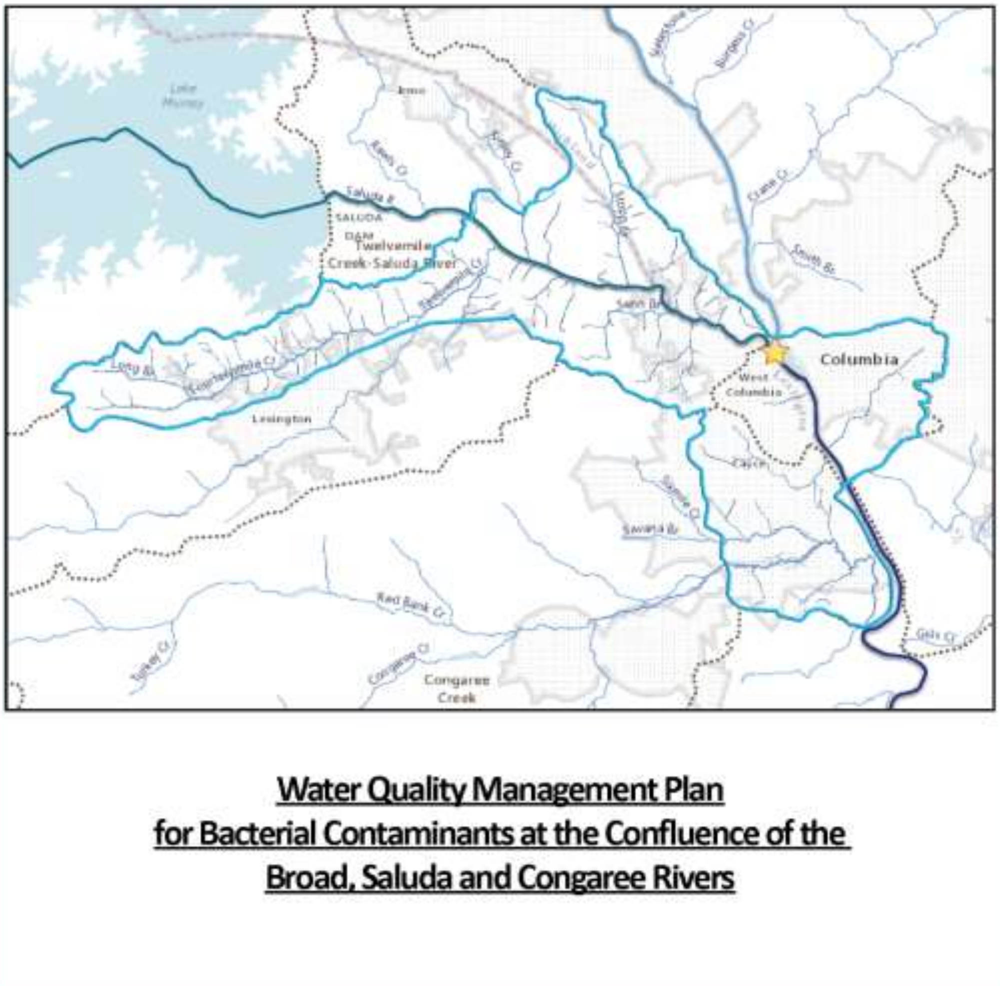
Three Rivers Watershed-Based Plan



Water Quality Management Plan for Bacterial Contaminants at the Confluence of the Broad, Saluda and Congaree Rivers

Prepared By

Prepared For

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Common Acronyms Used in This Document

Abbreviation	Description
3RW	Three Rivers Watershed
3RWBP	Three Rivers Watershed-Based Plan
BMP	Best Management Practice
FC	Fecal Coliform
LDC	Load Duration Curve
TMDL	Total Maximum Daily Load
WBP	Watershed-Based Plan
WTM	Watershed Treatment Model
MRC	Midlands River Coalition
SCDHEC	South Carolina Department of Health and Environmental Control

Glossary and Water Quality Standards Referenced in This Document

Terminology	Definitions
Bacterial Contamination (*Fecal Coliform*)	A group of bacteria found in the intestines of warm-blooded animals (including humans). The presence of coliforms in water is an indication of pathogenic contamination.
Best Management Practices (BMP)	A practice or combination of practices found to be effective means of preventing or reducing the amount of pollution generated by nonpoint sources.
Biochemical Oxygen Demand	The amount of oxygen consumed by microorganisms (mainly bacteria) and by chemical reactions in the process of degrading organic matter in the water.
Nonpoint Source Pollution	A pollution source that is diffuse and does not have a single point of origin or specific outlet, generally carried off by water runoff over land.
Nutrient Pollution	Excessive concentration of nutrients, such as phosphorus or nitrogen, that impairs aquatic ecosystem function.
Point Source Pollution	A single, identifiable source of pollution.
Total Maximum Daily Load (TMDL)	Under the US Clean Water Act, it is a limit on the amount of pollution discharged over time in an area.
Turbidity	Indicates the optical clarity of water, based on the presence of suspended or colloidal particles.
pH	A logarithmic scale indicating the hydrogen ion concentration in water, used to determine the level of acidity or basicity.
Watershed	A land area that drains to one stream, lake, or river.

State Water Quality Standards		
Pollutant	**Freshwater**	**Trout Water**
Bacterial Contamination (*Fecal Coliform)*	349 cfu/100mL or less	349 cfu/100mL or less
Dissolved Oxygen	4.0 mg/L or more	6.0 mg/L or more
Nephelometric Turbidity Units (NTU)	50 NTU or less	10 NTU or less
pH	Between 6.0 and 8.5	Between 6.0 and 8.0

Acknowledgements

The development of this plan would not have been possible without the coordination and support by the Three Rivers Watershed Stakeholder group. The information and technical support provided by the stormwater managers, utility engineers, and government staff members was invaluable in determining priorities and areas of concern. We would also like to acknowledge the insight provided by the many stakeholders that participated through the outreach process, such as river outfitters, state agency staff, conservation planners, and parks and recreation officials. High praise and deep gratitude must be given to Gregory Sprouse at Central Midlands Council of Governments (CMCOG), who researched the historical background of the Three Rivers Watershed Area and provided invaluable institutional knowledge regarding water quality planning in the region.

Special commendation must be given to the staff at Carolinas Integrated Sciences and Assessments (CISA); their extensive knowledge of climate science and continued technical support was critical in analyzing long-term climate impacts within a watershed management and source water protection context. Their contributions regarding environmental justice impacts gives us the opportunity to make this plan more than a water quality management plan, but a holistic, economic development plan that considers the systemic impacts of addressing bacterial contamination within the Three Rivers Watershed Area.

This plan was partially funded by the South Carolina Department of Health and Environmental Control (SCDHEC) watershed-based plan competitive grant process. Originating from the United States Environmental Protection Agency's (EPA) Drinking Water State Revolving Fund (DWSRF) for Source Water Protection (SWP), these planning activities and recommendations support the goal of protecting drinking water sources by addressing the ambient surface water pollutants that can impact them. This plan would not have been possible without additional funding provided by the Lexington Countywide Stormwater Consortium (LCSC), Richland County Stormwater Management Division, and the City of Columbia.

The scale of addressing regional water quality concerns might look daunting when considering the size of the Three Rivers Watershed Area. But this area is dynamic, blessed with unique environmental resources and many people interested in its long-term success. It will take all of us to improve it, a little at a time. We hope that this plan is not the culmination of a process, but the beginning of a journey.

Executive Summary

Background Information

The consultant team comprised of McCormick Taylor Inc. (MT), KCI, and Three Oaks Engineering, was selected by the Central Midlands Council of Governments (CMCOG) to develop a watershed-based plan (WBP) identifying and quantifying sources of bacteria pollution and providing project recommendations within the contributing 11 subwatersheds draining to the confluence of the Lower Saluda, Broad, and Congaree Rivers. The Three Rivers Watershed Area (also referenced as the 3RW Area throughout this document) consists of portions of several HUC-12 watersheds, specifically: Lower Twelvemile Creek (030501091402), Outlet Saluda River (030501091403), Upper Congaree River (030501100301), Middle Congaree River (030501100303), and Lower Congaree Creek (030501100104).

This watershed encompasses 55.6 square miles of land in the heart of the Columbia metropolitan area and extends across seven different political jurisdictions consisting of two counties (Richland and Lexington), five municipalities (Columbia, West Columbia, Cayce, Town of Lexington, and Irmo), and eight Municipal Separate Storm Sewer System (MS4) areas (SCDOT, Richland County, Lexington County, Columbia, West Columbia, Cayce, Town of Lexington, and Irmo).

The total population in this watershed is 94,480. In current conditions, the largest land use categories in the overall Three Rivers Watershed are medium-density residential (18%), forest (17%), and low-density residential (13%). Other developed land uses include commercial (13%), public/institutional (11%), high-density residential (7%), developed open space (5%), roadways (5%), multifamily (3%), and industrial (3%). The amount of impervious surfaces in the Three Rivers Watershed is estimated to be 10,127 acres (28%) in total. Ongoing research from the Center for Watershed Protection mentions a variety of indicators that link impervious cover to watershed health, including stream corridor integrity, geomorphology, stream warming, and water quality (bacteria, nutrients, trash, etc.). According to the Impervious Cover Model (ICM) the Three Rivers Watershed would be considered "impacted," indicating a higher likelihood of bacteria standards violations, eutrophication because of nutrient inputs, signs of toxicity in aquatic life, increased stream bank erosion and downstream sediment delivery, and stream warming as a result of urban heat islands and pavement heating.

This Watershed-Based Plan (WBP) for the Three Rivers Watershed is developed to address key issues impacting natural resources and water quality within the watershed that are not currently under Total Maximum Daily Load (TMDL) requirements. The watershed faces many of the problems typically associated with increased urbanization and its associated stormwater impacts, including stream erosion, water quality degradation, and loss of natural resources. In addition to meeting the nine element requirements of the EPA's WBP development guidance, the plan will incorporate components that address climate change consideration and the protection of the public drinking water sources in the watershed (including intakes from the City of Columbia and City of West Columbia). The unique concerns of this watershed include source water protection and potential climate change considerations. This WBP accounts for these impacts in both current and future conditions (year 2050) scenarios by integrating future climate and land use models with the bacteria pollution analyses. Two methods – load duration curves (LDC's) and the Watershed Treatment Model (WTM) – were used to identify the source of pollutants and quantify the loads associated with the sources.

Climate Considerations

Climate influences soil formation and erosion processes, stream flow patterns, vegetation coverage, and a significant part of the geomorphology of a watershed. Precipitation not only provides water to streams and vegetation, but the intensity, frequency, and amount of rainfall can greatly influence watershed characteristics and delivery of nonpoint source pollution to receiving waterbodies. The Columbia, SC Metro Area where the Three Rivers Watershed is located, is in the southeastern climatic region of the US and has a temperate climate with a mean annual temperature of 65.4°F and a mean annual rainfall of 46 inches.

In the 3RW Area, climate change is resulting in an increase in average temperature over time. Models suggest a doubling of days per year above 100°F, a ~60% increase in days above 95°F, and a ~2°F increase in average annual temperature by the mid-century. Temperature change could drive increased recreational use of the 3RW Area and potentially affect BMP efficacy and upkeep. Additionally, climate change is resulting in an increase in average rainfall and increasing number of extreme rainfall events in the 3RW Area. Precipitation change introduces water quality planning considerations such as managing stormwater runoff, flooding, sampling water quality measures, fecal bacterial loads, and BMP capacity and efficacy.

Climate change impacts on water quality were considered in the WTM by adjusting the future land use (USGS LandCarbon data), precipitation (predicted 60" annual amount), and bacteria concentration (increase by 15%) in stormwater runoff based on the assumption of a high carbon emissions future in the year 2050. The Fourteen Mile Creek subwatershed was selected to examine the effects of increased rainfall scenario, the increased bacteria concentration scenario, and the two scenarios combined. Without climate impacts, future land use changes in the watershed are predicted to result in a 13% increase in annual bacteria loads from existing conditions. The increased rainfall and increased bacteria concentration scenarios resulted in 28% and 44% increases over the annual bacteria loads in existing conditions, respectively; and the combined scenario resulted in a 64% increase in annual bacteria loading.

Analysis of Pollutant Loads and Sources

Two methods were used to assess and quantify pollution in the watershed. The first approach involved using available flow and monitoring data to generate load duration curves, in accordance with United States Environmental Protection Agency (EPA) guidelines. For this WBP, three LDCs were created for fecal coliform bacteria: Saluda River, Congaree River, and Rocky Branch.

The Saluda River LDC shows that 11% of the *E. coli* samples taken during that period reflected pollutant loads in excess of the allowable loading. On average the degree of exceedance was 206%, or slightly more than double, of the allowable load according to the water quality standard. This level of exceedance indicates that, on average, a 51% reduction in existing fecal bacteria loads would be required to approximate compliance with Federal and State water quality standards. The highest incidence of exceedances in the Saluda River LDC (21%), approximately twice the average rate, occurred during dry conditions. A high incidence of exceedance in this segment of the flow regime would indicate that sources such as failing and leaking sanitary sewer systems, non-compliant point source discharges, and failing on-site septic systems may be important considerations in understanding bacterial pollution in the watersheds draining to the Saluda River.

The Congaree River LDC shows that 7% of the *E. coli* samples taken during that period reflected pollutant loads in excess of the allowable loading, and that on average the degree of exceedance was 270%, or considerably more than double, of the allowable load according to the water quality standard. This level of exceedance indicates that, on average, a 63% reduction in existing fecal bacteria loads would be required to approximate compliance with Federal and State water quality standards. Most of the exceedances in the Congaree River LDC occur during wet conditions and high flows. These results suggest that pollutant build-up and wash-off mechanisms, such as riparian buffer maintenance and precipitation intensity, that deliver loads in stormwater runoff are important factors to consider when addressing bacterial pollution in the Congaree River.

The Rocky Branch LDC shows that 83% of the *E. coli* samples reflected pollutant loads in excess of the allowable loading, and that on average the degree of exceedance was 1,663%, or more than an order of magnitude greater than the allowable load according to Federal and State water quality standard. This level of exceedance indicates that, on average, a 94% reduction in existing fecal bacteria loads would be required to approximate compliance with water quality standards. Exceedances in Rocky Branch were consistently recorded across all flow conditions. However, exceedance generally increased in both frequency and degree during wet conditions and high flows, indicating that pollutant build-up and wash-off mechanisms that deliver loads in stormwater runoff, such as road curb length and precipitation intensity, are also important considerations in this highly urbanized stream.

The second method to quantify bacterial pollution in the 3RW Area was the Watershed Treatment Model (WTM), which was used to estimate pollutant loads based off the current land use conditions in the watershed. Under existing conditions, the WTM calculated a total annual runoff volume as 49,491 acre-ft for the entire 3RW Area: 21,350 ac-ft from commercial; 20,078 ac-ft from residential; 5,228 ac-ft from roadways; 2,160 ac-ft from industrial; 631 ac-ft from rural; and 44 ac-ft from forested land uses. For the entire 3RW Area, the total amount of TN estimated by the WTM is 331,677 lb/year and the largest contributing sources are commercial (37%), residential (35%), and roadway (10%) land uses. The estimated annual load for TP is 46,677 lb/year and the largest sources are residential (36%), commercial (27%), and channel erosion (14%). The total TSS estimate is 16,430,153 lb/year and the largest contributors are channel erosion (50%), residential (16%), and commercial (15%). Finally, the total estimated load of fecal coliform bacteria is 1.47×10^{7} MPN/yr. The largest sources of bacteria come from runoff associated with commercial (36%) and residential (34%) land use. The developed land uses generate large volumes of stormwater runoff, which can wash off pollutants from the surface and carry them to receiving waterbodies.

Recommendations

KCI used the WTM to develop retrofit scenarios that reached load reduction goals for fecal coliform in the 11 subwatersheds. Based on the LDC's developed for this watershed plan, the subwatersheds draining to the Congaree River require a reduction of 63% of the fecal coliform load to approximate compliance with water quality standards; the subwatersheds draining to the Saluda River require a reduction goal of 51%, and Rocky Branch requires a reduction of 94%. The reduction goal of 94% for Rocky Branch could not be achieved within the context of WTM even when the subwatershed was completely retrofitted with new stormwater BMPs and/or redeveloped with improved stormwater management.

The purpose of the retrofit scenarios was two-fold: to illuminate the levels of effort required to approximate compliance with the water quality standard for fecal coliform bacteria loading in each subwatershed and to guide resource managers in prioritizing those management efforts that will achieve the greatest reductions. The retrofit model scenarios utilized non-structural measures such as pet waste education programs, impervious cover disconnection, and improved riparian buffer maintenance and protection to reach watershed load reduction goals. On-site sewage disposal system (OSDS) education and repair and sanitary sewer overflows (SSO) repair programs were also included in retrofit models. In the WTMs best management practice analysis, implementing catch basin cleanouts, street sweeping, and erosion and sediment control had no impact on reduction of fecal coliform and were not considered retrofit options.

After applying the non-structural management efforts in the WTM, the modeling team applied a combination of stormwater BMP retrofits, riparian buffer restoration areas, and areas of urban redevelopment with improved stormwater management as necessary to reach the bacteria pollution reduction target for each subwatershed as determined by the Load Duration Curve analysis. The selection of BMP types utilized for the stormwater retrofits was evenly divided between bioretention cells, filter BMPs, constructed stormwater wetlands, conventional wet ponds, and infiltration practices because they are assigned the highest levels of bacteria pollutant removal within the WTM framework.

Riparian buffer enhancement and stormwater retrofits are responsible for the largest amount of bacteria reduction (44% and 45% respectively). Although the recommendations were focused on bacteria reduction (estimated 52% reduction for the entire 3RW Area), they also provide water quality benefits by reducing runoff volume (40%) which in turn helps reduce nitrogen (50%), phosphorus (70%), and sediment (28%) in the Three Rivers Watershed.

1.0 Introduction

1.1 Background, Purpose, and Need

1.1.1 Reading this plan

Each section of the Three Rivers Watershed Based Plan (also referenced as the 3RWBP in this document) is designed to cover the following broad topics concerning water quality in the Three Rivers Area (referenced as the 3RW Area)

Section 1. Introduction – Introduces the Watershed Management Plan, Goals and Objectives, and the overall planning context.

> **Section 1.4.1** details how each of these sections addresses the nine elements of the watershed-based planning process established by the US Environmental Protection Agency (EPA).

Section 2. Analysis of Watershed Conditions – Provides a detailed description of the watershed climate, landscape, land use, living resources, and political boundaries. This section is largely based on research from existing data and reports.

Section 3. In-Stream Water Quality Monitoring – Provides a summary of available historic and current monitoring data in the watershed and a description of current water quality impairments.

Section 4. Pollutant Load Analysis – Provides a discussion of the Load Duration Curve and Watershed Treatment Model methods and results for understanding fecal coliform bacteria loading in the 3RW Area.

Section 5. Pollutant Source Assessment – Describes the potential causes of water quality degradation in the watershed. This section also introduces the calculation of the pollutant loading based on existing land cover/land use conditions and assists in identifying the sources of various pollutants.

Section 6. Implementation Plan – Includes descriptions of the recommended management strategies and restoration projects, estimates of the water quality benefits that would be realized from plan implementation, and a schedule of future activities. This section includes cost estimates for strategy implementation, identifies potential funding sources, and describes schedules and monitoring programs to document plan implementation and changes in the watershed condition over time.

1.1.2 Watersheds and Why They Matter

A watershed, according to the US EPA, is a land area that drains to one stream, lake, or river. Watersheds exist at different geographic scales and "nest" within one another based on landscape composition qualities such as topography, geomorphology, and soil composition. A smaller subwatershed that drains into a smaller stream may be within much larger watershed where the smaller stream eventually drains into a lake or a larger river. In this sense, the concept of the watershed facilitates tracking water as it travels through different stages of the water cycle.

All water travels over a watershed as surface water runoff, or underground as groundwater, eventually draining into a larger water body. Along this process, water may function as a vehicle that carries material across a watershed, until it eventually reaches a larger body of water. Sediment, nutrients, and pollution may travel this way until eventually accumulating in the larger water body.

This accumulation of pollution from across a watershed is considered nonpoint source (NPS) pollution because the sum of pollution cannot be pinpointed to a single entity (or point source). Changes to a watershed, such as a storm event that deposits significant precipitation, or a construction project that disturbs soil, may eventually be reflected in the larger water body.

Watersheds are independent of any political boundaries but are significantly impacted by human activity. The presence of impervious terrain, such as asphalt roads, parking lots, or bridges reduces the infiltration capacity of soil and facilitates the transfer of runoff over land. Human-induced pollution is more easily carried over impervious surfaces (**Figure 1-1**), negatively impacting water quality.

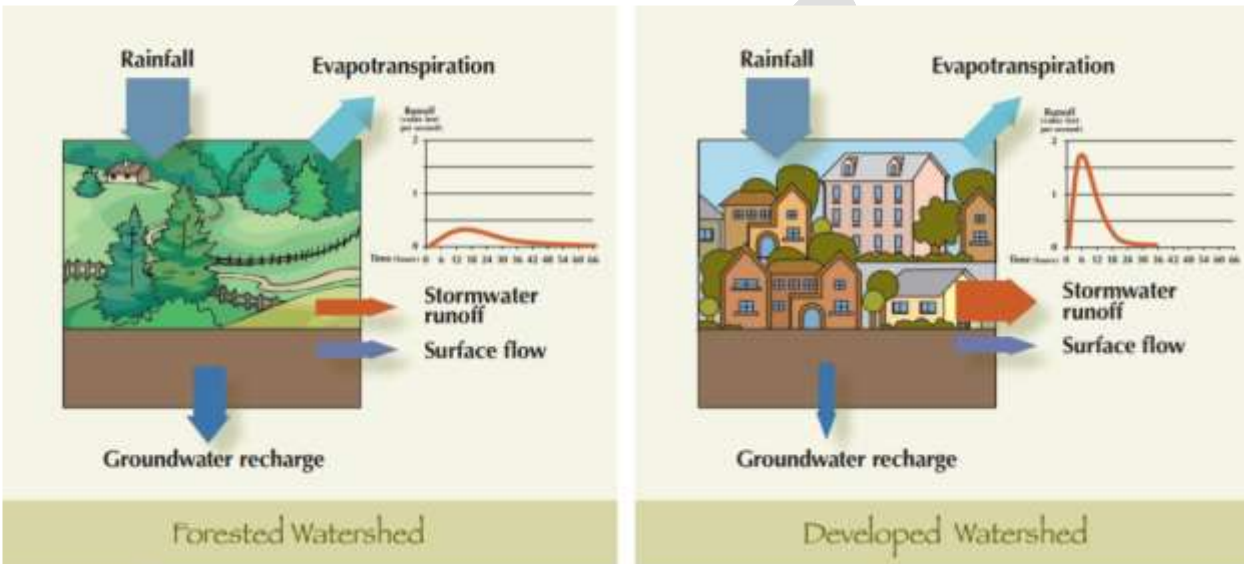

Figure 1-1: Visual representation of runoff differences between forested and developed urban watersheds[1]

Understanding watersheds and addressing water quality from a watershed-based approach facilitates understanding how small changes can accumulate to generate region-wide impacts. While this does not make the problem any less complex, it illustrates how a solution to water quality issues must be, by necessity, holistic and inclusive of all potential stakeholders within an area.

1.2 Three Rivers Impairment and Potential TMDL

The 3RWBP is a concerted, watershed-based approach to address bacterial contamination issues within what is considered the 3RW Area.

The area of interest for the 3RWBP represents the non-TMDL portions of the Upper Congaree, Outlet Saluda River, Lower Congaree Creek, and Lower Twelvemile Creek-Saluda River watersheds. A Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. The majority of the existing TMDLs for watersheds that surround the 3RW Area are related to fecal coliform.

[1] Image from SC Sea Grant, SCDNR, and NOAA

The 3RW Area includes the 55.6 square mile area that extends from the Town of Lexington to below the confluence of the Broad, Saluda, and Congaree rivers. This watershed is unique and of critical importance because it represents the heart of the Columbia metropolitan area and extends across nine different political jurisdictions consisting of two counties (Richland and Lexington), five municipalities (Columbia, West Columbia, Cayce, Town of Lexington, and Irmo), and eight MS4 areas (SCDOT, and the aforementioned political jurisdictions).

Bacterial contamination has been a historic problem in the region, with a total of 10 approved TMDL's in adjacent portions of the four HUC12 watersheds. These TMDL's date back to 2001, targeting streams and tributaries which flow directly into the 3RW Area. While there are currently no TMDL's in place for the 3RW Area, three SCDHEC monitoring stations were listed on the 2016 303(d) list of impaired waters for bacteria impairments. The SCDHEC 2018 303(d) list identifies three additional impaired stations within the 3RW Area (**Figure 1-2** summarizes all currently listed stations).

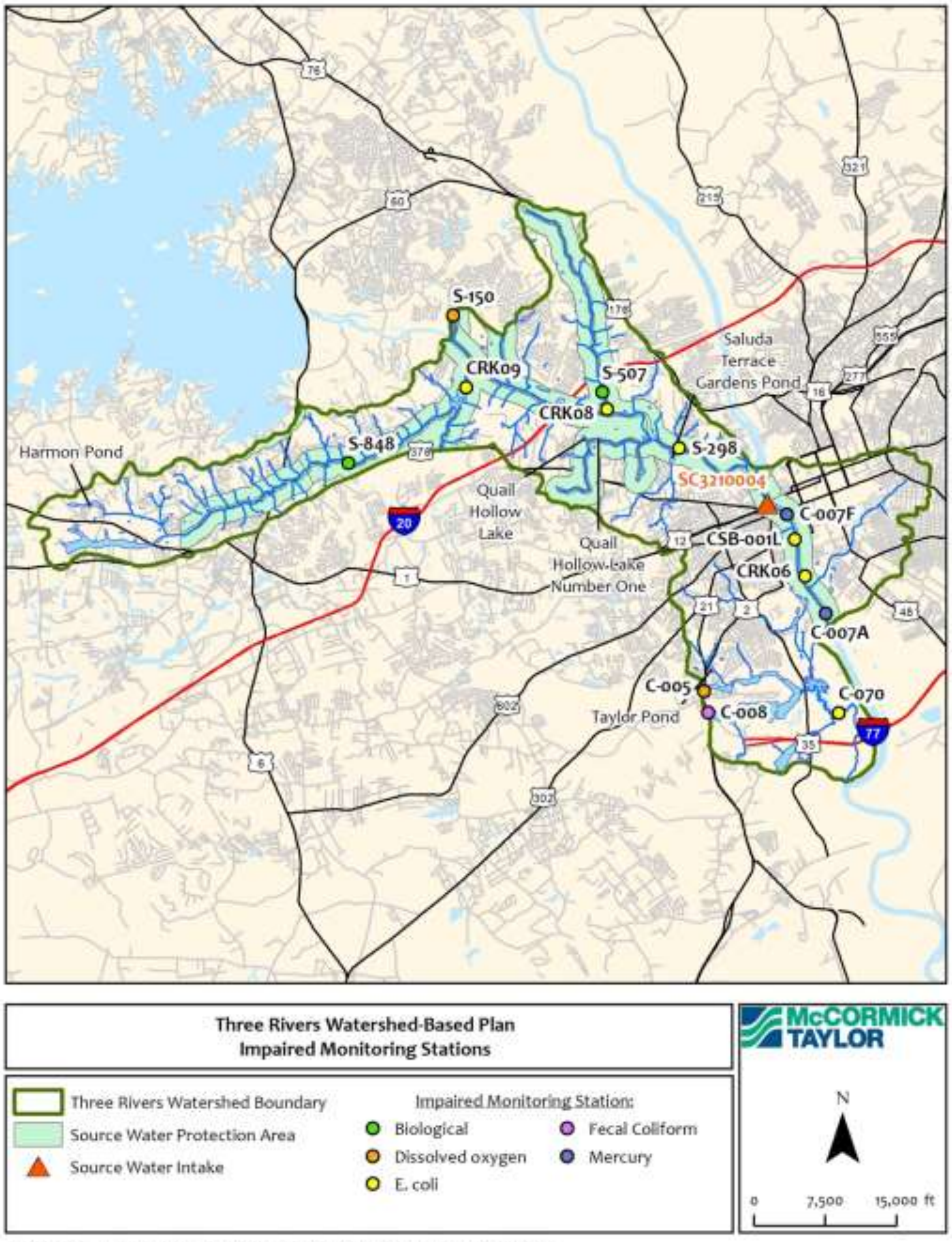

Figure 1-2: Three Rivers Watershed impaired monitoring stations

The 2018 303(d) list also includes one station as a protection priority within the 3RW Area, a source water intake for the City of West Columbia (SC3210004). Two other source water intakes, one for the City of Columbia (SC4010001) and another for the City of West Columbia (SC3210004), are upstream of the 3RW Area located right by Lake Murray. In total, these source water intakes serve around 380,000 residents in the Columbia Metro area.

Due to these impairments and protection priorities, SCDHEC has indicated a TMDL for the 3RW Area will likely be developed in the next several years. The long-term bacterial pollutant load assessments used in this plan, which consider climate and land use patterns up to the year 2050, provide additional context for the importance of protecting these source waters as the 3RW Area continues to be developed. The recommendations of this watershed-based plan (WBP) address these source water protection priorities by improving water quality throughout the 3RW Area. Recommendations such as riparian buffer maintenance could help reduce bacterial pollution near source water intakes, promoting long-term source water protection.

1.3 Organization and Committee Structure

1.3.1 3RW Stakeholder Group

Local interest in addressing these impairments and protecting water resources in the 3RW Area is high. Since 2016, a multi-jurisdictional coalition of stakeholders has been coordinating efforts to address bacterial contamination issues in the region. Active participants in this 3RW Stakeholder Group (**Table 1-1**) represent five local governments, a regional council of governments, one state agency, and one non-profit advocacy organization. The jurisdictions also represent eight MS4s, three drinking water utilities, and five wastewater utilities. By combining resources and information, the 3RW Stakeholder Group has improved inter-jurisdictional communication and developed a coordinated water quality monitoring strategy that includes a common standard operating procedure, the identification of potential monitoring locations, and a commitment to ongoing coordination.

Table 1-1: Three Rivers Watershed Stakeholder Group Organizational Members

Organization
Central Midlands Council of Governments
Lexington Countywide Stormwater Consortium
Richland County
City of Cayce
City of Columbia
City of West Columbia
Town of Lexington
Town of Irmo
SC Department of Transportation
Congaree Riverkeeper

The next logical step for this stakeholder group is to develop a WBP to assist in identifying pollutant sources, establishing common water quality goals, and implementing local and regional scale best management practices (BMPs). Because of the collaborative, multi-jurisdictional nature of the 3RW Stakeholder Group, it is well positioned to successfully develop a WBP, as many of the stakeholders usually involved in this type of project are already at the table and are committed to participate and work towards implementation.

1.3.2 3RW Focus Groups

In addition to the core stakeholder group in **Table 1-1**, the development of the 3RWBP also involved recruiting stakeholders from the larger community. Stakeholders were broken into focus groups based on type of land use: Sewer Utilities (**Table 1-2**) and Urban/Rural Pollutant Source Focus Group (**Table 1-3**).

Table 1-2: 3RW Sewer Utility Focus Group Organizational Members

Organization
Central Midlands Council of Governments
McCormick Taylor
City of Columbia Water
City of Cayce Utilities
Town of Lexington
Palmetto Utilities

Table 1-3: 3RW Urban/Rural Pollutant Focus Group Organizational Members

Organization
Central Midlands Council of Governments
McCormick Taylor
Lexington County Soil & Water Conservation District
Richland County Soil & Water Conservation District
Lexington County
City of Columbia
Irmo-Chapin Recreation Commission
Congaree Riverkeeper
Clemson Extension
South Carolina Department of Health and Environmental Control
Lexington Countywide Stormwater Consortium
City of Cayce
City of Columbia
City of Columbia Parks and Recreation
City of West Columbia
Carolina Integrated Sciences and Assessments (CISA)

A summary of the focus group meeting minutes is included as part of **Appendix A**.

1.4 Watershed-Based Plan

1.4.1 EPA Required Nine Elements

The US Environmental Protection Agency has established a series of essential Nine Elements (A – I criteria) that must be addressed in a watershed-based plan for projects to be eligible for restoration and preservation funds under Section 319 of the federal Clean Water Act. The plan was designed to satisfy these requirements. Following are these Nine Elements and their corresponding plan sections:

A. Identification of pollutant causes and sources to achieve load reductions addressed in watershed management plan:
    - Chapter 2 **Analysis of Watershed Conditions**
    - Chapter 4 **Pollutant Load Analysis**
        - Section 4.2 **Load Duration Curve Results**
        - Section 4.3 **Watershed Treatment Model Results**
    - Chapter 5 **Pollutant Source Assessment**
        - Section 5.1 **Point Sources**
        - Section 5.2 **Nonpoint Sources due to Human Waste**
        - Section 5.3 **Other Nonpoint Sources**
        - Section 5.4 **Pollutant Source Assessment Summary**

B. Estimate of load reductions anticipated to be achieved through specified management measures:
    - Section 6.2.7 **Pollutant Load Reductions**

C. Description of nonpoint source management measures necessary to achieve load reductions:
    - Section 6.2 **Strategies to Address Nonpoint Sources of Bacteria Pollution**

D. Estimate of technical and financial assistance, cost, and authorities necessary to implement the watershed management plan:
    - Section 6.5.1 **Priorities**
    - Section 6.5.2 **Estimated Costs**
    - Section 6.5.3 **Potential Funding Sources**
    - Section 6.5.4 **Financing Mechanisms and Timelines**

E. Information or education component to enhance public understanding of watershed management:
    - Section 6.6 **Community Engagement**

F. Schedule for implementing the nonpoint source management measures specified in plan:
    - Section 6.7 **Schedules and Milestones**

G. Interim, measurable milestones to determine implementation of nonpoint source management measures:
    - Section 6.7 **Schedules and Milestones**
    - Section 6.8 **Measures of Success**

H. Criteria to determine if load reductions are being achieved:
    - Section 6.8.2 **Evaluation Methods**

I. Monitoring component to evaluate effectiveness of implementation efforts:
    - Section 6.8.1 **Monitoring Program**

1.4.2 Relationship to 319 Program

The 3RWBP was partially funded through the South Carolina Department of Health and Environmental Control competitive grant process for developing watershed-based plans. This funding from the EPA's Drinking Water State Revolving Fund (DWSRF) for Source Water Protection (SWP) supports the goal of protecting drinking water sources by addressing ambient surface water pollutants that can impact source waters. Selection for funding to develop this WBP does not guarantee future 319 implementation funding. However, having an approved WBP (with all required Nine Elements) is a prerequisite for certain funding opportunities, such as Section 319 grants.

1.5 Project Goals and Objectives

The 3RWBP is designed to leverage the current collaborative efforts of the 3RW Stakeholder Group with the ultimate goals of creating a regional framework for meeting water quality standards within the 3RW Area and protecting drinking water sources. After years of coalition building and stakeholder coordination, the next logical goal for the 3RW Stakeholder Group is to develop a WBP to assist in identifying pollutant sources, establishing common water quality management goals and strategies, and implement local and regional scale BMPs. As such, the 3RWBP will serve as a practical regional guideline and progress monitoring tool to reduce bacterial contamination and improve water quality in the 3RW Area.

This plan is designed to provide a series of both local and regional water quality management strategies. The strategies vary in scope and obligation, from regional programmatic water quality monitoring coordination systems, to targeted stream restoration projects. While 319 implementation funds are envisioned as a viable funding source for many of the strategies, this plan also provides actions which could be successfully implemented by individual jurisdictions or through the leveraging of regional coalitions such as the 3RW Stakeholder Group, MS4s, or stormwater management consortiums. The coordination and financial investment demonstrated by the 3RW Stakeholder Group make it an ideal vehicle for further collaboration in restoring water quality within and surrounding the confluence of the Three Rivers Watershed.

Additional Project Objectives

- Water Quality Modeling
- Stream/Floodplain/Habitat Restoration and Preservation
- Flood Mitigation
- Stakeholder Coordination/Collaboration
- Social Equity Impact Analysis
- Others, as appropriate to improving bacterial pollution related water quality conditions

2.0 Analysis of Watershed Conditions

2.1 Location and Boundaries

2.1.1 Jurisdictional Boundaries

The Three Rivers Watershed encompasses 35,587 acres of land across the Columbia metropolitan area (as shown in **Figure 2-1),** extending across seven different political jurisdictions consisting of two counties (Richland and Lexington), five municipalities (Columbia, West Columbia, Cayce, Town of Lexington, and Irmo), and eight Municipal Separate Storm Sewer System (MS4) areas (SCDOT, Richland County, Lexington County, Columbia, West Columbia, Cayce, Town of Lexington, and Irmo)**.** Although, geographically, Pine Ridge and South Congaree do not manage significant areas within the watershed boundary, their input was included as they are both members of the Lexington Countywide Stormwater Consortium and as potential upstream influence to the 3RW Area. The Town of Irmo was engaged for similar reasons, and for their input and experience concerning sanitary sewer overflows in the 3RW Area.

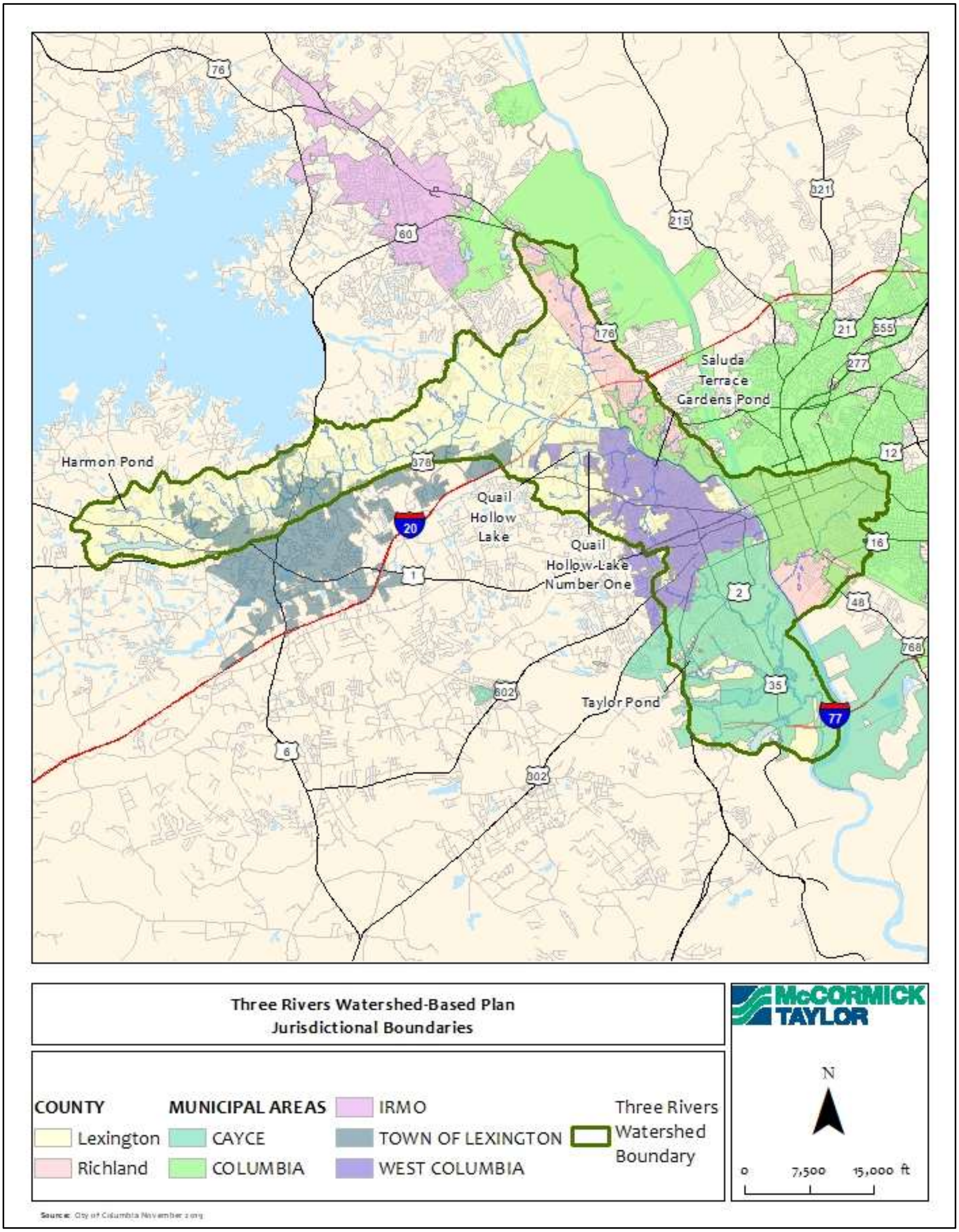

Figure 2-1: Three Rivers Watershed Jurisdictional Boundaries

2.1.2 Watershed Boundaries

The Three Rivers Watershed was subdivided into 11 subwatersheds, as shown in **Table 2-1** and **Figure 2-2.** The Rocky Branch Watershed has already been delineated and modeled by the City of Columbia. The remaining subwatersheds were aligned with existing monitoring stations where possible in order to facilitate better use of the water quality models in the future. The smallest is Congaree River East and the largest subwatershed is Fourteenmile Creek. This largest subwatershed was not subdivided into smaller watersheds because there are no jurisdictional breaks, the land use is very consistent, and there are no additional monitoring stations that would justify creating additional watersheds. All 11 subwatersheds were modeled as described in **Section 4.3**.

Table 2-1: Subwatersheds of the Three Rivers Watershed

Name	Size (acres)
Lower Sixmile-Congaree	2,733
Fourteenmile Creek	8,921
Congaree River East	1,416
Congaree River West	2,180
Congaree Creek Outlet	2,962
Kinley Creek-Saluda River	3,919
Saluda River North	1,976
Senn Branch and Double Branch	3,995
Stoop Creek	2,729
UT to Congaree Creek	1,691
Rocky Branch	2,670

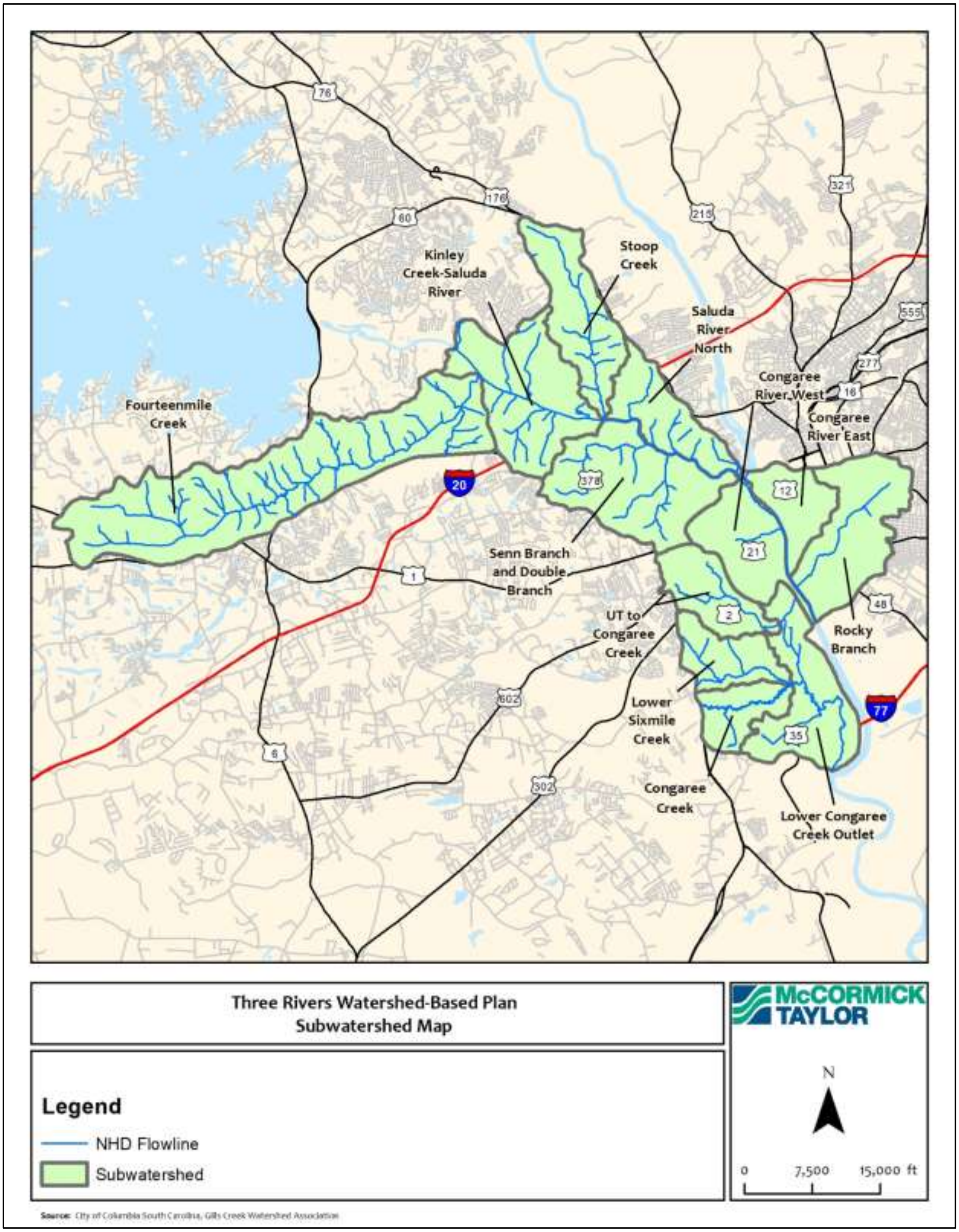

Figure 2-2: Three Rivers Watershed Area Subwatershed Delineations

2.2 Climate

2.2.1 Historic Climate Conditions in Watershed

Climate influences soil formation and erosion processes, stream flow patterns, vegetation coverage, and a significant part of the geomorphology of a watershed. Precipitation not only provides water to streams and vegetation, but the intensity, frequency, and amount of rainfall can greatly influence watershed characteristics. The Columbia, SC Metro Area, where the Three Rivers Watershed is located, is in the southeastern climatic region of the US and has a temperate climate with a mean annual temperature of 65.4°F and a mean annual rainfall of 45.69 inches (SC Climatology Office) as summarized in **Table 2-2**. The mean annual rainfall is the precipitation value utilized by the WTM for the water quality analysis.

Table 2-2: Monthly Climate Record for Columbia, SC (1954-2020)

Month	Average Min. Temp (F)	Average Max. Temp (F)	Mean Precipitation (in)
January	37.1	59.8	4.03
February	41.7	61.4	3.80
March	44.8	67.9	4.41
April	59.1	72.1	3.19
May	68.5	79.6	3.43
June	75.2	85.2	5.01
July	78.2	88.0	5.60
August	77.8	88.3	4.78
September	69.2	83.8	3.94
October	60.0	72.6	3.16
November	50.5	65.0	2.87
December	40.0	59.9	3.48
Annual Mean	**59.9**	**68.7**	**45.69**

Source: South Carolina State Climate Office (Menne et al., 2012[2])

2.2.2 Future Temperature Projections

There are several broad areas for climate considerations in the 3RWBP which have implications for watershed management issues, such as changes in temperature and precipitation projections. Climate considerations potentially change current and future water quality management actions, which could result in future cost savings and a more resilient watershed. These considerations prompted a WTM exercise that envisions a future climate scenario which integrates modeled changes to temperature and precipitation in the 3RW Area (the results of which can be found in **Section 4.3.3**). These climate impacts were also considered through the context of watershed planning and the EPA Nine Elements of a Watershed-Based Plan. The climate projection analysis of the 3RW Area indicates a need to plan for shifts in temperature and precipitation, and their potential future impacts on bacterial contamination. The

[2] Menne, Matthew J., Imke Durre, Bryant Korzeniewski, Shelley McNeal, Kristy Thomas, Xungang Yin, Steven Anthony, Ron Ray, Russell S. Vose, Byron E.Gleason, and Tamara G. Houston (2012): Global Historical Climatology Network - Daily (GHCN-Daily), Version 3. [Retrieved by South Carolina State Climatology Office via xmACIS]. NOAA National Climatic Data Center. doi:10.7289/V5D21VHZ, April 2020

following sections describe some of these implications and provide potential strategies to address them, helping create a more resilient Three Rivers Watershed.

In the 3RW Area, climate change is resulting in an increase in average temperature over time, and changes in seasonal and daily temperature patterns (for instance, a warming of overnight lows and a rise in average winter temperatures)[3]. Extreme heat will be a core impact of climate change in the 3RW Area, which is expected to see more frequent and severe heatwaves in most climate scenarios[4]. In the watershed area, Coupled Model Intercomparison Phase 5 (CMIP5) models suggest a doubling of days per year above 100 °F, a ~60% increase in days above 95 °F, and a ~2 °F increase in average annual temperature by the mid-century[5]. Temperature change could drive increased recreational use of the 3RW Area[6] and potentially affect BMP efficacy and upkeep[7].

2.2.3 Future Precipitation Projections

Climate change is resulting in an increase in average rainfall in the 3RW Area. It is also changing the frequency and intensity of precipitation events and patterns, which in turn impacts the frequency and intensity of both drought and heavy rainfall events[8]. The number of extreme rainfall events observed since the 1950s is increasing and their frequency is expected to further double or triple by the end of the century[9]. Precipitation change introduces water quality planning considerations such as managing stormwater runoff, flooding, sampling water quality measures, fecal bacterial loads, and BMP capacity and efficacy. Increases in extreme rainfall events and flooding can pose a particular challenge for watershed management if a short duration rainfall event exceeds BMP capacity.

Because precipitation is a key input into the WTM model, CISA evaluated available annual precipitation data from Coupled Model Intercomparison Phase (CMIP6) models and compared it against available historical averages (see **Section 2.2.1**). A recent evaluation of CMIP6 models suggest that CMIP6 models continued to improve in accuracy for the southeast region but tend to underestimate shifts in precipitation indices representing both averages and extreme precipitation conditions[10]. In CISA's analysis, model data from the watershed area show an increase in annual precipitation over time, in line with existing projections available for the Southeast (See **Figure 2-3**). Each dot represents one year's median precipitation for the area nearest to the 3RW Area. The curve is a default local polynomial regression (LOESS) curve fitted to the data. Shared Socioeconomic Pathway 5 (SSP5) is the scenario used in the model and is equivalent to Representative Concentration Pathway 8.5 (RCP 8.5), or a high carbon emissions future. CISA engaged with the CMCOG and McCormick Taylor to use these data to develop a future scenario for the WTM model. Additional details may be found in **Appendix E – WTM Model Methodology.**

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[3] 4th National Climate Assessment Southeast Chapter, see https://nca2018.globalchange.gov/chapter/19/
[4] 4th National Climate Assessment Southeast Chapter, see https://nca2018.globalchange.gov/chapter/19/
[5] Climate and Hazard Mitigation Planning (CHaMP) Tool, see https://champ.rcc-acis.org/
[6] For instance, during a heatwave water activities may be more attractive
[7] For instance, via heat tolerance of plants in green infrastructure or strain on grey infrastructure
[8] 4th National Climate Assessment Southeast Chapter, see https://nca2018.globalchange.gov/chapter/19/
[9] 4th National Climate Assessment Section 7.2.2, see https://science2017.globalchange.gov/chapter/7/
[10] For several examples, see the NOAA Climate Program Office's Water Utility Study. https://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/Water-Resources/Water-Utility-Study

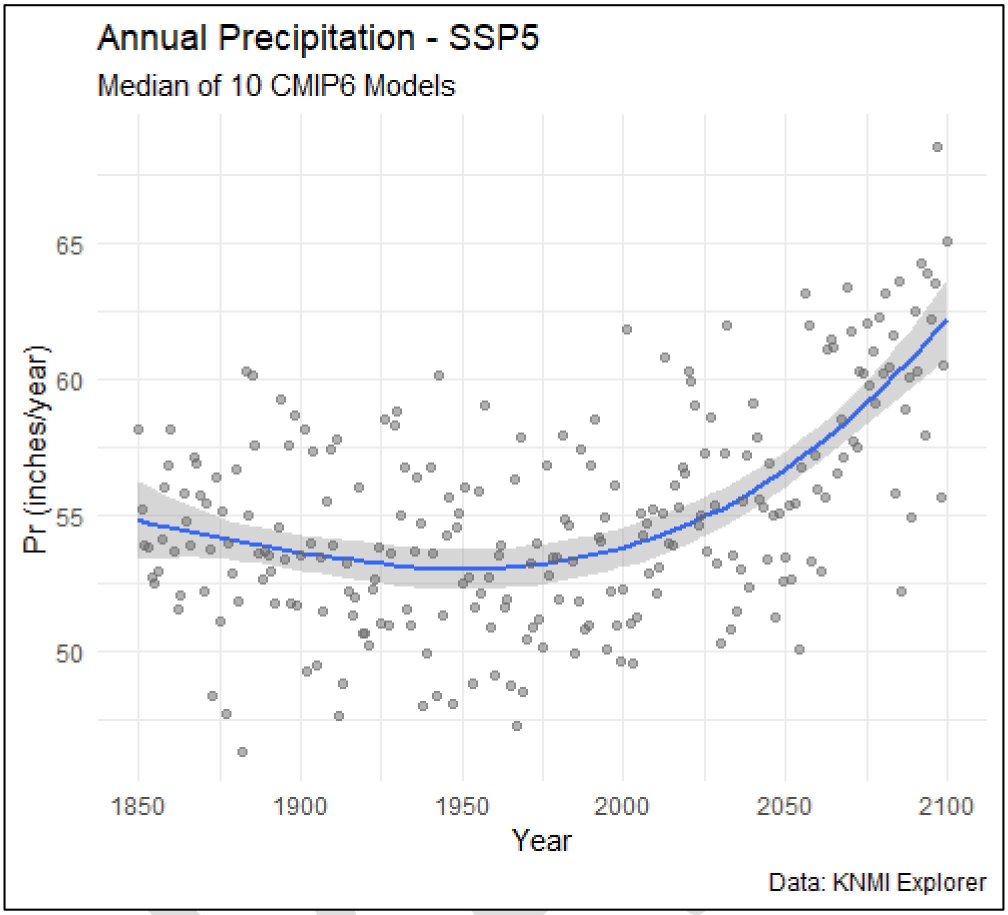


Figure 2-3: Annual precipitation in inches per year for the 10 models CISA evaluated.

In addition to the future scenario, it is also helpful to consider that a projected increase in rainfall due to climate change will have impacts throughout the watershed. For example, **Figure 2-4** shows the linear relationship the WTM uses when rainfall shifts in the watershed. Variables represent total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), fecal coliform bacteria, and runoff volume. This relationship does not capture extreme rainfall events (which are also projected to increase) but does suggest that solely planning for current rainfall conditions could leave BMPs that are unprepared for a future increase in rainfall. Existing watershed plans are investigating using both statistical and qualitative decision scenarios to ensure that management can cope with changing future conditions[11].

[11] For several examples, see the NOAA Climate Program Office's Water Utility Study. https://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/Water-Resources/Water-Utility-Study

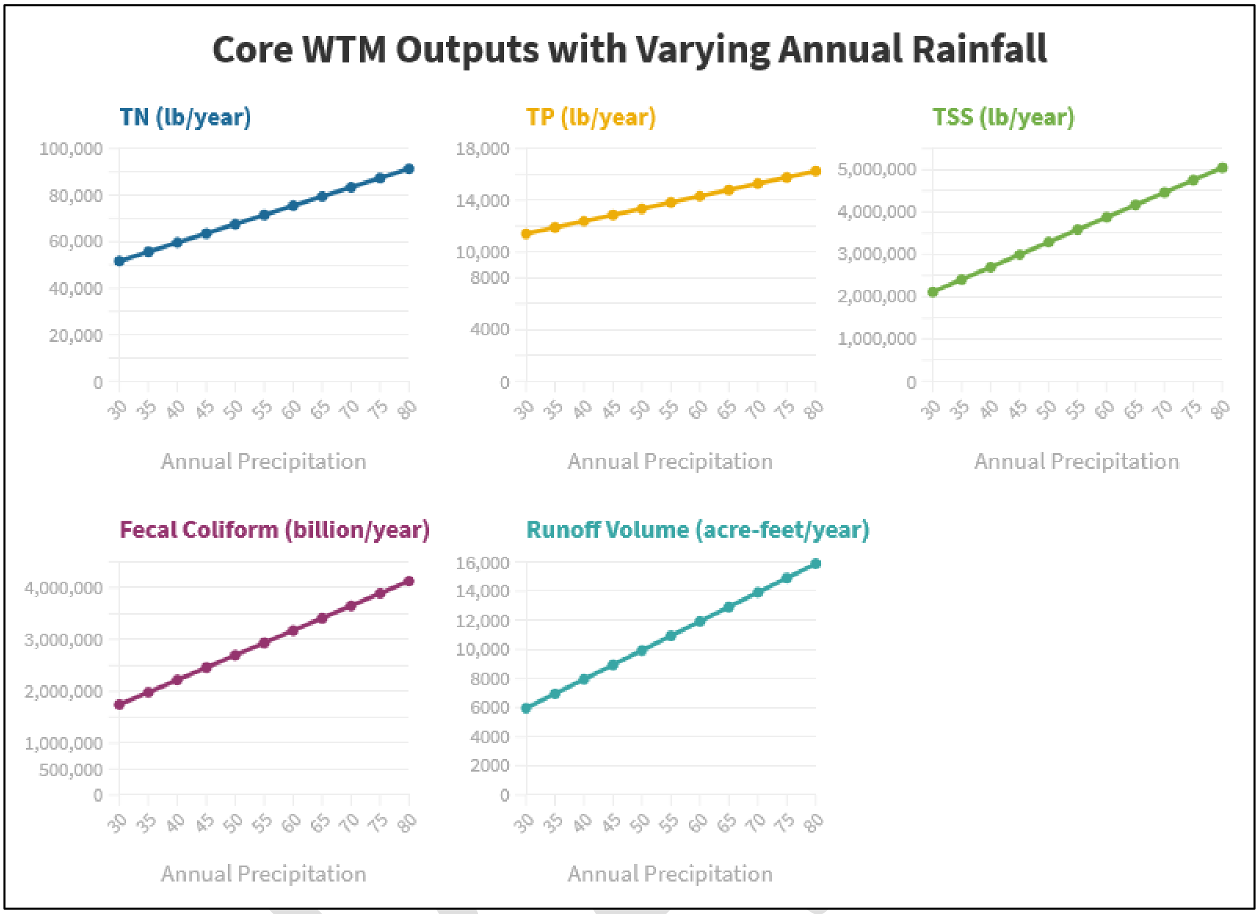


Figure 2-4: WTM model output variables in response to increasing total annual rainfall in the Fourteenmile Creek watershed.

2.3 Physiography

The Three Rivers Watershed encompasses a variety of geographic features pertaining to surface water features, geology and soils, and land cover and land use. As shown in **Figure 2-5**, the topography of the watershed reveals the main flow pathways of the main rivers and their associated tributaries. The highest elevations are found near the western side of Fourteenmile Creek (about 171 ft) and the lowest elevations are the streams, rivers, and ponds.

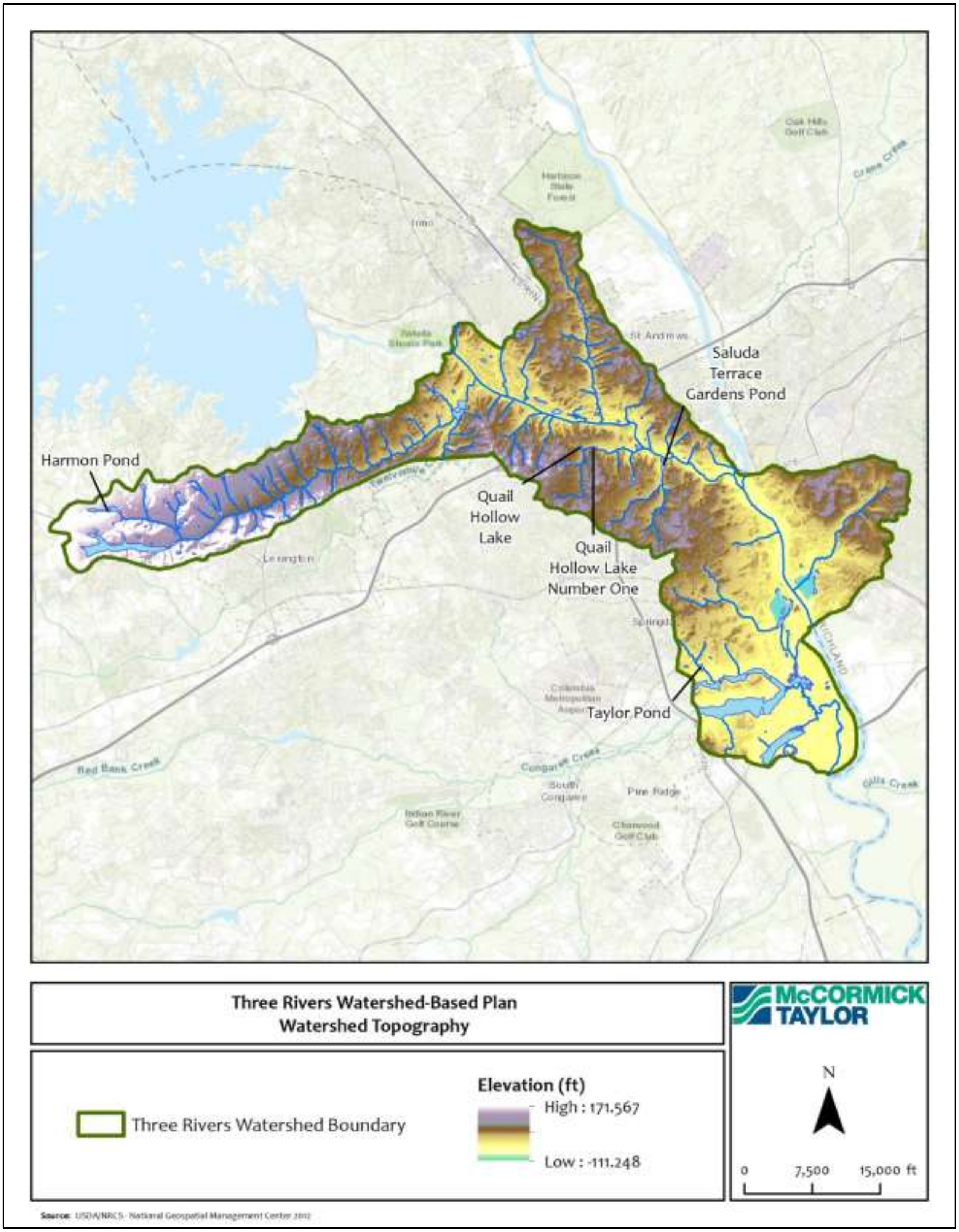


Figure 2-5: Three Rivers Watershed Area Topography

2.4 Surface Water Resources

2.4.1 Streams and Rivers

According to the 2018 National Hydrography dataset, the Three Rivers Watershed contains 109.35 miles of streams (as summarized in **Table 2-3** and shown in **Figure 2-6**). There are currently nine SCDHEC regulated dams along these waterways. Note that Rocky Branch is not explicitly listed in the NHD dataset, so it is most likely included in the "Unnamed" category.

The hydrology of the Three Rivers Watershed is strongly influenced by upstream watersheds and dams. Water flow conditions can change rapidly in the Lower Saluda River as a result of releases from the hydroelectric power facility at Lake Murray. Daily river flows may range from 400 to 20,000 cubic feet per second (cfs) and levels may range from 2 to 10 feet[12]. Dams can be associated with changes to hydrology, water quality, habitat, and river morphology[13]. Reservoirs can become sinks for sediment, nutrients, and toxic substances and the operation of the dams determines how these pollutants are stored in the reservoir or released downstream. Additionally, a slow-moving or still reservoir can heat up and create a favorable environment for algal blooms and decreased dissolved oxygen. Some reservoirs become temperature stratified and can release water with low dissolved oxygen and/or colder temperatures from the bottom of the reservoir into the tailwater. **Section 3.4** of this WBP discusses the water quality implications in the 3RW Area based on historic water quality sampling.

[12] Information from Lower Saluda Scenic River Project, https://www.dnr.sc.gov/water/river/scenic/saluda.html

[13] https://www.epa.gov/sites/default/files/2015-09/documents/chapter_4_dams_web.pdf

Table 2-3: Proportion of Rivers and Streams within the contributing subwatersheds in the 3RW Area

HUC12 Watershed Name	HUC14 Subwatershed Name	Stream Name	Stream Miles within Subwatershed	Stream Miles Percentage within Subwatershed
Lower Congaree Creek	Congaree Creek Outlet	Congaree Creek	4.26	46.30%
		Unnamed streams	4.94	53.70%
	UT to Congaree	Unnamed streams	3.97	100.00%
	Lower Sixmile - Congaree	Congaree Creek	4.24	39.66%
		Sixmile Creek	2.54	23.76%
		Unnamed streams	3.91	36.58%
Outlet Saluda River	Stoop Creek	Stoop Creek	4.88	57.28%
		Unnamed streams	3.64	42.72%
	Kinley Creek - Saluda River	Kinley Creek	1.12	8.24%
		Lorick Branch	0.59	4.34%
		Saluda River	3.56	26.20%
		Twelvemile Creek	0.03	0.22%
		Unnamed streams	8.29	61.00%
	Senn Branch - Double Branch	Double Branch	2.05	16.65%
		Saluda River	2.85	23.15%
		Senn Branch	2.32	18.85%
		Stoop Creek	0.01	0.08%
		Unnamed streams	5.08	41.27%
	Saluda River North	Saluda River	0.89	14.08%
		Stoop Creek	0.11	1.74%
		Unnamed streams	5.32	84.18%
Upper Congaree River	Congaree River East	Broad River	0.19	23.46%
		Congaree River	0.62	76.54%
	Congaree River West	Broad River	0.12	3.48%
		Congaree River	2.03	58.84%
		Saluda River	0.24	6.96%
		Unnamed streams	1.06	30.72%
	Rocky Creek	Congaree River	0.71	16.67%
		Unnamed streams	3.55	83.33%
Lower Twelvemile Creek - Saluda River	Fourteenmile Creek	Fourteenmile Creek	9.78	27.01%
		Long Branch	2.26	6.24%
		Twelvemile Creek	2.12	5.85%
		Unnamed streams	22.05	60.89%

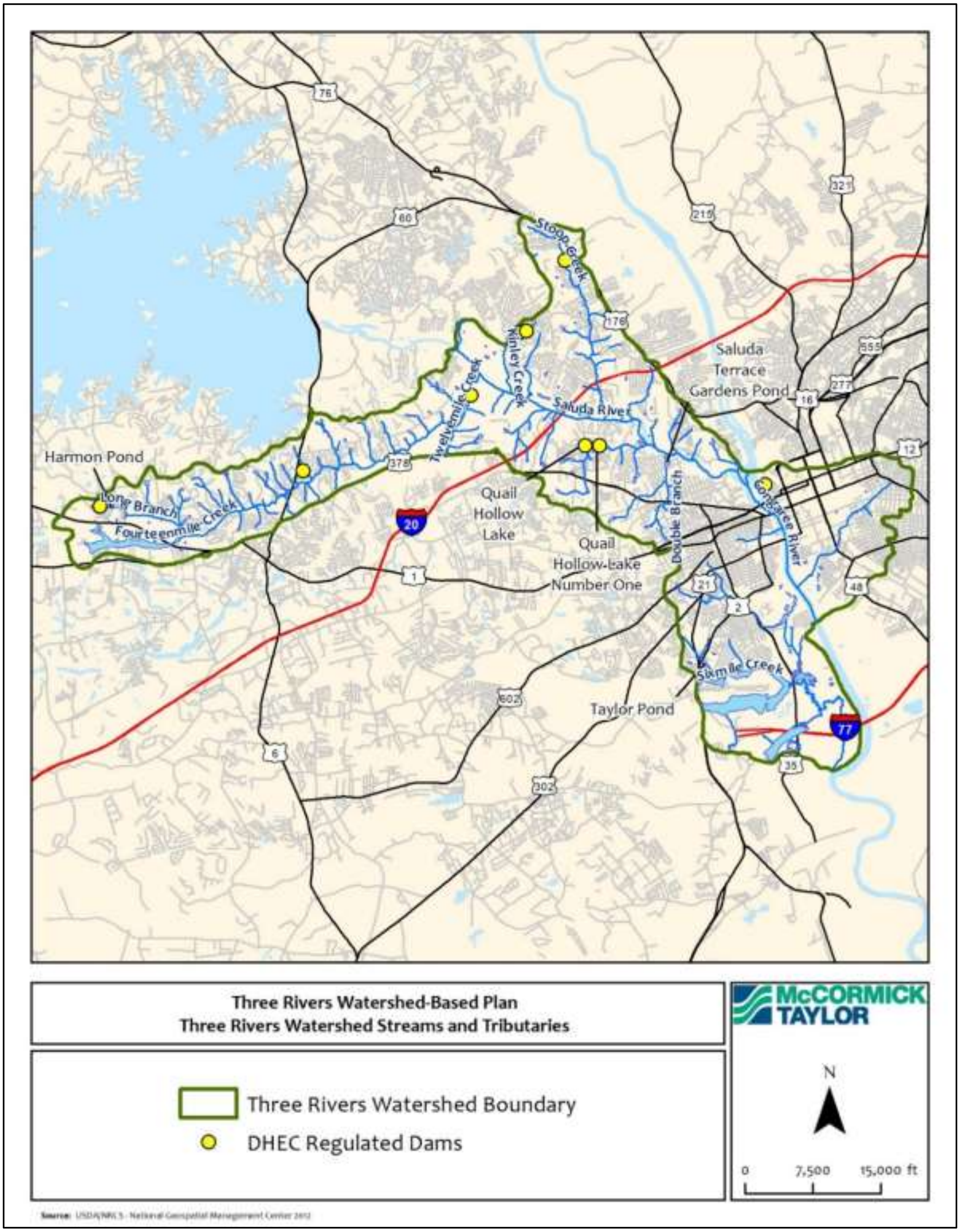


Figure 2-6: Three Rivers Watershed Streams and Tributaries

2.4.2 Riparian Buffer Analysis

The consultant team performed a desktop GIS analysis of the current condition of riparian buffers in the watershed. Streamlines were defined by the National Hydrography Dataset (NHD). The CMCOG provided a summary table of buffer requirements (**Table 2-4**) by each jurisdiction in the watershed.

Table 2-4: Buffer Requirements by Jurisdictional Area

Jurisdiction	Buffer Requirements
Lexington County	• Perennial streams – 100 ft • Intermittent streams – 50 ft • Floodway (AE and A Zones) – buffer is width of floodway, if floodway is greater than 100 ft; if floodway is less than 100 ft from top of bank, the distance to bring buffer to 100 ft will be added • Wetlands associated with perennial streams – if wetland is less than 100 ft, then add buffer width to bring total wetland & buffer to 100 ft • Wetlands associated with intermittent streams – if wetland is less than 50 ft, then add buffer width to bring total wetland & buffer to 50 ft • All other wetlands – extent of wetland + 50 ft beyond wetland edge
City of West Columbia	• Same as Lexington County
City of Cayce	• Same as Lexington County
Town of Lexington	• Flood Prevention Ordinance – standards for streams without established base flood elevations and floodways – 100’ of the streambank unless certified encroachment will not result in increased flood levels
Town of Irmo	• Same as Lexington County
Richland County	• Jurisdictional perennial & intermittent streams identified by the USACE, not associated with a floodplain or wetlands, the buffer shall be at least fifty (50) feet • Floodways – equal to floodway but not less than 50 ft • Delineated wetland areas associated with perennial & intermittent streams, the buffer shall be at least fifty (50) feet • All other wetlands – extent of wetland + 50 ft beyond wetland edge
City of Columbia	• 50 ft for most streams and wetlands • Floodways – width of floodway or 50 ft, whichever is greater (AE & A zones) o 25 ft when: All stormwater is captured and routed to water quality control; No untreated sheet flow discharging into buffer; ¼ ac or less lot sizes with restricted area o Base + 20 ft, if storing hazardous substances or petroleum facility o Base + 50 ft, if solid waste landfill or junkyards

Two buffer zones, 50 ft and 100 ft, were generated around the streamlines. Aerial imagery was used to assess when a development, roadway, or other impervious surface encroached within the two buffer zones. Beginning at the headwaters, each segment of the stream centerline was traced until a change in condition occurred, such as a change in jurisdiction or change in buffer classification. All roadway crossings (culverts, bridges) were considered encroachments within the buffer of the stream because of the potential to increase erosion or other pollutant sources into the river. Many of the stream segments that are classified as less than 50 ft buffer widths are due to roadway crossings.

A summary of the results of the analysis is contained in **Table 2-5** and **Figure 2-7** below. A complete description of the buffer analysis workflow can be found in **Appendix B – Riparian Buffer Analysis Documentation**. Recommendations for improving riparian buffers are included in **Section 6.2.4**.

Table 2-5: Buffer Widths in Three Rivers Watershed

Classification	Miles	Percent
<50 ft	20.72	19%
>100 ft	82.73	76%
50-100 ft	6.01	5%
Total	**109.46**	**100%**

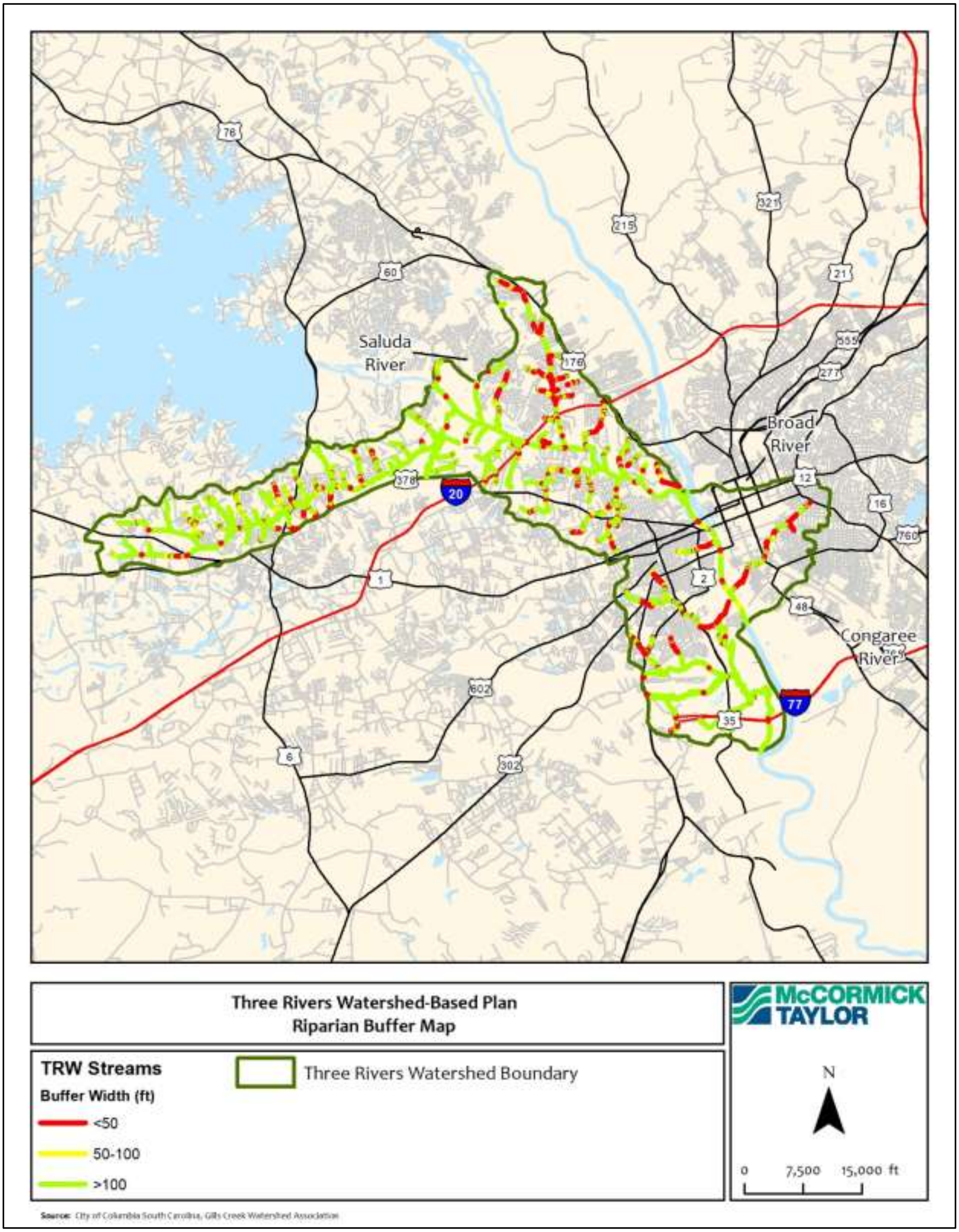


Figure 2-7: Riparian Buffer Widths in Three Rivers Watershed

2.4.3 Wetlands

Section 404 of the Clean Water Act[14] defines wetlands as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Wetlands generally include swamps, marshes, bogs, and similar areas."

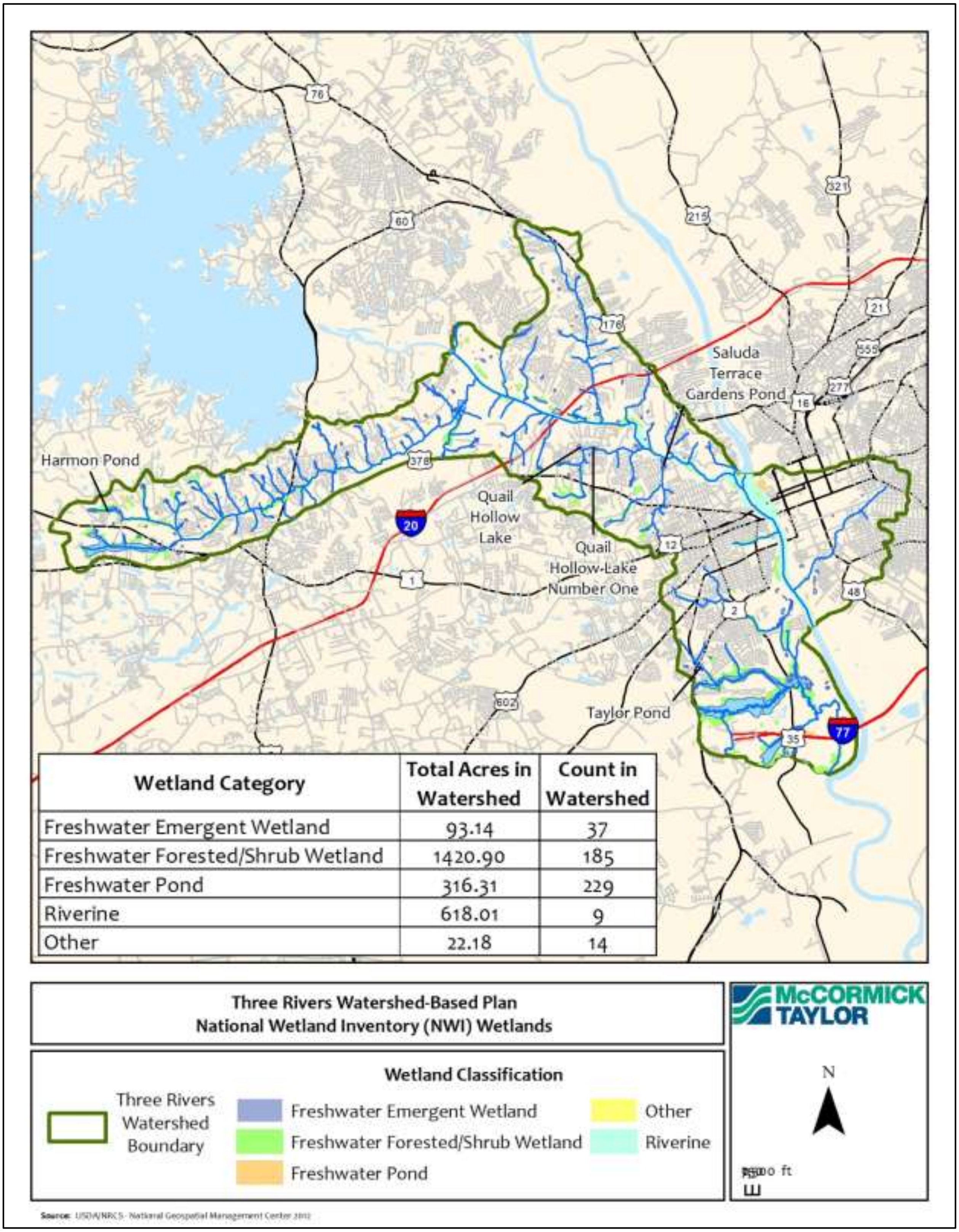
Wetlands are environmentally sensitive habitats that play an integral part in supporting the water quality and water storage of a watershed. These reservoirs help to control flooding by retaining surface runoff and releasing steady flows of water downstream. Wetlands also support biological diversity, erosion control, and sediment retention.

Table 2-6 summarizes the National Wetland Inventory for the 3RW Area. There are 2,471 acres of wetland habitat throughout the watershed[15], the majority of which are freshwater forested/shrub wetlands (1,421 acres). Note that these wetlands have not been field-verified and there may be wetlands present in the watershed that may not be shown in the NWI. **Figure 2-8** shows wetland types from the NWI in the watershed.

Table 2-6: Wetlands in Three Rivers Watershed

Wetland Category	Acres	Percent
Freshwater Emergent Wetland	93	3.8%
Freshwater Forested/Shrub Wetland	1421	57.5%
Freshwater Pond	316	12.8%
Lake	0.00	0.0%
Riverine	618	25.0%
Other	22	0.9%
Total	**2,471**	**100%**

[14] EPA, 1972
[15] USFWS, 2016



Wetland Category	Total Acres in Watershed	Count in Watershed
Freshwater Emergent Wetland	93.14	37
Freshwater Forested/Shrub Wetland	1420.90	185
Freshwater Pond	316.31	229
Riverine	618.01	9
Other	22.18	14

Figure 2-8: National Wetland Inventory Map for the Three Rivers Watershed

2.4.4 Floodplains

The process by which streams swell during storms and spill out onto their floodplain is natural. The FEMA 100-year floodplains are shown in **Figure 2-9**. Anthropocentric concerns with flooding problems often stem from land development occurring in flood-prone areas and/or structures being built in floodplains. Such flooding concerns are exacerbated when development throughout the watershed, and the associated impervious surfaces, result in increased volumes of runoff and expansion of those flood-prone areas over time. These concerns are also provoked by the gradually increasing storm intensity and frequency experienced as a result of climate change.

Flooded areas have the potential to convey pollution (such as motor oil, litter, fertilizers, detergents, pet waste, etc.) from roadways, sewers, hazardous waste sites, industrial plants, and farms to receiving waterways. This is relevant for drinking water protection areas located around freshwater intakes and groundwater wells, and especially concerning in parts of the highly urbanized Three Rivers Watershed where riparian buffers are not properly protected or maintained (see Figure 2-7). Furthermore, the cost of flooding can be particularly difficult for specific communities vulnerable to natural hazards or less economically resilient to these events, such as: older adults, people with disabilities, the unemployed, and mobile homeowners[16]. Management strategies to maximize co-benefits that will benefit these vulnerable populations are later discussed in **Section 6.4 Climate Ready Planning**.

[16] https://www.hydrotech-group.com/blog/impact-of-flooding-on-water-quality

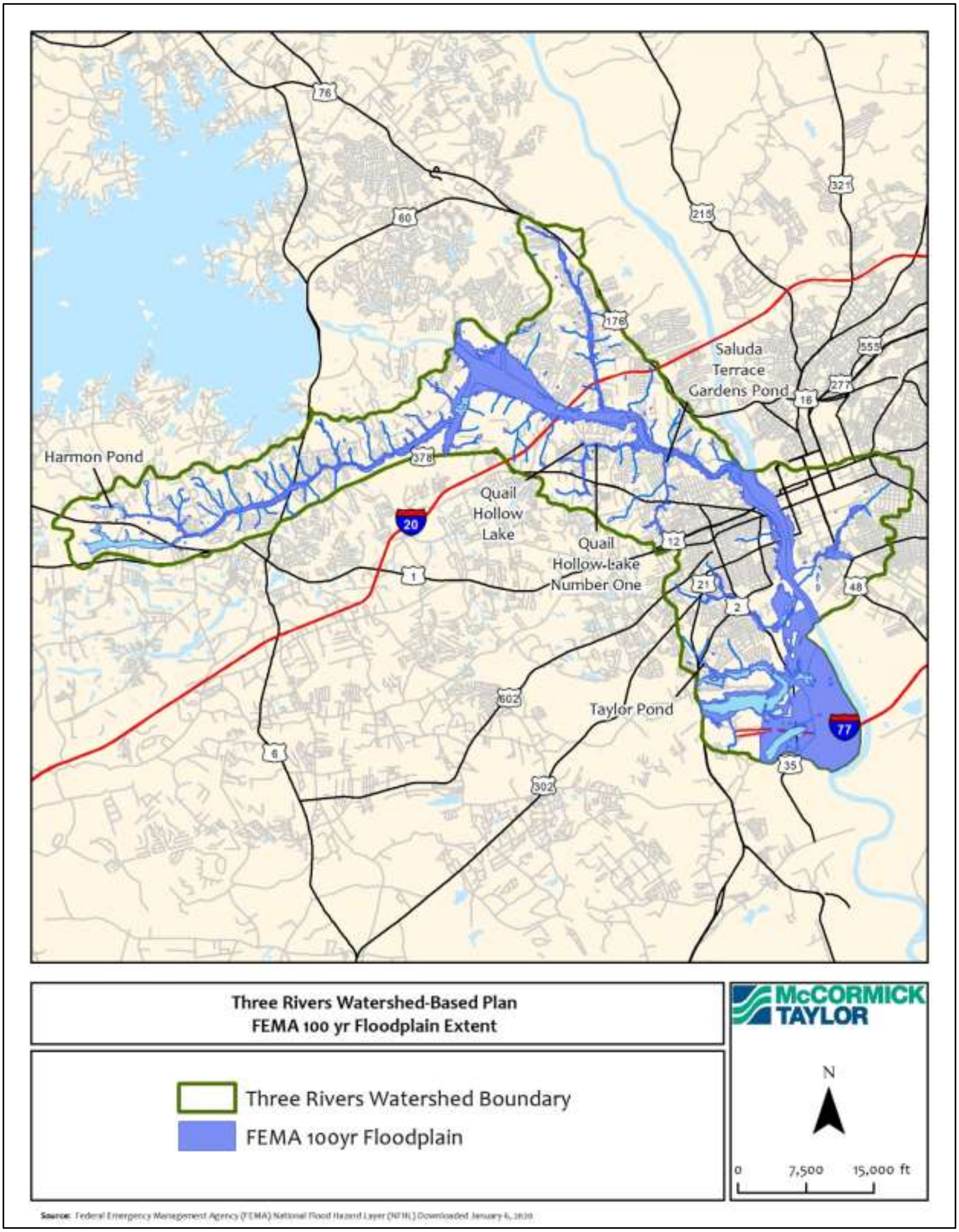


Figure 2-9: 100-year FEMA Floodplain for Three Rivers Watershed

2.5 Geology and Soils

2.5.1 Geology

The geologic formations underlying a watershed have a significant effect on the water resources. Geology is a major determinant of the type of topography and surface features in an area. The chemical composition and minerals of the parent rock or unconsolidated sediments determines in large part the soil characteristics, including erodibility and infiltration rates.

Ecoregions are areas of general similarity in the type, quality, and quantity of environmental resources. Currently, the EPA has mapped four levels of detail for the southeast region. The Three Rivers Watershed is located within the Southeastern Plains ecoregion, specifically the Sand Hills. This region is composed primarily of Cretaceous-age marine sands and clays, capped in places with Tertiary sands, deposited over the crystalline and metamorphic rocks of the Piedmont. Ridges formed by the deep deposits of Pliocene and Pleistocene sands range from 300 to 600 feet above mean sea level and tend to be excessively drained and low in fertility.

2.5.2 Soils

The most common soil series[17] in the 3RW Area are Dothan-Urban land complex (10%), Urban land (7%), Dothan loamy sand (5%), and Troup-Urban Land complex (5%). The Dothan series consists of very deep, well drained soils that formed in thick beds of unconsolidated, medium to fine-textured marine sediments. Dothan soils are located on interfluves (elevated areas between two rivers in the same drainage area) along slopes ranging from 0 to 15 percent. The Troup series consists of very deep, somewhat excessively drained soils that formed in unconsolidated sandy and loamy marine sediments. Troup soils are found on ridges and hillslopes, with slopes ranging from 0 to 15 percent. Urban Soils are found in areas of high population density in the built environment. These soils can exhibit a wide variety of conditions and properties, and thus are unique for every city.

Figure 2-10 illustrates the locations of the Hydrologic Soil Group (HSG) classifications in both watersheds, as assigned by the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS). The HSG describes a group of soils having similar runoff potential under similar storm and cover conditions:

- Group A are soils having a high infiltration rate (or low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained sands or gravelly sands. These soils have a high rate of water transmission.
- Group B are soils having a moderate infiltration rate when thoroughly wet.
- Group C are soils having a slow infiltration rate when thoroughly wet. These soils typically have a layer that impedes the downward movement of water.
- Group D are soils that have a very slow infiltration rate (or high runoff potential) when thoroughly wet. Generally, these are soils that have a clay layer at or near the surface; soils that have a high water table; and/or soils that are shallow over nearly impervious material.

[17] All soils data obtained from the USDA-NRCS Web Soil Survey https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

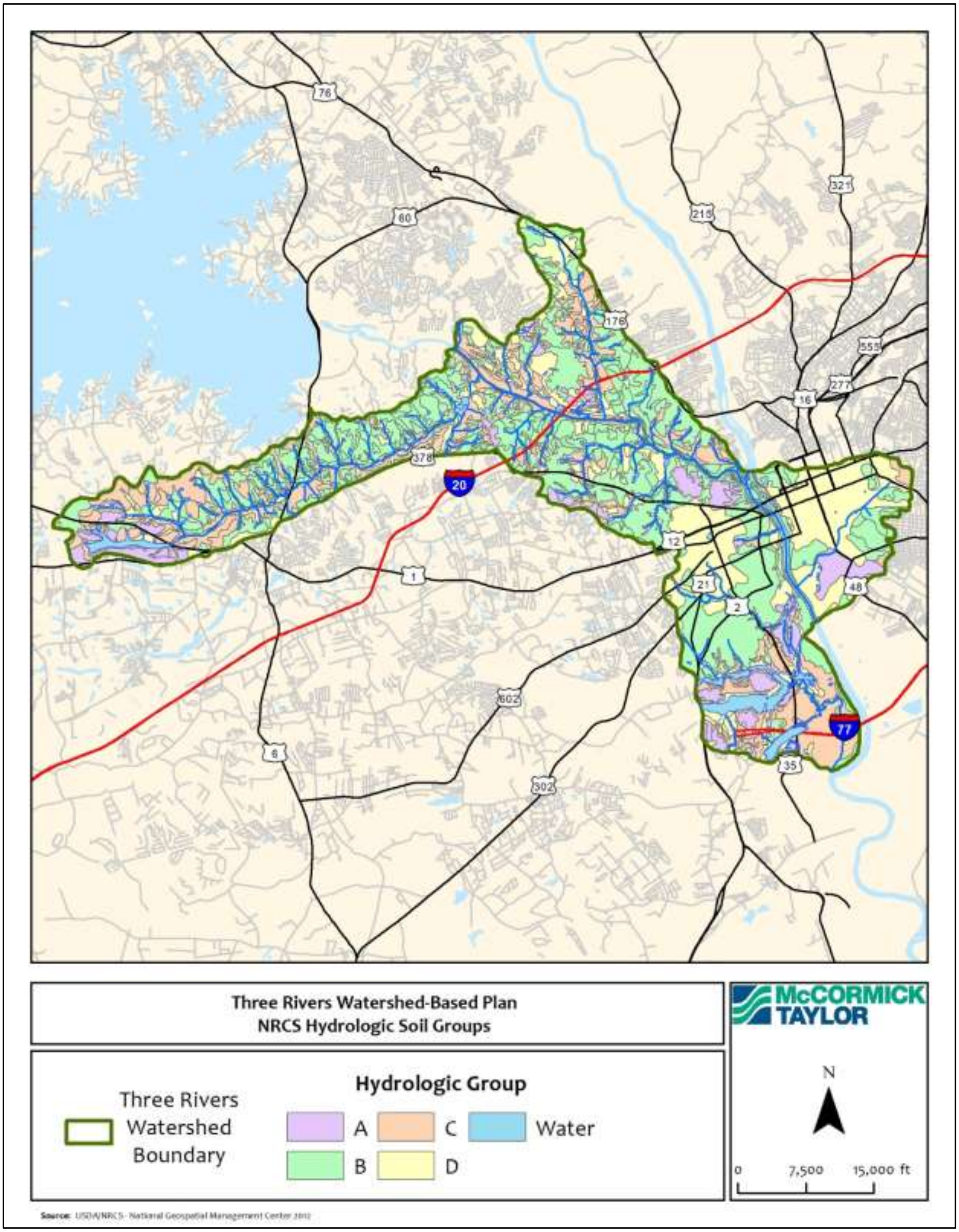


Figure 2-10: Three Rivers Watershed Hydrologic Soil Groups

Table 2-7 provides a breakdown of the soil composition and distribution throughout the 3RW Area. There are also three dual HSG classifications (A/D, B/D, and C/D). These soils are given two classifications to make a distinction between a drained and undrained condition. For the purposes of this watershed study, in order to make a conservative estimate of runoff potential, all three dual HSG groups were assumed to be undrained (HSG D). The soils within the 3RW Area are predominantly well-drained, with almost half (48%) of the soils in the watershed being classified as hydrologic group A and B. The remaining of the 3RW Area is 21% hydrologic group C and 28% hydrologic group D.

Table 2-7: Hydrologic Soil Group Classifications

Soil Series Name	HSG	Acres	Sum (Acres)	Percent
Brogdon loamy sand, 0 to 2 percent slopes	A	66	2,623	7%
Lakeland soils, undulating	A	874		
Lakeland-Urban land complex, 2 to 6 percent slopes	A	431		
Lakeland sand, 6 to 15 percent slopes	A	167		
Orangeburg loamy sand, 0 to 2 percent slopes	A	193		
Orangeburg loamy sand, 2 to 6 percent slopes	A	544		
Orangeburg loamy sand, 6 to 10 percent slopes	A	142		
Troup sand, 0 to 6 percent slopes	A	206		
Alamance very fine sandy loam, 2 to 6 percent slopes	B	6	14,556	41%
Appling sandy loam, 2 to 6 percent slopes	B	52		
Appling sandy loam, 6 to 10 percent slopes	B	22		
Cecil fine sandy loam, 2 to 6 percent slopes	B	395		
Cecil fine sandy loam, 6 to 10 percent slopes	B	284		
Cecil fine sandy loam, 10 to 15 percent slopes	B	586		
Dothan loamy sand, 0 to 2 percent slopes	B	131		
Dothan loamy sand, 2 to 6 percent slopes	B	1,850		
Dothan-Urban land complex, 0 to 6 percent slopes	B	3,649		
Faceville sandy loam, 2 to 6 percent slopes	B	21		
Fuquay-Urban land complex, 0 to 6 percent slopes	B	28		
Georgeville silt loam, 2 to 6 percent slopes	B	59		
Georgeville silt loam, 2 to 6 percent slopes	B	1,191		
Georgeville silt loam, 6 to 10 percent slopes	B	105		
Georgeville silt loam, 6 to 10 percent slopes	B	1,435		
Georgeville very fine sandy loam, 10 to 15 percent slopes	B	686		
Goldsboro sandy loam, 0 to 2 percent slopes	B	60		
Herndon silt loam, 2 to 6 percent slopes	B	423		
Herndon silt loam, 2 to 6 percent slopes	B	740		
Nanford silt loam, 6 to 10 percent slopes	B	4		
Orangeburg loamy sand, 2 to 6 percent slopes	B	35		
Orangeburg-Urban land complex, 2 to 6 percent slopes	B	1,366		
Orangeburg-Urban land complex, 6 to 15 percent slopes	B	492		
State sandy loam, 0 to 2 percent slopes	B	222		
Toccoa loam	B	664		
Udorthents	B	50		
Blaney sand, 2 to 10 percent slopes	C	752	7,536	21%
Blaney-Vaucluse complex, 10 to 25 percent slopes	C	7		

Soil Series Name	HSG	Acres	Sum (Acres)	Percent
Congaree silt loam	C	1,562		
Craven fine sandy loam, 0 to 2 percent slopes	C	730		
Dothan-Urban land complex, 0 to 6 percent slopes	C	124		
Faceville sandy loam, 2 to 6 percent slopes	C	1,031		
Fuquay loamy sand, 6 to 10 percent slopes	C	115		
Herndon silt loam, 6 to 10 percent slopes	C	77		
Herndon-Urban land complex, 2 to 6 percent slopes	C	306		
Nason silt loam, 2 to 6 percent slopes	C	63		
Nason silt loam, 6 to 15 percent slopes	C	873		
Tatum silt loam, 15 to 25 percent slopes	C	1,243		
Vaucluse loamy sand, 2 to 6 percent slopes	C	32		
Vaucluse loamy sand, 6 to 10 percent slopes	C	72		
Vaucluse loamy sand, 10 to 15 percent slopes	C	0.1		
Vaucluse loamy sand, 10 to 25 percent slopes	C	134		
Wedowee loamy sand, 2 to 6 percent slopes	C	153		
Wedowee loamy sand, 10 to 30 percent slopes	C	262		
Altavista silt loam, 0 to 2 percent slopes	D	80		
Chastain silty clay loam	D	82		
Chewacla loam, 0 to 2 percent slopes, frequently flooded	D	17		
Cecil-Urban land complex, 0 to 8 percent slopes	D	241		
Cecil-Urban land complex, 8 to 15 percent slopes	D	409		
Chenneby silty clay loam	D	234		
Chenneby soils	D	136		
Clay pit	D	144		
Coxville fine sandy loam	D	6		
Enon silt loam, 2 to 6 percent slopes	D	54		
Enoree silt loam, 0 to 2 percent slopes, frequently flooded	D	108		
Gravel pit	D	18		
Johnston soils	D	1,418	9,915	28%
Lumbee sandy loam	D	424		
Lynn Haven loamy sand	D	37		
Mecklenburg silt loam, 6 to 10 percent slopes	D	59		
Orange loam, 0 to 4 percent slopes	D	554		
Pelion loamy sand, 2 to 6 percent slopes	D	437		
Pelion loamy sand, 6 to 10 percent slopes	D	194		
Pickens slaty silt loam, 6 to 15 percent slopes	D	86		
Quarry	D	108		
Rains sandy loam	D	620		
Smithboro loam	D	22		
Troup-Urban land complex, 0 to 6 percent slopes	D	1,805		
Urban land	D	2,616		
Wahee sandy loam, 0 to 4 percent slopes	D	9		
Water	W	958	958	3%
TOTAL:		**35,587**	**35,587**	**100%**

2.5.3 Soil Erodibility

Modification of the hydrologic regime due to land disturbance in a watershed can result in elevated volumes of stormwater runoff flowing into streams, and other waterbodies. Increased volumes and the quick delivery of these runoff events can lead to scour of stream channels, incision, and streambank erosion. Hydrologic scour of the streambed can also limit key microhabitats (e.g. leaf packs, sticks, and coarse substrate) for aquatic species. While it is difficult to delineate the different sources of sediment that are being delivered to streams (e.g. streambank erosion as opposed to upland sources such as construction sites), instream sedimentation and subsequent lack of microhabitat are a result of sediment input to streams from processes that include streambank erosion. Channel widening through streambank erosion can also exacerbate low flow conditions because channels become overly wide and shallow.

The influence of streambank erosion was quantified throughout the Three Rivers Watershed using a geospatial assessment that involved an analysis of the Universal Soil Loss Equation (USLE) K-factor values within 10 feet of all existing natural stream channels. This data was obtained from the USDA NRCS web soil survey. The USLE K-factor—having units of tons/acre—is a measure of the susceptibility of a soil to particle detachment and transport by rainfall. The K-factor was calculated from direct soil loss measurements for a series of benchmark soils from study plots located across the United States. It is calculated assuming the highest potential for erosion: soil is in cultivated (plowed or disturbed), continuous fallow conditions (bare soil, no vegetation or protective cover[18]). Without field measurements, it is the best available measure of a specific soil's susceptibility to streambank erosion. Moreover, the K-factor values most likely underestimate the risks of streambank erosion because the erosive power of stream flows are greater than that of rainfall. The sub-surface K-factor was used so that bank and channel erodibility was most closely reflected by the data. The degree of soil erodibility is classified as shown in **Table 2-8** and **Figure 2-11.**

Table 2-8: 3RW Area Stream Soil Erodibility

K-factor	Length (ft)	Percent
Low Erodibility <0.24	131,219	29%
Medium Erodibility 0.24-0.32	188,098	42%
High Erodibility >0.32	132,946	29%

The average sub-surface K-factor related to streambank erosion for the entire 3RW Area ranges from 0.02 to 0.49 tons/acre, and the area weighted average is 0.27 tons/acre.

[18] Schwabb et al., 1993

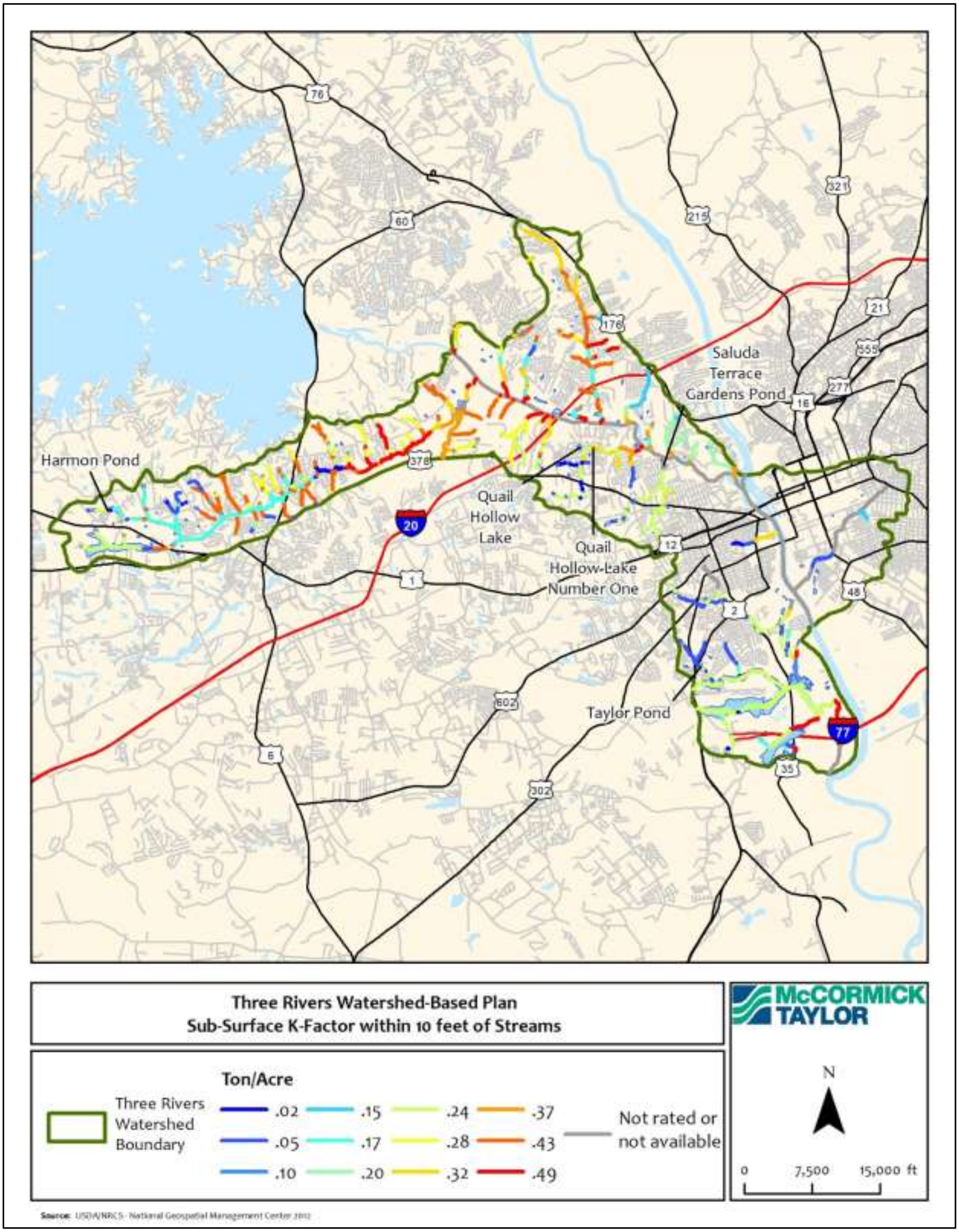


Figure 2-11: Sub-surface K-Factor within 10 feet of Streams

2.6 Endangered or Protected Species

Table 2-9 and

Table 2-10 summarize the rare, threatened, and endangered species that have ranges or habitat in the Three Rivers Watershed, according to a report (included in **Appendix C – SC Natural Heritage Program Species Screening Report**) by the SC Department of Natural Resources Heritage Trust Program (SCNHP)[19]. There are 80 tracked species that are found within the 3RW Area boundary; however, the exact locations of these species are not labeled in the SCNHP report due to the sensitive nature of this information. In total, about 1,000 species are tracked by the SCNHP and are considered rare for a variety of reasons: there is a lack of data, the species are regionally or locally endemic or rare, or they are beginning to show a downward trend in population. Each species is given a global rank by Natureserve (G-rank) and a state rank (S-rank) which indicates its relative state of imperilment across its range; these ranks are often different if a species is widespread/may be more common in other parts of North America but are considered rare or in decline in SC. The rankings are as follows:

1. Critically imperiled: typically having 5 or fewer occurrences or 1,000 or fewer individuals
2. Imperiled: typically having 6 to 20 occurrences, or 1,001 to 3,000 individuals
3. Vulnerable/rare: typically having 21 to 100 occurrences, or 3,001 to 10,000 individuals
4. Apparently secure: uncommon but not rare, but with some cause for long-term concern; typically having 101 or more occurrences, or 10,001 or more individuals
5. Secure: common, widespread, abundant, and lacking major threats or long-term concerns

The 2015 State Wildlife Action Plan (SWAP)[20] is a comprehensive plan that addresses the species that the State deemed had the greatest conservation need due to factors such as rarity, threats, lack of management funding, and lack of data.

Table 2-9: Rare, Threatened, or Endangered Plant Species

Common Name	Scientific Name	G-Rank/S-Rank	Protection Status*	SWAP Priority
Wireleaf Dropseed	*Sporobolus teretifolius*	G2/S1	ARS	High
Carolina Fluffgrass	*Tridens carolinianus*	G3G4/S1	N/A	Moderate
Yellow Moonseed	*Menispermum canadense*	G5/S2S3	N/A	N/A
Nestronia	*Nestronia umbellula*	G4/S3	N/A	N/A
Sandhills Milkvetch	*Astragalus michauxii*	G3/S2	N/A	High
Savanna Cowbane	*Oxypolis ternata*	G3/S1	N/A	High
Rocky-Shoal Spiderlily	*Hymenocallis coronaria*	G3/S2	N/A	High
Southern Water-Purslane	*Ludwigia spathulata*	G2/S2	N/A	High
Stalkless Marshcress	*Rorippa sessiflora*	G5/S2	N/A	N/A
Standing Cypress	*Ipomopsis rubra*	G4G5/S2	N/A	N/A
Southern Tickseed	*Coreopsis gladiata*	G4G5/S3	N/A	N/A
Whisk Fern	*Psilotum nudum*	G5/S1	N/A	Moderate
Winter Grapefern	*Sceptridium lunarioides*	G4/S1	N/A	Moderate

** ARS = At Risk Species, ST = State Threatened, SE = State Endangered, FE = Federally Endangered*

[19] SC Natural Heritage Program information available at https://schtportal.dnr.sc.gov/portal/apps/sites/#/natural-heritage-program
[20] State Wildlife Action Plan available at https://www.dnr.sc.gov/swap/index.html

Table 2-10: Rare, Threatened, or Endangered Animal Species

Common Name	Scientific Name	G-Rank/ S-Rank	Protection Status*	SWAP Priority
Bald Eagle	*Haliaeetus leucocephalus*	G5/S3	ST	High
Shortnose Sturgeon	*Acipenser breviostrum*	G3/S3	FE, SE	High
Baltimore Oriole	*Icterus galbula*	G5/S3S4	N/A	High
Banded Killifish	*Fundulus diaphanus*	G5/S1	N/A	Moderate
Blueback Herring	*Alosa aestivalis*	G3G4/S4S5	N/A	Highest
Carolina Lance	*Elliptio angustata*	G4/S3	N/A	Moderate
Carolina Slabshell	*Elliptio congaraea*	G3/S3	N/A	Moderate
Creeper	*Strophitus undulatus*	G5/S2	N/A	Highest
Eastern Creekshell	*Villosa delumbis*	G4/S4	N/A	Moderate
Eastern Elliptio	*Elliptio complanata*	G5/S5	N/A	Moderate
Eastern Fox Squirrel	*Sciurus niger*	G5/S3S4	N/A	Moderate
Eastern Pondhorn	*Uniomerus carolinianus*	G4/S3	N/A	N/A
Flat Bullhead	*Ameiurus platycephalus*	G4/S4	N/A	Moderate
Greenfin Shiner	*Cyprinella chloristia*	G4/S4	N/A	Moderate
Highfin Carpsucker	*Carpiodes velifer*	G4G5/S3S4	N/A	Highest
Lowland Shiner	*Pteronotropis stonei*	G5/S3S4	N/A	Moderate
Northern Lance	*Elliptio fisheriana*	G4/SNR	N/A	N/A
Notchlip Redhorse	*Moxostoma collapsum*	G5/S4	N/A	Moderate
Panhandle Pebblesnail	*Somatogyrus virginicus*	G2G3/SNR	N/A	High
Quillback	*Carpiodes Cyprinus*	G5/S4	N/A	High
Rayed Pink Fatmucket	*Lampsilis splendida*	G3/S2	N/A	High
Roanoke Flatshell	*Elliptio roanokensis*	G3/S2	N/A	High
Seagreen Darter	*Etheostoma thalassinum*	G4/S3S4	N/A	High
Striped Bass	*Morone saxatilis*	G5/S4S5	N/A	Moderate
Variable Spike	*Elliptio icterina*	G5/S4	N/A	N/A
Yellow Lampmussel	*Lampsilis cariosa*	G3G4/S2	N/A	Highest

** ARS = At Risk Species, ST = State Threatened, SE = State Endangered, FE = Federally Endangered*

2.7 Growth and Development Patterns

2.7.1 Historical Development

The Broad, Congaree, and Saluda Rivers and their tributaries are recognized as outstanding recreational, cultural, and economic resources. These Three Rivers provide critical wildlife habitat; they are a regional and statewide paddling, swimming, and fishing destination; they support several domestic and industrial wastewater discharges; they anchor an extensive regional greenway system; and they provide a critical source of drinking water for the Cities of Cayce, Columbia, and West Columbia.

The Lower Saluda River has always played an important role defining human settlement patterns[21]. The area's earliest inhabitants were primarily hunter-gatherers making use of the abundant freshwater resources and mature forest land. Early European settlers described the Dutch Fork area in terms of large trees with clear understory and rivers and streams that were clear and teeming with fish. Native Americans in the area mostly consisted of Cherokee, some Catawbas, and several smaller groups such as the Saludas and Congarees. The banks of the Saluda provided an important east-west trading path that started at the confluence and extended into the upstate where it intersected with important north-south routes. European settlers began arriving in the area in the early 1700s and by the early 1800s economic development began along the Lower Saluda with the building of the Saluda factory, Saluda canal, and the Saluda bridge. A dam and fishing sluice was also built at the present-day location of the millrace rapids, the remnants of which can still be seen today. The foundation of a large cotton mill is currently listed on the national register of historic places.

Due to local piedmont soil conditions, no large-scale farming operations ever took hold in the lower portions of the Dutch Fork area. These trends resulted in an agrarian society largely made up of small family farmers that never rivaled the level of affluence achieved by the larger plantation economy dominant in the low country and northeastern portions of the state. For much of its early modern history the area was limited in development potential because of the river systems which made transportation infrastructure difficult and expensive to build and maintain.

The completion of the Columbia Canal in 1891, however, helped to transform the city into a major industrial center for the middle part of the state. It was both a significant engineering feat and allowed for the introduction of a power plant that produced electricity for Columbia's buildings and expanding industry. Cotton mills were the most important of these industrial advancements.

One of the first major infrastructure investments in the area drastically changed the natural hydrology of the watershed forever. A permit to construct the Lake Murray Dam was issued in 1927. This massive undertaking to build a 208-foot-high earthen dam, which was the world's largest at the time, would create a 50,000-acre lake 40 miles long, 14 miles wide, with a water storage capacity of 763 billion gallons. The project would require assembling over 1,000 parcels of land and would displace 5,000 people, 6 schools, 3 churches, and 193 graveyards. Over 11 million cubic yards of earth would be moved with much of the sand, gravel, and stone coming from nearby borrow pits and quarries.

The next stage of development in the watershed consisted of rapid urban expansion. With the advent of the automobile, residential development slowly began to push out into the Dutch Fork area, but because

[21] (Moore, 1992)

there was a lack of sufficient road access across the rivers, most of this development was concentrated near the Broad River Road bridge and along Broad River Road. As better access was provided between West Columbia and Columbia across the Congaree River, early auto-oriented suburban developments were concentrated within the Double Branch watershed.

Development patterns quickly changed, however, in the post-war period as the federal government began building the interstate highway system. Once I-26 and I-126 were constructed in 1958, commercial and residential development exploded in the Dutch Fork area pulling development activity away from West Columbia and the Columbia central business district. The construction of Dutch Square mall in the late 1960s further exacerbated this major commercial and residential exodus from its historic urban core[22].

The emerging areas of the Dutch Fork, known at the time as the I-126 Growth Corridor, were marketed by developers as having the best accessibility to regional employment centers because of the brand-new freeway system which could whisk commuters in and out of downtown at a much more efficient rate[23]. As the federal and local government invested heavily in the metropolitan areas regional highway system, personal automobile ownership began to rise at an unprecedented level[24]. The total number of automobiles in Lexington County increased 76% between 1960 and 1970 and 40% in Richland County with a high percentage of residents in both counties purchasing second and third automobiles per household[25].

The impacts of urbanization have been felt within the watershed since the height of the development boom from the 1960s to 1980s[26]. To tap into these emerging markets for auto-oriented development, several new large-scale suburban residential developments were built in close proximity to key interstate interchanges[27]. By the 1990s, much of the watershed was completely built out and the development began to push out further to northwest Richland County, around the Town of Chapin, and around the Town of Lexington.

Because much of these early residential subdivisions were built prior to floodplain regulations, lot lines were extended all the way to the stream banks and houses and commercial structures were built in highly flood prone areas. Many acres of land were paved over as parking lots, roads, and driveways and stormwater infrastructure was discharged directly into local waterbodies with little to no provisions for treatment and retention. Newspaper articles from this time period highlighted many flooding events in these new developments in the Rawls and Kinley Creek sub-watersheds[28,29].

In addition to stormwater runoff, sanitary sewer service for these early developments also created considerable local water quality issues. Initially, because no centralized sewer service was available, many of these new developments were equipped with individual septic systems that were prone to failure because of inadequate design and localized soil conditions. In the 1960s developers began

[22] (Carroll, 1969)
[23] (Webb, 1975)
[24] (Wilbur Smith and Associates, Ninth Street Greystone Boulevard Extension, 1973)
[25] (Wilbur Smith and Associates, Travel Demands and Recommended Transportation Plan, 1966)
[26] (Central Midlands Regional Planning Council, Columbia Metropolitan Water Quality Management Plan: Technical Report No. 7, Public Participation, 1978)
[27] (Monk, 1982)
[28] (Goodwin, 1973)
[29] (Shealy, 1988)

marketing residential developments with their own sewer systems[30]. Whitehall, which eventually grew to include over 1,200 homes, was marketed as the first development with a sewer system outside of Columbia. These extensive gravity-based sewer collection systems drained into a series of sewage lagoons or cesspools located along the stream banks.

When the first regional water quality assessments were conducted after the passage of the Clean Water Act, many of the streams containing sewer lagoons were found to have some of the highest levels of pollution[31]. Regional sewerage plans began targeting these facilities for consolidation and many were closed out over the next several decades[32]. This trend of sewer system expansion to rural areas and consolidation of smaller sewer or septic systems continues throughout the region in the 21st Century. Multiple sewer treatment providers are connecting their sewer collection systems, such as the Town of Lexington and City of Cayce. Creating these centralized sewer treatment systems has effectively increased water quality treatment capacity, reduced points of failure, and permitted a larger focus on repairing old infrastructure and improving the level of treatment provided.

2.7.2 Demographic Characteristics

Data from the 2017 US Census American Community Survey (ACS) estimates the population of the watershed at 94,480. According to CMCOG population projections, the watershed is expected to grow to 138,322 people by the year 2050 – representing an overall population increase of 68%. Census Block level information indicate that a large portion of the 3RW Area has 51% or more of the population considered to be in low or moderate level income households (**Figure 2-12**). These types of areas should be a focus for considerations of social and environmental equity into watershed planning choices, as is discussed in further detail in the portion of **Section 6.4.2** that discusses *Equitable Adaptation*.

Since much of the Lower Saluda watershed was built out by the year 2000, population trends are expected to remain relatively stable with incremental growth occurring in limited areas containing greenfield development and greyfield redevelopment opportunities. The 2010 population of the watershed was 66,351 people and the projected 2020 population is 71,181 people, a 7% increase (4,830 people). The highest population densities are found in the Rawls, Kinley, Stoop, and Double Branch watersheds. Rawls, Kinley, and Double Branch also have the highest proportion of owners to renters and Stoops Creek has the highest proportion of renters of all the watersheds. Owner occupancy is an important statistic to note for outreach and education initiatives. Homeownership may influence how much of a vested interest residents have in local community issues (such as water quality planning), and have more flexibility in enacting changes in their properties that could impact water quality.

[30] (Central Midlands Regional Planning Council, Consolidated inventory of regional natural resources and infrastructure, 1996)
[31] (Central Midlands Regional Planning Council, Columbia Metropolitan Water Quality Management Plan: Plan Summary, 1979)
[32] (Fifteen wastewater facilities closed, 1986)

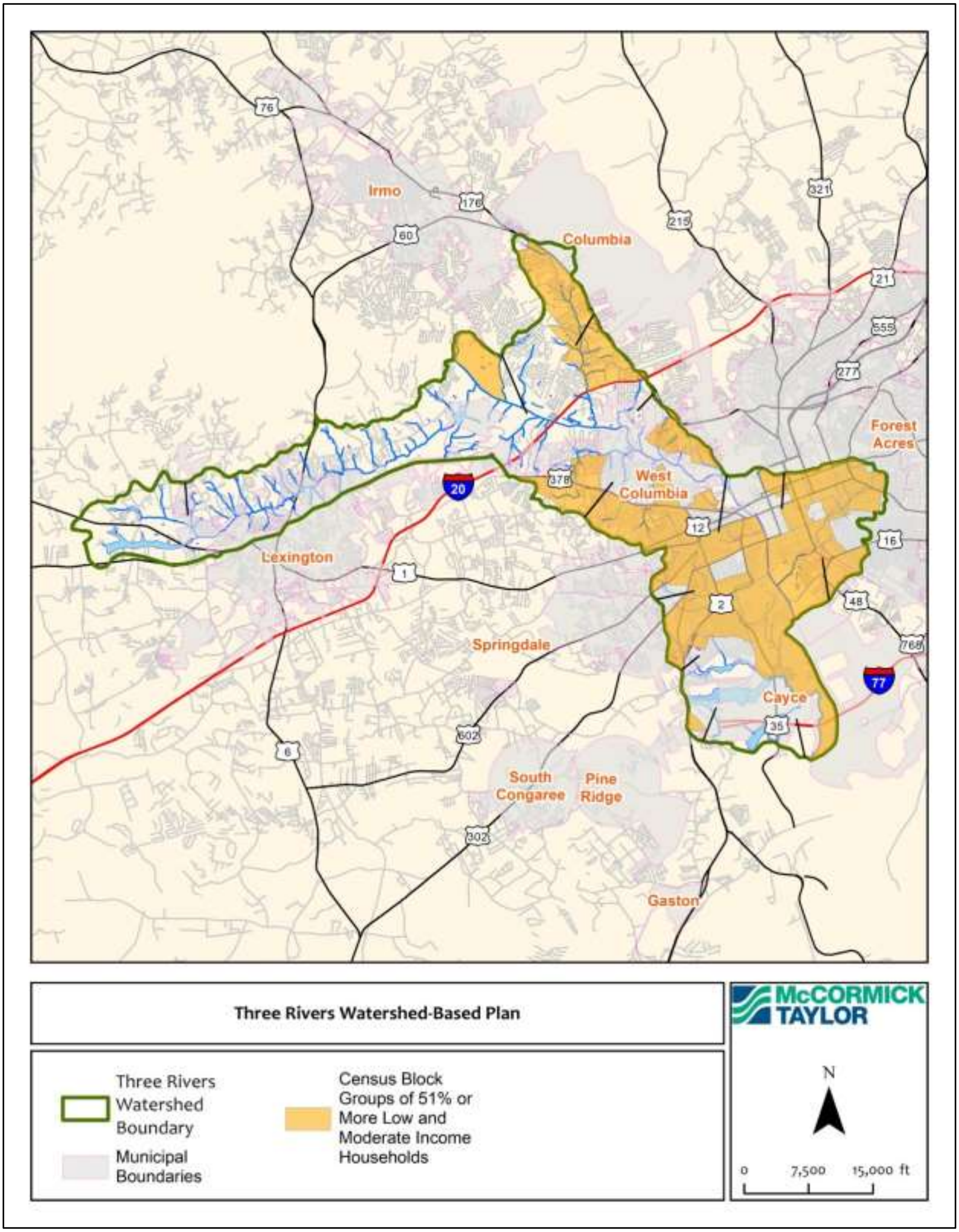


Figure 2-12: Three Rivers Watershed Demographic Information

2.7.3 Cultural Resources

Cultural resources include any natural or manmade sites, events, activities, or historic structures and can have a general social significance in the community. Cultural resources within and around the 3RW Area enhance community interaction, provide beneficial social outlets for the community, and can support water quality education activities. Locations and activities include:

- Riverbanks Zoo & Garden
- Three Rivers Greenway
- The Vista along the Congaree River
- South Carolina State House
- Downtowns of Columbia and West Columbia
- EdVenture Children's Museum
- Riverwalks in Cayce, Columbia, West Columbia
- Farmers Markets in Columbia, Cayce, and surrounding jurisdictions

Ethnic festivals, holiday celebrations, and other regular or one-time events not listed above provide more opportunities to engage the public in water quality planning and education. Being aware of these resources is critical from a project development standpoint, as many regulations and grant applications have Environmental Planning and Historic Preservation (EHP) requirements. For example, it is a condition of the FEMA Building Resilient Infrastructure and Communities (BRIC) funding applications to assess potential impacts of a project on physical, cultural (historic and archaeological), and social resources.

2.7.4 Land Cover and Land Use

Land cover indicates the physical land type, such as forest or open water. Land use describes how people are managing the landscape, such as for development or conservation. Different types of land cover can be managed or used differently, such as rural vs. residential areas. For the purposes of the 3RWBP, the project team evaluated both current and future land use.

Determination of existing land cover and land use was based on the most recent National Land Cover Dataset (NLCD), published in 2016[33]. Land cover classifications were combined with zoning data provided by the CMCOG. This data was organized into 10 different categories that were used as inputs into the Watershed Treatment Model (see **Figure 2-13)** and are summarized for the subwatersheds in **Figure 2-14.** Some land cover classifications were combined to fit a particular land use category in the WTM. Forest areas included forest, shrub/scrub, and wetlands NLCD land covers. Rural areas included barren, dwarf scrub, herbaceous, and planted/cultivated NLCD land covers. Roadway areas were estimated by creating a 10-ft buffer around road centerlines.

The largest land use categories in the 3RW Area current conditions are medium-density residential (6,405 acres, 18%), forest (6,087 acres, 17%), and low-density residential (4,504 acres, 13%). Rural (1,016 acres, 3%) and open water (652 acres, 2%) were the smallest land use categories in the 3RW Area.

[33] https://www.mrlc.gov/national-land-cover-database-nlcd-2016

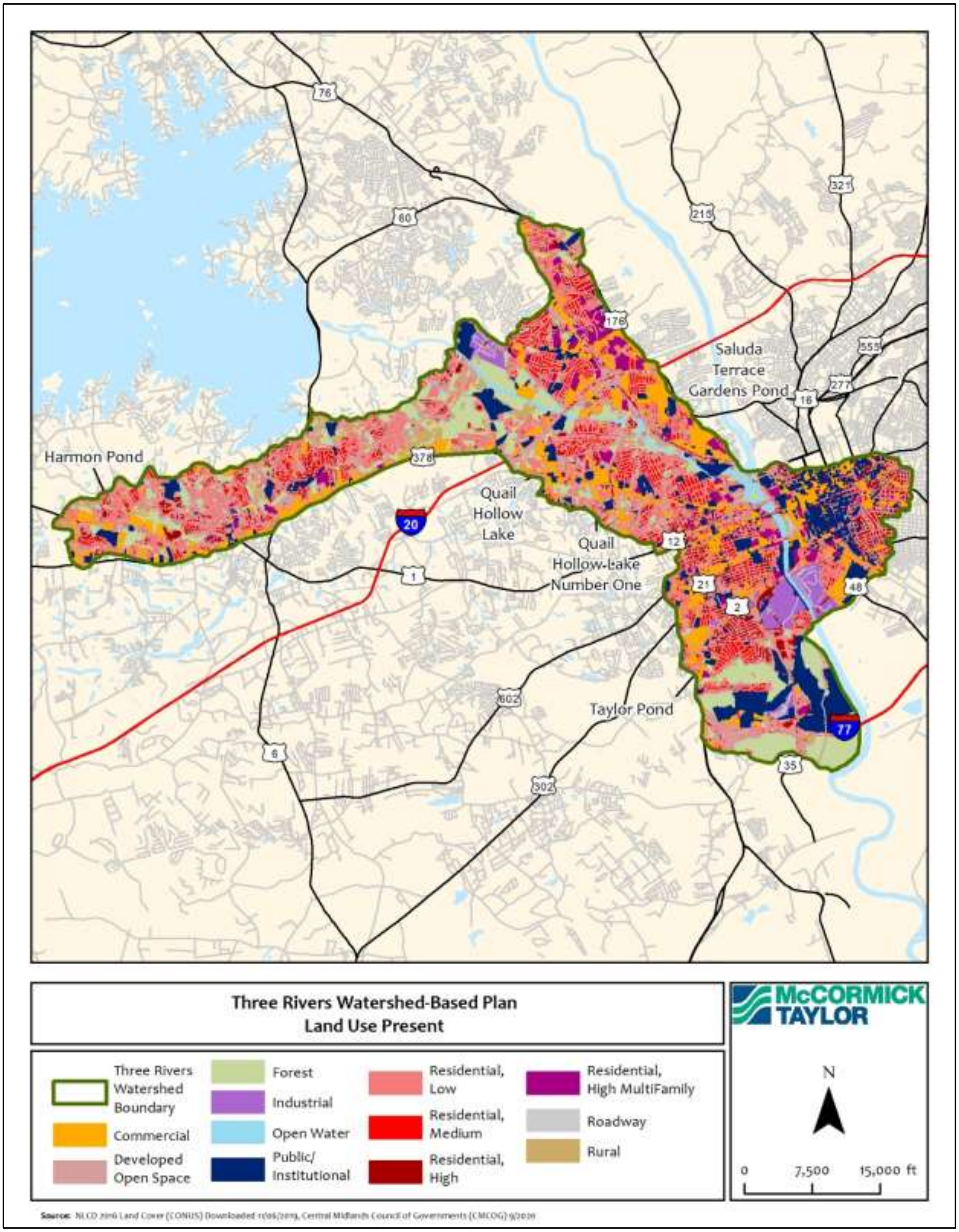


Figure 2-13: Existing Land Use Condition in Three Rivers Watershed

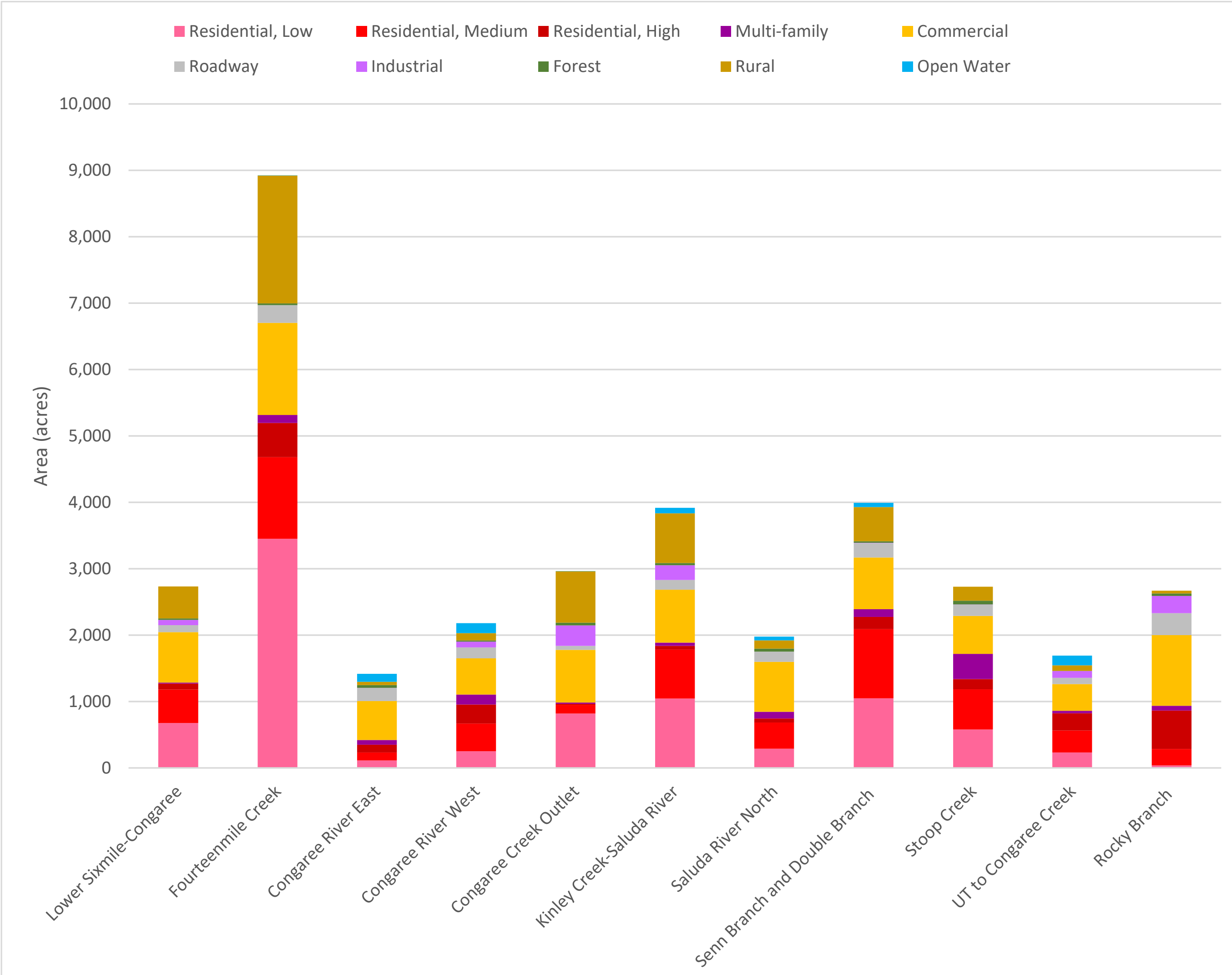


Figure 2-14: Summary of Current Land Uses by Subwatershed in the Three Rivers Watershed

Determination of future land cover and land use was based on the future land use dataset developed as part of the US Geological Survey LandCarbon project[34]. This dataset includes scenarios of future land cover and land use through 2100 that were modeled for four IPCC Special Report on Emissions Scenarios (SRES). For the 3RWBP, the Project Team selected the USGS year 2050, A1B scenario/RCP 8.5 (higher emissions scenario). The USGS land use categories have 11 different undeveloped categories and one "developed" category (that would encompass seven of the specific WTM categories). **Figure 2-15** shows the predictions for developed and undeveloped land in the 3RW Area, and **Table 2-11** compares the current and future conditions for developed and undeveloped lands; not surprising, the estimates show almost a 20% increase in developed areas for future conditions (which also means about a 20% decrease in undeveloped land). In order to estimate the area proportions that would correspond to the 10 different WTM land use input categories in the future land use data, the consultant team followed a process that is described in **Appendix E – WTM Model Methodology** in the "Future Scenarios in WTM's" section.

Table 2-11: Comparison of Existing and Future Developed Land Use in the 3RW Area

Land Use	Existing Condition (2021)	Future Condition (2050)
Undeveloped	30.5%	13.8%
Developed	69.5%	86.2%

[34] Coterminous United States Land Cover Projections – 1992 to 2100 available at https://www.sciencebase.gov/catalog/item/5b96c2f9e4b0702d0e826f6d

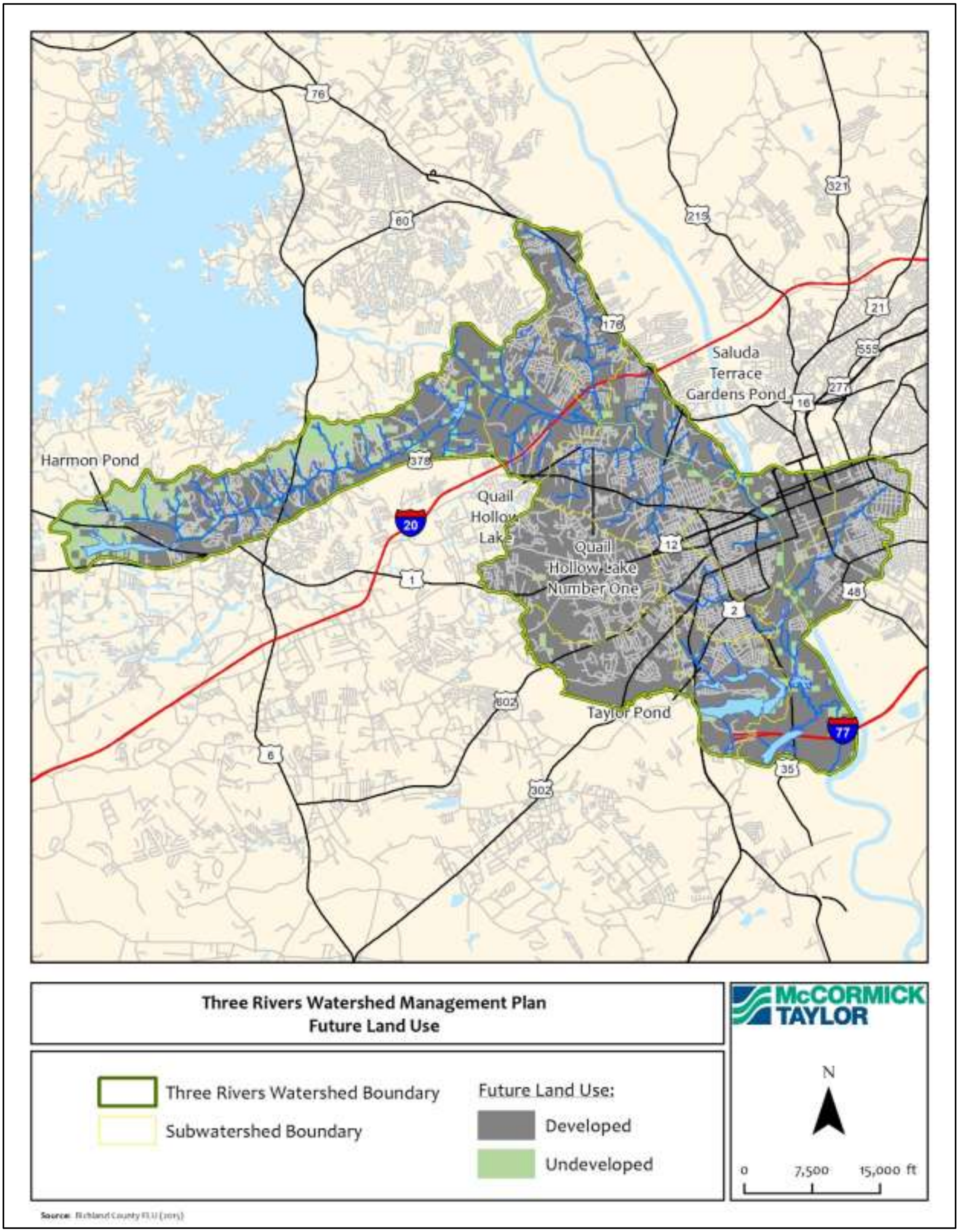


Figure 2-15: Future Estimates of Developed Land Use Types in Three Rivers Watershed

2.7.5 Imperviousness

Impervious surfaces are hard surfaces that do not allow water to infiltrate slowly into the ground as it would in pervious landscapes, such as a forest, meadow, or open field. Examples of impervious surfaces include roadways, parking lots, driveways, sidewalks, and rooftops. These surfaces generate higher volumes of stormwater runoff, typically concentrated into drainage infrastructure (such as gutters, pipes, and ditches), which in turn accelerate flow rates and direct stormwater to a receiving waterbody. This accelerated, concentrated runoff often causes stream erosion and habitat degradation. Runoff from impervious surfaces picks up and washes off pollutants (such as fecal coliform bacteria, oil, metals, sediment, etc.) and is highly contaminated relative to the minimal amounts of runoff generated from pervious areas. In general, undeveloped watersheds with small amounts of impervious cover are more likely to have better water quality in local streams than urbanized watersheds with greater amounts of impervious cover. Impervious cover is a primary factor when determining pollutant characteristics and loadings in stormwater runoff.

The degree of imperviousness in a watershed affects aquatic life. There is a strong relationship between watershed impervious cover and the decline of a suite of stream indicators (such as runoff volume, turbidity, and dissolved oxygen concentrations). As imperviousness increases the potential stream quality decreases (*Figure* **2**-**16**), as referenced in research indicating that stream quality begins to decline at or around 10% imperviousness[35]. However, there is considerable variability in the response of stream indicators to impervious cover observed from 5-20% imperviousness due to historical effects, watershed management, riparian width and vegetative protection, co-occurrence of stressors, and natural biological variation. Due to this variability, one cannot conclude that streams flowing through low impervious cover will automatically have good habitat conditions and high-quality aquatic life.

The Three Rivers Watershed contains impervious cover in the residential, industrial, and commercial areas, as illustrated in **Figure 2-17.** Approximately 81% of the watershed (28,848 acres) consists of land uses associated with impervious surfaces – 41% of the entire 3RW Area is residential land use, 13% is commercial land use, 11% is public/institutional and 5% are roads. Even in these developed areas, impervious surfaces do not cover every square foot of land area. The amount of actual impervious surface cover is less than the total area, and not every land use category includes the same proportions of actual impervious cover. For example, as a percentage, low density residential use includes less impervious cover than commercial or institutional development. The 2013 WTM documentation provides estimated ranges of impervious area.

Table 2-12 estimates these ranges for the 10 different land uses with associated impervious cover (forest and open water were excluded). The amount of impervious surfaces in the watershed is estimated to be 10,127 acres (28%) of the entire 3RW Area. At this level of imperviousness in a watershed, the stream health is predicted to be non-supporting, as indicated from *Figure* **2**-**16**.

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[35] Schueler, T., L. Fraley-McNeal, and K. Cappiella. 2009. Is Impervious Cover Still Important? Review of Recent Research. Journal of Hydrologic Engineering. 14(4). https://doi.org/10.1061/(ASCE)1084-0699(2009)14:4(309)

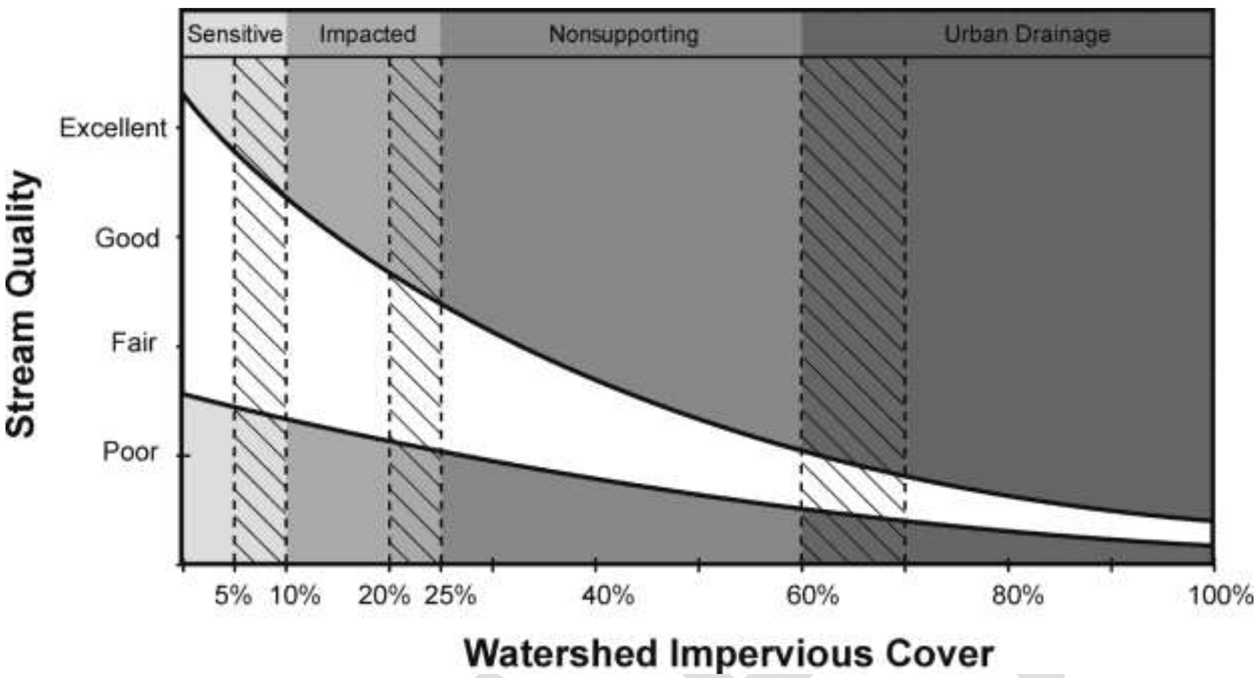

Figure 2-16: Stream Water Quality as a result of Watershed Impervious Cover[36]

Table 2-12: Three Rivers Watershed Impervious Area Estimate

Land Cover/Land Use	Land Use Area (acre)	Mean Impervious Cover %	Impervious Area (acre)
Rural	1,016	2	20
Residential Development			
Low Intensity	4,504	14	631
Medium Intensity	6,405	21	1,345
High Intensity	2,431	33	802
Multifamily	1,144	44	504
Developed Open Space	1,917	9	173
Public/Institutional	3,967	34	1,349
Commercial	4,495	72	3,237
Industrial	1,144	53	606
Roadway	1,827	80	1,462
Total	28,849		10,127

[36] (Schueler, Fraley-McNeal, & Cappiella, 2009)

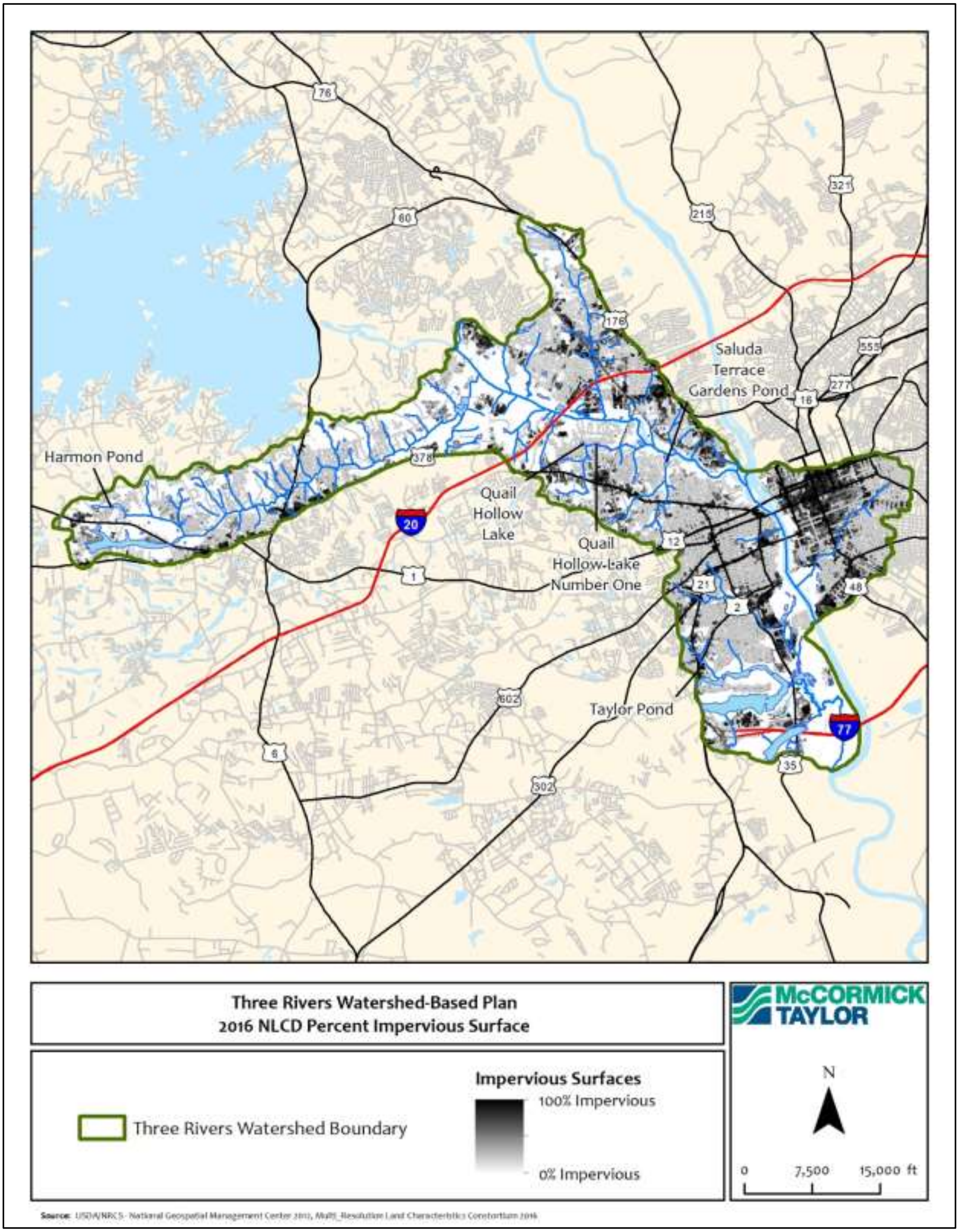

Figure 2-17: Percent Imperviousness of Land Cover in Three Rivers Watershed

2.8 Political Jurisdictions/Relevant Authorities

2.8.1 Federal, State, Local

The 3RW Area includes portions of the highly urbanized Columbia Metro Area. This includes the state capital, the administration buildings of multiple state agencies, and various local government facilities. As such, it is a nexus of federal, state, and local government organizations and programs.

Table 2-13 includes government agencies or local government jurisdictions with responsibility over water quality in the 3RW Area which have participated in the development of this Plan. This includes stormwater effluent through MS4 programs (detailed in **Section 2.9**) and/or sewer treatment (detailed in **Section 2.11**). State government agencies such as SCDHEC and SCDOT administer programs and projects that manage nonpoint source pollution, which is why they are included as stakeholders in this systemic view of water quality and bacterial contamination management. In the case of SCDOT, the extensive roadway network they own and manage contributes to the total impervious surface in the region, which in turn impacts nonpoint source bacterial contamination transport and deposition in the 3RW Area.

Table 2-13: Three Rivers Watershed Jurisdictional Authorities

Organization
SC Department of Transportation
SC Department of Health and Environmental Control
Richland County
City of Cayce
City of Columbia
City of West Columbia
Town of Lexington
Town of Irmo

2.8.2 Special Purpose Districts

The 3RW Area includes one countywide consortium and a special purpose district (shown in **Table 2-14**). The Lexington Countywide Stormwater Consortium (LCSC) is a collaborative, water quality education program that streamlines collaboration by the MS4s in Lexington County. It includes stakeholders in the 3RWBP and jurisdictions that may have upstream impacts on the 3RW Area, such as: Lexington County, Town of Lexington, City of Cayce, City of West Columbia, Town of Irmo, Town of Pine Ridge, and Town of South Congaree. Although, geographically, the Towns of Pine Ridge and South Congaree do not manage a significant area within the watershed boundary, they were engaged through the Lexington Countywide Stormwater Consortium as potential upstream influence to the 3RW Area. This framework helps coordinate countywide MS4 water quality education activities for participating jurisdictions, and facilitates regional water quality monitoring, analysis and remediation activities. The water quality education programs and activities of LCSC staff and its member organizations significantly contributes to regional collaboration where it concerns stormwater and water quality management.

The Irmo-Chapin Recreation Commission (ICRC) was formed in 1969 to serve the Lexington County portion of Lexington-Richland School District 5. Its mission to "*enhance the quality of life for all citizens of the district through the development of recreation programs that promote a lifestyle of wellness, physical* *activities and cultural experiences for all ages*" is fulfilled by ICRC through the five parks it manages in the vicinity of the Lower Saluda River and Lake Murray. The ICRC offers dozens of children and adult recreational and education programs. Saluda Shoals Park, with access to the Lower Saluda River, runs outdoor recreation rentals and offers environmental education programs for all ages through its Environmental Center. The impact of these programs extends beyond the ICRC special purpose district, attracting residents and tourists from throughout the region.

Table 2-14: Three Rivers Watershed Special Purpose Districts

Organization
Lexington Countywide Stormwater Consortium
Irmo-Chapin Recreation Commission

2.8.3 Other

The Central Midlands Council of Governments (CMCOG), formed in 1969, provides planning and technical support services to the four counties in the Midlands region of South Carolina (i.e. Fairfield, Lexington, Newberry, and Richland Counties). It advocates on behalf of regional government collaboration by providing a regional forum to discuss issues between its 15 member governments. The CMCOG stewards various regional planning activities in coordination with state agencies, such as the Hazard Mitigation Planning process with the South Carolina Emergency Management Department (SCEMD) and the 208 Water Quality Management Planning process with SCDHEC.

Table 2-15: Three Rivers Watershed Other Relevant Authorities

Organization
Central Midlands Council of Governments

2.9 Surface Water Withdrawals/Drinking Water Intakes

Four publicly operated water treatment and distribution systems are in the 3RW Area, as described below.

2.9.1 Columbia Water

Columbia Water, the water utility department of City of Columbia, has the largest customer base in the 3RW Area with approximately 375,000 customers. It has two source water locations, one on the Broad River through a diversion canal, and the other on Lake Murray. The Broad River canal was built in 1906, has undergone six major expansion phases. It has a capacity of 85 Million Gallons per Day (MGD) and serves the area east of the Broad River and south of I-20. The Lake Murray water plant began construction in 1980 and has a capacity of 75 MGD. It serves the area west of the Broad River and north of I-20. Columbia Water has one major intake location in the Congaree River. **Figure 2-18** shows the drinking water treatment process used by Columbia Water.

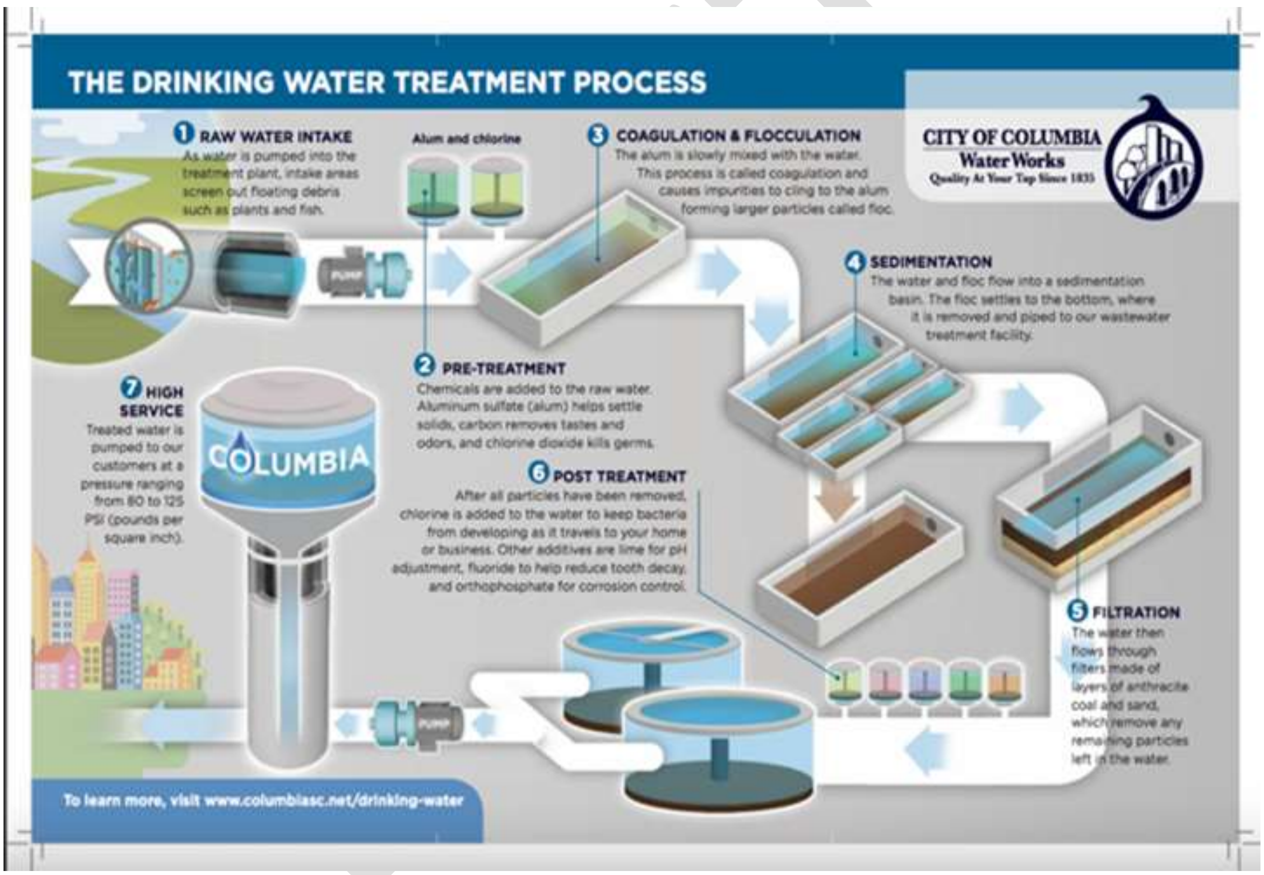

Figure 2-18: City of Columbia water treatment process diagram[37]

2.9.2 Cayce Water

The City of Cayce water utility serves 7,100 customers, with the source water located on the Congaree River. Their water treatment facility was upgraded in 2000 and currently produces up to 9.6 MGD. The water service area is concentrated within the City of Cayce but reaches nearby areas such as the Columbia International Airport, the Lexington and Saxe Gotha industrial parks, and portions of Lexington County.

[37] Columbia Water

2.9.3 West Columbia

The City of West Columbia provides water services to 40,000 residences and businesses. It has two source water locations, one on the Saluda River, and another on Lake Murray. The Saluda River facility provides up to 6 MGD while the Lake Murray facility provides up to 22.5 MGD. These facilities provide water to the City of West Columbia itself and portions of Lexington County.

2.9.4 Town of Lexington

The Town of Lexington provides water service through an agreement with the City of West of Columbia. The Saluda River facility of West Columbia provides up to 5.5 MGD to a customer base of around 9,400 customers. The potable water is treated according to the City of West Columbia water treatment process (see **Section 2.11.3 City of West Columbia**).

2.10 MS4s and Stormwater

2.10.1 Phase I and II Stormwater Permits

Urban areas designated by EPA and SCDHEC as significant dischargers of stormwater runoff can represent a significant source of sediment, nutrients, bacteria, metals, other dissolved substances, and erosive stream flows. Stormwater is addressed generally under **Section 4.2**, but it is also important to consider where significant sources of stormwater are identified by the federal and state governments.

SCDHEC Bureau of Water requires jurisdictions with significant urban area to develop municipal stormwater management programs as part of EPA's Phase I and II stormwater requirements. The jurisdictions are termed Municipal Separate Storm Sewer Systems (MS4s). As shown in **Figure 2-19**, much of the 3RW Area is included in an urbanized MS4 area. Within the watershed there is one large MS4 (SC Department of Motor Vehicles), two medium MS4s (City of Columbia and Richland County), and five small MS4s (Cayce, Irmo, Lexington, Lexington County, and West Columbia).

Large and medium MS4s must prepare and submit a permit application to address each of the following elements:

- Structural control maintenance
- Roadway runoff management
- Municipal-owned operations such as landfills, wastewater treatment plants, etc.
- Hazardous waste treatment, storage, or disposal sites
- Regulation of sites classified as associated with industrial activity
- Public education and outreach
- Areas of significant development or redevelopment
- Flood control related to water quality issues
- Application of pesticides, herbicides, and fertilizers
- Illicit discharge detection and elimination
- Construction and post-construction site runoff control

Small MS4s must develop a program to cover each of the following minimum control measures:

- Public education and outreach
- Public participation/involvement
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction site runoff control
- Pollution prevention/good housekeeping

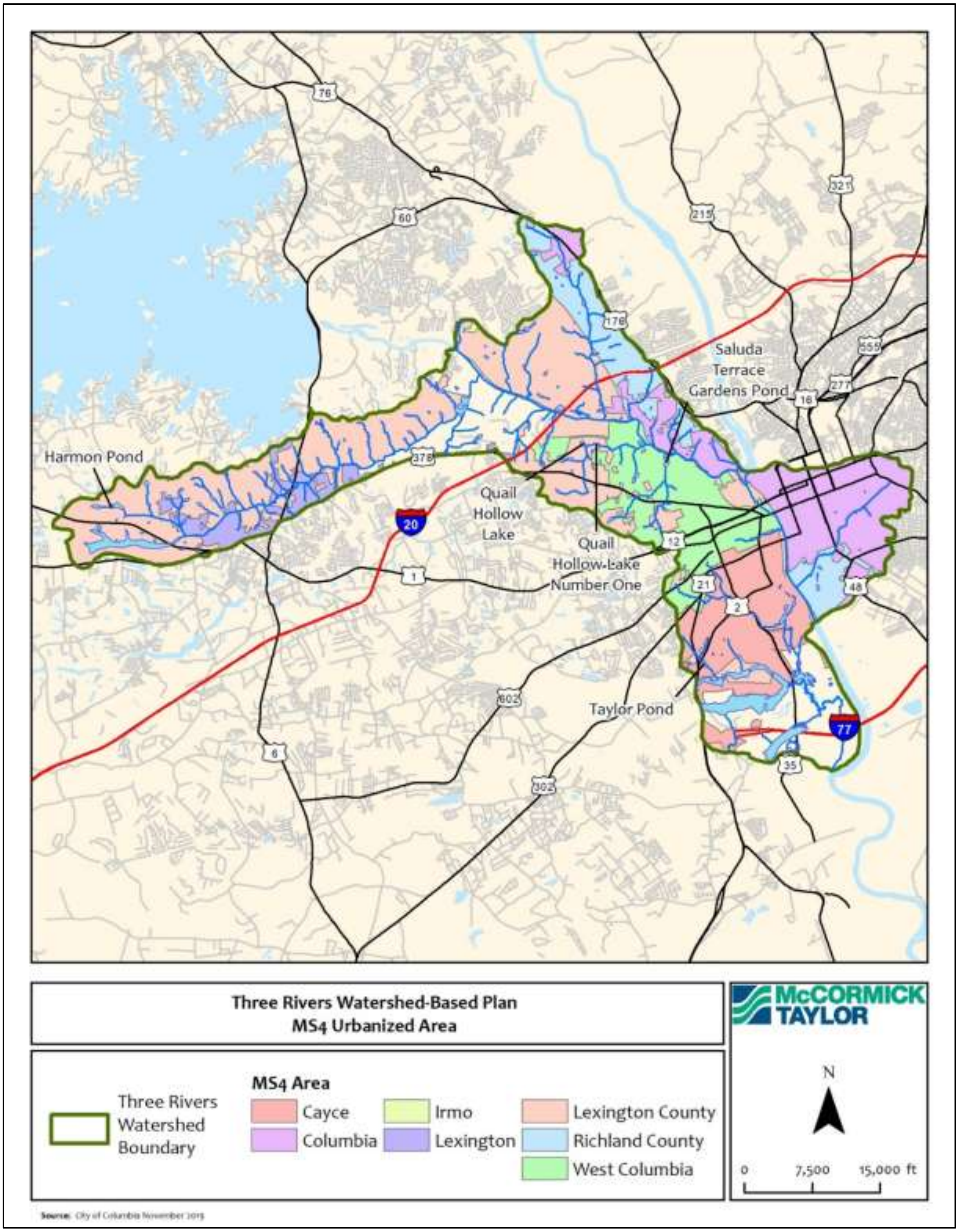

Figure 2-19: Municipal Separate Stormwater Systems in the Three Rivers Watershed

2.11 Sanitary Sewer Providers

Figure 2-20 illustrates the service areas of sanitary sewer providers described in the following sections.

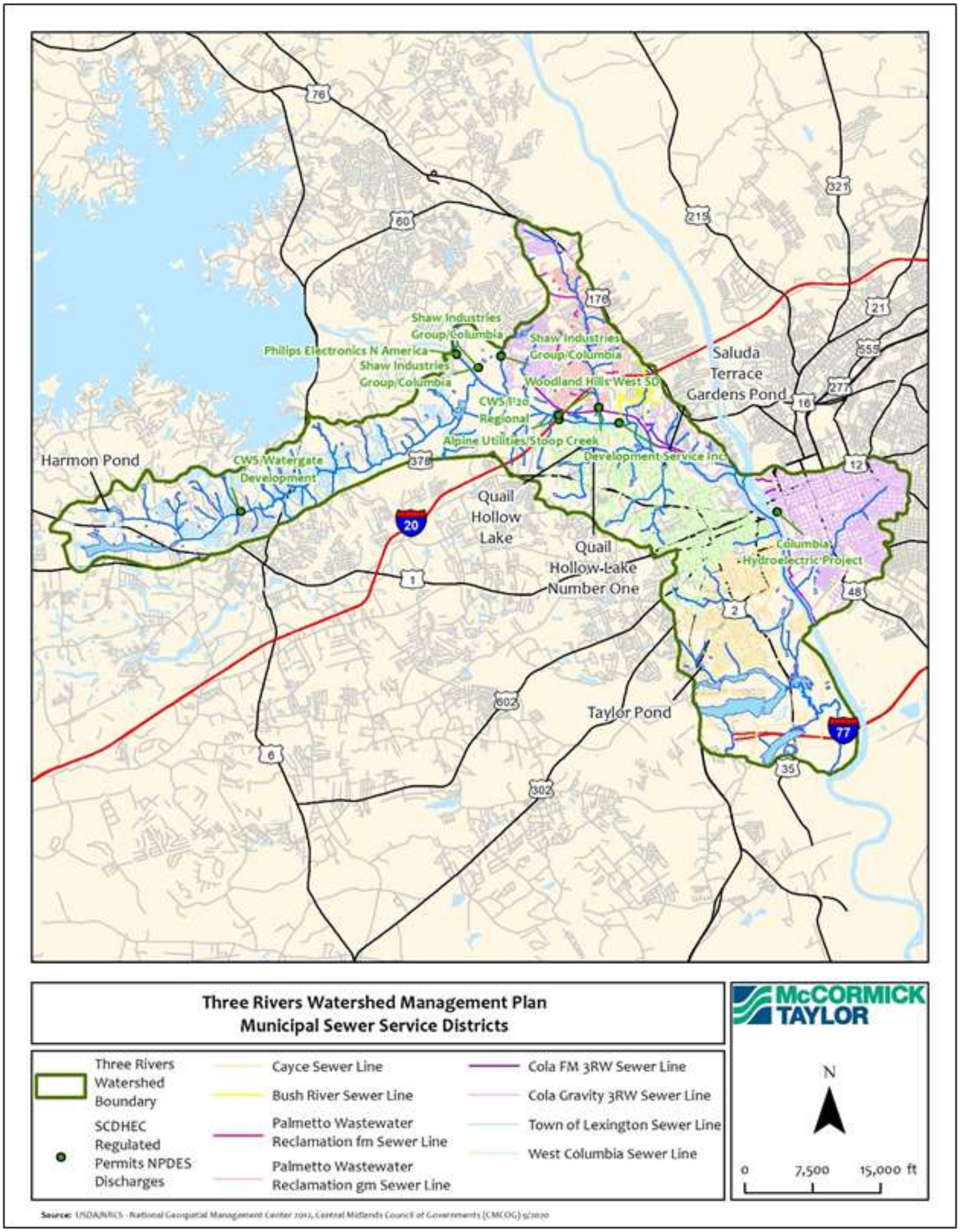

Figure 2-20: Municipal Sewer Service Districts

2.11.1 City of Columbia

Columbia Water manages the City of Columbia Metropolitan Wastewater Treatment Plant, a facility with the capacity to treat 60 MGD of wastewater. Columbia Water serves more than 60,000 residential, commercial, and industrial connections in Lexington and Richland Counties, averaging 35 MGD of treated sewage. Treatment at the plant consists of flow equalization and metering, screening and grit removal, primary and secondary clarification, diffused air flotation, solids handling and dewatering, anaerobic digestion, incineration, activated sludge aeration, return and waste activated sludge operations, chlorination and dechlorination (as shown in **Figure 2-21**).

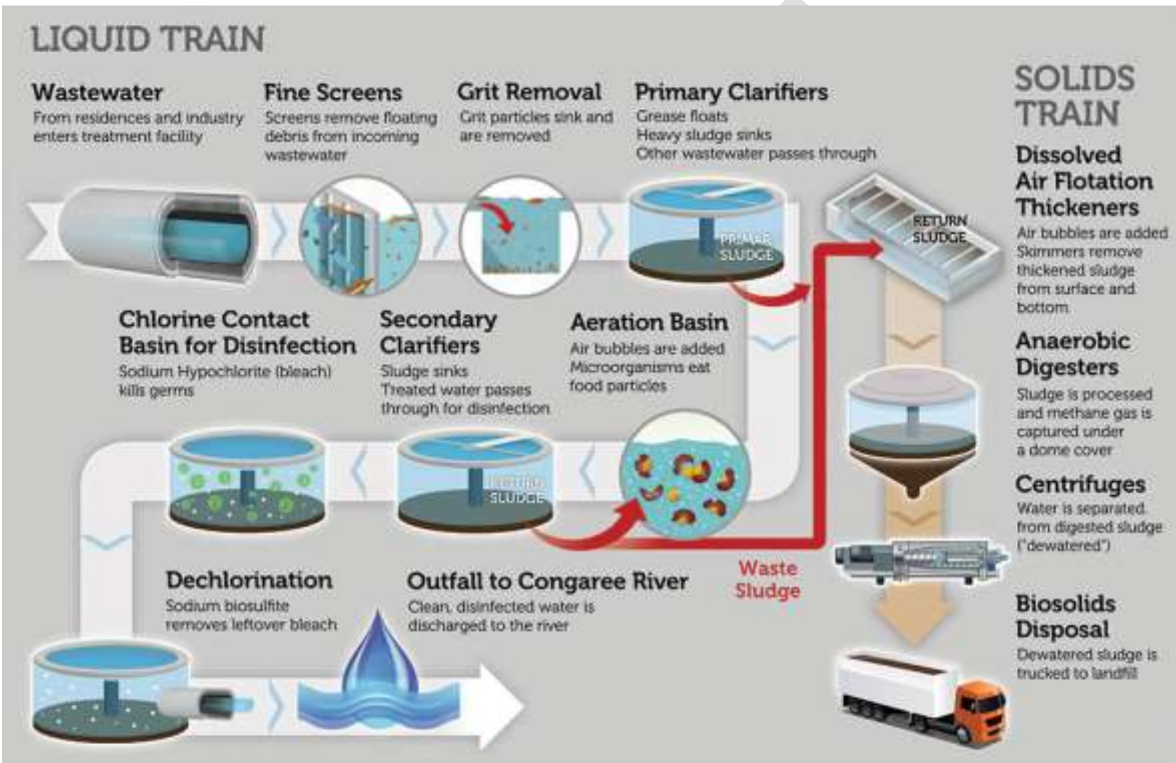

Figure 2-21: WWTP process diagram (Source: Columbia Water)

2.11.2 City of Cayce

The new City of Cayce Regional Wastewater Treatment Plant began operation in October 2012, replacing an earlier plant built in the early 1970s. The facility has a 25 MGD capacity and can treat up to 80,000 homes and businesses, or the equivalent of a half million people. Since its inception, the Regional Wastewater Treatment Plant has consolidated satellite sewer systems and has expanded their collection system to treat wastewater for more of the region. This includes portions of Lexington County, the City of Cayce itself, the Town of Lexington, the Joint Municipal Water & Sewer Commission, and portions of adjacent counties. The City of Cayce also manages a separate 300,000 gallon storage tank for restaurant grease and septage, respectively, and are permitted for 100,000 gallons per day. The facility is located behind the City of Cayce Regional Wastewater Treatment Plant.

The Regional Wastewater Treatment Facility uses an advanced biological treatment process and can remove pollutants such as nitrogen and phosphorus from treated wastewater, making it one of the most advanced treatment facilities in the Midlands region. Membrane digestion represents an innovative and sustainable approach to solids handling by reducing the use of polymers; producing reuse-quality water and lowering the amount of nutrients released into our waterways. An automatic control system helps plant staff monitor the treatment process and equipment, and quickly notifies staff when problems arise. The facility not only provides long term economic benefits to Lexington County by ensuring the continued availability of wastewater treatment capacity, but also protect the waters of the region from the by-products of this growth.

2.11.3 City of West Columbia

The City of West Columbia treats its potable water through a multi-stage process which removes sediment, bacteria, and other contaminants. **Figure 2-22** shows the water treatment process utilized in the Saluda and Lake Murray water treatment plants in the Saluda River and Lake Murray. The water quality monitoring program used in these plants also tracts other pollutants not regulated by the EPA/SCDHEC, and the city regularly shares this information with the public. The City of West Columbia also manages a sewer collection system for their residents and businesses. This wastewater is eventually treated in the City of Columbia Metropolitan Wastewater Treatment Plant, where West Columbia has a reserve capacity to treat 3.27 MGD.

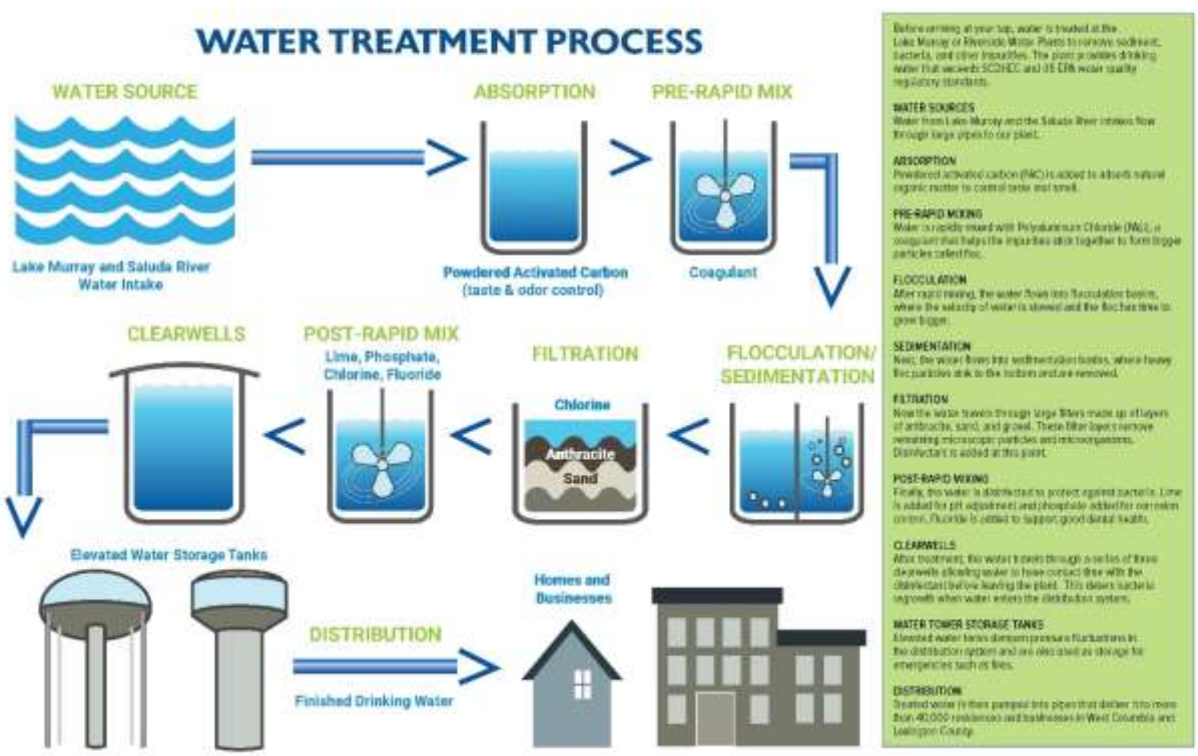

Figure 2-22: City of West Columbia water treatment process diagram (Source: City of West Columbia, 2019)

2.11.4 Town of Lexington

The Town of Lexington manages and maintains more than 300 miles of sewer lines within the Town and throughout Lexington County. The Town has a customer base of around 18,500 residential and commercial customers, the majority outside of the Town boundaries. Through an agreement with City of

Cayce, Town of Lexington has the capacity to treat up to 12.49 MGD of wastewater through the Cayce Regional Wastewater Treatment Plant.

2.11.5 Satellite Sewer Systems

Satellite sewer systems are sewer collection systems that are connected to a different sewer system and depend on that separate system for final wastewater treatment. Historically, satellite sewer systems were established before wastewater facility construction standards were updated, and as such they are not typically covered under the NPDES or State Land Application Permit process. Instead, they are covered under a general operation system that requires the owners to maintain the collection system, report any Sanitary Sewer Overflows (SSOs), and track ownership transfers of the system. Examples of satellite sewer systems include apartment complexes, mobile home parks, and pre-treatment facilities of some industries.

The permitting and maintenance structure for satellite sewer systems has the potential to negatively impact the larger sewer systems that they are connected to, which in turn has multiple implications and impacts on regional water quality, such as:

1. The satellite sewer system owner has the final responsibility to maintain the sewer collection system. While the owner is required to have the equipment and ability to maintain the collection system, they may not have the capability to consistently track and repair any issues. Any issues caused by an old satellite sewer collection system (e.g. infiltration, sedimentation) can be reflected downstream in the larger collection system. This can lead to worsening environmental conditions as the larger sewer system is not able to respond to issues that impact its system even if they are aware of them. The collection system that provides the wastewater treatment also must account for the additional cost of these impacts while the issue is being addressed.
2. Similarly, the satellite sewer system owner is responsible for tracking and reporting any SSOs that occur in their collection system. How quickly SSOs are reported is highly dependent on the capability of the owner to maintain their sewer collection system. Events may go unreported for extended periods of time, causing significant environmental impacts while they are not being addressed.

2.12 Recreational Uses

Most rivers and tributaries of the 3RW Area are classified as *Freshwater* under SCDHEC water classifications and standards. This type of classification allows for use as a drinking water supply (after suitable treatment), and primary and secondary contact recreation. The kind of recreational activities allowable in *Freshwaters* include swimming, diving, fishing, boating, waterskiing, and other water sports. The stem of the Saluda River that flows from the Lake Murray dam to its intersection with the Broad River, where it converges and turns into the Congaree River, is classified as *Trout Put, Grow, and Take* (TPGT) waters. In addition to the recreational activities permitted in *Freshwaters*, the colder temperature of the Lake Murray dam outflow is suitable for the growth of stocked trout populations with a balanced community of indigenous flora and fauna.

Access to the riverfront, availability of facilities, and a connected network of trails and boardwalks has been in development for the 3RW Area for almost three decades. The River Alliance, a non-profit public-private partnership, has led a coalition of organizations and local government jurisdictions to develop the riverfront, conserve the natural ecosystem, and increase the recreational opportunities available around the confluence of the Three Rivers Watershed. The Three Rivers Greenway, an interconnected network of paved trails, comprises more than 12 miles of riverfront in the Broad, Saluda, and Congaree Rivers. Plans are in place to develop a trail on the north side of the Lower Saluda River, extending the trail network all the way to the Lake Murray Dam.

These conditions provide the residents within and around the 3RW Area with a variety of opportunities to engage with the watershed in a recreational capacity. River outfitters, such as Palmetto Outdoors, coordinate kayak and tubing trips in the Broad and Saluda Rivers. Organizations such as Palmetto Paddlers and Saluda River Trout Unlimited encourage watershed stewardship and conservation through their paddling and fishing events, respectively. Finally, some organizations combine recreation with education and advocacy, such as the Irmo-Chapin Recreation Commission, Congaree Riverkeeper, and the Gills Creek Watershed Association. This includes posting watershed educational signage, tours that teach watershed stewardship for all ages, and litter clean-up events.

2.13 Stakeholder Input

2.13.1 2019 Clemson Extension's Carolina Clear Survey

"South Carolina Residents' Awareness of and Attitudes Toward Stormwater Pollution" surveyed 2,004 individuals across the six Carolina Clear regional consortia by phone during August-September 2019. Although Richland and Lexington Counties were not included in the survey, it is possible to glean helpful information about the general public from this study.

- 87% of residents are concerned about pollution in their local waterways; those groups most likely to be very concerned tended to be Black, female, urban residents older than 35
- 77% said that pollution from the land reaches local waterways via stormwater; 20% didn't know.
- 26% of residents think stormwater is treated at a wastewater treatment plant
- 67% of residents always pick up after their dog; 15% never do. 77% of those who pick up pet waste dispose of it in the trash. The most common reasons people do not pick up the waste were:
  - It is on their own property
  - They believe it is biodegradable or could be used as a fertilizer
  - It is inconvenient
  - There is nowhere to dispose of it
- 34% of residents have a septic tank, and 36% of them have not inspected or maintained it in the last two years
- 56% of respondents have experienced flooding on their property

Having the survey information is a good start to understanding how citizens view water quality in their neighborhoods and workplaces. The Project Team included more site-specific stakeholder information regarding the conditions in the Three Rivers Watershed in the following sections.

2.13.2 Three Rivers Watershed Stakeholder Survey and Webmap

The Project Team created an interactive survey and webmap that was distributed to members of the Project Advisory Committee (PAC). The survey was open from October 2020 to February 2021 and 48 unique users provided responses (some questions allowed for multiple answers, so the total number of responses varies). The following figures (Figure 2-23 through Figure 2-30) show the number of responses to each. In general, most respondents get their drinking water from a municipal water treatment plant. This underscores the importance of source water protection for stakeholders in this watershed.

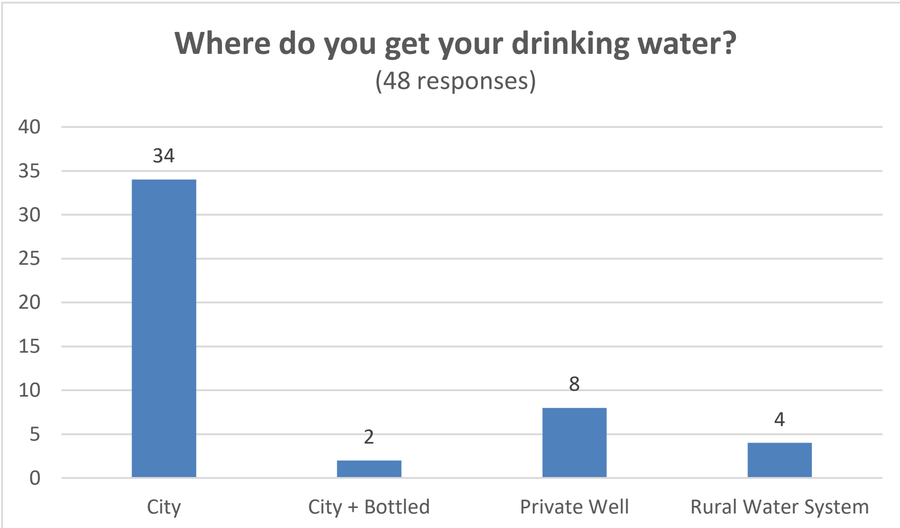

Figure 2-23: Sources for Stakeholder Drinking Water

The next series of questions were utilized to gauge the respondent's knowledge of stormwater treatment and pollution sources in the 3RW Area. Many responses were split between believing that stormwater gets directed to a stormwater conveyance system (drains or ditches to streams or rivers) to downstream waterbodies (without a treatment mechanism).

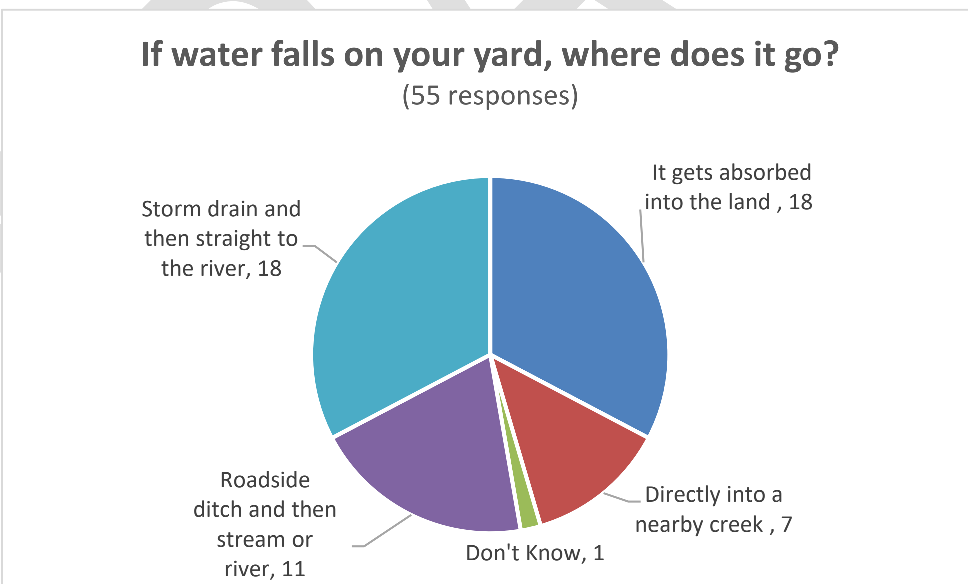

Figure 2-24: Stakeholder Runoff Destination Responses

Most responses indicated that agricultural activities did not contribute to water quality problems in the watershed. As is summarized in the stakeholder hotspot map, only a few small farms were identified within the watershed boundary. This is further supported by the lack of SCDHEC regulated permits for livestock operations in the watershed. How those small hobby farms impact water quality in the 3RW Area is discussed in **Section 5.3.1 Agriculture** of the 3RWBP.

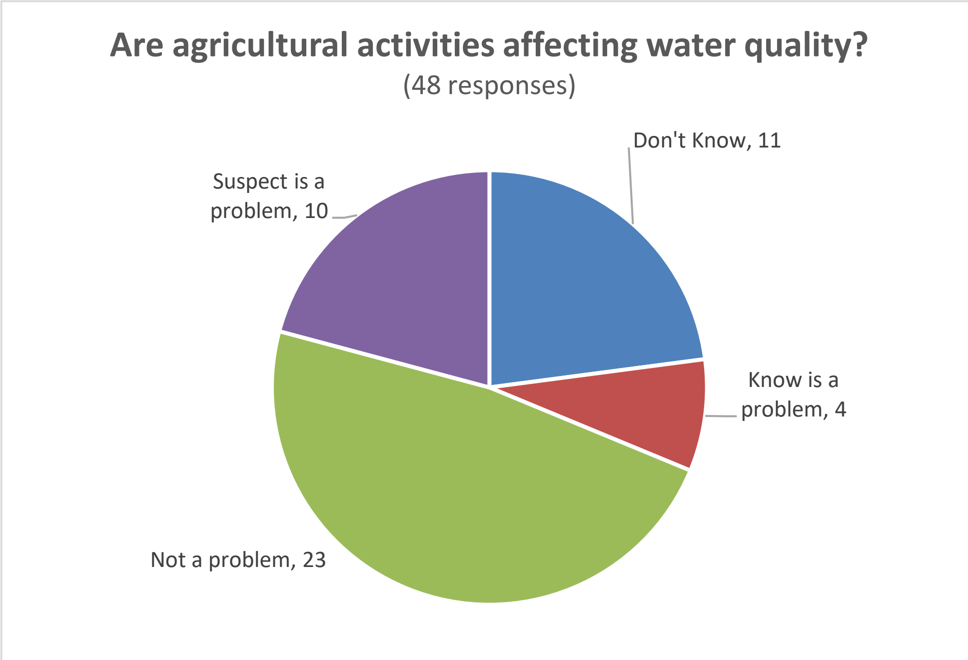

Figure 2-25: Stakeholder Agricultural Activity Responses

Many respondents indicated that construction activities were a known problem (17) or suspected they were (21). Construction activities vary temporally and spatially, so they were not explicitly inventoried as part of the 3RWBP; however, the default assumption for the WTM is that typical stormwater runoff from active construction sites is 1 mg/L for Total Nitrogen, 0.2 mg/L for Total Phosphorus, and 680 mg/L for Total Suspended Solids.

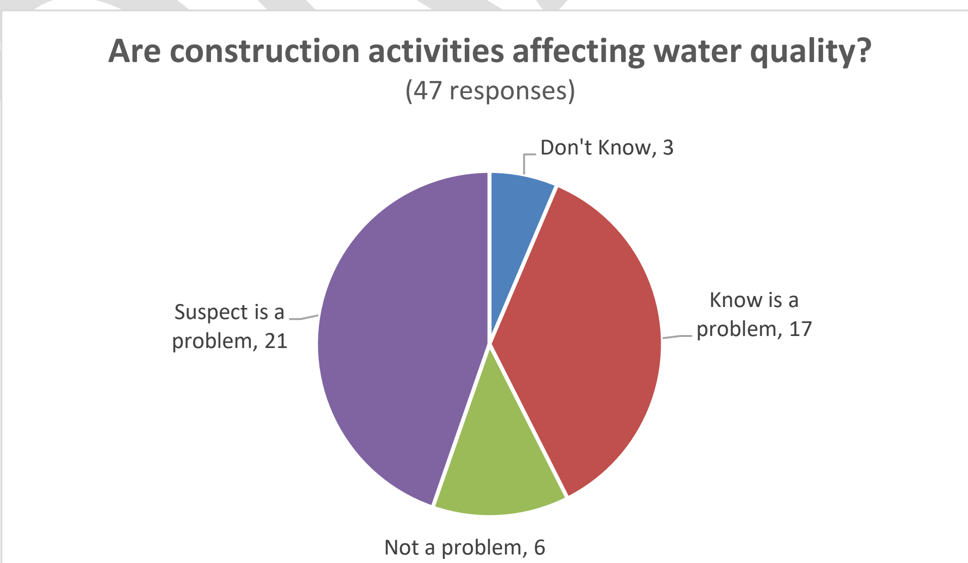

Figure 2-26: Stakeholder Construction Activity Responses

Stakeholders appeared uncertain about the impacts of septic systems on water quality, with the greatest response being "don't know." This represents an opportunity for outreach and education for septic systems (as will be described in **Section 6.2.3 Septic Systems**).

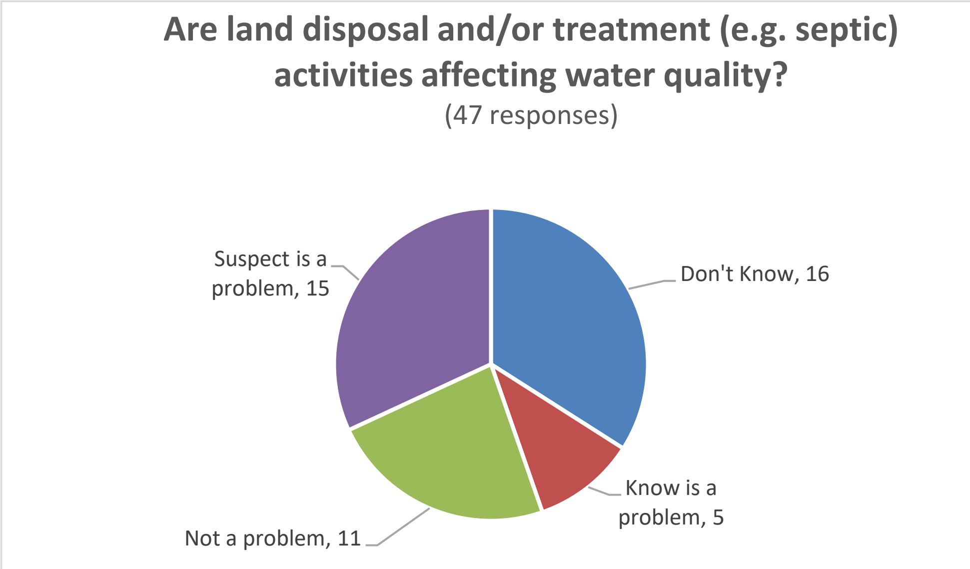

Figure 2-27: Stakeholder Land Disposal Responses

The majority of stakeholders thought that urban runoff is a known problem (18) or suspect it is a problem (17). The Project Team has provided more analysis and discussion of this source of nonpoint pollution in **Section 5.3.4 Urban/Suburban Runoff.**

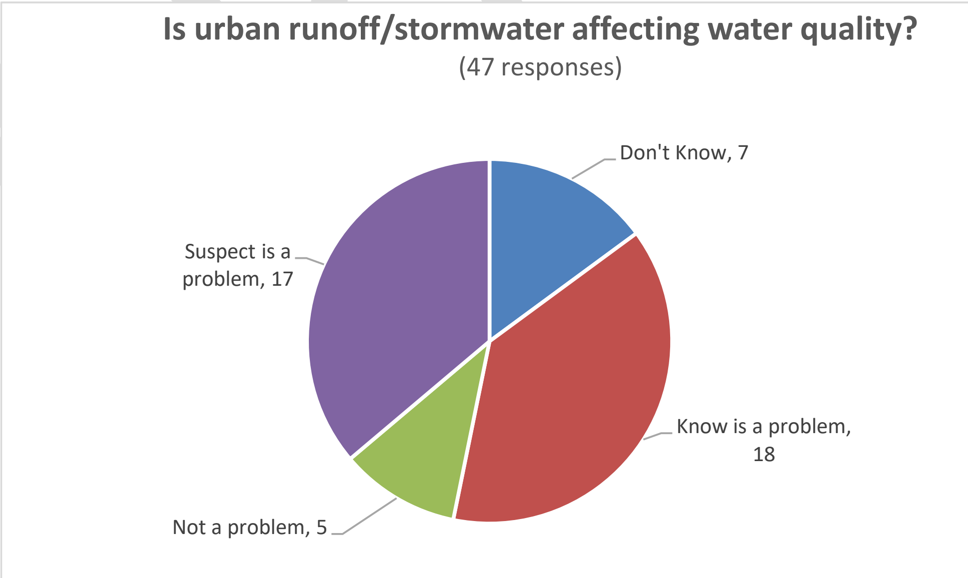

Figure 2-28: Stakeholder Effect of Urban Runoff Responses

Most of the respondents (19) were unsure if other problems, such as spills or wildlife, affect water quality in the 3RW Area. This WBP provides discussion of a variety of sources, including those specifically related to human waste (**Section 5.2**), and other nonpoint sources (**Section 5.3**).

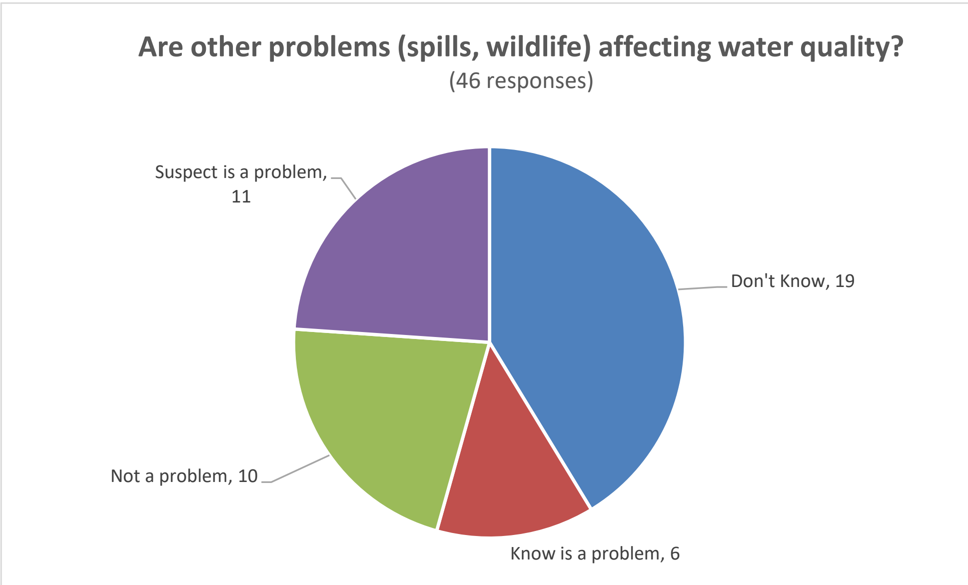

Figure 2-29: Stakeholder Other Problems Responses

Stakeholders identified urban runoff as the leading cause of bacterial contamination. A discussion on how the Project Team evaluated the sources of bacteria in the subwatersheds using two different methods is included in **Section 4.2 Load Duration Curve Results** and **Section 4.3 Watershed Treatment Model Results** .

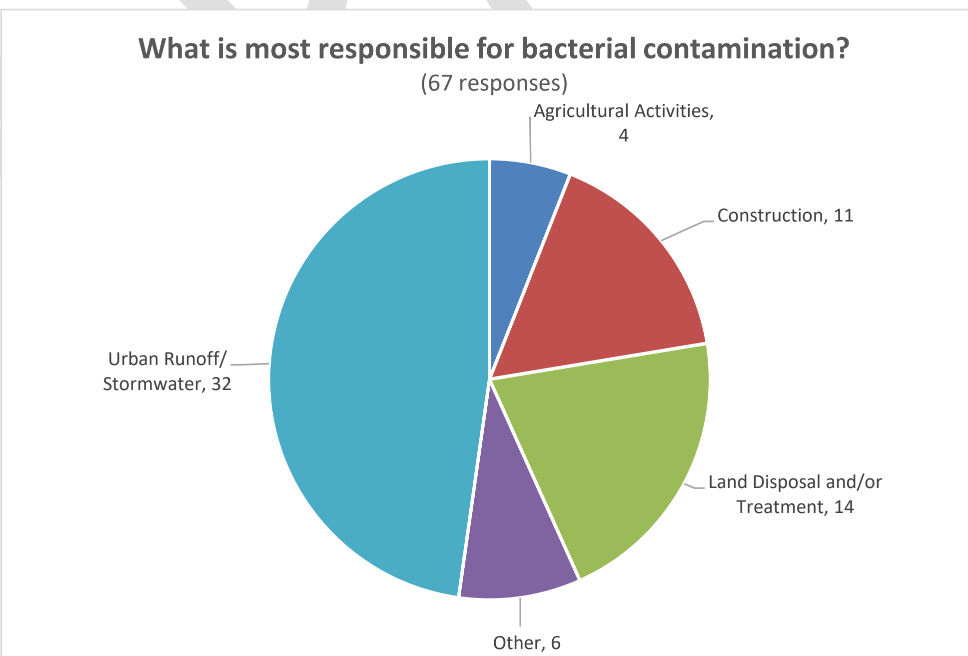

Figure 2-30: Stakeholder Bacterial Contamination Source Responses

In addition to the survey questions, stakeholders were also asked to place color-coded dots representing different hotspot types on a webmap (see Figure 2-31**)**. Over 130 responses were recorded, but of those, only 79 fell within watershed boundaries (see **Table 2-16**). The most common issues identified in the watershed were litter hotspots followed by recreational areas that are regularly used by the public. The survey also identified potential hotspots of nonpoint source pollution related to sedimentation and septic or sanitary sewer overflows. Finally, some potential hotspots were related to specific activities, such as agriculture, construction, or brownfield sites that require contaminant remediation.

Table 2-16: Stakeholder Responses on Hotspot Map

Type	Count
Litter	19
Recreation areas	19
Sedimentation	8
Septic/Sanitary	6
Wildlife	6
Flooding	5
Construction Sites	4
Riparian Buffer	3
Small farms	3
Brownfields	2
Erosion	2
(blank)	1
Pet waste	1
Total	**79**

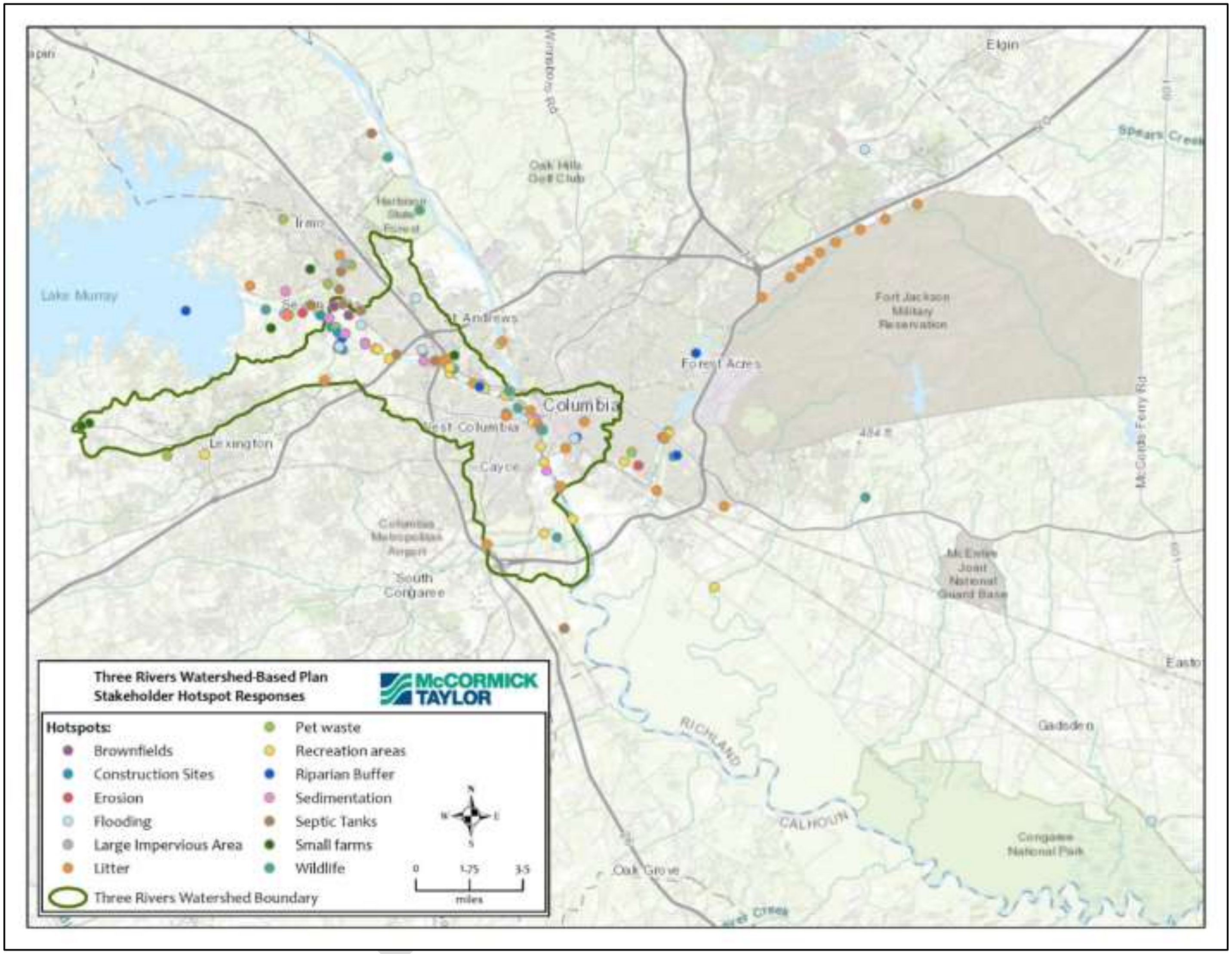

Figure 2-31: Stakeholder Hotspot Map

2.13.3 Three Rivers Watershed Stakeholder Group Meetings

Due to the COVID-19 pandemic and safety guidelines by the Centers for Disease Control and Prevention (CDC), meetings for the development of the 3RWBP were facilitated virtually through videoconferencing software such as Zoom (as shown in **Table 2-17**). Meetings or workshops focused on gathering actionable stakeholder projects and gathering data for the water quality analysis. This table does not include periodic email updates and individual outreach to Project Advisory Committee (PAC) members.

The 3RWBP is a living document and will be reviewed and amended by stakeholders on a regular basis into the future.

Table 2-17: Record of Stakeholder Meetings

Meeting Type	Date
Kick-off Meeting	19/February/2020
Consultant Introduction to PAC	9/July/2020
PAC Project Update Meeting #1	10/September/2020
Urban/Rural Source Focus Group #1	17/November/2020
Sewer Utility Focus Group	18/November/2020
Urban/Rural Source Focus Group #2	19/November/2020
PAC Project Update Meeting #2	18/February/2021
West Columbia Project Prioritization Call	9/April/2021
Lexington County Project Prioritization Call	12/April/2021
PAC Project Update Meeting #3	20/May/2021
MS4 Goal Discussion and Project Update	13/September/2021
Stormwater/Sewer Utility Discussion	15/September/2021

3.0 In-Stream Water Quality Monitoring

3.1 Use Designations and Classifications

State water quality standards are determined based on the water use classification for each waterbody. Water use classifications are based on the desired uses of a waterbody and not necessarily the actual water quality. Classifications are used to determine NPDES permit limits. This also means that waterbodies can be reclassified if the desired or existing use justifies reclassification. The tributaries and lakes in the 3RW Area are all freshwater (FW) and are defined by SCDHEC in SC Regulation R.61-68 (2020):

> *Freshwaters (FW) are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.*

In addition to water use classifications, the state has four "use support" designations:

1. Aquatic Life Use Support (AL) – based on the composition and functional integrity of the biological community.
2. Recreational Use Support (REC) – the degree to which a waterbody meets E. coli bacteria water quality standards for primary contact recreation. Waters with a monthly average of 126 MPN/mL or a daily maximum of 349 MPN/100mL are considered non-supporting of recreational uses.
3. Fish Consumption Use Support (FISH) – a risk-based approach is used to evaluate fish tissue data and to issue consumption advisories.
4. Drinking Water Use Support (DW) – nonattainment occurs when the median concentration (based on a minimum of three samples) for any pollutant exceeds the appropriate drinking water Maximum Contaminant Level (MCL).

3.2 Antidegradation Rules

The SC Regulation R.61-68, *Water Classifications and Standards*, details the State's antidegradation rules. Antidegradation rules provide a minimum standard of protection to all waters of the State and includes exceptional conditions under which water quality degradation is allowed. The State's antidegradation rules require existing uses be maintained and water quality be protected regardless of the water's classification. Conditions under which water quality degradation is allowed that apply to the Three Rivers Watershed include:

- Existing uses and water quality necessary to protect uses may be affected by instream modifications as long as the stream flows protect classified and existing uses and water quality supporting these classified uses is consistent with riparian rights to reasonable use of water;
- Benefits the people and economy of an area where water quality would remain adequate to fully protect existing and classified uses; and
- Natural conditions cause a depression of dissolved oxygen (DO).

3.3 Numeric and Narrative Criteria

Water quality standards for waters classified as freshwater are listed in **Table 3-1**.

Table 3-1: Freshwater Water Quality Standards in the State of South Carolina (R. 61-68)

Parameter	Standard
(a) Garbage, cinders, ashes, oils, sludge or other refuse	None allowed
(b) Treated wastes, toxic wastes, deleterious substances, colored or other wastes, except those given in (a) above	None alone or in combination with other substances or wastes in sufficient amounts to make the waters unsafe or unsuitable for primary contact recreation or to impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
(c) Toxic pollutants listed in the appendix	As prescribed in Section E of this regulation
(d) Stormwater, and other nonpoint source runoff, including that from agricultural uses, or permitted discharge from aquatic farms, concentrated aquatic animal production facilities, and uncontaminated groundwater from mining	Allowed if water quality necessary for existing and classified uses shall be maintained and protected consistent with antidegradation rules.
(e) Dissolved oxygen	Daily average not less than 5.0 mg/l with a low of 4.0 mg/l.
(f) *E. coli*	Not to exceed a geometric mean of 126/100 ml based on at least four samples collected from a given sampling site over a 30-day period, nor shall a single sample maximum exceed 349/100 ml.
(g) pH	Between 6.0 and 8.5
(h) Temperature	As prescribed in E.12 of this regulation
(i) Turbidity (except for Lakes) Lakes only	Not to exceed 50 NTUs provided existing uses are maintained. Not to exceed 25 NTUs provided existing uses are maintained.

3.4 Historic Water Quality Sampling Data

Water quality monitoring in the Three Rivers Watershed has been conducted by multiple state, municipal, and local groups. Current monitoring stations include fourteen by SCDHEC; two by City of Columbia; four by Congaree Riverkeeper; and 11 by the MRC (**Figure 3-1**). Available monitoring data (see **Table 3-2**) spans from January 1999 to March 2020, however, no single station has continuous data for the duration of this time period. For the purposes of this WBP we will be compiling and analyzing the historical data for four different measurements: *Escherichia coli* (ECOLI), dissolved oxygen (DO), total nitrogen (TN), total phosphorus (TP), and turbidity (TURB). The aforementioned measurements are also standard Watershed Treatment Model outputs that help inform watershed characteristics beyond the level of bacterial pollution. Note that the sites highlighted in **Table 3-2** were used in developing the three Load Duration Curves for the Congaree, Saluda, and Rocky Branch basins (as will be discussed in further detail in **Section 4.2 Load Duration Curve Results**)

Other water quality planning initiatives impacting the 3RW Area include CMCOG 208 water quality planning and the Midlands Rivers Coalition (MRC) recreational water quality monitoring. Since the passage of the Clean Water Act, CMCOG has been developing regional plans for eliminating and consolidating domestic wastewater treatment facilities. This process has led to the consolidation of more than two hundred small sewage treatment systems into larger regional collection and treatment systems. A critical goal of this ongoing planning effort has been to eliminate the domestic discharges from the Lower Saluda River. The MRC is a broad-based coalition of stakeholders dedicated to protecting the water resources of the Broad, Lower Saluda, and Congaree Rivers. Since 2017, MRC has been monitoring for bacteria on a weekly basis during the summer recreational season at ten stations within the watershed. This dataset will be used in the development of the 3RWBP. MRC will also be a key stakeholder group during the planning process.

Within the 3RW Area, watershed-based plans have been developed for Rocky Branch and Smith Branch Creeks. Outside of (but adjacent to) the 3RW Area, a WBP has also been developed for Congaree Creek. All three of these plans provide extensive information on upstream conditions from the 3RW Area and recommendations of BMPs applicable in their respective locations. These plans will provide crucial information in discussing regional water quality management strategies and solutions. There are currently no Source Water Protection Plans (SWPP) in place for the watershed. **Section 6.0** of the 3RWBP includes considerations and identifies opportunities for better protecting the source water intakes within the watershed.

Table 3-2: Monitoring Stations in Three Rivers Watershed

Station	Organization	Watershed Location	Time Period[1]
B-080	SCDHEC	Congaree River East	1999 - 2000, 2004, 2017 - 2019
C-005	SCDHEC	Lower Sixmile-Congaree	1999-2001; 2006
C-008	SCDHEC	Lower Sixmile-Congaree	1999 – 2001; 2006; 2015-2020
C-070	SCDHEC	Congaree Creek Outlet	2001 – 2008; 2010 – 2019
CSB-001L	SCDHEC	Congaree River West	1999 – 2000; 2006; 2015 –2020
CSB-001R	SCDHEC	Congaree River East	1999 – 2000; 2006; 2015 –2020
RS-15262	SCDHEC	Lower Sixmile-Congaree	2015
S-149*	SCDHEC	Kinley Creek – Saluda River	1999 – 2001; 2006
S-150*	SCDHEC	Kinley Creek – Saluda River	1999 – 2001; 2006
S-260*	SCDHEC	Kinley Creek – Saluda River	1999 – 2001; 2006
S-294	SCDHEC	Fourteenmile Creek	1999 – 2001; 2006; 2013 – 2018
S-298	SCDHEC	Saluda River North	1999 – 2020
S-955	SCDHEC	Rocky Branch	Sept 2004 – Feb 2005
RocA	City of Columbia	Rocky Branch	Jan 2017 – June 2020
RocB	City of Columbia	Rocky Branch	Jan 2017 – June 2020
CRK02	Congaree Riverkeeper	Saluda at I-20	May 2015 – Mar 2020
CRK06	Congaree Riverkeeper	Rocky Branch	May 2015 – Mar 2020
CRK08	Congaree Riverkeeper	Stoop Creek	May 2015 – Mar 2020
CRK09	Congaree Riverkeeper	12 Mile Creek	May 2015 – Mar 2020
MRC-B337	Midlands Rivers Coalition	Stoop Creek	2018 – 2020
MRC-BRRC	Midlands Rivers Coalition	Stoop Creek	2018 – 2020
MRC-CSB-001L	Midlands Rivers Coalition	Congaree River West	2017 – 2020
MRC-CSB-001R	Midlands Rivers Coalition	Congaree River East	2017 – 2020
MRC-I-20	Midlands Rivers Coalition	Kinley Creek-Saluda River	2017 – 2020
MRC-RBZ	Midlands Rivers Coalition	Saluda River North	2017 – 2020
MRC-RDL	Midlands Rivers Coalition	Rocky Branch	2017 – 2020
MRC-S-298	Midlands Rivers Coalition	Saluda River North	2017 – 2020
MRC-SRE	Midlands Rivers Coalition	Senn Branch and Double Branch	2018 – 2020
MRC-SSLL	Midlands Rivers Coalition	Kinley Creek-Saluda River	2017 – 2020

[1]at time of WBP draft and LDC development

* no *E.coli* sampling at this station; historic data included FC and ENTERO

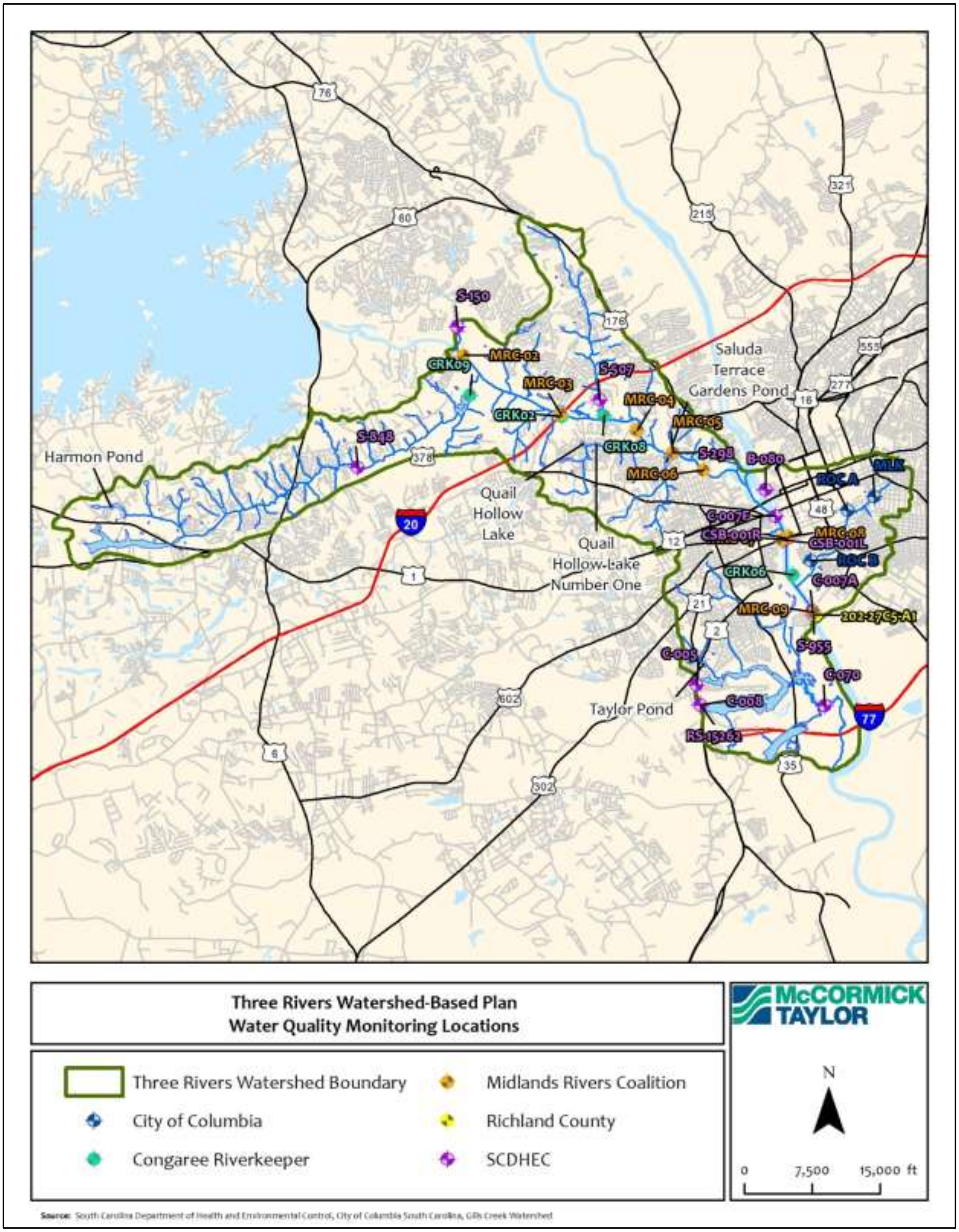

Figure 3-1: Water Quality Monitoring Locations in Three Rivers Watershed

3.4.1 Bacteria

Figure 3-2 summarizes the monitoring stations with available *E. coli* data (note that SCDHEC stations C-025, S-149, S-150 and S-260 did not have measurements for *E. coli*). The state E. Coli fecal bacteria freshwater and trout water quality standards are for "*349 MPN/100mL or less*". Please note that the scale is set to logarithmic, so that the highest recorded measurements are two orders of magnitude higher than the water quality standard.

In total, 1,719 measurements were taken by four different organizations from September 2004 to October 2020. The lowest recorded measurement was 2 MPN/100 mL at MRC SSCL in May 2020, and the largest was 48,390 MPN/100 mL at Roc A in October 2018. Over the entire record, 11 measurements (0.6%) were below detection limit, 1,422 measurements (83%) were below the standard of 349 MPN/100 mL, and 286 measurements (17%) were above the standard. The top 20 highest measurements of *E. coli* concentrations were observed at Roc A and Roc B.

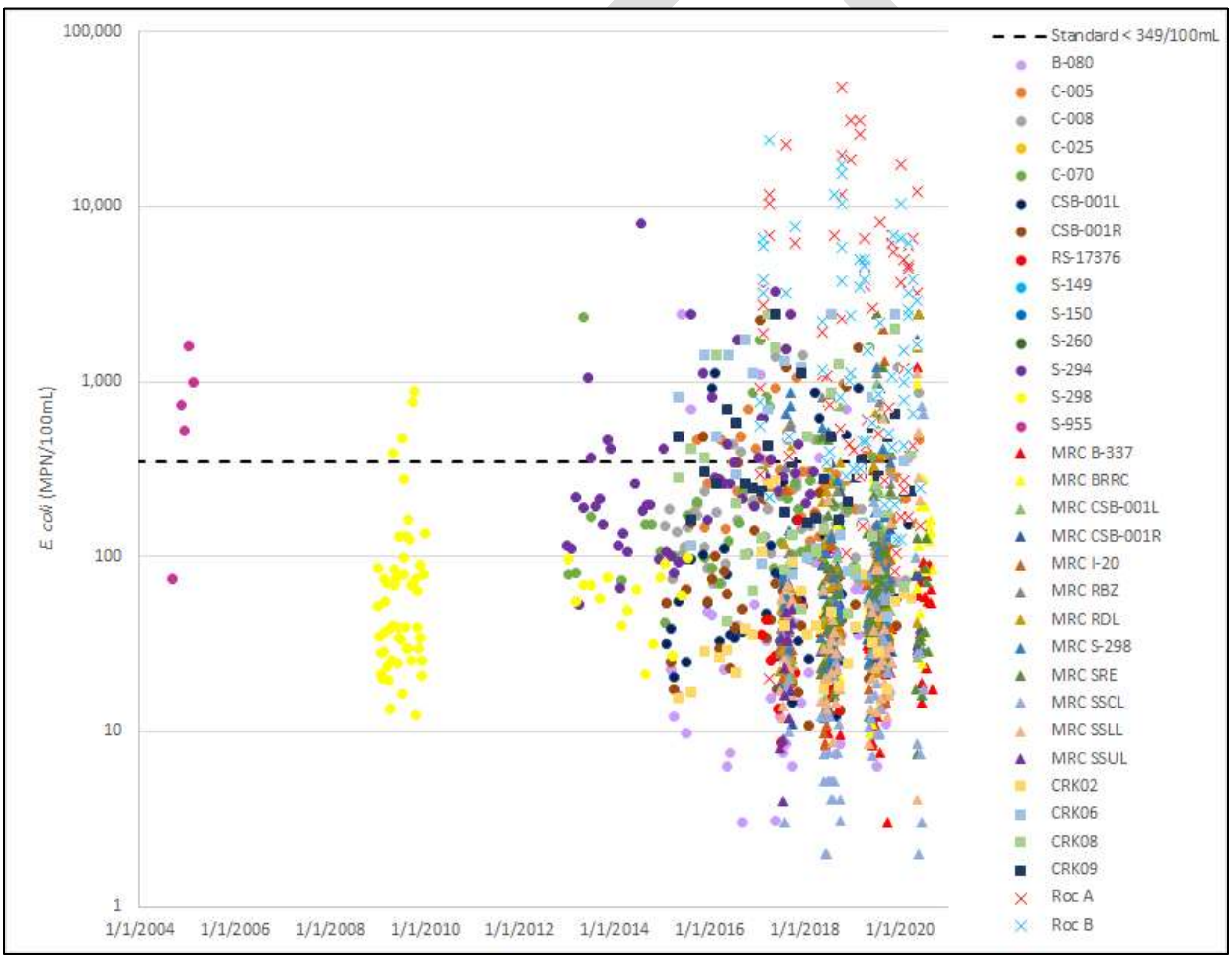

Figure 3-2: Monitoring Results for E. coli in Three Rivers Watershed

3.4.2 Dissolved Oxygen

Figure 3-3 summarizes available historical monitoring data for dissolved oxygen (DO) at various SCDHEC ambient surface water monitoring stations from January 1999 to March 2020. These data were selected for presentation in the watershed management plan due to their relevance to stations listed on the 2018 303(d) list for impairments related to aquatic life; DO is a standard output in the WTM but was not analyzed in the load duration curves. The state water quality standard for DO freshwaters is for a "*daily average not less than 5.0 mg/L with a low of 4.0 mg/L*."

The SCDHEC monitoring stations have records of 833 DO measurements, of which 23 (3%) were below the water quality standard (5.0 mg/L) and 810 (97%) were above the water quality standard. The lowest measured value was 0.62 mg/L and the highest was 13.86 mg/L (and there were two outliers: 22.7 mg/L at CSB-001L and 71 mg/L at S-150)

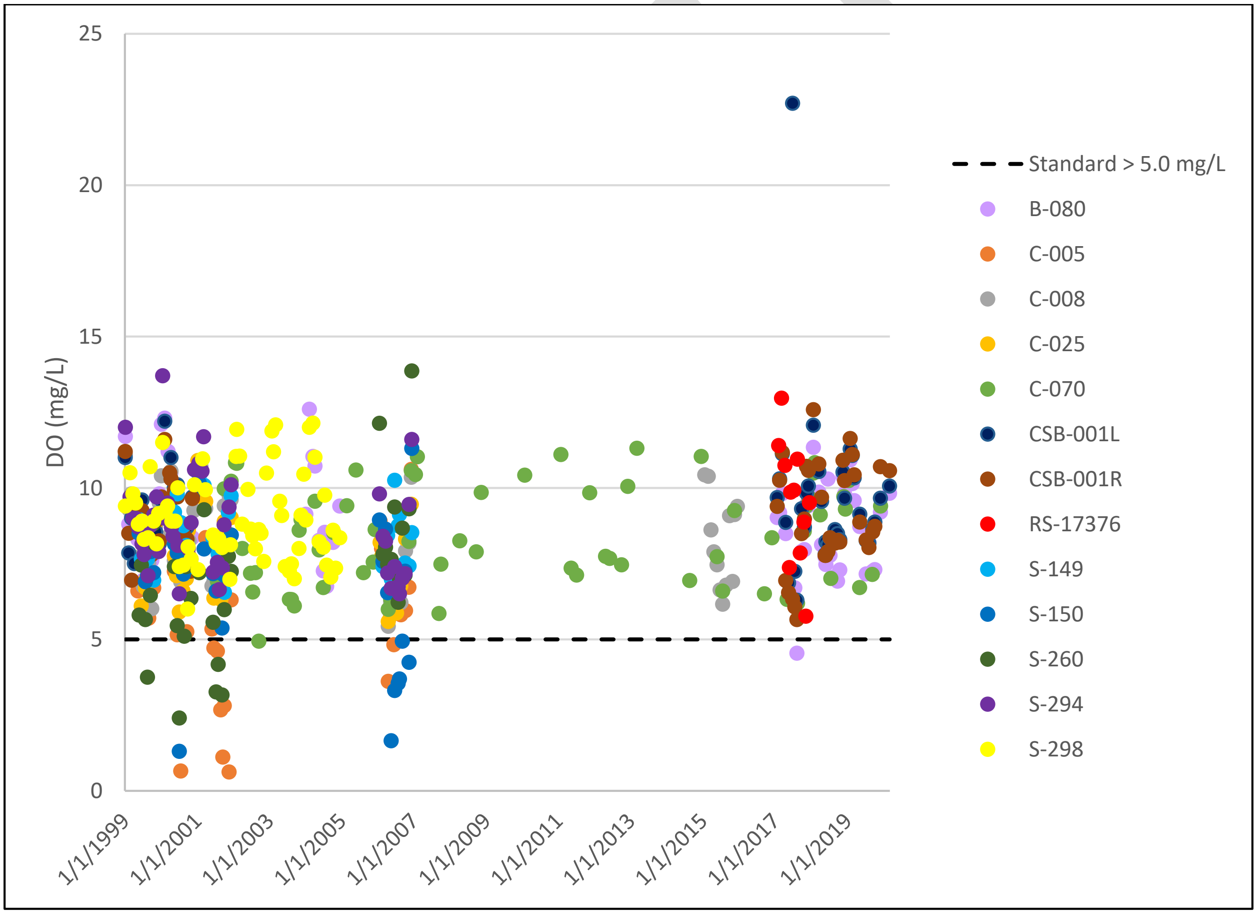

Figure 3-3: Monitoring Results for Dissolved Oxygen in the Three Rivers Watershed

3.4.3 Nutrients

Figure *3-4* and **Figure 3-5** summarize available historical monitoring data for total nitrogen (TN) and total phosphorus (TP) at various SCDHEC ambient surface water monitoring stations from May 1999 to March 2020. Note that there are currently no nutrient standards in South Carolina for freshwater streams or rivers; therefore, the EPA's Ecoregional Nutrient Criteria for Rivers and Streams[38] has been cited to provide some context for the historical nutrient monitoring results observed in the Three Rivers Watershed (which is located in ecoregion IX). The recommended TN standard is 0.69 mg/L and 36.56 µg/L for TP.

Sources of nitrogen and phosphorus in the watershed may include runoff from fertilizer use, leaching from septic tanks, sewage, or erosion of natural deposits[39]. It is important to consider the impacts to both the natural ecosystem and drinking water sources. Note that the National Primary Drinking Water Regulations have established criteria for nitrate (10 mg/L) and nitrite (1 mg/L) in potable water[40], but none for phosphorus. The purpose of these limits is to protect infants below the age of six months who could become seriously ill, in if untreated, die if they drink water contains nitrates and nitrites above these thresholds.

The SCDHEC monitoring stations have records of 516 TN measurements, of which 67 (13%) were below detection limits, 260 (50%) were below the recommended water quality standard (0.69 mg/L) and 189 (37%) were above the recommended water quality standard. The lowest measured value was 0.146 mg/L and the highest was 5.08 mg/L.

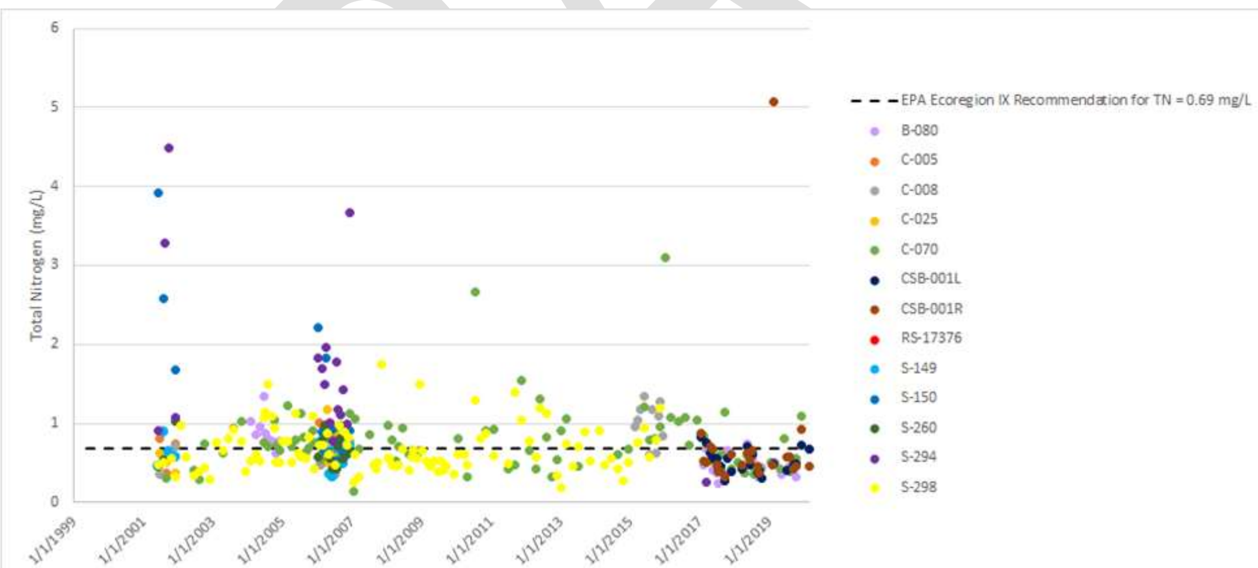

Figure 3-4: Monitoring Results for Total Nitrogen in the Three Rivers Watershed

[38] EPA. 2000. https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-rivers-and-streams
[39] EPA. 2021. https://www.epa.gov/nutrientpollution/sources-and-solutions
[40] EPA. 2022. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

Figure 3-5 illustrates the results of 535 total phosphorus samples collected by SCDHEC from January 2002 to March 2020. In total, 146 (27%) were below detection limits, 188 (35%) were below the water quality standard, and 201 (38%) were above the water quality standard. The lowest measured TP concentration was 0.02 mg/L at C-070 in January 2002, and the highest was 1.1 mg/L at S-150 in May 2006.

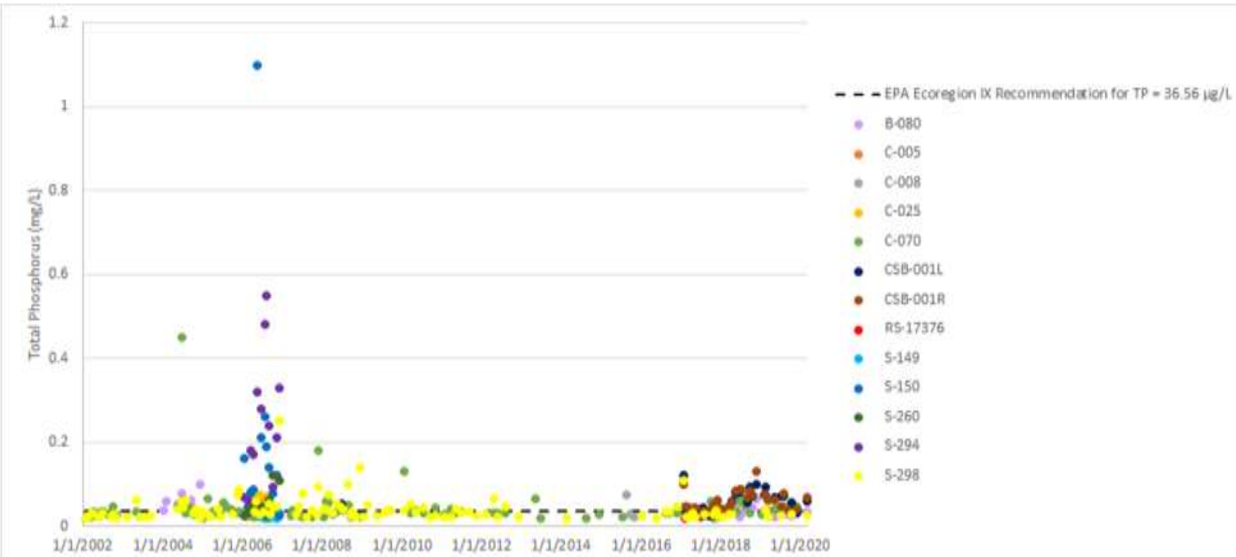

Figure 3-5: Monitoring Results for Total Phosphorus in the Three Rivers Watershed

3.4.4 Turbidity

Figure 3-6 illustrates the SCDHEC turbidity monitoring results from 847 samples collected from January 1999 to March 2020. Note that turbidity is not calculated as part of the WTM analysis. However, Total Suspended Solids (TSS) is calculated in WTM. There are no standards for TSS currently in R.61-68, but there is a state freshwater standard for turbidity which is "not to exceed 50 NTU providing existing uses are maintained". Turbidity and TSS are typically well-correlated; however, the relationships are site specific and dependent on factors like organic matter content, particle size, and color. From a source water treatment perspective, higher levels of turbidity are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria.

Turbidity measurements at these stations ranged from a low of 0.75 NTU to a high of 260 NTU. One sample was below the detection limit, 826 (98%) of the samples were below the water quality standard, and 20 samples (2%) were above the water quality standard.

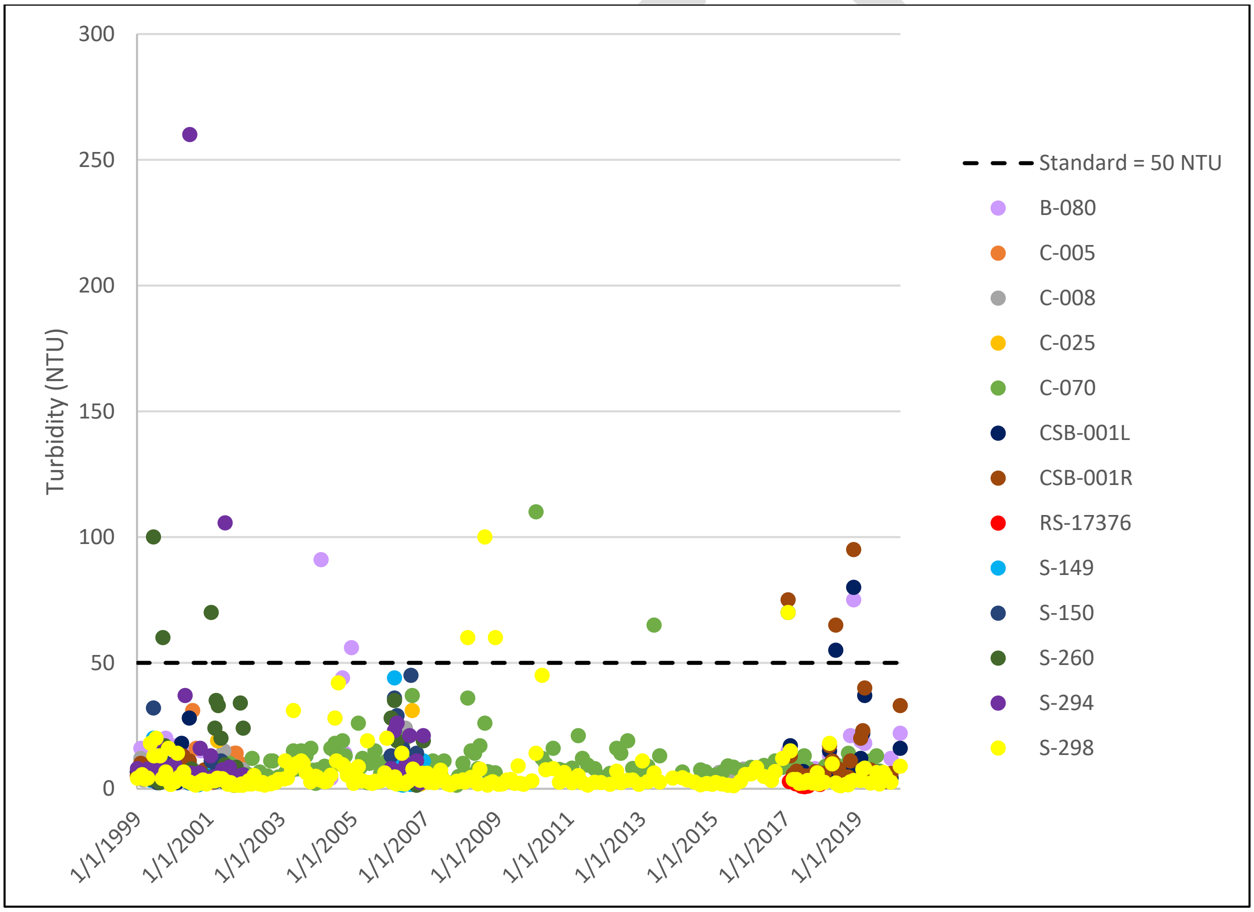

Figure 3-6: Monitoring Results for Turbidity in the Three Rivers Watershed

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3.5 Impaired Waters

Waterbodies that do not meet these designated uses are impaired and identified by the state in accordance with the Federal Clean Water Act Section 303(d), known as the 303(d) list of impaired waters. The 303(d) list is updated every two years by SCDHEC. SC Regulation 61-68 defines Freshwaters as those suitable for primary and secondary contact recreation and as a source for drinking water. The quality standards for these waters are such that garbage, cinder, oils, or other refuse are not allowed. Furthermore, stormwater and other nonpoint source runoff are allowed if water quality is maintained and protected such that it is consistent with anti-degradation rules.

In 2014, SCDHEC updated R.61-68 *Water Classifications & Standards*. Previously, the standard for fecal coliform in freshwater was "Not to exceed a geometric mean of 200/100 ml, based on five consecutive samples during any 30-day period; nor shall more than 10% of the total samples during any 30-day period exceed 400/100 ml." The current standard for *E. coli* in order to protect recreational uses in freshwaters is a monthly average of 126 MPN per 100 ml or a daily maximum of 349 MPN per 100 ml.

Waterbodies in the Three Rivers Watershed identified on the SCDHEC 2018 303(d) list are listed in **Table 3-3**. The state uses the 303(d) list to target waterbodies that need to be restored to meet water quality standards. Generally, a total maximum daily load (TMDL) is developed for waters identified on the 303(d) list. A TMDL is the calculation of the maximum amount of a pollutant that is allowed to enter a waterbody so that the waterbody will meet its water quality standards for a particular pollutant. A TMDL must include both point and nonpoint sources of pollution and some margin of safety. Seven monitoring stations in the Three Rivers Watershed are included in three different TMDL plans for E. coli. High levels of bacteria increase the probability that people will become ill if they come in contact with the waterbody.

Table 3-3: Summary of SCDHEC's Impaired Stations and TMDLs in the Three Rivers Watershed

Station	Description	Use/s	Cause/s	Use Supported	TMDL
C-005	Sixmile Creek on US 21 S of Cayce	AL REC	DO FC	Not Supported	InTMDL (010-04)
C-008	Congaree Creek at US 21 Cayce	REC	FC	Fully Supported	InTMDL (010-04)
C-025	Lake Caroline Spillway at Platt Springs Rd.	REC	FC	Not Supported	InTMDL (010-04)
C-070	Congaree Creek at S-32-66	REC	ECOLI	To be Determined	Under Development
CSB-001L	Congaree River at Blossom St.	REC	ECOLI	To be Determined	Under Development
S-149	Saluda River at MEPCO intake	AL REC	TURBIDITY FC	Not Supported	InTMDL (011-04)
S-150	Lorick Br. upstream of junction with Saluda	AL REC	DO FC	Not Supported	InTMDL (018-04)
S-260	Kinley Creek at St. Andrews Rd.	AL REC	BIO FC	Not Supported	InTMDL (011-04)
S-294	Twelvemile Creek at US Route 378	AL REC	BIO FC	Not Supported	InTMDL (011-04)
S-298	Saluda River at USGS Gage	REC	ECOLI	To be Determined	Under Development

4.0 Pollutant Load Analysis

4.1 Overview of Pollutant Load Methods

Two tools were utilized to understand pollution in the Three Rivers Watershed: Load Duration Curves (LDCs) and the Watershed Treatment Model (WTM).

4.1.1 Watershed Treatment Model Description

The WTM was selected to create water quality models for the 11 subwatersheds of the Three Rivers Watershed study area to calculate bacteria loads for three separate conditions:

1) existing land use conditions and mean annual precipitation amount;
2) future land use and climate scenarios, incorporating future growth, increased bacteria concentrations in runoff, and increased precipitation within the study area; and
3) future retrofit scenarios, in which the management measures available within the WTM framework were applied to reduce pollutant loads below current existing conditions.

Individual WTMs were developed for each of the 11 delineated subwatersheds in **Figure 2-2: Three Rivers Watershed Area Subwatershed Delineations**. The City of Columbia developed the Rocky Branch WTM and the McCormick Taylor-KCI Project Team developed the remaining 10.

The WTM is a steady state spreadsheet modeling tool best utilized for the rapid assessment and quantification of various watershed treatment options and management measures. The WTM estimates pollutant loads for sediment, nutrients, bacteria, and runoff volume. The WTM calculates pollutant loading on an annual basis and will not simulate seasonal loads or the short-term variability of pollutant loads due to shorter periods of climate variability. Please note that the WTM calculates bacteria loads in terms of fecal coliform (FC). In order to reflect the current water quality standard, all FC loads calculated in WTM were converted to E. coli by multiplying the WTM loads by 0.8725[41].

The Pollutant Sources component of the WTM estimates the load from a watershed without treatment measures in place. The pollutant sources component estimates the load from a watershed without treatment measures in place and considers primary (land use) and secondary sources (sewage treatment, nutrient concentration in stream channels, urban channel erosion). Treatment options include turf management, erosion and sedimentation control, stormwater structural best management practices, pet waste education, riparian buffers, and street sweeping. The Treatment Options component estimates the reduction in this uncontrolled load from a wide suite of treatment measures for both existing and future conditions. Finally, the Future Growth component allows the user to account for future development in the watershed, assuming a given level of treatment for that development.

4.1.2 Load Duration Curves Description

A detailed description of the methodology used to develop LDCs for the subwatershed is included in **Appendix E** of this WBP. For this WBP, three LDCs were created for *E. coli*: Saluda River, Congaree River, and Rocky Branch.

** Fecal coliform conversion factor methodology may be found in
https://scdhec.gov/sites/default/files/media/document/Synopsis%20E.%20coli%20Standard%20Adoption.pdf

Load duration curves (LDCs) are an effective way to process and visualize water quality data from advective-flowing streams and rivers. They provide users and resource managers with the capacity to understand which conditions in the stream are most conducive to infringe on water quality standards and illustrate patterns in the data that can provide significant inferences as to pollutant sources. The insights, in turn, can be used to identify the reductions necessary to achieve or approximate compliance with water quality standards and guide development of the management strategies necessary to address problem pollutants. It is important to note that LDCs are not water quality models in that they do not predict future water quality conditions in response to management actions nor do they simulate water quality fluctuations over time.

The elements required to develop an LDC include a significant body of water quality data for the targeted parameter and a coincident, detailed record of stream flow at the same location, or in very close proximity. USGS streamflow monitoring station data supplemented the corresponding SCDHEC bacteria monitoring stations in each selected watershed, as shown in **Table 4-1**. The LDC is developed by multiplying each level of flow that has occurred in the river at least once over the monitoring period by the daily maximum water quality standard for *E. coli* of 349 colony forming units (CFU) per 100 ml. That series of allowable loads is plotted as the exceedance interval curve shown as the solid blue line sloping downward from left to right across the graph in Figure 4-1, Figure 4-2**,** Figure 4-3. Note that exceedance interval plots are slightly counter-intuitive in that the highest flows (those flow conditions exceeded least frequently) are on the left side of the graph, and the lowest flows (those exceeded most often) are on the right side.

Table 4-1 - USGS streamflow monitoring stations used in developing LDC in the 3RW Area.

Watershed	USGS Flow Monitoring station	Corresponding SCDHEC Bacteria Monitoring Station
Saluda River	02169000 Saluda River near Columbia	S-298
Congaree River	02169500 Congaree River at Columbia, SC	CSB-01, CSB-02
Rocky Branch	02169506 Rocky Branch at Whaley St, Columbia	Rocky Branch B

The interpretive power of the LDC is harnessed by utilizing the body of actual concentrations of *E. coli* recorded along with the river/stream flows reported for the same days in which the coliform concentrations were recorded to calculate the actual *E. coli* pollutant loads for those days. The actual pollutant loads are plotted against the LDC and those points above the LDC blue line are exceeding water quality standards and those that fall below the line are compliant with water quality standards. The average degrees of exceedance can then be calculated to determine the reduction necessary to achieve an improved overall state of compliance with water quality standards. The relative flow conditions at which exceedances occur can also infer information as to sources of bacterial loading which can inform management strategies. Watersheds in which bacterial pollutant loading sources are driven by build-up/wash-off mechanisms and delivered by stormwater runoff will obviously show great incidence of exceedance during high flow conditions. Bacteria loads stemming from sanitary sewer overflows also tend to be exerted more at high flows. Bacterial pollutant loading from improperly treated point source discharges or leaking/failing sanitary sewer collection systems can occur across the entire flow regime, but those loads tend to be more pronounced in the LDC plots at low flows when they are the more dominant source. Failing on-site septic systems also tend to be more pronounced at low flows for the same reason.

4.2 Load Duration Curve Results

4.2.1 Saluda River

A LDC was developed for the Saluda River (**Figure 4-1**) at SCDHEC monitoring station S-298 located approximately two river miles upstream from the confluence with the Broad River. The data for the LDC spans from 2009 to 2020 and includes data from both the USGS and the MRC. The LDC shows that 11% of the *E. coli* samples taken during that period reflected pollutant loads in excess of the allowable loading, and that on average the degree of exceedance was 206% of, or slightly more than double, the allowable load according to the water quality standard. This level of exceedance indicates that, on average, a 51% reduction in existing fecal bacteria loads would be required to approximate compliance with water quality standards. That 51% pollutant load reduction target was used in the WTM to guide the management scenarios developed for the study area watersheds that drain to the Saluda River.

The highest incidence of exceedances in the Saluda River LDC (21%), approximately twice the average rate, occurred during the range of river flows reflecting Dry Conditions. A high incidence of exceedance in this segment of the flow regime would indicate that sources such as failing and leaking sanitary sewer systems, non-complaint point source discharges, and failing on-site septic systems are important in the subwatersheds draining to the Saluda River. This indication is consistent with the Saluda subwatersheds having some of the largest remaining rural areas in the study area, resulting in higher proportions of on-site septic systems.

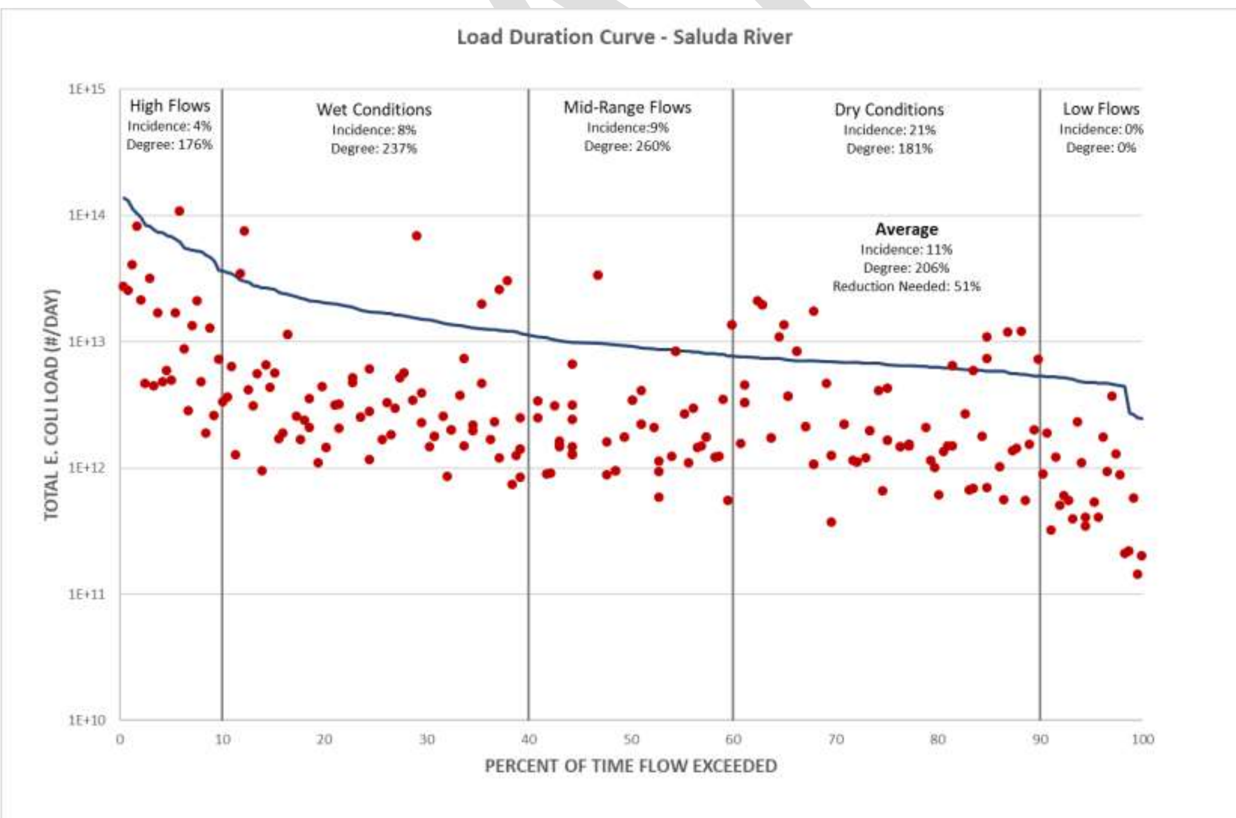

Figure 4-1: Saluda River Load Duration Curve

4.2.2 Congaree River

A LDC was developed for the Congaree River (**Figure 4-2**) at SCDHEC monitoring stations CSB-01 and CSB-02 located at the Blossom Street Bridge, approximately 1.5 river miles downstream from the confluence of the Saluda and Broad Rivers. The data for the LDC spans from 2015 to 2020 and includes data from the USGS. At the Blossom Street Bridge, the Congaree River is over 800 feet wide, and samples are collected from each side of the river. Prior to development of the LDC, the two data sets were compared and found to be highly similar in variability and response to different segments of the flow regime, so the two data sets were combined to make for a single, more robust, LDC. The LDC shows that 7% of the *E. coli* samples taken during that period reflected pollutant loads in excess of the allowable loading, and that on average the degree of exceedance was 270% of, or considerably more than double the allowable load according to the water quality standard. This level of exceedance indicates that, on average, a 63% reduction in existing fecal bacteria loads would be required to approximate compliance with water quality standards. That 63% pollutant load reduction target was used in the WTM's to guide the management scenarios developed for the study area watersheds which drain to the Congaree River.

Exceedances in the Congaree River LDC are noticeably clustered on left side of the graph, in the ranges of river flows reflecting Wet Conditions and High Flows. A high incidence of exceedance in these segments of the flow regime would indicate that pollutant build-up and wash-off mechanisms that deliver loads in stormwater runoff are important in the Congaree River. Interpreting the results of the Congaree LDC in terms of the implications for the study area is somewhat confounded by the fact that prior to being impacted by the study area, the contributing Broad River basin receives runoff from a 5,310 square mile watershed extending up to the upstate regions of South Carolina and into the upper Piedmont of North Carolina in the vicinity of Rock Hill. However, it remains likely that the pollutant loads from the urbanized study area and the immediate surroundings which constitute the Greater Columbia Metropolitan Area still have a tangible impact on bacteria levels in the river due to extensive areas of impervious surface, high levels of stormwater runoff, and immediate pollutant delivery to the river at this location.

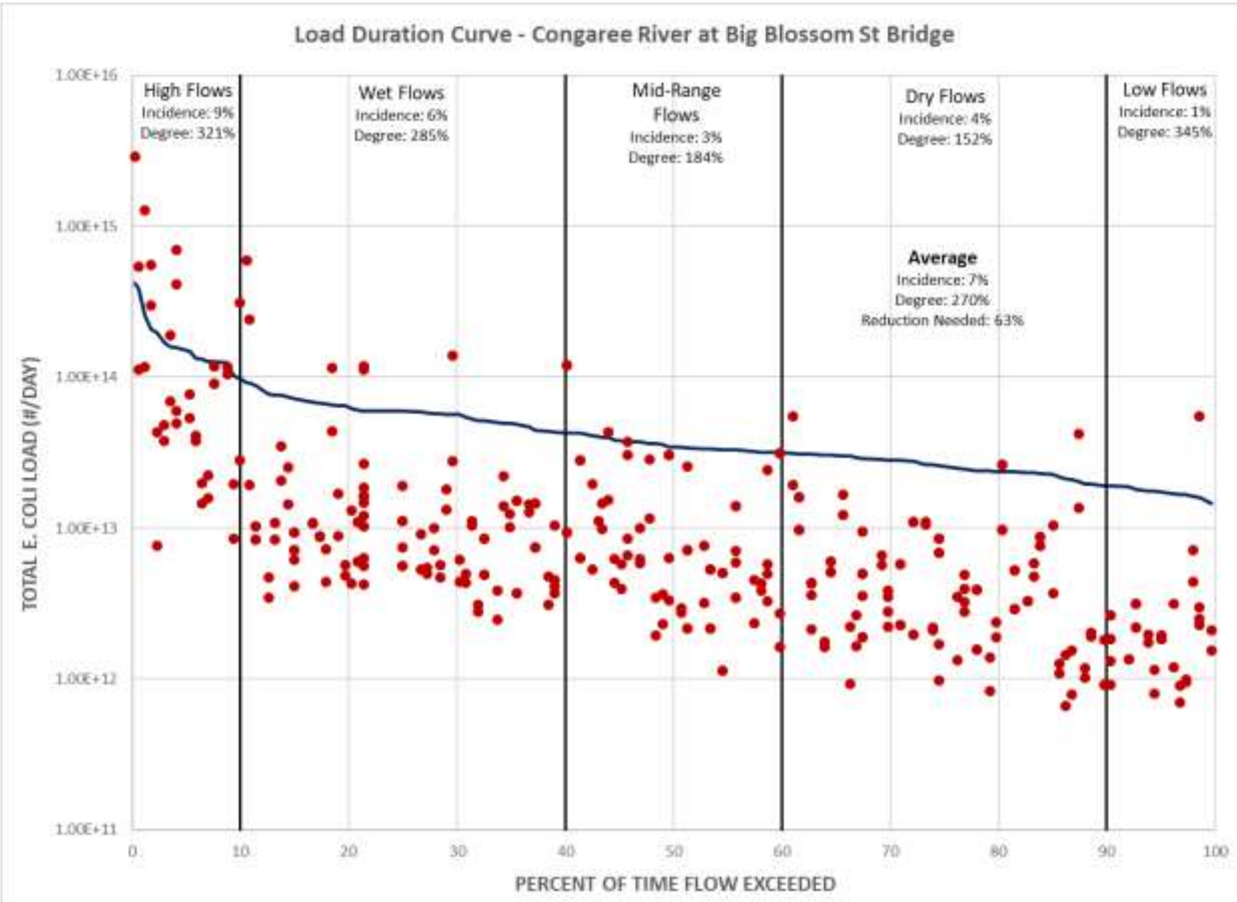

Figure 4-2: Congaree River Load Duration Curve

4.2.3 Rocky Branch

The City of Columbia maintains two monitoring stations on Rocky Branch: Rocky Branch A in the upstream portion of the watershed and Rocky Branch B in the downstream portion. A LDC was developed only for the downstream site at Rocky Branch B (**Figure 4-3**), approximately 0.5 stream miles upstream from the confluence with the Congaree River. The data for the LDC spans from 2017 to 2020 and both the flow and the water quality data to support the LDC were obtained from the City of Columbia. The LDC shows that 83% of the *E. coli* samples taken during that period reflected pollutant loads in excess of the allowable loading, and that on average the degree of exceedance was 1663% of, or more than an order of magnitude greater than the allowable load according to the water quality standard. This level of exceedance indicates that, on average, a 94% reduction in existing fecal bacteria loads would be required to approximate compliance with water quality standards.

Exceedances in Rocky Branch were consistently recorded across all flow conditions. However, evaluating the various segments of the flow regime reveals that exceedance generally increased in both frequency and degree during Wet Conditions and High Flows, indicating that pollutant build-up and wash-off mechanisms that deliver loads in stormwater runoff are also important in Rocky Branch. This phenomenon is not surprising in that Rocky Branch is one of the most urbanized subwatersheds in the study area. As a result, it has high proportions of impervious surface and much of the storm drainage system is piped, allowing for efficient and immediate delivery of pollutant loads to the stream network.

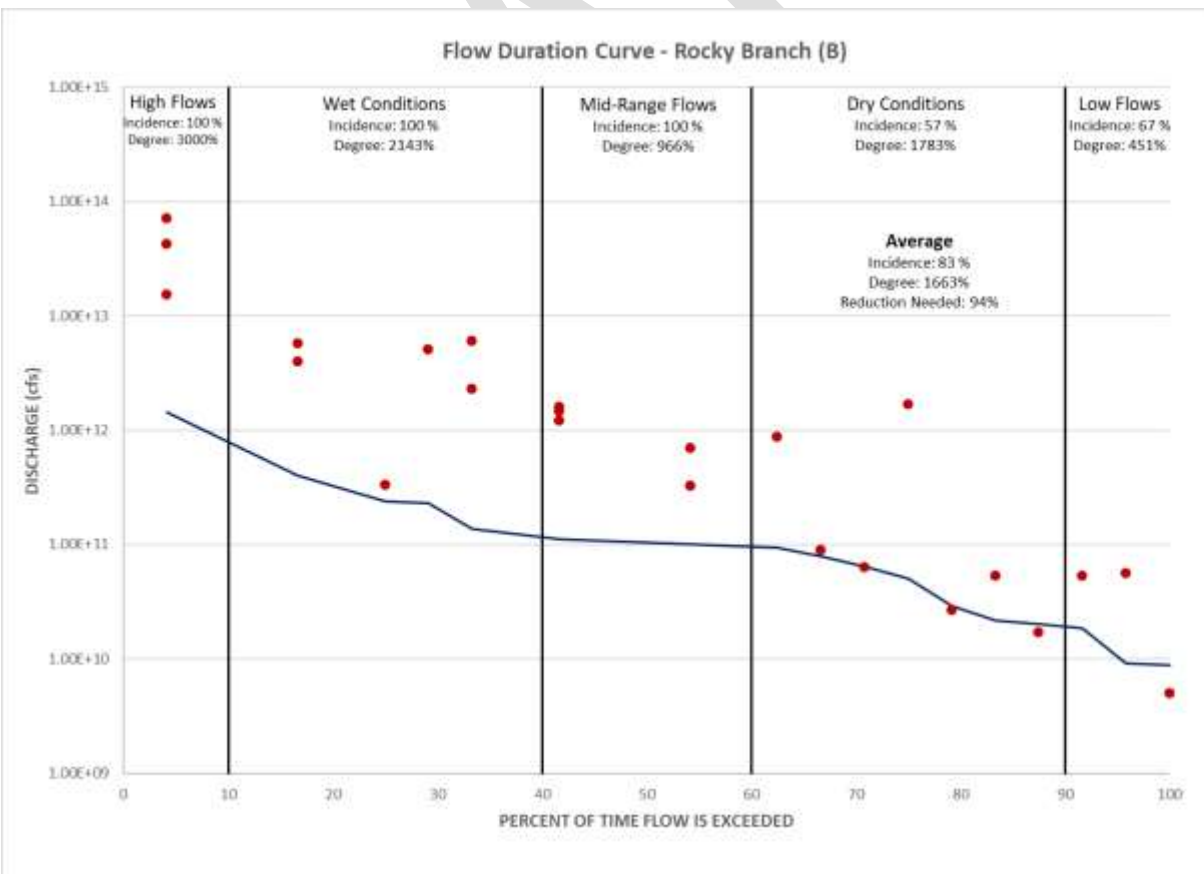

Figure 4-3: Rocky Branch Load Duration Curve

4.3 Watershed Treatment Model Results

4.3.1 Estimated Pollutant Loads from Existing Conditions

Pollutant sources were modeled in the 11 unique subwatershed WTM's by inputting information on the existing land use conditions, streams, annual rainfall, soils, riparian buffer conditions, lengths of sanitary sewer collection systems, and on-site septic systems. Livestock data was also included in the WTM, if applicable to the subwatershed. Point sources (wastewater treatment plant discharges) were not considered in the WTM models because their overall contributions to bacteria pollutant loads are very low relative to nonpoint sources, provided compliance with discharge standards is maintained. Nutrient concentrations in stream channels were not considered because the modeling analysis was focused on bacteria pollution. Combined sewer overflows and marina runoff were not considered because there are no combined sewer systems, nor marinas in the study area. Illicit discharge connections to the storm drain system were not considered as available data to approximate their impacts were unavailable. Roadway sanding was not considered because the practice is not significantly frequent in the region. Existing stormwater management practices, turf management practices, and riparian buffers were included in the Existing Conditions models. The WTM's did not include, erosion and sediment control, street sweeping, catch basin cleanouts, or marina pump outs as existing practices, while such measures were approximated in the Management Scenario models. More extensive detail on model development and the treatment of input variables is provided in **Appendix E – WTM Model Methodology**.

The WTM load estimates for all pollutants under exiting conditions are presented in **Table 4-2** and the spatial distribution of fecal coliform loads for existing conditions is illustrated in **Figure 4-4** for storm-derived loads and **Figure 4-5** for non-storm loads. The units in the table and the figures, expressed in billion colony forming units per year, are staggeringly high because the bacteria are microscopic, and these are the cumulative loads for a full year. When evaluating coliform bacteria data, it is important to focus on relative differences and changes rather than the numbers themselves. In both map figures the loads are normalized by square mile to illustrate the spatial variation of loading intensity. **Figure 4-4** illustrates that the highest intensity pollutant loads emanate from the most urbanized subwatersheds that typically exhibit the highest densities of intensities surface. As described in the previous section on load duration curves, the storm-derived loads are typically dominated by bacteria delivered through build-up/wash-off mechanisms which are greatly influenced by the presence of impervious surfaces. Conversely, non-storm loads are driven by factors such as sanitary sewer system leaks and failing or poorly performing on-site septic systems. For these reasons, the subwatersheds with the highest concentrations of septic systems figure more prominently in the non-storm loading intensities shown in **Figure 4-5**. Note also that the storm loads are an order of magnitude higher than the non-storm loads across all subwatersheds.

The sources that contribute to the current pollutant loadings in the watershed are summarized in **Section 5.0 Pollutant Source Assessment**.

Table 4-2: Existing Annual Pollutant Loads by Watershed for All WTM Output Parameters

Watershed	TN (lb/year)	TP (lb/year)	TSS (lb/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-feet/year)
Lower Sixmile-Congaree	2.41E+04	4.11E+03	5.64E+02	8.77E+14	3.58E+03
Fourteenmile Creek	6.83E+04	1.27E+04	1.48E+03	2.23E+15	9.13E+03
Congaree River East	1.76E+04	2.43E+03	4.74E+02	6.85E+14	2.61E+03
Congaree River West	2.34E+04	3.71E+03	5.47E+02	8.73E+14	3.17E+03
Congaree Creek Outlet	2.57E+04	4.21E+03	6.15E+02	8.60E+14	3.71E+03
Kinley Creek-Saluda River	3.30E+04	5.65E+03	7.88E+02	1.10E+15	4.69E+03
Saluda River North	2.22E+04	3.49E+03	5.25E+02	7.90E+14	3.22E+03
Senn Branch and Double Branch	3.40E+04	5.90E+03	7.94E+02	1.25E+15	5.02E+03
Stoop Creek	2.61E+04	4.72E+03	6.38E+02	1.06E+15	4.01E+03
UT to Congaree Creek	1.79E+04	2.82E+03	4.19E+02	6.56E+14	2.50E+03
Rocky Branch	3.41E+04	5.81E+03	1.01E+03	1.47E+15	5.48E+03
Total	**3.26E+05**	**5.55E+04**	**7.85E+03**	**1.19E+16**	**4.71E+04**

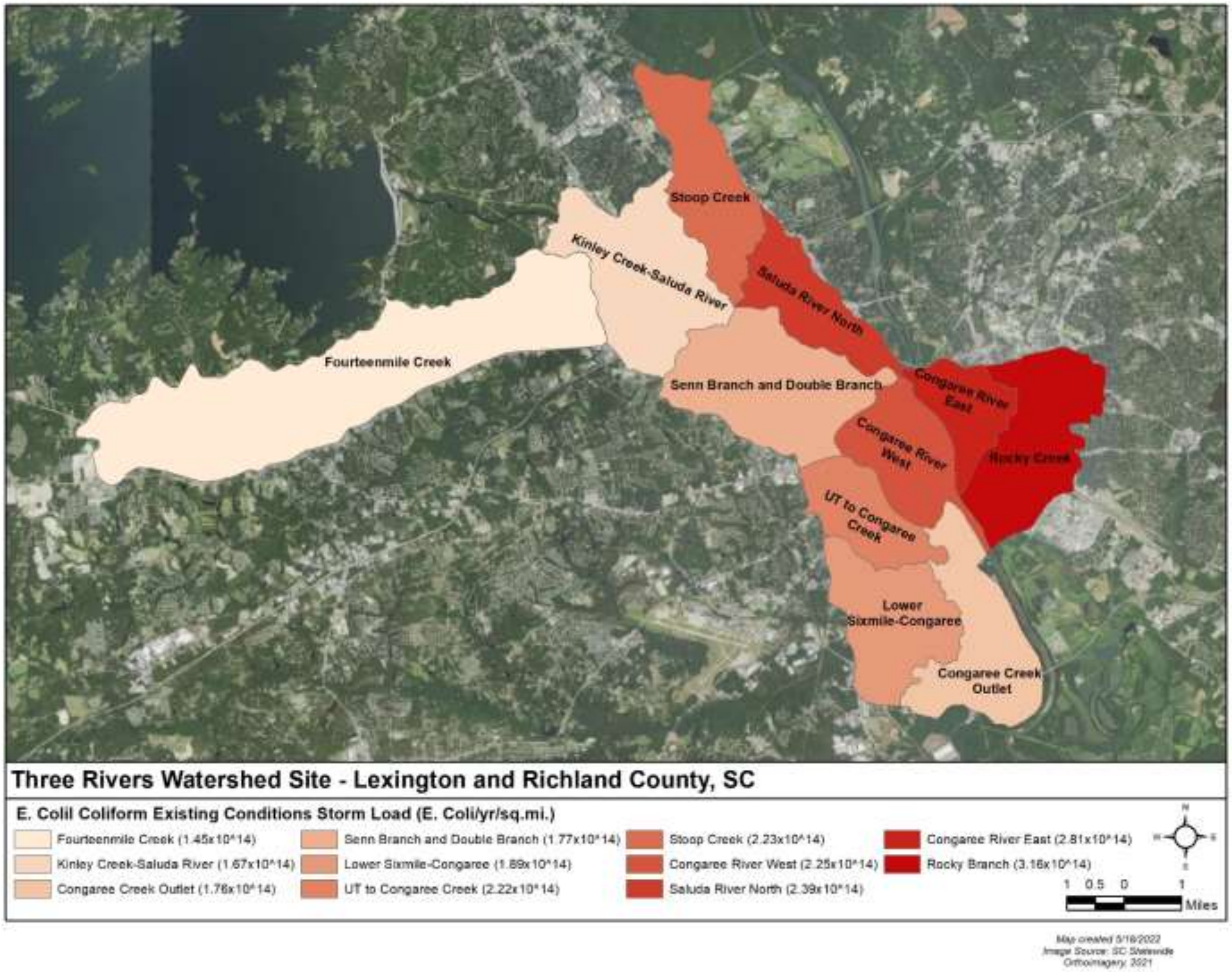

Figure 4-4: Storm-Derived Fecal Coliform Loads Per Square Mile for Existing Conditions

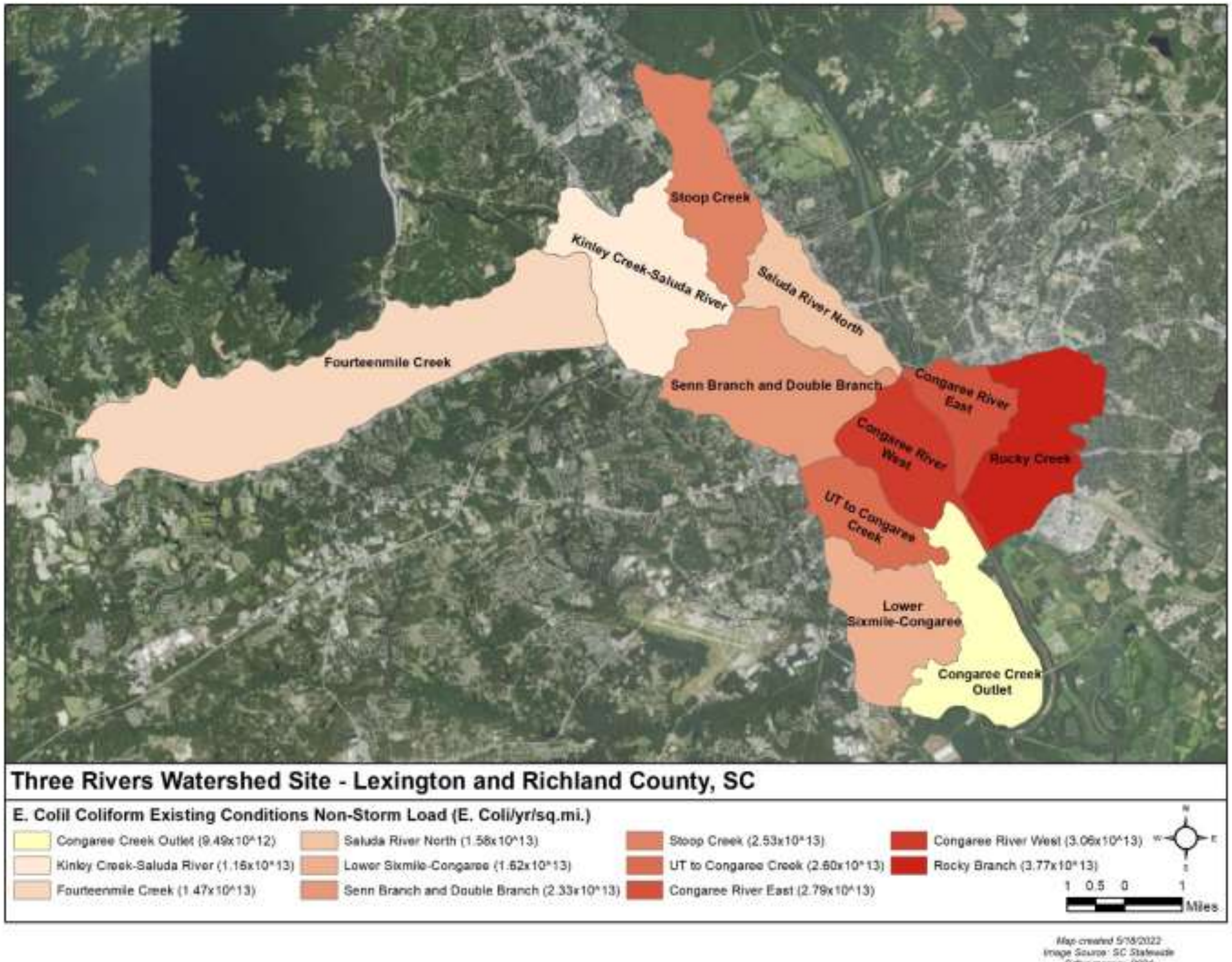

Figure 4-5: Non-Storm Fecal Coliform Loads Per Square Mile for Existing Conditions

4.3.2 Pollutant Loads from Retrofit Scenarios

KCI used the Watershed Treatment Model (WTM) to develop retrofit scenarios that reached load reduction goals for fecal coliform in the 11 subwatersheds. In this instance, the term retrofit refers to management action of implementing stormwater treatment/control practices retroactively within previous developed/built-upon landscapes at the watershed scale, as opposed to the management action of affecting improvements to individual stormwater BMPs to improve their performance. Based on the Load Duration Curves developed for this WBP (Refer to **Section 5.2** and **Appendix F**), the subwatersheds draining to the Congaree River require a reduction of 63% of the fecal coliform load to approximate compliance with water quality standards; the subwatersheds draining to the Saluda River require a reduction goal of 51%, and Rocky Branch requires a reduction of 94%.

Table 4-3 below delineates the pollutant reduction goal applied to each subwatershed by this distribution. It should be noted that the reduction goal of 94% set forth for Rocky Branch could not be achieved within the context of WTM even when the subwatershed was completely retrofitted with new stormwater BMPs and/or redeveloped with improved stormwater management. The core purpose of the Retrofit Scenarios was to illuminate the levels of effort required to approximate compliance with water quality standard for fecal coliform bacteria loading in each subwatershed, and to guide resource managers in prioritizing those management efforts that will achieve the greatest reductions.

Table 4-3: Bacteria Load Reduction Goals by Subwatershed

Congaree River (63%)	Saluda River (51%)	Rocky Branch (94%)
Congaree River East	Fourteenmile Creek	Rocky Branch
Congaree River West	Kinley Creek	
UT to Congaree Creek	Stoop Creek	
Lower Sixmile Creek	Saluda River North	
Congaree Creek Outlet	Senn Branch & Double Branch	

The retrofit model scenarios utilized non-structural measures such as *pet waste education programs*, *impervious cover disconnection*, and improved *riparian buffer maintenance and protection* to reach watershed load reduction goals. *On-site sewage disposal system (OSDS) education* and *sanitary sewer overflows (SSO) repair* programs were also included in retrofit models. KCI did not consider marina pump outs and urban downsizing as retrofit options for the watershed. In the WTMs, implementing catch basin cleanouts, street sweeping, and erosion and sediment control had no impact on reduction of fecal coliform and were not considered retrofit options. Complete details on how each of the management options available within the WTM platform were applied are provided in **Appendix E – WTM Model Methodology**. The resulting fecal coliform pollutant loads are illustrated relative to existing and future conditions (explained in the next section) in **Figure 4-6**.

The way the user controls for future management measures are structured within WTM results in a series of measures that can be turned on or off by the user, and once switched on, they are applied to the entire modeled area with accompanying assumptions, some of which can also be controlled by the user. The following is an accounting of the watershed-wide management measures applied within the WTM Retrofit Scenarios herein:

- Pet Waste Education Program implemented – assuming 40% of the total population achieved awareness of the message.
- Impervious Area/Rooftop Disconnection Program implemented – assuming the program was applicable to 90% of residential areas and 25% of the population was reached with education and outreach efforts.
- Improved Riparian Buffer Maintenance and Protection – In Existing Conditions Scenarios it was assumed that riparian buffer protection ordinances were in place in all subwatersheds, but those ordinances did not specifically restrict activities within the buffers. In the Retrofit Scenarios it was assumed that the buffer ordinances were improved to restrict activities, such as mowing and tree harvesting, that would diminish buffer pollutant removal effectiveness.

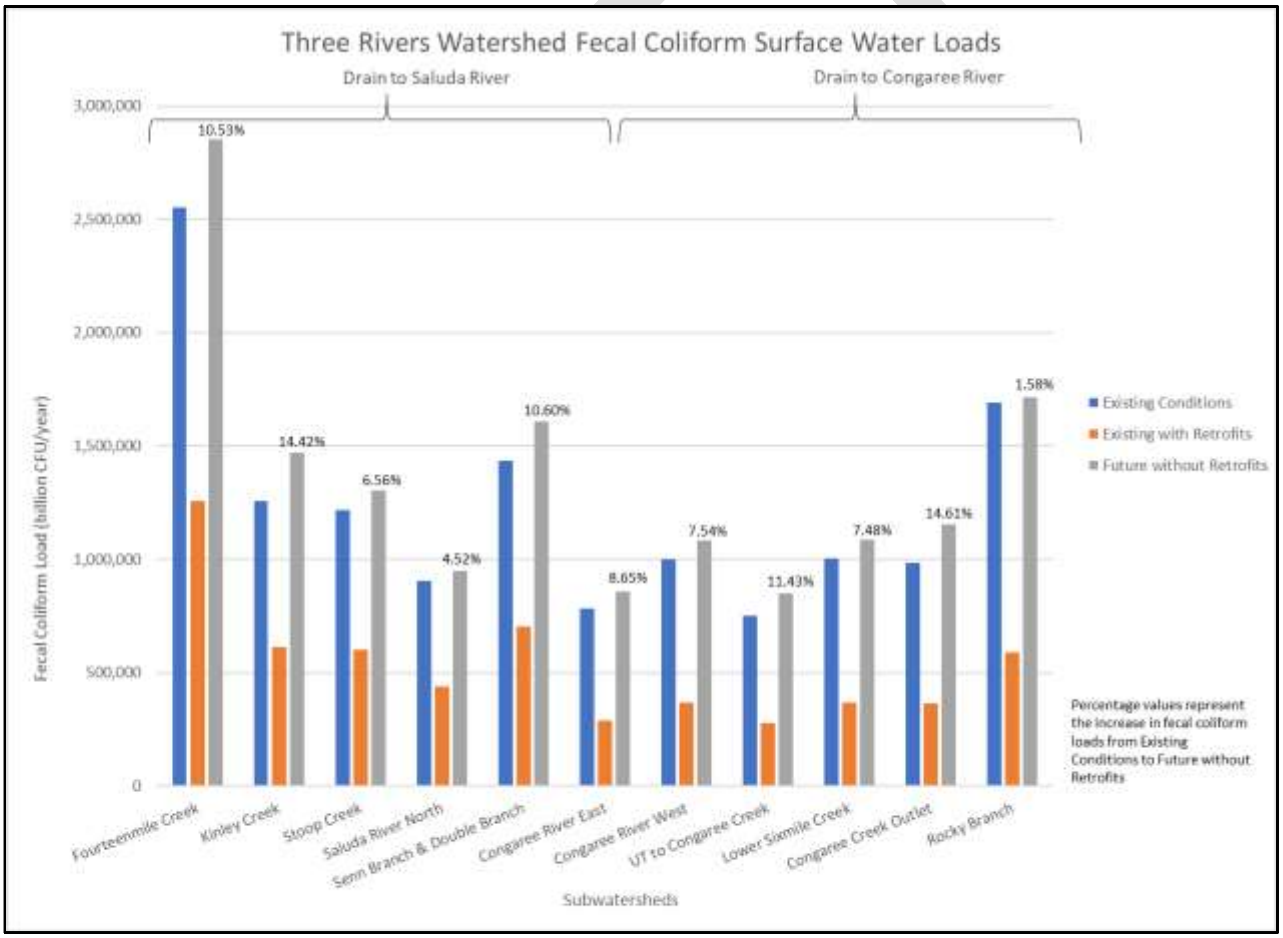

Figure 4-6: Relative Pollutant Loads for All WTM Scenarios by Subwatershed

Once these standardized controls were applied and reductions realized, the modeling team then applied a combination of stormwater *BMP retrofits*, *riparian buffer restoration* areas, and areas of *urban redevelopment* with improved stormwater management as necessary to reach the bacteria pollution reduction target for each subwatershed as determined by the Load Duration Curve analysis. A certain area of the watershed had to be treated with stormwater retrofits over and above the area already served by existing stormwater BMPs. **Table 4-4** reports the area that had to be subject to treatment by stormwater retrofits, buffer restoration areas and redevelopment areas necessary to achieve the bacteria pollutant reduction targets stipulated. All riparian buffers which were found to be in the minimum width of 0-50 feet wide (entered in WTM as 25 feet) in the existing condition were "restored" to the intermediate width category of 50-100 feet (entered in WTM as 75 feet). Areas of redevelopment of existing built-upon lands varying from 50 acres to 200 acres for each subwatershed based on professional judgement of the need and opportunity within that subwatershed were also applied within WTM, with assumptions that stormwater management would be significantly improved over existing conditions for any redevelopment projects. A higher level of redevelopment was assumed in Rocky Branch, because the need was greater to help meet the higher reduction goal. Beyond that, redevelopment is more likely to occur in the older and more urbanized communities within the watershed. Buffer restoration opportunities were maximized, and redevelopment was accounted for before the necessary stormwater retrofit areas were determined.

It should be noted that the selection of BMP types utilized for the stormwater retrofits was evenly divided between *bioretention cells*, *filter BMPs* (e.g. catch basin inserts and sand filters), constructed *stormwater wetlands*, *conventional wet ponds*, and *infiltration practices* (e.g. level spreaders, bioswales, etc.). These specific BMP types were selected because they are assigned the highest levels of bacteria pollutant removal within the WTM framework.

Table 4-4: Levels of Treatment Required to Achieve Reduction Goals by Subwatershed

WTM Subwatershed	Subwatershed Area (Acres)	Land Area Required to be Captured by Stormwater Retrofits in Model (Acres)	Percentage of Subwatershed Area Required to be Captured by Stormwater Retrofits in Model (%)	Required Stream Buffer Restoration Area (Acres)	Percentage of Subwatershed Area Redeveloped in Model (%)	Percentage Pollutant Load Reduction Achieved in Model (%)
Fourteenmile Creek	8,921	2,150	24	40	2	51
Kinley Creek	3,919	950	24	19	1	51
Stoop Creek	2,729	825	30	51	4	51
Saluda River North	1,975	450	23	27	5	51
Senn Branch & Double Branch	3,994	850	21	29	3	51
Congaree River East	1,416	750	53	0	7	63
Congaree River West	2,180	875	40	7	5	63
UT to Congaree Creek	1,692	775	46	19	3	63
Lower Sixmile Creek	2,733	1,100	40	18	7	63
Congaree Creek Outlet	2,962	1,200	44	15	3	63
Rocky Branch	2,670	2,400	90	33	10	65

After buffer restoration opportunities were maximized and redevelopment was accounted for, Fourteenmile Creek is the greatest area of the watershed required to be treated by retrofit BMPs at 2,150 acres, and the Saluda River North is the smallest area of the watershed, requiring retrofit BMPs at 450 acres. However, the large requirement for Fourteenmile Creek is primarily driven by the fact that is by far the largest watershed in the study area. Note that the 2,150 acres only amounts to 24% of the total watershed area. The subwatersheds draining to the Saluda River, which tend toward more rural and suburban character, required approximately 20-30% of their watershed areas to be retrofitted with new stormwater BMPs to achieve the 51% bacteria load reduction stipulated. By contrast, the subwatersheds draining to the Congaree River, which tend to be more urbanized, required 40-50% or more of their watershed areas to be retrofitted with new stormwater BMPs to achieve the necessary 63% bacteria load reduction.

Rocky Branch offers a somewhat different case study in that, per the indications of the load duration curve, a pollutant load reduction goal of 95% was required in that most heavily urbanized watershed. Despite aggressive retrofitting of 90% of the watershed area with new stormwater BMPs; allowing for redevelopment with improved stormwater management in the remaining 10% of the land area; and exercising all opportunities for riparian buffer restoration, an overall bacteria load reduction of 65% was the maximum that could be achieved within the context of the WTM model. This should not be taken as a reflection of the limitations of improved stormwater treatment and other management efforts to improve water quality so much as a reflection on the limitation of the WTM, which is a steady-state spreadsheet model with very simplified representations of bacteria source loading and pollutant load reduction options that do not always fit real-world scenarios. However, numerous studies and TMDL development efforts have been forced to confront the fact that bacteria pollution in urban landscapes can be quite ubiquitous, persistent, and difficult to manage. Often, the implementation plans for such studies call for aggressive adoption of a wide array of strategies to address this problem. For examples, see:

- Lincoln Urban Pollutant Reduction Strategies
- Implementation Plan for the Restoration of the Shellfish Harvesting Areas in the Lockwoods Folly River
- Implementation Plan for Bacterial TMDLs in the Back Bay Watershed
- Bacteria Reduction Implementation Plan for the Middle Huron River Watershed
- TMDL for Escherichia coli (E. coli) in the Upper Emigration Creek Watershed
- Implementation Plan for the Fecal Coliform TMDL for Four Mile Run, Virginia

In order to provide resource managers and decision makers with insights as to which management measures provided the greatest benefit in terms of bacteria pollutant load reduction, the modeling team conducted a sensitivity analysis on selected subwatersheds by toggling each management measure on and off and recording the load reduction derived from that measure. The comparative results are shown from three subwatersheds in **Table 4-5**. In all subwatersheds, most of the load reduction was achieved by stormwater retrofits and buffer restoration, along with improved buffer protection and maintenance. In areas of urban redevelopment, significant reductions were typically achieved through improved stormwater management and reduced imperviousness within each subwatershed.

Note that **Table 4-5** is not intended to convey the cost-effectiveness of management scenarios, which would require some normalization of the reduction on a per dollar basis. Rather, the table is intended to illustrate which management measures generate the greatest reductions in order to aid decision makers in prioritizing future efforts. The fact that the greatest benefits stem from retrofitting stormwater control practices and riparian buffer restoration reaffirms that most of the pollutant loading originates from stormwater runoff in this modeling analysis.

Table 4-5: Comparison of Pollutant Load Reduction Effectiveness of Management Measures

Subwatershed	Existing Bacteria Load (billion CFU/year)	Future Practice	Bacteria Load Reduction (billion CFU/year)	Percent Reduction of Existing Load	Proportion of Total Reduction
Congaree River East	785,389	Riparian Buffer Maintenance & Restoration	207,259	26%	42%
		Redevelopment with Improvements	25,993	3%	5%
		Stormwater Retrofits *	236,109	30%	48%
		OSDS Programs	9	0%	0%
		SSO Repair/ Abatement	26,612	3%	5%
Total Reduction:	63%	Pet Waste	793	0%	0%
Six Mile Creek	1,005,026	Riparian Buffer Maintenance and Restoration	268,336	27%	42%
		Redevelopment with Improvements	51,658	5%	8%
		Stormwater Retrofits *	285,605	28%	45%
		OSDS Programs	174	0%	0%
		SSO Repair/ Abatement	29,648	2%	5%
Total Reduction:	63%	Pet Waste	1,728	0%	0%
Rocky Branch	1,689,884	Riparian Buffer Maintenance & Restoration	1,888	0%	0%
		Redevelopment with Improvements	69,008	4%	6%
		Stormwater Retrofits *	946,572	56%	86%
		SSO Repair/ Abatement	66,620	4%	6%
Total Reduction:	65%	Pet Waste	2,047	0%	0%

*Reduction from stormwater retrofits includes reduction due to impervious surface/rooftop disconenction program

4.3.3 Estimated Pollutant Loads from Future Scenario

The WTM was utilized to develop Future Scenarios for the purpose of illustrating the fecal coliform load growth trends for *increased development across the study area, should no additional management measures be implemented*. The Future Scenarios were not evaluated using the same management measures (goals for percent FC reduction for each of the three basins) applied in the Retrofit Scenarios. This is because the load duration curves cannot be used to determine the degree of reduction that would be necessary to achieve approximate compliance with water quality standards in the future. A detailed description of the development of the future land use conditions utilized for these Future Scenarios is included in **Appendix E – WTM Model Methodology**.

The estimated future pollutant loads for all parameters are presented in **Table 4-6** below, and the relative percentage increase in pollutant loading for each watershed is represented in **Figure 4-6**. The largest pollutant load increases, those of 10% or more, relative to existing conditions were found to occur in the more rural subwatersheds which have greater opportunity for increases in development intensity and distribution, which are Fourteenmile Creek, Kinley Creek, Senn Branch & Double Branch, and the Congaree Creek Outlet. Congaree Creek Outlet is predicted to experience the largest increase in future pollutant loads at 14.61% of the existing load. The relatively small increases in all subwatersheds relative to existing loads across all subwatersheds are indicative of the existing condition in which the vast bulk of the study area is taken up by urban and suburban land uses.

Table 4-6: Future Pollutant Loads by Subwatershed for All WTM Output Parameters

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (lb/year)	E. coli Bacteria (MPN/year)	Runoff Volume (acre-feet/year)
Lower Sixmile-Congaree	2.60E+04	4.56E+03	6.23E+02	9.83E+14	3.91E+03
Fourteenmile Creek	7.53E+04	1.49E+04	1.71E+03	2.65E+15	1.04E+04
Congaree River East	1.92E+04	2.67E+03	5.26E+02	7.50E+14	2.91E+03
Congaree River West	2.56E+04	4.15E+03	6.10E+02	9.65E+14	3.50E+03
Congaree Creek Outlet	2.90E+04	4.87E+03	7.24E+02	1.04E+15	4.40E+03
Kinley Creek-Saluda River	3.76E+04	6.74E+03	9.40E+02	1.34E+15	5.56E+03
Saluda River North	2.30E+04	3.64E+03	5.51E+02	8.29E+14	3.39E+03
Senn Branch and Double Branch	3.89E+04	7.26E+03	9.46E+02	1.52E+15	5.72E+03
Stoop Creek	2.78E+04	5.13E+03	6.95E+02	1.16E+15	4.36E+03
UT to Congaree Creek	2.03E+04	3.32E+03	4.92E+02	7.63E+14	2.90E+03
Rocky Branch	3.46E+04	5.91E+03	1.03E+03	1.50E+15	5.59E+03
Total	**3.57E+05**	**6.31E+04**	**1.77E+07**	**8.84E+03**	**5.26E+04**

Lastly, the WTM for the Fourteen Mile Creek watershed was utilized to examine the potential impacts due to climate change. Specifically, the model was utilized to examine the increase in overall fecal coliform bacterial pollutant loads from potential increases in annual rainfall rates and potential *increases in* bacterial source concentrations driven by climate change conditions.

For the rainfall analysis, CISA compared the predicted increases in average annual rainfall rates for the Three Rivers Watershed area from 10 leading climate prediction models. Based on the analysis, summarized in **Section 2.2** and illustrated in **Figure 2-3**, CISA recommended increasing the average annual rainfall from 46 to 60 inches per year. Close examination of **Figure 2-3** shows that within the intended planning horizon of 40-50 years, the median of the 10 model predictions does not quite reach 60 inches/year, but the number of models predicting that level of rainfall increase also dramatically increases by then. Between 2050 and 2075, the median prediction by all models exceeds 60 inches/year. The analysis of model predictions of annual rainfall is presented in detail in **Appendix D – Summary of CISA Research**.

For the analysis of potential changes in bacteria source concentrations, CISA staff conducted a literature review of numerous studies focused on potential changes in fecal coliform bacteria and other pathogens as a result of climate change. The review, presented in **Appendix D** identified three primary mechanisms by which bacteria pollutant concentrations will potentially increase in the environment:

Increases in temperature result in:

- Increased evaporation rates, contributing to increased water quality issues that lead to infections, altered BMP efficacy, and/or extend the seasonality of some harmful pathogens.

Shifts in precipitation patterns have a corresponding impact on:

- Bacterial impairment, with an increase in precipitation increasing water quality issues.

Extreme precipitation events (either droughts or heavy rainfall / storms):

- Likely cause non-linear spikes that increase bacterial contamination by multiple orders of magnitude.

Based on the review, CISA recommended evaluating a 15% increase in bacteria source concentrations from all land use categories.

The Fourteen Mile Creek WTM was utilized to examine the increased rainfall scenario, the increased bacteria concentration scenario, and the two scenarios combined. The results are shown in **Figure 4-7**, along with the load predictions from the Existing Conditions and Future Land Use Change scenarios; the relative percent increase in loading from existing conditions is shown for each scenario as well. Without climate impacts, future land use changes in the watershed are predicted to result in a 13% increase in annual bacteria loads from existing conditions. The increased rainfall and increased bacteria concentration scenarios resulted in 28% and 44% increases over the annual bacteria loads in existing conditions, respectively; and the combined scenario resulted in a 64% increase in annual bacteria loading.

The Retrofit Scenarios developed for all subwatersheds were developed to determine the levels of watershed retrofitting and treatment required to reduce pollutant loads form Existing Conditions in order to achieve an approximation of compliance with water quality standards for bacteria. As a result, those retrofit models did not account for potential increases in bacteria loading from future land use development, or the potential adverse impacts of climate change. For this reason, retrofitting of stormwater control practices and other management measures to address this water quality challenge will need to be done even more aggressively to account for these additional impacts going forward. Evaluating how changes for specific precipitation return intervals (such as rainfall depth, intensity, and duration) are outside the scope of this WBP. However, stormwater managers in the 3RW Area should consider how these changes could affect conveyance, storage, and treatment capacity of stormwater BMPs. Some measures that can help adapt to climate change include:

1. Implementing Low Impact Development practices at the site scale;
2. Modifying practices to prevent bypass during intense storm events;
3. Periodically reevaluating the predicted intensity of storms occurring at regular intervals (e.g. the intensity of storm we would expect, statistically, to occur every 5 years) and the resulting increase in mapped floodplain areas;
4. Creating adaptable planting plans (use native plants); and
5. Using stormwater as a resource (e.g. irrigation or other non-potable uses)[42].

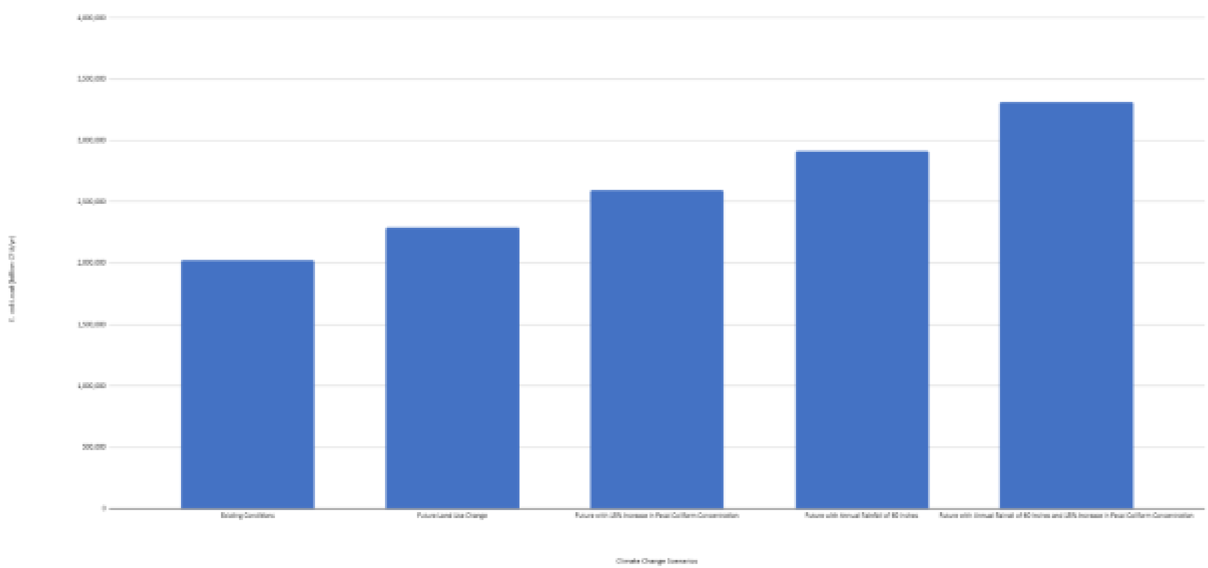

Figure 4-7: Fourteenmile Creek Fecal Coliform Storm Loads for Future and Climate Change Scenarios with Percent Increases Relative to Existing Load

[42] Appendix G: "Adapting Stormwater Management for Climate Change." *Low Impact Development in Coastal South Carolina: A Planning and Design Guide.* Available for download at: https://www.scseagrant.org/wp-content/uploads/LID-in-Coastal-SC-low-res.pdf

5.0 Pollutant Source Assessment

Potential sources of pollutants are reviewed in the following section using available data and information. Sources of nutrients, sediment, metals, bacteria, and other pollutants are considered in relation to where these sources may occur in the watershed and the potential impacts they may have on water quality and aquatic life.

5.1 Point Sources

5.1.1 NPDES Permits

The National Pollutant Discharge Elimination System (NPDES) was developed by EPA to regulate point source pollutant discharges to surface waters. In South Carolina, NPDES permitted dischargers must comply with discharge limitations that are set by SCDHEC to protect downstream waterbodies.

Table 5-1 lists and **Figure 5-1** shows the locations of the 37 NPDES permitted facilities within the SCDHEC database, with both active and inactive permits. Three NPDES permitted facilities are active dischargers to surface waters in the watershed. If non-compliant with their permit, the NPDES discharges may contribute to declines in aquatic species populations in combination with other sources of potential toxins (stormwater runoff, agriculture, and hazardous waste), and some may be significant pollutant sources in the watershed.

Table 5-1: NPDES Permits in the Three Rivers Watershed

NPDES	Name	Status	Type	Description
SC0029483	ALPINE UTILITIES/STOOP CREEK	Active	Domestic	Land Subdividers and Developers, Except Cemeteries
SCG646014	CAYCE, CITY OF WTP	Active	Municipal	Water Supply
SCG646055	CITY OF CAYCE WTP	Active	Municipal	
SCG646026	COLUMBIA CANAL WTP	Active	Municipal	Water Supply
SC0002062	COLUMBIA HYDROELECTRIC PROJECT	Active	Industrial	Electric Services
SC0035564	CWS/I-20 REGIONAL	Active	Domestic	Land Subdividers and Developers, Except Cemeteries
SC0027162	CWS/WATERGATE DEVELOPMENT	Active	Domestic	Operators of Dwellings Other Than Apartment Buildings
SC0032743	DEVELOPMENT SERVICE INC	Active	Domestic	Land Subdividers and Developers, Except Cemeteries
SCG730263	MARTIN MARIETTA/CAYCE QUARRY	Active	Industrial	
SC0048330	PHILIPS ELECTRONICS N AMERICA	Active	Industrial	Electronic Capacitors
SC0003557	SHAW INDUSTRIES GROUP/COLUMBIA	Active	Industrial	Manmade Organic Fibers, Except Cellulosic
SC0003557	SHAW INDUSTRIES GROUP/COLUMBIA	Active	Industrial	Manmade Organic Fibers, Except Cellulosic
SC0003557	SHAW INDUSTRIES GROUP/COLUMBIA	Active	Industrial	Manmade Organic Fibers, Except Cellulosic
SCG730054	VULCAN CONST MAT/COLUMBIA QUAR	Active	Industrial	Crushed and Broken Granite
SCG646005	WEST COLUMBIA/CITY OF/WTP	Active	Municipal	
SC0029475	WOODLAND HILLS WEST SD	Active	Domestic	Operators of Dwellings Other Than Apartment Buildings
SC0044946	AMERADA HESS #40234	Inactive	Industrial	Gasoline Service Stations
SC0003425	BC COMPONENTS INC	Inactive	Industrial	Electronic Capacitors
SC0003425	BC COMPONENTS INC	Inactive	Industrial	Electronic Capacitors

NPDES	Name	Status	Type	Description
SC0003425	BC COMPONENTS INC	Inactive	Industrial	Electronic Capacitors
SC0040924	CAYCE, CITY OF WTP	Inactive	Industrial	Water Supply
SCG830007	FORMER GULF/CHEVRON #336297	Inactive	Industrial	
SCG830004	KEENAN OIL CO/PHILLIPS 66 STA	Inactive	Industrial	
SC0034436	LEXINGTON/LAKEWOOD WWTP	Inactive	Municipal	Operators of Dwellings Other Than Apartment Buildings
SC0043541	LEXINGTON/WHITEFORD SD WWTP	Inactive	Municipal	Sewerage Systems
SCG730640	MERRY LAND CLAY/CORLEY MINE	Inactive	Industrial	
SC0037613	RIVERBANKS ZOOLOGICAL PARK	Inactive	Industrial	Arboreta and Botanical or Zoological Gardens
SC0037613	RIVERBANKS ZOOLOGICAL PARK	Inactive	Industrial	Arboreta and Botanical or Zoological Gardens
SC0037613	RIVERBANKS ZOOLOGICAL PARK	Inactive	Industrial	Arboreta and Botanical or Zoological Gardens
SC0037613	RIVERBANKS ZOOLOGICAL PARK	Inactive	Industrial	Arboreta and Botanical or Zoological Gardens
SC0037613	RIVERBANKS ZOOLOGICAL PARK	Inactive	Industrial	Arboreta and Botanical or Zoological Gardens
SC0041386	SC DEPT AGRIC/CALIBRATION STAT	Inactive	Industrial	Heavy Construction, NEC
SC0041386	SC DEPT AGRIC/CALIBRATION STAT	Inactive	Industrial	Heavy Construction, NEC
SC0044814	SCE&G/COIT GAS TURBINE	Inactive	Industrial	Electric Services
SC0044296	SCE&G/HOLLAND STREET CREW QTRS	Inactive	Industrial	Gasoline Service Stations
SC0045128	SPEEDWAY SUPERAMERICA LLC #289	Inactive	Industrial	Gasoline Service Stations
SCG730054	VULCAN CONST MAT/COLUMBIA QUAR	Inactive	Industrial	Crushed and Broken Granite

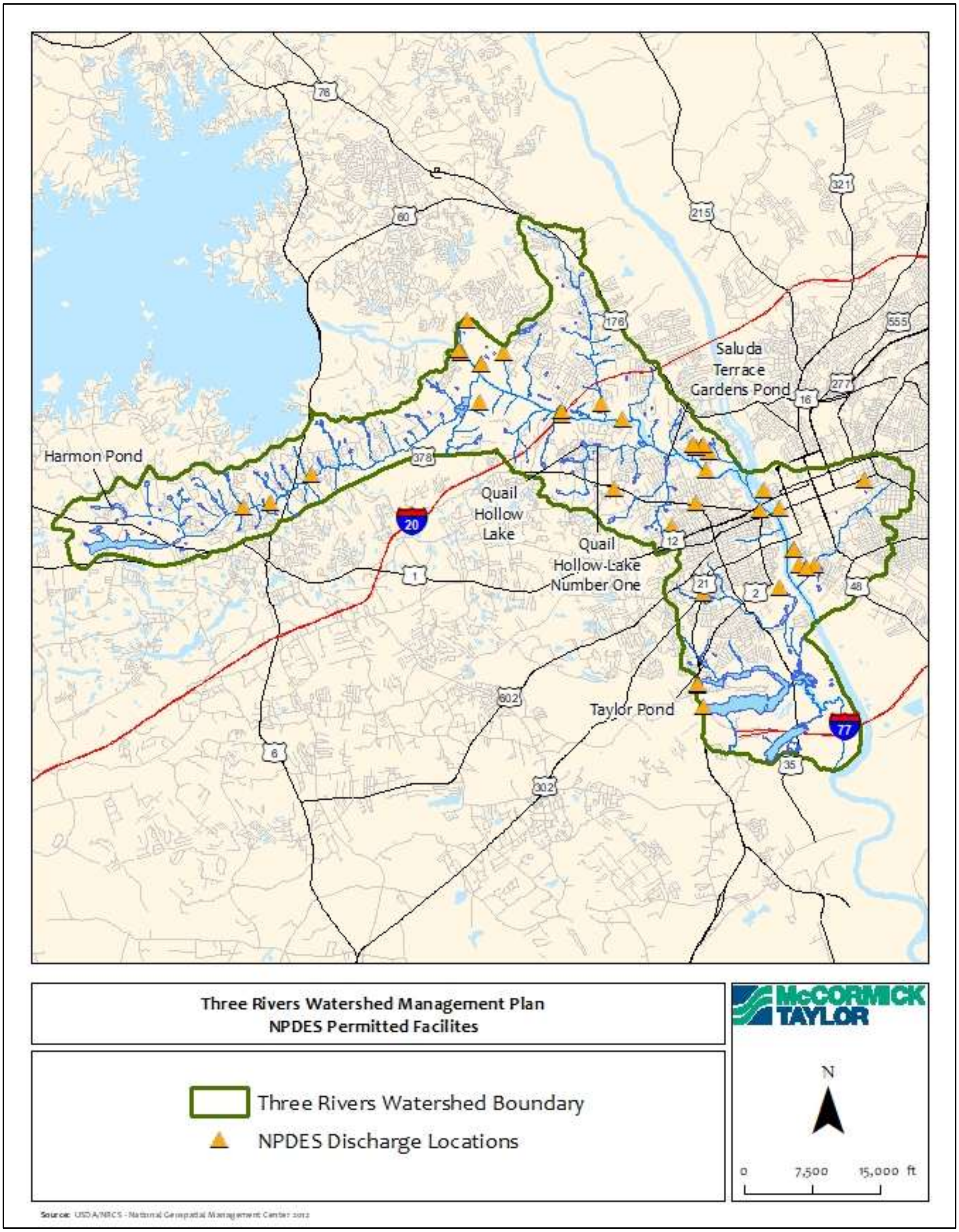

Figure 5-1: SCDHEC Permitted Facilities (NPDES and Mines)

5.2 Nonpoint Sources due to Human Waste

Human waste is a direct contributor to *E. coli* pollution, and negatively impacts water quality if it contacts surface water resources through sanitary sewer spills or septic system infiltration. This section provides estimates of sewer infrastructure in the 3RW Area and the potential negative impacts that poor maintenance of these systems may have in water quality.

5.2.1 SSOs

Sanitary Sewer Overflows (SSOs) are sources of sediment, nutrients, bacteria, and toxins during storm events. These overflows are caused when surface water enters sewer systems beyond their designed flow capacity, causing the sewers to overflow and release raw sewage. During these events, the released sewage may enter nearby waterbodies and cause an acute increase in pollutant concentrations. **Table 5-2** summarizes the length of pipelines in municipal sewer districts in the Three Rivers Watershed; in total there are 532 miles of sanitary sewer lines (including gravity and forcemain) connecting homes and business in the watershed to their respective wastewater treatment service providers. SSO reports[43] can be obtained from SCDHEC that estimate the volume of wastewater spilled in an area; but the current system does not allow querying by spatial boundaries (e.g. the 3RW boundary line). **Table 5-3** is an overview of local SSO data in Richland and Lexington Counties between 2017 and 2020. **Table 5-4** summarizes the WTM estimates for the total annual loads associated with SSOs in the entire 3RW Area current conditions (all 11 subwatersheds) to be 2.25×10^{3} lb/yr TN; 5.41×10^{2} lb/yr TP; 1.08×10^{1} ton/yr TSS; and 2.14×10^{15} bacteria/yr.

Table 5-2: Sanitary Sewer Pipe Lengths in Three Rivers Watershed

System Name	Length (miles)
Bush River	4
Cayce	97
Cola FM	8
Cola Gravity	159
Town of Lexington	95
PWR	47
West Columbia	119
Total	**532**

[43] https://epermweb.dhec.sc.gov/ncore/external/overflow/list

Table 5-3: SCDHEC Sanitary Sewer Overflow Records

County	Responsible Party	# Spills	Average Volume (gallons)	Max spill (gallons)
Richland	Blue Granite	1	900	
	Synergy Utilities LP	1	5,000	
	City of Columbia	539	3,457	134,863
Lexington	City of Cayce	13	1,854	4,500
	Town of Lexington	8	1,663	5,000
	Palmetto Wastewater Reclamation (PWR)	19	3,315	53,487
	Richland County Utilities	1	4,000	
	Serenity Apartments	1	200	
	Synergy Utilities	2	3,500	5,000
	City of West Columbia	5	2,880	5,000

Table 5-4: Estimated Pollutant Loads Resulting from SSO's

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (lb/year)	*E. coli* Bacteria (MPN/year)
Congaree Creek Outlet	1.33E+02	2.20E+01	4.45E-01	8.81E+13
Congaree River East	1.88E+02	3.10E+01	6.25E-01	1.24E+14
Congaree River West	3.17E+02	5.30E+01	1.06E+00	2.09E+14
Fourteenmile Creek	6.00E+02	1.00E+02	2.00E+00	3.96E+14
Kinley Creek	2.15E+02	3.60E+01	7.16E-01	1.42E+14
Lower Sixmile Creek	2.09E+02	3.50E+01	6.97E-01	1.38E+14
Rocky Branch	4.70E+02	7.80E+01	1.57E+00	3.10E+14
Saluda River North	1.45E+02	2.40E+01	4.83E-01	9.56E+13
Senn Branch & Double Branch	4.38E+02	7.30E+01	1.46E+00	2.89E+14
Stoop Creek	3.27E+02	5.50E+01	1.09E+00	2.16E+14
UT to Congaree Creek	2.08E+02	3.50E+01	6.93E-01	1.37E+14
Total	**3.25E+03**	**5.41E+02**	**1.08E+01**	**2.14E+15**

5.2.2 Septic Systems

Septic systems that are not properly maintained are a potential source of nutrients and bacteria in surface and groundwater. As previously shown in **Figure 2-20: Municipal Sewer Service Districts**, although the watershed is served by multiple municipal sewer systems, there are still many areas without sanitary sewer connections. Estimates for areas on septic systems are provided in **Table 5-5**. The assumption is that new or recent development is likely to be served by municipal sewer systems and not septic systems. Older development may be served by septic systems or other onsite wastewater facilities. However, exact geographic locations for these systems are not known. Based on an assumption of 10% failure rate, sandy soils, and conventional systems, the WTM predicts the average annual loading associated with septic systems (**Table 5-6**) to be 4.82×10^3 lb/yr TN; 8.04×10^2 lb/yr TP; 1.60×10^1 ton/yr TSS; and 6.36×10^{12} bacteria/yr.

Table 5-5: Three Rivers Watershed Septic Estimates

Subwatershed	Area (acres)	Potential Septic	Total Buildings	Percent Septic
Congaree Creek Outlet	2,962	16	42	38%
Congaree River East	1,416	6	707	1%
Congaree River West	2,180	121	3,229	4%
Fourteenmile Creek	8,921	1,166	5,740	20%
Kinley Creek-Saluda River	3,919	147	1,835	8%
Lower Sixmile-Congaree	2,733	131	1,541	9%
Rocky Branch	3,180	0	7,301	0%
Saluda River North	1,975	536	1,297	41%
Senn Branch and Double Branch	3,994	459	3,882	12%
Stoop Creek	2,729	68	2,994	2%
UT to Congaree Creek	1,692	270	1,801	15%
Total		**2,920**	**30,369**	**10%**

Table 5-6: Estimated Pollutant Loads Resulting from Septic Systems

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (lb/year)	Fecal Coliform (billion/year)
Congaree Creek Outlet	2.80E+01	5.00E+00	9.15E-02	3.66E+10
Congaree River East	1.20E+01	2.00E+00	4.05E-02	1.57E+10
Congaree River West	2.06E+02	3.40E+01	6.87E-01	2.72E+11
Fourteenmile Creek	1.98E+03	3.30E+02	6.60E+00	2.61E+12
Kinley Creek	2.53E+02	4.20E+01	8.44E-01	3.34E+11
Lower Sixmile Creek	2.26E+02	3.80E+01	7.53E-01	2.98E+11
Rocky Branch	-	-	-	-
Saluda River North	9.23E+02	1.54E+02	3.08E+00	1.22E+12
Senn Branch & Double Branch	7.90E+02	1.32E+02	2.63E+00	1.04E+12
Stoop Creek	1.19E+02	2.00E+01	3.96E-01	1.57E+11
UT to Congaree Creek	2.79E+02	4.70E+01	9.32E-01	3.69E+11
Total	**4.82E+03**	**8.04E+02**	**1.60E+01**	**6.36E+12**

These estimates can be adjusted as better information is made available. For example, on March 2021 in collaboration with the Lexington County GIS department, a desktop GIS analysis was undertaken to estimate the number of properties that are not currently tied to a sewer system[44]. Utilizing a combination of older data on septic system distribution, the US Census Bureau, and tax records, this preliminary analysis estimated that 7,300 buildings are utilizing septic systems throughout the Lexington County portion of the 3RW Area. This analysis would need to be extended across the whole 3RW Area to provide updated pollutant loadings through the WTM. But based on a linear relationship of pollutant load and septic system count, a 10% failure rate, sandy soils, and conventional systems, these updated estimates could average annual loadings of 17,937 lb/yr TN; 2,988 lb/yr TP; 119,586 lb/yr TSS; and 27,144 billion bacteria per year. This exemplifies both the value and need of refining data sources as BMP planning and implementation continues throughout the 3RW Area. This can be achieved through an updated methodology like the one utilized in the Lexington County portion of the 3RW Area and supplemented with surveys or other methods that would validate these data.

5.2.3 Illicit Discharges, Sewer Disconnect Issue

In many communities across South Carolina, citizens receive their water and sewer service from separate providers. As a result of this multi-utility structure, a customer's sewer service can be terminated for non-payment while still receiving water service. This may create a scenario where, despite sewer service being disconnected for lack of payment, residents can use the water utility service to illegally discharge untreated sewage directly into neighborhoods and local waterways, contributing to environmental and public health risks.

Coordination between separate sewer and water utility services may improve response to this type of illegal discharge of untreated sewage. But the larger issue is procedural in nature: water utility services, if being paid by a resident, typically are not able shut off service without providing proper notice of the upcoming disconnection. The lack of payment, and disconnection, of a separate sewer utility may have no legal bearing in this process. The water service may continue to be utilized as normal during the disconnection notice period, possibly discharging untreated sewage for an extended period.

A common way to address the issue is to report the illicit discharge to SCDHEC as a Sanitary Sewer Overflow (SSO). While this process eventually stops the illicit discharge, it limits the types of actions utility providers may implement to immediately address these SSOs. This protracted process may allow an environmental and public health risk to continue unabated, possibly leading to larger environmental damage than if they were addressed in a timely manner. During the development of this plan, the 3RW Stakeholder Group supports cross-jurisdictional programmatic or legal recommendations that address this issue and facilitate rapid response to SSOs when a property is provided water and sewer utility service by separate entities.

[44] Personal communication, 14 June 2021

5.3 Other Nonpoint Sources

5.3.1 Agriculture

Livestock

Livestock production can lead to increased pollutant concentrations in downstream waterbodies. Where livestock have unlimited access to streams, animals may contribute fecal matter directly to streams and cause severe disturbance to stream banks. Runoff from livestock facilities (pasture, paddocks, manure storage areas, etc.) can introduce sediment, nutrients, bacteria, and toxins to surface waters. Very few livestock operations were successfully identified in the watershed. Responses in the stakeholder hotspot map identified several small hobby farms with a total of about 70 cows, all within the Fourteenmile Creek subwatershed. The estimated pollutant loads from these cows are 1,995 lb/yr TN; 228 lb/yr TP; and 7,600 billion bacteria/yr.

Rural Land

In the WTM, rural areas (1,016 acres or about 3% of the total 3RW Area) included barren, dwarf scrub, herbaceous, and planted/cultivated NLCD land covers. Nonpoint source pollutants associated with agricultural crop production include nutrients, sediment, bacteria, and toxins. Sediment loading occurs through erosion of bare or disturbed soils. Nutrients in agricultural runoff originate from exposed soil as well as from applied fertilizers. Bacteria may originate from livestock manure applied to agricultural land. Toxins in agricultural runoff, including pesticides, typically originate from chemical applications to cropland. Metals, which are potential toxins, may also be released in agricultural runoff, and these toxins may originate from both manure and mineral-based fertilizer applications. Toxins from chemical applications may contribute to declines in aquatic species populations in combination with other sources (urban/suburban runoff, point sources, and hazardous waste). The WTM estimates the total annual loading associated with rural/cropland areas (**Table 5-7**) to be $2.32\text{x}10^{4}$ lb/yr TN; $3.53\text{x}10^{3}$ lb/yr TP; $2.52\text{x}10^{2}$ ton/yr TSS; $1.72\text{x}10^{14}$ E. Coli/yr; and 631 acre-ft of runoff per year.

Table 5-7: Estimated Pollutant Loads Resulting from Rural/Cropland Land Uses

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (lb/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	3.57E+03	5.43E+02	3.88E+01	2.64E+13	1.03E+02
Congaree River East	2.29E+02	3.50E+01	2.49E+00	1.70E+12	8.00E+00
Congaree River West	5.04E+02	7.70E+01	5.48E+00	3.73E+12	8.00E+00
Fourteenmile Creek	8.86E+03	1.35E+03	9.63E+01	6.55E+13	2.34E+02
Kinley Creek	3.44E+03	5.23E+02	3.74E+01	2.54E+13	9.80E+01
Lower Sixmile Creek	2.20E+03	3.35E+02	2.39E+01	1.63E+13	6.10E+01
Rocky Branch	1.25E+02	1.90E+01	1.36E+00	9.22E+11	4.00E+00
Saluda River North	5.63E+02	8.60E+01	6.12E+00	4.16E+12	1.40E+01
Senn Branch & Double Branch	2.37E+03	3.61E+02	2.58E+01	1.75E+13	6.30E+01
Stoop Creek	9.74E+02	1.48E+02	1.06E+01	7.21E+12	2.80E+01
UT to Congaree Creek	3.88E+02	5.90E+01	4.22E+00	2.87E+12	1.10E+01
Total	**2.32E+04**	**3.53E+03**	**2.52E+02**	**1.72E+14**	**6.31E+02**

5.3.2 Forests and Silviculture

Silviculture, which involves managing forests for a particular goal, can have both positive and negative effects on water quality and aquatic habitat. When forest is managed to prevent catastrophic fires, a watershed is at less risk for high sediment loading than would occur after a catastrophic event. On a much smaller scale, fire prevention techniques may increase sediment loading due to removal of vegetation during prescribed burns or thinning. Forests account for 6,087 acres in the Three Rivers Watershed, but there are no large silviculture industries in the watershed.

The WTM estimates that pollutant loads associated with forested land in the 3RW Area to be8.68x10^2 lb/yr TN; 6.90x10^1 lb/yr TP; 1.74x10^1 ton/yr TSS; 3.63x10^{12} bacteria/yr; and 631 acre-ft of runoff per year.

Table 5-8: Estimated Pollutant Loads Resulting from Forested Land Uses

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	9.90E+01	8.00E+00	1.99E+00	4.15E+11	1.03E+02
Congaree River East	1.09E+02	9.00E+00	2.18E+00	4.55E+11	8.00E+00
Congaree River West	4.30E+01	3.00E+00	8.52E-01	1.78E+11	8.00E+00
Fourteenmile Creek	6.30E+01	5.00E+00	1.26E+00	2.63E+11	2.34E+02
Kinley Creek	8.30E+01	7.00E+00	1.65E+00	3.46E+11	9.80E+01
Lower Sixmile Creek	6.00E+01	5.00E+00	1.20E+00	2.51E+11	6.10E+01
Rocky Branch	9.80E+01	8.00E+00	1.96E+00	4.09E+11	4.00E+00
Saluda River North	1.15E+02	9.00E+00	2.30E+00	4.81E+11	1.40E+01
Senn Branch & Double Branch	6.00E+01	5.00E+00	1.20E+00	2.52E+11	6.30E+01
Stoop Creek	1.34E+02	1.10E+01	2.67E+00	5.60E+11	2.80E+01
UT to Congaree Creek	5.00E+00	0.00E+00	1.09E-01	2.27E+10	1.10E+01
Total	**8.68E+02**	**6.90E+01**	**1.74E+01**	**3.63E+12**	**6.31E+02**

5.3.3 Wildlife

Natural areas that support wildlife generally represent the unimpacted state of the watershed, and wildlife feces are considered a background source of nutrients and bacteria in surface water. The wildlife-supporting land uses could include forest, rural, open water, low density residential and medium density residential areas. The WTM does not explicitly calculate a specific loading associated with wildlife; it is the recommendation of this plan to focus on reducing the loads from the human sources of bacteria. If jurisdictions in the 3RW Area feel further study is warranted, they can pursue microbial source tracking (MST) to determine if bacteria found in surface waters are due to human waste, domestic animal waste, and wildlife (for example, private companies can determine if bacteria in runoff comes from wildlife such as geese, gulls, deer, and beavers).

5.3.4 Urban/Suburban Runoff

Urban/suburban runoff is like agricultural runoff in that it includes nutrients, sediment, bacteria, and toxins. However, a major difference lies in how and when the runoff from urban and suburban landscapes is delivered to waterbodies. Urban/suburban runoff is usually routed from impervious surfaces either directly to waterbodies or somewhere just upstream of waterbodies. These different runoff characteristics threaten streams and other waterbodies from urban/suburban runoff in several different ways. The first, and potentially most influential threat, is from the increased stormwater discharges that are delivered directly to streams where both the volume and velocities of the flows are often drastically higher than runoff from undeveloped lands. Secondly, the increased overland flow that is often associated with urban/suburban impervious surfaces decreases the amount of stormwater that flows through subsurface processes from which groundwater is recharged, thus leading to lower base flows. Thirdly, urban/suburban land uses can increase pollutant loads in stormwater runoff through erosion from disturbed areas (e.g., construction sites), build-up and wash-off of pollutants, illicit connections, and dumping into storm sewers. Another common threat from urban/suburban development is the increase in stream temperatures due to lack of shading as well as heated stormwater runoff from ponds and impervious surfaces. Finally, a decreased population and diversity of plants and animals is usually observed in urban/suburban areas due to the poor quality of habitat. All these mechanisms can contribute to waterbody impairment, both from a human health and aquatic life perspective.

A significant portion of the Three Rivers Watershed has been developed into urban/suburban lands (25,917 acres or 73%), which includes residential, commercial, industrial, and roadway land uses. Estimates of loads from these land uses are summarized in the tables below. As shown in **Table 5-9**, the low-density residential land use is estimated to create the most runoff (7,921 acre-ft per year) and thus generates the most pollutants in the entire 3RW Area. Multi-family land use contributes the least amount of runoff and pollutant loading. This reflects the difference in size of these areas (13% low density residential vs. 3% multifamily). The largest overall residential contributors to bacteria in the 3RW Area subwatersheds were estimated as follows:

- Fourteenmile Creek, LDR (6.88×10^{14} bacteria/yr)
- Fourteenmile Creek, MDR (3.08×10^{14} bacteria/yr)
- Senn Branch & Double Branch, MDR (2.62×10^{14} bacteria/yr)
- Kinley Creek, LDR (2.13×10^{14} bacteria/yr)
- Senn Branch & Double Branch, LDR (2.1×10^{14} bacteria/yr)
- Kinley Creek, MDR (1.88×10^{14} bacteria/yr)
- Rocky Branch, HDR (1.87×10^{14} bacteria/yr)

Table 5-9: Estimated Pollutant Loads Resulting from Residential Land Uses for Entire 3RW Area

Land Use	TN (lb/year)	TP (lb/year)	TSS (ton/year)	E. Coli (MPN/year)	Runoff Volume (acre-ft/yr)
Low Density Residential (LDR)	45,111	6,659	5.26E+02	1,958,032	7,921
Medium Density Residential (MDR)	38,246	5,646	4.46E+02	1,660,077	6,716
High Density Residential (HDR)	19,484	2,876	2.27E+02	845,724	3,421
Multifamily	11,508	1,699	1.34E+02	499,523	2,021
Total	**114,350**	**16,880**	**1.33E+03**	**4,963,355**	**20,078**

Table 5-10 summarizes pollutant loads associated with commercial and industrial land uses. Across the entire 3RW Area, commercial land creates 2.14×10^{4} acre-ft of runoff annually, which contains 4.60×10^{15} bacteria/yr; 1.22×10^{5} lb/yr of TN; 1.27×10^{4} lb/yr TP; and 1.24×10^{3} ton/yr of TSS. Industrial land generates

2.16×10^{3} acre-ft of runoff annually, which contains 4.6×10^{14} bacteria/yr; 1.29×10^{4} lb/yr of TN; 1.46×10^{3} lb/yr TP; and 2.37×10^{2} ton/yr of TSS. The watersheds with the greatest overall bacteria loads from commercial land use are Fourteenmile Creek and Rocky Branch; the subwatersheds with the greatest overall bacteria loads from industrial land use are Congaree Creek Outlet and Rocky Branch.

Table 5-10: Estimated Pollutant Loads Resulting from Commercial & Industrial Land Uses

Subwatershed	Land Use	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	Commercial	1.15E+04	1.20E+03	1.17E+02	4.34E+14	2.01E+03
Congaree Creek Outlet	Industrial	3.72E+03	4.22E+02	6.84E+01	1.34E+14	6.23E+02
Congaree River East	Commercial	8.51E+03	8.92E+02	8.72E+01	3.22E+14	1.50E+03
Congaree River East	Industrial	5.00E+00	1.00E+00	9.50E-02	1.87E+11	1.00E+00
Congaree River West	Commercial	7.72E+03	8.08E+02	7.90E+01	2.92E+14	1.36E+03
Congaree River West	Industrial	1.03E+03	1.17E+02	1.89E+01	3.71E+13	1.72E+02
Fourteenmile Creek	Commercial	2.00E+04	2.10E+03	2.05E+02	7.58E+14	3.51E+03
Fourteenmile Creek	Industrial	-	-	-	-	-
Kinley Creek	Commercial	1.15E+04	1.21E+03	1.18E+02	4.36E+14	2.02E+03
Kinley Creek	Industrial	2.70E+03	3.07E+02	4.97E+01	9.75E+13	4.52E+02
Lower Sixmile Creek	Commercial	1.10E+04	1.15E+03	1.12E+02	4.15E+14	1.92E+03
Lower Sixmile Creek	Industrial	9.77E+02	1.11E+02	1.80E+01	3.53E+13	1.64E+02
Rocky Branch	Commercial	15,357	1,609	1.57E+02	5.82E+14	2.70E+03
Rocky Branch	Industrial	3,128	355	5.76E+01	1.13E+14	5.24E+02
Saluda River North	Commercial	10,839	1,136	1.11E+02	4.10E+14	1.90E+03
Saluda River North	Industrial	-	-	-	-	-
Senn Branch & Double Branch	Commercial	11,199	1,173	1.15E+02	4.24E+14	1.97E+03
Senn Branch & Double Branch	Industrial	25	3	4.67E-01	9.16E+11	4.00E+00
Stoop Creek	Commercial	8,259	865	8.46E+01	3.13E+14	1.45E+03
Stoop Creek	Industrial	56	6	1.03E+00	2.03E+12	9.00E+00
UT to Congaree Creek	Commercial	5,780	606	5.92E+01	2.19E+14	1.02E+03
UT to Congaree Creek	Industrial	1,253	142	2.31E+01	4.53E+13	2.10E+02
Total		**1.34E+05**	**1.42E+04**	**1.48E+03**	**5.07E+15**	**2.35E+04**

Finally, roadways are a key component of the urban/suburban landscape and contribute to water quality degradation. As stormwater flows over streets, it can carry pollutants such as sediment, nutrients, fertilizers, pesticides, oil, bacteria, and trash along the way. To address this pollution, MS4s can implement control strategies to prevent or eliminate the discharge of bacteria, including source control and preemptive activities such as street sweeping, cleaning up illegally dumped materials, public education campaigns for litter, and structural BMPs such as retention and detention devices, infiltration devices, and diversion of stormwater[45]. **Table 5-11** summarizes the pollutant loads associated with roadways in each of the 11 subwatersheds of the 3RW Area. The subwatersheds with the largest total bacteria loads are Rocky Branch, Fourteenmile Creek, and Senn Branch & Double Branch.

Table 5-11: Estimated Pollutant Loads Resulting from Roadways

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	1.07E+03	1.16E+02	3.10E+01	3.68E+13	1.71E+02
Congaree River East	3.39E+03	3.69E+02	9.88E+01	1.17E+14	5.44E+02
Congaree River West	2.79E+03	3.03E+02	8.12E+01	9.64E+13	4.47E+02
Fourteenmile Creek	4.54E+03	4.93E+02	1.32E+02	1.57E+14	7.28E+02
Kinley Creek	2.48E+03	2.69E+02	7.22E+01	8.57E+13	3.97E+02
Lower Sixmile Creek	1.76E+03	1.91E+02	5.13E+01	6.09E+13	2.82E+02
Rocky Branch	5.69E+03	6.18E+02	1.66E+02	1.97E+14	9.12E+02
Saluda River North	2.63E+03	2.86E+02	7.65E+01	9.08E+13	4.21E+02
Senn Branch & Double Branch	3.75E+03	4.07E+02	1.09E+02	1.30E+14	6.01E+02
Stoop Creek	2.89E+03	3.15E+02	8.43E+01	1.00E+14	4.64E+02
UT to Congaree Creek	1.63E+03	1.77E+02	4.75E+01	5.63E+13	2.61E+02
Total	**3.26E+04**	**3.54E+03**	**9.50E+02**	**1.13E+15**	**5.23E+03**

5.3.5 Channel Erosion

Modification of the hydrologic regime due to land development in a watershed can result in elevated volumes of stormwater runoff being delivered to creeks, streams, and waterbodies. These increased volumes and the quick delivery of these runoff events can lead to scour of stream channels, incision, and streambank erosion. Hydrologic scour of the streambed can also limit key microhabitats (e.g., leaf packs, sticks, and coarse substrate) for aquatic species. While it is difficult to delineate the different sources of sediment that are being delivered to streams (e.g., streambank erosion as opposed to upland sources

[45]The National Academies of Sciences, Engineering and Medicine. *Transportation Research News*. July-August 2020. Number 328. Available online at https://onlinepubs.trb.org/onlinepubs/trnews/trnews328.pdf

such as construction sites), instream sedimentation and subsequent lack of microhabitat are, to some degree, a result of sediment input to streams from streambank erosion. Additionally, channel widening through streambank erosion can also exacerbate low flow conditions because channels become overly wide and shallow. **Section 2.5.3 Soil Erodibility** of this watershed plan describes how the USLE K-factor was calculated and used to estimate the soil's susceptibility to erosion.

Table 5-12 records the estimated annual loads in the Three Rivers Watershed that can be attributed to stream channel erosion in each of the 11 3RW Area subwatersheds. The overall total loads are 8.21×10^3 lb/yr TN; 6.57×10^3 lb/yr TP; and 4.10×10^3 ton/yr TSS. Channel erosion does not increase runoff volume or contain fecal coliform. The subwatersheds with the greatest estimated contribution of pollutants due to channel erosion are Rocky Branch (due high imperviousness causing stream scour and channel erosion) and Fourteenmile Creek (due the large size of the watershed and greater number of streams).

Table 5-12: Estimated Pollutant Loads Resulting from Channel Erosion

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	6.37E+02	5.10E+02	3.19E+02	0	0
Congaree River East	4.75E+02	3.80E+02	2.37E+02	0	0
Congaree River West	5.61E+02	4.48E+02	2.80E+02	0	0
Fourteenmile Creek	1.59E+03	1.28E+03	7.97E+02	0	0
Kinley Creek	8.33E+02	6.67E+02	4.17E+02	0	0
Lower Sixmile Creek	5.93E+02	4.74E+02	2.96E+02	0	0
Rocky Branch	1.04E+03	8.31E+02	5.19E+02	0	0
Saluda River North	5.31E+02	4.24E+02	2.65E+02	0	0
Senn Branch & Double Branch	8.63E+02	6.90E+02	4.31E+02	0	0
Stoop Creek	6.54E+02	5.23E+02	3.27E+02	0	0
UT to Congaree Creek	4.32E+02	3.46E+02	2.16E+02	0	0
Total	**8.21E+03**	**6.57E+03**	**4.10E+03**	**0**	**0**

5.4 Pollutant Source Assessment Summary

As the previous sections have stated, there are a variety of land use types across watersheds that contribute pollutants to the entire Three Rivers Watershed at different rates. This summary describes the sources of total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and bacteria as illustrated in **Figure 5-2** below. Additionally, the WTM calculated a total annual runoff volume as 4.71×10^4 acre-ft for the entire 3RW Area: 2.14×10^4 ac-ft from commercial; 2.01×10^4 ac-ft from residential; 5.23×10^3 ac-ft from roadways; 2.16×10^3 ac-ft from industrial; 631 ac-ft from rural; and 44 ac-ft from forested land uses.

For the entire 3RW Area, the total amount of TN estimated by the WTM is 331,677 lb/year and the largest contributing sources are commercial (37%), residential (35%), and roadway (10%) land uses. The estimated annual load for TP is 5.55×10^4 lb/year and the largest sources are residential (36%), commercial (27%), and channel erosion (14%). The total TSS estimate is 7.85×10^3 ton/year and the largest contributors are channel erosion (50%), residential (16%), and commercial (15%). Finally, the total estimated load of fecal bacteria is 1.19×10^{16} *E. coli* bacteria/yr. The largest sources of bacteria come from runoff associated with commercial (36%) and residential (34%) land use.

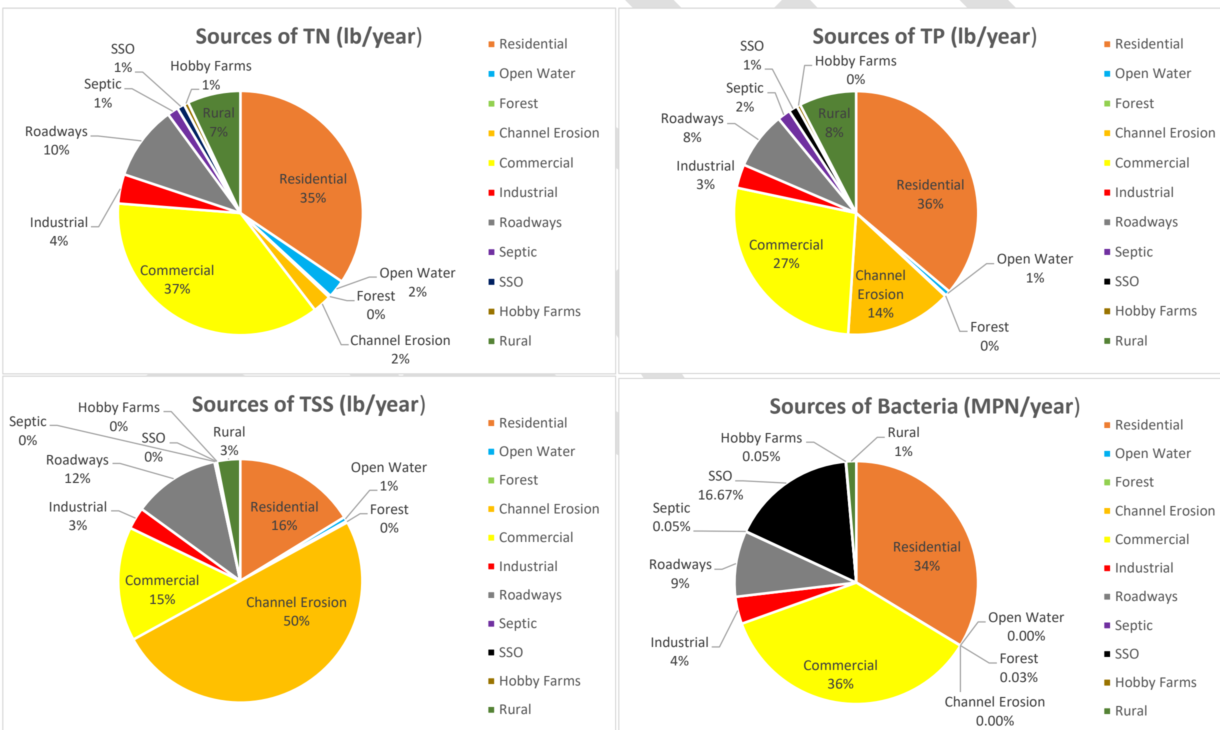

Figure 5-2: Pollutant Sources for Three Rivers Watershed

6.0 Implementation Plan

The Implementation Plan includes a description of the recommended management strategies and restoration projects and provides an estimation of the water quality benefits that would be realized from plan implementation. This section includes cost estimates for strategy implementation (based on the recommendations in **Sections 4.3.2 and 4.3.3** of this WBP), identifies potential funding sources and partners, and describes monitoring programs to document plan implementation and changes in the watershed condition over time.

Given the widespread prevalence of bacteria from multiple sources, the Project Team recommends that jurisdictions within the 3RW Area implement as many practices and management strategies as possible throughout the watershed. Practices that provide the most benefit for bacteria reduction include repairs to failing sanitary and septic systems, structural stormwater BMPs (bioretention, filters, stormwater wetlands, wet ponds, and infiltration practices), and proper disposal of pet waste.

6.1 Stakeholder Involvement

To address the watershed impacts described in Sections 5 and 6, an implementation plan for stormwater retrofit projects was developed through a collaborative process with the Plan Advisory Committee (PAC) that was convened by the Central Midlands Council of Governments (CMCOG). The PAC included representatives from various stormwater managers for the jurisdictions in the 3RW and held meetings periodically during the development of the plan. Discussions with the PAC established an understanding of the severity of the water quality problems, and the consultant team worked collaboratively with the CMCOG to develop a list of various solutions and strategies to address problems. The PAC utilized a webmap tool to sketch out point, line, and polygon features to brainstorm potential projects to be included in the watershed map, as shown in **Figure 6-1** and responses are tabulated in **Table 6-1**. A summary of the comments submitted with the potential project suggestions is included in Appendix H. There was at least one project recommended for each of the subwatersheds except for Congaree Creek Outlet and Lower Sixmile Creek. The most frequently recommended projects were pet waste stations (46), parking lot improvements with pervious pavement/bioretention (6), and constructed stormwater wetlands (6).

Ultimately, the Project Team opted not to locate individual projects in specific locations, but chose treatment goals for each subwatershed to achieve the desired overall bacteria load reduction (see **Table 4-4**). While the focus of this plan is on fecal bacteria pollution, nutrient and sediment loads and reductions estimated as part of the WTM are included to provide additional context on water quality conditions within the 3RW Area. The structural treatment options included BMP retrofits (evenly divided among bioretention, filters, stormwater wetlands, wet ponds, and infiltration practices), riparian buffer restoration, and urban redevelopment. Additional practices that were applied to all subwatersheds included OSDS programs, SSO repair/abatement, and pet waste education.

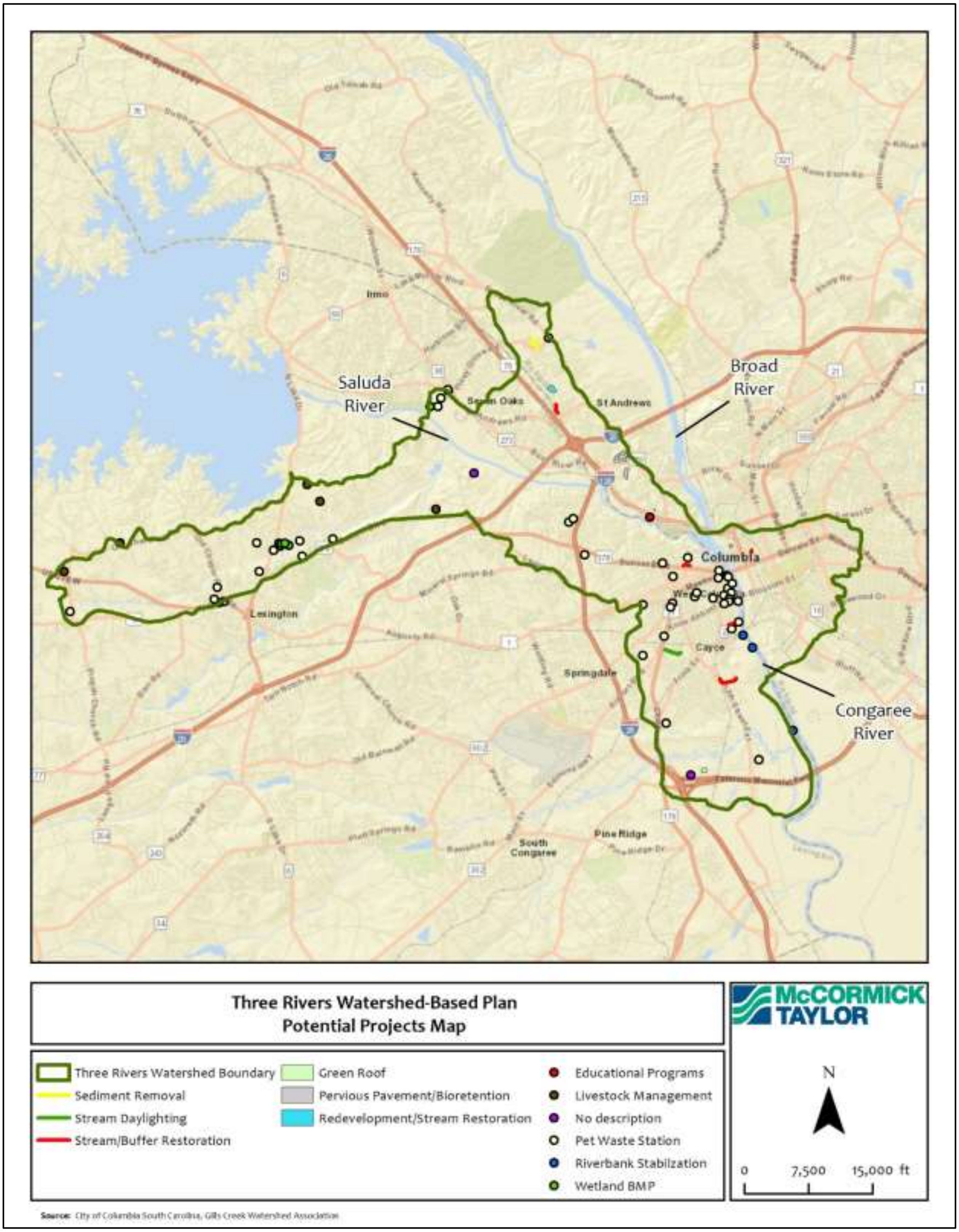

Figure 6-1: Stakeholder suggestions for potential future projects

Table 6-1: Project Summary by Type and Location

Project Type	Number		Subwatershed	Number
Educational Programs	1		Congaree River East	2
Green Roof	2		Congaree River West	28
Livestock Management	5		Fourteenmile Creek	21
No description	2		Kinley Creek	6
Pervious Pavement/Bioretention	6		Lower Congaree Creek	4
Pet Waste Station	46		Rocky Branch	1
Redevelopment/Stream Restoration	1		Saluda River North	5
Riverbank Stabilzation	3		Senn Branch and Double Branch	4
Sediment Removal	1		Stoop Creek	4
Stream Daylighting	1		UT to Congaree Creek	4
Stream/Buffer Restoration	5			
Wetland BMP	6			
Total	**79**		**Total**	**79**

6.2 Strategies to Address Nonpoint Sources of Bacteria Pollution

As described in **Section 4.2 Load Duration Curve Results**, the storm-derived loads shown in **Figure 4-4** are typically dominated by bacteria delivered through build-up/wash-off mechanisms which are greatly influenced by intensities of impervious surface. Conversely, non-storm loads are driven by factors such as sanitary sewer system leaks and failing or poorly performing on-site septic systems. For these reasons, the subwatersheds with the highest concentrations of septic systems figure more prominently in the non-storm loading intensities shown in **Figure 4-5**. Note also that the storm loads are an order of magnitude higher than the non-storm loads across all subwatersheds.

This section provides discussion of different strategies that can be utilized to achieve load reductions in the Three Rivers Watershed, as described in **4.3.1 Estimated Pollutant Loads from Existing Conditions.** Knowing that bacteria pollution in urban landscapes can be quite ubiquitous, persistent, and difficult to manage, the 3RWBP Implementation Plan recommends an aggressive adoption of a wide array of strategies to address this problem, as described in the following sections.

Given that the Three Rivers Watershed study area comprises 11 subwatersheds that intersect nine distinct jurisdictions across approximately 56 square miles, the development of watershed-specific stormwater BMP retrofit opportunities would be well beyond the level of resources invested in this plan. The degree of fecal coliform pollutant load reductions estimated to be necessary by the modeling analysis presented in **Section 4**, ranging from 51-65% of existing loads would indicate that all the jurisdictions involved need to pursue the full range of recommended measures with all due diligence. However, there are some more general priorities for the array of management actions based on an overview of pollutant sources, costs of those actions, and the logistics of implementation. Some basic recommendations for implementation priorities are as follows:

The WTM models estimate the lion's share of the bacteria load stemming from stormwater runoff, so in the absence of other factors, give higher priority to retrofitting best management practices to already-built landscapes to reduce runoff loads from those developed areas. Retrofitting stormwater BMPs is challenging due to factors such as land availability and constraints from existing utilities and other infrastructure. With such challenges, which often drive significant costs, priority should be given to treating watersheds that offer the best "bang for the buck." Hence, the retrofitting of BMPs in subwatersheds which are already developed at the highest intensities (such as Congaree River East and Rocky Branch) and tend to be older parts of the community developed prior to the existence of modern stormwater control requirements will typically capture runoff that exhibits the highest pollutant load intensities.

Stormwater BMP retrofits should not be prioritized to the exclusion of other management measures, as there are also significant reductions that may be achieved from other efforts. Targeting management measures that improve the effectiveness of on-site septic system to those subwatersheds with the highest numbers of such systems present can also result in significant and cost-effective bacteria reductions. By the same token, targeting riparian buffer restoration efforts to those sites where the largest opportunities exist can result in more cost-effective pollutant load reductions because buffer restoration projects benefit from economy of scale as they get bigger.

6.2.1 Urban/Suburban Runoff

Urban/suburban runoff from residential, commercial, industrial, and roadway land uses account for 83% of the bacteria load in the 3RW Area (see **Figure 5-2**). Three recommendations are directly related to reducing bacteria pollution associated with these land uses: stormwater retrofits, redevelopment, and pet waste education. Recommended stormwater retrofit options include bioretention cells, filter BMPs (e.g. catch basin inserts and sand filters), constructed stormwater wetlands, conventional wet ponds, and infiltration practices (e.g. level spreaders, bioswales, etc.). Some suggested strategies for incorporating stormwater retrofits into the 3RW Area include the following:

Bioretention cells are planting areas installed in shallow basins in which the stormwater runoff is temporarily held and then treated by filtration through soil media and the biological and biochemical reactions within the soil matrix and plant root zones. The bioretention areas are designed to capture and temporarily store stormwater runoff in the engineered soil media, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils. As a result, bioretention can be applied in most soils or topography and in many types of land uses (from rural to suburban to urban), making it a flexible option for all three HUC-12 watersheds modeled for BMP recommendations. The engineered soil media is comprised of sand, soil, and organic matter. For more information, see Section 4.2 *Bioretention* in *Low Impact in Coastal South Carolina: A Planning and Design Guide*[46].

Rain Gardens/Bioswales are a subset of bioretention. Rain gardens and bioswales can be smaller and constructed without a formal engineering design plan. They can be incorporated in future capital improvement projects and provide an opportunity for educational signage for the public, as shown in an example project from the City of Aiken (**Figure 6-2**). Vegetated stormwater BMPs like these can also qualify for a diverse array of certifications if they incorporate native plants (and milkweed), such as Monarch Waystations[47], Audubon Bird-Friendly Communities[48], and Palmetto Wildlife Habitat[49]. The PAC

[46] https://www.scseagrant.org/sc-lid-guide/
[47] https://monarchwatch.org/waystations/
[48] https://www.audubon.org/news/post-your-plants-birds-sign-and-spread-word
[49] http://www.scwf.org/habitats

members will also encourage residents to participate in workshops and programs, such as the Carolina Rain Garden Initiative[50], to install rain gardens on private property. Educational messaging to residents should include information about how rain gardens provide opportunities to infiltrate and absorb stormwater runoff, mange erosion, beautify the home landscape, create pollinator and bird-friendly habitats, and protect clean water downstream.

Figure 6-2: Example rain garden and educational signage in City of Aiken

Wet ponds are stormwater detention practices that are widely applicable to most land uses and are best suited for large drainage areas (10-25 acres). They typically consist of a permanent pool, micro-pool, or shallow marsh that promotes settling of suspended sediments and biological uptake of nutrients. Runoff from each new storm enters the pond and displaces pool water from previous storms. They can be attractive amenities in development and simultaneously provide wildlife habitat. Generally, they have low construction and maintenance costs. For more information, see Section 4.11 Wet Detention Ponds in *Low Impact in Coastal South Carolina: A Planning and Design Guide*.

Stormwater wetlands, sometimes referred to as constructed wetlands, are shallow vegetated depressions that receive stormwater inputs for water quality treatment. Like wet ponds, the runoff from each new storm displaces the runoff stored in the wetland from previous storms. Stormwater wetlands provide moderate to high pollutant removal through biological uptake, gravitational settling, and

[50] https://www.clemson.edu/extension/raingarden/

microbial activity. An advantage of stormwater wetlands is that they can operate effectively in poor soils (HSG C and D) and provide wildlife habitat. For more information, see Section 4.12 Stormwater Wetlands in *Low Impact in Coastal South Carolina: A Planning and Design Guide*.

Filter Practices are systems that capture and temporarily store stormwater and pass it through a filter bed of sand media. The filtered stormwater is then allowed to return to the conveyance system or partially infiltrate the soil. Filter practices are especially useful in small (drainage area of two acres or less), highly impervious areas, including stormwater hotspots. For more information, see Section 4.9 Stormwater Filtering Systems in *Low Impact in Coastal South Carolina: A Planning and Design Guide*.

Tree Planting can be easily combined with other practices and provides stormwater interception, beauty, and shade. Trees can intercept a significant amount of rainfall before it becomes runoff, especially where their canopy covers impervious surfaces such as roadways and parking lots. Furthermore, trees improve water quality through the processes of evapotranspiration and nutrient uptake. The *Southern Lowcountry Regional Stormwater Design Manual*[51] gives stormwater retention credits for two size classes of newly planted trees:

- Small trees: species with an average mature spread less than or equal to 40 feet are assumed to provide 5 cubic feet of stormwater retention
- Large trees: species with an average mature spread greater than or equal to 40 feet are assumed to provide 10 cubic feet of retention.

Complete Streets can be considered for redevelopment or new development. These designs vary based on community needs and desires, but typically provide elements such as bike lanes, public transportation stops, and modified vehicle travel lanes[52]. As communities are moving toward integrating this approach to design roadways for safe use and mobility for all ages and abilities, this also provides an opportunity to provide additional stormwater treatment. Complete Streets can incorporate green infrastructure through the use of landscape treatments, median islands, and pervious surfaces. For examples, see **Figure 6-3** below. Examples[53] include (clockwise from top right) a bioretention bump out, stormwater planter, and stormwater tree trench.

Permeable pavement is a type of paving surface that captures and temporarily stores stormwater by filtering the runoff through voids in the pavement surface into an underlying stone reservoir. The filtered runoff can be collected and returned to the conveyance system or allowed to partially infiltrate into the underlying soil. This type of BMP is particularly well suited for use on urban development sites and in low traffic areas, such as overflow parking lots. Permeable pavement systems can provide measurable reductions in stormwater runoff rates, volumes, and pollutant loads. However, one drawback of these systems is their relatively high construction and maintenance costs. For more information, see Section 4.3 Permeable Pavement Systems in *Low Impact in Coastal South Carolina: A Planning and Design Guide*.

[51] https://www.townofbluffton.sc.gov/704/Southern-Lowcountry-Stormwater-Ordinance
[52] https://www.transportation.gov/mission/health/complete-streets
[53] https://www.phila.gov/documents/green-streets-design-manual/

Figure 6-3: Examples of green infrastructure added to roadway designs

Rain Barrels/Downspout Disconnect – Many towns and cities have traditionally used gutter and downspout systems to ‘connect’ stormwater runoff from homes, businesses, and schools to the storm drain system. Disconnecting these systems to direct rainwater from roofs to open grassy areas or to rain barrels and cisterns reduces the overall volume of stormwater runoff, conserves water use, reduces pollutants entering the stream, and provides clean water for gardens and everyday outside use. An education program can include rain barrel workshops to distribute rain barrels and instruct on their installation and use. Programs can be implemented by the MS4 communities. Additionally, the Clemson Extension program offers a “Master Rain Gardener” certification program[54] that is focused on rain garden and rainwater harvesting system design for both residents and landscape professionals. For more information, see Sections 4.6 Rainwater Harvesting and 4.7 Impervious Surface Disconnection in *Low Impact in Coastal South Carolina: A Planning and Design Guide*. In the WTM, impervious cover

[54] https://www.clemson.edu/extension/raingarden/mrg/index.html

disconnection is treated as an educational program that is accounted for within the stormwater treatment practices, and not as a separate line item.

The total estimated pollutant load reductions (refer to **Section 4.3.3**) from the combined stormwater retrofits (including wet ponds, wetlands, filters, bioretention, infiltration practices, and impervious surface disconnection) for each subwatershed are summarized in Error! Reference source not found.**.**

Table 6-2: Estimated Pollutant Loads Reductions due to Stormwater Retrofits

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	5.58E+03	1.28E+03	9.69E+01	2.72E+14	2.90E+02
Congaree River East	4.03E+03	7.94E+02	8.46E+01	2.06E+14	2.19E+02
Congaree River West	4.88E+03	1.10E+03	8.06E+01	2.01E+14	3.79E+02
Fourteenmile Creek	9.94E+03	2.69E+03	1.48E+02	4.16E+14	7.87E+02
Kinley Creek	4.77E+03	1.16E+03	7.76E+01	2.06E+14	3.89E+02
Lower Sixmile Creek	5.70E+03	1.33E+03	8.95E+01	2.49E+14	4.70E+02
Rocky Branch	1.64E+04	3.27E+03	3.39E+02	8.26E+14	8.76E+02
Saluda River North	2.56E+03	5.42E+02	4.29E+01	1.14E+14	2.15E+02
Senn Branch & Double Branch	4.19E+03	1.06E+03	6.76E+01	1.79E+14	3.39E+02
Stoop Creek	4.21E+03	1.02E+03	6.97E+01	1.84E+14	3.48E+02
UT to Congaree Creek	4.15E+03	9.53E+02	7.10E+01	1.83E+14	3.45E+02
Total	**6.64E+04**	**1.52E+04**	**1.17E+03**	**3.04E+15**	**4.66E+03**

In order to support water quality goals and ensure long-term effectiveness of any stormwater retrofit project, maintenance is essential. Maintenance activities range in time (seasonal vs. yearly tasks), degree of effort required (simple activities volunteers can accomplish such as litter removal to more difficult tasks that professionals should undertake), and cost. Education and outreach are essential parts of a successful maintenance program. Maintenance responsibilities should be clearly described and adequately enforced. Agreements should be put in place that assign long-term responsibility for funding and performing maintenance for each project. The SCDHEC *BMP Handbook*[55] is a good reference for maintenance specifications for stormwater BMPs. For specific maintenance checklists for different practice types, please refer to Appendix F in *Low Impact Development in Coastal South Carolina: A Planning and Design Guide*.

Redevelopment areas were selected from existing built-upon lands varying from 50 acres to 200 acres for each subwatershed based on professional judgement of the need and opportunity within that subwatershed. The net benefits of redevelopment are summarized in Error! Reference source not found.. Redevelopment is more likely to occur in the older and more urbanized communities located in a given watershed. The WTM assumes that the load reduction results from the fraction of impervious cover removed from the landscape. This can be accomplished using Better Site Design[56] (BSD) techniques such as narrowing street widths, reducing the size and number of parking lot spaces, and encouraging open space development (smaller lot sizes to minimize total impervious area). Additionally, BSD promotes directing parking lot runoff to bioretention areas, filter strips, or other practices that can be integrated into landscaping areas. Similarly, driveways should be constructed with pervious materials and/or have

[55] https://www.scdhec.gov/environment/bureau-water/stormwater/bmp-handbook
[56] https://owl.cwp.org/mdocs-posts/better-site-design-part-1/

runoff directed to pervious areas such as yards, open channels, or vegetated areas. Additionally, redevelopment should avoid directing runoff to the roadway and the stormwater conveyance system.

Table 6-3: Estimated Pollutant Loads Reductions as a Result of Redevelopment

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	6.21E+02	7.70E+01	7.67E+00	2.25E+04	1.04E+02
Congaree River East	6.33E+02	7.50E+01	8.62E+00	2.27E+04	1.05E+02
Congaree River West	5.96E+02	7.70E+01	7.76E+00	2.19E+04	1.02E+02
Fourteenmile Creek	1.23E+03	1.67E+02	1.45E+01	4.50E+04	2.09E+02
Kinley Creek	3.11E+02	4.00E+01	3.84E+00	1.13E+04	5.20E+01
Lower Sixmile Creek	1.24E+03	1.59E+02	1.48E+01	4.51E+04	2.09E+02
Rocky Branch	1.68E+03	2.00E+02	2.31E+01	6.02E+04	2.79E+02
Saluda River North	3.09E+02	3.80E+01	3.84E+00	1.13E+04	5.20E+01
Senn Branch & Double Branch	6.18E+02	8.30E+01	7.58E+00	2.25E+04	1.05E+02
Stoop Creek	6.21E+02	8.30E+01	7.65E+00	2.26E+04	1.05E+02
UT to Congaree Creek	3.12E+02	4.00E+01	3.95E+00	1.13E+04	5.20E+01
Total	**8.17E+03**	**1.04E+03**	**1.03E+02**	**2.96E+05**	**1.37E+03**

Pet Waste Education – In many neighborhoods, improperly disposed pet waste can be a source of bacteria and nutrients, particularly from dogs. An outreach program to educate residents on the environmental and hygiene/health impacts of pet waste disposal is already in place within several jurisdictions in the PAC, such as the Scoop the Poop campaign in Richland County and the City of Columbia. The program should be coupled with pet waste disposal stations, signage in high-traffic dog walking areas, and possibly a local ordinance for removal and proper disposal of pet waste. The WTM predicts that a pet waste education program, assuming 40% of the audience (assumed message is distributed via television/radio/newspaper to reach the entire Three Rivers Watershed population) receives the message and changes their behavior, could reduce pollutant loads by 3,210 lb/yr TN; 419 lb/yr TP; and 2.44x10^{13} bacteria per year, as summarized in **Table 6-4**.

Table 6-4: Estimated Pollutant Loads Reductions due to Pet Waste Education

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	5	1	-	4.10E+10	-
Congaree River East	91	12	-	6.92E+11	-
Congaree River West	416	54	-	3.16E+12	-
Fourteenmile Creek	740	97	-	5.62E+12	-
Kinley Creek	237	31	-	1.80E+12	-
Lower Sixmile Creek	199	26	-	1.51E+12	-
Rocky Branch	235	31	-	1.79E+12	-
Saluda River North	167	22	-	1.27E+12	-
Senn Branch & Double Branch	501	65	-	3.80E+12	-
Stoop Creek	386	50	-	2.93E+12	-
UT to Congaree Creek	232	30	-	1.76E+12	-
Total	**3,210**	**419**	**-**	**2.44E+13**	**-**

6.2.2 Sanitary Sewer Overflows

SSOs were estimated to contribute 17% of the annual bacteria load to the 3RW Area. In general, human sewage contamination presents the greatest health risk and is a controllable source. To reduce the risk of human exposure to pathogenic viruses and bacteria, leaky or broken sanitary sewer lines should be replaced or repaired as necessary. Problems that can cause chronic SSOs include:

- Too much rainfall or snowmelt infiltrating through the ground into leaky sewer systems;
- Runoff that is directly connected to sewer systems;
- Sewers and pumps too small to carry sewage from newly developed areas;
- Blocked, broken, or cracked pipes due to tree roots, pipe settlement, and material build-up within pipes;
- Power failures that prevent the system from functioning; or
- Vandalism to the sanitary sewer conveyance system.

Practices to reduce or eliminate SSOs include routine sewer system cleaning or maintenance; repairing broken or leaking sewer service lines; enlarging or upgrading the sewer/pump station capacity or reliability; and construction of wet weather storage and treatment facilities to treat excess flows. Additionally, the PAC can provide public education to prevent blockages in existing sanitary sewer systems by discouraging flushing wipes and encouraging residents to dispose of fats, oils, and grease (FOG) properly. The WTM model estimates that a SSO repair/abatement program with a goal of 75% reduction/25% completion of all SSOs would result in pollutant reductions of 607 lb/yr TN; 103 lb/yr TP; 2.03 tons/yr TSS; and 4.02×10^{14} bacteria per year, as described in **Table 6-5**.

Table 6-5: Estimated Pollutant Loads Reductions due to SSO Programs

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	2.50E+01	4.00E+00	8.35E-02	1.65E+13	-
Congaree River East	3.50E+01	6.00E+00	1.17E-01	2.32E+13	-
Congaree River West	5.90E+01	1.00E+01	1.98E-01	3.92E+13	-
Fourteenmile Creek	1.12E+02	1.90E+01	3.75E-01	7.43E+13	-
Kinley Creek	4.00E+01	7.00E+00	1.34E-01	2.66E+13	-
Lower Sixmile Creek	3.90E+01	7.00E+00	1.31E-01	2.59E+13	-
Rocky Branch	8.80E+01	1.50E+01	2.94E-01	5.81E+13	-
Saluda River North	2.70E+01	5.00E+00	9.05E-02	1.79E+13	-
Senn Branch & Double Branch	8.20E+01	1.40E+01	2.74E-01	5.42E+13	-
Stoop Creek	6.10E+01	1.00E+01	2.05E-01	4.05E+13	-
UT to Congaree Creek	3.90E+01	6.00E+00	1.30E-01	2.57E+13	-
Total	**6.07E+02**	**1.03E+02**	**2.03E+00**	**4.02E+14**	**-**

6.2.3 Septic Systems

Septic systems, or on-site disposal systems (OSDS), can be contributors of viruses, pathogens, and nitrogen to the groundwater and eventually to surface waters. Although septic systems represent 0.05% of the total annual bacteria load in the entire 3RW Area, it is still important to address this source of contamination as it represents a direct threat to water quality and human health. Like SSOs, failing septic systems represent an opportunity to address a direct health risk from a controllable source. Regular maintenance of these systems is necessary to ensure long-term operation and safe water supplies. Educational materials and workshops can be developed to present recommendations and explain existing local ordinances for septic tank pumping, drain field care and percolation testing, proper disposal of household hazardous waste, and general best management practices for proper maintenance and operation. Outreach should also include information on upgrading septic systems with nitrogen-removing best available technology (BAT), which can effectively cut nitrogen loads from septic systems in half. Programs could be organized by the counties, municipalities, and wastewater utilities, with support from SCDHEC. The WTM offers several options to estimate reductions of the pollutant loads associated with septic systems. These four practices represent different techniques that either improve performance or reduce the number of septic systems in the watershed: OSDS education (benefits summarized in **Table 6-6**), OSDS repair, OSDS upgrade, and OSDS conversion to sanitary sewer/WWTP. It is the recommendation of this plan to gather more detailed information pertaining to the current status of septic systems in this watershed before determining exactly which systems to target for repair, upgrades, or retirement (connect to sanitary sewer system). Septic system inspection and repair can be funded through various grant opportunities, such as 319 funds.

Table 6-6: Estimated Pollutant Loads Reductions due to Septic System Education Programs

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	1.40E+01	2.00E+00	4.70E-02	1.83E+10	-
Congaree River East	6.00E+00	1.00E+00	2.05E-02	7.85E+09	-
Congaree River West	1.05E+02	1.80E+01	3.51E-01	1.39E+11	-
Fourteenmile Creek	4.39E+02	7.30E+01	1.46E+00	5.79E+11	-
Kinley Creek	1.29E+02	2.20E+01	4.31E-01	1.70E+11	-
Lower Sixmile Creek	1.15E+02	1.90E+01	3.84E-01	1.52E+11	-
Rocky Branch	-	-	-	-	-
Saluda River North	4.71E+02	7.90E+01	1.57E+00	6.22E+11	-
Senn Branch & Double Branch	4.03E+02	6.70E+01	1.34E+00	5.32E+11	-
Stoop Creek	6.10E+01	1.00E+01	2.02E-01	8.03E+10	-
UT to Congaree Creek	1.43E+02	2.40E+01	4.76E-01	1.88E+11	-
Total	**1.89E+03**	**3.15E+02**	**6.29E+00**	**2.49E+12**	**-**

6.2.4 Riparian Buffer Enhancements & Stream Restoration

Well-managed and adequately sized buffers are important for processing nutrients, filtering pollutants, providing habitat, retaining flood waters, and providing erosion prevention. Research has indicated that approximately 80% of nitrogen removal is achieved by stream buffers approximately 80-90 ft wide and widths of 150 feet or wider are more likely to consistently achieve their maximum potential for nitrogen removal[57]. The minimum 80-foot stream buffer width recommended for nitrogen removal was estimated to provide around 66% removal of total phosphorus. As discussed in **Section 4.3.2**, the Consultant Team recommends all riparian buffers which were the minimum width of 0-50 feet wide (entered in WTM as 25 feet) in the existing condition should be restored to the intermediate width category of 50-100 feet (entered in WTM as 75 feet). The result of this enhancement is that the WTM estimates pollutant load reductions (as summarized in **Table 6-7**) would be $8.61\text{x}10^4$ lb/yr TN; $1.58\text{x}10^4$ lb/yr TP; $1.05\text{x}10^3$ ton/yr TSS; and $2.96\text{x}10^{15}$ bacteria per year. The annual runoff reduction would be $1.38\text{x}10^4$ acre-feet.

Table 6-7: Estimated Pollutant Loads Reductions due to Riparian Buffer Enhancements

Subwatershed	TN (lb/year)	TP (lb/year)	TSS (ton/year)	*E. coli* Bacteria (MPN/year)	Runoff Volume (acre-ft/yr)
Congaree Creek Outlet	6.66E+03	1.14E+03	7.94E+01	2.30E+14	1.07E+03
Congaree River East	5.01E+03	7.44E+02	7.22E+01	1.81E+14	8.40E+02
Congaree River West	8.60E+03	1.50E+03	1.08E+02	2.86E+14	1.33E+03
Fourteenmile Creek	1.74E+04	3.60E+03	1.96E+02	5.85E+14	2.72E+03
Kinley Creek	9.14E+03	1.70E+03	1.12E+02	3.14E+14	1.46E+03
Lower Sixmile Creek	6.76E+03	1.22E+03	7.94E+01	2.34E+14	1.09E+03
Rocky Branch	3.67E+02	5.60E+01	5.39E+00	1.34E+13	6.30E+01
Saluda River North	7.41E+03	1.21E+03	9.25E+01	2.61E+14	1.21E+03
Senn Branch & Double Branch	1.10E+04	2.14E+03	1.35E+02	3.78E+14	1.76E+03
Stoop Creek	8.22E+03	1.54E+03	1.03E+02	2.87E+14	1.34E+03
UT to Congaree Creek	5.48E+03	9.72E+02	7.03E+01	1.92E+14	8.95E+02
Total	**8.61E+04**	**1.58E+04**	**1.05E+03**	**2.96E+15**	**1.38E+04**

One stakeholder suggestion for a potential project included the daylighting of 2,056 linear feet (LF) of an unnamed tributary at Mt. Zion Baptist Church (in the UT to Congaree Creek watershed). The Central Midlands COG would like to work with the church to try to connect the housing tracts in this area to the shopping centers upstream with a greenway. In the interim, the church has expressed interest in daylighting the segment of the stream that is on their property (approximately 300 LF) and creating an educational opportunity for their school and the residential area. Much of the surrounding community went to school at the church school and remember playing in the stream before it was closed in, so there is a lot of community support to restore the stream. The WTM estimates pollutant removals of 154 lb/yr TN, 140 lb/yr TP, and 509,888 lb/yr TSS, although additional benefits from flood resilience to ecological services are not included in this calculation.

[57] Bason, C. 2008. Recommendations for an Inland Bays Watershed Water Quality Buffer System. Available at: https://www.inlandbays.org/wp-content/uploads/2011/01/Recommendations-for-an-Inland-Bays-Watershed-Buffer-System-Final.pdf

6.2.5 Agriculture

Both crops and several small hobby farms (about 70 cows total) contribute to pollution in the 3RW Area. Voluntary public education programs, such as manure management and composting offered by Clemson Extension, would help manage the bacteria runoff associated with the livestock in the Fourteenmile Creek. Cooperative relationships with the USDA-NRCS agents and Soil and Water Conservation Districts in Richland and Lexington Counties could help identify appropriate land management BMPs to reduce polluted runoff from rural/agricultural lands, too.

6.2.6 Benefits Summary

Each management strategy has its own set of watershed benefits. Benefits include estimated pollutant reductions (**Table 6-2** through **Table 6-7**), improvements to aquatic and riparian habitat, and community benefits such as improved aesthetics or access to recreational opportunities.

Table 6-8 presents the relative benefit of each practice as it relates to major benefit categories. In this table, a primary benefit is the intended outcome of the initiation of a specific action while a secondary benefit is an ancillary benefit provided through the initiation of a specific action, but not considered to be the determining factor in the execution of that action. The following sections address the overall impact that the suite of management measures will have on water quality in terms of the pollutants that the practice reduces. See **Section 6.4 Climate Ready Planning** to learn how the co-benefits associated with these practices can provide additional advantages for communities in the Three Rivers Watershed, such as carbon sequestration and protection from extreme heat.

Table 6-8: Watershed Benefits for Selected Practices

Practice	Water Quality	Runoff Reduction	Channel Protection	Flood Control	Instream Habitat	Community Aesthetics	Community Engagement
Bioretention	●	○	○	○		●	○
Wet Pond	●		○	●		●	○
Constructed Wetland	●		○	○		●	○
Filter Practice	●						
Tree Planting	●	●	○	○	○	●	○
Redevelopment	●	●	○	●	○	●	○
Complete Streets	●	●	○	●	○	●	●
Permeable Pavement	●	●	○	●	○	●	○
Rain Barrels / Downspout Disconnect	●	●	○		○		●
Lawn Care Education	●				○	●	●
Pet Waste Education	●				○	●	●
Sanitary Sewer Overflow Repair/ Abatement	●				○	○	●
Septic System Education	●				○	○	●
Riparian Buffer Enhancements and Protection	●	○	○	○	●	●	○
Key: ● Primary benefit ○ Secondary benefit							

6.2.7 Pollutant Load Reductions

A summary of the benefits from implementing all recommended stormwater projects and programs in the Three Rivers Watershed are listed in **Table 6-9**, and the reductions attributed to projects that address bacteria are shown in **Figure 6-4**. Riparian Buffer Enhancement and Stormwater Retrofits are responsible for the largest amount of bacteria reduction (44% and 45% respectively).

Table 6-9: Overall Potential Benefits from Proposed Projects

Future Projects	Total Potential Pollutant Reductions			
	TN (lb/yr)	TP (lb/yr)	TSS (ton/yr)	*E. coli* Bacteria (MPN/yr)
Riparian Buffers	8.61E+04	1.58E+04	1.05E+03	2.96E+15
Redevelopment	8.17E+03	1.04E+03	1.03E+02	2.96E+14
Pet Waste Education	3.21E+03	4.19E+02	0.00E+00	2.44E+13
Stormwater Retrofits	6.64E+04	1.52E+04	1.17E+03	3.04E+15
SSO repair/abatement	6.09E+02	1.02E+02	2.03E+00	4.02E+14
Septic Programs	1.89E+03	3.14E+02	6.29E+00	2.49E+12
Total	**1.66E+05**	**3.29E+04**	**2.33E+03**	**6.72E+15**

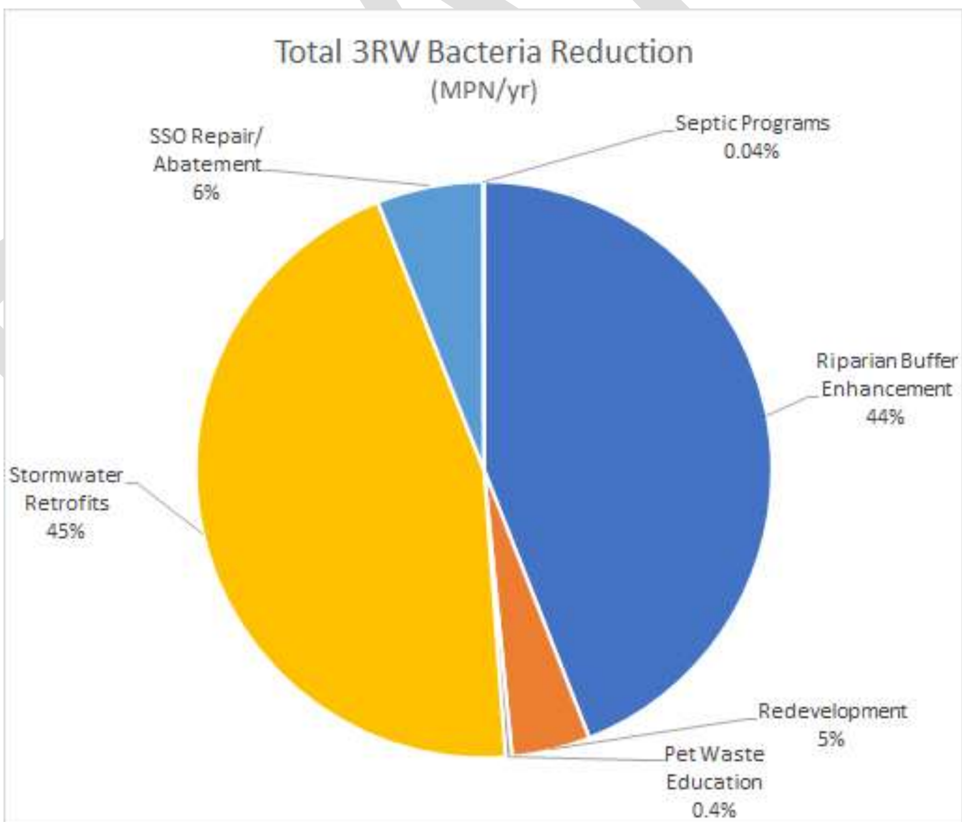

Figure 6-4: Summary of bacteria reduction from recommended practices in the 3RW Area

If implemented completely, the recommendations in this WBP will produce significant reductions in both stormwater runoff volume and pollutant loads, as summarized in **Table 6-10**. Please refer to Section **4.3.2 Pollutant Loads from Retrofit Scenarios** to see how the watershed located within the three different watershed groups (Saluda River, Congaree River, and Rocky Branch) differed in bacteria reduction goals (51%, 63%, and 94% respectively). Also note that although the recommendations were focused on bacteria reduction, they also provide water quality benefits by reducing nitrogen, phosphorus, and sediment in the Three Rivers Watershed.

Table 6-10: Overall 3RW Area Load Reduction Estimate

Load Calculation	TN (lb/yr)	TP (lb/yr)	TSS (ton/yr)	*E. coli* Bacteria (MPN/yr)	Runoff Reduction (ac-ft)
Overall 3RW Existing Load	3.32E+05	4.67E+04	8.22E+03	1.29E+16	49,491
Recommended Projects Reduction	1.66E+05	3.29E+04	2.33E+03	6.72E+15	19,803
New Load	1.65E+05	1.38E+04	5.88E+03	6.14E+15	2.97E+04
Percent Reduction	**50%**	**70%**	**28%**	**52%**	**40%**

It will take a much larger effort for a watershed to meet water quality standards after it is impaired than it took for it to become polluted in the first place. While the best management practices proposed provide an overall net reduction between 28% and 70% for all four pollutants analyzed in the WTM, any progress, however small, is a change in the right direction. The members of the PAC will build off each success and use adaptive management strategies to periodically evaluate and change priority projects and programs.

6.3 Additional Considerations

6.3.1 Conservation Areas

Conserving portions of the watershed in a natural state has multiple benefits for watershed management and water quality remediation. Directing development away from low-lying areas helps maintain the assimilative capacity of the watershed floodplain, mitigating the economic impacts of flooding in developed areas. This extends beyond the riparian zone of rivers and streams, as reducing overall impervious terrain supports surface water runoff infiltration and limits pollutant transport across the watershed.

Strategic identification and acquisition of conservation properties supports the function of water quality BMPs and may reduce the need of other management actions. Practices would encourage protecting or enhancing the riparian buffer of impacted streams and increasing the overall hydrologic connection in the watershed. Strategies such as conservation easements or property purchases for environmental conservation purposes facilitate this process, while still allowing for certain uses to be enjoyed by the property owner.

An analysis of parcel records in the 3RW Area (see **Figure 6-5**) provides an overview of owning entities and overall extent of properties across the watershed. To filter the information for economic feasibility and return on investment, parcels in this analysis were limited to an area 10 acres or more. Out of the 198 parcels identified in this analysis, 166 are privately owned, 28 belong to a private utility provider, and three are publicly owned. Most of the parcels (95%) are in the Lexington County portion of the 3RW Area, and 73% of the parcels have been designated for agricultural use.

The information presents properties of the 3RW Area already dedicated to conversation, including riparian properties owned by Dominion Energy, the Riverbanks Zoo and Garden by the Lower Saluda River, the Three Rivers Greenway, and parcels owned by the Congaree Land Trust. This shows properties that could serve as anchors for other BMP recommendations in this plan, and suggests areas and partnerships that may, through a strategic conservation strategy, become part of connected conservation corridor that benefits water quality remediation.

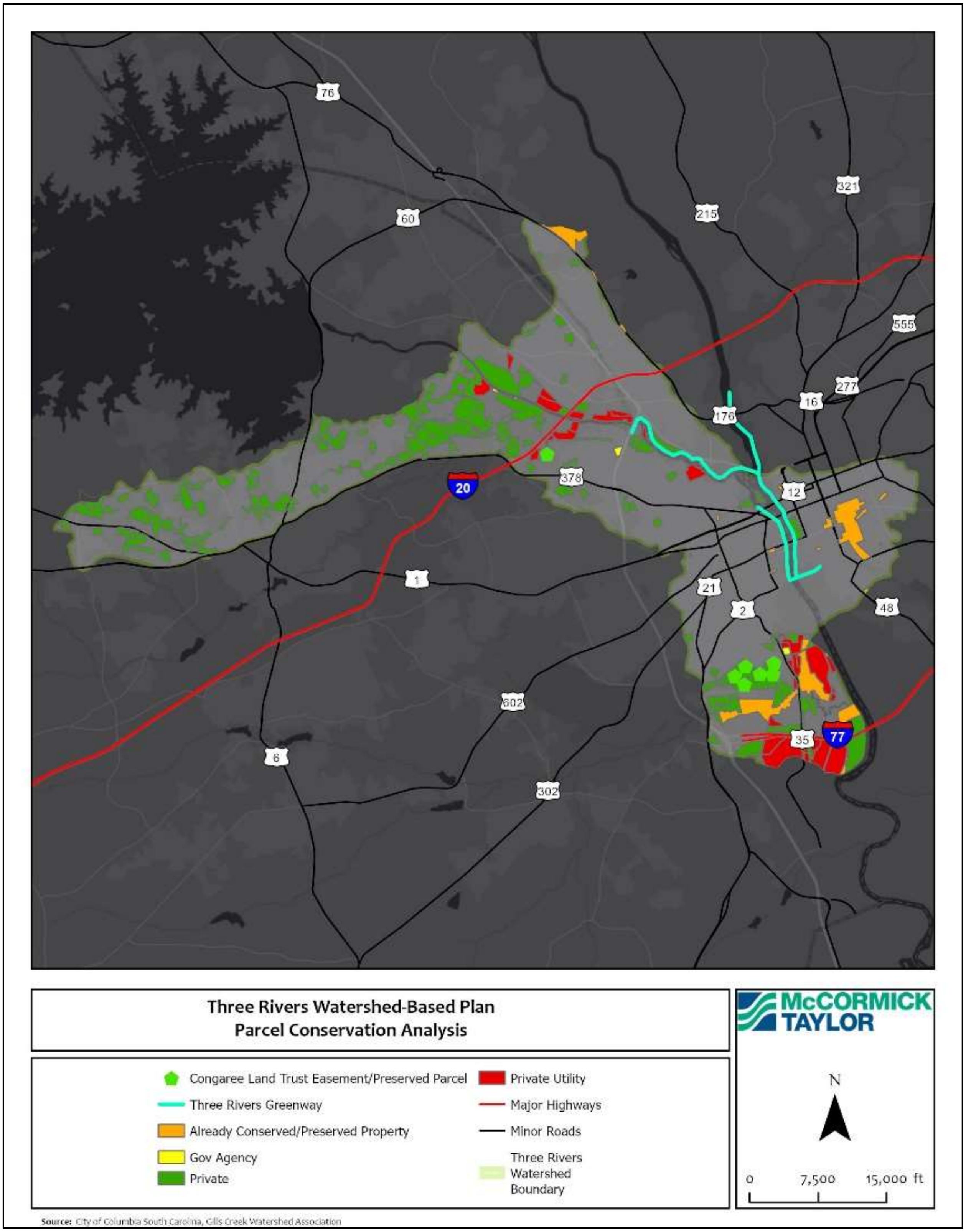

Figure 6-5: Overview of Conservation Opportunities in the 3RW Area

6.3.2 Watershed Management/Source Water Protection Considerations

Bacteria

A literature review (see **Appendix D**) was conducted for the WTM scenario exercise to evaluate how climate change affects bacterial impairment in watersheds, a key consideration of the 3RWBP. Studies in comparable contexts (e.g., location, land use, etc.) consistently find that observed shifts in temperature and precipitation will increase bacterial loads. Although no specific bacteria forecast has been produced for the 3RW Area, results from comparable areas can provide an indication of the types of changes to expect as temperature and precipitation shifts in the 3RW Area might impact bacteria concentrations:

- Increases in temperature result in increased evaporation rates, increased water quality issues that lead to infections, altered BMP efficacy, and/or extend the seasonality of some harmful pathogens.
- Shifts in precipitation patterns have a corresponding impact on bacterial impairment, with an increase in precipitation increasing water quality issues.
- Extreme precipitation events (either droughts or heavy rainfall / storms) likely cause non-linear spikes that increase bacterial contamination by multiple orders of magnitude.

These findings have led other cities in the US and Canada to institute policy measures including continuous bacterial monitoring sensors, installing multiple BMPs in the same geography for redundancy, and public health measures such as automatically limiting river access after rainfall exceeds a certain threshold[58]. Considering the high recreational use of freshwater streams within the 3RW Area, the CMCOG and other partners could explore similar measures to address bacterial contamination.

Streamflow

Changes in precipitation and runoff impact other streamflow characteristics, which in turn may affect water availability and quality. The USGS South Atlantic Water Science Center is currently incorporating climate model data to forecast future water availability and streamflow characteristics for the Southeast region, which includes the 3RW Area[59]. Set to be completed by Q3 2021, these data can inform implementation of the 3RWBP by offering forecasts for future streamflow characteristics such as frequency, magnitude, timing, etc[60].

For long term effectiveness, BMPs should have a capacity that remains above potential future shifts to characteristics critical to their function, such as precipitation in water quality BMPs. For example, when available the data could be used to size a BMP that considers both current conditions and a higher future mean flow rates due to a shift in precipitation and/or runoff. These data may also be used in conjunction

[58] Usually 1-2 inches in 24 hours, or a 90-95th percentile rain event
[59] See the project landing page here: https://secasc.ncsu.edu/science/water-availability/
[60] Data products are available via the USGS: https://www.sciencebase.gov/catalog/item/5b9ffcbae4b08583a5c2776f

with scientific studies to help ascertain co-occurring changes in the watershed such as an increase in impervious surface alongside climate change[61].

6.4 Climate Ready Planning

Climate adaptation is the practice of implementing plans and strategies in response to predicted climate impacts, usually with the goal of decreasing damage and increasing resilience[62]. Reasons for using climate ready planning include saving communities money (by mitigating future damages), increasing equitable outcomes and co-benefits, and broadening planning by directly linking watershed management to other local planning goals[63]. This section provides a process for implementing climate considerations into watershed planning in the 3RW Area, with recommendations on:

1. Seeing the watershed as infrastructure
2. Adopting a climate planning framework
3. Integrating climate planning with the EPA 9 Elements

6.4.1 Step 1: See the Watershed as Infrastructure

River landscapes are complex systems that benefit individuals and neighborhoods, forming part of the community landscape[64]. Viewing watershed planning as a solely technical problem decreases the likelihood that planning goals will be met. Plans that instead recognize watersheds as sources of social and economic value are more likely to achieve their goals and bring value to the community[65], because planning that considers changing conditions is flexible and able to adjust to a changing climate[66].

There is a growing paradigm of viewing water systems through an infrastructure lens. Through this lens, the watershed becomes an "essential service" to the community[67]. Watersheds create and distribute benefits to the community, and management strategies that consider these benefits a form of infrastructure are more likely to succeed[68]. Planning that only considers traditional inputs (such as impervious surface or bacterial contamination) in isolation is more likely to fail[69].

6.4.2 Step 2: Adopting a Climate Planning Framework

Through a series of focused planning discussions, the CMCOG and research partners at Carolinas Integrated Sciences & Assessments (CISA) selected two planning frameworks, *Co-Benefits* and *Equitable Adaptation*, that could be used to guide climate-ready planning in the 3RW Area. Frameworks are useful

[61] Bhaskar et al. (2020). Hydrologic Signals and Surprises in U.S. Streamflow Records During Urbanization. https://doi.org/10.1029/2019WR027039
[62] IPCC AR5, Chapter 15. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap15_FINAL.pdf
[63] For examples of climate ready planning, consult the Adaptation Clearinghouse Water Sector Database: https://www.adaptationclearinghouse.org/sectors/water/
[64] Burbach et al. (2019). Catalyzing Change: Social Science for Water Resources Management. https://doi.org/10.1111/j.1936-704X.2019.03307.x
[65] Verbrugge et al. (2019). Integrating sense of place in planning and management of multifunctional river landscapes: experiences from five European case studies. https://doi.org/10.1007/s11625-019-00686-9
[66] Bloemen et al. (2018). Lessons learned from applying adaptation pathways in flood risk management and challenges for the further development of this approach. https://doi.org/10.1007/s11027-017-9773-9
[67] Logan & Guikema. (2020). Reframing Resilience: Equitable Access to Essential Services. https://doi.org/10.1111/risa.13492
[68] Narayanan et al. (2020). From Awareness to Action: Accounting for Infrastructure Interdependencies in Disaster Response and Recovery Planning. https://doi.org/10.1029/2020GH000251
[69] Schell et al. (2020). The ecological and evolutionary consequences of systemic racism in urban environments. https://doi.org/10.1126/science.aay4497

because they simplify the planning process and allow a community to focus on its goals and the actions it can take to meet them.

Co-Benefits

Co-Benefits is the idea that climate planning is more likely to be successful if it considers more than one benefit to the community[70]. This framework has been used in a variety of urban planning contexts, particularly where problems intersect within a confined geographic area and multiple groups can join to collaborate[71]. Implementing co-benefits through a WBP is as simple as listing and categorizing them according to local priorities, and then using this list as a baseline in decision making (See **Figure 6-6**). For a given BMP (in this example a rain garden), all the benefits are listed and grouped by topic. Some topics may address the goals of the WBP, while others are co-benefits that may be goals in other local plans and/or provide tangible benefits to the community. Consideration of co-benefits can lower risk and increase resilience. For example, two BMPs may be comparable when solely considering watershed pollutant reductions, but a green infrastructure BMP could have additional benefits such as increasing the watershed's recreational value, absorbing carbon pollution from the atmosphere (carbon capture) and providing protection from extreme heat by lowering nearby ground temperatures. If initial cost is the only metric used to make planning decisions, then a BMP which provides fewer co-benefits could be chosen instead of a BMP which provides more co-benefits or a higher cost-benefit ratio. Depending on the co-benefits considered, this would increase risk and decrease resilience.

[70] Diringer et al. (2020). Incorporating Multiple Benefits into Water Projects: A Guide for Water Managers. https://pacinst.org/publication/incorporating-multiple-benefits-into-water-projects/
[71] Rotatori et al. (2020). Breathing Life Back into Cities. https://rmi.org/insight/breathing-life-back-into-cities

Figure 6-6: A diagram from Diringer et al. illustrating an implementation of the co-benefits framework for watershed management.

Equitable Adaptation

The Equitable Adaptation framework incorporates considerations of social and environmental equity into climate planning choices. Managing risks from climate change while adequately addressing equity concerns is often a challenge for community planning[72]. Equity means removing barriers and providing assistance so everyone in a community can thrive[73]. Without equitable adaptation to climate throughout a community, future changes in climate and resulting impacts (e.g., extreme weather events or watershed disturbances) will not be felt equally in the community, which could worsen pre-existing inequality[74].

Research in other contexts shows that not meeting this challenge can result in maladaptation, or the failure of adequately adapting to the situation at hand[75]. In the area of watershed planning and stormwater management, there is a growing recognition of the utility of considering equitable adaptation in managing future impacts [76]. The Chesapeake Bay Watershed is a leading example in incorporating equity into watershed management. Their Environmental Justice and Equity Dashboard (see **Figure 6-7**) includes information that can be used to create outreach programs for at-risk communities and help locate green infrastructure projects in socially vulnerable areas[77]. The watershed dashboard assists local governments in the watershed in creating projects that benefit underserved communities by breaking down demographic and watershed data using a web-based Geographic Information System (GIS).

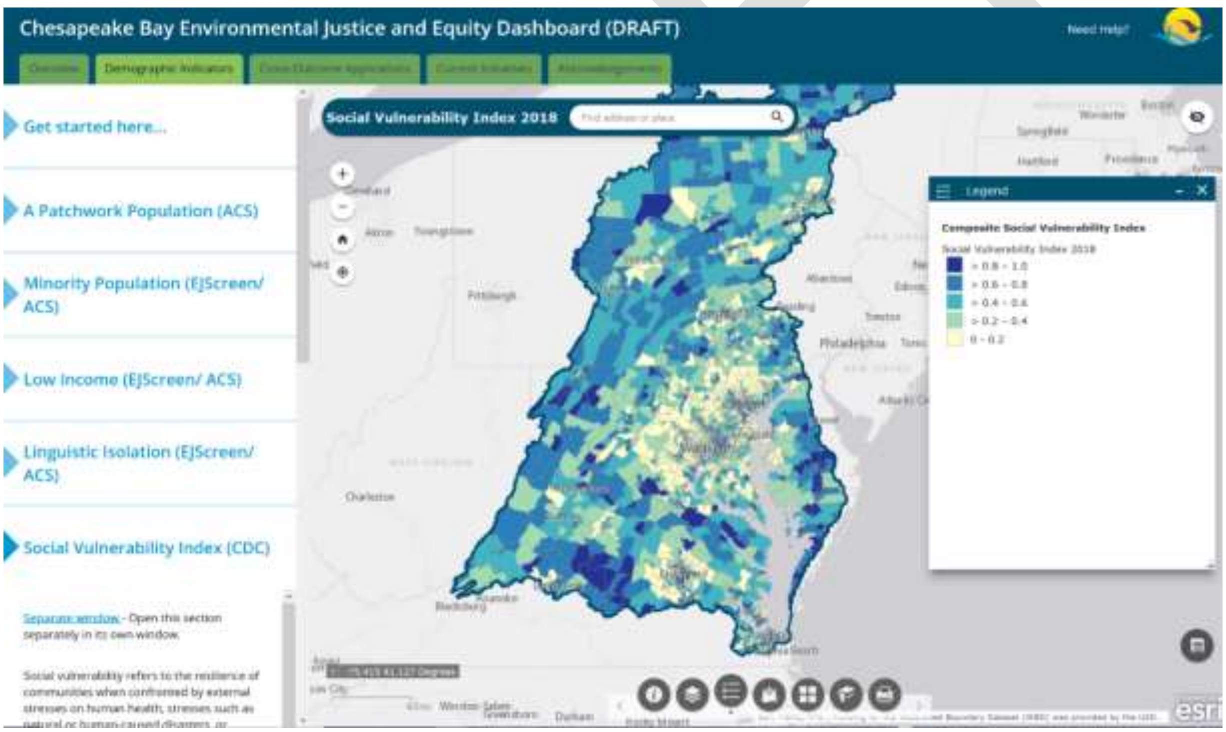

Figure 6-7: A screenshot of the Chesapeake Bay Program's GIS dashboard

[72] Jabobs & Street. (2020). The next generation of climate services. https://doi.org/10.1016/j.cliser.2020.100199
[73] U.S. Climate Action Network, see https://www.usclimatenetwork.org/justice_equity_diversity_and_inclusion
[74] Hsiang et al. (2017). Estimating economic damage from climate change in the United States. https://doi.org/10.1126/science.aal4369
[75] Magnan et al. (2016). Addressing the risk of maladaptation to climate change. https://doi.org/10.1002/wcc.409
[76] Georgetown Equitable Adaptation Toolkit, see https://www.georgetownclimate.org/adaptation/toolkits/equitable-adaptation-toolkit/resilient-water.html
[77] View the dashboard live at https://gis.chesapeakebay.net/diversity/dashboard

There are several longstanding equity concerns in the 3RW Area. For example, historical trends from redlining could still have present impacts that shape the watershed, such as availability of green spaces or concentrating vulnerable populations in undesirable properties. The map of Columbia's neighborhoods in 1927 (shown in **Figure 6-8** and **Figure 6-9**) illustrates the divisions drawn by the federal government's Home Owners' Loan Corporation in red[78]. This process led to the term "redlining," where lack of equitable access to financial opportunities pushed "undesirable" people into less economically valuable land. This process resulted in a difference in the ability to build wealth over time through homeownership, resulting in spatial patterns of economic inequality that continue to the present. On the map, areas colored in yellow and red were negatively affected. This is just one example of historical inequality that continues to impact present watershed characteristics.

A first step to consider this in the 3RWBP is a socioeconomic spatial analysis (such as information included in **Section 2.7.2**) which could be expanded and integrated with watershed community outreach efforts. Relevant local plans such as the Columbia Compass[79] and NC Climate Risk Assessment and Resilience Plan[80] provide examples to draw from.

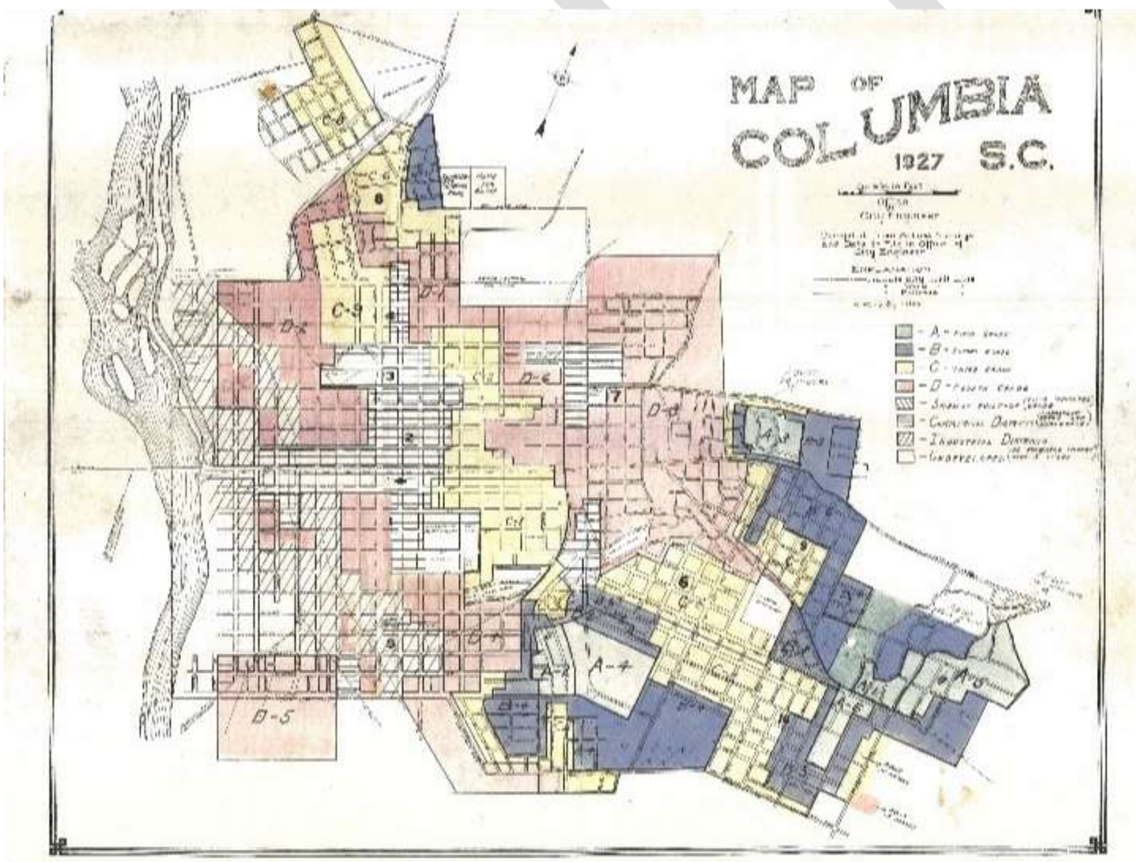

Figure 6-8: A map of Columbia, SC in 1927 showing redlining

[78] Robert K. Nelson, LaDale Winling, Richard Marciano, Nathan Connolly, et al., "Mapping Inequality," *American Panorama*, ed. Robert K. Nelson and Edward L. Ayers, accessed March 11, 2021, https://dsl.richmond.edu/panorama/redlining/
[79] Columbia Compass Report, see https://www.columbiacompass.org/
[80] North Carolina DEQ, see https://secasc.ncsu.edu/2020/06/15/north-carolina-climate-risk-assessment-and-resilience-plan/

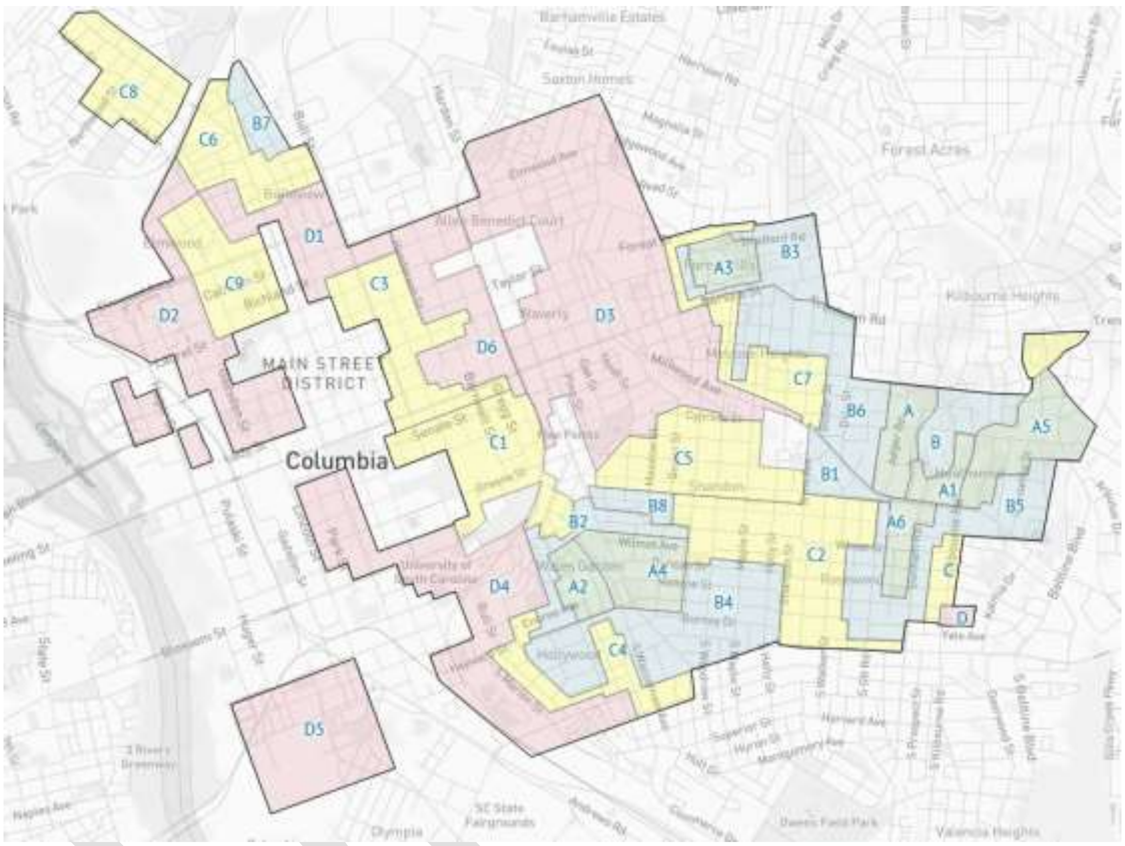

Figure 6-9 - A modern map of Columbia, SC showing areas that were redlined in 1927

6.4.3 Step 3: Integrate Climate Planning with EPA 9 Elements

Climate planning can be used to expand the reach of management measures in the 3RWBP and achieve the goals of the EPA 9 Elements of a Watershed-Based Plan. The potential application of climate informed planning is particularly prominent in three of the EPA's 9 Elements. These elements are Best Management Practices, Education and Outreach, and Implementation Schedule.

Nine Elements #3 - Best Management Measures (BMPs)

Because they serve as new components in the watershed system, Best Management Practices (BMPs) can be a source of co-benefits and may reduce structural inequality if equity is considered in their design, location, and implementation. Concentrating stormwater management investment in certain areas may disproportionately benefit that area and can lead to green-gentrification or other unintended planning consequences. Investment should prioritize community needs and directly involve them in decision-making processes to better connect the benefits associated with water quality improvements to those communities.

Incorporating co-benefits and equitable adaptation in locating and prioritizing investment for new watershed infrastructure could lead to prioritizing green infrastructure BMPs[81]. Green infrastructure BMPs can be less expensive compared to other types of BMPs[82].

Green Infrastructure BMP Guides

- SC Forestry Commission's Evaluating and Conserving Green Infrastructure Across the Landscape: A Practitioner's Guide.
- FEMA's Building Community Resilience With Nature-Based Solutions: A Guide for Local Communities.
- NOAA Office for Coastal Management's Natural Instructure Hub.
- EPA's Soak Up the Rain Hub.

Green Infrastructure BMP Examples

- Charleston SC
- SC Floodwater Commission
- American Forest partner cities
- the Nature Conservancy partner geographies
- MIT
- the Center for Watershed Protection

Nine Elements #5 Education and Outreach

Community groups in the watershed may be a reservoir of community knowledge and resilience: faith-based organizations, ethnic networks, community-based organizations, etc. These groups directly experience adverse watershed impacts such as low water quality or flooding events. Co-management can

[81] Seddon et al. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. https://doi.org/10.1098/rstb.2019.0120
[82] Odefey et al. (2012). Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. Link.

engage these community assets, but the relationship between citizens and government must go beyond stakeholder engagement and involve them in the decision-making process[83]. This co-management strategy can be aided by considering how communications about the watershed take place in the community[84]; framing communications to resonate with different priority community concerns while still addressing broad water quality remediation goals[85].

To align with SCDHEC guidelines, educational outreach activities must be created to encourage public participation and awareness. Building equity into the communication ensures all segments of the population (e.g. low-income communities, people of color, or other frontline communities) have a voice throughout the process and ensures education reaches communities that did not have prior access to information [86]. Considering co-benefits may further broaden the pool of stakeholders who are connected to the watershed. Community education and outreach are instrumental to a successful watershed-based plan and are more successful when directed towards vulnerable populations, warranting increased attention to accessibility[87]. For example, in the Michigan Huron Watershed area communicating relevant watershed impacts was highly effective because all citizens were informed of the risk and involved in decision-making[88]. Following are examples of guides and toolkits available to draw from:

Education and Outreach Guides and Toolkits

- NOAA Office for Coastal Management's Enhanced Engagement and Risk Communication for Underserved Communities: Research Findings and Emerging Best Practices.
- American Rivers' Water Justice Toolkit: A Guide to Address Environmental Inequities in Frontline Communities.

Nine Elements #6 - Implementation Schedule

Cities are increasingly preparing their watersheds and stormwater infrastructure to protect against the impacts of extreme rainfall events and other climate changes[89]. Considering climate change in this way can save money, while failing to proactively address climate risks can increase costs and limit the ability to raise capital[90].

Cities are also using specialized income taxes and financial tools to fund green infrastructure projects. For example, in response to lack of funds and growing climate risks, Grand Rapids, Michigan set a 1.5% income tax and a stormwater credit trading program to fund green infrastructure BMPs[91]. In addition to creative

[83] Wyborn et al. (2019). Co-Producing Sustainability: Reordering the Governance of Science, Policy, and Practice. https://doi.org/10.1146/annurev-environ-101718-033103
[84] Yuen et al. (2017). Guide to Equitable, Community-Driven Climate Preparedness Planning. https://www.adaptationclearinghouse.org/resources/guide-to-equitable-community-driven-climate-preparedness-planning.html
[85] Orlove et al. (2020). Climate Decision-Making. https://doi.org/10.1146/annurev-environ-012320-085130
[86] Georgetown Equitable Adaptation Toolkit, see https://www.georgetownclimate.org/adaptation/toolkits/equitable-adaptation-toolkit/resilient-water.html
[87] Floress et al. (2015). The Role of Social Science in Successfully Implementing Watershed Management Strategies. https://doi.org/10.1111/j.1936-704X.2015.03189.x
[88] Cheng et al. (2017). Risk Communication and Climate Justice Planning: A Case of Michigan's Huron River Watershed. https://doi.org/10.17645/up.v2i4.1045
[89] Morrison. (2021). What lurks beneath: A new answer to more intense storms. https://www.washingtonpost.com/climate-solutions/2021/06/06/stormwater-infrastructure-sensor/
[90] Painter. (2020). An inconvenient cost: The effects of climate change on municipal bonds. https://doi.org/10.1016/j.jfineco.2019.06.006
[91] For more information, see http://glpf.org/blog/creative-partnership-forges-a-path-to-innovative-green-infrastructure-funding-in-grand-rapids/

financing tools[92], considering climate change can also unlock new sources of funding and meet federal requirements of various planning activities:

1. Private firms seeking carbon offsets: certain BMPs (e.g., permanent green infrastructure projects which absorb sufficient carbon) may have co-benefits such as carbon capture which can be monetized as carbon offsets and sold to private firms. While the marketplace and standards for carbon offsets are emerging, this could become a viable source of supplemental funding. Recent research found 30% of companies in the US have set a net zero target, suggesting this market may emerge within the timeline for the implementation schedule set for this plan[93]. For example, Microsoft is spending $1 billion on carbon offsets by 2025, some of which could potentially be allocated towards green infrastructure[94]. At least one project in South Carolina has already been funded by a carbon market[95].
2. Federal grant requirements: Partners implementing the 3RWBP may be required to consider environmental justice when seeking federal funding. For example, the Justice 40 initiative will require that 40% of federal investments in certain categories go to disadvantaged communities for covered programs. In the interim guidance, one such category includes all federal programs investing in "Critical clean water and waste infrastructure"[96]. Considering equitable adaptation and other climate considerations is also likely to benefit applications for other types of grant-based or philanthropic funding.

6.4.4 Putting Climate Ready Planning into Practice

The team that put together this report has already taken actions to share how climate considerations were included as part of the watershed-based planning process. A short communications piece summarizing the lessons learned from this process was submitted to the SC Journal of Water Resources in February 2022 and is awaiting review. If it is accepted, it will be published later in 2022 and could inform other watershed planners seeking to learn from our process. Select members of the team are also presenting the key findings of climate considerations in the 3RW Area at the Climate Ready Columbia conference on April 1st, 2022. This plan also includes steps intended to move forward in putting climate ready planning into practice. Specific suggestions are included in the project prioritization priorities (see **Table 6-11**) and the plan's recommendations (see **Section 6.8.2 Evaluation Methods** and **Section 7.0 Recommendations**). These steps are intended to focus on fostering new behavioral change so that the watershed is well positioned to weather different environmental conditions. After the plan is released, this work can be continued by further engaging with local communities and building in recommended actions as the plan continues to evolve and work begins on implementation.

[92] A useful tool for 3RW partners is the American Flood Coalition's funding database, see https://floodcoalition.org/resources/floodfundingfinder/

[93] Cullen et al. (2021). Leveling up net zero climate leadership in the United States: An analysis of subnational net zero targets & recommendations for the Federal Government. https://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper21-01.pdf

[94] For more information, see https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/

[95] For more information, see https://www.postandcourier.com/news/sc-forests-are-protected-for-trapping-carbon-with-a-little-help-from-california/article_323ee998-39ed-11e9-a438-df43b4df1939.html

[96] White House Guidance Memo M-21-28, see https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf

6.5 Implementation Schedule

6.5.1 Priorities

This WBP did not specify individual project locations, but rather gives overall goals for project types to implement on the watershed level (see **Table 4-4**). The recommended BMP types (bioretention, sand filter, stormwater wetland, wet pond, and infiltration practices) were prioritized for their documented ability to provide the greatest bacteria removal. The generalized recommendations for levels of treatment leave flexibility for the many jurisdictions and partners to select areas within their boundaries to prioritize future projects.

The 3RW Stakeholder Group was engaged with a survey to rank these overall goals and determine which project types would be prioritized from the perspective of both an individual organization and as a coalition. **Figure 6-10** presents BMP types that are prioritized for implementation as a coalition of stakeholders throughout the 3RW Area. In this case the implementation of SSO tracking and response programs was considered as the highest priority for the 3RW Stakeholder Group.

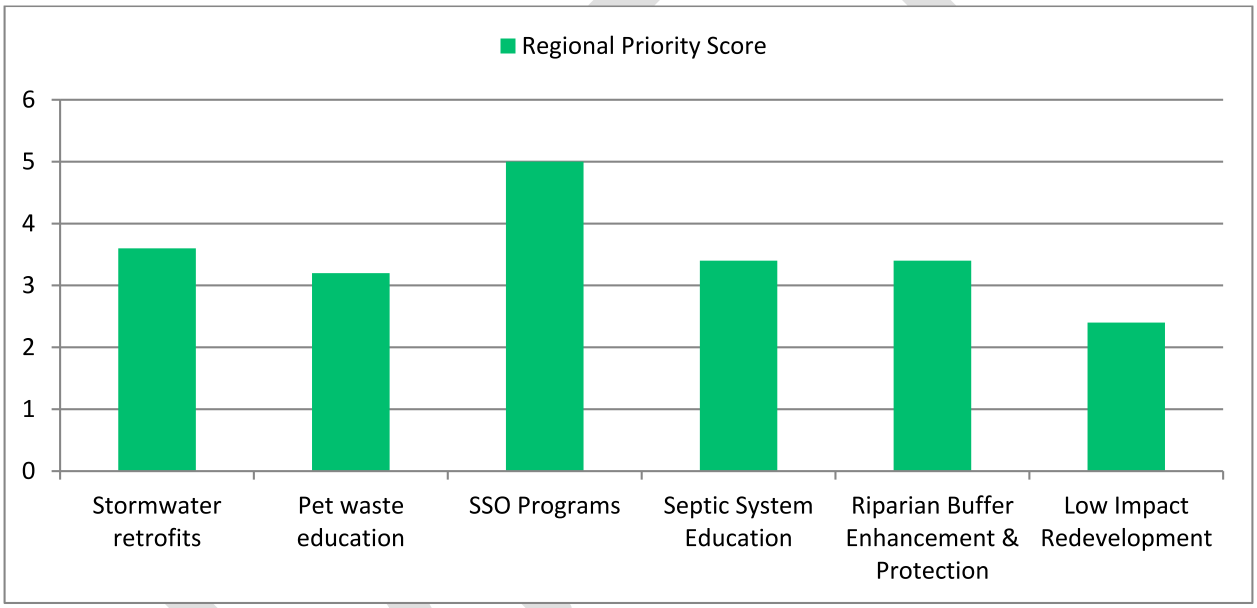

Figure 6-10 - Regional BMP Priorities, indicating which BMP Type will be prioritized as joint coalition projects. 1=lowest priority, 5=highest priority

Figure 6-11 compiles the results of individual project priorities for the overall 3RW Stakeholder Group. In this case the implementation of stormwater retrofits, both as a flood and pollution management measure, would be prioritized as individual project application and implementation. SSO tracking and response programs, and riparian buffer enhancement and protection policies followed as the priorities to be pursued individually by stakeholders throughout the watershed. **Appendix H** presents these results per individual respondent.

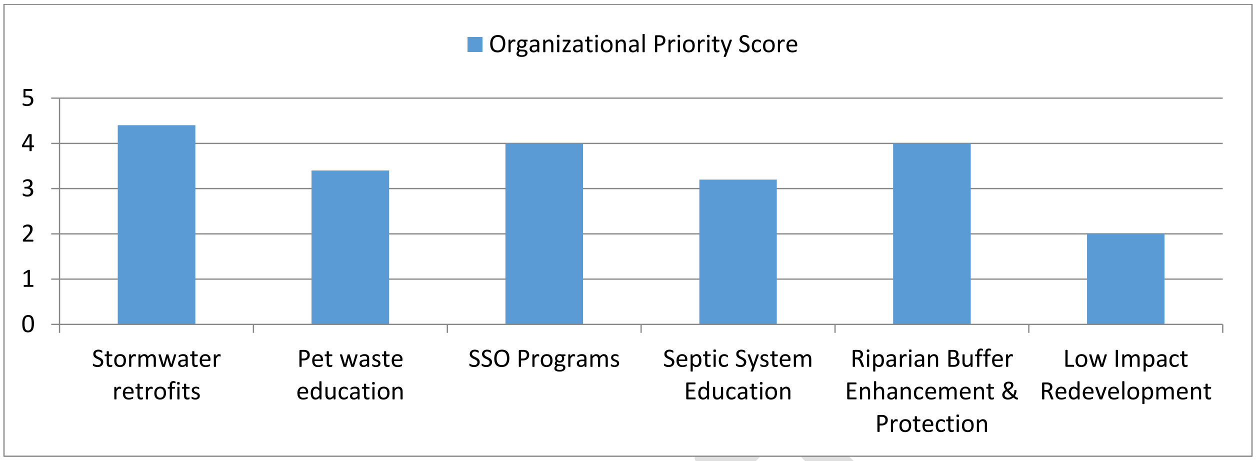

Figure 6-11 - Organizational BMP Priorities, indicating which BMP Type will prioritized for individual projects. 1=lowest priority, 5=highest priority

These results highlight how the coalition overall sees a benefit to implementing SSO management and coordination programs to capture SSO events in a timely manner and curtail bacterial nonpoint source pollution throughout the 3RW Area. However, organizations would need to prioritize stormwater retrofit projects when applying for individual funding opportunities due to the level of remediation required to meet water quality standards within the 3RW Area. All jurisdictions must be continuously applying for and implementing. All jurisdictions must be continuously applying to and implementing stormwater retrofits throughout the 28-year planning horizon of the 3RWBP, such as bioretention cells, or constructed wetlands. As such, implementing these strategies should be pursued both as a coalition and as individual jurisdictions, building regional resiliency while addressing local water quality concerns. This implementation schedule is described on **Table 6-18**.

In addition to these regional and organizational priorities, several 319 eligible projects have been mentioned by stakeholders within the 3RW Area. These include:

- The CMCOG would like to work with the Mt. Zion Baptist Church, Neriah Community Development Corporation, and the City of Cayce to explore opportunities for developing a park and greenway system along an unnamed tributary in the Congaree Creek watershed that would connect adjacent residential and commercial areas. The project would include daylighting and restoration of approximately 2,056 LF of stream. The church property, which includes an approximately 300 LF section of the stream, could provide environmental education and outdoor recreation opportunities for youth programs and area residents. For this project, the WTM estimates pollutant removals of 154 lb/yr TN, 140 lb/yr TP, and 509,888 lb/yr TSS, although additional benefits from flood resilience to ecological services are not included in this calculation.
- The Lexington Countywide Stormwater Consortium has expressed interest in mitigating bacterial pollution from agricultural sources in the Lexington County portions of the 3RW Area (seen in **Table 5-7**). This includes strategies such as installation of exclusion fencing, pipelines, water troughs and heavy use area for small farms with animals in the 3RW Area. Quantity of farms would have to be determined for a future 319 grant application, but these strategies are estimated to cost about $20,000 per farm.

For further project prioritization, the consultant team suggests starting with a Project Evaluation and Ranking Criteria like in **Table 6-11** to help the individual jurisdictions prioritize potential project location areas. This can be adjusted according to the needs of each watershed or jurisdictional area.

Table 6-11: Example Project Evaluation and Ranking Criteria

Metric	Total Score	Potential Points Awarded					
Construction Cost	10	<500k = 10	\$500k - \$1 mil = 7	\$1 mil - \$5 mil = 5	\$5 mil - \$10 mil = 3	> \$10 mil = 1	
Location near Bacteria Hotspot	10 each	Satellite sewer	Dog park	Septic systems			
Percent Imperviousness of Drainage Area	15	> 30% = 15	20 – 30% = 10	10 – 20% = 5	< 10% = 1		
Estimated Bacteria Load Reduction (10^6 MPN/yr)	10	> 10,000 = 10	5,000 – 10,000 = 7	1,000 – 5,000 = 5	< 1,000 = 1		
Runoff Reduction	5	>1,000 af-ft = 5	500 – 1,000 ac-ft = 3	< 500 ac-ft = 1			
Maintenance Burden	5	BI = 5	AN = 3	IL = 1	DAIL = 0		
Landowner Cooperation	5	PUB, MIN = 5	PUB, MAJ = 4	ROAD = 3	PRIV, MIN = 2	PUB, MAJ = 1	PRIV, MAJ = 0
Permitting Burden	5	NP = 5	TP = 4	T + E = 3	T + B = 2	EIP = 1	
Visibility/Education Opportunity	5	HI, PUB = 5	HI, PRIV = 3	LOW = 2	HI, CI = 1		
Accessibility	5	NAI = 5	MAI = 3	MULT = 2	MJAI = 1		
Co-Benefits	15	> 20 = 15	10-20 = 10	5-10 = 5	< 5 = 0		
Equitable Adaptation	10	YES = 10	NO = 0				
Total	**100**						
		BI = minimal biennial maintenance *AN = minimal annual maintenance* *IL = intensive landscaping* *DAIL = difficult access, intensive landscaping* *PUB = public owned property* *PRIV = privately owned property* *MAJ = major impact on property* *NP = no permits* *TP = typical permits* *T+E = typical plus environmental permits*			*T+B = typical plus building permits* *EIP = environmental impact permits* *HI = high visibility* *LOW = low visibility* *CI = conflict of interest/goals* *NAI = no access impediments (ROW)* *MAI = minor access impediments* *MULT = multiple private access points* *MAJ = major access impediments*		

6.5.2 Estimated Costs

Current cost estimates of individual BMPs, as provided by Dr. Bill Hunt at NC State University[97], can be calculated by assuming a certain range of costs based on the area of each BMP. For example:

- Bioretention (with media & underdrain): $12-$15/ sf
- Permeable pavement: $15- $18/sf
- Constructed Wetlands: $100K-$200K/ acre
- Infiltration Basins: $8-$12/ sf

The Consultant Team chose to allocate costs based on the acreage of the watershed that was treated[98] and adjust according to the rise in infrastructure construction cost indexes (**Table 6-12**). Infrastructure construction cost indexes are aggregated indexes intended to produce quarterly or year-over-year measures of the degree of change in construction costs. Any given index is only intended to be compared to itself, and as such, has no units. An example is the Dow Jones Industrial Average (DJIA), which takes the price per share of numerous selected indicator stocks and aggregates them together as an index of the value of the NY Stock Exchange. The DJIA is only intended for comparison to itself to show the relative change in value of the total NYSE from day to day, month to month, etc. Similarly, the six major infrastructure construction price indexes take factors such as the prices of key raw materials and aggregate them into indexes to illustrate the rate of change in infrastructure construction costs.

The average of the six infrastructure construction cost indexes (includes cost of things like concrete and steel) was 63 points in 2003 and 114 points in 2020, which represents an 81% projected increase in construction costs over 17 years (depending on location, the actual cost will vary). The increase is forecast to be above the recent historical trend this year and over the next few years, as a result of impacts from COVID-19 and supply chain issues. The cost of construction and maintenance of recommended BMPs and buffers in the watersheds ranges from $12,554,405 in Congaree River East to $45,359,785 in Rocky Branch. If all BMPs and buffers are constructed and installed as recommended by the 3RWBP, the total cost (including a 20-year maintenance period) in 2021 dollars is estimated to be $266,013,551 over the 28 years of the proposed implementation (goal of 100% completion by 2050).

The MS4 and non-MS4 jurisdictions in the Three Rivers Watershed cannot support the financial burden of all the recommended projects in this WBP without help from outside grant funding opportunities. This watershed plan has included several potential funding programs and financing mechanisms that could support the implementation of these activities. The following ranked list suggests which of these might be appropriate pursuits based on several factors including the timing of the opportunity, the project(s) it could support, and the organizational capacity needed to pursue it.

[97] Personal communication, 12 November 2021

[98] Wossink, A. and W. Hunt. 2003. The Economics of Structural Stormwater BMPs in North Carolina. UNC-WRRI-2003-344. Available at https://digital.ncdcr.gov/digital/collection/p249901coll22/id/4646

Table 6-12: Cost Estimates to Implement BMPs and Buffers in 3RWBP

Subwatershed	BMP Construction Cost	BMP 20-yr Maintenance Cost	Riparian Buffer Construction Cost[99]	Buffer 20-yr Maintenance Cost	Total Cost
Fourteenmile Creek	$42,856,377	$344,695	$9,461,232	$121,968	$43,323,040
Kinley Creek	$15,407,867	$236,976	$4,494,085	$57,935	$20,196,863
Stoop Creek	$13,495,037	$222,411	$12,063,071	$155,509	$25,936,028
Saluda River North	$7,663,437	$170,155	$6,386,332	$82,328	$14,302,253
Senn Branch & Double Branch	$13,878,559	$225,409	$6,859,393	$88,427	$21,051,788
Congaree River East	$12,341,275	$213,129	$0	$0	$12,554,405
Congaree River West	$14,261,584	$228,362	$1,655,716	$21,344	$16,167,006
UT to Congaree Creek	$12,726,419	$216,273	$4,494,085	$57,935	$17,494,712
Lower Sixmile Creek	$17,689,294	$253,229	$4,257,554	$54,886	$22,254,963
Congaree Creek Outlet	$19,203,119	$263,449	$7,805,516	$100,624	$27,372,708
Rocky Branch	$37,090,777	$362,867	$7,805,516	$100,624	$45,359,785
Total	**$206,613,745**	**$2,736,955**	**$65,282,500**	**$841,580**	**$266,013,551**

[99] NOAA OCM. 2020. https://coast.noaa.gov/data/digitalcoast/pdf/nature-based-solutions-installation-maintenance.pdf

Cost estimates associated with implementing the recommended public outreach and educational programs, such as workshops, are summarized in **Table 6-13**. Members of the PAC have established stormwater education consortiums as well as an active Scoop the Poop Campaign, which will make implementing this aspect of the plan more streamlined.

Table 6-13: Cost Estimates for Public Education and Outreach Programs in the 3RW Area

Project Type	Cost	Unit	Quantity	Extended Cost
Workshop (general cost)				
Printed materials (fliers)	$0.72-$1.0	Per flier	200	$173
Printed materials (tri-fold brochure)	$1.60-$2.40	Per brochure	200	$480
Printed materials (maps / posters)	$6.00-$40.00	Per map	5	$115
Newspaper ad in local paper	$312-$540	Per advertisement	1	$426
Workshop staff	No cost	Per workshop	-	-
Workshop supplies and food	$100-$200	Per workshop	1	$150
		Per workshop		$1,344
Septic System Repairs				
Septic Inspection	$300	Per system	292	$30,000
Septic Repairs	$3,000	Per system	292	$500
Workshop	$1,544	Per workshop	1	$1,344
		Practice Total		$531,344
Pet Waste Education				
Bag stations	$400	Per station	46	$800
Waste pick-up signage	$100	Per sign	2	$200
Workshop	$1,544	Per workshop	1	$1,344
		Practice Total		$2,344
Rain Barrel / Downspout Disconnect Education				
Rain barrel distribution	$100	Per barrel	50	$2,750
Workshop	$1,544	Per workshop	1	$1,344
		Practice Total		$4,094

Practices that were not included in the cost estimate include sanitary sewer overflow inspections/ repairs, as these fall within the normal budgets of the sewer providers in the 3RW Area. A cost estimate for urban redevelopment was not explicitly created because it will be driven by market forces in the Columbia area, which has a strong local economy.

6.5.3 Potential Funding Sources

Funding needed to implement components of the plan will depend on the type of strategy. Funding will come from current program resources, local and state government funding, and a variety of grants, cost share programs, and private programs that focus on water quality, and environmental restoration. Examples of grant funding sources and the types of projects they may serve are listed in **Table 6-14**.

Table 6-14: Funding Source Summary

Program	Funder/Partner	Program Goals or Outcomes
Nonpoint Source Implementation Program (Section 319)	SCDHEC/EPA	Assistance in implementing projects for urban and agricultural runoff, land conservation for water quality benefits, natural channel design, and streambank stabilization.
Resilient Communities Program	NFWF	Enhance community capacity to plan and implement resiliency projects and improve the protections afforded by natural ecosystems by investing in green infrastructure and other measures.
Building Resilient Infrastructure and Communities	FEMA	Provides proactive investment in community resilience through innovate approaches to partnerships such as shared funding mechanisms and/or project design.
Five Star & Urban Waters Restoration Program	NFWF	Design and planning services for habitat, water quality, and social media campaigns.
Environmental Justice Grants	EPA	Supports and empowers communities working on solutions to local environmental and public health issues.
Hazard Mitigation Grant Program	FEMA	Increase understanding and proactive action to help communities reduce losses from natural hazards.
Healthy Watersheds Consortium	EPA, NRCS, US Endowment	Assist municipalities in efforts to protect freshwater ecosystems and watersheds through the stewardship of existing landscape; includes implementation of large-scale watershed protection or green infrastructure.
SC Rural Infrastructure Authority (RIA) Grants	SC RIA	Assist municipalities in keeping up with repairs or upgrades to aging or overburdened infrastructure.
State Revolving Fund (SRF)	SCDHEC	Provide low-interest rate loans for sanitary sewer repairs and stormwater quality improvement projects

6.5.4 Financing Mechanisms and Timelines

The consultant team recommended stormwater retrofit and riparian buffer projects that will advance the goals of the 3RW Stakeholder Group. The consultant team has included several potential funding programs and financing mechanisms that could support the implementation of these activities. The following ranked list suggests which of these might be appropriate pursuits based on several factors including the timing of the opportunity, the project(s) it could support, and the organizational capacity needed to pursue it.

1) Nonpoint Source Implementation Program (Section 319)
https://scdhec.gov/environment/your-water-coast/watersheds-program/section-319-nonpoint-source-implementation-grants

Source/Agency

Funding is allocated by the EPA to SCDHEC for distribution to applicants. Availability of funds is dependent upon federal budgets.

Type of Funding Provided

Distributed funds are in the form of grants, with a match requirement of 40% non-federal monies to be provided by the applicant. They are issued as quarterly reimbursements.

Description of Eligibility

South Carolina public organizations such as state agencies, local governments, public universities, soil and water conservation districts, regional planning commissions, watershed organizations and nonprofit organizations are eligible to receive NPS grants. Most project proposals cover a geographic scope of one to four 12-digit Hydrologic Unit Codes (HUCs).

Some activities recommended in a WBP may be considered eligible for funding or as match under a 319(h) grant if they represent efforts, approaches, or applications that go "above and beyond" any elements associated with a NPDES permit. For example, if the permit itemizes the installation of nine septic system replacements, funds to replace septic systems 10 and up would be above and beyond the permit requirement.

Application Process

A call for proposals typically comes out in February, initial proposals are due mid-March, and final proposals are due in late May. To be considered, interested groups must submit an initial proposal form and can be requested via email to NPSGrants@dhec.sc.gov.

Note: Any organization applying for funding for activities within an area covered by an MS4 permit must request approval to apply.

2) NFWF Resilient Communities Program

https://www.nfwf.org/programs/resilient-communities-program?activeTab=tab-2

Source/Agency

The National Fish & Wildlife Foundation (NFWF) is a private non-profit foundation, chartered by Congress in 1984, to work in collaboration with the US Fish & Wildlife Service, as well as other public and private entities, to raise and organize funds and award conservation grants to protect and restore our nation's fish, wildlife, plants and habitats for current and future generations.

Type of Funding Provided

The 2020 Grant Slate for this program included 11 awards ranging from $100,000-500,000 per award. The program typically awards 9-12 grants annually. Details on the 2020 awards can be found here: https://www.nfwf.org/sites/default/files/2020-10/resilient-communities-2020-grant-slate.pdf

The ratio of matching contributions offered is considered during the review process, and projects are required to meet or exceed a 1:1 match ratio to be competitive. Matching contributions must be non-federal in nature and may include in-kind contributions of staff and volunteer time, work performed, materials and services donated, cash or other tangible contributions to the project objectives and outcomes. The cost of recent land acquisition or easement may also qualify as match for a project involving work at the acquired site. Partner contributions can also serve as matching contributions and grantees for this grant program commonly use a large amount of in-kind matching contributions to reach this threshold by utilizing their community partnerships to generate match.

Description of Eligibility

In 2017, Wells Fargo and NFWF launched the Resilient Communities Program, designed to prepare for future environmental challenges by enhancing community capacity to plan and implement resiliency projects and improve the protections afforded by natural ecosystems by investing in green infrastructure and other measures. Specific funding priorities for this program include:

- High-impact resiliency adaptations to help communities prepare for fire in the US West, floods and droughts in the Mid-West, and sea-level rise on the Eastern seaboard
- Community demonstration and capacity-building projects that help communities understand environmental risks and opportunities and organize and take actions to improve local resiliency by enhancing natural buffers and system functions
- Scalable, nature-based resilience solutions benefiting affordable housing and/or small businesses in communities vulnerable to impacts from natural disasters

The program places special emphasis on inclusion and helping traditionally underserved or low- and moderate-income communities build capacity for resiliency planning and investments in "greener" infrastructure. Eligible applicants include non-profit 501(c) organizations, local governments, state government agencies and federally recognized tribes in the US.

Application Process

Pre-proposals are due mid-March and awards are announced in September. An applicant webinar is usually made available mid-January. All application materials must be submitted online through National Fish and Wildlife Foundation's Easygrants system at https://easygrants.nfwf.org

3) FEMA Building Resilient Infrastructure and Communities

https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

Source/Agency

Funding is allocated by the Federal Emergency Management Agency (FEMA) under the Department of Homeland Security. State level emergency management/hazard mitigation agencies participate in the administration and ranking of applications.

Type of Funding Provided

Distributed funds are in the form of grants, with a match requirement of 25% non-federal monies to be provided by the applicant. In-kind services may be counted toward the local match.

Description of Eligibility

Local governments, including cities, townships, counties, special district governments, state agencies, and federally recognized tribal governments are eligible to apply as sub-applicants. Funds are awarded at the state level and distributed to the selected sub-applicants. Private and non-profit organizations are not eligible applicants.

Note: BRIC grants cannot be utilized solely for water quality improvement projects. However, if entities in the 3RW Area pursue BRIC funding for resilience projects anywhere in the planning area, BRIC encourages the integration of green infrastructure with projects they fund. This presents an opportunity to combine green stormwater retrofits along with a bigger project and improve the scoring of any BRIC application.

Application Process

Notice of funding opportunity typically releases in August, and interested sub-applicants must communicate their interest to the state emergency management agency by November. State applications are due in January with a pre-award notice typically coming out in the Summer. The whole process takes about a year for a sub-applicant, with formal awards announced sometime in the Winter.

Local governments, including cities, townships, counties, special district governments, state agencies, and federally recognized tribal governments (who choose to apply as subapplicants) are considered subapplicants and must submit subapplications to their state/territory/tribal applicant agency. The state agency will then select the highest ranked subapplications to submit in the state-level application to FEMA. More information on the South Carolina BRIC can be found here: https://www.scemd.org/recover/mitigation/

4) Five Star & Urban Waters Restoration Program

https://www.nfwf.org/fivestar/Pages/home.aspx

Source/Agency

The National Fish and Wildlife Foundation (NFWF) and the Wildlife Habitat Council (WHC), in cooperation with the US Environmental Protection Agency (EPA), USDA Forest Service (USFS), US Fish and Wildlife Service (USFWS), FedEx, Southern Company, and Alcoa Foundation, will award approximately $1.7 million in grants nationwide. The Five Star and Urban Waters restoration grant program seeks to develop community capacity to sustain local natural resources by providing funding to local partnerships focused on improving water quality, watersheds, and the species and habitats they support.

Type of Funding Provided

Awards of $20,000 to $50,000 are provided, with about 40-50 grants awarded per year. Grants should span one to two years in length; applications requesting more than $30,000 should propose projects longer than one year. These grant funds must be matched 1:1 with non-federal funds.

Description of Eligibility

Eligible applicants include non-profit 501(c) organizations, state governmental agencies, local governments, municipal governments, Indian tribes, and educational institutions.

Grant funds may to be used to support ongoing efforts to comply with legal requirements, including permit conditions, mitigation, and settlement agreements. However, grant funds may be used to support projects that enhance or improve upon existing baseline compliance efforts.

Application Process

Request for proposals are usually released late Fall. Applications are submitted through the NFWF Easygrants online system: https://easygrants.nfwf.org

5) EPA Environmental Justice Grants

https://www.epa.gov/environmentaljustice/environmental-justice-grants-funding-and-technical-assistance

Source/Agency

Funding is allocated by the US Environmental Protection Agency under the Department of the Interior to support and empower communities as they develop and implement solutions that significantly address environmental and/or public health issues at the local level.

Type of Funding Provided

The Environmental Justice Collaborative Problem-Solving (EJCPS) Cooperative Agreement Program awards up to $120,000 per award in financial assistance over a two-year period to enable community-based organizations to partner with stakeholders from across industry, government, academia to develop and implement solutions that will significantly address environmental and/or public health issues at the local level. Cooperative agreements between collaborating entities can be awarded in amounts of up to $200,000 per award. No non-federal match is required.

Description of Eligibility

Eligible entities include:

- Incorporated non-profit organizations—including, but not limited to, community-based organizations, grassroots organizations, environmental justice networks, faith-based organizations and those affiliated with religious institutions
- US Territories

- Tribal governments, either federally-recognized or state-recognized – including Alaska Native Villages; or
- Tribal organizations
- Freely Associated States (FAS) – including state and local governmental entities and local non-profit organizations in the Federated States of Micronesia, the Republic of the Marshall Islands, and Palau

Projects to improve water quality or conduct sampling programs are eligible for funding.

Application Process

The typical annual schedule for this grant has a call for applicants around March, a pre-award notice sometime in the Summer, and a formal award around October. All applications must be submitted electronically through www.grants.gov. Applications transmitted via postal mail, fax, and/or email will not be considered.

6) SC Rural Infrastructure (RIA) Grants

https://ria.sc.gov/grants/

Source/Agency

The SC Rural Infrastructure Authority was established by the General Assembly under Title 11, Chapter 50 of the SC Code of Laws. The purpose of the RIA is to assist municipalities in keeping up with repairs and or upgrades to aging or overburdened infrastructure—aka, "basic infrastructure" such as stormwater and wastewater management facilities—through provision of grant funding.

Type of Funding Provided

Maximum amount of grant money awarded for a single project is $500,000.00. These grant funds may be used to build, upgrade, improve, or extend publicly owned water, sewer, and storm drainage infrastructure throughout the state. Grant funds can only be used on construction activities, with a match requirement of 25% of the total project construction cost required by grantees in Tier I and II counties. In all cases, grantees must cover non-construction costs related to the project. The applicant is responsible for design, engineering, permitting, acquisition, legal, and other non-construction costs associated with the project.

Description of Eligibility

Local governments, special purpose and public service districts, as well as public works commissions may apply directly to RIA for grant funding. Local governments may also apply for grant funding on behalf of not-for-profit water and sewer companies that serve the local government. For-profit utilities are not eligible for RIA grant funding.

Application Process

While grant application deadlines are generally in September and March of each year, specific due dates are announced at the beginning of the state's fiscal year in July. Applications received after the announced deadline will be considered in the next funding round.

Application information can be found here: https://ria.sc.gov/grants/how-to-apply/

6.6 Community Engagement

Development of the plan has included community engagement efforts to both inform the public about watershed issues and to engage them to participate in identifying possible pollutant hotspots and BMP locations. The following sections describe efforts in place throughout the assessment and planning process, and the strategies for future outreach.

6.6.1 The 3RW Stakeholder Group

The 3RW Stakeholder Group is a multi-jurisdictional coalition of organizations that have been communicating since 2016 to address issues in the region related to bacterial contamination. Active participants represent five local governments, a regional council of governments, one state agency, and one non-profit advocacy organization. The jurisdictions also represent eight MS4s, three drinking water utilities, and five wastewater utilities.

The coordination and communication efforts throughout the development process of this plan positions the 3RW Stakeholder Group to steward the implementation of watershed management BMPs in the 3RW Area. The group can support periodic, regional coordination of activities such as water quality monitoring, and BMP design and implementation. This structure also allows the group to reduce duplication of efforts in watershed and water quality management, and to share financial and staff resources to apply for grant funds and coordinate program implementation, such as it did through the development of this plan.

The 3RW Stakeholder Group also has access to other organizations, coalitions, and programs that support the goals and recommendations of this plan. This includes coalitions such as the Midlands Area Joint Installation Consortium (MAJIC), and effort by the South Carolina National Guard to protect the training resources at Fort Jackson, Shaw Air Force Base, McEntire Joint National Guard Base, Poinsett Bombing Range, and McCrady Training Center. MAJIC, through strategies such as coalition building and a targeted conservation program, promotes sustainable development and habitat conservation to preserve the military training mission of military installations in the Midlands region of South Carolina. The Congaree National Park is leading a similar coalition through the Congaree Biosphere Region (CBR), which was developed through the United Nation Educational, Scientific, and Cultural Organization (UNESCO) Man and Biosphere Programme. The coalition supports cultural resource capacity building, water quality monitoring, and sustainable development in a region around the Congaree National Park which includes the eastern portion of the 3RW Area. Finally, the CMCOG regularly convenes the Environmental Planning Advisory Committee (EPAC), a regional committee made up of water and sewer utility providers that support water quality planning efforts under the requirements of Section 208 of the Clean Water Act.

6.6.2 Partner Organizations

Throughout the process of developing this plan, organizations represented through the 3RW Stakeholder Group were able to network with other organizations active in watershed management, water quality remediation, conservation, and environmental advocacy. These are organizations which would be ideal partners in executing different portions of the 3RWBP. These include, but are not limited to, those listed in **Table 6-15**.

Table 6-15: Outreach and Education Partnerships

Program	Program Goals or Outcomes
Clemson Extension	Provide stormwater education, outreach, and public involvement opportunities for water quality and livestock waste management
Congaree Land Trust	Provide public education for conservation, riparian buffers, water quality
Long Leaf Alliance	Provide public education for conservation, riparian buffers, water quality
Richland and Lexington County Soil & Water Conservation Districts	Develop and implement programs to protect and conserve soil, woodland, riparian, and wetland resources
Natural Heritage Program	Provide information regarding rare, threatened, or endangered species with ranges in the watershed
South Carolina Native Plant Society	Provide speakers/information/plants for rain garden and sustainable landscaping practices
Palmetto Pride	Provide support for litter removal
SC Wildlife Federation	Provide support for invasive species removal
Sustainable Midlands	Non-profit organization that strives to create a healthy, vibrant, and environmentally sustainable Midlands community that both current and future generations can be proud of through advocacy, education, and celebration.
Friends of Congaree Swamp	Non-profit organization that strives to protect and restore the ecological systems and natural beauty of Congaree National Park, such as through the promotion of compatible land uses outside of the park.
River Alliance	Non-profit organization whose mission is to help the regional community become more engaged with the Broad, Saluda and Congaree Rivers by making the rivers accessible to everyone while keeping them protected.

6.6.3 Outreach Strategies

Due to the size of the Three Rivers Watershed and the multiple active jurisdictions within it, establishing a messaging strategy and a communication outlet for the 3RW Area could be beneficial in multiple ways: it would facilitate feedback on regional projects, coordinate watershed education across jurisdictions, and provide the public with a centralized location for updates. The following strategies will be used to gain additional community support and involvement, refining BMPs to improve their potential outcomes. Ways to track the impact of these strategies may be found in **Section 6.82**.

Website – Members of the PAC maintain and update individual websites to disseminate important information about local stormwater management, upcoming events, and accomplishments to the public. These individual efforts may direct residents to the larger, regional efforts of the 3RW Stakeholder Group.

Social Media – Facebook and Instagram accounts, both already existing and created specifically for the Three Rivers Watershed, may be used to publicize information related to programs, engage residents, and share accomplishments. This is another means of providing quick, engaging updates to all interested parties without having to produce a formal update to the website.

Media Coverage – Publicizing and reporting on activities related to the implementation of the Three Rivers Watershed Plan can be accomplished through broadcast and print news media outlets, such as The State newspaper.

Mailings – Direct mailings allow the MS4 jurisdictions to fill potential information gaps (people who do not read the paper, participate in social media, or follow local government news). Fliers, postcards, and posters can all be used to inform residents in the Three Rivers Watershed about the benefits of the proposed stormwater practices. They could generate a list of the addresses of the residents in the watershed, which could be used to send invitations to meetings and workshops or provide other information about nonpoint source pollution outreach events (for example: storm drain markings, construction of stormwater detention basins, etc.).

Factsheets – The MS4 jurisdictions could choose to develop their own standardized version of stormwater management factsheets to coordinate their education programs across the 3RW Area. They could also take advantage of the publications already available from Clemson University's Home & Garden Information Center's database of factsheets, including these specifically geared towards water: https://hgic.clemson.edu/category/water/

- Aquatic and Shoreline Plant Selection (HGIC 1709)
- Rainwater Harvesting Systems Guidance for Schoolyard Applications (HGIC 1729)
- Illicit Discharges and Water Pollution (HGIC 1850)
- Shorescaping Freshwater Shorelines (HGIC 1855)
- Bioretention Cells: A Guide for Your Residents (HGIC 1862)
- Introduction of Bioswales (HGIC 1863)

Community Meetings – Providing stakeholders in the Three Rivers Watershed, such as residents and business owners, the opportunity to provide feedback and receive updates on aspects of this plan and its implementation will greatly enhance the public's support of this work. Topics of meetings may include:

- Overview of watershed, implementation strategy, and benefits
- Possible funding sources
- General stormwater education seminars (what is stormwater and why is it a problem)

Individual Outreach – Working with property owners in the Three Rivers Watershed is a crucial link between the planning and implementation phases. Through the other education outreach/involvement opportunities listed in this section, it may be possible to identify individuals who would be willing to participate in activities such as stream restoration, riparian buffer plantings, and other stormwater BMPs.

Watershed Association – Interested citizens, MS4 representatives, professionals, and educational partners can form a Three Rivers Watershed Association to oversee the implementation and periodic evaluation of this watershed management plan. This organization would function as a non-profit organization that can partner with the MS4 jurisdictions to apply for grants and implement public outreach/education endeavors. There are many examples of successful groups in the state of South Carolina (such as the Gills Creek Watershed Association in Columbia) and across the nation (such as the Ellerbe Creek Watershed Association in Durham, NC) that could be used as a reference for the organization and work of a watershed organization.

Workshops – Workshops related to specific measures that organizations or residents can implement on their property will both build support and provide the tools for individual action. Potential workshop topics are varied and may include lawn care, pet waste, septic system maintenance, native and invasive vegetation, and rain gardens.

Professional Training Opportunities – Training geared towards specific audiences (HOAs, landscapers, maintenance crews, etc.) will allow the MS4 communities to prepare the "boots on the ground" in the 3RW Area to manage newly-installed BMPs effectively. Examples of courses offered through Clemson Extension are the *Master Pond Manager* and *Master Rain Gardener* certifications:

- https://www.clemson.edu/extension/water/hybrid-training/mpm/index.html
- https://www.clemson.edu/extension/raingarden/mrg/index.html

6.7 Schedules and Milestones

Over the 28-year planning horizon (2022-2050), implementation of this WBP requires aggressive installation of BMPs and riparian buffer restoration. To break this down into more manageable goals, the implementation was broken into seven equal-length four-year phases, as shown in **Table 6-16**. This approach would require a total of 12,325 acres of developed land to be treated by stormwater retrofits and 258 acres of riparian buffer should be installed over the next 28 years. This equates to 1,761 acres treated by BMPs and 37 acres of riparian buffers installed for each four-year Implementation Phase.

Table 6-16: Phased Goals for Implementation of BMP and Riparian Buffer Projects

Subwatershed	Total Area Treated by BMPs (acres)	BMP Phased 4-year Goal (acres)	Total Riparian Restoration Required (acres)	Buffer Phased 4-year Goal (acres)
Fourteenmile Creek	2,150	307	40	6
Kinley Creek	950	136	19	3
Stoop Creek	825	118	51	7
Saluda River North	450	64	27	4
Senn Branch & Double Branch	850	121	29	4
Congaree River East	750	107	-	-
Congaree River West	875	125	7	1
UT to Congaree Creek	775	111	19	3
Lower Sixmile Creek	1,100	157	18	3
Congaree Creek Outlet	1,200	171	15	2
Rocky Branch	2,400	343	33	5
Total	**12,325**	**1,761**	**258**	**37**

Table 6-17 provides a template for activities that should occur during each of the seven phases of implementation of this WBP. This three-year span represents one typical project application and implementation cycle, as the rate of BMP implementation would be impacted by the capacity of each participating jurisdiction. Larger jurisdictions and regional coalitions would be more capable of having concurrent applications and projects. A similar schedule should be followed for the program to improve on-site septic systems or restore riparian buffers.

Table 6-17: Implementation Phase Activities by Year

Year	Task Description
1	Identify priority site(s)l apply for and obtain funding
2	Design Retrofit(s) and obtain necessary permits
3	Construct Retrofit(s)

The number of BMPs required to meet the pollutant reduction goals for this WBP can be estimated based on the average contributing drainage area that each practice should be designed to treat, as summarized in **Table 6-18.** Overall, the total number of BMP retrofits to be implemented in the 28 years of this WBP planning horizon include 986 bioretention cells, 493 filters, 70 constructed wetlands, 248 wet ponds, and 1,234 infiltration practices. Rocky Branch requires the greatest number of BMP retrofits, reflective of the high level of impairment in this subwatershed. The PAC will coordinate to allocate BMPs by jurisdictional area in each watershed; however, available land for BMP retrofits may be the limiting factor, and communities will need to take advantage of all available opportunities. BMP prioritization strategies are discussed in **Section 6.5.1**.

Table 6-18: Phased Goals for Implementation of Projects

Subwatershed	Area Treated* by BMPs (acres)	Bioretention (2.5 ac)	Filters (5 ac)	Constructed Wetland (35 ac)	Wet Pond (10 ac)	Infiltration Practice (2 ac)
Fourteenmile Creek	2,150 total (430 each)	172	86	12	43	215
Kinley Creek	950 total (190 each)	76	38	5	19	95
Stoop Creek	825 (165 each)	66	33	5	17	83
Saluda River North	450 total (90 each)	36	18	3	9	45
Senn Branch & Double Branch	850 total (170 each)	68	34	5	17	85
Congaree River East	750 total (150 each)	60	30	4	15	75
Congaree River West	875 total (175 each)	70	35	5	18	88
UT to Congaree Creek	775 total (155 each)	62	31	4	16	78
Lower Sixmile Creek	1,100 total (220 each)	88	44	6	22	110
Congaree Creek Outlet	1,200 total (240 each)	96	48	7	24	120
Rocky Branch	2,400 total (480 each)	192	96	14	48	240
Total Number of BMPs		**986**	**493**	**70**	**248**	**1,234**

*"Total" refers to entire treatment requirement for watershed; "each" is the total amount divided evenly among the five BMP types

6.8 Measures of Success

6.8.1 Monitoring Program

Monitoring data for any waterbody is a crucial element that can assist in determining current conditions, developing targeted management strategies, and tracking progress over time. It is recommended that additional monitoring be conducted to better pinpoint sources of pollutants, to establish a solid baseline of conditions, to track progress made towards attaining water quality standards, and to track changes in stream and watershed conditions as implementation of restoration projects occur. This is also known as adaptive management. Some specific recommendations are provided here:

Stream Monitoring – The sampling conducted by SCDHEC, City of Columbia, and the Midlands Rivers Coalition (MRC), as shown in **Figure 3-1**, should be repeated regularly to track trends in baseflow water quality. Additional monitoring locations could be added later to evaluate the success of stormwater BMP retrofits, riparian buffers, and/or redevelopment that occurs after adoption of this WBP. Additional monitoring sites should be added in areas that will help measure the effect of implemented programs and practices. This can include new sampling in tributaries that are not currently monitored, or those that drain to current monitoring stations, such as those listed in **Table 6-19**. Each subwatershed in the 3RW Area should have at least one monitoring station located near its respective outlet; because Fourteenmile Creek is so large, there should be several monitoring stations in that watershed to help better pinpoint pollution hotspots and measure impact of BMPs.

Monitoring could be conducted by the MS4 community the station is located in. Members of the PAC can work with the SC Adopt-a-Stream (SC AAS) program to train volunteers to take water quality samples in additional monitoring locations. SC AAS is a public water quality monitoring network administered by Clemson Public Service and Agriculture. SC AAS is comprised of local communities, educators, volunteers, and local government officials, tasked with a role in providing baseline information about stream conditions, and helping to monitor and track water quality parameters[100].

Project success would depend on the watershed and BMPs implemented. For example, in the subwatersheds with the greatest number of septic systems (Fourteenmile Creek, Saluda River North, and Senn Branch & Double Branch), we anticipate that after implementing inspection, repair, and education programs that the bacteria concentrations during dry weather flows should decrease. In the subwatersheds with the greatest amount of developed land uses (Rocky Branch 97%, Stoop Creek 90%, and Saluda River North 89%) where stormwater BMP retrofits are implemented, the bacteria concentrations in wet conditions should decrease.

[100] https://www.clemson.edu/public/water/watershed/scaas/

Table 6-19: Suggested Supplemental Monitoring Stations

Stream	Existing Station	Existing Monitoring Group	Suggested Upstream Monitoring Group
Upstream Stoop Creek	Downstream CRK08	Congaree Riverkeeper	Adopt-A-Stream, Richland County
Senn Branch	None	None	Adopt-A-Stream, Lexington County
Double Branch	None	None	Adopt-A-Stream, Lexington County
Kinley Creek	None	None	Adopt-A-Stream, Richland County
Drafts Branch	None	None	Adopt-A-Stream, Lexington County
Twelvemile Creek	None	None	Adopt-A-Stream, Lexington County
Long Branch @ confluence with Fourteenmile Creek	None	None	Adopt-A-Stream, Lexington County
Fourteenmile Creek	None	None	Adopt-A-Stream, Lexington County
Lower Congaree Creek	None	None	Adopt-A-Stream, Lexington County
UT to Congaree Creek	None	None	Adopt-A-Stream, Lexington County
Lower Sixmile Creek	None	None	Adopt-A-Stream, Lexington County
UT to Congaree Creek	None	None	Adopt-A-Stream, Lexington County
Congaree River West (upstream)	MRC-07	Midlands Rivers Coalition	

Microbial Source Tracking (MST) – Sources of bacteria throughout the watershed are cause for concern. We know that the upstream influences in the Congaree River come from a much larger Broad River watershed that includes potential agricultural/livestock sources of bacteria. Initiating a Microbial Source Tracking effort can identify the source of the bacteria (e.g. human, pets, or wildlife), which will then help managers control the problem. For example, if the source is indicated as canine, a focus on pet waste education and the installation of pet waste stations would be more helpful than if the human marker is detected; then the focus would shift to searching for potential septic or sanitary sewer sources.

The cost of MST has been declining in recent years, and there are many options of laboratories (private companies and higher education), including:

- LuminUltra: https://www.luminultra.com/lab-testing-services/
- Clemson University: https://www.clemson.edu/public/water/watershed/projects/qpcr.html
- USC School of Public Health

6.8.2 Evaluation Methods

In addition to the monitoring data proposed in **Section 6.8.1**, the success of this watershed plan will be evaluated based on several criteria:

1. Urban Sources (Residential, Commercial, Industrial, and Roadway land use types)
    a. The number of contacts for outreach/education (through television, billboards, etc.)
    b. The number of pet waste stations installed
    c. The number of marked storm drains
    d. The number of rain barrels distributed/voluntarily installed
    e. The area of impervious surfaces treated by installation of stormwater retrofits
    f. The acres of redevelopment completed (and including stormwater BMP improvements)
2. Sewer Sources
    a. The number of attendees at FOG and wipes educational programs
    b. The length of sewer lines inspected and upgraded (coordinate with utilities)
    c. The measured reduction of SSOs reported per year
3. Septic Sources
    a. The number and location of septic systems identified and mapped
    b. The number of septic systems inspected
    c. The number of septic systems upgraded to more efficient systems
    d. The number of households on septic that connect to sanitary sewer system
4. Channel Erosion
    a. The length of 75-ft buffer restored in deficient riparian areas
5. Agriculture
    a. The number of cows fenced out of riparian buffer areas
    b. The number of hobby farmers who attend manure management training
6. Climate Change Adaptation
    a. Incorporation of equitable adaptation into stormwater retrofits and redevelopment in at least 40% of projects within the 3RW Area
    b. Incorporation and documentation of diverse co-benefits into stormwater retrofit projects in at least 40% of projects within the 3RW Area

7.0 Recommendations

The purpose of this WBP is to provide recommendations for improving source water protection, reducing bacteria loading, and improving water quality overall, both for recreational and aquatic life uses.

Recommendations that will help improve and protect source water in the Three Rivers Watershed include:

- Incorporating climate change into stormwater and development planning considerations (see **Section 2.2 Climate** and **Section 6.4 Climate Ready Planning**).
- Focusing on implementing programs and practices in the subwatersheds with the highest bacteria loading (See **Figure 4-4** and **Figure 4-5**).
- Encourage MS4 jurisdictions and wastewater service providers to seek out project partnering opportunities.

Recommendations that will help reduce bacteria loading into Three Rivers Watershed include:

- Continuing outreach efforts to educate the public about the importance of proper pet waste disposal;
- Coordinating with sanitary sewer providers to conduct a sanitary system assessment in the watershed to determine if there are any leaking pipes and manholes, particularly along stream and water crossings;
- Ensure proper maintenance and permitting of satellite sewer systems, as well as the proper tracking and reporting of any SSO's that occur in the collection system
- Determining the locations of any remaining septic systems and ensuring that they are maintained, or that the property owners take the necessary steps to repair or replace them.
- Continue outreach with Stormwater Consortium to provide educational workshops and opportunities for homeowners to implement small-scale runoff reduction on their properties (rain barrels, rain gardens, downspout disconnection)

Recommendations that will help reduce nutrient and sediment loading in the Three Rivers Watershed include:

- Ensuring that the existing stormwater infrastructure in the watershed is maintained properly;
- Identifying and coordinating with property owners where the vegetated buffer around the tributaries should be restored; and
- Conducting the recommended outreach workshops, specifically strategies that homeowners should employ to retain stormwater on their own property (e.g. rain gardens, rain barrels, and impervious surface disconnection).

As a continuing watershed management strategy, it is recommended that further evaluation of the list of potential stormwater retrofits and riparian restoration sites be undertaken in future phases of this management plan. This evaluation should include detailed estimates for permitting and preliminary construction drawings. Communication with the owners of the private stormwater retrofit and riparian buffer restoration sites identified for priority consideration should also be started. Cooperation from these landowners will vary, but landowner cooperation and collaboration are essential for program success.

Decisions that prepare for anticipated future environmental conditions are more likely to result in a vibrant and resilient watershed. Management and planning decisions, especially those that are long term, should consider climate changes within the watershed, including how future temperature and precipitation may change compared to historic conditions. Refining primary data sources utilized in plan evaluation methods should also be considered throughout the planning horizon of the 3RWBP. This includes updating estimates on septic system availability, sewer system distribution, and tracking the implementation of BMPs such as stormwater retrofits throughout the 3RW Area.

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Appendix A – 3RWBP Focus Group Meetings Summary

Over the course of three meetings, the Project Team met with 24 stakeholders in the Urban/Rural Focus Group and five for the Sewer Utility Focus Group. The discussions took place virtually and attendees were provided with an agenda and interactive webmap (for identifying pollutant hotspots in the watershed) prior to the meeting.

Dates and Attendees

November 17, 2020
Urban/Rural Source

- Gregory Sprouse, CMCOG
- Guillermo Espinosa, CMCOG
- Katie Ellis, McCormick Taylor
- Jason Hetrick, McCormick Taylor
- Larry Nates, Lexington Soil & Water Conservation District
- Alan Rickenbacker, Lexington County Planning
- Bill Stangler, Congaree Riverkeeper
- Charly McConnell, Clemson Extension
- Holland Leger, Lexington County Planning
- John Oxner, Lexington Soil and Water Conservation District
- Mark Smyers, Irmo Recreation Commission
- Michael Long, Woolpert
- James Kilgo, Richland Soil and Water Conservation District

November 18, 2020
Sewer Utility

- Gregory Sprouse, CMCOG
- Guillermo Espinosa, CMCOG
- Jason Hetrick, McCormick Taylor
- David Patton, Town of Lexington
- Stephen Shealy, City of Columbia Water
- Joseph Jaco, City of Columbia Water
- Adam Delk, Palmetto Utilities
- Karalyn Miskie, City of Cayce Utilities

November 19, 2020
Urban/Rural Source

- Gregory Sprouse, CMCOG
- Guillermo Espinosa, CMCOG
- Katie Ellis, McCormick Taylor
- Jason Hetrick, McCormick Taylor
- Gary Price, Lexington County
- Sheri Armstrong, Lexington County
- Carroll Williamson, City of Cayce
- Angela Vandelay, Wood Environment
- Warren Hankinson, City of Columbia
- AJ Jessee, City of Columbia
- Leigh DeForth, City of Columbia
- Jennifer Dowden, City of West Columbia
- Bill Marshall, SCDNR
- Shea McCarthy, SCDHEC
- Jordan Elmore, SCDHEC
- Chester Sandsbury, SCDHEC
- John Grego, USC, Friends of Congaree Swamp, Richland County Conservation
- Karen Kustafik, City of Columbia Parks
- Jory Fleming, CISA

Urban/Rural Source Notes

- **Potential Sources of Bacteria**
  - Lexington Landfill
  - SSOs/wastewater:
    - SSOs and line maintenance are an issue
    - Sewer disconnects
    - Blue Granite has a history of leaky pipes
    - Kinley Creek, Saluda Trail, Stoop Creek/Palmetto Wastewater
    - Apartment complexes additional sources of underreported SSOs from satellite sewer systems; DHEC not actively permitting these facilities
  - Litter
    - Midlands has lots of problems with roadway trash and litter
    - Rawls Creek, Kinley Creek receive a lot of trash from neighborhoods
  - Construction runoff and erosion/sedimentation
  - Pet waste
    - Leash rules enforcement helps keep walkers close to trail; free roaming dogs off trail less likely to have waste picked up
    - Student housing in Olympia, Grande Hills: pet stations used infrequently and lots of waste accumulates.
  - Current developments
    - Whitehall/Lexington County
  - Future development
  - Agriculture:
    - Not a lot of agriculture in this area; not perceived as major contributor
  - Wildlife
    - Harbison Pond goose poop
    - Geese in front of Shaw property, goes into Kinley Creek
    - North of Saluda, strip of forest and geese on fields
  - Large impervious areas
    - Impervious surface layer in development for Lexington County
    - Dutch Square drainage into Saluda
  - Other
    - Weak stormwater code and water quality buffers contribute significantly to the problem
- **Suggestions for projects & programs**
  - Recreation/conservation
    - How can we connect community to water and way of life
    - Hwy 6 and Platt Springs Rd.
    - Trail parallel to river
  - Impervious area reduction
    - Huge parking lots never need that capacity and are low-hanging fruit; incentivize reducing size
    - Large building footprints (shopping areas, big gox stores) could be incentivized to install green roofs (reduction in stormwater fee)
  - Policy
    - Local ordinance fixes for sewer getting capped in residences that are delinquent for paying utility bills
    - Enforce maintenance of existing BMPs on private property

        - Stormwater design guidance/requirements
            - Reconsider design storm (update precipitation intensity, duration, frequency)
            - Encourage green infrastructure, complete streets
        - Stormwater utility fee
            - City of Columbia stormwater utility (SWU) credits; in particular Harbison area will be important
            - Lexington County considering implementing SWU, could include incentives
        - Riparian buffers
            - requirements different types of waterways in Lexington County
            - protecting and restoring buffers in floodplain areas will take people and property out of harm's way
            - should be a priority as they are "last line of defense"
            - wider buffers are more robust, able to withstand high flow events
        - Application for tracking private BMP inspections
    - Education/Outreach
        - Combined messaging for MS4s; targeted outreach for entire region; develop materials singularly and distribute through existing channels
        - Success with installation/demonstration events such as stream bank repair, pond management
        - Grade school education, 5^{th} grade curriculum tailored to watershed protection will be implemented within Project Area (Richland SWCD)
    - Other
        - Septic to sewer conversion projects
        - Source tracking to identify cause of pollution
        - The water systems in the project area should work with the SC Rural Water Association or WaterWorks Group to create plans, and work with DHEC as well.
        - Obtain water quality (*E. coli*) data from surface water intakes
        - Contact SCDOT stormwater engineers about impacts of Carolina Crossroads.

- **Perceived climate impacts in watershed**
    - Public health
        - Senior citizens vulnerable to heat and cold
        - Warmer temperatures increase bacteria levels (impact drinking water and recreation)
    - Drinking water
        - Town of Lexington sent out notices during warmer weather regarding funny taste due to algae
    - Water quantity
        - Droughts, low water levels (not as common as 10-15 years ago) has caused cancellation of events
        - Flash droughts (come fast/go away fast) impacting agriculture
        - As population grows (Lexington County is one of fastest growing areas) will there be enough drinking water capacity?
    - Nuisance aquatic vegetation
        - Warmer weather has prolonged the growing season and increased water temperatures, which has promoted aquatic plant growth (in combination with nutrients)
        - More pond calls to Clemson Extension related to plant growth (algae)
    - Safety
        - High floods, more frequent flooding

            - What are flood waters carrying with them?
        - Extreme weather events in the upstate flow downstream and are managed/detained by the lake; however, high flows are seen over a longer period of time
            - high flow in river (>1600 cfs) is too high for recreation (e.g. kayaking)
    - Other
        - 2015 flooding caused a lot of tree loss from extreme saturation (uprooted trees, roots dying)
        - Urban heat island effect missing data to convince policymakers
            - DNR report for climate change/habit & Wildlife: https://www.dnr.sc.gov/pubs/CCINatResReport.pdf
            - City of Columbia Compass, climate change data available on p B-63 & B-64 of comprehensive plan:
            - https://www.columbiacompass.org/uploads/1/1/8/8/118862009/appx-b-naturalresources.pdf

Sewer Utility Notes

- Potential Sources of bacteria related to sewer/water utilities
    - Old infrastructure:
        - City of Cayce applying for funds to refurbish old sewer lines
            - Lloyd Woods (south of 3RW area)
            - Churchill Heights
        - Alpine/Woodland area built in late 60s/early 70s (old sewer lines)
    - Satellite sewer systems for apartments, commercial buildings
        - 25-30 in Palmetto Utilities area
        - No cameras or smoke inspections of satellite systems
        - Sign of overflows in some of these areas, which was reported to SCDHEC
        - PSC/ORS mentioned they don't want Palmetto Utilities to take on satellite sewer systems, which is a burden on apartment complexes to maintain proper flow. This is a continuing conversation with PSC/ORS to bring satellite sewer systems up to par with Palmetto Utilities standards. Tying on these systems before raising standards would potentially increase the burden of the rest of ratepayers.
    - Infiltration & Inflow (I&I)
        - Stoop's Creek
    - Sewer disconnects
        - City of Columbia cannot do this preemptively; only if DHEC approaches them
    - Removing cleanouts
    - Septic
        - Morningside area, between Front End/Broad River Rd
    - Culvert owned by CSX rail company creating stormwater issues. This area has flooding issues (up to 13' from regular water levels)
- Planned, Programmed, or potential sewer mitigation strategies
    - COVID has impacted revenues
    - Equalization basin tying to Friarsgate helps to control downstream stormwater flow. Located at the end of Radio Tower Rd.
    - Refurbishing older sewer systems
        - Town of Lexington
        - City of Columbia
    - Satellite sewer systems rebuilding pump stations soon in Town of Lexington
    - Potential for use of 319 grant funding to help residences connect to sewer utilities

  - Paul from SC Aqualaw mentioned there's work on a flushable wipe product that is not as obtrusive to sewer systems.
- Bacteria/Climate change impact to drinking water
  - Not perceived as issue by representatives from
  - City of Cayce has raw water storage as backup in case up upstream spills
  - Eutrophication from Lake Murray releases every year
  - Adam Delk: could provide source water protection strategies/documentation
- Climate change considerations
  - City of Columbia
    - Working on secondary intake for their water treatment plant
    - Not explicitly working on climate change
    - CIP includes upgrades to pump stations, backups, elevation changes, as they occur in the field
    - Could provide an executive summary of their contingency plans, which could relate to hazard mitigation planning activities (not open to public for security reasons)
  - City of Cayce
    - Not working on flood/drought considerations, but starting conversations about water utility capacity and installing a second intake.
    - Upgrades to existing infrastructure
  - Palmetto Utilities
    - Not concerned about source water protection as their customers provide dirty water

Appendix B – Riparian Buffer Analysis Documentation

Three Rivers Watershed
EPA 9 Element Watershed Based Plan

Stream Analysis: Workflow Procedure

Lexington and Richland Counties, SOUTH CAROLINA

Prepared for:

CENTRAL MIDLANDS Council of Governments

McCORMICK TAYLOR

Prepared by:

THREE OAKS ENGINEERING

March 24, 2021

Three Oaks Engineering Inc. was tasked with producing a geodatabase of existing streams within the project boundary. The information contained within the geodatabase includes approximate stream centerlines, attribute data that highlights specific stream segments that either meet or do not comply with the stream/riparian buffer requirements established by MS4 jurisdictions within the project area, and stream segments that have the potential for restoration. The process by which this data analysis was performed is described below:

1. The streamlines as defined by SCDHEC and the MS4 jurisdictional boundaries within the Three Rivers Watershed project boundary were added into an ArcMap '.mxd' file.

2. The streamlines were converted to a geodatabase (shapefile) and the attribute table was built to compile the following types of data:
   - Stream Name
   - Jurisdiction
   - Buffer Classification (<50, 50-100, >100)
   - Meets Requirements? (Yes, No)
   - Length (feet)
   - Notes

3. Analysis of each streamline was conducted to assign or classify each of the attributes established for the project.

4. Two buffer areas were then generated around the streamlines: 50ft and 100ft. These buffers are based on the stream/riparian buffer ordinances established within each MS4 jurisdiction.

5. The MS4 Boundaries for each jurisdiction were used to assess which jurisdiction each segment of a stream was within. Aerial imagery was used to assess when a development, roadway, or other impervious surface encroached within the 100ft and 50ft buffer areas.

6. Beginning at the headwaters, each segment of the streamline was traced and the data for that segment of stream was entered into the attribute table. Each segment was traced until a change in conditions occurs:
   - Change in jurisdiction.
   - Change in buffer classification.
     - All roadway crossings (culverts, bridges) were considered encroachments within the buffer of a stream. Many of the segments of stream that have

'<50 ft' buffer classification and do not meet the jurisdictional requirements are roadway crossings.

7. When the change in jurisdiction or buffer classification occurred, the previous stream segment was ended. A new stream segment was then started at this same vertex. Attributes were assigned to each individual stream section.

8. For streamlines within the SCDHEC streamline dataset that did not have a pre-assigned name, a naming convention was established. This allows for the analysis of each stream within the Project Boundary, as well as to provide an order of separation from the main named streams within the watershed.

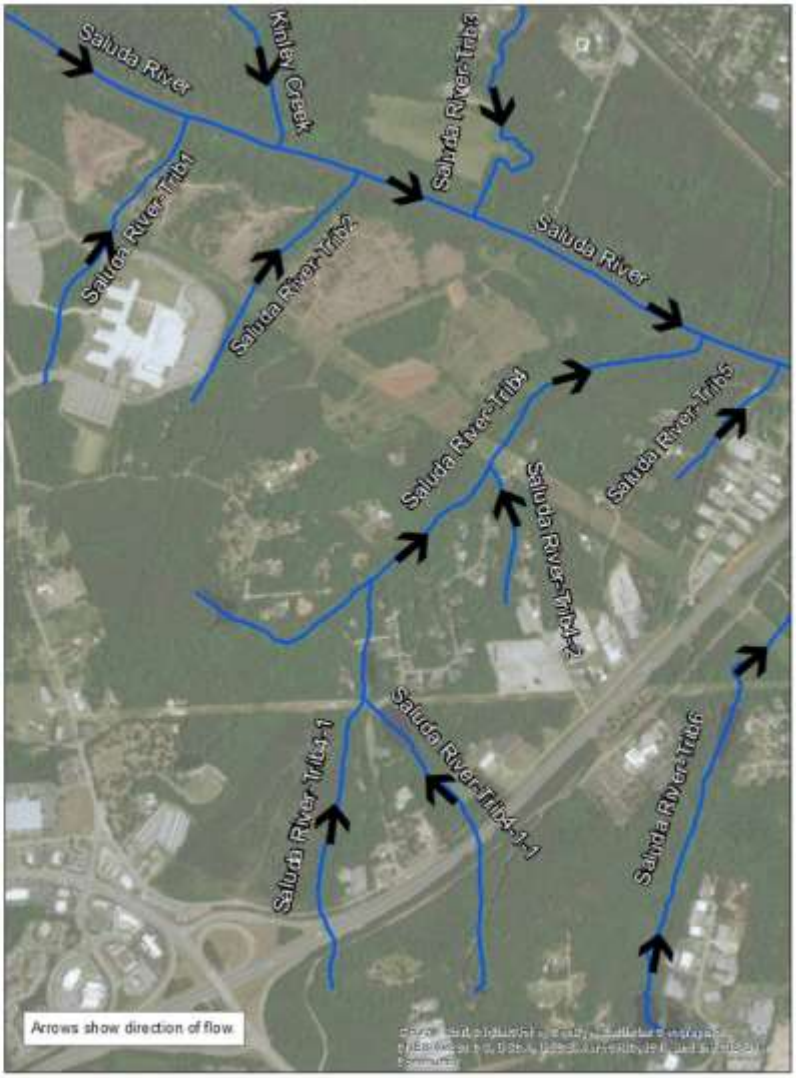
9. Each unnamed stream was assigned a name that corresponds to the adjacent named stream to which it flows. A numerical value was also included to indicate the order in which the unnamed stream connects along the adjacent named stream. Numerical values were sequentially ordered in the downstream direction. The same naming convention was applied to any unnamed tributaries connected to the unnamed streams.
   - 'StreamName'-Trib#-#
   - Examples:
     - Beginning at the headwaters of the Saluda River, the first unnamed stream found reaching the Saluda River is named "Saluda River–Trib1"
     - Beginning at the headwaters of Saluda River-Trib1, the first unnamed stream found is named "Saluda River-Trib1-1"
   - The figure on Page 3 illustrates this naming convention.

10. Steps 5-9 were repeated for all streamlines within the Project Boundary.

Segments of streamlines that occur outside of the MS4 Jurisdictional Boundaries were not assigned a jurisdiction and therefore do not have buffer requirements. All other data types were still entered for these stream segments.

Assumptions and Disclaimers:

- The streamlines are estimated locations of streams constructed on a state/ national scale and were not created by the project team.
- The streamlines used for analysis may not match the location of streams on aerial imagery or as observed in the field.


Saluda River
Kinley Creek
Saluda River-Trib3
Saluda River-Trib1
Saluda River-Trib2
Saluda River
Saluda River-Trib4
Saluda River-Trib5
Saluda River-Trib4-2
Saluda River-Trib4-1
Saluda River-Trib4-1-1
Saluda River-Trib6
Arrows show direction of flow

Appendix C – SC Natural Heritage Program Species Screening Report

South Carolina Department of

Natural Resources

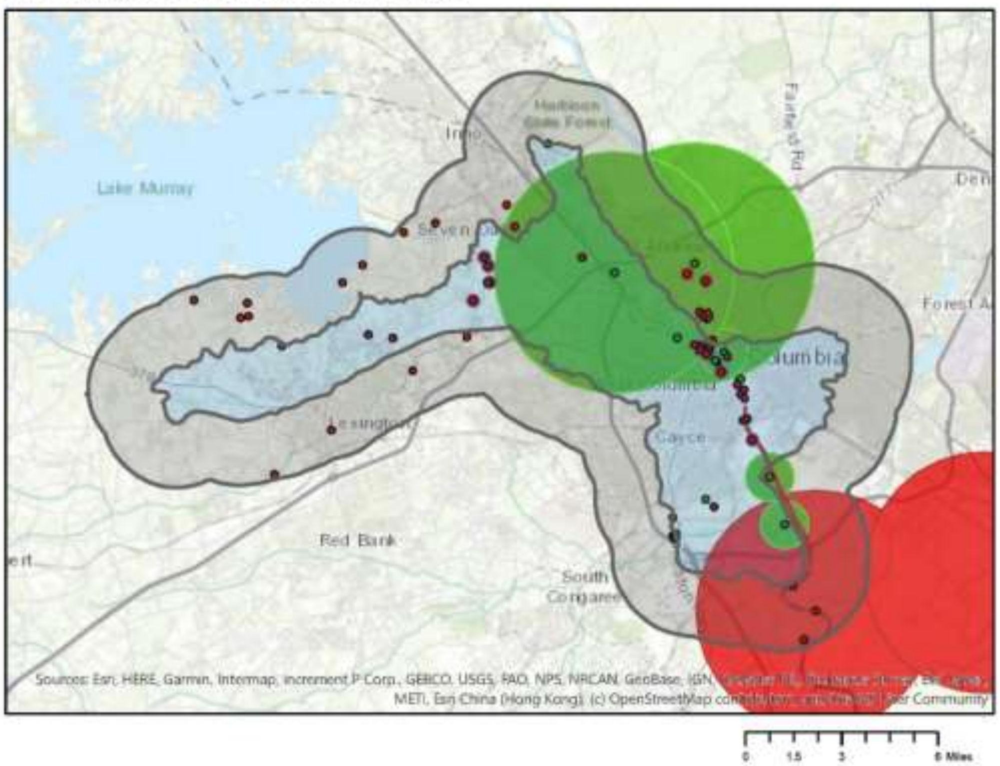
PO Box 167
Columbia, SC 29202
(803) 734-1396
speciesreview@dnr.sc.gov

Robert H. Boyles, Jr.
Director
Emily C. Cope
Deputy Director for
Wildlife and Freshwater Fisheries

Requested on Wednesday, September 30, 2020 by *Kathryn Ellis*.

Re: Request for Threatened and Endangered Species Consultation
Central Midlands Council of Governments - Three Rivers Watershed Plan - Land Protection - Lexington-Richland County, South Carolina

The South Carolina Department of Natural Resources (SCDNR) has received your request for threatened and endangered species consultation of the above named project in Lexington-Richland County, South Carolina. The following map depicts the project area and a 2 mile buffer surrounding:



South Carolina Department of
Natural Resources

Robert H. Boyles, Jr
Interim Director

Emily C. Cope
Deputy Director for
Wildlife and Freshwater Fisheries

This report includes the following items:
A - A report for species which intersect the project area
B - A report for species which intersect the buffer around the project area
C - A list of best management practices relevant to species near to or within the project area
D - A list of best management practices relevant to the project type
E - Instructions to submit new species observation records to the SC Natural Heritage Program

The technical comments outlined in this report are submitted to speak to the general impacts of the activities as described through inquiry by parties outside the South Carolina Department of Natural Resources. These technical comments are submitted as guidance to be considered and are not submitted as final agency comments that might be related to any unspecified local, state or federal permit, certification or license applications that may be needed by any applicant or their contractors, consultants or agents presently under review or not yet made available for public review. In accordance with its policy 600.01, Comments on Projects Under Department Review, the South Carolina Department of Natural Resources, reserves the right to comment on any permit, certification or license application that may be published by any regulatory agency which may incorporate, directly or by reference, these technical comments.

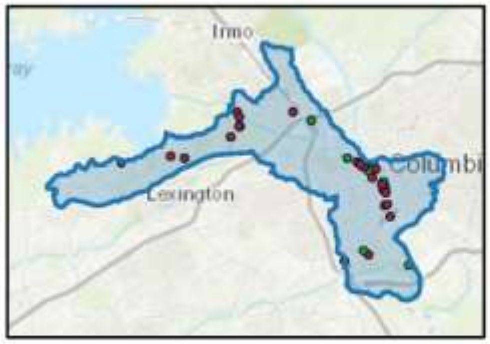
Interested parties are to understand that SCDNR may provide a final agency position to regulatory agencies if any local, state or federal permit, certification or license applications may be needed by any applicant or their contractors, consultants or agents. For further information regarding comments and input from SCDNR on your project, please contact our Office of Environmental Programs by emailing environmental@dnr.sc.gov or by visiting www.dnr.sc.gov/environmental. Pursuant to Section 7 of the Endangered Species Act, requests for formal letters of concurrence with regards to federally listed species should be directed to the USFWS.

Should you have any questions or need more information, please do not hesitate to contact our office by email at speciesreview@dnr.sc.gov or by phone at 803-734-1396.

Sincerely,

Joseph Lemeris, Jr.
Heritage Trust Program
SC Department of Natural Resources

A. Project Area - Species Report (1 of 2)



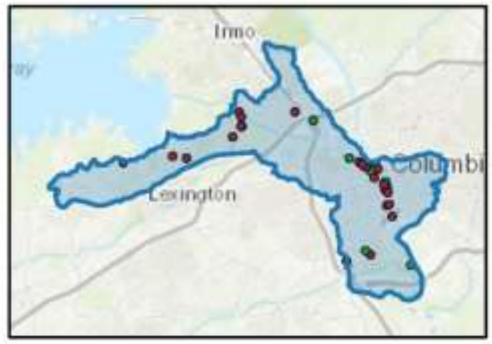
There are 80 tracked species records found within the project foot print. The following table outlines occurrences found within the project footprint (if any), sorted by listing status and species name. Please keep in mind that this information is derived from existing databases and do not assume that it is complete. Areas not yet inventoried may contain significant species or communities. You can find more information about global and state rank status definitions by visiting Natureserve's web page. Please note that certain sensitive species found on site may be listed in this table but are not represented on the map. Please contact speciesreview@dnr.sc.gov should you have further questions related to sensitive species found within the project area.

Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Common Name	Scientific Name	Federal Protection Status	State Protection Status	SWAP Priority	Last Observation Date
Wireleaf Dropseed	*Sporobolus teretifolius*	ARS: At-Risk Species	Not Applicable	High	1998-10-27
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	1977-01-01
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2016
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2016
Shortnose Sturgeon	*Acipenser brevirostrum*	LE: Federally Endangered	SE: State Endangered	Highest	2019-01-01
Baltimore Oriole	*Icterus galbula*	Not Applicable	Not Applicable	High	2014/03/18
Baltimore Oriole	*Icterus galbula*	Not Applicable	Not Applicable	High	2014/02/26
Banded Killifish	*Fundulus diaphanus*	Not Applicable	Not Applicable	Moderate	1949-07-13
Blueback Herring	*Alosa aestivalis*	Not Applicable	Not Applicable	Highest	No Date
Blueback Herring	*Alosa aestivalis*	Not Applicable	Not Applicable	Highest	No Date
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-07-11
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Slabshell	*Elliptio congaraea*	Not Applicable	Not Applicable	Moderate	2006-07-11
Carolina Slabshell	*Elliptio congaraea*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Slabshell	*Elliptio congaraea*	Not Applicable	Not Applicable	Moderate	2006-07-12
Carolina Slabshell	*Elliptio congaraea*	Not Applicable	Not Applicable	Moderate	2008-5-24
Carolina Triodia,	*Tridens carolinianus*	Not Applicable	Not Applicable	Moderate	1998-10-27
Creeper	*Strophitus undulatus*	Not Applicable	Not Applicable	Highest	2005-08-21
Creeper	*Strophitus undulatus*	Not Applicable	Not Applicable	Highest	2006-07-18
Eastern Creekshell	*Villosa delumbis*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Creekshell	*Villosa delumbis*	Not Applicable	Not Applicable	Moderate	2006-07-11
Eastern Creekshell	*Villosa delumbis*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Creekshell	*Villosa delumbis*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Elliptio	*Elliptio complanata*	Not Applicable	Not Applicable	Moderate	2006-07-11
Eastern Elliptio	*Elliptio complanata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Elliptio	*Elliptio complanata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Elliptio	*Elliptio complanata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Elliptio	*Elliptio complanata*	Not Applicable	Not Applicable	Moderate	2006-07-12
Eastern Fox Squirrel	*Sciurus niger*	Not Applicable	Not Applicable	Moderate	1980-06-01
Eastern Pondhorn	*Uniomerus carolinianus*	Not Applicable	Not Applicable	Not Applicable	2007-10-02
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	2010-09-03
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	No Date
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	No Date
Greenfin Shiner	*Cyprinella chloristia*	Not Applicable	Not Applicable	Moderate	No Date
Greenfin Shiner	*Cyprinella chloristia*	Not Applicable	Not Applicable	Moderate	1976-09-26
Greenfin Shiner	*Cyprinella chloristia*	Not Applicable	Not Applicable	Moderate	No Date

A. Project Area - Species Report (2 of 2)

There are 80 tracked species records found within the project foot print. The following table outlines occurrences found within the project footprint (if any), sorted by listing status and species name. Please keep in mind that this information is derived from existing databases and do not assume that it is complete. Areas not yet inventoried may contain significant species or communities. You can find more information about global and state rank status definitions by visiting Natureserve's web page. Please note that certain sensitive species found on site may be listed in this table but are not represented on the map. Please contact speciesreview@dnr.sc.gov should you have further questions related to sensitive species found within the project area.

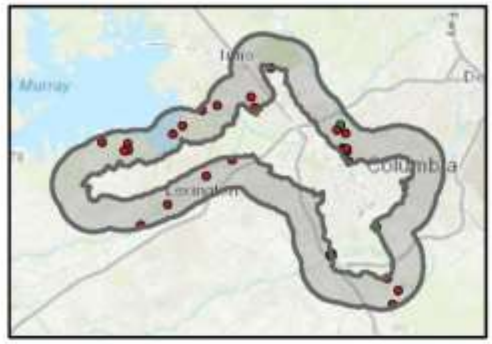


Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Common Name	Scientific Name	Federal Protection Status	State Protection Status	SWAP Priority	Last Observation Date
Highfin Carpsucker	*Carpiodes velifer*	Not Applicable	Not Applicable	Highest	No Date
Highfin Carpsucker	*Carpiodes velifer*	Not Applicable	Not Applicable	Highest	No Date
Lowland Shiner	*Pteronotropis stonei*	Not Applicable	Not Applicable	Moderate	1953-04-26
Moonseed, Yellow	*Menispermum canadense*	Not Applicable	Not Applicable	Not Applicable	1986
Nestronia, Conjurer's-	*Nestronia umbellula*	Not Applicable	Not Applicable	Not Applicable	1888-04-01
Northern Lance	*Elliptio fisheriana*	Not Applicable	Not Applicable	Not Applicable	1996-7-6
Notchlip Redhorse	*Moxostoma collapsum*	Not Applicable	Not Applicable	Moderate	No Date
Notchlip Redhorse	*Moxostoma collapsum*	Not Applicable	Not Applicable	Moderate	No Date
Notchlip Redhorse	*Moxostoma collapsum*	Not Applicable	Not Applicable	Moderate	No Date
Panhandle Pebblesnail	*Somatogyrus virginicus*	Not Applicable	Not Applicable	High	2007-06-06
Quillback	*Carpiodes cyprinus*	Not Applicable	Not Applicable	High	No Date
Quillback	*Carpiodes cyprinus*	Not Applicable	Not Applicable	High	No Date
Rayed Pink Fatmucket	*Lampsilis splendida*	Not Applicable	Not Applicable	High	2005-09-25
Rayed Pink Fatmucket	*Lampsilis splendida*	Not Applicable	Not Applicable	High	2007-09-20
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	2005-09-26
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	2006-07-12
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	2006-07-12
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	2006-07-12
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	2006-10-04
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	No Date
Sandhills Milkvetch,	*Astragalus michauxii*	Not Applicable	Not Applicable	High	1971-06-02
Savanna Cowbane	*Oxypolis ternata*	Not Applicable	Not Applicable	High	1998-10-23
Seagreen Darter	*Etheostoma thalassinum*	Not Applicable	Not Applicable	High	No Date
Seagreen Darter	*Etheostoma thalassinum*	Not Applicable	Not Applicable	High	No Date
Seagreen Darter	*Etheostoma thalassinum*	Not Applicable	Not Applicable	High	No Date
Shoals Spiderlily,	*Hymenocallis coronaria*	Not Applicable	Not Applicable	High	1996-05-16
Southern Water-purslane	*Ludwigia spathulata*	Not Applicable	Not Applicable	High	1977-07-01
Stalkless Marshcress	*Rorippa sessiliflora*	Not Applicable	Not Applicable	Not Applicable	1980-04-26
Standing-cypress,	*Ipomopsis rubra*	Not Applicable	Not Applicable	Not Applicable	1982-06-01
Striped Bass	*Morone saxatilis*	Not Applicable	Not Applicable	Moderate	No Date
Striped Bass	*Morone saxatilis*	Not Applicable	Not Applicable	Moderate	No Date
Striped Bass	*Morone saxatilis*	Not Applicable	Not Applicable	Moderate	No Date
Swamp Coreopsis	*Coreopsis gladiata*	Not Applicable	Not Applicable	Not Applicable	1998-10-23
Variable Spike	*Elliptio icterina*	Not Applicable	Not Applicable	Not Applicable	2006-07-09
Whiskfern	*Psilotum nudum*	Not Applicable	Not Applicable	Moderate	1979-11-01
Winter Grapefern	*Sceptridium lunarioides*	Not Applicable	Not Applicable	Moderate	1890
Yellow Lampmussel	*Lampsilis cariosa*	Not Applicable	Not Applicable	Highest	2005-09-25
Yellow Lampmussel	*Lampsilis cariosa*	Not Applicable	Not Applicable	Highest	2006-07-20
Yellow Lampmussel	*Lampsilis cariosa*	Not Applicable	Not Applicable	Highest	1996-7-6
Yellow Lampmussel	*Lampsilis cariosa*	Not Applicable	Not Applicable	Highest	No Date

B. Buffer Area - Species Report (1 of 2)

The following table outlines rare, threatened or endangered species found within 2 miles of the project footprint, arranged in order of protection status and species name. Please keep in mind that this information is derived from existing databases and do not assume that it is complete. Areas not yet inventoried may contain significant species or communities. You can find more information about global and state rank status definitions by visiting Natureserve's web page. Please note that certain sensitive species found within the buffer area may be listed in this table but are not represented on the map.

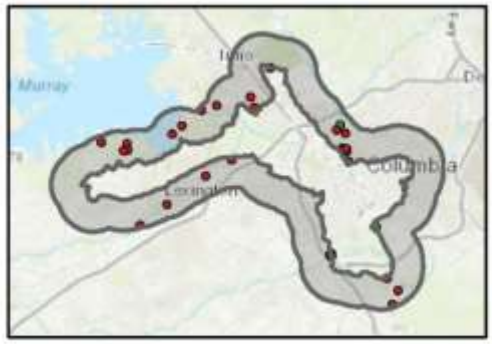


Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Common Name	Scientific Name	Federal Protection Status	State Protection Status	SWAP Priority	Last Observation Date
Carolina Birds-in-a-nest,	*Macbridea caroliniana*	ARS: At-Risk Species	Not Applicable	High	2019-07-19
Carolina Birds-in-a-nest,	*Macbridea caroliniana*	ARS: At-Risk Species	Not Applicable	High	2017-06-14
Carolina Birds-in-a-nest,	*Macbridea caroliniana*	ARS: At-Risk Species	Not Applicable	High	2017-06-14
Carolina Birds-in-a-nest,	*Macbridea caroliniana*	ARS: At-Risk Species	Not Applicable	High	2017-07-14
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	1977-01-01
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2001
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2009
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2016
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2017
Bald Eagle	*Haliaeetus leucocephalus*	Bald & Golden Eagle Protection Act	ST: State Threatened	High	2016
Red-cockaded	*Picoides borealis*	LE: Federally Endangered	SE: State Endangered	Highest	1974-05-11
Shortnose Sturgeon	*Acipenser brevirostrum*	LE: Federally Endangered	SE: State Endangered	Highest	2019-01-01
American Wahoo,	*Euonymus atropurpureus*	Not Applicable	Not Applicable	Moderate	1978-10-05
Atlantic Spike	*Elliptio producta*	Not Applicable	Not Applicable	High	2006-04-09
Banded Killifish	*Fundulus diaphanus*	Not Applicable	Not Applicable	Moderate	1949-07-13
Blueback Herring	*Alosa aestivalis*	Not Applicable	Not Applicable	Highest	No Date
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-06-19
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-06-20
Carolina Lance	*Elliptio angustata*	Not Applicable	Not Applicable	Moderate	2006-10-05
Eastern Creekshell	*Villosa delumbis*	Not Applicable	Not Applicable	Moderate	2006-10-05
Eastern Elliptio	*Elliptio complanata*	Not Applicable	Not Applicable	Moderate	2006-10-05
Eastern Floater	*Pyganodon cataracta*	Not Applicable	Not Applicable	Not Applicable	2006-06-20
Eastern Floater	*Pyganodon cataracta*	Not Applicable	Not Applicable	Not Applicable	2006-06-20
Eastern Fox Squirrel	*Sciurus niger*	Not Applicable	Not Applicable	Moderate	1980-06-01
Eastern Lampmussel	*Lampsilis radiata*	Not Applicable	Not Applicable	High	No Date
Eastern Pondhorn	*Uniomerus carolinianus*	Not Applicable	Not Applicable	Not Applicable	2006-06-19
Eastern Pondhorn	*Uniomerus carolinianus*	Not Applicable	Not Applicable	Not Applicable	2006-06-20
Eastern Pondhorn	*Uniomerus carolinianus*	Not Applicable	Not Applicable	Not Applicable	2006-06-20
Eastern Pondhorn	*Uniomerus carolinianus*	Not Applicable	Not Applicable	Not Applicable	2007-10-22
Eastern Pondmussel	*Ligumia nasuta*	Not Applicable	Not Applicable	High	2005-09-25
Eastern Pondmussel	*Ligumia nasuta*	Not Applicable	Not Applicable	High	No Date
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	2011-06-15
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	2008-07-08
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	1976-07-15
Flat Bullhead	*Ameiurus platycephalus*	Not Applicable	Not Applicable	Moderate	1976-07-26
Greenfin Shiner	*Cyprinella chloristia*	Not Applicable	Not Applicable	Moderate	2007-06-07
Highfin Carpsucker	*Carpiodes velifer*	Not Applicable	Not Applicable	Highest	No Date
Lowland Shiner	*Pteronotropis stonei*	Not Applicable	Not Applicable	Moderate	1953-04-26
Moonseed, Yellow	*Menispermum canadense*	Not Applicable	Not Applicable	Not Applicable	1986
Nestronia, Conjurer's-	*Nestronia umbellula*	Not Applicable	Not Applicable	Not Applicable	1888-04-01

B. Buffer Area - Species Report (2 of 2)

The following table outlines rare, threatened or endangered species found within 2 miles of the project footprint, arranged in order of protection status and species name. Please keep in mind that this information is derived from existing databases and do not assume that it is complete. Areas not yet inventoried may contain significant species or communities. You can find more information about global and state rank status definitions by visiting Natureserve's web page. Please note that certain sensitive species found within the buffer area may be listed in this table but are not represented on the map.



Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Common Name	Scientific Name	Federal Protection Status	State Protection Status	SWAP Priority	Last Observation Date
Northern Lance	*Elliptio fisheriana*	Not Applicable	Not Applicable	Not Applicable	2012-10-22
Notchlip Redhorse	*Moxostoma collapsum*	Not Applicable	Not Applicable	Moderate	No Date
Panhandle Pebblesnail	*Somatogyrus virginicus*	Not Applicable	Not Applicable	High	2007-06-06
Paper Pondshell	*Utterbackia imbecillis*	Not Applicable	Not Applicable	Not Applicable	2006-06-19
Paper Pondshell	*Utterbackia imbecillis*	Not Applicable	Not Applicable	Not Applicable	2006-06-20
Paper Pondshell	*Utterbackia imbecillis*	Not Applicable	Not Applicable	Not Applicable	2006-05-17
Piedmont Darter	*Percina crassa*	Not Applicable	Not Applicable	High	2006-06-30
Quillback	*Carpiodes cyprinus*	Not Applicable	Not Applicable	High	No Date
Rayed Pink Fatmucket	*Lampsilis splendida*	Not Applicable	Not Applicable	High	2006-07-12
Roanoke Slabshell	*Elliptio roanokensis*	Not Applicable	Not Applicable	High	2006-07-12
Sandhills Milkvetch,	*Astragalus michauxii*	Not Applicable	Not Applicable	High	1971-06-02
Sawcheek Darter	*Etheostoma serrifer*	Not Applicable	Not Applicable	Moderate	1976-07-26
Seagreen Darter	*Etheostoma thalassinum*	Not Applicable	Not Applicable	High	2011-06-15
Seagreen Darter	*Etheostoma thalassinum*	Not Applicable	Not Applicable	High	2008-07-08
Shoals Spiderlily,	*Hymenocallis coronaria*	Not Applicable	Not Applicable	High	1996-05-16
Snail Bullhead	*Ameiurus brunneus*	Not Applicable	Not Applicable	Moderate	No Date
Snail Bullhead	*Ameiurus brunneus*	Not Applicable	Not Applicable	Moderate	2003-08-19
Snail Bullhead	*Ameiurus brunneus*	Not Applicable	Not Applicable	Moderate	2003-08-20
Southern Water-purslane	*Ludwigia spathulata*	Not Applicable	Not Applicable	High	1977-07-01
Stalkless Marshcress	*Rorippa sessiliflora*	Not Applicable	Not Applicable	Not Applicable	1980-04-26
Standing-cypress,	*Ipomopsis rubra*	Not Applicable	Not Applicable	Not Applicable	1982-06-01
Striped Bass	*Morone saxatilis*	Not Applicable	Not Applicable	Moderate	No Date
Striped Bass	*Morone saxatilis*	Not Applicable	Not Applicable	Moderate	No Date
Swamp Rabbit	*Sylvilagus aquaticus*	Not Applicable	Not Applicable	High	1989-01
Variable Spike	*Elliptio icterina*	Not Applicable	Not Applicable	Not Applicable	2006-10-04
White Catfish	*Ameiurus catus*	Not Applicable	Not Applicable	Moderate	No Date
White Catfish	*Ameiurus catus*	Not Applicable	Not Applicable	Moderate	No Date
White Catfish	*Ameiurus catus*	Not Applicable	Not Applicable	Moderate	1976-07-26
Winter Grapefern	*Sceptridium lunarioides*	Not Applicable	Not Applicable	Moderate	1890

C. Species Best Management Practices (1 of 1)

SCDNR offers the following comments and best management practices (BMPs) regarding this project's potential impacts to species of concern which may be found on or near to the project area. Please contact speciesreview@dnr.sc.gov should you have further questions with regard to survey methods, consultation, or other species-related concerns.

Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

An active bald eagle nest(s) is known to occur within or near to your project area. Surveys to rule out nests in the project area are advised to avoid negative impacts to bald eagle. Bald eagles are a state listed threatened species and are federally protected under the Bald and Golden Eagle Protection Act. If bald eagle nests are found to be within the project area, please consult with the U.S. Fish and Wildlife Service before proceeding with any construction activities.
Red-cockaded woodpecker, a federal and state listed endangered species, is known to occur within or near your project area. Surveys of mature pine trees (50-years or older) to rule out RCW within the project footprint is advised, regardless of habitat condition, and use of heavy machinery is prohibited within 200-feet of a cavity tree during the breeding season (April through July). If RCW are found within the project area, please consult with the U.S. Fish and Wildlife Service before proceeding with any construction activities.
In the interest of preserving plant diversity, the South Carolina Plant Conservation Alliance performs native plant rescues in order to protect and preserve our diversity of native plants. If you are interested in assisting with this important endeavor please contact Mrs. April Punsalan at (843) 727-4707 ext. 218, or by email: scpca@lists.fws.gov before any development occurs onsite. There may be plants of interest on the project site that the Alliance would like to preserve.
Species in the above table with SWAP priorities of High, Highest or Moderate are designated as having conservation priority under the South Carolina State Wildlife Action Plan (SWAP). SWAP species are those species of greatest conservation need not traditionally covered under any federal funded programs. Species are listed in the SWAP because they are rare or designated as at-risk due to knowledge deficiencies; species common in South Carolina but listed rare or declining elsewhere; or species that serve as indicators of detrimental environmental conditions. SCDNR recommends that appropriate measures should be taken to minimize or avoid impacts to the aforementioned species of concern.

D. Project Best Management Practices (1 of 2)

SCDNR offers the following comments and best management practices (BMPs) regarding this project's potential impacts to natural resources within or surrounding the project area. Please contact our Office of Environmental Programs at environmental@dnr.sc.gov should you have further questions with regard to best management practices related to this project area.

Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Review of available data, National Wetlands Inventory and hydric soils, indicate that wetlands or waters of the United States are present within your project area. These areas may require a permit from the U.S. Army Corps of Engineers (USACE), as well as a compensatory mitigation plan. SCDNR advises that you consult with the USACE Regulatory to determine if jurisdictional wetlands are present and if a permit and mitigation is required for any activities impacting these areas. For more information, please visit their website at www.sac.usace.army.mil/Missions/Regulatory. Additionally, a 401 Water Quality Certification may also be required from the SC Department of Health & Environmental Control. For more information, please visit their website at https://www.scdhec.gov/environment/water-quality/water-quality-certification-section-401-clean-water-act.
If this project is associated with the Federal Government and the project area is or once was used as farmland, we recommend that consultation occur with the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) per the Farmland Protection Policy Act; areas of the site are classified as prime farmland or farmland of statewide importance.
• All necessary measures must be taken to prevent oil, tar, trash and other pollutants from entering the adjacent offsite areas/wetlands/water. • Once the project is initiated, it must be carried to completion in an expeditious manner to minimize the period of disturbance to the environment. • Upon project completion, all disturbed areas must be permanently stabilized with vegetative cover (preferable), riprap or other erosion control methods as appropriate. • The project must be in compliance with any applicable floodplain, stormwater, land disturbance, shoreline management guidance or riparian buffer ordinances. • Prior to beginning any land disturbing activity, appropriate erosion and siltation control measures (e.g. silt fences or barriers) must be in place and maintained in a functioning capacity until the area is permanently stabilized. • Materials used for erosion control (e.g., hay bales or straw mulch) will be certified as weed free by the supplier. • Inspecting and ensuring the maintenance of temporary erosion control measures at least: a. on a daily basis in areas of active construction or equipment operation; b. on a weekly basis in areas with no construction or equipment operation; and c. within 24 hours of each 0.5 inch of rainfall. • Ensuring the repair of all ineffective temporary erosion control measures within 24 hours of identification, or as soon as conditions allow if compliance with this time frame would result in greater environmental impacts. • Land disturbing activities must avoid encroachment into any wetland areas (outside the permitted impact area). Wetlands that are unavoidably impacted must be appropriately mitigated. • Your project may require a Stormwater Permit from the SC Department of Health & Environmental Control, please visit https://www.scdhec.gov/environment/water-quality/stormwater

D. Project Best Management Practices (2 of 2)

SCDNR offers the following comments and best management practices (BMPs) regarding this project's potential impacts to natural resources within or surrounding the project area. Please contact our Office of Environmental Programs at environmental@dnr.sc.gov should you have further questions with regard to best management practices related to this project area.

Map Credits: Source: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

- If clearing must occur, riparian vegetation within wetlands and waters of the U.S. must be conducted manually and low growing, woody vegetation and shrubs must be left intact to maintain bank stability and reduce erosion.
- Construction activities must avoid and minimize, to the greatest extent practicable, disturbance of woody shoreline vegetation within the project area. Removal of vegetation should be limited to only what is necessary for construction of the proposed structures.
- Where necessary to remove vegetation, supplemental plantings should be installed following completion of the project. These plantings should consist of appropriate native species for this ecoregion.

E. Instructions for Submitting Species Observations

The SC Natural Heritage Dataset relies on continuous monitoring and surveying for species of concern throughout the state. Any records of species of concern found within this project area would greatly benefit the quality and comprehensiveness of the statewide dataset for rare, threatened and endangered species. Below are instructions for how to download the SC Natural Heritage Occurrence Reporting Form through the Survey123 App.

Map Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Instructions for accessing the SC Natural Heritage Occurrence Reporting Form

For use in a browser (on your desktop/PC):

1) Follow http://bit.ly/scht-reporting-form-point
2) Select 'Open in browser'
3) The form will open and you can begin entering data!

This method of access will also work on a browser on a mobile device, but only when connected to the internet. To use the form in the field without relying on data/internet access, follow the steps below.

For use on a smartphone or tablet using the field app:

1) Download the Survey123 App from the Google Play store or the Apple Store. This app is free to download. Allow the app to use your location.

2) No need to sign in. However, you will need to provide the app with our Heritage Trust GIS portal web address. You will only need to do this once: (this is a known bug with ESRI's software, and future releases of the form should not require the below steps. Bear with us in the meantime!).
   a. Tap 'Sign in'
   b. Tap the settings (gear symbol) in the upper right corner
   c. Tap 'Add Portal'
   d. After the 'https://', type schtportal.dnr.sc.gov/portal
   e. Tap 'Add Portal'
   f. Tap the back-arrow icon (upper left corner) twice to return to the main sign in page.

3) Use the camera app (or other QR Reader app) to scan the QR code on this page from your smartphone or tablet. Click on the 'Open in the Survey123 field app'. This will prompt a window to allow Survey123 to download the SC Natural Heritage Occurrence Reporting Form. Select 'Open.'

4) The form will automatically open in Survey123, and you can begin entering data! This form will stay loaded in the app on your device until you manually delete it, and you can submit as many records as you like.

Appendix D – Summary of CISA Research

Precipitation Data Analysis

CISA evaluated precipitation data from the historic record and climate models (Coupled Model Intercomparison Project Phase 6, or CMIP6) in preparation for a future scenarios exercise in the Watershed Treatment Model (WTM). Annual precipitation data was the focus of the analysis because it is a key input variable in the WTM. Although existing projections for the region (e.g. the National Climate Assessment, Southeast Chapter) project an increase in heavy rain events over time due to climate change, changes in heavy rainfall events were not analyzed because it is not an input to the WTM. Future analysis focused on heavy rain events could aid in planning for BMP implementation and resiliency.

Annual Precipitation in the Historic Record

CISA obtained historic data from the NOAA National Centers for Environmental Information (NCEI)[101]. Annual precipitation data were downloaded for the Columbia weather station (station ID 381944) and the three climate divisions covering the midlands region of SC (3, 5, & 6) for the years 1895-2019 (see **Figure A-1**). The average for annual rainfall is around 45 inches, although the record shows some years below 30 inches or above 60 inches.

[101] NOAA NCEI U.S. Climate Divisional Dataset. https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php

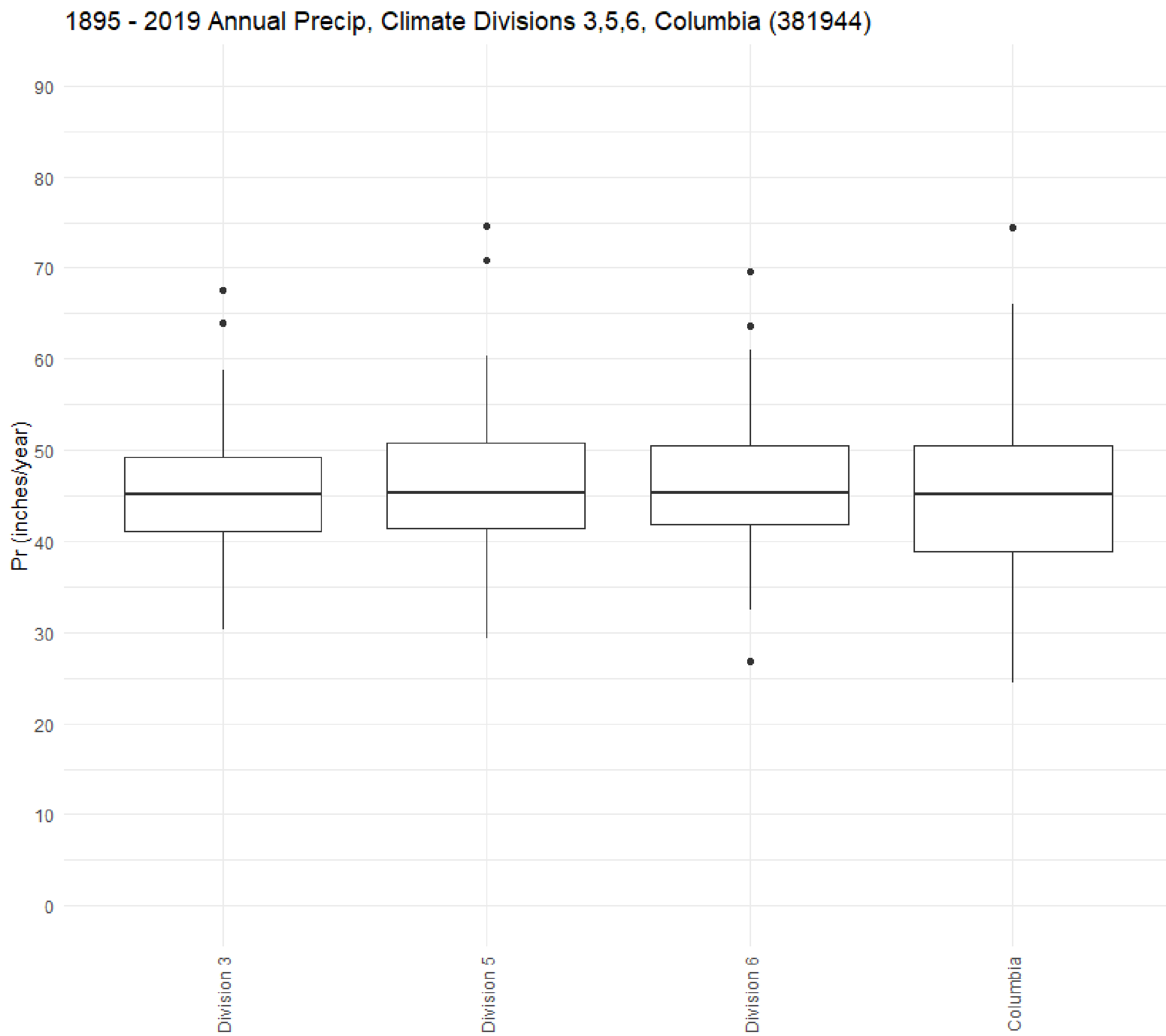


Figure A-1 - A boxplot highlighting historic observed annual precipitation values covering the Three Rivers Watershed area. NOAA NCEI data.

Annual Precipitation from CMIP6 Models

Background on Global Climate Models

The Coupled Model Intercomparison Project Phase 6 (CMIP6) provides data from the latest global climate models available. Global climate models model planetary processes and add in emissions of greenhouse gases in order to forecast the resulting changes over time in climate variables such as temperature and precipitation[102]. These forecasts occur in grid cells that are usually 100 kilometres (62 miles) in size. There can be a variety of types of uncertainty in climate models, including forecasting how much carbon

[102] Zeke Hausfather. (2019). CMIP6: the next generation of climate models explained. https://www.carbonbrief.org/cmip6-the-next-generation-of-climate-models-explained

pollution will be emitted in the future (scenario uncertainty), incomplete understanding of every atmospheric process (scientific uncertainty), slight differences when running the same model twice (internal variability), and drawing conclusions in a small area from a global scale model (geographic variability). Observations show that climate change in the past decade is accelerating.[103] The rate of change suggests a possibility that future extremes may also exceed model forecasts. In many cases, climate models accurately projected existing changes that are occurring currently. Overall uncertainty for future forecasts continues to decrease as climate models improve[104]. Climate models are used in a variety of applications including determining risk in planning and finance[105].

When viewing the climate model data in this report, CISA recommends focusing on the overall direction and magnitude of change. CISA also advises that some risks to the watershed will not appear because the analysis focused on annual precipitation projections and does not account for other short-term events, such as increases in heavy rainfall.

Model Data Source

CISA obtained CMIP6 models from the World Meteorological Organization via the KNMI Climate Explorer database[106]. Outputs from these first available 10 CMIP6 models were used: BCC-CSM2-MR, CAMS-CSM1-0, CanESM5, CESM2, CESM2-WACCM, FGOALS-3, MIROC6, MIROC-ES2L, MRI-ESM2-0, and UKESM1-0-LL. Annual precipitation totals were downloaded for the grid cell nearest to 34 degrees North latitude, 81 degrees West longitude (downtown Columbia, SC). CISA validated the data by ensuring the variable ranges were reasonable and comparing the data to a nearby grid cell. The model output for this grid cell conforms to findings from larger studies, where some models show a wet bias but agree on future trends[107].

Summary of CISA Data Analysis

Two models (BCC-CSM2-MR and CAMS-CSM1-0) match historical data better than the remaining 8 models, which show a wet bias. In aggregate the 10 models show an upward trend for precipitation in a high emissions scenario (see **Figure A-2**). The curve is a default local polynomial regression (LOESS) curve fitted to the data. SSP5 is the scenario used in the model and is equivalent to RCP 8.5, or a high emissions future. This finding agrees with the projections from the latest comprehensive national climate assessment, which forecasts an increase in average precipitation and a doubling in extreme precipitation events for the Southeast region[108].

[103] NASA. (2021). 2020 Tied for Warmest Year on Record, NASA Analysis Shows. https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows
[104] Srivastava et al. (2020). Evaluation of historical CMIP6 model simulations of extreme precipitation over contiguous US regions. https://doi.org/10.1016/j.wace.2020.100268
[105] For examples, see Fiedler et al. (2021). Business risk and the emergence of climate analytics. https://doi.org/10.1038/s41558-020-00984-6 and Terando et al. (2020). Using Information From Global Climate Models to Inform Policymaking – The Role of the U.S. Geological Survey. https://doi.org/10.3133/ofr20201058
[106] Database is accessible via https://climexp.knmi.nl/start.cgi
[107] Srivastava et al. (2020). Evaluation of historical CMIP6 model simulations of extreme precipitation over contiguous US regions. https://doi.org/10.1016/j.wace.2020.100268
[108] See 4th National Climate Assessment, Southeast chapter. https://nca2018.globalchange.gov/chapter/19/

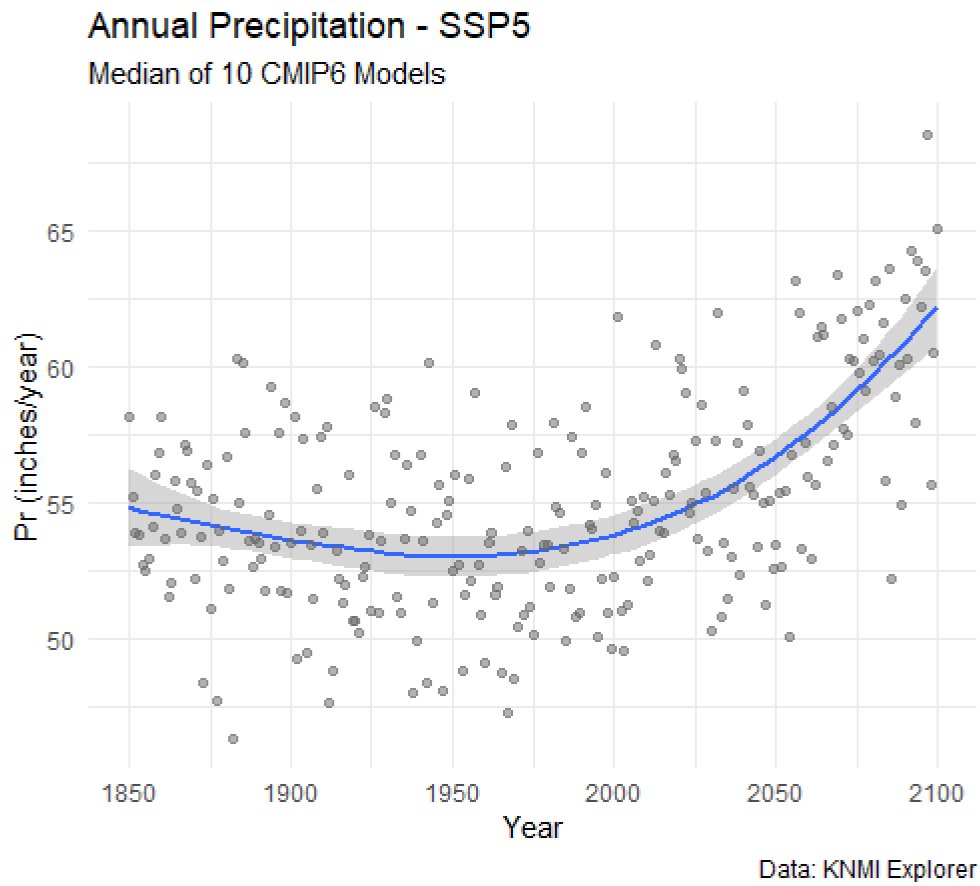


Figure A-2 - The median value across 10 models for each year in the model data, each dot represents one year's median precipitation.

Annual Precipitation in the WTM Scenario Exercise

Through a deliberative process CISA, McCormick Taylor, KCI and the CMCOG evaluated the initial results shown above to determine a representative future scenario to use for a WTM model. The scenario chosen represents a mid-century year in a high carbon emissions future. CISA then evaluated the model data for this time period relative to a historic period. An annual precipitation value of 60 inches was selected to use as the total annual rainfall input to the WTM. Representing a value 33% over the historical average value, 60 inches has been observed in the historic record and is within the upper quartile of most model ranges shown (see **Figure A-3**). Averaging these differences across all models (the boxplot on the far right) results in a shift upwards by several inches within the next few decades. With climate change increasing both average rainfall and changing the frequency and intensity of heavy rainfall events, a mid-century year with a high rainfall value was considered useful to build into a planning scenario. Watershed management that plans for a higher value is more robust to a smaller shift in average precipitation over time.

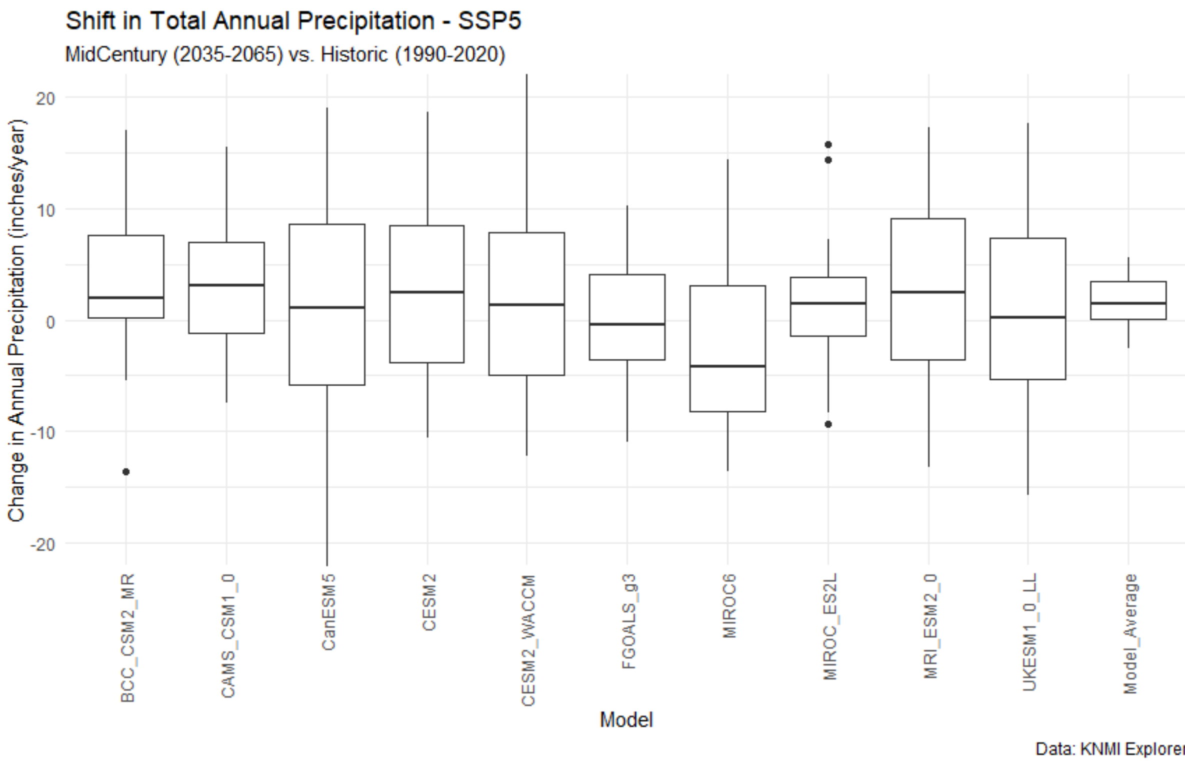


Figure A-3 - A historic average was calculated for model years 1990-2020, and these boxplots show the difference between that historic average and each year in a three-decade period around mid-century (2035-2065).

Literature Review on the Intersection of Climate Change and Bacteria Loading

PubMed & Web of Science Search in Consultation with UofSC Public Health Research Librarian, February 2021

Note on Goals & Limitations of the Literature Review

CISA consulted with the UofSC Public Health Librarian and performed a literature review on several scientific and health databases. The primary goal of this review was to obtain examples from literature to ground a numeric shift in WTM default of median runoff bacterial loading of 20,000 MPN / 100mL. Several relevant case studies (either geographically or via watershed characteristics) and a few key review papers are cited. The search is not meant to be exhaustive and should not be considered publication-quality, but it does provide summaries of relevant evidence from prior academic studies. Only high-level information or numbers that potentially related to ongoing work in the watershed plan are listed. Future research studies that evaluate the intersection of climate change and bacteria loading in the Three Rivers Watershed could add detail to the findings summarized here.

Reviews

Guzman Herrador, B. R., De Blasio, B. F., MacDonald, E., Nichols, G., Sudre, B., Vold, L., … Nygård, K. (2015, March 27). Analytical studies assessing the association between extreme precipitation or temperature and drinking water-related waterborne infections: A review. Environmental Health: A Global Access Science Source. BioMed Central Ltd. https://doi.org/10.1186/s12940-015-0014-y

- Reviewed studies between 2001-2013.
- Most studies identified a positive association of increased infection for precipitation and/or temperature, but not all. A few studies found the inverse. Thresholds for extremes and time lag may have some influence here. Local geography may explain variance, or other variables like water treatment method.
- Both heavy precipitation and extended low precipitation are potential avenues for waterborne infection.
- Many infectious agents are sensitive to temperature conditions, positive association.
- Linking extreme weather to waterborne disease is an emerging area of research, can be modified by local factors (water treatment, geography, etc.).

Semenza, J. C. (2020, May 1). Cascading risks of waterborne diseases from climate change. Nature Immunology. Nature Research. https://doi.org/10.1038/s41590-020-0631-7

- Both mean temperature/precipitation and atypical weather events are climate concerns regarding transmission pathways of waterborne infectious agents.
- Interactions with exposure (water infrastructure, community) and vulnerability (demographics, inequities) compound health risks from weather hazards.
- “Cascading” risks are of extra concern. Heavy rainfall / flooding can increase stormwater runoff and impact infrastructure, increased general temperature can extend transmission

season for pathogens, increase replication rate and survival time, and lead to increased pathogen load from animal reservoirs.

- Increased surveillance (enhanced seasonal and/or real-time monitoring) and automatic public health measures (e.g. temporary water-use restrictions after exceeding rain threshold) can interrupt cascading risk cycle.
- **Figure A-1** contains a useful diagram overviewing how risks cascade through a watershed.

Levy, K., Smith, S. M., & Carlton, E. J. (2018). Climate Change Impacts on Waterborne Diseases: Moving Toward Designing Interventions. Current Environmental Health Reports. Springer. https://doi.org/10.1007/s40572-018-0199-7

- Solid body of evidence linking temperature and precipitation to waterborne illness. Few studies projecting future diseases rates in relation to future climate conditions. Few studies include social and ecological factors to modify this relationship.
- The IPCC states with "very high confidence" that increased water-borne diseases can be expected "if climate change continues as projected across the representative concentration pathway (RCP) scenarios until mid-century".
- Heavy rainfall events were a specific concern in US & Canadian studies. This concern has been present for close to two decades.
- Neighborhood infrastructure and demographic characteristics (especially age and pre-existing health conditions) modulate vulnerability.
- The relationship between climate conditions and bacteria / pathogens is often non-linear, increasing both predictive uncertainty and risk.
- A 2016 study projected 2.2 million increases cases from E.Coli in Bangladesh, other studies indicate that even high income countries will face adaptive limits for public health interventions / planning.
- Social and environmental infrastructure drive disease dynamics and are thus key levers for interventions, reducing exposure in vulnerable populations is the most effective, followed by preparing drinking water systems for extreme precipitation events and flooding.
- Milwaukee has integrated regional climate projections into its engineering models.

Levy, K., Woster, A. P., Goldstein, R. S., & Carlton, E. J. (2016). Untangling the Impacts of Climate Change on Waterborne Diseases: A Systematic Review of Relationships between Diarrheal Diseases and Temperature, Rainfall, Flooding, and Drought. Environmental Science and Technology. American Chemical Society. https://doi.org/10.1021/acs.est.5b06186

- Evaluated 141 articles.
- Agreement of an increase in disease with ambient temperature, heavy rainfall, and flooding events. Insufficient evidence for link to drought.
- For ambient temperature, the relationship is highly positive. Studies found positive influence ranging from moderate to extremely significant.
- For heavy rain, the relationship is highly positive. Any rainfall increases illness rates by ~10%, further increases with precipitation quantity and also sensitive to dry period prior to the rain event.

- Bacteria and protozoa respond more to these parameters than viruses.
- One systematic review found that heavy rainfall was of particular concern for residents on private water systems. Heavy rainfall preceded 24% of disease outbreaks.

Walker, J. T. (2018, September 1). The influence of climate change on waterborne disease and Legionella: a review. Perspectives in Public Health. SAGE Publications Ltd. https://doi.org/10.1177/1757913918791198

- A review of prior studies, links for temperature and heavy rain to increased illness risk appear robust.
- Temperature remaining above thresholds may extend the "seasonality" of waterborne pathogens.

Ahmed, W., Hamilton, K., Toze, S., Cook, S., & Page, D. (2019). A review on microbial contaminants in stormwater runoff and outfalls: Potential health risks and mitigation strategies. Science of the Total Environment, 692, 1304–1321. https://doi.org/10.1016/j.scitotenv.2019.07.055

- Redundancy and use of multiple of BMPs increase removal rates
- Water temperature is a key factor governing removal of microbial pathogens

Hofstra, N. (2011). Quantifying the impact of climate change on enteric waterborne pathogen concentrations in surface water. Current Opinion in Environmental Sustainability. Elsevier. https://doi.org/10.1016/j.cosust.2011.10.006

- Further supports a just under 1:1 relationship. One model indicates a shift in temperature/precipitation/discharge of 10% would increase E.Coli concentration by 9%

Feldman, D. L., & Ingram, H. M. (2009). Making science useful to decision makers: Climate forecasts, water management, and knowledge networks. Weather, Climate, and Society, 1(1), 9–21. https://doi.org/10.1175/2009WCAS1007.1

- Knowledge networks and boundary organizations are key to integrate climate information with water resources decision making.
- Watershed plans should harmonize competing objectives and goals of numerous users, require locally tailored solutions. These solutions should be built by dialogue between experts and stakeholders, and must change based on concerns raised by residents, NGOs, or community groups.

Schijven, J., Bouwknegt, M., de Roda Husman, A. M., Rutjes, S., Sudre, B., Suk, J. E., & Semenza, J. C. (2013). A Decision Support Tool to Compare Waterborne and Foodborne Infection and/or Illness Risks Associated with Climate Change. Risk Analysis, 33(12), 2154–2167. https://doi.org/10.1111/risa.12077

- Increases in heavy rainfall events lead to peaks in infection risk.

<u>Case Studies</u>

Olds, H. T., Corsi, S. R., Dila, D. K., Halmo, K. M., Bootsma, M. J., & McLellan, S. L. (2018). High levels of sewage contamination released from urban areas after storm events: A quantitative survey with sewage specific bacterial indicators. PLOS Medicine, 15(7), e1002614. https://doi.org/10.1371/journal.pmed.1002614

- Strong link between waterborne disease and heavy precipitation events.
- Climate change to increase the frequency of storm events causing water quality concerns.
- Degree of urbanization, impervious surface, pipe infrastructure, sewer overflows all significantly worsen impacts from storm events. These effects are higher order when combined with precipitation than the precipitation itself. (E.g. during a storm event, larger watersheds have higher bacteria than smaller, although both are elevated). Sewage overflows caused from heavy precipitation outweigh all other variables if present.
- Heavy rain events are significant, total rainfall depth is significantly correlated to fecal indicator bacteria.
- Sampling identified rainfall exceeding 2 inches in 24 hours as a key threshold for storms causing contamination. Fecal indicator bacteria concentrations spike significantly past this threshold. A spike is multiple orders of magnitude, ~1,000-fold.
- Study findings suggest that E.Coli as an indicator severely underestimates other fecal bacteria species, including those that cause disease. This break is especially significant during storm events. (e.g. during heavy precipitation events, E.Coli measurements did not indicate water quality concerns despite large sewage contamination).
- Milwaukee has recognized this link, integrating climate model data into their water infrastructure planning since at least 2012: https://www.accesswater.org/publications/-280579/effect-of-climate-change-on-sewer-overflows-in-milwaukee
- Study data from watershed surrounding Milwaukee, Wisconsin can be found in Table 1, including rainfall depth, mean streamflow, and resulting counts of harmful bacteria.

Chhetri, B. K., Galanis, E., Sobie, S., Brubacher, J., Balshaw, R., Otterstatter, M., … Takaro, T. K. (2019). Projected local rain events due to climate change and the impacts on waterborne diseases in Vancouver, British Columbia, Canada. Environmental Health: A Global Access Science Source, 18(1). https://doi.org/10.1186/s12940-019-0550-y

- Precipitation extremes are linked to outbreaks of 2 waterborne illnesses in a Canadian city, further risk if the extreme is preceded by 30 or more dry days in past 60 days.
- Used relationships and RCP 8.5 precipitation data to estimate future illness (used mean of 12 downscaled CMIP5 models).
- An increase in rain events > 90^{th} percentile increase disease risk by 8% in 2040s, 12% in 2060s, 16% by 2080s (Table 2). The mean increase in the highest category of rain events is ~5% in the 2040s, ~6% in the 2060s, and ~7% in the 2080s.

Lee, S., Suits, M., Wituszynski, D., Winston, R., Martin, J., & Lee, J. (2020). Residential urban stormwater runoff: A comprehensive profile of microbiome and antibiotic resistance. Science of the Total Environment, 723. https://doi.org/10.1016/j.scitotenv.2020.138033

- Analyzed the relationship between rainfall depth/intensity and E.Coli in stormwater outflows in Columbia Ohio, Spring/Summer 2017.
- Significant positive relationship between rainfall intensity and E.Coli density, prevalent contamination from fecal contamination from agriculture/wildlife (91% of samples).
- An increase in rainfall intensity of delta0.5 inch/hr is tied to an order of magnitude increase in E.Coli density (e+1 CFU/100mL).

De Roos, A. J., Kondo, M. C., Robinson, L. F., Rai, A., Ryan, M., Haas, C. N., … Fagliano, J. A. (2020, February 1). Heavy precipitation, drinking water source, and acute gastrointestinal illness in Philadelphia, 2015-2017. PLoS ONE. Public Library of Science. https://doi.org/10.1371/journal.pone.0229258

- Philadelphia, 2015-2017 measurements of GI (gastro-intestinal) illness cases combined with daily precipitation and stream streamflow.
- Observed a link between heavy precipitation and subsequent increase in GI cases (peaking 8-16 days post event).
- Precipitation above the 95^{th} percentile were tied to a 102% increase in GI cases 7-16 days later.

Coulliette, A. D., & Noble, R. T. (2008). Impacts of rainfall on the water quality of the Newport River Estuary (Eastern North Carolina, USA). Journal of Water and Health, 6(4), 473–482. https://doi.org/10.2166/wh.2008.136

- Newport River, NC. Sampling 2004 – 2006 over a variety of conditions.
- E.Coli increases significantly after 2.54 cm (1 inch) and “management action threshold [exceeding 14MPN/100mL]” of 3.81 cm (1.5 inch). [averages of 111.8MPN/100mL and 221MPN/100mL, respectively. These events shutdown shellfish harvesting 87% and 93% of the time, respectively].
- Summer conditions are worse, suggesting influence of temperature.
- Any rainfall at all still exceeded management threshold 67% of the time.
- Figure 2 shows the relationship the study data observed between rainfall amounts and harmful bacteria.

Tornevi, A., Bergstedt, O., & Forsberg, B. (2014). Precipitation effects on microbial pollution in a river: Lag structures and seasonal effect modification. PLoS ONE, 9(5). https://doi.org/10.1371/journal.pone.0098546

- 7 years of rainfall, E.Coli, turbidity data for an urban river in Sweden.
- Water quality worsens for 48 hours after rainfall.
- Rain events of >15mm/24 hr (local 95^{th} percentile) tied to 3-fold increase in E.Coli conc. and 30% higher turbidity.
- The general relationship between rainfall and E.Coli was exponential. This effect held across seasons and time lengths (days).

Hart, J. D., Blackwood, A. D., & Noble, R. T. (2020). Examining coastal dynamics and recreational water quality by quantifying multiple sewage specific markers in a North Carolina estuary. Science of the Total Environment, 747. https://doi.org/10.1016/j.scitotenv.2020.141124

- Beaufort, North Carolina. 2018 samples.
- Strong correlation between human indicator microbes and rainfall within the past 12 hours ($r = 0.57$, $p<0.001$).
- Storm conditions are >6mm of rain in prior 12 hours (would be >0.5 inch in a day if extended).
- Concentrations were orders of magnitude higher than dry events (mean EColi 158MPN/100mL vs 25.7MPN/100mL). 35.8% of samples exceeded NC threshold of 104MPN/mL. All exceedances occurred during storm conditions.

Leight, A. K., & Hood, R. R. (2018). Precipitation thresholds for fecal bacterial indicators in the Chesapeake Bay. Water Research, 139, 252–262. https://doi.org/10.1016/j.watres.2018.04.004

- Restrict shellfish harvest after >1 inch of rain in 24 hr.
- Precipitation and bacteria data from 2004 – 2014.
- Both storm events (> 1 inch) and total rain in last 3 weeks were strong positive relationships with FC elevations.
- For rain in last 3 weeks above 1 inch, exceedances rose from 7% baseline to 37%.
- Increases in open water, wetlands decrease bacteria counts in proportional rain events, suggesting that thresholds can vary slightly from 1-inch threshold by % cover across the sub-watershed tracts.

McKee, B. A., Molina, M., Cyterski, M., & Couch, A. (2020). Microbial source tracking (MST) in Chattahoochee River National Recreation Area: Seasonal and precipitation trends in MST marker concentrations, and associations with E. coli levels, pathogenic marker presence, and land use. Water Research, 171. https://doi.org/10.1016/j.watres.2019.115435

- Study area near Atlanta, recreational water body frequently exceeding E.Coli standards. Sampling 2015-2017 in real-time on the waterbody and not along surrounding input watersheds / rivers.
- Land use features play a key role, especially wastewater treatment plants.
- Human and dog fecal bacteria both had higher concentrations during samples collected after rain events (any rainfall at all; 0.01 inch threshold).
- Management implication: dog waste is significant E.Coli health risk if it rains at all (any rain) [Atlanta may be too urbanized to use a similar metric in Columbia. The implication would be shut down river access for 24hr following any rain above 0.01 inch.]

Aguilera, R., Gershunov, A., & Benmarhnia, T. (2019). Atmospheric rivers impact California's coastal water quality via extreme precipitation. Science of the Total Environment, 671, 488–494. https://doi.org/10.1016/j.scitotenv.2019.03.318

- In California, climate change is likely to cause dry spells followed by extreme rainfall, with severe implications for water pollution loads.
- Evaluated gridded daily precipitation and 500 weekly monitoring stations across 2003-2009 in coastal California.
- Over two-thirds of pollution spikes were tied to extreme rainfall events.

Gronlund, C. J., Cameron, L., Shea, C., & O'Neill, M. S. (2019). Assessing the magnitude and uncertainties of the burden of selected diseases attributable to extreme heat and extreme precipitation under a climate change scenario in Michigan for the period 2041-2070. Environmental Health: A Global Access Science Source, 18(1). https://doi.org/10.1186/s12940-019-0483-5

- The extreme heat causal pathways are mostly heat-morbidity, not watershed related. An exception is respiratory infection caused by pathogens (e.g. Legionella) which thrive in warm water.

- There are multiple pathways between extreme precipitation and health outcomes. Risk increases due to rainfall, increased turbidity, HABs, flooding, and sewer overflows. There is uncertainty which varies. The link between general increase in precipitation is hard to gauge, while sewer overflows present an immediate risk that is easily tied to health outcomes.
- GI illness --- Water quality --- extreme precipitation is the most important health risk/link.
- Note these are all causes, not linked just to watersheds, for Michigan. Mortality increases with extreme heat, 240 deaths attributable annually. Extreme precipitation increases emergency department visits per capita. Most mortality is associated with extreme heat.
- Equity is a major concern, disproportionate impacts face the elderly and those in poverty.

Appendix E – WTM Model Methodology

<u>Sources and Existing Conditions in Watershed Treatment Models (WTMs)</u>

KCI selected the Watershed Treatment Model (WTM) from the Center for Watershed Protection to create water quality models for the 11 watersheds of the Three Rivers Watershed study area to determine baseline fecal coliform (FC) bacteria loads for three separate conditions: 1) existing land use conditions and mean annual precipitation amount; 2) future land use and climate scenarios, incorporating future growth, increased bacteria concentrations in runoff, and increased precipitation within the study area; and 3) future retrofit scenarios, in which the management measures available within the WTM framework were applied to reduce pollutant loads below current existing conditions. Individual WTMs were developed for each of the 11 delineated watersheds. The City of Columbia developed the Rocky Branch WTM and the McCormick Taylor-KCI Project Team developed the remaining 10.

The Watershed Treatment Model (WTM) is a steady state spreadsheet modeling tool best utilized for the rapid assessment and quantification various watershed treatment options and management measures. The WTM estimates pollutant loads for sediment, nutrients, bacteria, and runoff volume. The WTM calculates pollutant loading on an annual basis and will not simulate seasonal loads or the short-term variability of pollutant loads due to shorter periods of climate variability. The Pollutant Sources component of the WTM estimates the load from a watershed without treatment measures in place. The Treatment Options component estimates the reduction in this uncontrolled load from a wide suite of treatment measures for both existing and future conditions. Finally, the Future Growth component allows the user to account for future development in the watershed, assuming a given level of treatment for that development (Caraco, 2013).

Pollutant sources were modeled in the 11 unique watershed WTMs by inputting information on the existing land use conditions, streams, annual rainfall, soils, riparian buffer conditions, sanitary sewer system lengths, and on-site septic systems. Livestock data was also included in the WTMs, if applicable to the watershed. Point sources (wastewater treatment plant discharges), nutrient concentration in stream channels, combined sewer overflows, illicit connections, marina runoff, and road sanding were not considered in the models. Existing stormwater management practices and riparian buffers were included in the Existing Conditions models. The WTMs did not include pet waste education programs, erosion and sediment control, street sweeping, catch basin cleanouts, or marina pump outs as existing practices.

The following sections describe the data sources and pre-processing steps that were utilized to develop the Existing Conditions models:

<u>Existing Land Use</u>

Land use data was combined and synthesized from three sources: Microsoft Virtual Earth Open Street Map, the Central Midlands COG zoning, and the 2016 National Land Cover Dataset (NLCD).

The first step was to delineate all roadways by creating a 10 ft buffer around the road centerlines.

Zoning data provided by the CMCOG took priority over the NLCD. Industrial, commercial, public/institutional, and multifamily areas from the CMCOG data were clipped to the Three Rivers Watershed boundary.

Areas identified as "Developed, High Intensity" in the NCLD layer, that also intersected with the Residential or Vacant/Undeveloped areas in the COG data became "Residential, High".

Areas identified as "Developed, Medium Intensity" in the NCLD layer, that also intersected with the Residential or Vacant/Undeveloped areas in the COG data became "Residential, Medium".

Areas identified as "Developed, Low Intensity" in the NCLD layer, that also intersected with the Residential or Vacant/Undeveloped areas in the COG data became "Residential, Low".

Areas identified as "Open Water" in the NCLD layer, that also intersected with the Vacant/Undeveloped areas in the COG data became "Open Water".

Areas identified as "Herbaceous, Barren Land, Hay/Pasture, or Cultivated Crops" in the NCLD layer, that also intersected with the Vacant/Undeveloped areas in the COG data became "Rural".

Areas identified as "Developed, Open Space" in the NCLD layer, that also intersected with the "Vacant/Undeveloped" areas in the COG data were split evenly between "Rural" and "Low Density Residential".

Areas identified as "Woody Wetlands, Shrub/Scrub, Mixed Forest, Evergreen Forest, Emergent Herbaceous Wetlands, or Deciduous Forest" in the NCLD layer, that also intersected with the Vacant/Undeveloped areas in the COG data became "Forest."

Rainfall

Annual rainfall was assumed to be 46 inches in all WTMs (South Carolina State Climatology Office).

Soils

GIS-based soils data were obtained from the USDA Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) and mapped for the entire 3RW Study Area. The soils data layer was intersected with watershed boundaries and the percentages of soils in each hydrologic group were calculated for each watershed. The percentages of soils within each of the groundwater depth categories stipulated by WTM (< 3 feet, 3-5 feet, >5 feet) were also determined using the USDA soils data.

Structural Stormwater Management Practices

GIS data on the locations of data on location of existing structural stormwater measures were available from Lexington County, Richland County, and the City of Columbia. The financial resources available to support this watershed modeling effort were not sufficient to support the investigation and input of structure types and characteristics of individual stormwater practices within the study area. In the interest of efficiency of effort, all existing structural practices were assumed to be conventional wet ponds. By the same token, the level of project resources would also not support the delineation of treatment watersheds of each of the 373 stormwater practices within the study area. In order to standardize treatment watersheds, the project team analyzed ten randomly selected stormwater ponds throughout the Three Rivers Watershed and delineated drainage area for each. The average of the resulting drainage areas was 12 acres, so the total area captured by stormwater practices (wet ponds) in each watershed was determined by multiplying the average drainage area of 12 acres by the number of ponds in the watershed. Stormwater management practices had three discount factors to input into the model.

The WTM input options for stormwater practices a design factor for the adequacy of existing design standards and a maintenance factor for any maintenance conducted of treatment practices. The project team assumed the design discount was 0.8 (specific design standards, including location and performance-enhancing features; not legally binding) and the maintenance discount was 0.6 (regular maintenance is specified in design guidance, but the community has a poor tracking system or limited staff to ensure maintenance occurs) in all WTMs. The impervious percentage for the area treated by stormwater ponds was assumed to be the weighted average of imperviousness in the watershed's developed land such as residential, commercial, roadway and industrial areas.

<u>On-Site Sewage Disposal Systems</u>

Given that data were not available from the local jurisdictions within the study area on the numbers or spatial distributions on-site septic systems, the project team conducted a geospatial analysis to estimate the numbers of on-site systems for each watershed. GIS data reflecting the distribution of wastewater collection systems were obtained for the entire study area and analyzed in conjunction with readily available data on the locations of buildings. The sewer lines were mapped, and all buildings that were located along street alignments with identifiable sewer lines associated were assumed to be connected to the sanitary sewer collection system, and all those located on un-sewered streets or excessive distances from the nearest sewer line were assumed to be utilizing on-site septic systems. The buildings outside identifiable areas of sewer service were tallied and the percentage of the total buildings was calculated for each watershed and entered in WTM. The failure rate of the septic systems was assumed to be 10%. The results of this analysis are summarized in Section 5.2.2 in this WBP.

<u>Riparian Buffers</u>

GIS shapefiles developed by Three Oaks Engineering were used to determine the width and length of existing riparian buffers in each watershed. Three Oaks staff conducted a spatial analysis to determine riparian buffer widths for each stream reach and assigned each reach to a category reflecting a buffer width of < 50 feet, 50-100 feet, or > 100 feet. Given that WTM will not accept buffer width inputs as ranges, the three categories of buffers were assumed to have widths of 25 feet, 75 feet or 100 feet wide, respectively. In WTM, riparian buffers have a design and maintenance discount factor to reflect any buffer disturbance by residents or design. For existing riparian buffers, the maintenance and design factor were assumed to be 0.4, meaning that the buffer ordinance has no restrictions on activities within the buffer, or no ordinance in place and that the buffers are not maintained (Caraco, 2013). KCI assumed all municipalities had an existing ordinance to establish riparian buffers and the ordinance had no restrictions on activities within the buffers, and no public education programs on riparian buffers were being conducted.

Livestock

Livestock inputs were included in the Fourteenmile Creek Watershed WTM. The WTM includes space for input of dairy cattle, layers, broilers, turkeys and pigs. McCormick Taylor provided the number of horses and cattle. WTM did not have an input option for horses, so the number of horses was converted to the cattle equivalent before being entered into the model. To determine the fecal coliform from horses, the consultant team utilized a spreadsheet tool that had been previously provided by SCDHEC (personal communication, S. Hylton 5/28/2020). A conversion factor (1.1) to convert horses to cows for fecal coliform loads was applied. The resulting number of cows to represent the horses in the watershed was then added to the total number of cattle in the WTM.

Retrofit Scenarios in Water Treatment Models (WTMs)

KCI used the Watershed Treatment Model (WTM) to develop retrofit scenarios that reached load reduction goals for fecal coliform in the 11 watersheds. Based on the Load Duration Curves developed for this watershed plan (Refer to **Section 4.2** and **Appendix F**) the subwatersheds draining to the Congaree River require a reduction of 63% of the fecal coliform load to approximate compliance with water quality standards; the subwatersheds draining to the Saluda River require a reduction goal of 51%, and Rocky Branch requires a reduction of 94%. See **Figure A-4**, which summarizes the reduction goals for each watershed. The core purpose of the Retrofit Scenarios is to illuminate the levels of effort required to approximate compliance with water quality standard for fecal coliform bacteria loading in each watershed, and to guide resource managers in prioritizing those management efforts that will achieve the greatest reductions.

Figure A-4 - Load Reduction Goals per Subwatershed

Congaree River (63%)	Saluda River (51%)	Rocky Branch (94%)
Congaree River East	Fourteenmile Creek	Rocky Branch
Congaree River West	Kinley Creek	
UT to Congaree Creek	Stoop Creek	
Lower Sixmile Creek	Saluda River North	
Congaree Creek Outlet	Senn Branch & Double Branch	

The retrofit model scenarios utilized measures such as pet waste education programs, impervious cover disconnection, redevelopment with improvements stormwater retrofits to reach watershed load reduction goals. On-site sewage disposal system (OSDS) education and sanitary sewer overflows (SSO) repair programs were also included in retrofit models. KCI did not consider marina pump outs and urban downsizing as retrofit options for the watershed. In the WTMs, implementing catch basin cleanouts, street sweeping, and erosion and sediment control had no impact on reduction of fecal coliform and were not considered retrofit options.

The practices in WTMs have corresponding literature value load reductions for pollutants. WTM applies 'discount factors' to the literature values of reduction for each practice, including design and maintenance discounts for stormwater management practices and awareness discounts for public outreach programs, to reflect limitations each practice may encounter during application.

Community Outreach Programs

For community outreach programs in all WTMs, there is an awareness discount input that reflects how effective the program is in reaching the public. For the future retrofit scenario it was assumed a TV campaign for pet waste education with 40% awareness of message and a radio campaign for residential impervious cover disconnection with 25% awareness of message would be implemented. Impervious cover disconnection was assumed to be applicable on residential areas labeled as low density residential (LDR) and medium density residential (MDR).

Riparian Buffer Maintenance and Expansion

Retrofit models assumed all existing 25-foot buffers would be expanded to 75 feet wide to reflect the management action of restoring riparian buffers in each sub-watershed. As described previously, the protection and maintenance discount for riparian buffers was assumed to 0.4 for existing conditions, assuming there is an existing buffer ordinance to establish buffer zones with no restrictions on activities within the buffers. In the Retrofit models, it was assumed the discount factor would increase to 0.6. The 0.6 discount factor assumes there will be a buffer ordinance that specifies activities allowed in riparian buffers but does not require signage. The maximum discount factor, 0.9, could be applied if the buffer ordinance specifies acceptable and unacceptable activities in the buffer, and requires signage and education for homeowners.

Urban Redevelopment

Area available for redevelopment in the models was estimated based off watershed size and existing development. This value ranges from 50-200 acres in the WTMs. Redeveloped area was assumed to result in 25% reduction of turf and 25% reduction in impervious area.

SSO Repairs

The models assumed 25% of repairs on SSO would be completed with a goal of 75% reduction in SSO events.

On-site Sewage Disposal Systems

OSDS exist within this watershed so OSDS Education, OSDS Repair, and OSDS Upgrade were included in the model. It was assumed for OSDS education, 40% of the residents with OSDS would be reached through a television campaign and 25% would be willing to improve maintenance and management of the OSDS. For OSDS repairs, it was assumed 40% of the existing OSDS would be inspected with 90% of owners completing repairs, given there is an incentive for owners. Lastly, for OSDS upgrades, the model assumes 30% of the existing OSDSs will be inspected for upgrades. It was assumed that given there is an incentive, 50% of owners will upgrade the OSDS.

Stormwater Retrofits

Stormwater retrofit options included bacteria reducing practices such as wet ponds, wetlands, and filters and retrofits that reduce runoff volume and bacteria such as bioretention and infiltration practices. The impervious percentage for the areas captured by BMPs was assumed to be the weighted average of imperviousness in the watershed's developed land such as residential, commercial, roadway and industrial areas. The stormwater retrofit options had a design storm of 1.0 inches. Future stormwater retrofits had two discount factor inputs. The model included a design factor for the adequacy of existing design standards and a maintenance factor for any maintenance conducted of treatment practices. The design discount factor was 80%, assuming there are specific design standards, but they are not legally binding. The maintenance design factor was input as 90% for all stormwater retrofits. It was assumed in the future scenarios, there would be regular maintenance of stormwater retrofits, specified by design guidance, managed by a private company or through community participation. The dominant soil type for the drainage areas of the retrofits was assumed to be the majority soil type in the sub-watershed. See **Figure A-5** for a summary of the majority soil types in each sub-watershed. The required area captured by the retrofits to meet fecal coliform reduction goals was determined through trial and error in the WTMs after other retrofits such as community outreach programs, impervious cover disconnection and SSO repairs had been input to the model.

Figure A-5 - Summary of Soil Composition per Subwatershed

Subwatershed	Dominant Soil Type
Fourteenmile Creek	B
Kinley Creek	B
Stoop Creek	B
Saluda River North	B
Senn Branch and Double Branch	B
Congaree River East	D
Congaree River West	A
UT to Congaree Creek	B
Lower Sixmile Creek	B
Congaree Creek Outlet	C
Rocky Branch	D

Future Scenarios in Water Treatment Models (WTMs)

In addition to the retrofit scenarios, the WTM models were utilized to develop Future Scenarios for the purpose of illustrating the increase in future coliform loads that will result from future development across the study area, should no additional management measures be implemented. The Future Scenarios were not evaluated using the same management measures for percent fecal coliform reduction applied in the Retrofit Scenarios. The load reduction curves used to determine the reduction goals for Retrofit Scenarios cannot be used to determine the degree of reduction that would be necessary to achieve approximate compliance with water quality standards in the future. The following is a description of how the future land use projections were developed to support the WTM Future Scenarios.

Through discussion with Carolinas Integrated Sciences and Assessments (CISA), the Project Team utilized a future land use dataset developed as part of the US Geological Survey LandCarbon project. A component of the USGS work was an assessment of historic, current, and future landscape change on biogeochemical cycling. Historic landscape change from 1992 to 2005 was mapped and modeled for the conterminous United States, while scenarios of future LULC through 2100 were modeled for four IPCC Special Report on Emissions Scenarios (SRES). For the purpose of the 3RWBP, the Project Team selected the USGS year 2050, A1B scenario/RCP 8.5 (higher emissions scenario). The USGS land use categories have 11 different undeveloped categories and one "developed" category (that would encompass seven of the specific WTM categories).

In order to determine the area proportions of roadways, industrial, commercial, and residential developed areas in the future land use, the first step was to calculate the distribution of developed and undeveloped land for the current conditions. For each watershed, the current land uses were separated into "developed" and "undeveloped," shown in **Figure A-6**. The total area for these two types was calculated separately, and then used to calculate the percent of each land use. For example, the percent commercial area is calculated as its respective area divided by the total developed area (including only commercial, residential, roadway, and industrial land uses). The percent forest is likewise its respective area divided by the total undeveloped area for that sub-watershed.

Figure A-6 - Summary of Land Use by Developed vs Undeveloped

Current Land Use	Category
Forest	undeveloped
Rural	undeveloped
Open Water	undeveloped
Commercial	Developed
Residential, Medium	Developed
Residential, High	Developed
Residential Low	Developed
Residential, High Multifamily	Developed
Industrial	Developed
Roadway	Developed

The percentage of each of the current land use types was then multiplied by the future developed or undeveloped area for each watershed. Here is an example from Lower Sixmile-Congaree. Note how the current developed area increases from 2,229.81 acres to 2,436.91 acres. As a result, the total undeveloped area in this watershed decreases from 502.79 acres to 295.68 acres. The percentage of each of the seven land uses for developed area remains the same, but their respective area increases to reflect the larger overall developed area.

The Fourteenmile Creek Watershed had three additional climate scenarios modeled. The climate scenarios considered the future resulting fecal coliform loads with elevated ambient temperatures and higher yearly precipitation. The climate scenarios assumed an annual precipitation of 60 inches and 15% increase in fecal coliform concentration to 23,000 MPN/100 mL. Separate scenarios were run to determine the resulting load from an increase in annual rainfall to 60 inches, an increase in fecal coliform concentration to 23,000 MPN/100 mL, and if both the annual rainfall and fecal coliform concentration increased.

SubWatershed:	**Lower Sixmile-Congaree**	% class	USGS future		**Fourteenmile Creek**	% class	USGS future		**Congaree River East**	% class	USGS future	
Current Land Use (acres):												
Low Residential	675.05	0.30		737.75	3452.205	0.50		3970.04	112.125	0.09		125.33
Moderate Residential	507.43	0.23		554.56	1227.52	0.18		1411.65	121.85	0.10		136.20
High Residential	89.12	0.04		97.40	515.13	0.07		592.40	116.6	0.10		130.34
Multi-family	14.86	0.01		16.24	120.83	0.02		138.95	71.51	0.06		79.93
Commercial	759.66	0.34		830.22	1388.99	0.20		1597.34	585.98	0.49		655.01
Roadway	102.88	0.05		112.44	265.37	0.04		305.18	197.15	0.16		220.37
Industrial	80.81	0.04		88.32	0	0.00		0.00	0.42	0.00		0.47
DEVELOPED TOTAL:	2229.81	1.00	2436.91	2436.91	6970.045	1.00	8015.55	8015.55	1205.635	1.00	1347.66	1347.66
Forest	23.99	0.05		14.11	25.19	0.01		11.69	43.53	0.21		14.20
Rural	478.8	0.95		281.57	1925.355	0.99		893.39	49.815	0.24		16.25
Open Water	0	0.00		0.00	0.08	0.00		0.04	117.43	0.56		38.30
UNDEVELOPED TOTAL:	502.79	1.00	295.68	295.68	1950.625	1.00	905.12	905.12	210.775	1.00	68.75	68.75
TOTAL:	**2732.60**		**2732.59**		**8920.67**		**8920.67**		**1416.41**		**1416.41**	
	CURRENT		**FUTURE**		**CURRENT**		**FUTURE**		**CURRENT**		**FUTURE**	
Developed (acres)	2229.81		2436.91		6970.045		8015.55175		1205.635		1347.66	
% Developed	82%		89%		78%		90%		85%		95%	
Undeveloped (acres)	502.79		295.68		1950.705		905.11825		328.205		68.75	
% Undeveloped	18%		11%		22%		10%		23%		5%	
					manual growth rate: 15%							

SubWatershed:	Congaree River West	% class	USGS future		Congaree Creek Outlet	% class	USGS future		Kinley Creek-Saluda River	% class	USGS future	
Current Land Use (acres):												
Low Residential	253.175	0.13		280.03	820.86	0.38		977.16	1044.095	0.34		1243.60
Moderate Residential	416.34	0.22		460.50	131.99	0.06		157.12	738.91	0.24		880.10
High Residential	285.25	0.15		315.50	12.89	0.01		15.34	54.07	0.02		64.40
Multi-family	149.43	0.08		165.28	18.52	0.01		22.05	51.54	0.02		61.39
Commercial	546.3	0.29		604.24	793.73	0.37		944.87	797.66	0.26		950.08
Roadway	165.02	0.09		182.52	62.19	0.03		74.03	144.69	0.05		172.34
Industrial	88.72	0.05		98.13	306.93	0.14		365.37	222.65	0.07		265.19
DEVELOPED TOTAL:	1904.235	1.00	2106.20	2106.20	2147.11	1.00	2555.95	2555.95	3053.615	1.00	3637.11	3637.11
Forest	17.03	0.06		4.56	39.7	0.05		19.79	33.07	0.04		10.75
Rural	109.635	0.40		29.36	775.31	0.95		386.40	747.605	0.86		243.09
Open Water	149.18	0.54		39.94	0.03	0.00		0.01	84.69	0.10		27.54
UNDEVELOPED TOTAL:	275.845	1.00	73.86	73.86	815.04	1.00	406.20	406.20	865.365	1.00	281.38	281.38
TOTAL:	**2180.08**		**2180.06**		**2962.15**		**2962.15**		**3918.98**		**3918.49**	
	CURRENT		**FUTURE**		**CURRENT**		**FUTURE**		**CURRENT**		**FUTURE**	
Developed (acres)	1904.235		2106.2		2147.11		2555.95		3053.615		3637.11	
% Developed	87%		97%		72%		86%		78%		93%	
Undeveloped (acres)	425.025		73.86		815.07		406.2		950.055		281.38	
% Undeveloped	19%		3%		28%		14%		24%		7%	

SubWatershed:	Saluda River North	% class	USGS future		Senn Branch & Double Branch	% class	USGS future		Stoop Creek	% class	USGS future	
Current Land Use (acres):												
Low Residential	288.435	0.16		304.33	1050.18	31%		1201.53	579.765	24%		632.90
Moderate Residential	396.82	0.23		418.69	1039.06	31%		1188.81	605.35	25%		660.83
High Residential	57.72	0.03		60.90	187.24	6%		214.22	153.11	6%		167.14
Multi-family	101.79	0.06		107.40	115.87	3%		132.57	380.45	15%		415.32
Commercial	753.22	0.43		794.74	777.21	23%		889.22	571.78	23%		624.19
Roadway	153.66	0.09		162.13	218.9	6%		250.45	168.84	7%		184.31
Industrial	0	0.00		0.00	2.1	0%		2.40	4.62	0%		5.04
DEVELOPED TOTAL:	1751.645	1.00	1848.19	1848.19	3390.56	100%	3879.20	3879.20	2463.915	100%	2689.74	2689.74
Forest	45.94	0.20		25.97	24.09	4%		4.60	53.46	20%		7.95
Rural	122.365	0.55		69.18	515.38	85%		98.37	211.775	80%		31.48
Open Water	56.14	0.25		31.74	64.44	11%		12.30	0	0%		0.00
UNDEVELOPED TOTAL:	224.445	1.00	126.90	126.90	603.91	100%	115.27	115.27	265.235	100%	39.43	39.43
TOTAL:	**1976.09**		**1975.09**		**3994.47**		**3994.47**		**2729.15**		**2729.17**	
	CURRENT		**FUTURE**		**CURRENT**		**FUTURE**		**CURRENT**		**FUTURE**	
Developed (acres)	1751.645		1848.19		3390.56		3879.2		2463.915		2689.74	
% Developed	89%		94%		85%		97%		90%		99%	
Undeveloped (acres)	280.585		126.9		668.35		115.27		265.235		39.43	
% Undeveloped	14%		6%		17%		3%		10%		1%	

SubWatershed:	UT to Congaree Creek	% class	USGS future		Rocky Branch	% class	USGS future	
Current Land Use (acres):								
Low Residential	234.345	16%		271.50	37.6	1%		38.39
Moderate Residential	331.42	23%		383.97	248.5	10%		253.74
High Residential	258.0594	18%		298.98	576.9	22%		589.07
Multi-family	38.28	3%		44.35	73.8	3%		75.36
Commercial	399.94	27%		463.35	1062.7	41%		1085.11
Roadway	95.01	7%		110.07	331.6	13%		338.59
Industrial	103.16	7%		119.52	257.6	10%		263.03
DEVELOPED TOTAL:	1460.2144	100%	1691.74	1691.74	2588.7	100%	2643.30	2643.30
Forest	2.17	1%			39.1	48%		12.84
Rural	84.445	37%			42.2	52%		13.86
Open Water	144	62%			0	0%		0.00
UNDEVELOPED TOTAL:	230.615	100%	0.00		81.3	100%	26.70	26.70
TOTAL:	**1690.83**		**1691.74**		**2670**		**2670**	
	CURRENT		**FUTURE**		**CURRENT**		**FUTURE**	
Developed (acres)	1460.2144		1691.74		2588.7		2643.3	
% Developed	86%		100%		97%		99%	
Undeveloped (acres)	374.615		0		81.3		26.7	
% Undeveloped	22%		0%		3%		1%	

Appendix F – Load Duration Curve Methodology

For development of the TMDLs, the EPA guidance document entitled An Approach for Using Load Duration Curves in the Development of TMDLs (2007) was utilized. For reference the guidance document can be found here:

https://www.epa.gov/sites/default/files/2015-07/documents/2007_08_23_tmdl_duration_curve_guide_aug2007.pdf.

Flow Duration Curves (FDC)

Daily flow (cfs) data was retrieved from USGS flow gauges for the three FDCs developed for this watershed plan: the Saluda River near Columbia (USGS Monitoring Station 02169000), the Congaree River at Blossom Street Bridge (USGS Monitoring Station 02169500), and Rocky Branch at Whaley Street (USGS Monitoring Station 02169506). The flow data was processed and ranked from highest flow to lowest; and the percent exceedance was also calculated for each value. The flow duration curve was created by plotting the flow vs. percent exceedance. Flow intervals were divided into five classes: low flows, dry conditions, mid-range flows, moist conditions, and high flows. The percentile ranges for these classes were: 0-10, 10-40, 40-60, 60-90 and 90-100, respectively.

Load Duration Curve (LDC)

The load duration curve (LDC) was calculated for each flow event (cfs) in the flow duration curve by multiplying the Escherichia coli (E.coli) daily maximum water quality standard of 349 cfu/100ml (MPN) by the daily flow (cfs) at that exceedance interval, applying appropriate unit conversion factors. These values were visually represented by flow (cfs) vs. percent of time flow exceeded resulting in the smooth dark blue line in the LDC graphic (example shown in **Figure A-7**) which illustrates the maximum allowable load for each flow condition in the subject river or stream.

Plotting Actual Data (LDC)

The actual recorded water quality samples for Escherichia coli levels were obtained from SCDHEC and the River Monitoring Coalition for the water quality monitoring sites located with the USGS flow gauges on the Saluda River (SCDHEC Station S-298), the Congaree River (CSB-001L and CSB-001R) and from the City of Columbia for Rocky Branch. At the Blossom Street Bridge, the Congaree River is over 800 feet wide, and samples are collected from each side of the river. Prior to development of the LDC, the two data sets were compared and found to be highly similar in variability and response to different segments of the flow regime, so the two data sets were combined. The data for each site was sorted by event date and matched with the recorded flow from the same site and date. The actual load per day was calculated by multiplying the measured E. coli value (#/100ml) by flow (cfs), applying appropriate unit conversion factors. The LDC and calculated actual loads load per day were compared to see if there was an exceedance of the allowed load. Those points falling above the LDC line represent exceedances of the water quality standard, while those falling below the line are less than the allowable load for that flow condition.

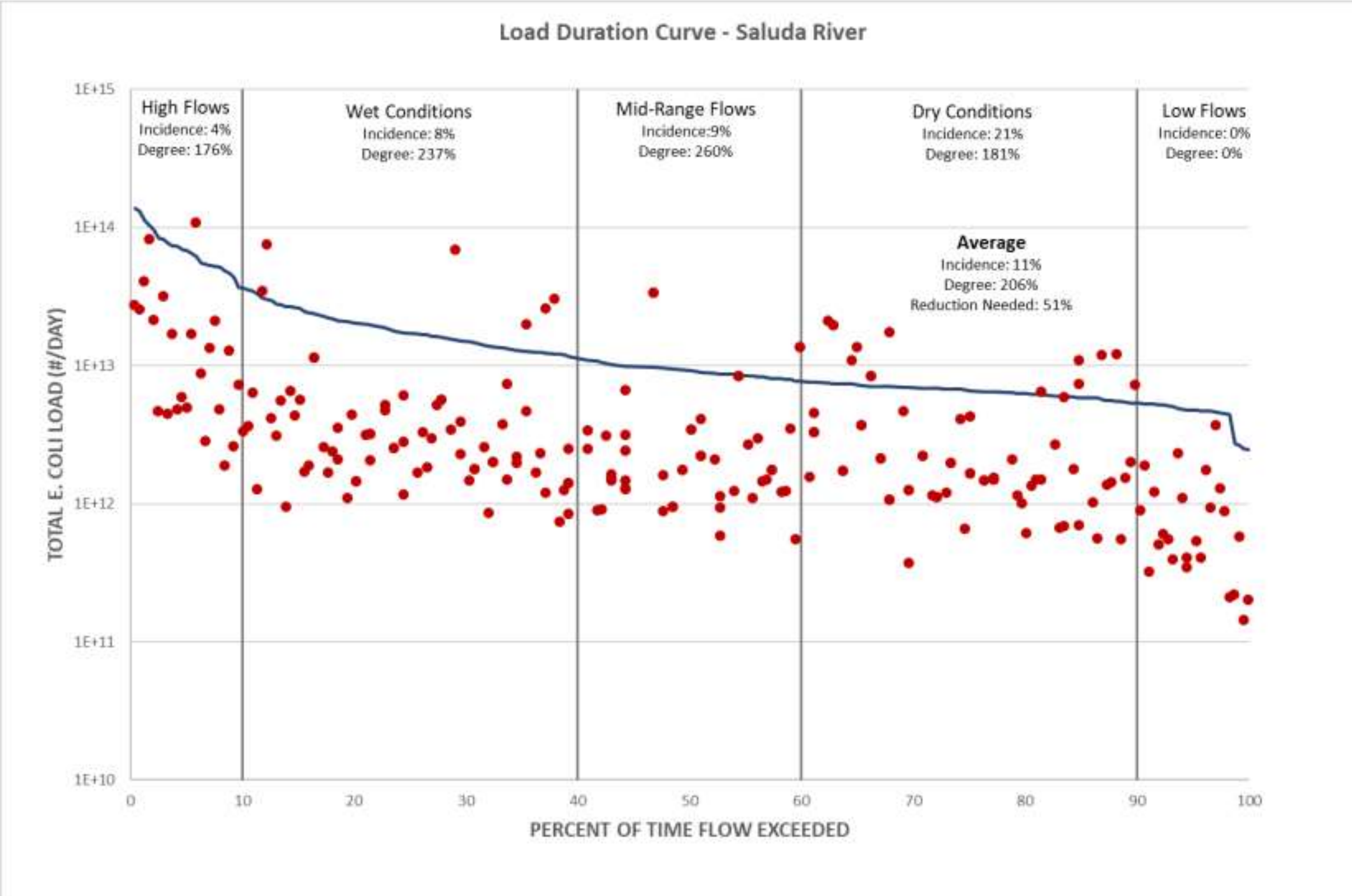


Figure A-7 - Example Load Duration Curve Graphic from the Saluda River

Appendix G – Detailed Cost Estimates by Watershed

Fourteenmile Creek

Subwatershed Area (ac): 8,921

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source	
Pet Waste Education							
Impervious Cover Disconnection	PSA	1,292				90% of dwelling units; 25% participation	5740 total dwelling units
OSDS Education	PSA	1,148				% of dwelling units	20
SSO Repair	miles of line	18 TBD				75% goal, 25% complete	95.3 total miles
riparian buffer restoration	acres	40	$5,227,200	$9,461,232	$121,968	NOAA OCM, 2020	
urban redevelopment	acres	178					
BMP retrofits	acres treated	2,150					
bioretention (in clay soil)		430	$7,450,628	$13,485,636	$8,639	Wossink and Hunt, 2003	
sand filter		430	$10,068,062	$18,223,192	$269,012	Wossink and Hunt, 2003	
wetland		430	$72,491	$131,209	$11,385	Wossink and Hunt, 2003	
wet pond		430	$818,440	$1,481,376	$47,020	Wossink and Hunt, 2003	
infiltration (bioretention in sand)		430	$40,736	$73,732	$8,639	Wossink and Hunt, 2003	
BMP Construction Cost:				$33,395,145			
BMP Maintenance Cost:					$344,695		
Total Cost:	$43,323,040						

Kinley Creek

Subwatershed Area (ac): 3,919

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	413				90% of dwelling units; 25% participation	1835	total dwelling units
OSDS Education	PSA	147				% of dwelling units	8	
SSO Repair	miles of line	6	TBD			75% goal, 25% complete	34.1	total miles
riparian buffer restoration	acres	19	2,482,920	$4,494,085	$57,935	NOAA OCM, 2020		
urban redevelopment	acres	39						
BMP retrofits	acres treated	950						
bioretention (in clay soil)		190	$3,063,819.02	$5,545,512	$7,630.45	Wossink and Hunt, 2003		
sand filter		190	$4,898,773.68	$8,866,780	$173,921.71	Wossink and Hunt, 2003		
wetland		190	$48,820.59	$88,365	$10,047.43	Wossink and Hunt, 2003		
wet pond		190	$472,735.62	$855,651	$37,745.65	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		190	$28,484.72	$51,557	$7,630.45	Wossink and Hunt, 2003		
BMP Construction Cost:				$15,407,867				
BMP Maintenance Cost:					$236,976			
Total Cost:	$20,196,863							

Stoop Creek

Subwatershed Area (ac): 2,729

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	674				90% of dwelling units; 25% participation	2994	total dwelling units
OSDS Education	PSA	60				% of dwelling units	2	
SSO Repair	miles of line	10	TBD			75% goal, 25% complete	52	total miles
riparian buffer restoration	acres	51	6,664,680	$12,063,071	$155,509	NOAA OCM, 2020		
urban redevelopment	acres	109						
BMP retrofits	acres treated	825						
bioretention (in clay soil)		165	$2,627,856.96	$4,756,421	$7,468.56	Wossink and Hunt, 2003		
sand filter		165	$4,325,611.77	$7,829,357	$161,300.53	Wossink and Hunt, 2003		
wetland		165	$45,598.28	$82,533	$9,832.88	Wossink and Hunt, 2003		
wet pond		165	$429,976.89	$778,258	$36,340.04	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		165	$26,777.86	$48,468	$7,468.56	Wossink and Hunt, 2003		
BMP Construction Cost:				$13,495,037				
BMP Maintenance Cost:					$222,411			
Total Cost:	$25,936,028							

Saluda River North

Subwatershed Area (ac): 1,975

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	292				90% of dwelling units; 25% participation	1297	total dwelling units
OSDS Education	PSA	532				% of dwelling units	41	
SSO Repair	miles of line	4	TBD			75% goal, 25% complete	23	total miles
riparian buffer restoration	acres	27	3,528,360	$6,386,332	$82,328	NOAA OCM, 2020		
urban redevelopment	acres	99						
BMP retrofits	acres treated	450						
bioretention (in clay soil)		90	$1,358,923.60	$2,459,652	$6,811	Wossink and Hunt, 2003		
sand filter		90	$2,534,361.68	$4,587,195	$116,698	Wossink and Hunt, 2003		
wetland		90	$34,004.76	$61,549	$8,962	Wossink and Hunt, 2003		
wet pond		90	$286,119.12	$517,876	$30,873	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		90	$20,534.12	$37,167	$6,811	Wossink and Hunt, 2003		
BMP Construction Cost:				$7,663,437				
BMP Maintenance Cost:					$170,155			
Total Cost:	$14,302,253							

Senn Branch & Double Branch

Subwatershed Area (ac): 3,994

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	873				90% of dwelling units; 25% participation	3882	total dwelling units
OSDS Education	PSA	2				20% of dwelling units	12	
SSO Repair	miles of line	13	TBD			75% goal, 25% complete	69.6	total miles
riparian buffer restoration	acres	29	3,789,720	$6,859,393	$88,427	NOAA OCM, 2020		
urban redevelopment	acres	120						
BMP retrofits	acres treated	850						
bioretention (in clay soil)		170	$2,714,611.08	$4,913,446	$7,503	Wossink and Hunt, 2003		
sand filter		170	$4,441,019.17	$8,038,245	$163,893	Wossink and Hunt, 2003		
wetland		170	$46,261.91	$83,734	$9,878	Wossink and Hunt, 2003		
wet pond		170	$438,689.85	$794,029	$36,633	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		170	$27,130.29	$49,106	$7,503	Wossink and Hunt, 2003		
BMP Construction Cost:				$13,878,559				
BMP Maintenance Cost:					$225,409			
Total Cost:	$21,051,788							

Congaree River East

Subwatershed Area (ac): 1,416

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	159				90% of dwelling units; 25% participa	707	total dwelling units
OSDS Education	PSA	0				% of dwelling units	1	
SSO Repair	miles of line	6	TBD			75% goal, 25% complete	29.8	total miles
riparian buffer restoration	acres	-	-	$0	-	NOAA OCM, 2020		
urban redevelopment	acres	99						
BMP retrofits	acres treated	750						
bioretention (in clay soil)		150	$2,369,007.74	$4,287,904	$7,361.15	Wossink and Hunt, 2003		
sand filter		150	$3,976,849.81	$7,198,098	$153,296.46	Wossink and Hunt, 2003		
wetland		150	$43,542.61	$78,812	$9,690.53	Wossink and Hunt, 2003		
wet pond		150	$403,300.94	$729,975	$35,420.18	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		150	$25,683.00	$46,486	$7,361.15	Wossink and Hunt, 2003		
BMP Construction Cost:				**$12,341,275**				
BMP Maintenance Cost:					**$213,129**			
Total Cost:	**$12,554,405**							

Congaree River West

Subwatershed Area (ac): 2,180

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	727				90% of dwelling units; 25% participation	3229	total dwelling units
OSDS Education	PSA	1				% of dwelling units	4	
SSO Repair	miles of line	9	TBD			75% goal, 25% complete	50.3	total miles
riparian buffer restoration	acres	7	914,760	$1,655,716	$21,344	NOAA OCM, 2020		
urban redevelopment	acres	109						
BMP retrofits	acres treated	875						
bioretention (in clay soil)		175	$2,801,590.06	$5,070,878	$7,536	Wossink and Hunt, 2003		
sand filter		175	$4,556,026.68	$8,246,408	$166,449	Wossink and Hunt, 2003		
wetland		175	$46,915.54	$84,917	$9,922	Wossink and Hunt, 2003		
wet pond		175	$447,319.13	$809,648	$36,920	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		175	$27,476.95	$49,733	$7,536	Wossink and Hunt, 2003		
BMP Construction Cost:				$14,261,584				
BMP Maintenance Cost:					$228,362			
Total Cost:	$16,167,006							

UT to Congaree Creek

Subwatershed Area (ac): 1,692

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	405				90% of dwelling units; 25% participation	1801	total dwelling units
OSDS Education	PSA	2				% of dwelling units	9	
SSO Repair	miles of line	6	TBD			75% goal, 25% complete	33	total miles
riparian buffer restoration	acres	19	2,482,920	$4,494,085	$57,935	NOAA OCM, 2020		
urban redevelopment	acres	51						
BMP retrofits	acres treated	775						
bioretention (in clay soil)		155	$2,455,048.51	$4,443,638	$7,398	Wossink and Hunt, 2003		
sand filter		155	$4,093,542.06	$7,409,311	$156,004	Wossink and Hunt, 2003		
wetland		155	$44,239.15	$80,073	$9,739	Wossink and Hunt, 2003		
wet pond		155	$412,286.21	$746,238	$35,734	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		155	$26,054.52	$47,159	$7,398	Wossink and Hunt, 2003		
BMP Construction Cost:				$12,726,419				
BMP Maintenance Cost:					$216,273			
Total Cost:	$17,494,712							

Lower Sixmile Creek

Subwatershed Area (ac): 2,733

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	347				90% of dwelling units; 25% participation	1541	total dwelling units
OSDS Education	PSA	2				% of dwelling units	9	
SSO Repair	miles of line	6	TBD			75% goal, 25% complete	33.2	total miles
riparian buffer restoration	acres	18	2,352,240	**$4,257,554**	**$54,886**	NOAA OCM, 2020		
urban redevelopment	acres	191						
BMP retrofits	acres treated	1,100						
bioretention (in clay soil)		220	$3,593,644.13	$6,504,496	$7,802	Wossink and Hunt, 2003		
sand filter		220	$5,574,982.44	$10,090,718	$188,085	Wossink and Hunt, 2003		
wetland		220	$52,410.57	$94,863	$10,275	Wossink and Hunt, 2003		
wet pond		220	$521,679.71	$944,240	$39,264	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		220	$30,373.79	$54,977	$7,802	Wossink and Hunt, 2003		
BMP Construction Cost:				**$17,689,294**				
BMP Maintenance Cost:					**$253,229**			
Total Cost:	**$22,254,963**							

Congaree Creek Outlet

Subwatershed Area (ac): 2,962

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	9				90% of dwelling units; 25% participation	42	total dwelling units
OSDS Education	PSA	8				% of dwelling units	38	
SSO Repair	miles of line	4	TBD			75% goal, 25% complete	21.2	total miles
riparian buffer restoration	acres	33	4,312,440	**$7,805,516**	**$100,624**	NOAA OCM, 2020		
urban redevelopment	acres	89						
BMP retrofits	acres treated	1,200						
bioretention (in clay soil)		240	$3,950,472.31	$7,150,355	$7,906	Wossink and Hunt, 2003		
sand filter		240	$6,019,674.59	$10,895,611	$197,030	Wossink and Hunt, 2003		
wetland		240	$54,664.90	$98,943	$10,413	Wossink and Hunt, 2003		
wet pond		240	$553,092.62	$1,001,098	$40,194	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		240	$31,553.71	$57,112	$7,906	Wossink and Hunt, 2003		
BMP Construction Cost:				**$19,203,119**				
BMP Maintenance Cost:					**$263,449**			
Total Cost:	**$27,372,708**							

Rocky Branch

Subwatershed Area (ac): 2,670

Recommended Practices	Unit Type	Units required	Implementation Cost	construction index increase	20-year maintenance	Source		
Pet Waste Education								
Impervious Cover Disconnection	PSA	1,643				90% of dwelling units; 25% participation	7301	total dwelling units
OSDS Education	PSA	-				% of dwelling units	0	
SSO Repair	miles of line	14	TBD			75% goal, 25% complete	74.6	total miles
riparian buffer restoration	acres	33	4,312,440	$7,805,516	$100,624	NOAA OCM, 2020		
urban redevelopment	acres	267						
BMP retrofits	acres treated	2,400						
bioretention (in clay soil)		480	$8,397,879.85	$15,200,163	$8,785	Wossink and Hunt, 2003		
sand filter		480	$11,093,829.09	$20,079,831	$285,287	Wossink and Hunt, 2003		
wetland		480	$76,455.20	$138,384	$11,578	Wossink and Hunt, 2003		
wet pond		480	$881,231.51	$1,595,029	$48,432	Wossink and Hunt, 2003		
infiltration (bioretention in sand)		480	$42,746.59	$77,371	$8,785	Wossink and Hunt, 2003		
BMP Construction Cost:				$37,090,777				
BMP Maintenance Cost:					$362,867			
Total Cost:	$45,359,785							

Appendix H – Survey of Stakeholder Priorities (March 2022)

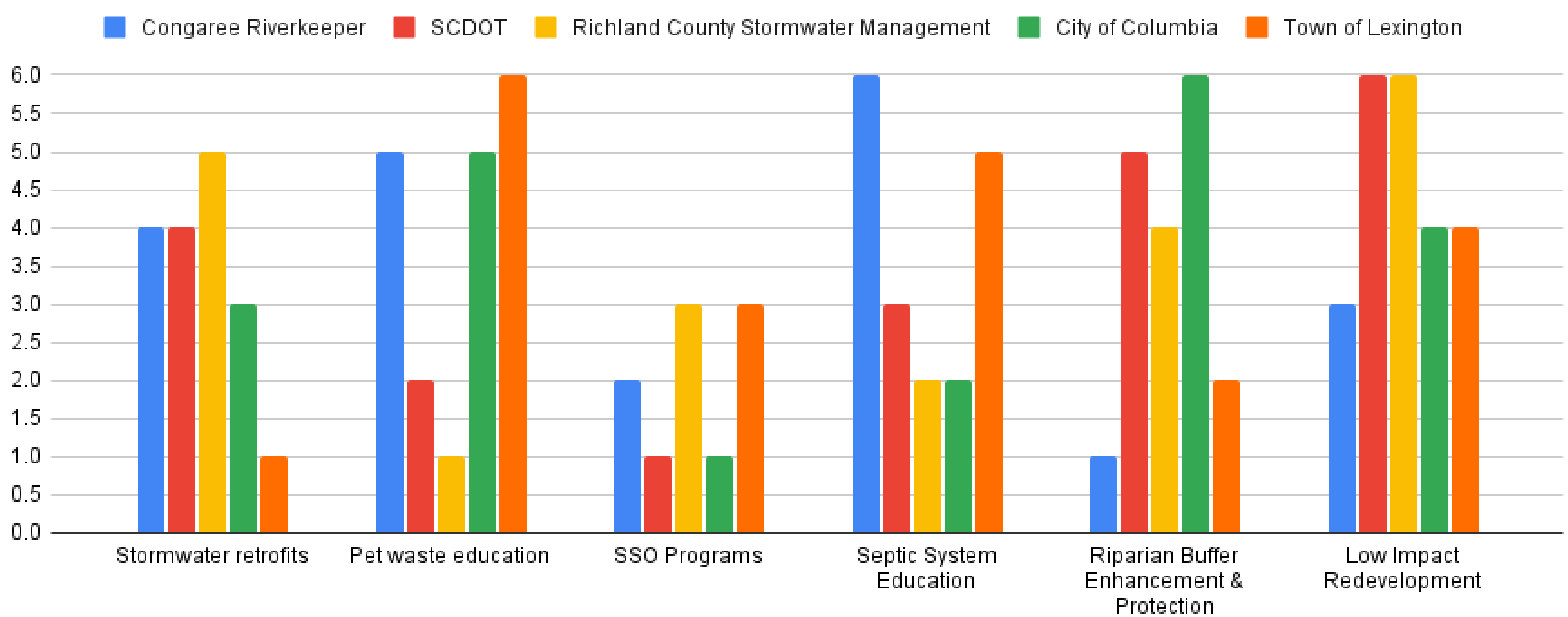


Figure A-8 - Regional BMP Priorities, indicating which BMP Type will prioritized as joint coalition projects. 1=lowest priority, 6=highest priority

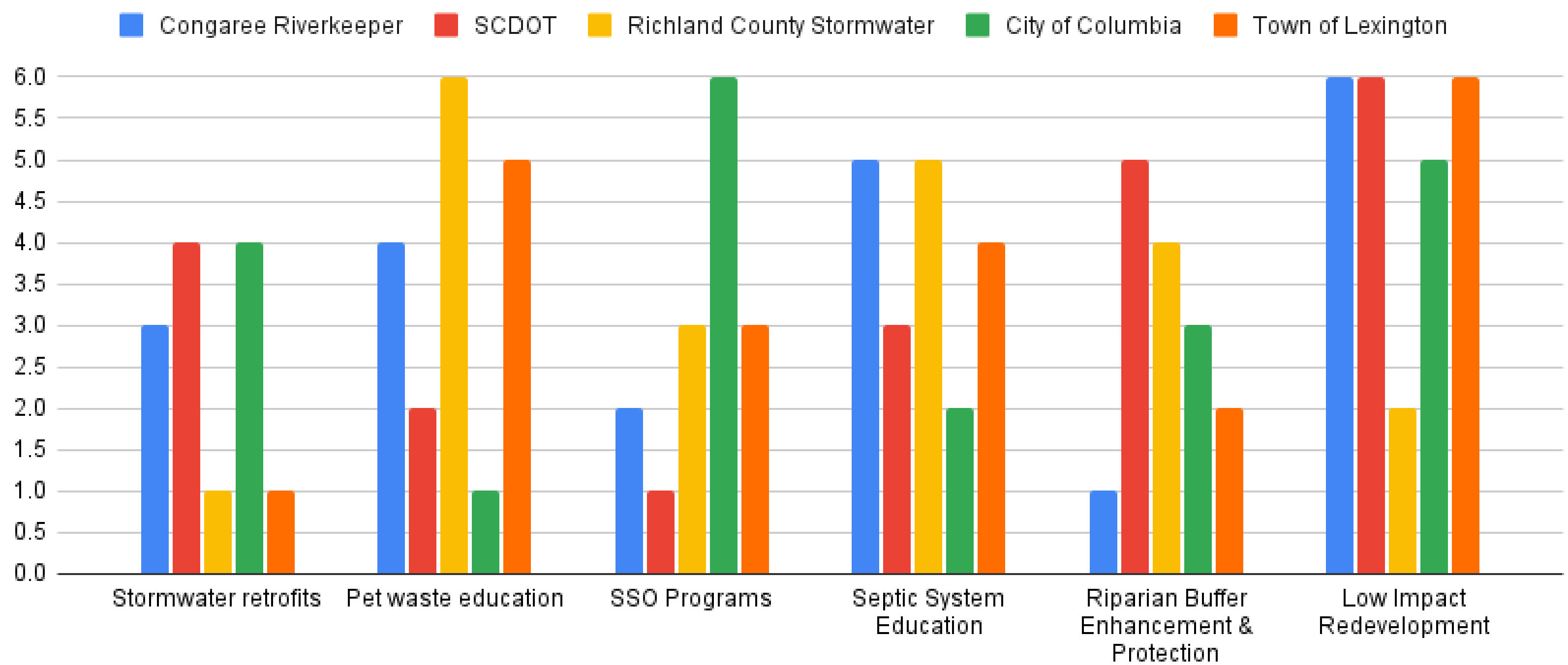


Figure A-9 - Organizational BMP Priorities by stakeholder. 1=lowest priority, 6=highest priority