public Works (contact: Director Tracy Stephenson, tstephenson@fuquay-varina.org, 919-753-1039)
- NC Cooperative Extension Service for backyard rain garden training and established relationships throughout the counties they serve
- NC Division of Soil and Water Conservation
- NCDWR Basinwide Planning for direct knowledge of conditions of the Neuse River Basin

9.0 CONCLUSION

The Upper Middle Creek watershed faces similar challenges to many watersheds in the burgeoning Triangle region. Downstream, agriculture and forestland predominate; rapid, ongoing (sub)urban growth over the last several decades has developed much of the headwaters. Local governments in the watershed implement some protective stormwater and agricultural projects and policies, but hold little public land on which to implement watershed restoration projects and have limited time to implement restoration projects above and beyond those required by regulation. Despite these challenges, Upper Middle Creek's dedicated local government staff and other stakeholders are committed to stormwater management and watershed restoration. As the watershed continues to grow and change, proactive restoration and conservation practices and policies will be important to preserve ecosystems and water quality in this watershed.

10.0 REFERENCES

15A NCAC 02B .0711, NEUSE NUTRIENT STRATEGY: STORMWATER

15A NCAC 02B .0731, TAR-PAMLICO NUTRIENT STRATEGY: STORMWATER

Chesapeake Bay Program. 2013. Appendix B Protocol 1 Supplemental Details for Final Draft Recommendation of Expert Panel on Stream Restoration. https://www.chesapeakebay.net/channel_files/19137/tracked_appendix_b_protocol_1_supplemental_details_030113_lfm1.pdf

Center for Watershed Protection. 2003. Impacts of Impervious Cover on Aquatic Systems: Watershed Protection Research Monograph. Center for Watershed Protection, Ellicott City, MD. https://owl.cwp.org/?mdocs-file=5031

Conservation Fund. (n.d.) "Upper Neuse Clean Water Initiative." https://www.conservationfund.org/projects/upper-neuse-clean-water-initiative

Christopher J Walsh, Allison H Roy, Jack W Feminella, Peter D Cottingham, Peter M Groffman and Raymond P Morgan, "The urban stream syndrome: current knowledge and the search for a cure," Journal of the North American Benthological Society 24, no. 3 (September 2005): 706-723.

Environmental Protection Agency. 2000. Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion IX.

Environmental Protection Agency. 2008. An Introduction to Freshwater Mussels as Biological Indicators Including Accounts of Interior Basin, Cumberlandian, and Atlantic Slope Species.

Environmental Protection Agency. 2009. "Total Maximum Daily Load for Addressing Impaired Biological Integrity in the Headwaters of Swift Creek Watershed, Neuse River Basin." North Carolina Department of Environment and Natural Resources Division of Water Quality.

Environmental Protection Agency. Welcome to STEPL and Region 5 Model. http://it.tetratech-ffx.com/steplweb/.

Gregory, J.H., M.D. Dukes, P.H. Jones, and G.I. Miller, "Effect of urban soil compaction on infiltration rate", Journal of Soil and Water Conservation 61, no. 3 (May/June 2006): 117-124.

H.W. Lochner, Inc. 2015. "Community Impact Assessment for Administrative Action Environmental Impact Statement, Complete 540 Triangle Expressway Southeast Extension." Prepared for North Carolina Department of Transportation / North Carolina Turnpike Authority. https://xfer.services.ncdot.gov/PDEA/Complete540/reports/C540_CIA_0615.pdf.

Johnson, David. 2019. "DOT Site Inspection Report." https://connect.ncdot.gov/search/Pages/results.aspx?k=070%2D003#k=092-020.

Michael Baker International. 2017. "Indirect and Cumulative Effects Memorandum (Quantitative ICE Assessment Memo #4)." Prepared for North Carolina Department of Transportation. https://www.ncdot.gov/projects/complete-540/Documents/indirect-cumulative-effects-december-2014.aspx

Miller, Jonathan, Kimia Karimi, Sankar Arumugan, and Daniel Obenour. December 2019. "Jordan Lake Watershed Model Report." Prepared for North Carolina Policy Collaboratory. https://files.nc.gov/ncdeq/Water%20Quality/Planning/NPU/Nutrient%20Scientific%20Advisory%20Board/Watershed-Model-Jordan-NCSU_Miller.pdf

Minnesota Stormwater Manual. 2018. "Total Suspended Solids (TSS) in Stormwater." https://stormwater.pca.state.mn.us/index.php/Total_Suspended_Solids_(TSS)_in_stormwater.

National Land Cover Database. 2019. Multi-Resolution Land Characteristics Consortium. https://www.mrlc.gov/data?f%5B0%5D=category%3Aland%20cover.

Natural Resources Conservation Service. 2019. United States Department of Agriculture Web Soil Survey. https://websoilsurvey.nrcs.usda.gov/.

NatureServe Explorer. n.d. https://explorer.natureserve.org/.

North Carolina Department of Environmental Quality. (n.d.) "2018 Integrated Report Category Assignment Procedure." https://files.nc.gov/ncdeq/Water%20Quality/Planning/IR-Assessment-Process-2018.pdf

North Carolina Department of Environmental Quality. (n.d.) 2018 NC Category 5 Assessments "303(d) List" Final. https://files.nc.gov/ncdeq/Water%20Quality/Planning/TMDL/303d/2018/2018-NC-303-d--List-Final.pdf

North Carolina Department of Environmental Quality. (2009.) "Neuse River Basinwide Water Quality Plan." https://deq.nc.gov/about/divisions/water-resources/planning/basin-planning/water-resource-plans/neuse-2009

North Carolina Department of Environmental Quality. (2010.) "Benthos Site Details." https://www.ncwater.org/?page=672&SiteID=JB068

North Carolina Department of Environmental Quality. (n.d.) "Biological Assessment Branch." https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/biological-assessment-branch

North Carolina Department of Environmental Quality. (n.d.) "Classifications." https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/classifications.
North Carolina Department of Environmental Quality. (n.d.) NCDWR Wadeable Streams Fish Community Assessments.https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=671b917c256c4d16a5a224f09e32bafd

North Carolina Department of Environmental Quality. n.d. "Division of Mitigation Services Map." https://deq.nc.gov/about/divisions/mitigation-services/dms-planning/dms-web-map.

North Carolina Department of Environmental Quality, Division of Mitigation Services. October 2018. "Year 5 (2018) Annual Monitoring Report – Pepperwood Farm Riparian Buffer Mitigation Site." https://deq.nc.gov/about/divisions/mitigation-services/dms-projects.

North Carolina Department of Environmental Quality. (n.d.) "Neuse Nutrient Strategy." https://deq.nc.gov/about/divisions/water-resources/planning/nonpoint-source-management/nutrient-strategies/neuse.

North Carolina Department of Environmental Quality Open Data. 2019. http://data-ncdenr.opendata.arcgis.com/

North Carolina Department of Transportation and North Carolina Turnpike Authority. 2018. "Expected Effects of the Preferred Alternative." https://www.ncdot.gov/projects/complete-540/Documents/expected-project-impacts.aspx.

North Carolina Department of Transportation and North Carolina Turnpike Authority. 2013. "Complete 540 Triangle Expressway Southeast Extension Public Information Meeting Brochure." https://www.ncdot.gov/projects/complete-540/Documents/Oct2013PublicMeetingHandout.pdf.

North Carolina Natural Heritage Program. 2003. "An Inventory of Significant Natural Areas in Wake County, North Carolina." https://digital.ncdcr.gov/digital/collection/p249901coll22/id/191033.

North Carolina Natural Heritage Program. 2020. Geographic Information System (GIS) data. NCDNCR, Raleigh, NC. Available at www.ncnhp.org. (Accessed: 4.23.2020).

North Carolina Natural Heritage Program. 2020. Natural Heritage Data Explorer [web application]. NCDNCR, Raleigh, NC. Available at www.ncnhp.org. (Accessed: 4.1.2020).

North Carolina Natural Heritage Program. 2020. "Upper Middle Creek - Element Occurrences." Custom report generated at www.ncnhp.org (Accessed: 4.3.2020).

North Carolina Wildlife Resources Commission. 2020. https://www.ncwildlife.org/Learning/Species/.

Olson, Eric. 2020. "First Phase Under Way to Finally Complete Raleigh's Triangle Expressway." January 27, 2020. https://www.constructionequipmentguide.com/first-phase-under-way-to-finally-complete-raleighs-triangle-expressway/47175.

Poulos, Helen M., Kate E. Miller, Ross Heinemann, Michelle L. Kraczkowski, Adam W. Whelchel and Barry Cherno, "Dam Removal Effects on Benthic Macroinvertebrate Dynamics: A New England Stream Case Study (Connecticut, USA)," Sustainability 11, no. 2875: (May 21, 2019):

Sorg, Lisa. 2018. "A Tollway's Toll: Human, Environmental Impact of 540 Expansion Loom Large in

Southern Wake County." NC Policy Watch. http://www.ncpolicywatch.com/2018/02/23/tollways-toll-human-environmental-impact-540-expansion-loom-large-southern-wake-county/.

Spectrum News Staff. 2019. "I-540 Extension Not Popular with Some Homeowners." https://spectrumlocalnews.com/nc/charlotte/news/2019/12/12/i-540-extension-not-popular-with-some-homeowners.

Stantec. (n.d.) "Nutrient Concentration in Stream Bank Soils." https://www.chesapeakebay.net/channel_files/24811/attach_b2_appendix_a1._stream_restoration_design_example.pdf

Three Oaks Engineering. 2017. "Aquatic Species Survey Report- Complete 540 Triangle Expressway Southeast Extension." https://www.ncdot.gov/projects/complete-540/Documents/aquatic-species-survey-report.aspx. Prepared by Three Oaks Engineering for NCDOT.

Town of Apex. n.d. "Interactive Development Map." http://apexnc.maps.arcgis.com/apps/OnePane/basicviewer/index.html?appid=fa9ba2017b784030b15ef4da27d9e795.

Wake County Open Data. 2019. http://data-wake.opendata.arcgis.com/

Wildlands Engineering and The Catena Group. 2014. "Neuse 01 RWP Preliminary Findings Report". Prepared by Wildlands for NC Ecosystem Enhancement Program (now NC Division of Mitigation Services.)

Wildlands Engineering and The Catena Group. 2014. "Neuse 01 RWP Preliminary Project Atlas". Prepared by Wildlands for NC Ecosystem Enhancement Program (now NC Division of Mitigation Services.)

US Department of Transportation Federal Highway Administration, North Carolina Department of Transportation, and North Carolina Turnpike Authority. 2018. "Complete 540 Record of Decision." https://www.ncdot.gov/projects/complete-540/Documents/record-of-decision.aspx.

US EPA Office of Water. 2011. "Recovery Potential Metrics Summary Form." https://www.epa.gov/sites/production/files/2015-11/documents/rp2wshedimperv1109.pdf.

US EPA Web Archive: Water: Monitoring and Assessment. n.d. "5.9 Conductivity."https://archive.epa.gov/water/archive/web/html/vms59.html.

US EPA Web Archive: Water: Monitoring and Assessment. n.d. "Chapter 4 Macroinvertebrates and Habitat." https://archive.epa.gov/water/archive/web/html/vms40.html

US Fish and Wildlife Service. 2019. "Biological/Conference Opinion - Revised - Complete 540, Triangle Expressway Southeast Extension in Wake and Johnston County, North Carolina." https://www.ncdot.gov/projects/complete-540/Documents/biological-conference-opinion-october-2019.pdf.

11.0 APPENDICES

Appendix I: NCDEQ Benthic Metrics at Current vs. Historic Sites

Appendix II: NCDEQ Benthic Species Data

Appendix III: NCDEQ Benthic Habitat Data

Appendix IV: NCDEQ Fish Community Data

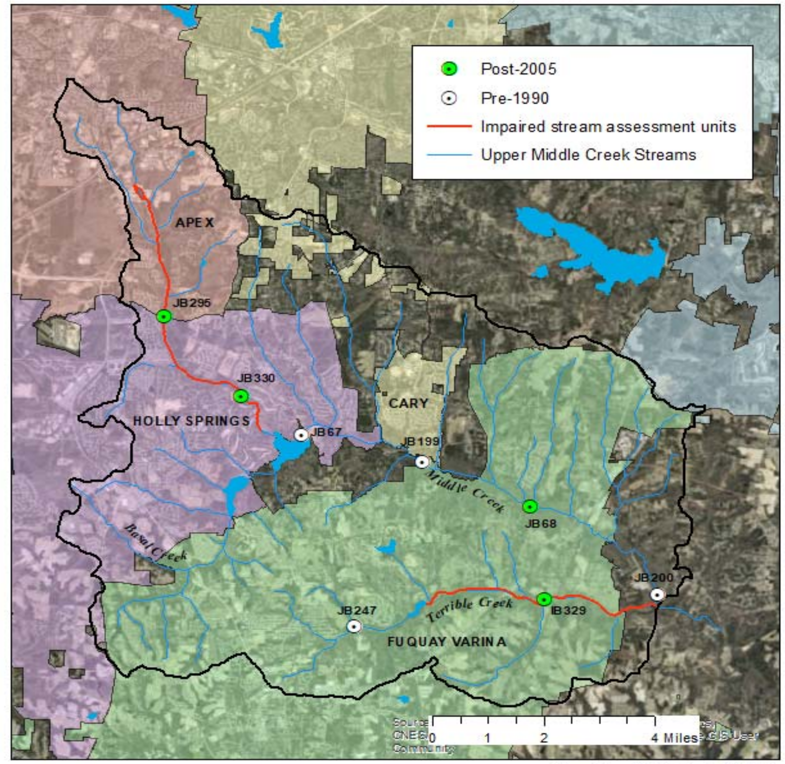
Appendix V: Summary Memo to Holly Springs to Inform Plan Implementation

Appendix I: NCDEQ Benthic Metrics at Current vs. Historic Sites

Benthic Community Table	Upstream				(Most recent only- have data back to 1986)	Downstream	Terrible Creek tributary data	
Stream	MIDDLE CR	MIDDLE CR	MIDDLE CR	MIDDLE CR	MIDDLE CR	MIDDLE CR	TERRIBLE CR	TERRIBLE CR
Site Location	SR 1301 AB SUNSET LAKE	SR 1152	SR 1301 BE SUNSET LAKE	TALLICUD RD	SR 1375	US 401	SR 2751	SR 1301
County	Wake	Wake	Wake	Wake	Wake	Wake	Wake	Wake
Site ID	**JB295**	**JB330**	**JB67**	**JB199**	**JB68**	**JB200**	**IB329**	**JB247**
Collection date	7/25/2005	7/13/2010	5/29/1986	5/30/1986	8/24/2015	6/2/1986	6/10/2010	9/5/1990
BAU sample number	9665	11009	3760	3762	11965	3764	10955	5492
Sample method	Full Scale	EPT	Full Scale	Full Scale	Full Scale	Full Scale	EPT	Full Scale
Criteria	Summer/ Piedmont	Summer/ Piedmont	Spring/ Piedmont	Spring/ Piedmont	Summer/ Piedmont	Summer/ Piedmont	Summer/ Piedmont	Summer/ Piedmont
Richness								
Ephemeroptera	5	5	5	6	6	13	5	6
Plecoptera	0	0	2	0	0	6	1	2
Trichoptera	7	3	2	4	7	7	6	8
Odonata	7		11	5	6	8		12
Megaloptera	0		2	1	0	3		2
Coleoptera	9		9	9	4	10		10
Chironomidae	11		20	23	18	27		24
non-Chironomidae Diptera	1		5	5	1	4		5
Oligochaeta	4		3	4	4	5		3
Mollusca	4		4	8	3	6		4
Other taxa	4		2	7	4	7		5
Total taxa richness	52		65	72	53	96		81
Other biological metrics								
Total EPT	**12**	8	9	10	13	26	12	16
Seasonal EPT			*0*	*0*				
Corrected EPT			*9*	*10*				
EPT abundance	77	50	36	36	89	105	54	75
EPT Biotic Index	5.85	6.03	5.95	5.96	4.96	4.87	5.64	5.14
NCBI	6.44	---	6.88	6.87	6.08	6.17	---	6.38
Seasonal Correction			*0.20*	*0.20*				
Corrected NCBI			*7.08*	*7.07*				
Bioclassification	Fair	Fair	Fair	Fair	Good-Fair	Good	Fair	Good-Fair

Data in this summary table copied by Maya Cough-Schulze from data sheets shared by Eric Fleek, Biologist Supervisor, NCDEQ Water Sciences Section- Biological Assessment Branch

Highlights and header notes added by Maya for reference only



Maya Cough-Schulze, 2/18/2020
2020 Jurisdiction Boundaries per Wake County Open Data

Appendix II: NCDEQ Benthic Species Data

		JB 295 MIDDLE CR SR 1301 Wake COUNTY 25 Jul 2005
Ephemeroptera		
Baetidae	Baetis flavistriga	A
	Baetis intercalaris	A
	Labiobaetis propinquus	R
Heptageniidae	Maccaffertium modestum	A
Isonychiidae	Isonychia spp	R
Trichoptera		
Hydropsychidae	Cheumatopsyche spp	A
	Hydropsyche (H.) betteni/depravata	A
Hydroptilidae	Hydroptila spp	R
Leptoceridae	Oecetis nocturna	C
	Oecetis persimilis	A
	Oecetis sp A	R
	Triaenodes ignitus	A
Odonata		
Coenagrionidae	Argia spp	C
	Enallagma spp	C
Cordulegastridae	Cordulegaster maculata	R
Corduliidae	Epitheca spp	R
Gomphidae	Progomphus spp	R
Libellulidae	Libellulidae	C
Macromiidae	Macromia spp	R
Hemiptera		
Corixidae	Corixidae	C
Coleoptera		
Dryopidae	Helichus fastigiatus	C
Dytiscidae	Hydrovatus pustulatus	R
	Neoporus spp	R
Elmidae	Ancyronyx variegatus	A
	Dubiraphia spp	A
	Macronychus glabratus	A
	Microcylloepus pusillus	R
	Stenelmis crenata	A
Psephenidae	Psephenus herricki	C
Diptera, chironomids		
Chironomidae	Cryptotendipes spp	R
	Microtendipes spp	C
	Natarsia spp	R
	Polypedilum flavum	C
	Polypedilum halterale gr	R

	Polypedilum scalaenum gr	R
	Procladius spp	A
	Tanytarsus sp 10	R
	Tanytarsus sp 2	C
	Thienemannimyia gr	R
	Tribelos jucundum	A
Diptera, other		
Tipulidae	Tipula spp	A
Oligochaeta		
Enchytraeidae	Enchytraeidae	R
Megadrile	Megadrile oligochaete	C
Tubificidae	Ilyodrilus templetoni	R
	Limnodrilus hoffmeisteri	A
Crustacea		
Cambaridae	Procambarus (O.) acutus acutus	C
Gastropoda		
Lymnaeidae	Fossaria spp	R
Planorbidae	Helisoma anceps	R
Viviparidae	Campeloma limum	C
Bivalvia		
Corbiculidae	Corbicula fluminea	A
Other		
Glossiphoniidae	Placobdella papillifera	C
Planariidae	Cura foremanii	A

		JB330 MIDDLE CR SR 1152 Wake COUNTY 13 Jul 2010
Ephemeroptera		
Baetidae	Baetis flavistriga	C
	Baetis intercalaris	C
	Callibaetis spp	
	Cloeon spp	
	Labiobaetis propinquus	R
Caenidae	Caenis spp	
Heptageniidae	Maccaffertium modestum	A
	Maccaffertium terminatum	A
	Stenacron interpunctatum	
Isonychiidae	Isonychia spp	
Plecoptera		
Perlidae	Eccoptura xanthenes	
	Perlesta spp	
	Perlinella ephyre	
Trichoptera		
Hydropsychidae	Cheumatopsyche spp	A
	Diplectrona modesta	
	Hydropsyche (H.) betteni/depravata	A
Leptoceridae	Oecetis nocturna	
	Oecetis persimilis	
	Triaenodes ignitus	C
Odontoceridae	Psilotreta frontalis	
Philopotamidae	Chimarra spp	
Polycentropodidae	Nyctiophylax spp	
Uenoidae	Neophylax oligius	
	Neophylax spp	

		MIDDLE CR SR 1375 Wake COUNTY 30 May 1986	MIDDLE CR SR 1375 Wake COUNTY 25 Jul 1991	MIDDLE CR SR 1375 Wake COUNTY 11 Aug 1995	MIDDLE CR SR 1375 Wake COUNTY 21 Aug 2000	MIDDLE CR SR 1375 Wake COUNTY 25 Jul 2005	MIDDLE CR SR 1375 Wake COUNTY 12 Aug 2010	MIDDLE CR SR 1375 Wake COUNTY 24 Aug 2015
Ephemeroptera								
Baetidae	Baetis flavistriga			C		R		
	Baetis intercalaris		A	A	A	A	A	A
	Centroptilum spp (dubious)		C		R			
	Labiobaetis propinquus		A	C	A	C	A	R
	Procloeon spp						R	
	Pseudocloeon spp (dubious)		R					
Caenidae	Caenis spp				R			
Ephemerellidae	Eurylophella temporalis gr	R						
	Teloganopsis deficiens	R						
Heptageniidae	Maccaffertium exiguum				R	C	C	A
	Maccaffertium modestum	A	A	A	A	A	A	A
	Maccaffertium terminatum						C	
	Stenacron interpunctatum	R	C					
Isonychiidae	Isonychia spp	C	A	C	C	A	R	A
Leptohyphidae	Tricorythodes spp				C	A	A	A
Plecoptera								
Perlidae	Perlesta placida (dubious)	A						
Trichoptera								
Dipseudopsidae	Phylocentropus spp	R						
Hydropsychidae	Cheumatopsyche spp	C	A	A	A	A	A	A
	Hydropsyche (H.) betteni/depravata	R	A	C	A	A	A	C
	Hydropsyche (H.) rossi						C	
	Hydropsyche (H.) spp							R
	Hydropsyche (H.) venularis				C			
Leptoceridae	Ceraclea maculata	R						
	Nectopsyche candida						C	
	Nectopsyche exquisita					R	A	A

	Nectopsyche pavida			R				
	Oecetis persimilis		C	C	A	A	A	C
	Oecetis sp D							R
	Triaenodes ignitus	R	A	C	A	A	A	A
Limnephilidae	Pycnopsyche guttifer	R						
	Pycnopsyche scabripennis	R						
Philopotamidae	Chimarra spp	R				C	C	
Odonata								
Aeshnidae	Basiaeschna janata		C					
	Boyeria vinosa	R	A	C	C	C		R
Calopterygidae	Calopteryx spp		R	R	C			R
Coenagrionidae	Argia spp	C	C	C	A	C	A	A
	Enallagma spp	C			R	R	C	
Corduliidae	Epicordulia/Tetragoneuria spp						R	
	Epitheca princeps					R		R
	Epitheca spp	R			C			
	Neurocordulia obsoleta				R			
	Neurocordulia spp		C	R				
Gomphidae	Dromogomphus spp			R				
	Gomphus spp		A	R	C			
	Hagenius brevistylus							R
	Progomphus spp	R				R		
	Stylogomphus albistylus/sigmastylus			R				
	Stylurus spp							R
Libellulidae	Libellula spp	R						
	Perithemis spp		C					
Macromiidae	Macromia spp	C	A	C		R		
Hemiptera								
Nepidae	Ranatra spp		R					
Megaloptera								
Corydalidae	Corydalus cornutus		C	R				
	Nigronia serricornis	R	C					
	Nigronia spp			R				
Sialidae	Sialis spp	A	A	C				

Coleoptera								
Dryopidae	Helichus basalis					R		
	Helichus fastigiatus						R	
	Helichus spp	C	C	C	C			
Dytiscidae	Dytiscus spp	A						
	Hydroporus spp (dubious)	C	A	R				
	Laccophilus spp	R						
	Neoporus spp						R	
Elmidae	Ancyronyx variegatus		A	A	A	A	A	C
	Dubiraphia spp	A	A			A	A	C
	Dubiraphia vittata				A			
	Macronychus glabratus	A	A	A	C	A	A	A
	Microcylloepus pusillus						C	
	Stenelmis spp			C	R		R	R
Gyrinidae	Dineutus spp		C					
	Gyrinus spp			A				
Diptera, chironomids								
Chironomidae	Ablabesmyia mallochi			R				R
	Ablabesmyia rhamphe gr	C						
	Chironomus spp	C				R		
	Cladotanytarsus cf daviesi		R				C	R
	Clinotanypus spp		R					
	Corynoneura spp		R					
	Cricotopus annulator complex	R			R			
	Cryptochironomus blarina gr		C					
	Cryptochironomus fulvus	C						
	Cryptochironomus spp						R	C
	Cryptotendipes spp							C
	Dicrotendipes neomodestus						C	A
	Dicrotendipes spp	C						
	Eukiefferiella brevicalcar gr	R						
	Labrundinia pilosella						R	
	Microtendipes pedellus gr						R	
	Microtendipes spp	A						

	Natarsia sp A						R	R
	Natarsia spp	R	C	R		C		
	Nilotanypus fimbriatus						C	
	Nilotanypus spp					R		
	Paracladopelma spp							R
	Parametriocnemus spp	R						
	Paratanytarsus longistylus						R	
	Pentaneura inconspicua		A	C	C		A	
	Phaenopsectra obediens gr	R						
	Phaenopsectra punctipes gr			C				
	Polypedilum fallax/sp A	R				R		C
	Polypedilum flavum		A	A	C	C	A	C
	Polypedilum halterale gr					R		C
	Polypedilum illinoense gr	C						
	Polypedilum scalaenum gr		A	C		R	A	C
	Procladius spp	A						R
	Rheocricotopus robacki	C			R			
	Rheocricotopus spp		R					
	Rheocricotopus tuberculatus			R				
	Rheotanytarsus spp	R					R	R
	Stenochironomus spp				R		C	C
	Tanytarsus allicis/buckleyi						C	
	Tanytarsus sp 3					R		
	Tanytarsus sp 6					R		
	Tanytarsus spp	C				R		R
	Thienemanniella spp		R				R	
	Thienemannimyia gr	C						A
	Tribelos fuscicorne							C
	Tribelos jucundum					A	R	C
	Tribelos spp	A	C	R				
	Xylotopus par					R		
Diptera, other								
Ceratopogonidae	Atrichopogon spp	R						
	Bezzia/Palpomyia complex	C	R					

Simuliidae	Simulium spp				C			
	Simulium vittatum	A						
Tipulidae	Pseudolimnophila spp	R						
	Tipula spp					R		C
Oligochaeta								
Enchytraeidae	Enchytraeidae					R		
Lumbriculidae	Lumbriculidae	R	C	C	C	A	C	
Megadrile	Megadrile oligochaete					C		A
Naididae	Dero spp				R	R		
	Nais spp							R
Tubificidae	Aulodrilus pluriseta				C			
	Branchiura sowerbyi					C	C	
	Ilyodrilus templetoni	A						
	Limnodrilus hoffmeisteri	C						C
	Limnodrilus spp				R	C		
	Tubificidae							C
Crustacea								
Cambaridae	Cambaridae	C	R	R			R	C
Gammaridae	Crangonyx spp				R			
Palaemonidae	Palaemonetes paludosus	C						A
	Palaemonetes spp		R				R	
Talitridae	Hyalella spp	C						
Gastropoda								
Ancylidae	Ferrissia spp	R						
	Laevapex fuscus		R		R			R
Hydrobiidae	Amnicola spp		R					
Physidae	Physa spp	C	C	R	R		R	R
Planorbidae	Helisoma anceps	R						
	Menetus dilatatus		R				R	
	Planorbella spp		R					
Viviparidae	Campeloma limum	A						
Bivalvia								
Corbiculidae	Corbicula fluminea		C	C	A	C	A	A
Sphaeriidae	Pisidium spp					R		

	Sphaerium spp	A	A					
Unionidae	Elliptio complanata	C						
	Elliptio icterina				R			
	Elliptio spp		C					
Other								
Erpobdellidae	Erpobdella/Mooreobdella spp							C
Glossiphoniidae	Glossiphoniidae						A	
	Placobdella papillifera	C					R	
	Placobdella parasitica		R					
Hydracarina	Hydracarina	A	R		C			C
Planariidae	Dugesia tigrina	C	R		C	R		
Platyhelminthes	Tricladida						C	
Sisyridae	Climacia spp	R						
Tetrastemmatidae	Prostoma graecense					R		

		JB67 MIDDLE CR SR 1301 BE SUNSET LAKE Wake COUNTY 29 May 1986	JB199 MIDDLE CR TALLICUD RD Wake COUNTY 30 May 1986	JB200 MIDDLE CR US 401 Wake COUNTY 02 Jun 1986
Ephemeroptera				
Baetidae	Baetis intercalaris	R		C
	Cloeon spp	A	C	R
	Heterocloeon amplum			R
	Labiobaetis propinquus		R	R
	Pseudocloeon spp (dubious)			A
Caenidae	Caenis spp		R	C
Ephemerellidae	Eurylophella bicolor			R
	Eurylophella temporalis gr	R		C
	Teloganopsis deficiens			A
Ephemeridae	Hexagenia spp			C
Heptageniidae	Maccaffertium modestum	R	A	A
	Stenacron interpunctatum	R	C	C
Isonychiidae	Isonychia spp		C	A
Plecoptera				
Capniidae	Allocapnia spp			
Nemouridae	Amphinemura spp			C
Perlidae	Acroneuria abnormis			C
	Eccoptura xanthenes	R		
	Paragnetina fumosa			R
	Perlesta placida (dubious)	A		A
Perlodidae	Isoperla davisi/nr transmarina			R
	Isoperla holochlora-light form			R
Taeniopterygidae	Strophopteryx spp			
Trichoptera				
Dipseudopsidae	Phylocentropus spp		C	C
Hydropsychidae	Cheumatopsyche spp	A	A	A
	Hydropsyche (H.) betteni/depravata		R	A
Leptoceridae	Mystacides sepulchralis			R
	Oecetis persimilis		R	
	Triaenodes ignitus			R
Limnephilidae	Ironoquia punctatissima			
	Pycnopsyche scabripennis	R		
Philopotamidae	Chimarra spp			R
Polycentropodidae	Polycentropus sensu lato spp			R
Odonata				
Aeshnidae	Aeshna spp	C		
	Boyeria vinosa	R	C	C
Coenagrionidae	Argia spp	C	C	C
	Enallagma spp	C	C	C

Cordulegastridae	Cordulegaster spp	C		
Corduliidae	Neurocordulia spp			R
	Somatochlora spp	C		
Gomphidae	Gomphus spp	R	C	A
	Progomphus spp	R		R
Libellulidae	Erythemis spp	R		
	Libellula spp			
	Pachydiplax longipennis	R		
	Perithemis spp			C
	Sympetrum spp	R		
Macromiidae	Macromia spp		R	R
Megaloptera				
Corydalidae	Corydalus cornutus			C
	Nigronia serricornis	R		R
Sialidae	Sialis spp	A	A	A
Coleoptera				
Dryopidae	Helichus spp	A	R	A
Dytiscidae	Dytiscus spp	C		C
	Hydroporus spp (dubious)	A	A	A
	Laccophilus spp	C		R
	Lioporeus spp		R	
	Prodaticus bimarginatus			R
Elmidae	Ancyronyx variegatus	A	A	
	Dubiraphia spp	C	C	C
	Macronychus glabratus	A	A	A
	Stenelmis spp	A		R
Gyrinidae	Dineutus spp	C	A	
Haliplidae	Peltodytes spp		R	
Hydrophilidae	Enochrus spp			
	Laccobius spp			R
	Tropisternus spp		R	
Psephenidae	Psephenus herricki			R
Diptera, chironomids				
Chironomidae	Ablabesmyia mallochi		C	C
	Ablabesmyia rhamphe gr	R	C	C
	Brillia spp			C
	Cardiocladius spp			A
	Chironomus spp	A	A	C
	Clinotanypus spp	R		
	Corynoneura spp	R		
	Cricotopus annulator complex		R	R
	Cricotopus bicinctus			R
	Cryptochironomus blarina gr		C	
	Cryptochironomus fulvus		C	
	Cryptochironomus spp			R
	Dicrotendipes neomodestus		C	
	Dicrotendipes nervosus		R	

	Dicrotendipes spp	C		R
	Eukiefferiella claripennis gr			
	Hydrobaenus spp			
	Kiefferulus dux			
	Labrundinia spp			R
	Microtendipes pedellus gr		C	
	Microtendipes spp	C		C
	Nanocladius spp	R	C	
	Natarsia spp	A	R	
	Orthocladius lignicola			R
	Orthocladius obumbratus gr			
	Orthocladius robacki			
	Paracladopelma loganae			R
	Paracladopelma spp	R		
	Parakiefferiella sp 4 (dubious)			
	Parametriocnemus spp	A		A
	Paratendipes spp	R		A
	Phaenopsectra obediens gr			A
	Phaenopsectra punctipes gr	R	4	
	Polypedilum aviceps	C		
	Polypedilum fallax/sp A	C		R
	Polypedilum flavum			A
	Polypedilum illinoense gr		A	R
	Polypedilum scalaenum gr	A	R	
	Procladius spp	R		A
	Rheocricotopus robacki		A	C
	Rheocricotopus spp	A		
	Rheocricotopus unidentatus			
	Rheotanytarsus spp	A	C	C
	Saetheria tylus		R	
	Smittia spp			
	Stenochironomus spp		C	C
	Tanytarsus spp	C	A	C
	Thienemanniella spp		R	
	Thienemannimyia gr	A	A	R
	Tribelos spp		A	A
	Tvetenia vitracies			R
	Zavrelimyia spp			
Diptera, other				
Ceratopogonidae	Bezzia/Palpomyia complex	A	A	C
	Culicoides spp			
Sciomyzidae	Sepedon spp	R		
Simuliidae	Simulium spp		A	
	Simulium tuberosum			C
	Simulium venustum		A	
	Simulium vittatum	R	C	A
Syrphidae	Eristalis spp			

Tipulidae	Hexatoma spp	C		
	Pseudolimnophila spp			
	Tipula spp	R	R	A
Oligochaeta				
Enchytraeidae	Enchytraeidae			
Haplotaxidae	Haplotaxis gordioides			R
Lumbriculidae	Lumbriculidae		C	A
Naididae	Nais spp	R		
	Stylaria lacustris		R	
Tubificidae	Branchiura sowerbyi			R
	Ilyodrilus templetoni	A	R	R
	Limnodrilus hoffmeisteri	A		
	Limnodrilus spp		R	R
Crustacea				
Asellidae	Caecidotea spp			
Cambaridae	Cambaridae			R
	Cambarus spp	C	C	
Gammaridae	Crangonyx spp			
Palaemonidae	Palaemonetes paludosus		R	C
Talitridae	Hyalella spp	A	A	A
Gastropoda				
Ancylidae	Ferrissia spp	A	R	C
Lymnaeidae	Pseudosuccinea columella		R	
	Stagnicola spp			
Physidae	Physa spp	A	A	A
Planorbidae	Helisoma anceps		A	C
	Menetus dilatatus	A		R
Viviparidae	Campeloma limum		A	A
Bivalvia				
Sphaeriidae	Pisidium spp		R	
	Sphaerium spp	R	C	A
Unionidae	Elliptio complanata		C	
Other				
Glossiphoniidae	Desserobdella phalera		C	
	Helobdella triserialis		R	
	Placobdella papillifera			C
Hydracarina	Hydracarina		C	C
Planariidae	Dugesia tigrina		C	R
Tetrastemmatidae	Prostoma graecense			R

			JB329 TERRIBLE CR SR 2751 Wake COUNTY 10 Jun 2010
Ephemeroptera			
	Baetidae	Baetis flavistriga	C
		Baetis intercalaris	R
		Callibaetis spp	
		Cloeon spp	
		Labiobaetis propinquus	
	Caenidae	Caenis spp	R
	Heptageniidae	Maccaffertium modestum	A
		Maccaffertium terminatum	
		Stenacron interpunctatum	
	Isonychiidae	Isonychia spp	A
Plecoptera			
	Perlidae	Eccoptura xanthenes	
		Perlesta spp	R
		Perlinella ephyre	
Trichoptera			
	Hydropsychidae	Cheumatopsyche spp	A
		Diplectrona modesta	
		Hydropsyche (H.) betteni/depravata	A
	Leptoceridae	Oecetis nocturna	R
		Oecetis persimilis	R
		Triaenodes ignitus	C
	Odontoceridae	Psilotreta frontalis	
	Philopotamidae	Chimarra spp	
	Polycentropodidae	Nyctiophylax spp	
	Uenoidae	Neophylax oligius	C
		Neophylax spp	

		TERRIBLE CR JB247 at SR 1301 Wake COUNTY 05 Sep 1990
Ephemeroptera		
Baetidae	Baetis flavistriga	R
	Callibaetis spp	C
	Cloeon spp	C
Heptageniidae	Maccaffertium modestum	A
	Stenacron interpunctatum	C
Isonychiidae	Isonychia spp	C
Plecoptera		
Perlidae	Eccoptura xanthenes	A
	Perlinella ephyre	R
Trichoptera		
Hydropsychidae	Cheumatopsyche spp	A
	Diplectrona modesta	R
	Hydropsyche (H.) betteni/depravata	A
Leptoceridae	Triaenodes ignitus	R
Odontoceridae	Psilotreta frontalis	C
Philopotamidae	Chimarra spp	C
Polycentropodidae	Nyctiophylax spp	A
Uenoidae	Neophylax spp	C
Odonata		
Aeshnidae	Boyeria vinosa	C
Calopterygidae	Calopteryx spp	A
Coenagrionidae	Argia spp	A
	Enallagma spp	A
Cordulegastridae	Cordulegaster fasciatus	R
Corduliidae	Epitheca spp	R
Gomphidae	Dromogomphus spp	R
	Progomphus spp	R
	Stylogomphus albistylus/sigmastylus	C
Libellulidae	Libellula spp	R
	Pachydiplax longipennis	R
	Perithemis spp	C
Megaloptera		
Corydalidae	Nigronia serricornis	A
Sialidae	Sialis spp	C
Coleoptera		
Dryopidae	Helichus spp	R
Dytiscidae	Hydroporus spp (dubious)	C
Elmidae	Ancyronyx variegatus	A
	Dubiraphia spp	A
	Macronychus glabratus	C

	Microcylloepus pusillus	C
	Optioservus spp	A
	Stenelmis spp	A
Haliplidae	Peltodytes spp	C
Psephenidae	Psephenus herricki	A
Diptera, chironomids		
Chironomidae	Ablabesmyia mallochi	A
	Ablabesmyia rhamphe gr	C
	Chironomus spp	C
	Cricotopus annulator complex	R
	Cryptochironomus spp	C
	Cryptotendipes spp	A
	Dicrotendipes modestus	A
	Dicrotendipes nervosus	C
	Labrundinia spp	A
	Nanocladius downesi	C
	Nanocladius spp	A
	Nilotanypus spp	R
	Paratendipes spp	C
	Phaenopsectra obediens gr	A
	Polypedilum flavum	A
	Polypedilum scalaenum gr	C
	Procladius spp	A
	Rheotanytarsus spp	C
	Saetheria tylus	R
	Synorthocladius spp	R
	Tanytarsus sp 2	A
	Thienemannimyia gr	A
	Tribelos spp	C
	Xylotopus par	C
Diptera, other		
Ceratopogonidae	Bezzia/Palpomyia complex	C
Rhagionidae	Atherix lantha	R
Simuliidae	Simulium spp	R
Tabanidae	Tabanus spp	R
Tipulidae	Hexatoma spp	C
Oligochaeta		
Lumbriculidae	Lumbriculidae	R
Naididae	Stylaria lacustris	A
Tubificidae	Limnodrilus hoffmeisteri	C
Crustacea		
Talitridae	Hyalella spp	A
Gastropoda		
Physidae	Physa spp	C
Planorbidae	Menetus dilatatus	C
Bivalvia		
Sphaeriidae	Pisidium spp	R

Unionidae	Elliptio complanata	C
Other		
Glossiphoniidae	Helobdella triserialis	R
	Placobdella papillifera	C
Hydracarina	Hydracarina	C
Planariidae	Dugesia tigrina	R

Appendix III: NCDEQ Benthic Habitat Data

Mountain/Piedmont Habitat Table - JB295

Stream	MIDDLE CR
Site Location	SR 1301 AB SUNSET LAKE
County	Wake
Site ID	JB295
Collection date	7/25/2005
BAU sample number	9665
Habitat Scores	
Channel modification (5)	5
In-stream habitat (20)	12
Bottom substrate (15)	13
Pool variety (10)	9
Riffle habitats (16)	7
Bank erosion (7)	2
Bank vegetation (7)	2
Light penetration (10)	7
Left riparian (5)	5
Right riparian (5)	5
Total Habitat (100)	67
Other Habitat	
Average stream width (m)	5
Average stream depth (m)	0.3
Canopy (%)	70
Substrate (%)	
Boulder	0
Cobble	15
Gravel	20
Sand	50
Silt	15
Other	
description	
Physicochemical	
Temperature (ºC)	24.8
Dissolved oxygen (mg/L)	5.9
Specific conductance (μmhos/cm)	319
pH	6.8

Mountain/Piedmont Habitat Table

Stream	MIDDLE CR
Site Location	SR 1152
County	Wake
Site ID	JB330
Collection date	7/13/2010
BAU sample number	11009

Habitat Scores	
Channel modification (5)	4
In-stream habitat (20)	11
Bottom substrate (15)	8
Pool variety (10)	10
Riffle habitats (16)	14
Bank erosion (7)	3
Bank vegetation (7)	5
Light penetration (10)	10
Left riparian (5)	5
Right riparian (5)	3
Total Habitat (100)	73

Other Habitat	
Average stream width (m)	6
Average stream depth (m)	0.8
Canopy (%)	90
Substrate (%)	
Boulder	0
Cobble	45
Gravel	30
Sand	25
Silt	
Other	
description	

Physicochemical	
Temperature (ºC)	24.8
Dissolved oxygen (mg/L)	7
Specific conductance (µmhos/cm)	482
pH	7.4

Mountain/Piedmont Habitat Table

Stream	MIDDLE CR	MIDDLE CR	MIDDLE CR	MIDDLE CR
Site Location	SR 1375	SR 1375	SR 1375	SR 1375
County	Wake	Wake	Wake	Wake
Site ID	JB68	JB68	JB68	JB68
Collection date	8/21/2000	7/25/2005	8/12/2010	8/24/2015
BAU sample number	8270	9666	11073	11965
Habitat Scores				
Channel modification (5)	5	5	5	5
In-stream habitat (20)	19	12	15	13
Bottom substrate (15)	3	3	9	6
Pool variety (10)	10	5	10	10
Riffle habitats (16)	3	5	7	6
Bank erosion (7)	6	2	5	2
Bank vegetation (7)	6	2	7	4
Light penetration (10)	10	6	10	9
Left riparian (5)	4	5	4	4
Right riparian (5)	4	5	3	4
Total Habitat (100)	70	50	75	63
Other Habitat				
Average stream width (m	9	7	7	10
Average stream depth (m	0.5	0.2	0.3	0.5
Canopy (%)	95	80	60	90
Substrate (%)				
Boulder	0	0	10	5
Cobble	0	0	15	
Gravel	10	15	20	30
Sand	70	75	50	50
Silt	20	10	5	10
Other				5
description				CPOM
Physicochemical				
Temperature (ºC)	22	26.5	29	24.7
Dissolved oxygen (mg/L)	6.3	5	6.2	5.9
Specific conductance (µr	240	221	299	393
pH	6.8	6.7	6.6	7.2

Mountain/Piedmont Habitat Table

Stream	TERRIBLE CR
Site Location	SR 2751
County	Wake
Site ID	IB329
Collection date	6/10/2010
BAU sample number	10955
Habitat Scores	
Channel modification (5)	4
In-stream habitat (20)	12
Bottom substrate (15)	8
Pool variety (10)	6
Riffle habitats (16)	14
Bank erosion (7)	3
Bank vegetation (7)	5
Light penetration (10)	10
Left riparian (5)	2
Right riparian (5)	5
Total Habitat (100)	69
Other Habitat	
Average stream width (m)	4
Average stream depth (m)	0.2
Canopy (%)	60
Substrate (%)	
Boulder	0
Cobble	20
Gravel	55
Sand	25
Silt	
Other	
description	
Physicochemical	
Temperature (ºC)	23.7
Dissolved oxygen (mg/L)	6.66
Specific conductance (µmhos/cm)	157
pH	5.7

FISH COMMUNITY SAMPLE

Appendix IV: NCDEQ Fish Community Data

Waterbody	Location	Station ID	Date	Bioclassification
MIDDLE CR	SR 1375	JF34	05/21/15	Good

County	8 digit HUC	Latitude	Longitude	Elevation (ft)	Reference Site
WAKE	03020201	35.635556	-78.728056	260	No

Level IV Ecoregion	Drainage Area (mi^2)	Stream Width (m)	Stream Depth (m)
Northern Outer Piedmont	35.6	10	0.4

Upstream NPDES Dischargers (≥ 1 MGD or < 1 MGD and within 1 mile)	NPDES Number	Volume (MGD)
Brighton Forest WWTP	NC0066150	0.117
Amherst WWTP	NC0061638	0.053
Crooked Creek WWTP	NC0062715	0.150
City of Cary's South Cary Water Reclamation Facility	NC0065102	16
Town of Apex's Water Reclamation Facility	NC0064050	3.6

Landuse (%)	Forest	Developed	Impervious	Cultivation	Grass/Herb/Shrub	Wetland	Water	Barren
1992	61.6	8.0	no data	25.1	no data	3.6	1.5	0.2
2001	42.3	29.1	5.6	14.2	9.0	4.4	0.9	0.0
2006	36.2	37.6	7.7	12.0	8.6	4.3	1.1	0.3
2011	34.1	41.5	9.2	10.5	8.5	4.2	1.1	0.2

Water Quality Parameters	2010	2011	2015
Temperature (°C)	17.5	25.7	22.6
Dissolved Oxygen (mg/L)	6.5	5.5	6.3
Specific Conductance (µS/cm)	250	320	288
pH (s.u.)	6.6	6.4	6.4

Habitat Assessment Scores (max score)	2014
Channel Modification (5)	5
Instream Habitat (20)	14
Bottom Substrate (15)	3
Pool Variety (10)	8
Riffle Habitat (16)	5
Bank Erosion (7)	4
Bank Vegetation (7)	6
Light Penetration (10)	10
Left Riparian Score (5)	5
Right Riparian Score (5)	5
Total Habitat Score (100)	65

Site Photograph

Water Clarity Clear/tannic

Substrate: Sand, gravel

Sample Date	Sample ID	Species Total	NCIBI Score	NCIBI Rating
05/21/15	2015-33	20	48	Good
06/02/11	2011-27	21	40	Good-Fair
04/21/10	2010-11	20	44	Good-Fair
07/20/04	2004-131	27	54	Excellent

Data Analysis

Watershed -- drains southeastern Wake County, including the increasingly developed cities of Fuquay-Varina, Cary, and Apex and their suburbs; seven NPDES facilities upstream discharging a total Q_w = 19.96 MGD; transitional zone between the Northern Outer Piedmont and the Rolling Coastal Plain; tributary to the Neuse River. **Habitats** -- moderate quality habitats, has ranged from 63 to 78 since 2004; Coastal Plain-like with extensive wetlands and bottomlands within both of the riparian zones; gravel riffle at upper end of reach; deadfalls and coarse woody debris snags; blow-out pools at bends in the creek; Oriental Privet growing in the riparian zones. **Water Quality** -- a detectable chlorine odor from the WWTP effluent; greatest specific conductance of any site in the Neuse Piedmont in 2015, has ranged from 250 µS/cm to 320 µS/cm since 2004. **2015** -- number of fish collected was very low (n = 145) and the Percentage of Tolerant Fish was relatively high (50%, primarily Eastern Mosquitofish, Redbreast Sunfish, Satinfin Shiner, and Flat Bullhead); an 8-point increase in the NCIBI Score and a one NCIBI Rating Class increase resulted from the collection of an additional species of darter (Glassy Darter), a very slight decrease in the Percentage of Insectivores (from 91% to 90% between 2011 and 2015), and a greater percentage of species with multiple age classes (65% in 2015 vs. 48% in 2011); as at other transitional sites, the Percentage of Omnivores+Herbivores was very low (7%) and the Percentage of Insectivores was high (90%); 11 large specimens (320-453 mm TL) of Notchlip Redhorse and V-lip Redhorse were encountered. **2004-2015** -- community shares faunal similarities with Coastal Plain and Piedmont fish communities; a very speciose community with 32 species known from the site, including 10 species of sunfish, 7 species of cyprinids, 4 species of darters, 3 species of suckers, and 3 Intolerant Species (Chainback Darter which has not been collected since 2004 and Pinewoods Shiner and Roanoke Darter); dominant species are the tolerant Redbreast Sunfish (2004-2011) and the tolerant Eastern Mosquitofish (2015); a consistently low number of fish collected (n = 121-231) along with a high percentage of them being Tolerant Fish (34%-50%), and a skewed trophic structure (~ 6% Omnivores+Herbivores and ~ 90% Insectivores); NCIBI Scores have varied from 40 to 54 with NCIBI Ratings ranging from a low Good-Fair to a low Excellent. **Recommendation** -- continue monitoring this transitional ecoregion and basinwide site in 2020 to determine any impacts from the WWTP and the continued suburbanization of its watershed.

Most Abundant Species	Eastern Mosquitofish (26, 18%)	Non-indigenous Species	Bluegill (7) and Redear Sunfish (1)	Imperiled Species	None

FISH COMMUNITY SAMPLE

Waterbody	Location	Station ID	Date	Bioclassification
TERRIBLE CR	SR 2751	JF35	03/30/15	Good-Fair

County	8 digit HUC	Latitude	Longitude	Elevation (ft)	Reference Site
WAKE	03020201	35.614444	-78.725000	260	No

Level IV Ecoregion	Drainage Area (mi^2)	Stream Width (m)	Stream Depth (m)
Northern Outer Piedmont	11.0	6	0.4

Upstream NPDES Dischargers (≥ 1 MGD or < 1 MGD and within 1 mile)	NPDES Number	Volume (MGD)
Town of Fuquay-Varina's Terrible Creek WWTP	NC0066516	6

Landuse (%)	Forest	Developed	Impervious	Cultivation	Grass/Herb/Shrub	Wetland	Water	Barren
1992	43.8	7.0	no data	44.7	no data	2.5	1.9	0.0
2001	29.8	23.4	5.2	25.9	14.0	4.3	1.2	0.0
2006	26.9	31.2	7.6	22.7	13.3	4.3	1.2	0.1
2011	26.1	34.6	8.5	21.3	12.6	4.2	1.1	0.4

Water Quality Parameters	2005	2010	2015
Temperature (°C)	17.7	16.0	10.3
Dissolved Oxygen (mg/L)	8.0	7.6	12.2
Specific Conductance (µS/cm)	97	138	139
pH (s.u.)	6.2	6.5	6.3

Habitat Assessment Scores (max score)	2014
Channel Modification (5)	5
Instream Habitat (20)	14
Bottom Substrate (15)	4
Pool Variety (10)	9
Riffle Habitat (16)	10
Bank Erosion (7)	4
Bank Vegetation (7)	6
Light Penetration (10)	8
Left Riparian Score (5)	3
Right Riparian Score (5)	5
Total Habitat Score (100)	68

Site Photograph

Water Clarity Slightly turbid/tannic

Substrate: Gravel, sand

Sample Date	Sample ID	Species Total	NCIBI Score	NCIBI Rating
03/30/15	2015-02	14	44	Good-Fair
04/21/10	2010-10	17	52	Good
04/08/05	2005-18	14	50	Good

Data Analysis

Watershed -- drains southeast Wake County northeast of the city of Fuquay-Varina, including the US 401 corridor; greatest percentage of its watershed in grassland/herbaceous/shrub than any other watershed in the Neuse Piedmont in 2015; one NPDES permitted discharger in the watershed (NC0066516, located ~ 0.3 miles upstream); tributary to Middle Creek. **Habitats** -- moderate quality habitats, same as in 2005 and 2010 (range 61-69 since 2005); strong, swift flow; gravel riffles; eroding banks on the left with blowouts; coarse woody debris and deadfalls creating pools; wide bottomland riparian zones in much of the reach; evidence of past very high water; becoming a more hydrologically flashy stream as its watershed is being increasingly developed. **Water Quality** -- a detectable odor of chlorine from the WWTP effluent; specific conductance elevated from the effluent and has ranged from 97 µS/cm in 2005 to 139 µS/cm in 2015. **2015** -- second fewest fish (n = 111) collected from any site in the Neuse Piedmont in 2015, 628 fish were collected in 2010; a 6-point decline in the NCIBI Score and one NCIBI Rating class decrease were attributed to the lower than expected total species richness, fewer fish, the loss of two species of intolerant darters (Roanoke Darter and Chainback Darter), and the loss of three species of sunfish (Warmouth, Redear Sunfish, and Largemouth Bass); collectively these metric decreases and the visible appearance of the site indicated that very high water might have scoured out the stream and re-structured the fish community, in fact between late December 2014 and mid-January 2015 there were two very high flow events (e.g., Middle Creek near Clayton was > 2,500 cfs in one event and ~ 2,000 cfs in the second event while the median flow was ~ 75 cfs). **2005-2015** -- 23 species are known from the site, including 7 species of sunfish, 6 species of cyprinids, 3 species of darters, 3 Intolerant Species (Pinewoods Shiner, Roanoke Darter, and Chainback Darter), and 2 species of sucker; dominant species are Bluehead Chub (2005) and Redbreast Sunfish (2010 and 2015); community appears to have shifted since 2005 from Bluehead Chub, White Shiner, and Swallowtail Shiner (66% to 42% to 16%) to Redbreast Sunfish (11% to 38% to 35%) with the the Percentage of Tolerant Fish increasing from 12% to 38% to 43%. **Recommendation** -- continue basinwide monitoring of this site in 2020 to continue document impacts from the expansion of the WWTP discharge from 1 MGD to 6 MGD and the increasing suburbanization of the watershed.

Most Abundant Species	Redbreast Sunfish (39, 35%)	Non-indigenous Species	Bluegill (21)	Imperiled Species	None

Appendix V: Summary Memo for Holly Springs

TRIANGLE J
COUNCIL OF GOVERNMENTS

May 17, 2022

Upper Middle Creek HUC 030202010901 9-Element Watershed Plan: Purpose, Goals, Takeaways and Recommendations

Project Purpose

The purpose of the Upper Middle Creek Watershed Plan ("Plan") is to guide restoration efforts that improve water quality in the 12-digit HUC 030202010901 ("Upper Middle Creek watershed") of Wake County, North Carolina following the US EPA's nine-element framework. A major driver of the Plan was the 2018 designation of two stream segments in the watershed as "impaired" by the North Carolina Department of Environmental Quality (NCDEQ) due to benthic macroinvertebrate community being rated as "Poor". The Plan document reviews available data and stakeholder information to outline current watershed conditions, priorities for future conservation and restoration, benchmarks for measuring success, and recommendations for ongoing improvement.

The following government bodies contributed to this planning effort:

Organization	**Role in Project**
Wake County Soil & Water Conservation District	Input on agricultural best management practice priorities, soil science, initiator of original grant-funded proejct
Town of Holly Springs	Input on stream restoration, water quality issues, stormwater management and planning solutions within Holly Springs' jurisdiction
Wake County	Input on watershed planning and restoration priorities and septic system issues in unincorporated Wake County
Town of Fuquay-Varina	Input on stormwater management and engineered or planning solutions within Fuquay-Varina's jurisdiction
Town of Apex	Input on stormwater management and engineered or planning solutions within Apex' jurisdiction
North Carolina Division of Water Resources	Project funders and technical experts on various water quality / nutrient management issues
Triangle J Council of Governments	Project manager, plan writer

Questions? Contact Maya Cough-Schulze, mcough-schulze@tjcog.org | 919.558.9389

Project Takeaways

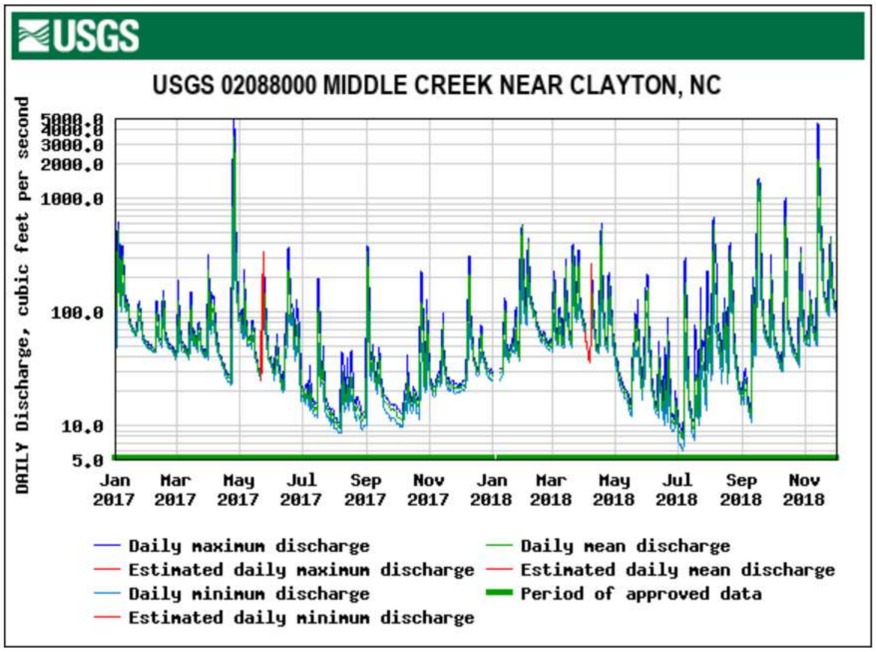
Based on available land use and water quality data and stakeholder input reviewed as part of this project, flashy stormwater flows and associated sediment are likely main contributors to the benthic community impairment in the watershed. Fecal coliform bacteria were also flagged as an additional potential pollutant of concern. To that end, the goals and objectives below outline ways to help restore and protect the watershed from impacts of stormwater runoff and associated pollutants.

LNBA Water Quality Monitoring Data Summary, 2005-2018

Station	Parameter	DO	Temp	pH	SpC	TSS	Total Nitrogen	Total Phosphorus	Fecal Coliform
J4690000	**Median**	7.1	20	6.9	224	5.7	2.03	0.35	250
	Max	13	28.2	8	598	277	15.01	8.46	6000
	Min	4.4	3.1	6.3	80	1.5	0.82	0.05	17
J4868000	**Median**	7.1	21.6	7.1	156	8.7	1.47	0.23	170
	Max	12.8	28.6	7.6	519	245	4.6	2.98	6100
	Min	4.4	3.2	6.6	72	2	0.49	0.05	2
J4980000	**Median**	7.2	20.4	7	164	10.5	1.33	0.17	147
	Max	12.7	28.4	7.8	494	295	7.04	2.99	5200
	Min	4.8	1.2	6.3	69	1.7	0.48	0.04	2
	Recommendation or standard	>4 mg/L		6.0 - 9.0					<200cfu

Red text indicates exceedance of EPA concern level (200cfu/100mL) for primary recreation

Hydrograph at USGS Gage Downstream of Upper Middle Creek Watershed Outlet (No Stream Gages in Upper Middle Creek HUC12)



Goals and Objectives

The ultimate goal of this plan is to recommend steps that will improve the benthic community rating to good-fair or better, which would indicate a diverse benthic macroinvertebrate community and remove the "impaired" stream segments from NCDEQ's impaired water list. Objectives and actions identified below address the observed stressors to the benthic community of flashy stormwater runoff and associated streambank erosion and sedimentation:

Primary Goal: Improve benthic community rating to good-fair or better, to ultimately meet biological water quality standards.
OBJECTIVES
1. Reduce peak stormwater flows by 20% to minimize impacts of potential pollution sources and stormwater volume/peak flows as the watershed continues to develop.
2. Preserve existing open space, forestland and farmland to prevent water quality and benthic community health from declining as the watershed develops.
3. Address identified animal and human fecal coliform pollution sources concurrently with reducing stormwater runoff.
4. Address sediment pollution stemming from streambank erosion (concurrently with reducing causes of erosion - stormwater runoff volume and velocity upgradient in the watershed.)
5. Continue and grow public outreach, education and involvement to promote community stewardship of water quality and ecosystem health in the Upper Middle Creek watershed.

Objective 1: Reduce peak stormwater flows by approximately 15%					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria**
1-1	Implement recommended types of stormwater control measures	Ongoing	Holly Springs, Apex, Cary, Fuquay-Varina, NCDWR, NCLWF, engineering firms	Funding, technical assistance, & staff time	# of SCMs installed, stormwater volume or peak flow reduced by the SCM, water quality data, value added ($/ft/yr)
Note: Apply for 319 or other grant funding to support.					
1-2	Identify and promote stormwater retrofits as part of future maintenance or redevelopment of publicly owned buildings, schools, parks, parking lots and drainage systems.	Ongoing	Apex, Holly Springs, Fuquay-Varina, Cary, Wake County Public Schools + Wake County Green Schools network, NC WRRI, NC Cooperative Extension, TJCOG, engineering firms	Technical assistance, staff time & training	# of SCMs installed, stormwater reduced, water quality data, value added ($/ft/yr)
Note: Apply for 319 or other grant funding to support. Prioritize highly visible sites for SCM retrofits, add signage to promote education and work with WRRI, extension partners to provide tours. Work with Wake County Green Schools Network to implement SCM retrofits on school grounds to promote youth understanding of the benefits of stormwater management.					
1-3	Promote street tree program and encourage stormwater	Mid	Apex, Cary, Holly Springs, Fuquay-Varina, landscaping	Funding, technical assistance, staff time, & training	# of street trees planted/SCMs, stormwater reduced, water quality data, value added ($/ft/yr)

	reduction measures on streets in future capital improvement projects		companies and nurseries recommended by practitioners for good tree installation practices		
Note: Identify streets that are wide enough to accommodate SCMs. Adjust ordinances using Code & Ordinance worksheet to accommodate.					
1-4	Work with Department of Transportation to incorporate retrofits into highway upgrades.	Mid	NCDOT, RPOs, Apex (at NC-55), other jurisdictions as opportunities allow	Staff time & technical assistance	# of SCMs installed, stormwater reduced, water quality data, value added ($/ft/yr)
Note: Coordinate with relevant RPOs.					
1-5	Develop cost share/incentive program to encourage SCMs on private property where best professional judgment deems appropriate	Mid	Cary, Holly Springs, possibly Apex in future with new stormwater utility, Cooperative Extension, businesses, & homeowners	Funding, technical assistance, educational materials, & staff time	# of SCMs installed, funding provided ($)
Note: This could include financial assistance, development incentives, or recognition programs for both structural or non-structural SCMs.					
1-6	Work with businesses and	Mid	Cary, Apex, Holly Springs,	Funding, educational	# of roofs disconnected, volume of stormwater reduced

	homeowners to disconnect roof drains		Fuquay-Varina, Wake County, CWEP, businesses, homeowners	materials, & staff time	
Note: Identify neighborhoods with direct roof drain connections. City could provide this service at no-cost to homeowners to incentivize.					
1-7	Reduce any sources of I/I that may be identified	Mid-Long	Apex, Holly Springs, Fuquay-Varina, Cary, NCDWI, NCDWR, engineering firms	Funding, technical assistance, & staff time (utility dept, not stormwater dept)	# of repairs made, volume of I/I reduced
Note: Include info about any potential leaks, connections, or other maintenance needs to stormwater and wastewater systems in plan update					
1-8	Consider establishing stronger recommendations or incentives to use LID in new development	Short	Cary, Apex, Holly Springs, Fuquay-Varina, Wake County, TJCOG, UNCSOG	Technical assistance, staff time, & elected official buy-in	N/A
Note: Use Code & Ordinance Worksheet tools.					
1-9	Incorporate watershed plan recommendations into other City/County plans	Short	Apex, Holly Springs, Fuquay-Varina, Cary, Wake County, TJCOG	Staff time	N/A

Objective 2: Preserve Existing Open Space, Forestland and Farmland					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria**
2-1	Work with Triangle Land Conservancy, recreation departments, and other partners to prioritize and acquire land for conservation	Short-Mid	All local governments, TLC, NCLWF, Extension, Wake SWCD, private landowners	Technical assistance, staff time, & willing property owners	Acres of land conserved, stormwater reduced, water quality data, value added ($/ft/year)
Note: Prioritize land in critical areas that provides multiple benefits. Aim for ≤10% impervious cover in each catchment.					
2-2	Use Code & Ordinance Tool to identify opportunities to improve open space protections in City/County ordinances	Short	Local Governments, TJCOG	Staff Time	# of strengthened policies
Note: Tools to evaluate Codes and Ordinances for open space protection exist from the Center for Watershed Protection and others, including NC Wildlife Resources Commission's Green Growth Toolbox.					

	Identify potential incentives to encourage open space preservation	Short	Local Governments, NCDEQ, TJCOG	Technical assistance & staff time	Acres of land conserved, stormwater reduced, water quality data, value added ($/ft/year)
See note above.					
2-3	Align conservation goals with local governments' Future Land Development Plans	Short	Local governments, TJCOG	Staff time	N/A
2-4	Explore floodplain protection and trail opportunities to meet conservation goals	Mid-Long	Local governments (including parks and recreation departments), TJCOG, TLC, NCLWF	Funding, technical assistance, & staff time	Acres of land conserved, miles of trail constructed
Note: Identify floodplain buyout opportunities.					

Objective 3: Address identified animal and human fecal coliform pollution sources concurrently with reducing stormwater runoff.

Action #	Specific Action	Timeframe	Partners Involved	Resources Needed	Evaluation Criteria
3-1	Pursue agricultural BMPs that prevent animal waste from reaching streams	Short	Wake SWCD, NCDEQ	Staff time, funding, technical assistance	# of BMPs installed, estimated fecal coliform reduction as calculated from references, or water quality data if available
Note: Pursue 319 grant funds to match Wake SWCD funds for agricultural BMP implementation					
3-2	Remediate any malfunctioning septic systems identified (continue to pursue data on identifying malfunctioning septic systems across the watershed)	Ongoing	Wake County, NCDEQ	Staff time, funding, technical assistance	# of septic systems repaired or replaced, estimated fecal coliform reduction as calculated from references, or water quality data if available
Note: If requested, pursue 319 grant funds to implement septic system repairs					

3-3	Local government stormwater and wastewater utility staff coordinate to address any wastewater-related fecal coliform pollution sources that may be identified from I/I or impacts of treated wastewater discharge to receiving streams	Mid-Long	All local governments coordinating between internal departments	Staff time, potentially funding for repair projects	# of repairs made, volume of I/I reduced
Note: TJCOG may be able to help faciliate intra-governmental department collaboration					
3-4	Implement and incentivize pet waste pickup and public education about its importance	Short	All local governments, TJCOG	Staff time, modest funding	# of pet waste pickup stations, estimated fecal coliform reduction as calculated from references if they exist
Note: Can use public education resources provided by TJCOG CWEP program, of which all local governments in watershed are members					

Objective 4: Address sediment pollution stemming from streambank erosion					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria**

4-1	Identify and replant riparian buffer on any denuded streambanks stable enough to be suitable without bank regrading or stabilization. Consider widening stream buffer beyond required where possible.	Short	Local governments, Wake SWCD, Extension, NCDEQ, TJCOG	Staff time, technical assistance, funding	Linear feet or area of riparian area revegetated, riparian plant survival after 5 years (or other interval)
4-2	Identify unstable, eroding streambanks shedding sediment beyond the capacity of riparian buffer planting to address		Local governments, Wake SWCD, Extension	Staff time, technical assistance, funding	Linear feet of streambank that could benefit from unstable streambanks
4-3	Stabilize unstable streambanks that are actively shedding sediment using nature-based practices/ designs as approved by local government staff and contractors.		Local governments, Wake SWCD, Extension, NCDEQ, TJCOG	Staff time, technical assistance, funding	Linear feet of streambank stabilized, macroinvertebrate community rating 5-10-15 years in future
Note: Apply for 319 and/or NCLWF grants to conduct this work					

4-4	If needed, restore stream channels that are actively degrading using nature-based practices/ designs as approved by local government staff and contractors.				
Note: Apply for 319 and/or NCLWF grants to conduct this work					

Objective 5: Continue and Expand Public Outreach and Education					
Action #	**Specific Action**	**Timeframe**	**Partners Involved**	**Resources Needed**	**Evaluation Criteria**
	Establish active Watershed Group to implement and monitor plan	Short	All	Staff time & stakeholder buy-in	# of milestones met
Note: Determine organizational responsibilities and meeting frequency.					
	Promote stewardship of Upper Middle Creek by seeking outdoor hands-on education options at CWEP direct education visits to Apex, Holly Springs and Fuquay-Varina	Short	Apex, Holly Springs, Fuquay-Varina, TJCOG CWEP program	Staff time and willing teachers or other education settings	Learning outcomes based on pre/post education visit survey, formation of any student groups to clean up Middle or Terrible Creeks or other parks in watershed adjacent to schools
Note: Connect CWEP with any relevant education settings, ie scouts, afterschool or other programs					

	Install education signage with any new, publicly-visible SCMs or stream restoration projects; promote tours for local residents	Mid	Any that install SCMs	Technical assisstance and staff time	# of signs installed; # of tours about SCMs' purpose for local residents
Note: If SCMs installed using 319 fund, signage costs are also eligible					
	Continue and expand direct education programs in coordination with CWEP program, as interest allows. One example: organize Stream Watch or Adopt-A-Stream volunteer groups	Short-Mid	TJCOG CWEP program, local government staff, local citizens to champion stream stewardship and education (teachers, students, others)	Techncial assistance, staff time & willing volunteers	# of volunteers as proxy for level of interest in program, # of streams monitored, citizen science data
	Work with partners to reduce pet waste and pesticide/fertilizer use from public and private property in watershed	Ongoing	TJCOG CWEP program, local government staff, private citizens, golf courses	Technical assistance & staff time	Public buy-in to any incentive programs, estimated lbs of N/P reduced, fecal coliform data

	Tailor messaging and explore other forms of media to reach all audiences	Short-Mid	Local governments	Technical assistance & staff time	# of new people reached

Recommendations

Holly Springs and Wake Soil and Water Conservation District identified specific SCM, stream restoration and agricultural best management practices to implement in the short- to medium-term. They and other project partners will continue to identify additional projects as time goes on to address both the benthic macroinvertebrate impairment and other pollutant concerns. Broadly speaking, the following types of projects should be prioritized to address the following priority pollutants/sources:

Implement restoration practices to address the following priority pollutants (sources)

- Stormwater volume/peak flow (due to development/impervious surfaces)
- Sediment (due to development/degraded buffers)
- Fecal coliform (due to development, wastewater, potentially livestock access and leaking septic)
- Potentially nutrients (due lawns/golf courses, livestock, wastewater)

Priority practices:

SCMs where feasible given available affordable land and suitable site for SCM implementation

- Public property: Bioretention
- Business sites: Infiltration for flow, plus Storm Filter for nutrients
- Subdivisions: Encourage use of stormwater wetlands or bioretention over wet ponds to protect creek
- Anywhere: Upfit dry ponds

Stream restoration projects where bank erosion is actively shedding sediment into creek and local governments can alleviate peak flows upgradient in catchment to ensure stream restoration project viability

Agricultural BMPs where near-stream agricultural activities are actively polluting the creek with sediment or animal waste due to cattle access