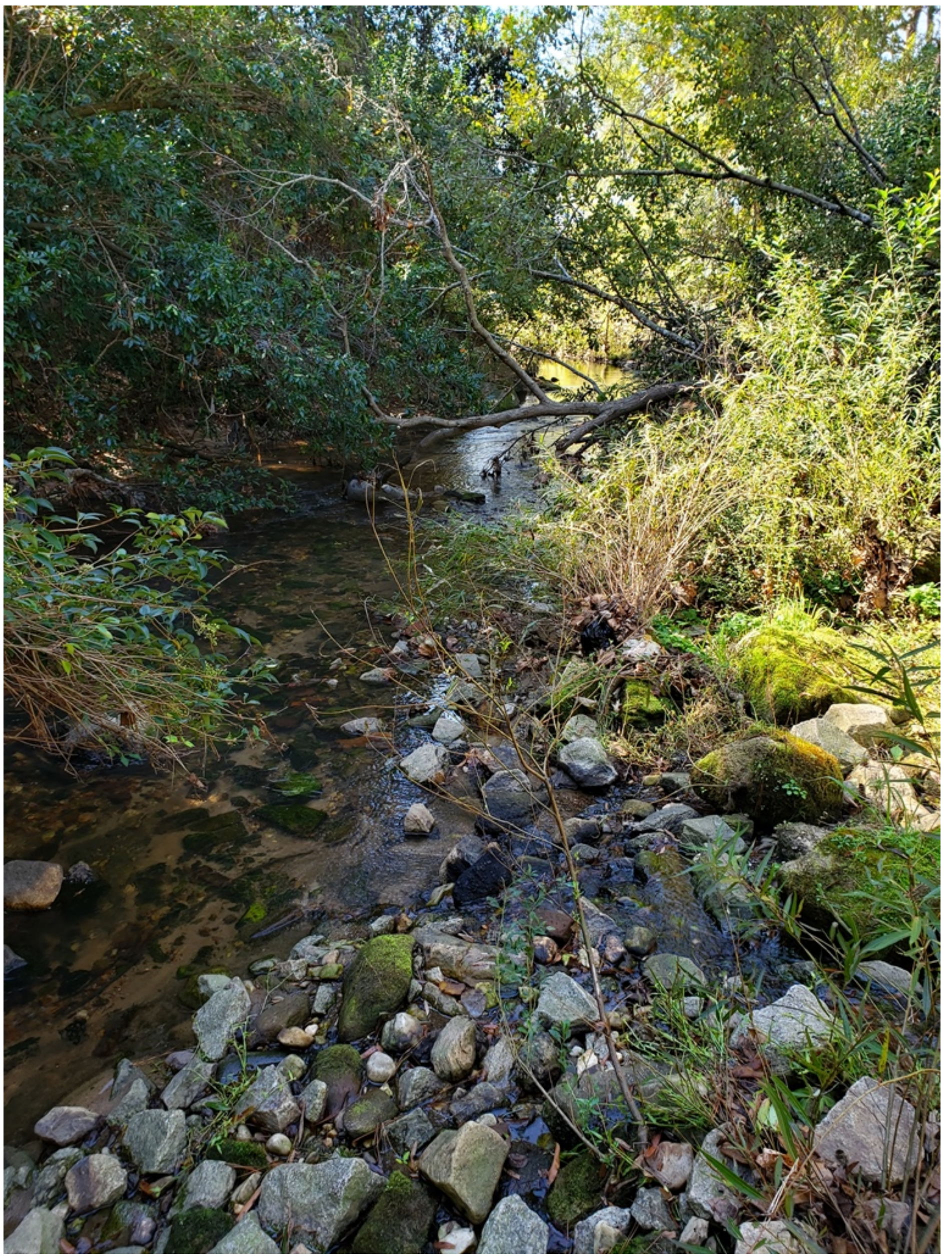
Rocky Branch Watershed Management Plan

EPA Required Nine Element Addendum



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Introduction

The City of Columbia, South Carolina, operates a Phase 1 Municipal Separate Storm Sewer System (MS4) regulated by the National Pollutant Discharge Elimination System (NPDES) and administered by the South Carolina Department of Health and Environmental Control (SCDHEC). The City maintains compliance with the associated permit requirements to reduce pollutant loads to receiving waters to the maximum extent practicable (MEP) via the elements enacted in its Stormwater Management Plan (SWMP). Additionally, to further the overall goal of improving water quality within waterways and for downstream users, the City is resolved to implement projects likely to achieve that aim. The Rocky Branch subwatershed of the Upper Congaree River Hydrologic Unit Code (HUC) 12 (030501100301) was delineated by modifying the boundary originally determined by Dr. Allan James at the University of South Carolina Department of Geography to align with subcatchment boundaries generated by the consultant, KCI. The Rocky Branch subwatershed is located almost completely within the City corporate limits.

Rocky Branch consists of 6.3 miles of open stream channel and its watershed encompasses approximately 4.1 square miles of the 10.8 square mile Upper Congaree River HUC 12 watershed. The Rocky Branch watershed is located in the southwestern portion of the City and includes most of the University of South Carolina Columbia campus, the Five Points shopping district, a portion of the City center, and portions of several historic and older established neighborhoods. Rocky Branch converges with the Congaree River on the north side of the Vulcan Materials Company mines site approximately 4,300 feet downstream from the Blossom Street Bridge. The most downstream portion of the watershed, within 1,500 feet of the Congaree River, is located within the source water protection area (SWPA) for the City of Cayce, SC. Cayce maintains a surface water intake for its public drinking water supply on the Congaree River, approximately 6,900 feet downstream from the river's confluence with Rocky Branch. The Rocky Branch watershed is highly urbanized and has an overall imperviousness of 49%, with most of the development predating stormwater control regulations. The watershed is essentially built-out and no major changes in land use are anticipated, therefore redevelopment of older construction will account for most future development within the watershed.

While SCDHEC does not maintain a water quality monitoring station on Rocky Branch, the Congaree Riverkeeper maintains an SCDHEC approved ambient surface water quality monitoring station on Rocky Branch (Station CRK06) approximately 60 feet upstream from its confluence with the Congaree River. Bacteria sampling at the station since July 2016 demonstrates that E. coli counts in the stream frequently exceed the SCDHEC daily maximum standard of 349 MPN per 100 ml.. Rocky Branch is included on the 2018 SC 303(d) List of Impaired Waters for E. coli due to these exceedances.

The City of Columbia operates two water quality monitoring stations on Rocky Branch where YSI sondes have continuously collected temperature, pressure/depth, pH, specific conductivity, turbidity, and dissolved oxygen data at 15 minute intervals since March of 2014. One (ROCA) is located in Maxcy Gregg Park just downstream from the Five Points Shopping District in the middle portion of the watershed and the other (ROCB) is located in the lower portion of the watershed just below the Rocky Branch culvert under Olympia Drive, approximately 4,000 feet upstream from its confluence with the Congaree River. Results from grab samples collected at these stations indicate that E. coli numbers often exceed SCDHEC standards, particularly during and following wet weather events. Monitoring station data also indicates that nutrient levels and TSS/turbidity may be elevated within the stream. Field surveys indicate that trash and refuse from various sources is common within the stream system. Throughout the entire intensive water quality monitoring timeframe, dissolved oxygen and pH measurements have been outside of SCDHEC water quality standard ranges in only an extremely few instances.

In addition to the two water quality monitoring stations, the City monitors five locations on Rocky Branch for depth, discharge rate, and flow volume using Sontek IQ velocity sensors and Campbell Scientific CS451 pressure transducers. This data, along with data from three City of Columbia rain gauges and data from USGS Stream gage 02169506 located in Rocky Branch at Whaley Street, show that Rocky Branch experiences sudden high flows and often floods during heavy rain events. The stream exhibits quick "flashy" flow responses to precipitation typical of a highly urbanized watershed with a high level of imperviousness.

The City has implemented and is considering various additional approaches to reduce general nonpoint source pollution (NPS) within the watershed, and to address conditions that may increase the likelihood of flooding and erosion within the stream system. These approaches include stream and floodplain restoration, bank and gully stabilization, stream buffer planting, best management practice (BMP) retrofits, low impact development (LID), and green infrastructure projects. Many of these potential water quality improvement projects were identified in the *Rocky Branch Watershed Assessment* completed for the City by McCormick Taylor in May 2016. Additionally, the City operates a Stormwater Utility Fee which encourages the minimization of impervious area for commercial and multi-family residential properties and the utilization of BMP's that protect water quality beyond minimum requirements.

The *Rocky Branch Watershed Assessment* provided a detailed and comprehensive evaluation of conditions within the stream and factors within the watershed affecting water quality. The assessment also identified 17 infrastructure improvement and 56 potential stormwater management, buffer establishment, and stream restoration projects that would improve water infiltration and storage, and improve water quality within the watershed. The City is working with stakeholders to evaluate these projects and others in an effort to prioritize them according to potential effectiveness as well as access, cost, and logistic feasibility. This document will build on the *Rocky Branch Watershed Assessment* to incorporate SCDHEC and Environmental Protection Agency (EPA) guidelines for a watershed based plan in order to provide a strong framework to achieve pollutant load reduction and address water quality and quantity impairments in Rocky Branch. This Watershed Based Plan will aid the City in identifying and implementing projects beyond the requirements of its MS4 Permit which will reduce stream channel degradation and improve instream habitat for fish and macroinvertebrates. The plan provides a strategy to reduce E. coli and other pollutant inputs to Rocky Branch in order to improve water quality within the stream and to address water quality impairments to the Congaree River below its confluence with Rocky Branch. Additionally, this plan will serve as a guide towards the City's objective of improving overall water quality and quantity issues within the watershed. These objectives include reducing flooding, runoff, and erosion, improving the biological condition of the stream and habitat for wildlife within the riparian corridor, and increasing awareness and connectedness of the community to Rocky Branch by improving habitat and recreational opportunities along the stream. Implementation of projects such as those described in this Plan will improve opportunities for watershed based education and outreach.

The EPA has identified nine key elements that are critical for achieving improvements in water quality. These elements are addressed to varying degrees in the *Rocky Branch Watershed Assessment* and are more fully addressed in this document. The document will assess pollutants within Rocky Branch in accordance with current federal and state water quality criteria and standards.

Use Classification and Water Quality Standards

Federal Regulation 40 CFR 131.10 requires states to specify appropriate water uses to be achieved and protected, 40 CFR 131.11 requires that states adopt water quality criteria that protect the designated use, and 40 CFR 131.12 requires that states develop and adopt a statewide antidegradation policy in which existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. The South Carolina Department of Health & Environmental Control (SCDHEC) is charged with classifying waters of the state, designating their uses, and developing standards to protect the existing and classified uses of the waters. Rocky Branch is classified as Freshwater for the purposes of State of South Carolina water quality regulations and standards. According to S.C. Regulation 61-68, Water Classifications and Standards (R.61-68) *"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."* The Antidegradation Rules from Section D of R.61-68 prescribe that "*existing water uses and the level of water quality necessary to protect these existing uses shall be maintained and protected regardless of the water classification*"

Section E of R.61-68 "General Rules and Standards Applicable to All Waters" prescribes:

5. All ground waters and surface waters of the State shall at all times, regardless of flow, be free from:

a. Sewage, industrial waste, or other waste that will settle to form sludge deposits that are unsightly, putrescent, or odorous to such degree as to create a nuisance, or interfere with classified water uses or existing water uses;

b. Floating debris, oil, grease, scum, and other floating material attributable to sewage, industrial waste, or other waste in amounts sufficient to be unsightly to such a degree as to create a nuisance or interfere with classified water uses or existing water uses;

c. Sewage, industrial, or other waste which produce taste or odor or change the existing color or physical, chemical, or biological conditions in the receiving waters or aquifers to such a degree as to create a nuisance, or interfere with classified water uses (except classified uses within mixing zones as described in this regulation) or existing water uses; and,

d. High temperature, toxic, corrosive, or deleterious substances attributable to sewage, industrial waste, or other waste in concentrations or combinations which interfere with classified water uses (except classified uses within mixing zones as described in this regulation), existing water uses, or which are harmful to human, animal, plant or aquatic life."

Narrative and numeric criteria and standards for all classified waters were developed in order to protect their designated uses and are included in Sections F and G, and in the Appendix of R.61-68. Standards for selected parameters for freshwaters are presented in table 1.

Item	**Standard**
Temperature	Shall not be increased more than 5°F (2.8°C) above natural temperature conditions and shall not exceed a maximum of 90°F (32.2°C) as a result of the discharge of heated liquids(1) (weekly average temperature for lakes).
pH	Between 6.0 and 8.5.
Turbidity	All except lakes - not to exceed 50 NTUs provided existing uses are maintained; Lakes - not to exceed 25 NTUs, provided existing uses are maintained for all freshwaters.
DO	Daily average not less than 5.0 mg/l with a low of 4.0 mg/l.
Bacteria	E. coli-Not to exceed a geometric mean of 126 MPN/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 MPN/100 ml.
Garbage, cinders, ashes, oils, sludge, or other refuse	None allowed.
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.
Toxic pollutants listed in the appendix.	None allowed (as described in Section E.5 of R.61-68)
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.

(1) unless a different site-specific temperature standard as provided for in C.12. has been established, a mixing zone as provided in C.10. has been established, or a Section 316(a) determination under the Federal Clean Water Act has been completed.

Table 1. SCDHEC Water Quality Standards for Selected Parameters For Freshwaters from SCDHEC's R.61-68

Appendix H of "The State of South Carolina's 2018 Integrated Report (IR) Part I: Listing of Impaired Waters (IR Part I)" describes the physical, chemical, and biological data that were evaluated to determine if water quality met the water quality criteria established to protect the State classified uses defined in R. 61-68.

1. Pollutant Source Assessment

As noted in the Table 6.1 of the *Rocky Branch Watershed Assessment*, the Rocky Branch watershed is highly urbanized, with 97% of the watershed identified as developed, and the remainder described as forested, herbaceous, scrub–shrub or woody wetlands, or barren land. No significant areas of cultivated crops or open water were identified in the assessment. Data and narrative from the *Rocky Branch Watershed Assessment* indicate that Rocky Branch exhibits chemical, physical, and biological effects typical of highly urbanized streams.

Urban Runoff and Stormwater Conveyance Systems

Numerous studies indicate that the amount of impervious cover in a watershed may directly affect water quality, stream flow, stream channel morphology, and instream habitat (National Research Council, 2009; Schueler, et. al. 2003; Schueler, et. al. 2009; Walsh, et al. 2005). Many of these studies indicate that stream quality generally declines when watershed impervious cover exceeds 10% and becomes severe when impervious cover exceeds 25%. Overall impervious cover within Rocky Branch is 49%, and subwatersheds within Rocky Branch contain up to 70% impervious cover. None of the 11 subwatersheds identified in the *Rocky Branch Watershed Assessment* had less than 10% impervious cover and only one had less than 25%. Fecal coliform, nutrients, and a wide variety of urban non-point source pollutants may be conveyed via impervious surfaces to stormwater networks that discharge to Rocky Branch and its tributaries. High levels of impervious cover with concomitant increased runoff volume and peak discharge, artificial stream channel confinement, and riparian vegetation removal may create stream scour, bed and bank erosion, sediment deposition, and stream blockages. These effects can be exacerbated by aging stormwater infrastructure and inadequately sized or maintained culverts and stormwater conveyance systems (O'Driscoll et al., 2010). The City of Columbia maintains a stormwater utility fee which encourages minimization of impervious surface cover and provides funding dedicated for maintenance, repair and improvement of the City's stormwater network within the watershed. The City provides additional funding for its stormwater system from other stormwater fee sources and from the City's general fund, including for larger stormwater infrastructure projects within the watershed through its allotment for Capital Improvement Projects (CIP).

Watershed Treatment Model

The Watershed Treatment Model (WTM) is a spreadsheet-based tool provided by the Center for Watershed Protection that was used to estimate pollutant sources and loads within the Rocky Branch watershed. The WTM can be used to estimate pollutant load from current and predicted land uses and reductions from a wide variety of stormwater management practices. Model input data for the Rocky Branch watershed included 2019 aerial imagery, City of Columbia GIS data for zoning, tax parcels, streets, streams, and sewer, USDA NRCS soils data, and 2010 US Census tract data. Land use categories were derived from City GIS Zoning categories and from The Rocky Branch Watershed Assessment. Land use outside City of Columbia corporate limits was categorized based on aerial imagery and Google Map address and business information. Residential density categories were determined by overlaying the parcel layer on residential zoning categories, verifying some parcels with aerial imagery and Google Maps, and summing parcel area binned by parcel size. Active construction acreage was determined by summing active construction area for permitted construction projects on a typical day as determined by the City's Stormwater Manager. Because the watershed is essentially built out and no significant changes in zoning are expected, no changes in future land use were assumed for the model.

WTM output results estimate that the Rocky Branch watershed has an uncontrolled annual runoff volume of 5,512 acre feet per year, or 5,478 acre feet annually after accounting for existing stormwater management practices. The model estimates current annual pollutant loads from this runoff without and with existing practices, respectively, at 33,554/34,078 lbs/year of total nitrogen (TN), 4,655/5,813 lbs/year of total phosphorus (TP), 2,080,146/2,013,798 lbs/year of total suspended solids (TSS), and 1,704,368/1,689,884 billion/year fecal coliform. Nutrient numbers reported by the model are increased with existing practices largely due to turf management practices. The vast majority of pollutant loading reported by the model comes from stormwater sources rather than non-storm related channel erosion and sewer line leakage and overflows.

WTM results presented in Tables 2,3, and 4 indicate that commercial land, which includes institutional uses such as schools and churches (including the University of South Carolina campus) was the greatest contributor of TN, TP, and fecal coliform loading within the watershed. Loading for these pollutants was approximately proportional to the percentage of watershed area classified as commercial/institutional. The same approximate proportionality was found for loading for these pollutants in the other land use categories without practices, although residential and industrial contributions are slightly below proportional and roadway pollutant contribution is slightly greater than land area proportional. As previously mentioned, loading for nutrients may increase slightly in urban land use categories when existing landscape practices are considered.

Model results predict that 50% of TSS loading comes from channel erosion. Roadways are the next greatest source, with their contribution slightly greater than proportional for their land area.

Source Loads (Without Practices)						
	Acres	TN (lb/year)	TP (lb/year)	TSS (lb/year)	Fecal Coliform (billion/year)	Runoff Volume (acre-feet/year)
Primary Source Load						
LDR (<1du/acre)	22.5	122	18	2845	5293	21
MDR (1-4 du/acre)	248.5	1683	249	39280	73070	296
HDR (>4 du/acre)	576.9	4950	731	115505	214864	869
Multifamily	73.8	755	112	17627	32791	133
Commercial	1062.7	15357	1609	314460	666586	2697
Roadway	331.6	5686	618	331258	225331	912
Industrial	257.6	3128	355	115171	129603	524
Forest	39.1	98	8	3910	469	5
Rural	27.1	125	19	2710	1057	4
Active Construction	30.2	141	28	96072	0	52
Primary Source Storm Load		**31935**	**3738**	**1038177**	**1349064**	**5512**
Primary Source Non-Stormwater Load		**111**	**8**	**662**	**0**	**0**
Total Surface Water Primary Source Load		**32046**	**3746**	**1038839**	**1349064**	**5512**
Secondary Source Load						
SSOs		470	78	3130	355305	0
Channel Erosion		1038	831	1038177	0	0
Secondary Source Storm Load		**1273**	**870**	**1039742**	**177652**	**0**
Secondary Source Non-Stormwater Load		**235**	**39**	**1565**	**177652**	**0**
Total Surface Water Secondary Source Load		**1508**	**909**	**1041307**	**355305**	**0**
Total Surface Load without Practices		**33554**	**4655**	**2080146**	**1704368**	**5512**

Table 2 Watershed Treatment Model pollutant source load results without practices (current conditions).

Loads with Existing Practices					
	TN (lb/year)	TP (lb/year)	TSS (lb/year)	Fecal Coliform (billion/year)	Runoff Volume (acre-feet/year)
Loads to Surface Waters					
Urban Land	32296	4867	930324	1333053	5417
Active Construction	52	10	35546	0	52
SSOs	470	78	3130	355305	0
Channel Erosion	1038	831	1038177	0	0
Forest	98	8	3910	469	5
Rural Land	125	19	2710	1057	4
Total Storm Load	**33732**	**5766**	**2011570**	**1512232**	**5478**
Total Non-Storm Load	**346**	**47**	**2227**	**177652**	**0**
Total Surface Water Load With Existing Practices	**34078**	**5813**	**2013798**	**1689884**	**5478**

Table 3. Watershed Treatment Model pollutant source load results with existing practices (current conditions).

Source Loads (Without Practices)					
`	TN %	TP %	TSS %	Fecal Coliform %	Watershed Area %
Primary Source Load					
LDR (<1du/acre)	0%	0%	0%	0%	1%
MDR (1-4 du/acre)	5%	5%	2%	4%	9%
HDR (>4 du/acre)	15%	16%	6%	13%	22%
Multifamily	2%	2%	1%	2%	3%
Commercial	46%	35%	15%	39%	40%
Roadway	17%	13%	16%	13%	12%
Industrial	9%	8%	6%	8%	10%
Forest	0%	0%	0%	0%	1%
Rural	0%	0%	0%	0%	1%
Active Construction	0%	1%	5%	0%	1%
Secondary Source Load					
SSOs	1%	2%	0%	21%	
Channel Erosion	3%	18%	50%	0%	

Table 4. Watershed Treatment Model pollutant source load results without practices and land use type by percentage (current conditions).

Data from water quality sampling and pollutant predictions from the Watershed Treatment Model, as well as potential pollutants from various industries and commercial and other sources within the Rocky Branch watershed, were analyzed in consideration of the requirements for state water quality standards and support of use classifications in accordance with R.61-68.

Recreational Use Support

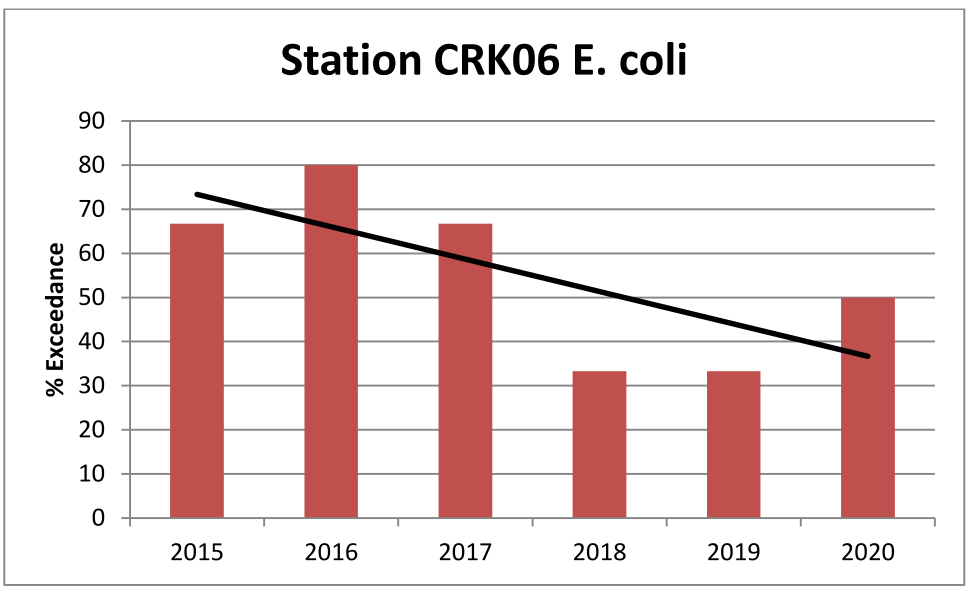
South Carolina's current water quality standard for primary contact recreational use in freshwaters is Escherichia coli as described in Table 1 above. Rocky Branch is included on the Draft 2018 SC 303(d) List of Impaired Waters for Recreation use impairment due to E. coli exceedances.

Escherichia coli / fecal coliform

The presence of Escherichia coli (E. coli) and fecal coliform in general in aquatic environments indicate that water is contaminated with human and/or animal fecal material, and associated potentially harmful pathogens. From the 2018 SCDHEC Draft 303(d) list and SCDHEC Regulation 61-68 Water Classifications and Standards: "*current water quality standard (WQS) for primary contact recreational use in freshwaters (Classes FW, TN, TPGT, and TPT) is Escherichia 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'. Prior to February 28, 2013, South Carolina's WQS for primary contact recreational use in freshwaters (Classes FW, TN, TPGT, and TPT) was fecal coliform bacteria: '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.'"*

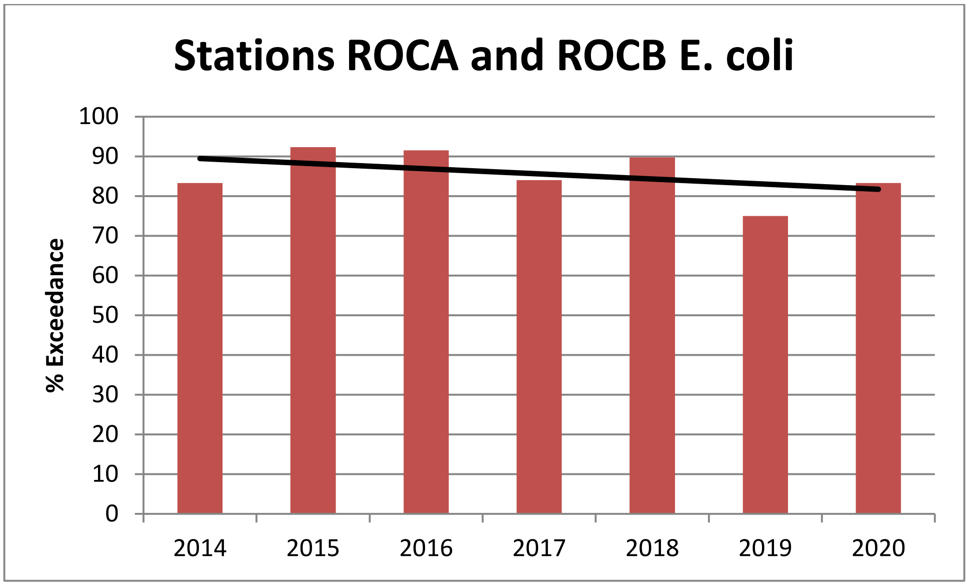
The Watershed Treatment Model reports bacteria loads as colony forming units (cfu's) of fecal coliform. Studies show a strong correlation between fecal coliform and E. coli concentrations, although the ratios vary somewhat between the studies (Crim, et al., 2012; Hachich, et al., 2012). Variability also occurs between the standard multiple-tube fermentation (MTF) decimal dilution analysis MPN procedure, which is specified for analysis of E. coli numbers, and the membrane filtration CFU procedure formerly used for fecal coliform analysis (Cho, et al., 2010; Gronewold and Wolpert, 2008). SCDHEC has determined that established fecal coliform total maximum daily loads (TMDLs) can be converted to E. coli TMDLs by multiplying the fecal coliform TMDL number by 0.8725. This ratio was determined based on a 2009 study of fecal indicator bacteria collected statewide (SCDHEC 2013).

Data provided by the Congaree Riverkeeper indicates that 15 of 28 (54%) of water samples collected at WQM Station CRK06 from May 2015 through March 2020 exceeded the 349/100 ml SCDHEC single sample water quality standard for E. coli. Rocky Branch is listed on the Draft 2018 SC 303(d) List of Impaired Waters for E. coli due to water quality data from station CRK06. Additionally, 85.1% of grab samples collected at the two City of Columbia monitoring stations between May 2014 and April 2020 exceeded the SCDHEC daily maximum standard for E. coli.



***Through March 2020**

Figure 1 Percentage of water quality samples at Station CRK06 exceeding SCDHEC water quality E. coli standard single sample maximum of 349/100 ml by year with trendline.



***Through 4/13/2020**

Figure 2 Percentage of water quality samples at Stations ROCA and ROCB exceeding SCDHEC water quality E. coli standard single sample maximum of 349/100 ml by year with trend line.

Streams in urbanized watersheds have been found to have higher concentrations of fecal indicator bacteria than streams in non-urbanized watersheds (Crim, et al., 2012; Mallin, et al. 2009; O'Driscoll et al., 2010). Many potential sources for E. coli occur in highly urbanized watersheds like Rocky Branch. Results from the Watershed Treatment Model indicate that 89.5% of the fecal coliform load in Rocky Branch comes from storm related sources. The model predicts that approximately 79% of fecal coliform load comes from urban stormwater runoff, while approximately 21% comes from SSO's. Water quality data collected by the City of Columbia at its two monitoring stations on Rocky Branch indicates a strong relationship between precipitation and higher E. coli concentrations within the stream, suggesting that urban runoff and non-point sources may be significant contributors of E. coli. However exceedances also occurred in 61% of samples collected during dry weather conditions, which suggests other sources are likely as well. Various non-point sources contribute to loading of fecal coliform and other pollutants in Rocky Branch, either directly or through stormwater discharge pipes from the City's MS4. Research on bacterial sources in urban watersheds suggests that a combination of diffuse runoff and MS4 point sources, leaking and overflowing sewer systems, pet waste, and waste from a variety of wildlife species are the most likely sources of fecal coliform within most urban watersheds (Shaver et al., 2007).

The Rocky Branch watershed is almost entirely urban and mostly within the limits of the City of Columbia, and there are no known septic systems within the watershed. Therefore, improperly designed, constructed, or maintained septic systems, which can deliver nutrients and harmful fecal bacteria to nearby streams via surface and subsurface routes in places where they are present, are not suspected to be a significant contributor to fecal coliform load in Rocky Branch. The Rocky Branch watershed contains no active NPDES permitted wastewater treatment plant (WWTP) point sources that may discharge harmful bacteria.

Pollutant loads from sanitary sewer overflows (SSO's) were estimated using the WTM default calculations for the length of sewer pipe in the watershed as measured using the City's GIS. SSO volume in the Rocky

Branch watershed as reported by the City of Columbia Wastewater Department has decreased significantly between 2015 and 2019, the most recent full year of reporting. The slight decreasing trend for E.coli seen in both the City's monitoring data (Stations ROCA and ROCB) and at station CRK06 over approximately the same time period (Figs 1 and 2) support the model's prediction that SSO's represent only a minor portion of the E.coli/fecal coliform load to Rocky Branch.

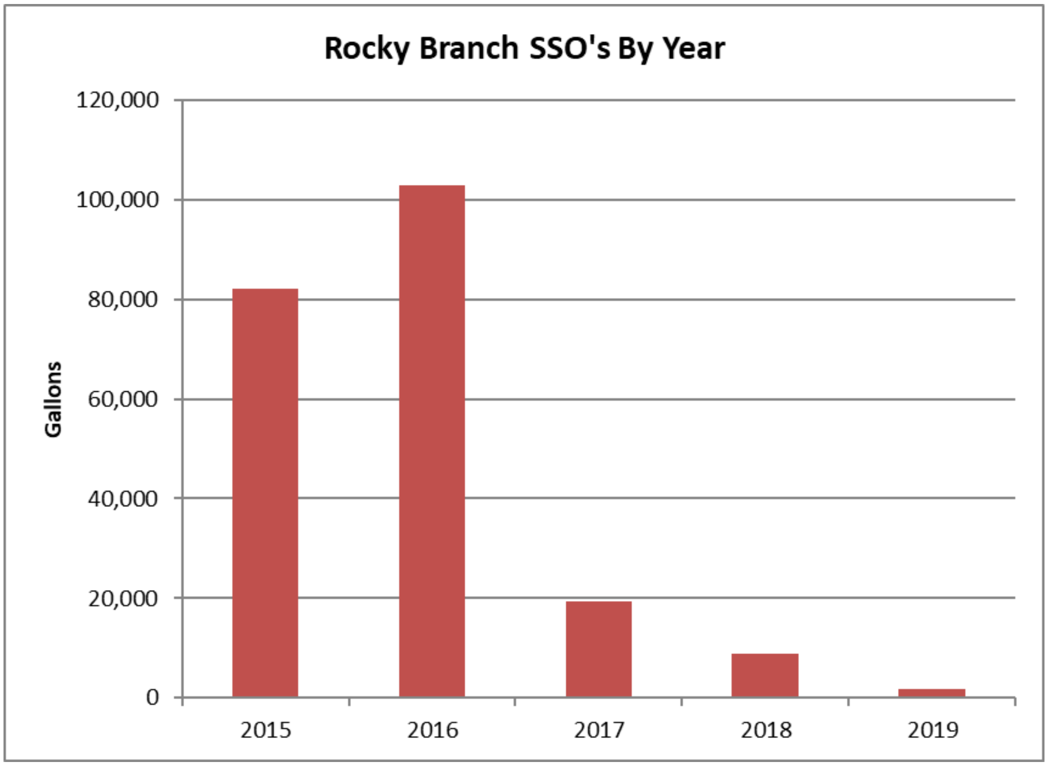


Figure 3. SSO gallons within the Rocky Branch watershed by year (City GIS Data).

The South Carolina Department of Natural Resources estimates a deer population density of 0 to 15 deer per square mile within the Rocky Branch watershed (http://www.dnr.sc.gov/wildlife/deer/deermap.html). Field observation during a stream survey conducted by City staff (for other purposes) and the highly urban nature of the watershed indicate that the deer population along Rocky Branch is likely close to zero throughout most of the watershed. However, other potentially significant wildlife contributors to fecal coliform within the watershed include raccoons, opossums, beaver, squirrels, rabbits, rats and other small mammals, and various bird species. No population estimates were available for these wildlife species within the watershed.

There are no known populations of livestock or any agricultural fields with manure applications which might be sources of fecal coliform within the Rocky Branch watershed. However domestic pets, and dogs in particular, may be significant contributors of fecal coliform within the watershed. According to 2010 census block group data there are approximately 20,589 people occupying 7,301 households within the Rocky Branch watershed. The American Veterinary Medical Association (AVMA) market research survey data for 2017 found a national average of 0.584 dogs per household, which indicates there are approximately 4,483 dogs residing within the watershed. Calculations made using SCDHEC provided Standards Engineering

Practices data show that total daily production of fecal coliform from dogs within the watershed is approximately 1.8 x 10^{13} cfu, or 6.7 x 10^{15} cfu annually. Assuming a 20 percent loading rate to the stream (SCDHEC provided "Pet Waste Formulas" worksheet) the potential bacteria load to Rocky Branch from dogs is approximately 1.34 x 10^{15} cfu annually. No estimates for waste load or fecal coliform production were available for cats or other pets but these may also be notable contributors within the watershed.

No permitted solid waste disposal sites exist within the watershed, however the *Rocky Branch Watershed Assessment* identified six suspected unauthorized trash dump sites along the stream. Trash can introduce a variety of pollutants to a waterway. These may include bacteria if the trash includes organic materials including food or fecal waste (Nelson, et al., 2008). Improperly disposed trash throughout the watershed may contribute to the fecal coliform load, particularly during storm events.

Aquatic Life Use Support

"The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters" emphasizes that a key goal of the Clean Water Act and State Standards is to "maintain the quality of surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora." The document continues: "The degree to which aquatic life is protected (Aquatic Life Use Support) is assessed by comparing important water quality characteristics and the concentrations of potentially toxic pollutants with numeric criteria. Support of aquatic life uses is determined based on the percentage of numeric criteria excursions and, where data are available, the composition and functional integrity of the biological community. Among the parameters assessed are: dissolved oxygen, pH, toxicants (priority pollutants, heavy metals, ammonia), nutrients, and turbidity." It further states," For aquatic life uses, the goal of the standards is the protection of a balanced indigenous aquatic community. Therefore, biological data are generally considered as the deciding factor, regardless of chemical conditions."

Evaluation of benthic macroinvertebrate population is a very common and long utilized method to determine the biological condition of a waterway. Benthic macroinvertebrates are easily sampled, have well studied and predictable responses to chemical, physical, and hydrological stressors, and spend much or all of their lives, which can be a year or more, within a small locality in a waterway due to their limited mobility. A stream bioassessment will typically analyze benthic macroinvertebrate abundance, diversity, and species assemblages, particularly the proportion of species which are less tolerant of poor water quality and habitat (Ephemenoptera, Plecoptera, Trichoptera (EPT)) to determine stream health (Cuffney et al. 2010; EPA- https://www.epa.gov/national-aquatic-resource-surveys/indicators-benthic-macroinvertebrates). *The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters* states that the EPT Index and the North Carolina Biotic Index (BI) are the main indices used in analyzing macroinvertebrate data, and that a habitat evaluation is conducted at each biological monitoring site and is considered in the aquatic community assessment score.

There are no SCDHEC approved macroinvertebrate monitoring stations within Rocky Branch, however it is well documented that stream habitat and aquatic species abundance and composition are severely affected by watershed urbanization (Lenat and Crawford, 1994; O'Driscoll et al., 2010; Walsh et al. 2005). A bioassessment conducted in Rocky Branch by University of South Carolina students in 2013 (Hopkins et al., 2013) found a very low abundance, diversity and proportion of sensitive EPT species. Likewise, an SC Adopt-

A-Stream sampling conducted on a site in Rocky Branch in 2017 found very few benthic macroinvertebrates and only one EPT species and one additional species classified as somewhat sensitive. The site therefore scored as poor for water quality based on benthic macroinvertebrates. Urban streams have been found to exhibit wide variations in chemical and physical water quality parameters during flood events, and to have greater seasonal and diurnal fluctuation than streams in rural watersheds, which collectively have negative impacts on aquatic life (Hasenmueller 2017). A variety of possible stressors have been identified that can contribute to a paucity of macroinvertebrate numbers and taxa in aquatic ecosystems. These stressors affect water quality, habitat, or both, and include high or low pH, low dissolved oxygen (DO), heavy metals and other inorganic compounds, toxic organics (herbicides, pesticides, other) temperature, sediment, nutrients, stream channel conditions, and flow (O'Driscoll et al., 2010; Paul & Meyer, 2001; Shaver et al. 2007).

Potential stressors were evaluated for likelihood of impairment to macroinvertebrates and other aquatic biota in Rocky Branch and placed in one of the following three categories:

Least Probable Stressors: Potential stressors with no apparent impact in Rocky Branch according to data and observations, and data indicates no or very few water quality exceedances.

Possible Stressors: Potential stressors with data or observations suggesting the possibility of negative impacts to macroinvertebrates and other aquatic biota, or with insufficient data but instream, riparian, or watershed conditions suggesting the possibility of a direct link to aquatic life impairment within Rocky Branch.

Most Probable Stressors: Potential stressors with conclusive data or observations linking them to impairment of macroinvertebrate and aquatic life populations and species diversity in Rocky Branch.

Least Probable Stressors: PH, Dissolved Oxygen, Nutrients, Temperature

Macroinvertebrates require a suitable range of pH in order to thrive, which is reflected in SCDHEC's standards requirements for a pH range of 6.0 to 8.5. Only 0.05% of over 200,000 pH measurements taken at Station ROCA and 0.01% of measurements from Station ROCB from March 27, 2014 to June 1, 2020, were outside of SCDHEC standards. *The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters* states, "For DO and pH, if 10 percent or less of the samples contravenes the appropriate criterion, then the criterion is said to be fully supported."

Low dissolved oxygen levels within a stream can result in anoxic sediment conditions that adversely affect most macroinvertebrate species. Only 0.01% of almost 199,000 dissolved oxygen measurements taken at Station ROCA and 0.10% of over 200,000 measurements taken at Station ROCB from March 27, 2014 and June 1, 2020, were below the SCDHEC minimum standard of 4.0 mg/L.

Excessive nutrient loads in water can stimulate growth of phytoplankton, filamentous algae or cyanobacteria which can lead to eutrophication and subsequent low dissolved oxygen levels. SCDHEC does not have standards for nutrients in streams, although nitrogen and phosphorus concentrations measured at the City's monitoring locations often exceed the SCDHEC concentrations for lakes larger than 40 acres, which are more susceptible to algae blooms. Section E of R.61-68, "Nutrients from General Rules and Standards Applicable to All Waters" states: "*Discharges of nutrients from all sources, including point and nonpoint, to waters of the State shall be prohibited or limited if the discharge would result in or if the waters experience growths of microscopic or macroscopic vegetation such that the water quality standards would be violated or the existing or classified uses of the waters would be impaired.*" Frequent high stream flow likely prohibits excessive algal growth within Rocky Branch, and no significant widespread evidence of eutrophication within the stream was reported in the *Rocky Branch Watershed Assessment* or in subsequent field investigations. Natural sources of nutrients within the watershed include soil, leaves and vegetative debris, and atmospheric deposition. Inadequate forested riparian buffer may reduce nutrient removal from shallow groundwater entering streams that are not excessively incised (O'Driscoll et al., 2010). WTM results indicate that SSO's account for only a very small percentage of nutrient input and that channel erosion may account for a significant (18%) of total phosphorus load, however excess fertilizer application to residential, commercial, and industrial landscaping and its efficient delivery to the stream via impervious surfaces and an effective stormwater network likely account for the majority of nutrient input to Rocky Branch (O'Driscoll et al., 2010).

Stream temperature increase is a typical response to increased development and impervious surface area within a watershed due to water flow over streets, parking lots, and other dark, solar energy absorbing hard surfaces. Decreased stream shading from riparian vegetation removal, and general increased temperatures in highly urban areas, particularly with temperatures increasing globally, may also lead to increased temperatures in urban streams. While it is likely that there has been some temperature increase within Rocky Branch in comparison with historic conditions, continuous monitoring by the City at its two Rocky Branch stations shows that stream temperature has not exceeded the state standard of 90 degrees Fahrenheit from March 27, 2014 to June 1, 2020.

Possible Stressors: Metals, Oil and Grease, Other Chemicals

The potential for a wide variety of chemical contaminants with varying levels of toxicity to enter the stream from stormwater runoff and other sources is concomitant with the highly urban nature of the Rocky Branch watershed. Among these pollutants are oils, greases, and metals from roadways and industrial and other sources, herbicides and pesticides from roadway, railway, and utility line right of way maintenance and from private and commercial landscaping, and volatile organic compounds and various other organic and inorganic chemicals from industrial sites, gas stations, roadways, railways and other sources (Shaver, et al.,2007). SSO's also have the potential to contribute a minimal amount of chemical contaminants to Rocky Branch. Due to the wide array of potential chemical inputs no monitoring is conducted for these pollutants within Rocky Branch, however known potential sources of chemical contaminants are monitored.

Pollutants are more efficiently transported to streams in urbanized areas with high levels of imperviousness and hydraulically efficient drainage systems. A study in Maine found that streams draining watersheds with greater than six percent total impervious area were characterized by an absence of pollutant intolerant macroinvertebrates (Morse et al., 2003). Results from the Rocky Branch bioassessment and Adopt-A-Stream surveys in Rocky Branch also showed a very low abundance and proportion of EPT species, with the few that were present being relatively pollutant tolerant species.

Specific conductivity is a measure of water's ability to pass electrical flow measured at 25 degrees Celsius and is directly correlated with the concentration of salts and other inorganic compounds (electrolytes) that dissociate into anions and cations in water. While the State of South Carolina has no water quality standards for specific conductivity or total dissolved solids, various studies show a strong negative correlation between increased conductivity and abundance and diversity of EPT and other pollution intolerant aquatic invertebrate species (Johnson et al., 2013.; Wenner et al., 2003; Zhao et al., 2016). As noted in the *Rocky Branch Watershed Assessment*, a study of Maryland streams found significant impairment to fish species assemblages when specific conductivity exceeded 0.171 mS/cm and to benthic macroinvertebrate species assemblages when specific conductivity exceeded 0.247mS/cm (Morgan et al., 2007). 1.57 % of over 200,000 specific conductivity measurements taken at Station ROCA and 2.78% of almost 201,000 measurements taken at Station ROCB from March 27, 2014 to June 1, 2020, exceeded the Maryland study threshold for aquatic invertebrate impairment. 9.92% of measurements at ROCA and 65.6% of measurements at ROCB during the same time period exceeded the Maryland study threshold for fish impairment. Thresholds for aquatic life impairments may differ between Rocky Branch and the streams in the Maryland studies because deicing salts are rarely used within the Rocky Branch watershed. Sources of increased specific conductivity in an urban watershed are varied and not fully studied, but include contaminants from roads, runoff from various residential, commercial, and industrial sources, SSO's, illicit stormwater connections, swimming pool drainage, and concrete infrastructure (Mikalsen, 2005; Peters, N. 2009; Wright et al., 2011).

SCDHEC provided data indicates there are numerous active and inactive underground storage tanks within the watershed which contain or contained fuels, oils, or a variety of other chemicals. These are inspected annually by SCDHEC for proper maintenance and any possible release of contents that might lead to soil or groundwater contamination. SCDHEC does not monitor above ground petroleum storage tanks, which are also present within the watershed. SCDHEC reports three inactive and one active permitted industrial National Pollutant Discharge Elimination System (NPDES) sites. The active permitted site is the Vulcan Construction Materials Quarry, which is located not far upstream from Rocky Branch's confluence with the Congaree River and is permitted for crushed and broken granite production. SCDHEC did not identify any solid waste disposal sites within the watershed.

The US Environmental Protection Agency (EPA) maintains The Facility Registry Services (FRS) database that identifies facilities and sites subject to environmental regulation or that are of environmental interest (https://www.epa.gov/frs). The FRS identifies four Superfund Enterprise Management System (SEMS) sites within the Rocky Branch watershed. These sites are active or historic hazardous wastes sites either proposed to be or in the screening process for possible inclusion on the National Priorities List in the Superfund Program. Two sites within the watershed are included on the FRS Toxic Release Inventory (TRI). TRI tracks the management of approximately 767 toxic chemicals that may pose a threat to human health and the environment. The TRI includes certain industries and facilities that manufacture, process or otherwise use these chemicals in amounts above established levels that must report annually how much of each chemical is released to the environment and/or managed through recycling, energy recovery and treatment. Thirty inactive and nineteen active Resource Conservation and Recovery Act (RCRA) sites, including one hazardous waste large quantity generator (LQG) were identified within the watershed by FRS. These facilities are regulated under the RCRA and Hazardous and Solid Waste Amendments (HSWA) and are monitored for events and activities that generate, transport, and treat, store, or dispose of hazardous waste. An RCRA LQG generates and accumulates hazardous, acutely hazardous waste, or residue or contaminated soil, waste, or other debris on a site beyond specified thresholds. Figure 4 depicts mapped NPDES and FRS locations within the Rocky Branch watershed.

The City and other governmental agencies monitor for illicit discharges and conduct inspections of industrial sites and monitoring for spills and releases of toxic chemicals throughout the watershed, but the potential still exists for some undetected stream inputs due to the diverse uses of the highly urbanized watershed.

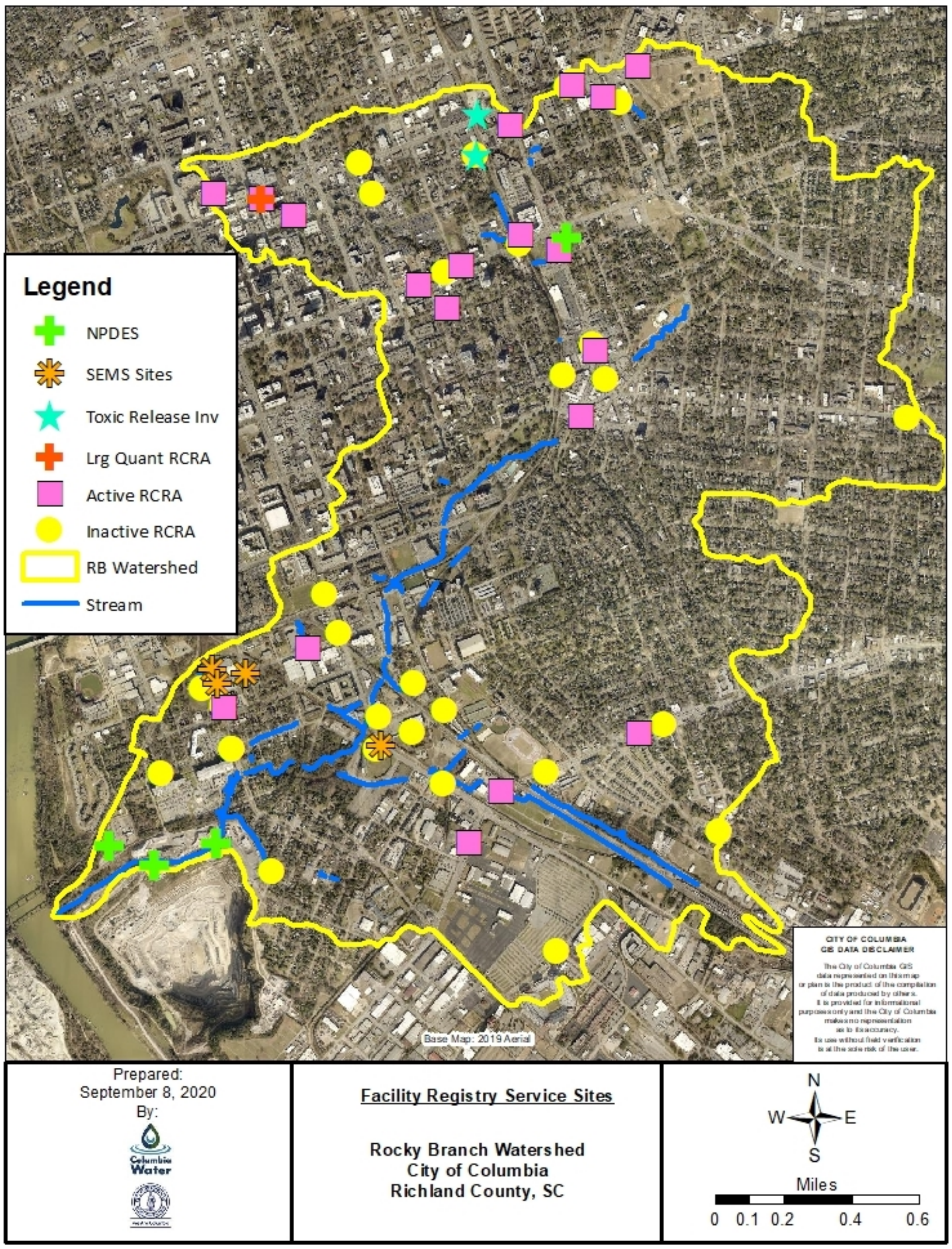


Figure 4. Facilities Services Registry sites within the Rocky Branch watershed.

Most Probable Stressors: Flow, Sediment, Habitat Alteration

High levels of imperviousness within a watershed, hydraulically efficient stormwater drainage systems, inadequate forested stream buffer, and stream channel alterations such as bridges, culverts, and channelization will drastically alter stream flow conditions, riparian and instream habitat, and erosion and sediment transport, all of which can be detrimental to macroinvertebrate populations and aquatic biota in general (Moore and Palmer, 2005, Shaver et al., 2007; Walsh et al., 2005). The *Rocky Branch Watershed Assessment* found overall imperviousness within the watershed to be approximately 49%, significantly greater than the 25% threshold for severe stream quality degradation indicated by many studies (Schueler 2003; Schueler et. al., 2009). It is well documented that streams with highly impervious watersheds exhibit "flashy" streamflow responses to precipitation, with higher and more rapid peak discharge and a greater total runoff volume than those in undeveloped watersheds (O'Driscoll et al., 2010; Shaver et al., 2007). A study conducted in the Rocky Branch watershed demonstrated that total volume of runoff is correlated with impervious area and that lag time from precipitation event to peak flow decreases with increasing density of stormwater pipes and roadways containing gutters and ditches (Ress et al., 2020). Additionally, streams in highly impervious watersheds exhibit increased magnitude, frequency, and duration of bankfull flows and decreased base flow or base flow supplemented by imported water from landscape irrigation and leaking sewer and water lines (O'Driscoll et al., 2010; Price, 2011; Shaver et al., 2007). These flow alterations cause changes to stream channel morphology over time. Typical responses to these altered flows are an enlargement of the cross sectional area of the stream through channel incision and/or widening, and a resultant disconnection of the stream from its floodplain with often a lowering of the adjacent water table (O'Driscoll et al., 2010). Flow alterations due to highly impervious watersheds negatively impact stream habitat for macroinvertebrates by reducing stream habitat diversity and structure and decreasing channel roughness and sinuosity (Shaver et. al, 2007). Studies show an inverse relationship between percent impervious area within a watershed and total aquatic insect and EPT species richness, with at least one study finding an abrupt species decline when watershed imperviousness exceeded 6% (Morse et al., 2003)

The process of channel enlargement from increased flows during precipitation events causes increased erosion of bed and bank material which increases sediment load in the stream. Increased stream sediment has a detrimental effect on macroinvertebrate habitat, feeding, and respiration. Turbidity is a measure of total suspended solids (TSS) in water. These typically include silt, sediment, sand, algae, plankton, and decomposing organic particulates. Studies show that streams in urbanized watersheds often have higher TSS loads than streams in non-urbanized watersheds (Lenat and Crawford, 1994; Mallin et al., 2009) and also show a link between turbidity and fecal coliform (Irvine et al., 2009; Mallin et al., 2009). Data from the City's two water quality monitoring stations on Rocky Branch indicate that turbidity is often elevated during storm events, however decreases rapidly to levels well within State standards after peak flows subside. Only 2.67% of over 200,000 turbidity measurements taken at Station ROCA and 2.65% of almost 193,000 measurements taken at Station ROCB from March 27, 2014 to June 1, 2020, exceeded the 50 NTU SCDHEC standards. This is well below *The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters* 25% criteria for non-support of aquatic life use and the 10-25% standard contravention requiring further site specific evaluation required to determine if standards violations indicate actual aquatic life use impairment or if water quality standards are fully attained. The *Rocky Branch Watershed Assessment* identified 2,778 linear feet of stream bank erosion within the stream network. Stream surveys conducted for the assessment identified channel widening as the predominant type of erosion, however channel downcutting and headcutting were also noted in places. Channel encroachment by various types of development was identified as the predominant cause of erosion.

Loss of riparian vegetation can also increase erosion and stream sedimentation and decrease the amount of cover, including large woody debris (LWD) and leaf packs. LWD provides macroinvertebrate habitat directly and indirectly by redirecting flows to produce more complex instream habitat. Leaf packs from riparian vegetation are also an important habitat and food source for some aquatic invertebrates. Shading from riparian vegetation also reduces stream temperatures, which is beneficial for aquatic species and may become increasingly important with global climate change. Moore and Palmer (2005) found a positive correlation between benthic macroinvertebrate diversity and intact riparian forest along urban streams. Field surveys for the *Rocky Branch Watershed Assessment* reported an average of 45% shading for 30 habitat assessment sites in the stream. The assessment identified 41,985 linear feet of inadequately forested buffer (total for both banks) and reported that over 60% of the stream had less than a 35 foot riparian buffer.

Human created channel alterations can significantly affect stream habitat, flow regimes, and sediment throughput. Bridges and culverts can alter stream flow, causing pooling and scour if unable to accommodate increased flows from a largely impervious watershed. These alterations can impact stream habitat and sediment transport by causing localized stream channel bed and bank erosion, or localized sediment deposition. Channelization of a stream with concrete lining impedes natural stream processes and conditions that provide varied habitat and cover for macroinvertebrates, and impedes aquatic plant growth and stream interaction with groundwater and natural streambed substrate, which together can alter stream flow, habitat, water chemistry, and stream productivity in ways that may adversely impact aquatic macroinvertebrates (Shaver et al., 2007). Extensive piping of streams common in older urbanized environments effectively eliminates habitat for most aquatic species, including macroinvertebrates. Much of the Rocky Branch watershed was developed decades ago and these manmade features are common within the stream network. The *Rocky Branch Watershed Assessment* identified 9,920 linear feet of severe channel alteration within Rocky Branch, which includes channel straightening and relocation, placement of road culverts, and channel armoring with man-made materials. The assessment also identified nine significant barriers to fish passage, eight of which were artificially created drops in stream bed of greater than six feet.

Stream habitat, riparian habitat, and habitat within the watershed as a whole are critical to plant and wildlife species. Surveys conducted for the assessment found that habitat for aquatic macroinvertebrates and other species was mostly poor in all Rocky Branch subwatersheds. The assessment identified lack of vegetative cover, poor substrate, sedimentation, bank instability, embeddedness, and channel alteration as common habitat impairments within the stream. Invasive plant species such as Japanese privet (*Ligustrum japonicum*), Chinese privet (*Ligustrum sinense*) Chinese wisteria (*Wisteria sinensis*), and kudzu (*Pueraria montana*) displace and outcompete native species in many places along Rocky Branch, which is typical of disturbed habitats (O'Driscoll et al., 2010). No threatened or endangered plant or animal species were identified within the Rocky Branch watershed by the South Carolina Heritage Trust Program's Natural

Heritage Database. This is likely due to elimination of habitat for sensitive species from the long history of urbanization and associated habitat degradation within the watershed.

Drinking Water Supply

Code of federal regulations 40 CFR Part 141 and 40 CFR Part 143 were established pursuant to the Safe Drinking Water Act and serve as the guidelines for the State of South Carolina's requirements for determining a safe source for public drinking water supply after conventional treatment. 40 CFR Part 141 and 143 contain maximum contaminant level requirements and goals for a wide variety of chemical, physical, and biological contaminants, including those that produce unpleasant taste and odor. These are adopted in R.61-68 as described in the narrative criteria and in the appendix. Potential sources of these pollutants are the same as described in the Aquatic Life Use Support-Possible Stressors section of this document.

Fish/Shellfish Consumption Use Support

The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters states "*Fish consumption use support is determined by the occurrence of advisories on human consumption for a given waterbody. For the support of consumption uses, a mercury or PCB advisory which limits fish consumption, indicates nonsupport of uses and is included on the §303(d) list of impaired waters.*" R. 61-68 places a limit of methylmercury concentration in fish or shellfish as not exceed 0.3 mg/kg in wet weight of edible tissue for the protection of human health. Numeric criteria for PCBs are described in the appendix of R. 61-68.

There is no monitoring of PCB's within Rocky Branch, however no impairments for PCBs are included on the *The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters* within the Congaree River downstream from its confluence with Rocky Branch.

The predominant source of mercury within streams is runoff of atmospheric deposition of coal combustion products within a watershed. Methylmercury, a highly bioavailable and toxic organic form of mercury, has been found to be particularly elevated in southeastern forested coastal plain streams. These streams often contain or drain wetlands that convert inorganic mercury to methylmercury. Mercury levels in fish are often lower in urban streams due to lack of wetlands and other conditions that allow for methylmercury production and bioaccumulation in fish (USGS https://www.usgs.gov/mission-areas/environmental-health/science/comprehensive-assessment-mercury-streams-explains-major?qt-science_center_objects=0#qt-science_center_objects). National Atmospheric Deposition Program/Mercury Deposition Network data indicate that annual wet deposition of mercury in the vicinity of Columbia, SC, ranged from 7.3 to 14.2 µg/m2 and averaged 10.5 µg/m2 from 1996 and 2018. While there are no monitoring stations for fish tissue mercury in Rocky Branch, SCDHEC station C-007A located in the Congaree River approximately 4,500 feet downstream from its confluence with Rocky Branch is listed as impaired for mercury in fish tissue on the *The State of South Carolina's 2018 IR Part I: Listing of Impaired Waters.*

2. Estimated Load Reductions

This watershed plan includes consideration of stream restoration and bank stabilization projects, stream buffer planting, stormwater management construction and retrofit projects, a variety of Green

Infrastructure / LID projects, and a robust stormwater outreach and education program. Information related to various planned practices was entered in the spreadsheet in the "Future Practices" section of the Watershed Treatment Model to estimate potential pollutant removal that might be obtained from construction or implementation of these projects. Future practices entered in the model include increased pet waste and residential lawn care education opportunities from constructed projects and other outlets, increasing frequency of street sweeping to monthly on residential streets, increasing frequency of catch basin cleanouts to semi-annual on all streets, and implementing a residential impervious cover disconnection program. Many practices recommended in the *Rocky Branch Watershed Assessment* were also entered in the model. These include restoration of the 2.3 miles of stream identified as restorable in the assessment, and establishing a 50-foot riparian buffer along 2.4 miles and a 25-foot buffer along 0.7 miles of the 5.1 miles of stream identified in the assessment as having an inadequate forest buffer.

The WTM allows for entry of information for individual planned stormwater management practices in its "Stormwater Retrofit Options" table of the "Future Practices" tab. Project and site information for a recently completed dry extended detention project in Martin Luther King Junior Park, as well as information for two additional planned City Capital Improvement dry extended detention projects was entered in this section. Project and site information for five stormwater management and sixteen low impact development (LID) projects identified in the *Rocky Branch Watershed Assessment* were also entered in the "Stormwater Retrofit Options" table. These projects were reviewed by City staff and are under consideration for construction or for discussion with the property owner. The 23 projects modeled in the "Stormwater Retrofit Options" table include construction of three dry extended detention ponds, rehabilitation of two wet ponds, construction of ten bioretention basins, construction of five green roofs, conversion of two dry ponds to wetland basins, and construction of one filter practice and one infiltration practice. Potential projects considered from the *Rocky Branch Watershed Assessment* are listed in the appendix along with estimated drainage area treated, and are described in more detail in the assessment. Net benefit for all potential future practices considered in the model is shown in Table 5 and annual pollutant removal effectiveness by BMP type for modeled retrofit projects is presented in Table 6.

Net Benefit (Load Reductions) of Future Practices					
	TN (lbs/year)	**TP (lbs/year)**	**TSS (lbs/year)**	**Bacteria (billion/year)**	**Runoff Reduction (acre-ft/yr)**
Reductions to Surface Water Loads					
Lawn Care Education	95	35	0	0	0
Pet Waste Education	471	61	0	4093	0
Street Sweeping	334	49	9749	0	0
Riparian Buffers	108	16	3260	4768	20
Catch Basin Cleanouts	542	59	51345	0	0
Stormwater Retrofits	1388	294	106334	52175	93
Channel Protection-Stream Restoration	263	211	263278	0	0
Storm Load Reduction	**3201**	**726**	**433965**	**61037**	**113**
Non-Storm Load Reduction	**0**	**0**	**0**	**0**	**0**
Total Surface Water Reduction	**3201**	**726**	**433965**	**61037**	**113**

Table 5. Net benefit of future practices modeled in the WTM by practice type and annual pollutant load reduction.

Watershed Treatment Model results indicate that construction of all modeled stormwater retrofit projects would reduce the greatest amount of nutrient and bacteria loads of the options considered, and have the greatest effect on runoff reduction. Improved pet waste and lawn care education opportunities provided by these projects will also provide significant improvement to bacteria and nutrient loads. The modeled stream restoration projects would reduce the greatest quantity of total suspended solids and provide significant nutrient reduction. Increased frequency of catch basin cleanout and street sweeping will significantly reduce TSS and nutrients, while riparian buffer enhancement will significantly reduce bacteria, nutrients, and TSS. Riparian buffer enhancement will also improve runoff reduction.

Stormwater Retrofits Summary - Annual Practice Effectiveness						
BMP Type	**Total Area Captured (acres)**	**TN (lb/year)**	**TP (lb/year)**	**TSS (lb/year)**	**Fecal Coliform (billions/yr)**	**Runoff Reduction (ac-ft/yr)**
Dry Extended Detention Pond	307.3	584.4	116.3	73,897.8	9,900.1	40.1
Wet Pond	67.3	266.8	85.5	15,568.3	18,455.2	0.0
Wetland	12.2	77.7	16.9	3,347.0	4,534.4	0.0
Filters	4.8	29.5	6.2	1,679.6	2,149.0	0.0
Green Roof	5.8	42.5	6.6	1,194.2	1,719.0	7.0
Rooftop Disconnection	0.0	1.7	0.2	51.0	73.4	0.3
Soil Amendments	0.0	69.7	14.2	1,823.3	2,624.6	0.0
Bioretention	23.5	257.0	39.5	7,036.6	10,128.9	36.4
Infiltration Practices	4.7	58.8	8.6	1,735.9	2,590.8	9.6

Table 6. Net benefit of future stormwater retrofit practices modeled in the WTM by practice type and annual pollutant load reduction.

The recently completed MLK Junior Park project and the additional stormwater dry extended detention Capital Improvement Projects planned by the City of Columbia will treat the greatest area, and WTM results predict these will reduce nutrients, TSS, and runoff by the greatest amount of the constructed and retrofit projects considered. The wet pond retrofit and bioretention projects modeled will reduce the next greatest amount of nutrients and TSS, and will reduce fecal coliform by the greatest amount of the projects modeled despite their much smaller treatment area.

3. Pollutant Management Measures

The Rocky Branch watershed is covered by three publically owned networks of stormwater conveyance systems, or Municipal Separate Storm Sewer Systems (MS4s). The three include South Carolina Department of Transportation, which operates a large MS4 (serving a population of 250,000 or more), and Richland County and The City of Columbia, which each operate medium MS4's (serving a population of 100,000 - 249,999). Section 402(p) of the Clean Water Act requires National Pollutant Discharge Elimination System (NPDES) MS4 permitees to reduce stormwater pollutant loads to receiving waters of the US to the maximum extent practicable. Large and medium MS4 permit recipients are required to address each of the following eleven elements in their Stormwater Management Plans:

- Structural Controls and Stormwater Collection Systems Operation
- Post-Construction Stormwater Management in New Development and Redevelopment
- Roadway runoff management
- Flood control related to water quality issues
- Municipal Waste Treatment, Storage, or Disposal Facilities Not Covered by an NPDES Stormwater Permit

- Application of pesticides, herbicides, and fertilizers
- Illicit discharge detection and elimination
- Regulation of sites classified as associated with industrial activity
- Construction and post-construction site runoff control
- Stormwater Monitoring for Pollutants
- Public Education and Outreach on Stormwater Impacts and Public Involvement/Participation

Approximately 90% of Rocky Branch watershed is located within the City of Columbia MS4. Per the requirements of its MS4 permit and in accordance with its stormwater management plan, the City has developed stormwater ordinances and a stormwater management program which address the above elements in an effort to minimize pollutant loading and negative impacts to Rocky Branch and all receiving waters of the US within its jurisdiction.

The City of Columbia has or is in process of developing a variety of regulations, incentives, and public outreach efforts designed to protect water quality and quantity impacts to Rocky Branch and other waterways. Existing regulations prohibit direct inputs of trash, oils and greases, and harmful chemicals to stormwater and waterways. A water quality buffer ordinance provides water quality, fish and wildlife habitat, and base flow benefit to jurisdictional streams and wetlands. Additional regulations control water quality and quantity impacts to the City's waterways from construction projects, and The *City of Columbia Best Management Practice (BMP) Design Manual* describes citywide planning and design requirements that control rate and volume of runoff and pollutant release from construction sites as well as more stringent requirements for flood problem areas, impaired waters and waters with TMDL's, and critical water bodies, including those within the Rocky Branch watershed. The City encourages nonstructural stormwater management, which is detailed in the *Stormwater Better Site Design* section of the BMP manual, and the City's stormwater utility fee encourages developers of commercial, industrial, and multi-family housing units to minimize impervious area on their properties. The City offers stormwater utility fee credits for stormwater related education and to further encourage the most effective stormwater management practices. The City is in process of identifying Special Protection Areas within the Rocky Branch watershed which will have additional requirements and incentives for increased stormwater management. The City will investigate the use of trash traps and other innovative systems for trash removal and pollutant reduction within Rocky Branch and other streams within its jurisdiction.

The City maintains a robust program aimed at reducing sources of harmful bacteria to its waters. These include requirements for hook up to the City's sanitary sewer system to remove septic systems within the City, educational outreach and oil and grease recycling to prevent SSO's, and ordinances and storm drain marking to prevent trash dumping in waterways and storm drains. The City provides covered trash and recycling bins to all residents to prevent bacteria from entering stormwater from their household trash and debris. The City's "Trash The Poop" program is designed to reduce bacterial loading to its waterways from pet waste sources. The program provides education and outreach through signage and various local area media outlets describing the importance of proper disposal of pet waste. The program is advertised extensively through social media, print, and digital advertising. The program also provides free pet waste stations to interested groups that meet requirements for pledged maintenance and usage and free poop bag leash holders with dog adoptions from the City's animal shelter and to citizens attending outreach events. The City's "My River Starts Here / Drains Aren't Dumps" program provides community involvement for marking of storm drains in order to educate the public on preventing disposal of various wastes, including pet waste, in storm drains. The City has a pet waste ordinance which allows for enforcement of proper pet waste disposal. The City also uses billboards and its very active online social media presence for stormwater, which includes its website, Instagram, Facebook and Twitter, to promote its "Trash The Poop," "Trash The Grease," "Trash The Wipes," and Southern Fried Fuels" water quality improvement programs. The City, in partnership with GE Biofuels, recycled over 1,000 gallons of used grease and cooking oil from restaurants and commercial consumers in 2019 through its "Southern Fried Fuels" program. The City of Columbia maintains compliance with criteria for recreational uses per C (13) of R.61-68 which states, "*For waters of the State, where a permit has been issued pursuant to R.61-9.122.26 and R.61- 9.122.34, the Department shall consider the permittee in compliance with the established bacterial (i.e., E. coli, enterococci, fecal coliform) criteria for recreational uses of the waterbody if the permittee is in compliance with their permit."* However, the City values its water resources and is committed to reducing bacteria and other pollutants to its waterways beyond the minimum permit requirements.

The City provides outreach to improve awareness and reduce erosion and sedimentation and stormwater pollutant inputs from herbicides and pesticides through its hosting and participation in the Blue Thumb Landscaper Conference and through partnering with Clemson University for pesticide applicator certification. The conference also promotes better stormwater management practices for landscaping, such as rain gardens and landscaping for erosion control, as well as planting and preserving stream and wetland buffers and use of native vegetation. The City provides outreach to reduce trash and other pollutants through its My River Starts Here/Drains Aren't Dumps program in which it partners with citizens to mark storm drains to inform the public that they can convey pollutants to streams and rivers. The City conducts a twice yearly gardening and composting workshop followed by a rain barrel and composting bin sale.

The City of Columbia is in process of a large scale program to evaluate and improve its wastewater system. The program, Clean Water 2020 (https://cleanwater2020.com/), has goals that include improving infrastructure, reducing sanitary sewer overflows, protecting the health and safety of Columbia's citizens, and improving water quality. This will be accomplished by sewer system assessment and rehabilitation, which includes replacement and capacity expansion of existing infrastructure and addition of new system infrastructure. Some of the infrastructure being improved includes the wastewater collection system, numerous pumping stations, and portions of the wastewater treatment plant. These improvements have already resulted in a 94% decrease in SSO's throughout the system.

The City is in process of repair, replacement, or expansion of over 17,000 linear feet of force main and gravity sewer, as well as repair, replacement, or upgrade of pump stations, lift stations, and other sewer equipment and infrastructure within the Rocky Branch watershed. Assessment and construction of further system improvement will continue. These improvements have resulted in the SSO improvements within the Rocky Branch watershed depicted in Figure 3.

The City has several large stormwater Capital Improvement Projects (CIP) in varying stages of planning and construction within the Rocky Branch watershed. These include stream restoration projects, stormwater detention and bioretention projects, and replacement and enhancement of aging stormwater infrastructure. Some planned stream restoration and riparian habitat improvement will be done in partnership with the University of South Carolina on portions of the stream that flow through its campus. At least two planned CIP projects will provide pollutant removal and water quantity control for large drainage areas with high percentages of impervious area in upper portions of the Rocky Branch watershed. The stream restoration projects will reduce stream bank erosion and downstream sedimentation, provide flood control, and improve habitat for fish and wildlife. The City's stormwater Capital Improvement Projects are partly funded by the City's Green Bonds, which are certified by the Climate Bond Initiative as environmentally responsible infrastructure investment. Capital Improvement Project locations and details can be viewed at the City of Columbia Stormwater Project Viewer website (https://www.columbiascwater.net/capital-improvement-projects/).

A City of Columbia CIP stormwater detention project was recently completed in Martin Luther King Junior Park within the Rocky Branch watershed and received the 2019 South Carolina American Public Works Association project of the Year Award in the category of Structures/Historical Restoration. The project included construction of three detention basins within a frequently flooded low lying area of the park near the stream. The basins attenuate floodwaters from Rocky Branch, providing 2.1 additional acre feet of flood storage during a ten year storm event, and treat runoff from a 3.1 acre drainage area. Modeling results show pollutant removal efficiencies for the annual probability storm event of 95.9% for sediment, 91.6% for nitrogen, 91.2% for phosphorus, and 94.2% for bacteria from the drainage area. The basins were planted with native vegetation chosen for pollutant removal ability and for survival in varying soil moisture conditions. The detention basins provide wildlife habitat and an aesthetically pleasing natural area which offer an excellent environmental education opportunity via an elevated handicap accessible boardwalk that provides access to Rocky Branch. The project was designed with consideration of increasing likelihood of extreme weather events due to climate change.

Additional proposed watershed improvement projects under consideration by the City include, but are not limited to, those from Table 8.1 of the *Rocky Branch Watershed Assessment*. The assessment describes 73 watershed improvement projects within the watershed. These include stream restoration and bank stabilization projects, stream riparian buffer planting, stormwater management construction and retrofit projects, and a variety of green infrastructure / LID projects. The projects will reduce storm flow impacts and/or bacterial loads and other pollutants delivered to Rocky Branch. Some projects will also provide improved instream and riparian habitat and provide stormwater education and outreach opportunities via public access, signage, and community involvement. The City evaluated these projects for feasibility, efficacy of pollutant removal and hydrological improvement, and benefit to the local community. Factors considered in this evaluation included property ownership, cost, permitting and logistical constraints, likelihood of long term water quality and/or quantity improvement, community usability, and community based partnership opportunity. Projects within City property were determined to be most favorable for an initial project phase. Several of the highest scoring projects are in the planning stage and a modified version of one, the previously mentioned Martin Luther King Junior Park project, has already been completed. The City is considering grouping smaller projects by proximity to minimize cost. The high visibility of projects constructed within City of Columbia parks and The University of South Carolina campus offer excellent opportunities for outreach and education (described below) that are expected to build public support for water quality improvement projects throughout the watershed. As construction of projects in the parks or campus proceed, the City will work with partners to evaluate and prioritize future water quality improvement projects according to the same criteria.

Figure 5. Rocky Branch in Martin Luther King Junior Park prior to water quality improvement project construction.

Figure 6. Detention basin adjacent Rocky Branch in Martin Luther King Junior Park in November 2020.

4. Identification of Funding and Technical Assistance Needs and Potential Sources

Funding Sources

The City of Columbia enacted legislation in 2003 which established a Stormwater Utility and associated fees. Stormwater Utility Fees are used to fund operations and maintenance of storm drainage structures and conveyances, stormwater Capital Improvement Projects (CIP), and stormwater personnel costs. The City's Green Bond sales will also provide significant funding dedicated to improvement and upgrade of the City's stormwater system including infrastructure improvements, stream restoration, detention and bioretention basins, and green infrastructure. Green Bonds allow public entities to finance capital construction in a way that supports environmentally responsible investment and will assist the City in meeting its goals of protecting life, property, and environment for its growing population in times of predicted increasing intense rainfall events and extended drought. Details regarding The City's Green Bonds can be found on the City's website (https://www.columbiasc.net/headlines/12-07-2018/Green-Bonds). The CIP budget, partly supported by the Stormwater Utility and Green Bonds, are anticipated to be the source of City funding for completion of projects under this Watershed Management Plan. Based on current Stormwater Utility revenues and expected costs of completing projects under this plan, the City should be well positioned to provide at least the minimum required matching funds for grant-funded projects. The University of South Carolina is expected to be able to provide some funding for water quality improvement projects located on its campus.

Technical assistance

The City Stormwater Management Program is housed in the City's Engineering Department, which employs engineering and scientific personnel capable of providing in-house technical support for projects. The City would likely procure a consultant to design, and a contractor to construct, projects under this watershed based plan. Selected consultants and contractors would provide specialized experience in addition to that of City personnel. Based on in-house and contract personnel to be assigned to these projects, the City will have a high level of technical expertise available for these projects.

The University of South Carolina is expected to provide additional technical expertise, especially for projects located on University property. Potential projects under consideration on the campus include a variety of stormwater LID and retrofit projects, as well as stream restoration and buffer enhancement. The City may also work with University partners to develop and implement innovative water quality improvement projects within the watershed. University partners with expertise in a variety of fields may provide increased opportunity and innovative methods of monitoring chemical, physical, and biological effects to Rocky Branch and changes in stream use by the community as project construction progresses.

5. Outreach Strategy

The City's Water Department maintains an extensive and active online social media presence which is used to promote its various water quality improvement programs and highlight stormwater and water quality improvement projects and goals. The City's Water Department staff will work with community organizations and community members throughout the project planning process, and will work with the community, partner organizations, and the City Parks departments to determine methods to best utilize each project in order to engage the public and improve awareness of water quality and stormwater related issues.

Many projects under consideration per this watershed management plan are expected to be constructed in City of Columbia parks or on the University of South Carolina campus. Both of these afford high visibility to the public and offer numerous opportunities for public engagement and education and are expected to build public support for water quality improvement projects throughout the watershed, and community connectedness to Rocky Branch. Rocky Branch flows through the three largest parks in the watershed: Martin Luther King Junior Park, Maxcy Gregg Park, and Olympia Park as an open channel stream. Projects within these parks provide excellent opportunity to improve public awareness of the concept of a watershed and of types and sources of pollutants and their impacts to the stream and to water quality in general. Projects located in City parks and on the university campus may also increase public awareness of bacterial pollution from pet waste by increasing opportunities for placement of signage and additional pet waste stations. The City Water Department outreach section has identified partnership opportunities with at least eight neighborhood groups within the watershed, as well as with the Five Points Association, The Devine Street Association and The University of South Carolina. Opportunities may also exist to partner with individual church groups, schools, and residents of apartment complexes and student housing complexes located in close proximity to individual projects or groups of projects.

The University of South Carolina Columbia campus, which covers approximately 400 acres of the Rocky Branch watershed, enrolled over 35,000 students and employed approximately 1,400 faculty and staff in 2019. A large portion the University's employees and attendees live within the watershed and utilize its commercial facilities, particularly the Five Points Shopping District. Rocky Branch flows through the University property as an open channel stream in several locations, which will provide excellent outreach opportunity for projects located on the campus. The campus has undergraduate and master's programs in environmental science as well as other majors and programs which would lend themselves well to improving awareness of water quality and stream habitat issues within Rocky Branch. The University has ten "Leadership in Energy and Environmental Design" (LEED) certified buildings, including two with green roofs, one of which is located atop one of its "Green Quad" buildings. The Green Quad is a sustainable living-learning community that involves and engages students, University staff, and community members in its learning center and in some of its operations. Rocky Branch flows adjacent the Green Quad and its permaculture garden, which provides an excellent outreach opportunity to a community concerned about environmental issues.

The City partners with Richland County on the annual Blue Thumb Landscaper Conference, which promotes environmentally responsible landscaping practices including reducing pollutants to stormwater and receiving waters. Topics covered in the conference include outdoor integrated pest management, considerations for fertilizer, herbicide, and pesticide application, stormwater BMP's for landscapers, including rain gardens, taming invasive plants, protecting riparian areas, and aquatic life protection. Clemson Extension presents at the Blue Thumb conference and the City also works with Clemson on the Adopt-A-Stream program. This program will be important in helping to determine success in water quality and habitat improvement in Rocky Branch as projects are constructed, and provides an excellent opportunity to improve community awareness of the stream and provide public engagement in improving its condition. The City's community partnership *My River Starts Here/Drains Aren't Dumps* program educates the public on stormwater conveyance and prevents trash, pet waste and other pollutants from entering Rocky Branch and streams throughout the City.

Water quality and stream habitat improvement projects within the Rocky Branch watershed offer partnership opportunities with a number of additional environmentally concerned organizations. Among these are The Congaree Riverkeeper, which promotes clean rivers; Sustainable Midlands, which promotes responsible growth and a healthy environment in the midlands, and its subsidiary organization The Rocky Branch Watershed Alliance which specifically promotes the environmental improvement of Rocky Branch and its watershed; The South Carolina Native Plant Society, which promotes use of native plants and sustainable landscaping practices; South Carolina Wildlife Federation, Richland County Soil and Water Conservation District, and The Congaree Land Trust, which support restoration, enhancement, and preservation of habitat for native plants and wildlife; and Palmetto Pride and Keep The Midlands Beautiful, organizations that promote litter removal.

Community Involvement

The City's stormwater staff will work with community groups and community members throughout the project planning process, and will work with the community, partner organizations, and the City Parks department to determine the best method to utilize each project to engage the public and improve awareness of water quality and stream and riparian habitat related issues. Topics which may be discussed at community meetings or onsite events or workshops during project planning and construction process may include

- An outline of the project and its impacts on park, neighborhood, or other property use
- Water quality issues and goals
- Impacts of pet waste on water quality
- Discussion of erosion and erosion controls
- Flood control benefits, especially with expectations from changing climate
- Benefit to habitat and wildlife
- Community impact and involvement
- Community education opportunities

City staff will keep community partners updated on each project by attending neighborhood association meetings as needed as each project progresses.

Upon project completion, some projects may lend themselves well to informing and educating residents about water quality issues and improvements they can make around the community and in their own backyard. The City or one of its partner organizations may offer onsite meetings, events, or workshops pertaining to a project and its water quality or ecological benefits to Rocky Branch. Topics that can be covered include:

- Erosion control, stormwater runoff management
- Rain gardens
- Planting native plants
- Stream and pond buffers
- The importance of proper pet waste disposal
- Stormwater BMPs
- LID
- Watershed planning

Local schools, churches, and other community groups could also benefit from workshops on water quality in the Rocky Branch watershed. The City Water Department staff may work with partner organizations and the City's Department of Parks and Recreation to host activities or events near projects in City Parks that can be used as a teaching location for lessons on riparian habitats and water quality.

Potential topics to be covered with school groups include:

- What is a watershed?
- Riparian habitats
- Non-point source pollution (sources and impacts, including pet waste)
- Water quality monitoring (hands-on water sampling and educational activities)
- BMPs for storm water (high school level engineering)
- Erosion and erosion controls (high school level engineering)

Signage

Signage and educational kiosks will play a key role in improving awareness of projects aimed at improving water quality in Rocky Branch, particularly for those projects located in highly visible public locations.

Educational signage can address water quality, erosion, and erosion control, as well as landscaping features and native plants. Messaging about water pollution and run-off can be targeted toward pet owners who frequent the park, neighborhood, or other public place, and can reinforce messaging already in place throughout the City of Columbia concerning proper disposal of pet waste. Additional pet waste stations will be installed in public places near new projects.

Signage will also be placed in the most visible and trafficked locations, and will address the benefits of an individual project to water quality and to the stream ecosystem as a whole. Whenever possible, signage will be placed in proximity to Rocky Branch in order to improve awareness of and community connectedness to the stream.

6. Timeline of Implementation Events

Pollutant Reduction Measure	**Time Frame (Years)**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Stream Monitoring	■	■	■	■	■	■	■	■	■	■	■	■
Stormwater Outreach and Education	■	■	■	■	■	■	■	■	■	■	■	■
Evaluate and Expand Pet Waste Stations and Education & Information	■	■	■	■	■	■	■	■	■	■	■	■
Wastewater Infrastrucure Evaluation and Improvement	■	■	■	■	■	■	■	■	■	■	■	■
Stormwater Infrastrucure Evaluation and Improvement	■	■	■	■	■	■	■	■	■	■	■	■
Illicit Connection Inspection and Removal	■	■	■	■	■	■	■	■	■	■	■	■
Stream Restoration 1	■	■	■									
Bank Stabilization 1			■	■	■							
Stream Restoration 2					■	■	■					
Bank Stabilization 2							■	■	■			
Stream Restoration 3									■	■	■	
Bank Stabilization 3											■	■
Riparian Buffer Planting 1			■	■	■							
Riparian Buffer Planting 2					■	■	■					
Riparian Buffer Planting 3							■	■	■			
Riparian Buffer Planting 4									■	■	■	
Detention Pond Install 1		■	■	■								
Detention Pond Install 2				■	■	■						
Project Grouping 1												
Underground Detention, Infiltration	■	■	■									
3 Bioretention, Sand Filter, or Pocket Wetlands	■	■	■	■	■							
2 Green Roofs	■	■	■	■	■							
Project Grouping 2												
Pond retrofit					■	■	■					
Bioretention boxes					■	■	■					
4 Bioretention Areas							■	■	■	■	■	
4 Bioretention or Sand Filters							■	■	■	■	■	
3 Green Roofs							■	■	■	■	■	
Project Grouping 3												
2 Tree boxes with Underground Detention											■	■
4 Green Roofs											■	■

Table 7. Estimated timeline for design to completion of potential water quality improvement projects within the Rocky Branch watershed.

7. Milestones

The City will provide management through at least the initial phase of projects implemented under this watershed management plan. Management will include oversight of project planning, design, and construction with quarterly reporting of progress toward project milestones. Milestones for individual projects may include measurements such as percentage completion, linear feet of stream restoration / bank stabilization completed, or acres/linear feet of buffer planting. Milestones for grouped smaller projects may include percentage completion or number of LID's implemented.

Evaluation of milestones for outreach and education will also be reported. Measurements of implementation of education and outreach may include number of new pet waste stations installed, number of pet waste bags used, amount of cooking oil collected at the City's recycling facilities, number of

SSO's, number of rain barrels distributed and installed, number of signs installed, number of storm drains marked within the watershed, and numbers of attendees at meetings and events.

8. Pollutant Reduction Criteria

The City will use monitoring data to determine pollution reduction progress of projects within Rocky Branch watershed. The City will use data before, during and after project or project grouping completion to evaluate the progress of pollution reduction. Monitoring will include TSS, nutrient, and bacterial sampling, and data from continuous monitoring sondes already present within Rocky Branch to evaluate pollution reduction. Supplemental monitoring or sampling will be considered for individual projects or project groupings if the additional data is determined to be beneficial. Pollution reduction targets will be evaluated based on sonde data and TSS, nutrient, and bacterial sampling. Individual projects completed within Rocky Branch watershed will be assessed based on the pollution reduction progress of specific interim targets.

9. Monitoring Strategy

The Congaree Riverkeeper maintains an SCDHEC approved ambient surface water quality monitoring station on Rocky Branch (Station CRK06) approximately 60 feet upstream from its confluence with the Congaree River. Bacterial sampling is conducted at the station on an approximately bi monthly basis. The City will continue to monitor reported E. coli data from the station in assessing efficacy of pollutant removal by projects implemented under this Watershed Management Plan along with the City's own monitoring data

Within the Rocky Branch watershed in the City of Columbia, five locations are currently monitored in order to provide an accurate accounting of discharge rate and volumes for flood model calibration within the City. These stations include ROC A, ROC B, MLK, Saluda, and Cookout. Although the configuration of equipment varies from station to station, each of these employ at least one Sontek IQ velocity sensor and Campbell Scientific CS451 pressure transducer. The CS451 pressure transducers at the Rocky Branch sites are programmed to take readings every minute to better monitor flashy events and provide an uninterrupted dataset of stage levels in the monitored waterways. The combination of these two sensor types allow for continuous and accurate discharge estimates during nearly all flow condition – a depth-to-flow relationship during generally predictable base flow conditions, and a velocity indexing approach for highly variable flow conditions. Although these relationships do not fully account for all flow conditions, they do account for the vast majority. Flow and discharge monitoring within Rocky Branch will allow the City to measure the effectiveness of stormwater projects that are designed to mitigate stormflow impacts to the stream.

The City of Columbia operates two water quality monitoring stations on Rocky Branch where YSI sondes have continuously collected temperature, pressure/depth, pH, specific conductivity, turbidity, and dissolved oxygen data at 15 minute intervals since March of 2014. One (ROCA) is located in Maxcy Gregg Park just downstream from the Five Points Shopping District in the middle portion of the watershed and the other (ROCB) is located in the lower portion of the watershed just below the Rocky Branch culvert under Olympia Drive, approximately 4,000 feet upstream from its confluence with the Congaree River. Precipitation data is also collected at the two monitoring stations and at Martin Luther King Junior Park by HyQuest TB4 Tipping Bucket Rain Gauges. This continuous monitoring allows the City to see real time conditions of Rocky

Branch in order to analyze data trends, and provides the City a robust database with which it can determine the effectiveness of pollutant reduction projects.

The City of Columbia collects water samples at least once quarterly during wet weather conditions at each of its two monitoring stations, and occasionally during dry weather to establish baseline conditions. These samples are analyzed for E. coli, total suspended solids, total phosphorus, and total nitrogen in accordance with 40 CFR 136 and are analyzed at a state certified environmental laboratory. These samples have been collected and analyzed within Rocky Branch regularly since March 2014.

As previously mentioned, The City will consider additional water quality sampling and monitoring sites to evaluate effectiveness of individual projects or project groupings. Furthermore, the City will work with volunteer groups involved in the “Adopt A Stream” program to recommend monitoring stations below the project sites which can monitor invertebrate populations and instream habitat conditions, as well as other parameters. This well considered array of water quality monitoring equipment and procedures should enable the City to determine efficacy of constructed projects and to better plan for future water quality improvement projects.

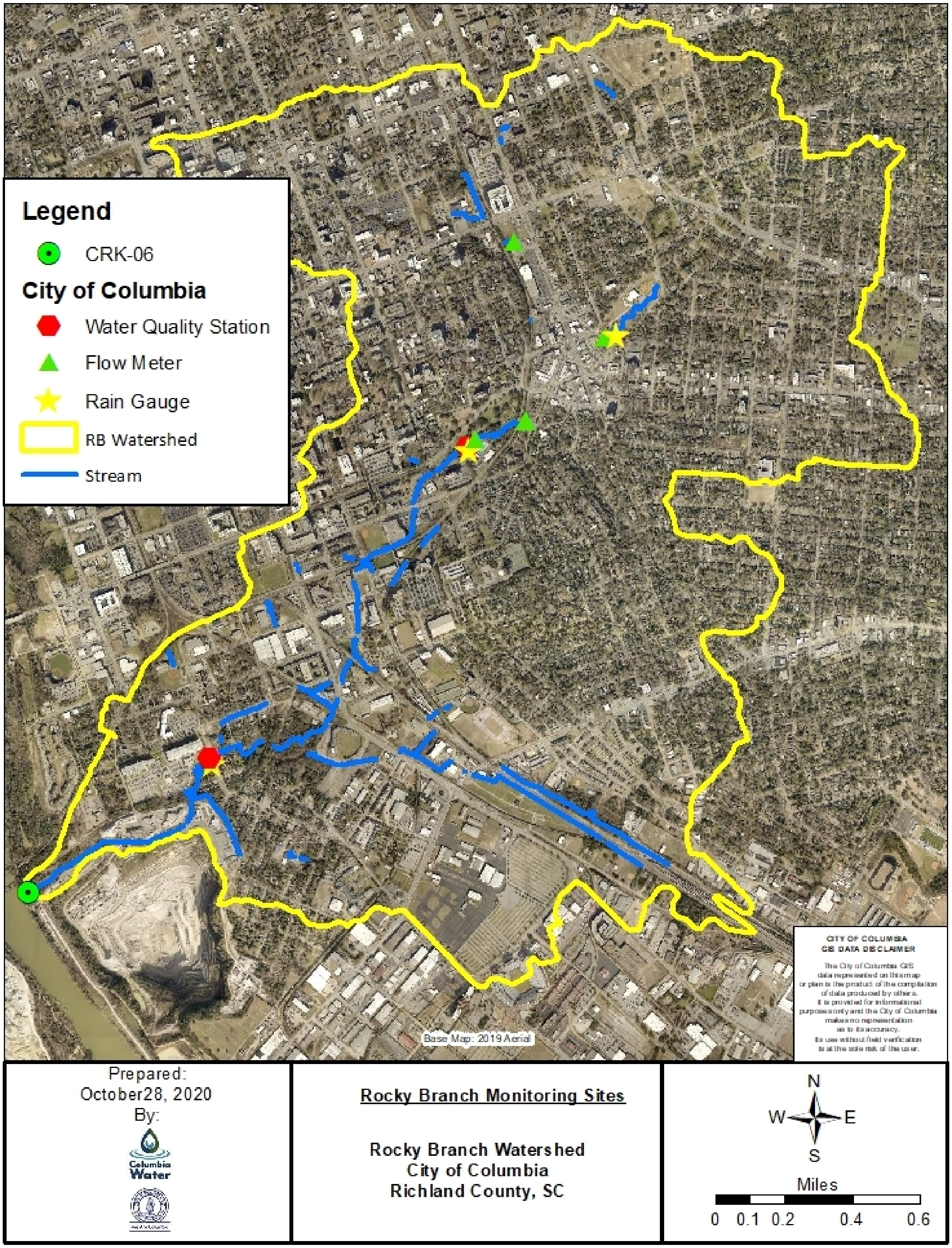


Figure 7. Water quality, streamflow, and precipitation monitoring sites within Rocky Branch watershed.

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Appendix A

Name	Acres	Depth to Water	Soil type	Impervious %
MLK Park	3.3	3-5	B	30
CIP 1	187.9	3-5	C	47
CIP 2	115.7	>5	B	70
SWM-1	5.1	3-5	B	53
LID-3	0.7	>5	A	40
SWM-2	7.1	>5	B	54
SWM-3	16.1	>5	B	41
SWM-4	51.2	>5	B	41
SWM-6	4.7	>5	B	70
LID-1	4.1	>5	B	54
LID-32	1.8	>5	B	53
LID-6	1.5	>5	B	53
LID-7	1.5	>5	B	53
LID-13	5.3	>5	B	54
LID-2	1.7	>5	B	53
LID-14	1.0	>5	B	70
LID-15	0.4	>5	B	70
LID-16	3.1	>5	B	70
LID-24	1.4	>5	B	70
LID-17	4.8	>5	B	70
LID-9	2.9	>5	B	54
LID-12	1.7	>5	B	54
LID-27	0.8	>5	B	54
LID-20	1.4	>5	B	54

Table 8. Drainage area details for potential future water quality improvement projects utilized in "Stormwater Retrofit Options" Table of "Future Practices" tab in the Watershed Treatment Model for Rocky Branch.