South Pacolet River

Watershed Based Plan for Nutrient Load Reduction in Lake Bowen and Municipal Reservoir #1

Spartanburg Water

Final Report

March 2018

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List of Acronyms

Abbreviation	Definition
BMP	Best Management Practice
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
FSA	Farm Service Agency
FTU	Formazin Turbidity Unit
HSG	Hydrologic Soil Group
HUC	Hydrologic Unit Code
LF	Linear Foot
MGD	Million Gallons per Day
MIB	2-methylisoborneol
MS4	Municipal Separate Storm Sewer System
NIFA	National Institute of Food and Agriculture
NTU	Nephelometric Turbidity Unit
PCA	South Carolina Pollution Control Act
SC DHEC	South Carolina Department of Health & Environmental Control
SRP	Soluble Reactive Phosphorus (*aka Orthophosphate)*
SSSD	Spartanburg Sanitary Sewer District
SW	Spartanburg Water
SWMP	Stormwater Management Plan
SWPP	Source Water Protection Program
T&O	Taste & Odor

Abbreviation	Definition
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus (as Phosphorus)
TPN	Total Particulate Nitrogen
TPP	Total Particulate Phosphorus
TSS	Total Suspended Solids
USD	United States Dollar
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WMP	Watershed Management Plan
WWTP	Wastewater Treatment Plant

1. Executive Summary

The South Pacolet River watershed is a 91.5 square mile watershed located in the Piedmont region of South Carolina. The watershed drains to two man-made reservoirs, Lake William C. Bowen and Municipal Reservoir #1, both of which serve as drinking water supply reservoirs. Spartanburg Water owns and operates both bodies of water, serving a population of more than 180,000 within Spartanburg and neighboring counties with drinking water.

In years preceding this report, portions of Lake Bowen and Municipal Reservoir #1 have experienced algal blooms, which have caused low dissolved oxygen levels and triggered taste and odor issues. As a result, Spartanburg Water, as the owner and operator of these resources, is interested in exploring a strategy to reduce watershed nutrient loadings, which are thought to be contributing to periods of lake eutrophication.

Through the use of existing watershed monitoring stations that measure streamflow and grab samples of nutrient constituents, along with EPA's STEPL model, an area-weighted estimate of total existing watershed loading was calculated at the discharge point of Municipal Reservoir #1. Also included herein is an estimate of reductions needed to achieve water quality targets.

Parameter	Estimated Current Load		Target		Percent Reduction Needed
	lb ac^{-1} yr^{-1}	lb yr^{-1}	Lake Conc. (mg/L)	Load (lb yr^{-1})	
TN	3.05	174,704	0.36	98,100	44%
TP	0.31	17,541	0.020	5,450	69%
TSS	35.6	518,563	--	--	--

The estimated existing Total Nitrogen (TN) load, based on monitoring results, is nearly the same as was estimated by USGS in 1976 (176,921 lbs-TN/yr), while the loading of Total Phosphorus (TP) has increased nearly threefold since 1976 (5,584 lb-TP/yr). While TN loading does not appear larger than estimated in 1976, an observed increase in nitrates over time could be attributed to untreated septic effluent or animal waste entering the lakes. Pastureland appears to be the largest single contributor of nutrient TN and TP loads within the watershed, with urban and septic sources also significant contributors.

The data are further explored and connected to Best Management Practices (BMPs) that would be the most effective in treating the nutrients entering Lake Bowen and Municipal Reservoir #1. Among them, vegetated buffer programs, conservation programs, septic tank repair programs, constructed wetlands, green infrastructure, stream restoration, and residential lawn management may provide the best opportunity to aid the watershed in lowering TP, TN, and chlorophyll-a concentrations to the recommended EPA lake concentrations specific to this ecoregion (IX). In addition to addressing nutrient loading, many of these BMPs will also assist in meeting bacteria standards within the watershed, which is subject to a bacteria TMDL.

The goal of the Watershed Based Plan is to reduce nutrient loading as depicted in the table above. In order to achieve a high quality drinking water supply, an initial estimate of implementation measures would need to result in a 76,604 lb Total Nitrogen (TN) load reduction and 12,117 lb phosphorus load reduction, which is 72% and 100% of the reduction needed to achieve the targets in the table above, respectively. An estimated cost of $46 million over the lifetime of management practices could be invested in improving the watershed. These water quality improvement measures would be implemented over time in a phased manner, using an adaptive management approach to consider the impact of implemented measures and need for further improvements. This estimate includes a preliminary cost estimate of $46M over the lifetime of the management practices (20-25 years).

Building on the success of the current monitoring framework will greatly enable BMP implementation and a feedback mechanism that tracks implementation year to year. This tracking, combined with a network of subject matter experts, community leaders, and other stakeholders engaging with multiple sources of funding and technical assistance for implementation, can support the long-term quality of Lake Bowen and Municipal Reservoir #1 as healthy public drinking water supplies.

2. Watershed Management Plan Overview

2.1 Overview

The goal of this plan is to document the level of nutrients and pollutants entering Lake Bowen and Municipal Reservoir #1, and to develop potential activities to assist stakeholders in the South Pacolet watershed in reducing or eliminating nutrients and pollutants. By doing so, negative water quality conditions, such as the presence of taste and odor compounds and noxious algae populations, will be reduced while preserving the drinking water supply. The plan will also suggest monitoring components to evaluate effectiveness of implementation efforts over time.

The plan will begin by introducing the watershed and describing the hydrologic characteristics of the South Pacolet River. The context of the watershed in its regulatory framework will be presented to act as a backdrop for future implementation efforts. Next, data provided by Spartanburg Water will be explored, elucidating some basic trends from 2009 to 2016. These data will provide some context as to which spatial areas should receive more attention from a nutrient management standpoint. The report will then introduce some potential causes based not only on findings in research and from other watershed management plans, but from the input of stakeholders in the spring of 2017 and analysis using EPA’s STEPL model.

The report will estimate nutrient loading for the South Pacolet River and the entire 91.5 square mile watershed. This value will then be compared to benchmark loadings, which will inform a framework for implementation of nutrient reduction measures at a high level.

3. South Pacolet River Watershed

3.1 Introduction

The South Pacolet River drains a 58,529-acre watershed in Greenville and Spartanburg Counties in the piedmont of South Carolina. Its 10-digit USGS Hydrologic Unit Code (HUC) is 0305010513, which is sub-divided further into two roughly equal area HUC-12 watersheds, the Upper and Lower South Pacolet River watersheds (030501051301 and 030501051302). The South Pacolet River watershed is one of numerous watersheds that ultimately comprise the Broad River Watershed, a 150-mile-long principal tributary of the Congaree River, which joins the Santee River in flowing to the Atlantic Ocean.

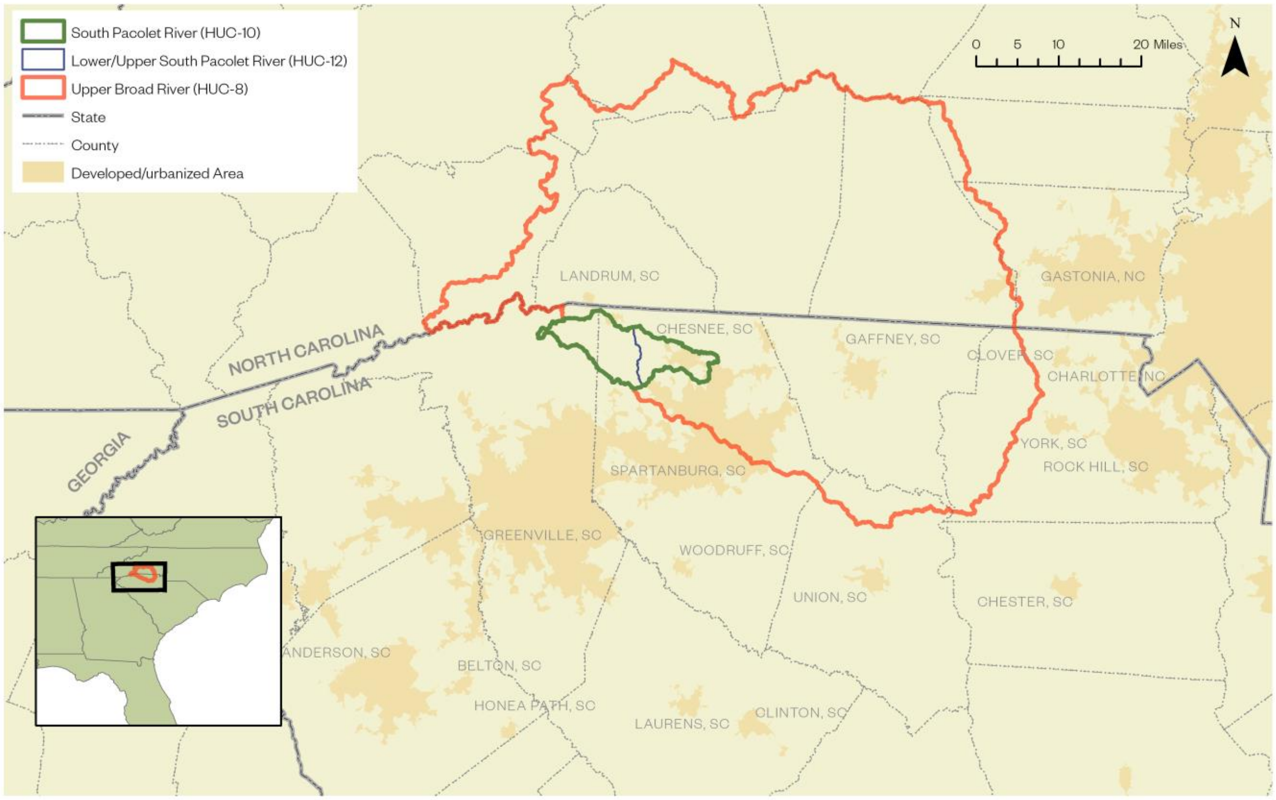

Figure 3-1: HUC-8, -10, and -12 watershed context map

The watershed encompasses parts or all of the following towns: Landrum, Campobello, Inman, Chesnee, and unincorporated residential development north of Spartanburg. Although the watershed is mostly rural development and agriculture, it is situated between the metropolitan areas of Greenville, South Carolina to the west, Asheville, North Carolina to the north, and Charlotte, North Carolina to the north-east. The South Pacolet River watershed lies between multiple major thoroughfares, including Interstate 26, SC-11, and US-176.

Lake William C. Bowen is a 1,530-acre manmade impoundment constructed in 1960. Downstream of this reservoir is the 272-acre man-made impoundment known as Municipal Reservoir #1, impounded in 1926. Municipal Reservoir #1 is 2,600 feet upstream of the confluence of the North and South Pacolet Rivers in Spartanburg County. Both reservoirs are owned and managed by Spartanburg Water. Lake Bowen and Municipal Reservoir #1 have maximum surveyed volumes of 286,500 and 30,300 acre-inches, respectively (Nagle, et al., 2008). Lake Bowen and Municipal Reservoir #1 are primarily purposed as drinking water reservoirs for Spartanburg Water customers. Lake Bowen has secondary uses, including aquatic life support and recreation. Municipal Reservoir #1 has a restriction on swimming, boating, and on-surface fishing due to the proximity to Spartanburg Water’s primary intake at the R.B. Simms Water Treatment Facility.

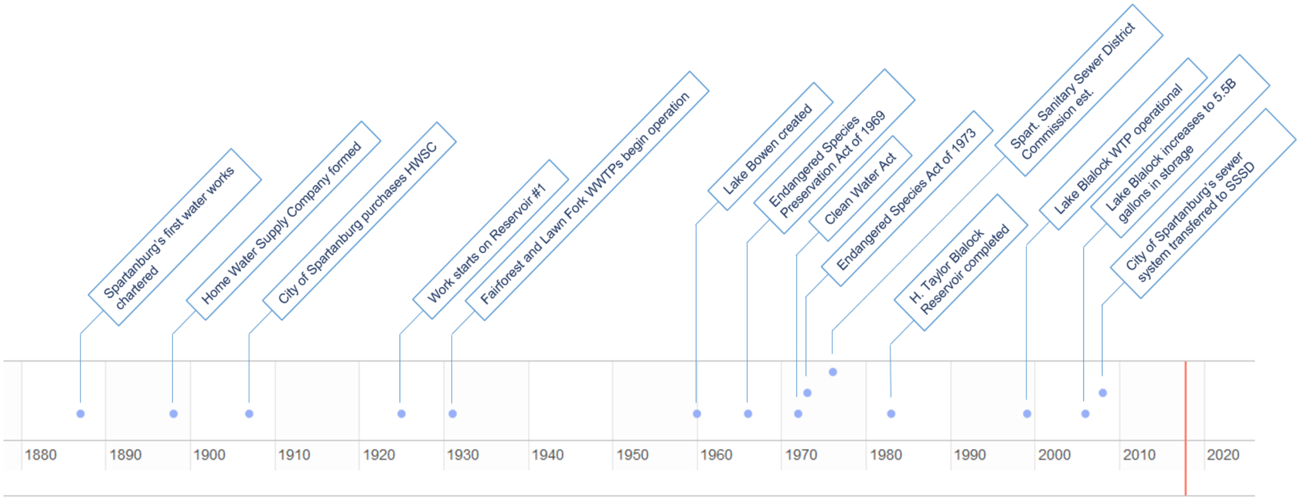

Figure 3-2: Select history of Spartanburg Water and water-related history (Source: spartanburgwater.org)

3.2 Hydrologic Characterization

The South Pacolet River and its tributaries constitute over 90 linear miles of rivers and streams. A USGS/Spartanburg Water partnership maintains three flow and/or stage monitoring stations in the vicinity of Lake Bowen and Municipal Reservoir #1 (Figure 3-3). While the gage just after Municipal

Reservoir #1 (2155500) does technically cover the entire watershed, its location just after the two water bodies makes watershed-only runoff calculations and assumptions difficult without more advanced modeling due to the influence of these reservoirs. As a result, the gage representing strictly watershed streamflow (2154790) was used for a majority of the nutrient loading calculations throughout this report. A snapshot of monthly average flow rates from 1990 to 2017 is shown for the three gaged streams in the watershed.

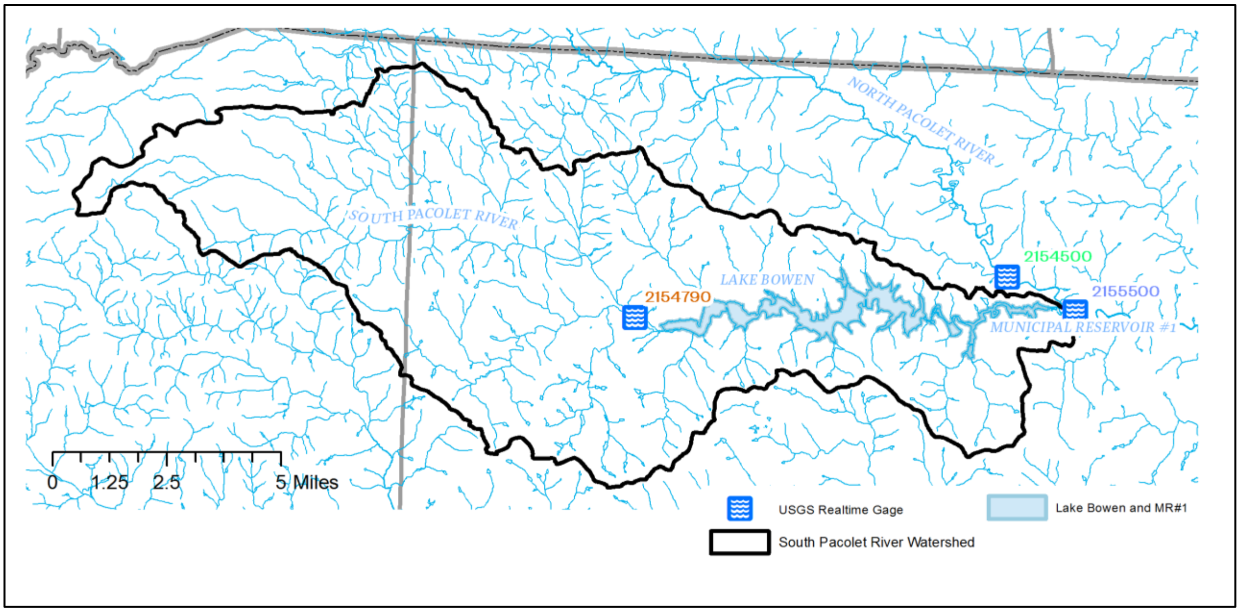

Figure 3-3: USGS real-time monitoring station locations and their respective station codes. Colors of stations are linked to colors on hydrograph shown in Figure 3-4.

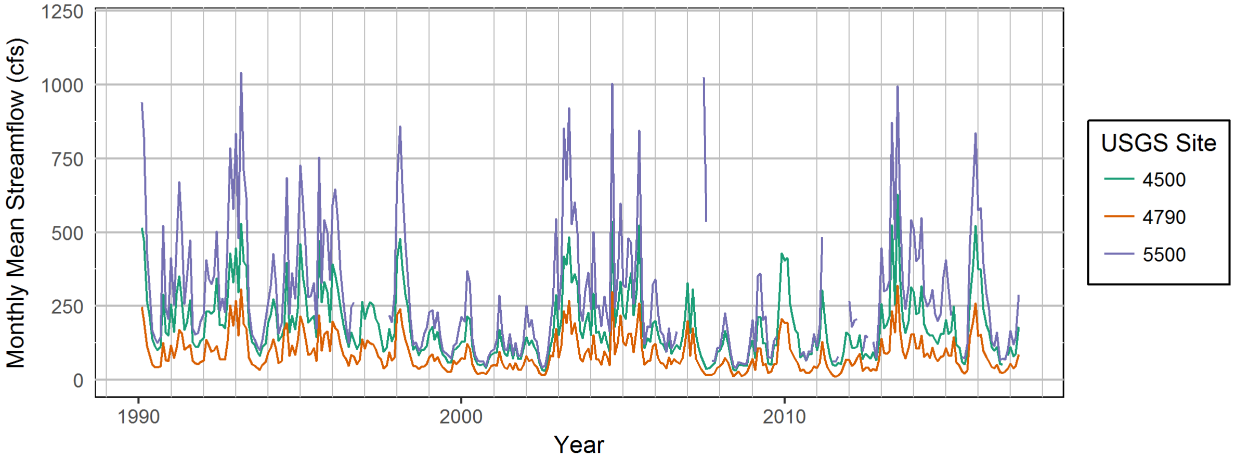

Figure 3-4: Monthly mean stream flow for the South Pacolet, North Pacolet, and the confluence of the two downstream from Municipal Reservoir #1

Quantifying various metrics of stream flow can identify ecologically-significant indices that can allow watershed managers to track land use changes occurring over time. Streams change under certain natural or manmade conditions over time. One metric that is useful in describing how streams respond to changes in land use is the "flashiness index". Flashiness refers to the frequency and rapidity of short term changes in streamflow, especially during stormwater runoff events. A "flashy" stream is one which has a significant peak of flow much higher than baseflow during rain events, which lasts only a short time before sharply returning to baseflow conditions. As a general rule, more pristine, forested watersheds should display much less flashiness in streamflow when compared to streams in close proximity to impervious surface development, steep slopes, or clay soils. A subset of the flow data for the three sites is shown in Figure 3-5. Periods of storms have larger spikes for watersheds that have "flashier" streams. While the South Pacolet River does not have large maximum flows when it does rain, the fact that its baseflow is much lower than the other two stations can be an indicator of flashiness.

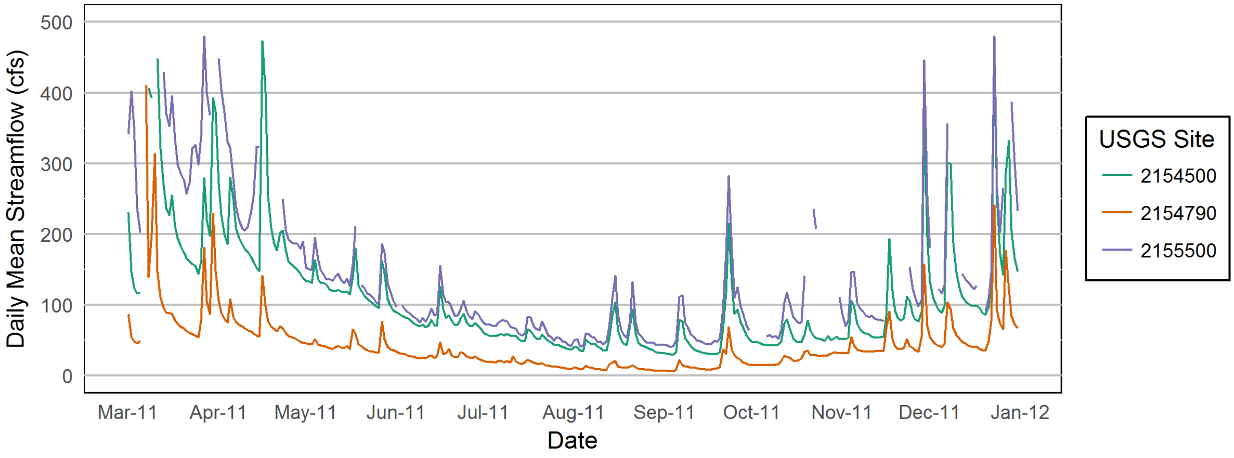

Figure 3-5: Daily mean flow data for calendar year 2011 at three gaging stations in South Pacolet River watershed

The Richards-Baker Flashiness Index is one recently-developed metric to quantify flashiness (Baker, et al., 2004). With a theoretical range from zero to two, this value was calculated for all three USGS stations in the vicinity of the South Pacolet River watershed for the period of 1990 – 2017, when the most comprehensive data for all three was available. Higher values of the index represent "flashier" streams. The result is shown in the table below.

Table 3-1: Richards-Baker Flashiness Index for three USGS stations in the South Pacolet River watershed.

Station	Drainage Area (sq. mi)	Average Annual Flashiness Index (1990 – 2017)
2154500	116	0.24
2154790	55	0.31
2155500	212	0.27

The South Pacolet River upstream of Lake Bowen is the flashiest of the three sites. This can likely be attributed to its close proximity to direct municipal discharges like Campobello, and it does not have a dampening effect of lake processes and manmade dam discharges. The site immediately downstream of the confluence of Municipal Reservoir #1 and the North Pacolet River is the least flashy. Additionally, smaller streams (by watershed size) are less flashy than larger ones (Baker, et al., 2004). As flow mixing from multiple stream networks occurs, stream flow changes are less correlated with huge influxes of stormwater-generated runoff.

Flashy streams can exist in rural watersheds. Increased agricultural practices that retain more runoff on site and slowly meter it as groundwater instead of surface water tend to have less flashy streams compared to farms without runoff control measures (tile drainage, no-till farming practices, and increased conservation reserve programs).

Because flashiness can be measured on an annual basis, it is interesting to observe if a stream is increasing or decreasing in flashiness over time. This can help watershed programs develop further BMP mitigation techniques at multiple scales if changing land use is changing stream geomorphology.

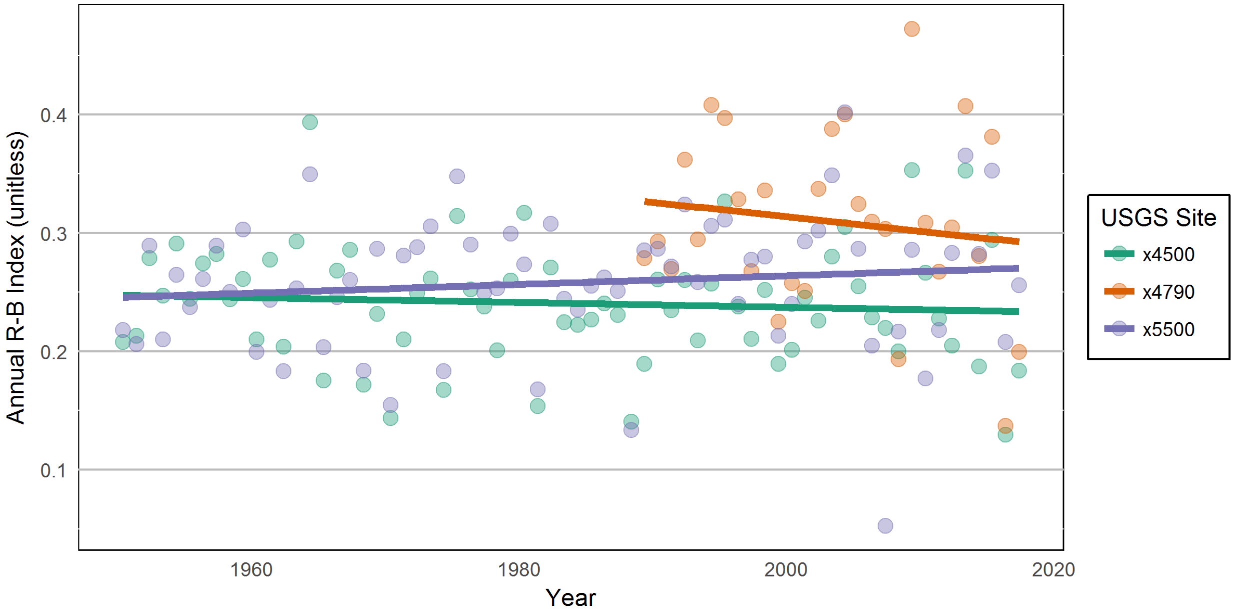

Figure 3-6: Flashiness index over time for three USGS gage stations in the watershed. Note that data is available since 1990 only for the South Pacolet station. Table 3-1 only calculates the flashiness index for that time period for all.

While Figure 3-6 seems to suggest that South and North Pacolet Rivers are becoming less flashy, the trend is not statistically significant, and should be monitored as the watershed develops further into the future.

3.3 Demographic and Land Use

3.3.1 Land Use

The South Pacolet River watershed is located in the Southern Piedmont ecoregion of South Carolina in Spartanburg and Greenville Counties. A majority of the 58,529 acres of the watershed (76%) resides in Spartanburg County. The largest land use category within the watershed is forest (47%), owing to the transition between the Southern Outer Piedmont to the Southern Inner Piedmont in Spartanburg County, and the foothills of the Blue Ridge Mountains in the western portion of Greenville County. While forests dominate the watershed's area in Greenville County, a large amount of agricultural land use is present in Spartanburg County, representing 30% of the total area of the South Pacolet River watershed (Table 3-2 and Figure 3-8).

Table 3-2: Land use summary of South Pacolet River watershed

Land Use	Area		Percent of Total
	(mi^2)	acres	
Forest	43.3	27,695	47.3
Agriculture	26.9	17,241	29.5
Herbaceous	*7.3*	*4,696*	*8.0*
Hay/Pasture	*19.6*	*12,515*	*21.4*
Cultivated Crops	*0.05*	*31*	*0.1*
Developed	14.5	9,250	15.8
Developed, Open Space	*11.9*	*7,604*	*13.0*
Developed, Low Intensity	*1.9*	*1,222*	*2.1*
Developed, Medium Intensity	*0.6*	*356*	*0.6*
Developed, High Intensity	*0.1*	*68*	*0.1*
Open water	3.2	2,069	3.5
Wetlands	1.9	1,237	2.1
Scrub and shrubland	1.2	744	1.3
Barren Land	0.5	293	0.5
TOTAL	**91.5**	**58,529**	**100.0**

Source: National Land Cover Dataset (USGS, 2011)

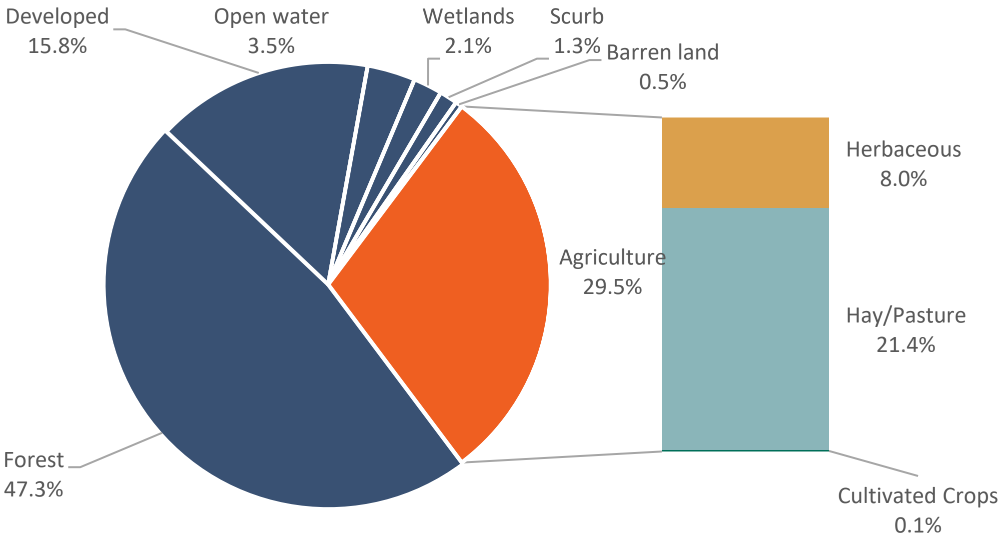

Figure 3-7: Visual representation of land use in the South Pacolet River watershed (NLCD 2011)

Although nearly a third of the watershed's area is dedicated to agriculture, only a minute fraction of that is classified as traditionally cultivated crop management. A large majority of the agriculture in the watershed is horse and cattle-related pasture. This presents unique water quality challenges compared to traditional cultivated crop management, as will be shown in load and concentration calculations later in the report.

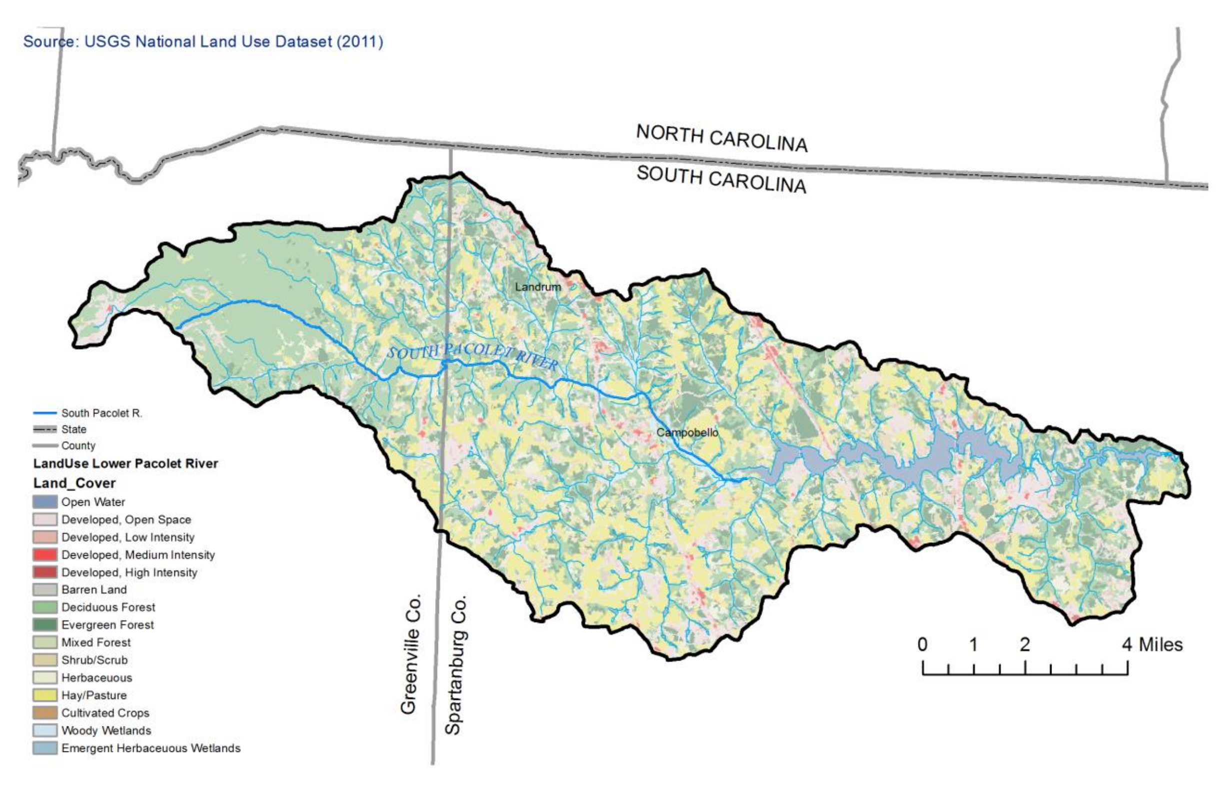

Figure 3-8: Land use map of South Pacolet River watershed

Roughly 16% of the watershed is classified as "developed"; however, a majority of that classification covers "Developed, Open Space", which is not as critical a component as directly-connected impervious area with respect to causing water quality and stream degradation. Most of the non-open space development is "Low Intensity" as of 2011, when the data was released.

As a rough measure in hydrologic research literature, watersheds with naturally healthy streams (diverse macroinvertebrate populations, high riparian cover, and preserved floodplain functionality) start to generally become impacted at about 10% total watershed impervious cover. As land gets converted from natural forest and meadow cover to pavement and building surfaces, changes to the watershed hydrology occur. As a rule of thumb, one could expect only about 5% of annual rainfall on a forested, pre-development plot of land to runoff the surface. Contrastingly, a post-development watershed can expect 50% of annual rainfall to be converted to runoff (Swank & Crossley, 1988)

As land gets converted from forested or prairie-like conditions to developed areas, a change in hydrology occurs. Impervious surfaces, such as streets and sidewalks, impact hydrology and water quality because they increase the volume of runoff and the rate at which it reaches streams. Often, developed areas are comprised of characteristic pollutants such as phosphorus and nitrogen (e.g. fertilizers), sediment (e.g. new construction, compacted soils), and heavy metals (e.g. asphalt degradation, automobile residue, cigarette butts). These pollutants become entrained in runoff and exported to receiving waters such as the South Pacolet River, Lake Bowen, and Municipal Reservoir #1.

The relationship between a watershed's percent impervious cover and receiving water quality has been well-documented (Schueler, et al., 2009). Based on 2011 land cover data, the entire 91 square mile watershed has 1.96% impervious cover (Figure 3-9). Of the watershed monitoring catchments outlined in green, the area just south of the Lake Bowen / Municipal Reservoir #1 dam, indicated with the arrow in the figure below, has the highest imperviousness at 7.4%. The next highest values of impervious area percentage for catchments in the figure are below 4%, indicating the potential for this area to result in more rapid changes in stream health in the future.

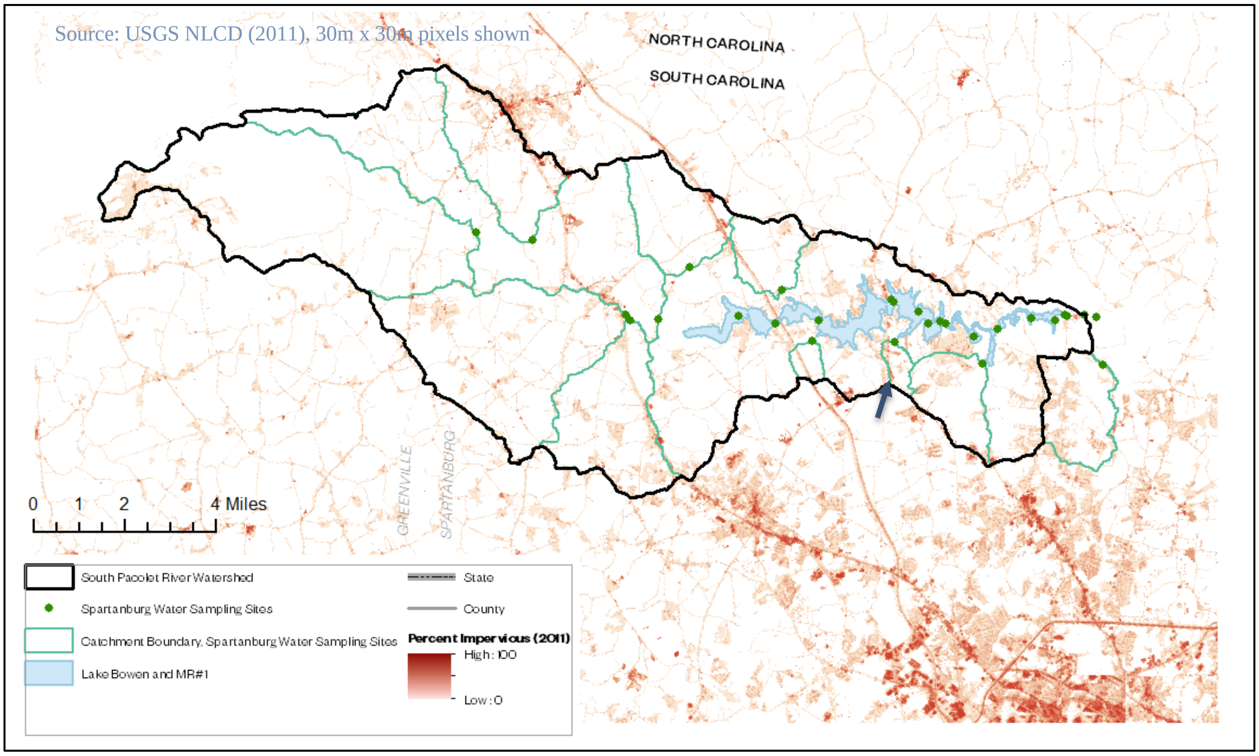
Source: USGS NLCD (2011), 30m x 30m pixels shown

Figure 3-9: Percent impervious cover for South Pacolet River watershed and surrounding area

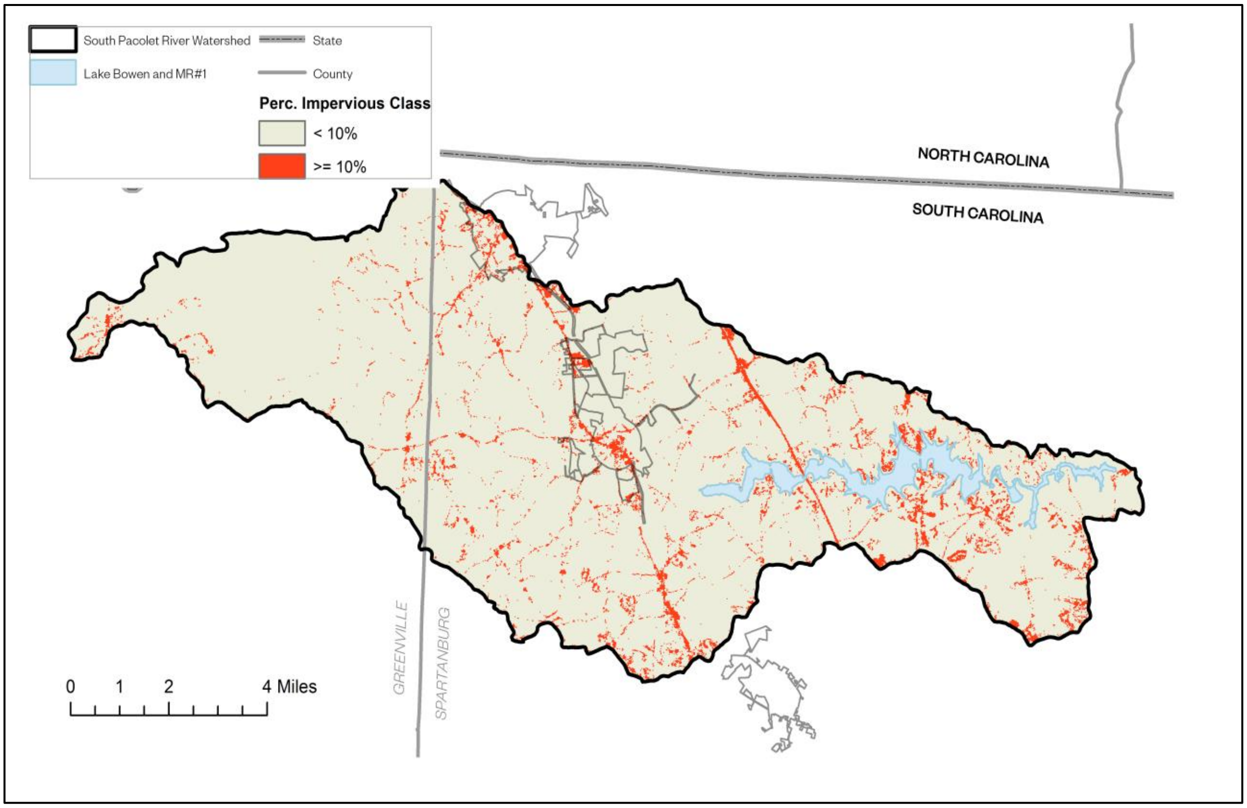

Figure 3-10: Classification of pixels (30m x 30m) containing 10% or more impervious area

The areas that exceed the 10% threshold discussed above are shown separately in Figure 3-10. Development south of the lake in unincorporated Spartanburg County, as well as development directly abutting Lake Bowen to the north can be easily seen. Additionally, a large source of impervious area in the watershed is related to transportation. Areas like Campobello and Landrum also contain pockets of land with more than 10% impervious cover.

3.3.2 Demographics

The watershed spans two counties that have historically shown population growth in rural areas. Specifically, the unincorporated areas south of Lake Bowen, north of Spartanburg, have developed rapidly. According to the data from the U.S. Census and the American Community Survey, average population growth in Spartanburg and Greenville Counties has averaged 1.7% and 1.0% annually since 1950, respectively. Development continues in both counties, with1-year annual county growth rates at their highest levels since the 2000-2010 decade. The estimated 2015 population living in the HUC-10 watershed is about 25,000 people, with a resulting land population density of 153 people per square mile. This is lower than the population densities of both Greenville and Spartanburg Counties (627 and 368 people per square mile, respectively).

A majority of the people and household units in the watershed, 71%, are classified as living in rural areas (U.S. Census, 2010). A quarter of the watershed resides in "urban areas", or census tracts and/or census blocks with total populations of 50,000 or more. Less than 4% reside in urban clusters, comprising 2,500 to 50,000 people. Per the 2010 decennial census, there are 9,815 total housing units in the watershed, which results in a residential density of 2.26 people per household unit.

3.4 Regulatory Framework

3.4.1 Federal Clean Water Act and Upper Broad River TMDL

Every even-numbered year, each U.S. state is required to assess streams and lakes and report their condition to the EPA under section 305(b) of the Clean Water Act (CWA). The South Carolina Department of Health & Environmental Control is responsible for collecting water quality information and reporting whether the water body is impaired, threatened, or in good condition.

Impaired waters do not meet water quality standards based on a designated use assigned to it by the state, which could include fishing, drinking, or recreational uses. The state also reports likely or measured causes of any potential impairments, which could be excessive nutrients, poor biological conditions, high heavy metal concentrations, or other factors. Once waters are identified as impaired, they are placed on the 303(d) list, which leads to the development of a pollution budgeting watershed management document known as a Total Maximum Daily Load (TMDL).

The South Pacolet River watershed contains six waterbodies or stream segments that have been assessed by South Carolina's Department of Health and Environmental Control (SC DHEC) (Table 3-3). For a reference to the locations of the items in the table, use the Map ID column and Figure 3-11.

Table 3-3: Assessed water bodies in the South Pacolet River watershed

Map ID	Waterbody ID	Location	Last Updated	Designated Use	Status	Cause of Impairment	TMDL Development Status
D	SCB-790	MOTLOW CRK. AT SR 888	2016	Aquatic Life Support	Impaired	Biology (Cause Unknown)	TMDL needed (Priority Rank 3)
B	SCB-302	S PACOLET RVR AT S-42-866 1 MI SE OF CAMPOBELLO	2016	Aquatic Life Support	Good	NA	NA
				Primary Contact Recreation	Not Supported	Fecal Coliform	TMDL completed
C	SCB-720	SOUTH PACOLET R. AT SR 183	2014	Aquatic Life Support	Good	NA	NA
A	SCB-103	SPIVEY CK AT S-42-208 2.5 MI SSE OF LANDRUM	2016	Primary Contact Recreation	Fully Supported	Fecal coliform (Pathogens)	In TMDL
E	SCB-340	LAKE BOWEN NEAR HEADWATERS, 0.4 KM W OF S-42-37	2014	Aquatic Life Support	Good	NA	NA
				Primary Contact Recreation	Good	NA	NA
F	SCB-339	LAKE BOWEN 0.3 MI W OF SC 9	2014	Aquatic Life Support	Good	NA	NA

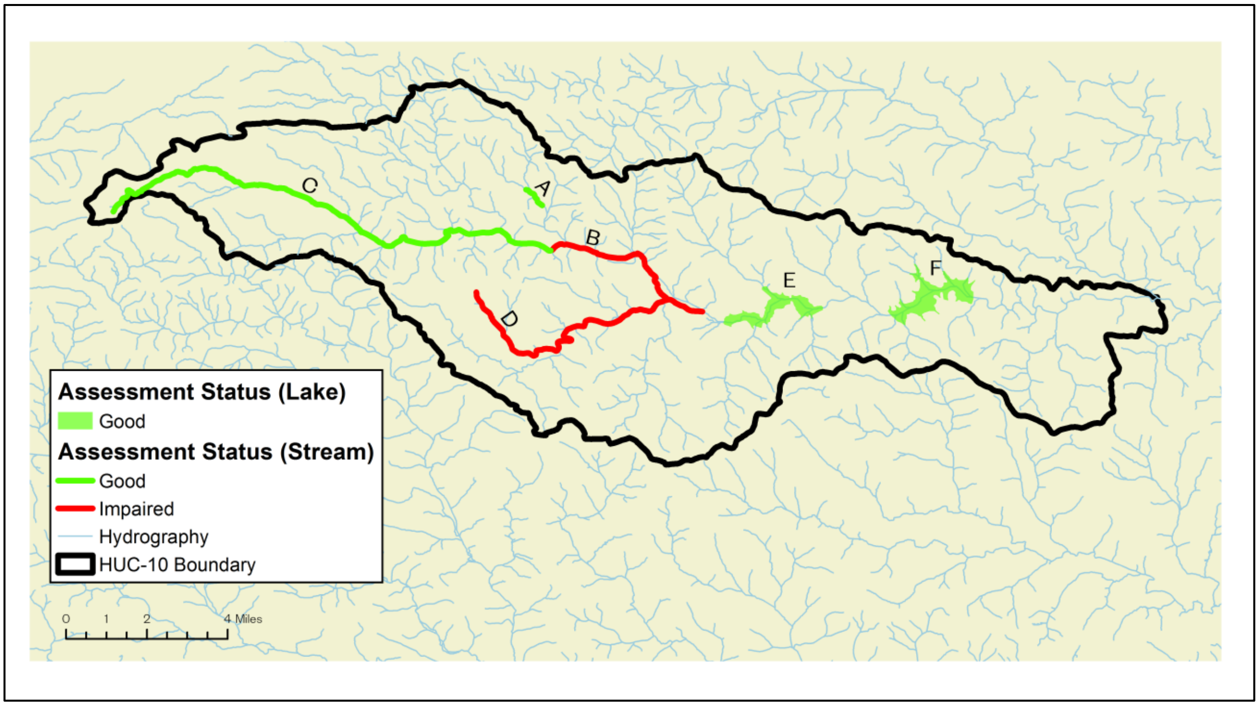

Figure 3-11: 305(b)-assessed water bodies in South Pacolet River watershed in 2014 included in the Upper Broad River TMDL, including 2016 updated 303(d) listings

Sites B-302 and B-102 were placed on the South Carolina's 303(d) list of impaired waters in 2002 for violations of the fecal coliform bacteria standard. In September 2004, a TMDL was developed for the Upper Broad River watershed, which includes the South Pacolet Watershed, to address fecal coliform bacteria at sites including the two shown in Table 3-3. Sources identified in the TMDL are some of the sources that will be discussed further in the next section, and include wildlife, agricultural activities and grazing, failing septic systems, and runoff from developed areas. As of February 2017, B-302 does not meet its supported use designation, while B-103 has been designated "fully attained" (South Carolina Department of Health & Environmental Control (SC DHEC), 2017).

Lake Bowen currently supports the following designated uses:

- Fish consumption
- Primary contact recreation
- Aquatic life support
- Drinking water

Municipal Reservoir #1 does not allow primary contact recreation or surface fishing due to the proximity to the primary intake at R.B. Simms WTF. As of 2014, all designated uses were being met under the US EPA waterbody assessment summary.

3.4.2 National Pollution Discharge Elimination System (NPDES)

NPDES permitting is part of the Clean Water Act, which regulates discharges into waters of the State. Currently, there are 8 sites or facilities in the South Pacolet River watershed that have active NPDES permits. General Permittees in Table 3-4 do not require a schedule of compliance, meaning they do not have an enforceable sequence of interim benchmarks leading to a CWA and regulatory compliance target (i.e. a wastewater treatment facility).

Table 3-4: NPDES Permittees in the watershed (data from 2001)

Permittee	MGD	Permit #	Permit Type
Spartanburg Water / Simms WTF	1.17	SCG643002	Minor Domestic
Spartanburg Water WWTP/Simms WWTP	0.012	SC0030279	Minor Domestic
Links O' Tryon Golf Community LLC	0.024	SCG0042684	Minor Domestic
Little Acres Sand/S Pacolet Mine	M/R	SCG730178	Minor Industrial
South Carolina Department of Transportation (SC DOT)	n/a	040001	MS4
Spartanburg Water Landrum WTF	0.032	SCG645029	Minor Domestic

3.4.3 Surface Water Withdrawal

Spartanburg Water has a water use pumping rate capacity of 64 MGD at the R.B. Simms Water Treatment Facility. The System supplies 54,989 residential customers, 6,366 commercial customers, and 54 industrial customers. SW operates three water treatment plants: R.B. Simms Water Treatment Facility, Myles W. Whitlock, Jr. Water Treatment Facility, and the Landrum Water Treatment Facility. R.B. Simms and the Landrum WTP are located within the watershed; however, the direct intake of the Simms source water—Lake Bowen and Municipal Reservoir #1—are fed by nearly the entirety of the watershed, while the Landrum facility withdraws from a small upper-subwatershed within the larger context of the South Pacolet. The Landrum plant intake is in Hogback Creek located near the top of Hogback Mountain and Vaughn's Creek near the Lake Lanier headwaters. In the state as a whole, 22% of residents get their drinking water from non-public drinking water services (SC DHEC, 2015) . Given the rural nature of this watershed, it is likely that many of the residents outside of developed clusters have private wells.

4. Causes and Sources of Pollutant Load

4.1 Data Source and Inventory

Monitoring was conducted by Spartanburg Water at multiple watershed and lake grab sample stations over the last decade. These stations collected various physical, biological, and chemical data that provide a strong basis for future implementation of nutrient-reduction measures, as watershed stakeholders will have a pre-management plan benchmark with which to compare. The sampling site locations are illustrated in Figure 4-1. Table 4-1 and Table 4-2 summarize constituent type (TN=Total Nitrogen, TP=Total Phosphorus, TSS=Total Suspended Solids, DO=Dissolved Oxygen, Chlor-a=Chloraphyll-a, algae=Total algae counts), location name, and duration for stream sites in the watershed and for lakes, respectively.

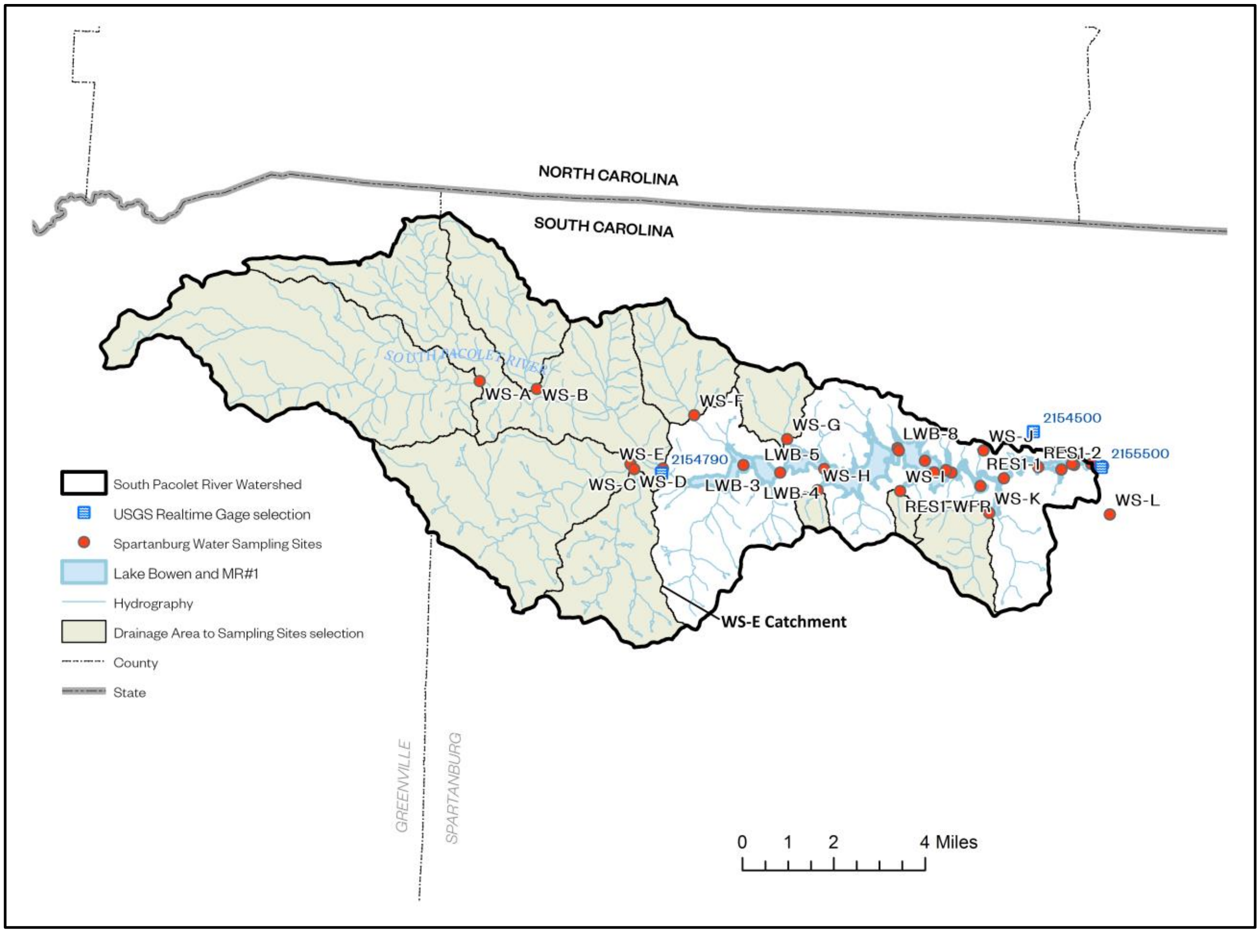

Figure 4-1: Map of Spartanburg Water sampling sites in the South Pacolet River watershed

Table 4-1: Watershed monitoring station data summary for nutrients and sediment[1]

Station ID	Span of Data		Drainage Area (mi^2)	Percent Impervious Cover (2011)	Number of Observations		
	Start	End			TN	TP	TSS
WS-I	09-29-2009	10-31-2016	0.53	7.4	16	65	65
WS-H	09-29-2009	10-31-2016	0.50	3.1	16	65	65
WS-F	09-29-2009	10-31-2016	4.06	2.2	16	65	65
WS-G	09-29-2009	10-31-2016	2.25	2.3	16	65	65
WS-J	01-30-2007	08-31-2009	--	--	0	28	27
WS-M	*02-22-2016*	*05-23-2016*	*22.52*	*NA*	*4*	*4*	*4*
WS-D	*02-02-2016*	*10-31-2016*		*NA*	*15*	*15*	*15*
WS-B	01-11-2016	10-31-2016	4.99	3.9	16	16	16
WS-N	*02-22-2016*	*05-23-2016*	*9.62*	*NA*	*4*	*4*	*4*
WS-C	02-02-2016	10-31-2016	12.18	1.6	15	15	15
WS-A	01-11-2016	10-31-2016	17.26	0.6	16	16	16
WS-E	01-30-2007	11-01-2016	55.4	1.6	28	105	97
WS-L			3.49	*NA*			
WS-K	01-30-2007	12-28-2010	2.77	3.3	0	53	52

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[1] Sites in grey italics are outside the watershed limits downstream of the South Pacolet River

Table 4-2: Lake Bowen and MR1 monitoring station data summary for nutrients and sediment

Station ID	Span of Data		Lake Depths Sampled (ft)[1]	Number of Observations (all depths)				
	Start	End		DO	TP	Chlor-*a*	Algae	TN
LWB-10	09-30-2009	11-01-2016	*s*, 3, 6, 9, 18, *b*	197	229	180	106	133
LWB-12	09-19-2016	11-01-2016	*s*, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, *t*, *b*	61	13	7	13	13
LWB-4	09-19-2016	11-01-2016	*s, b*	10	10	10	10	10
LWB-5	09-30-2009	11-01-2016	*s*, 3, 6, 9, 12, 15, 18, *b*	120	125	59	74	76
LWB-9B	09-19-2016	11-01-2016	*s*, 3, 6, 9, 12, 15, 18, 21, 24, 27, *t, b*	55	12	7	12	12
LWB-8B	09-30-2009	11-01-2016	*s*, 3, 6, 9, 12, 15, 18, 24, 27, *b*	137	126	58	74	76
LKW-cb	01-30-2007	08-31-2009	*g*	21	28	--	--	--
LWB-dam	01-30-2007	10-24-2016	*s*	43	65	3	35	37
RES1-1	09-20-2016	10-24-2016	*s*, 3, 6, 9, *b*	19	8	6	8	8
RES1-100	09-20-2016	10-24-2016	*s*, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, *t*, *b*	98	19	15	8	8
RES1-12	09-30-2009	11-16-2009	3, 18,	6	6	4	--	--
RES1-15	09-30-2009	10-25-2011	3, 18	8	6	4	--	--
RES1-2	09-20-2016	10-24-2016	*s*, 3, 6, 9, 12, 15, 18, 21, 24, *b*	75	18	14	8	8
RES1-MUDCRK	09-16-2015	10-24-2016	*s*	18	23	2	21	23
RES1-RLMS	09-16-2015	10-24-2016	*s*, 1, 3. 6, 9, 12, *b*	52	74	4	70	74
RES1-INT	01-29-2010	11-04-2016	*s*, 3, 6, 9, 12, 15, 18, 21, 24, 27, *b*	2,384	118	186	697	96
RES1-INT25yds	09-16-2015	12-28-2015	*s,* 9	30	--	4	70	74
RES1-WFR	09-16-2015	10-24-2016	*s,* 3, 9, *b*	45	74	4	70	74

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[1] *s* = surface, *b* = bottom, *g* = general (i.e. unknown depth), *t* = thermocline

Sample sites in the watershed (“WS”) were re-named for simplification based on absolute distance northwest from 0° Latitude, 0° Longitude (e.g. the sampling site furthest to the northwest is WS-A). All of the data were organized, processed, and visualized using the open source R Statistical Software (R Core Team, 2013). Site names were grouped based on monitoring maps and a GIS layer provided by Spartanburg Water. About 28% of all measured data for all sites were flagged as at or below minimum laboratory detection limits. As such, data points were multiplied by 0.5 for the purposes of this report following standard procedures used in summary statistics of water quality data. Because nitrate (NO_3) and nitrite (NO_2) were measured as nitrogen, they were summed and lumped together as nitrate/nitrite-N where applicable.

4.2 Water Quality Constituents of Interest

Various chemical, physical, and biological parameters were measured at the sampling sites depicted in Table 3-2. The data generally analyzed for the purpose of this report were nutrient constituents, sediment, and chlorophyll-a for Lake Bowen and Municipal Reservoir #1. While monitoring data exists outside of the watershed due to the extended jurisdiction of Spartanburg Water's distribution system, the analysis results are primarily restricted to sampling sites within the HUC-10 boundary.

Below is a short summary of each constituent of interest and its general effect on the aquatic ecosystem, along with a later visualization and discussion of their presence in the South Pacolet River or the two reservoirs.

4.2.1 Nitrogen

Nitrogen is one of the most common elements in nature, and thus is present in many forms throughout the physical environment. Organisms depend on nitrogen in order to either build proteins needed for cellular function and growth, or as a carrier of oxygen groups needed in the processing of carbon. As a general rule of thumb, nitrogen is considered more limiting (i.e. is the least available) nutrient in *freshwater* ecosystems, meaning its presence in limiting environments correlates well with the responding growth of aquatic lifeforms, although this is not a definitive trait of all waterbodies and watersheds. In contrast to phosphorus, nitrogen is highly-mobile and does not easily accumulate in soils, meaning it can wash off and become part of the aquatic ecosystem relatively easily based on various land use practices.

Nitrogen in the aquatic ecosystem can exist in multiple forms, including:

- dissolved nitrogen gas (N_2)
- organic nitrogen, typically bound to larger carbon structures or in proteins
- ammonia (NH_3) and ammonium (NH_4^+)
- nitrite ion (NO_2^-)
- nitrate ion (NO_3^-)

For the ammoniacal and nitrate/nitrite species, the pH of the water and/or the microorganism metabolism in that area will dictate which form the ion will take; for instance, in most waters at neutral pH, ammonium (NH_4) is the more common form. Ammonia can also be created in the environment simply by the breakdown of organic matter and NH_4 into NH_3. At a pH of 7, most of this resulting NH_3 gets converted back into NH_4, but at pH levels nearing 9, the ammonia concentration begins to increase rapidly in equilibrium.

Concentrations of NH_3, however, are often low in non-problematic waters—however even moderate amounts of NH_3 in the aquatic environment are highly toxic to fish. As the pH and temperature of water increases, the levels and toxicity of ammonia increases. Algae and aquatic plants, on the other hand, are often not negatively impacted by ammonium in the water—they often used the no-ionized form (NH_3) as a nutrient. Because ammonia in surface waters is very temperature and pH dependent, SC DHEC does not have a uniform numerical standard. Instead, they provide equations as guidance based on pH, temperature, duration of the exposure, and the life stage of the fish (SC DHEC, 2014). Generally speaking, the freshwater toxicity range begins above about 0.53 mg/L NH_3 (Oram, 2014).

Ammonia primarily originates from commercial fertilizers, industrial chemicals, the decomposition of organic matter like manure and detritus, gas exchange with the atmosphere (of which 78% is elemental Nitrogen), forest fires, animal and human waste, and nitrogen fixation processes, and can be introduced to waters either via point sources (wastewater treatment plants, municipal discharges), or through non-point sources such as agricultural runoff, decomposition processes, and septic tank discharges. Finally, a large quantity of nitrogen can get introduced through deposition of particulates from the atmosphere that contain nitrogen. In the upstate region of South Carolina, an average of about 4.2 lb-TN/acre/year are deposited as dry deposition, while about 3 lb-TN/acre/year are introduced when rainfall interacts with these compounds in the air as particulates or gases, and then wash into streams and lakes (NADP, 2017).

Nitrate can be formed from the decomposition of organic nitrogen via the nitrification process. This pathway is often expressed in the application of animal-based manure on farmlands in the United States. Organic N gets broken down into ammonium (NH_4) groups, which are broken down further by bacteria in soils to nitrate and nitrite, which are easily washed off to surface waters or percolated into the groundwater table. Because the conversion of organic nitrogen and ammonium into nitrites and nitrates requires the presence of oxygen, water bodies with high amounts of nitrogen often result in lowered levels of dissolved oxygen in locations with high metabolism by sediment bacteria, phytoplankton, algae, or aquatic plant species. Only in localized areas with virtually no oxygen present (such as the bottom of lake sediment) can the resulting nitrate be transformed into the inert gas N_2, which dissolves and is eventually released to the atmosphere. Furthermore, increased biological activity due to nutrient loading into *streams* can be problematic because fish species in those streams may be adapted to narrow ranges of DO, and thus when the stream concentrations are perturbed, their reproductive and metabolic stress may increase. This is especially important in areas with cold-water, sensitive trout streams.

Nitrate itself can pose a risk to human health. Its presence in drinking water can cause methemoglobinemia (“blue baby syndrome”) in infants less than six months of age if ingested at high doses. The current EPA standard for nitrate in drinking water in the United States is 10 mg/L nitrate-nitrogen. While Spartanburg Water has no problem with nitrates in their system (non-detect is the most common finding in the last few water quality reports), it is important that drinking water outside of Spartanburg Water’s preview—namely private groundwater wells in rural areas—be cognizant of the nitrate levels in the environment.

Even in watersheds that have not been impacted by human development or land use change, there is a background level of nitrogen that can be quite high; however, this is primarily expressed in the form of organic and immobile nitrogen (Novotny, 2003). Even agriculturally-derived nitrogen that does not get washed away into direct surface runoff can still enter surface waters at alarmingly-high levels through the groundwater system. Sediment that is eroded from the landscape can contain nitrogen in the form of organic matter and NH3, which are often not available to plant life. These constituents can be converted to the more mobile nitrate and ammonia species, which are readily utilized by aquatic lifeforms including algae. In all, the inter-relationships between dissolved oxygen, nitrogen, carbon, and fish are complex and often require arduous modeling and data collection efforts.

4.2.2 Phosphorus

Phosphorus occurs naturally in soil through the weathering of phosphate minerals over time and in wildlife waste. Sources of phosphorus from human-induced activities include industrial, agricultural, and residential fertilizers, manure application in agriculture, sewage (septic tanks and direct wastewater treatment plant discharges), and detergents. Phosphorus is significant because plants require it as a nutrient in their metabolism, and uptake it from soils in which it is present. The proportion of phosphorus compared to carbon and nitrogen (often expressed as the C:N:P ratio) in phytoplankton is widely seen as 106 C to 16 N to 1 P, meaning phosphorus is often a limiting nutrient, especially in ocean ecosystems. It is important to plants in that phosphorus makes up the nucleic acids, proteins, and energy molecules of the cell. Plants without enough phosphorus are often stunted, which is why low-phosphorus soil is often anathema to highly-productive agricultural yields.

Phosphates (PO_4^{3-}) are formed from phosphorus compounds, or added directly into fertilizers or originate in human or animal waste. Phosphates exist in three forms: orthophosphate, metaphosphate, and organically-bound phosphate. Orthophosphate (also known as *soluble reactive phosphorus*, or SRP) is the form that plant cells can take up, and is the form which is most often measured to discern the dissolve phosphorus level of a water ecosystem. In natural water systems, SRP is often found at very low concentrations in unpolluted waters with healthy amounts of oxygen. This is due to the fact that SRP in moderate to small quantities are bound to small soil particles and do not wash out as easily as nitrate. However, over time and with excess fertilizer application, soils can become overloaded with bound phosphate, and any excess easily dissolves in storm water runoff and can be transported to surface waters.

SRP in excessive amounts can lead to “overproduction” of the lake or reservoir, with a disproportionate amount of biomass being produced by primary producers such as algae. When overproduction occurs, the eventual die-off of this biomass can create a highly-unstable oxygen uptake episode when the algal cells decompose (which requires oxygen). The bacteria doing the decomposing use dissolved oxygen in the process, and themselves release phosphorus as a result of their decay. This phosphorus may be bound in the sediments of lake systems after those bacteria die off and settle. Because this phosphorus may become released into the lake from the sediment bottom in anoxic conditions, it is important to monitor the dissolved oxygen levels at the bottom of the lake.

Not only can anoxia occur in eutrophic (or “well nourished”) systems, but lack of biological diversity can follow, which could cause an unstable food supply in the lake ecosystem. Finally, some algae produce chemicals that can be toxic or malodorous to humans, such as cyanobacteria, which can produce cyanotoxins or malodorous compounds such as 2-methylisoborneol (MIB).

4.2.3 Sediment

Sediment is the broad term that encompasses soil that is delivered via stream flow or wet-weather runoff. Sediment is often measured *in-situ* as “Total Suspended Solids” (TSS) or, as is more often the case in fluvial geomorphology, “Suspended Sediment Concentration” (SSC). TSS is the more common parameter due to its ubiquity in both water and wastewater fields, and is the parameter that will be discussed throughout this report. The most common sources of anthropogenic erosion are from agriculture, changes in impervious cover from development, and streambank/shoreline erosion.

Excess sediment in surface waters is most often attributed to erosion. Erosion can occur as a result of land disturbance without the proper post-construction engineering practices to mitigate runoff flow force. When water runs across the land, it can physically dislodge soil and transport it long distances. Because of the large land area associated with agricultural land use change, agriculture can be responsible for large amounts of a watershed's sediment budget. The following conditions can cause excessive agricultural erosion (Novotny, 2003):

- Farming on steep slopes without terraces
- Frequent tilling of the soil
- Poor crop stands
- Intense cultivation near streams
- Elimination of vegetated stream buffers
- Feedlots close to streams or without adequate sedimentation ponds
- Exposure of bare soil between harvests or in rotating to different crops

Erosion as a result of new development most often occurs during the construction process. Counter-intuitively, after construction has been completed and the land is stabilized by the building of impervious surfaces and lawns, the rate of erosion often drops below the level of erosion prior to development. However, the result of land use change often produces much more stormwater runoff volumes and at higher flow rates, which can dislodge stream bank or bed sediment, resulting in a net erosion increase. Streams that drain areas with new or dense development that have been disconnected from the floodplain and have vertical exposed banks are often signs of streams that were or are being eroded due to this phenomenon.

Sediment transport and erosion are typically exacerbated in highly-sloped watersheds with highly-erodible soils (pure silts, sands, and, to a lesser extent, clay). Sediment in lake ecosystems often causes a decrease in dissolved oxygen levels due to the blocking of sunlight from reaching photosynthetic, oxygen-producing organisms. As opposed to various chemical constituents like SRP and chlorophyll-a, there is not widespread agreement on a threshold for TSS measurements, above which signals definite problems in the water body such as algal growth or taste and odor concerns. Instead, some jurisdictions set broad, highly-variable standards based on the designated use, such as "TSS shall not reduce light penetration" or "not cause an unnatural physical property change in turbidity, color, etc." Light penetration, itself correlated with the amount of sediment or particulates in the water, has variable standards based on designated use and ecology. In South Carolina, the freshwater standard for turbidity is 25 NTUs in lakes, providing the existing uses are maintained by the lake (SC DHEC, 2014). The American Water Works Association (AWWA) states that 5 NTUs is acceptable for recreational purposes. North Carolina allows up to 10 NTUs for trout waters, 25 NTUs for non-trout streams, and 50 NTUs for non-trout lakes (Fondriest Environmental, Inc., 2017). It is important to note that turbidity in lakes is not only the result of erosion causing exogenous sediment to enter the lake system, but is an indicator of algal biomass, which itself can prevent light from penetrating the water column.

Best management practices used in both agriculture and in the developed land use stormwater context are most effective in reducing sediment concentrations when compared to other constituents. SC DHEC has a comprehensive clearing house of runoff control, sediment control, and erosion prevention BMPs within their BMP Handbook (SC DHEC, 2005).

4.2.4 Chlorophyll-a

Because eutrophication—the process of lakes becoming nutrient rich—is not itself synonymous with "pollution", it is important to look at the parameters that are themselves responses of nutrient pollution, such as chlorophyll-a. Chlorophyll-*a* is the chemical pigment in algal cells that give primary producers their green color. Because they are indicative of primary production, their concentration in surface waters is directly connected with the amount of algae or photosynthetic plankton living in the water.

Table 4-3: Ranges of values for various parameters that encompass "trophic state" of lake

Indicator	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic	Source
Chlorophyll-*a* (ug/L)	0 – 2.6	2.6 – 20	20 – 56	56 – 155+	Carlson et al. (1996)
Secchi-transparency (m)	>8 – 4	4 – 2	2 – 0.5	0.5 – <0.25	Carlson et al. (1996)
TP (mg/L)	0 – 0.012	0.012 – 0.024	0.024 – 0.096	0.096 – 0.384+	Carlson et al. (1996)
Hypolimnetic oxygen (% saturation)	>80	10 – 80	<10	--	US EPA (1974)

4.2.5 Dissolved Oxygen

Dissolved oxygen is highly linked to fish and aquatic biota well-being in many freshwater lakes. Dissolved oxygen problems are particularly evident where shallow or highly-productive streams enter deeper reservoirs. Here, photosynthesis, and thus, overall ecosystem production, is occurring at higher rates in the stream due to the ability of light to penetrate deeper into the water column than in a lake. At that confluence point, streamflow with highly productive organisms in the water column is followed by a deeper section, where respiration is the primary metabolic process that is occurring (because light is not penetrating very far into the water column in that deeper reservoir section to support photosynthesis). At this headwater location of the reservoir, only the top layer is producing photosynthetic algae, which may result in lower oxygen levels at more moderate depths (Novotny, 2003). Additionally, increased BOD levels, combined with excessive organic material, can lower oxygen locally.

Stratification of reservoirs can impact water quality in important ways. During summer and early fall months a "thermocline" can divide the surface portion ("epilimnion") and bottom portion ("hypolimnion") of a lake cross section. In stratified waters, diffusion of constituents from the top to the bottom portion can be reduced, which may deprive the hypolimnion of oxygen during that time period.

The South Pacolet River is classified as a TN (trout-natural) water body from its headwaters to highway 116, but this does not represent the majority of the stream in this watershed. The portion from Hwy 116 to the Pacolet River, however, is classified as FW (Freshwaters) per SCDHEC R.61-69. The SCDHEC standard for FW streams is to have daily average dissolved oxygen concentration greater than 5.0 mg/L, with a minimum dissolved oxygen concentration of 4.0 mg/L.

4.3 Causes and Sources of Impairments

4.3.1 Sewer Infrastructure

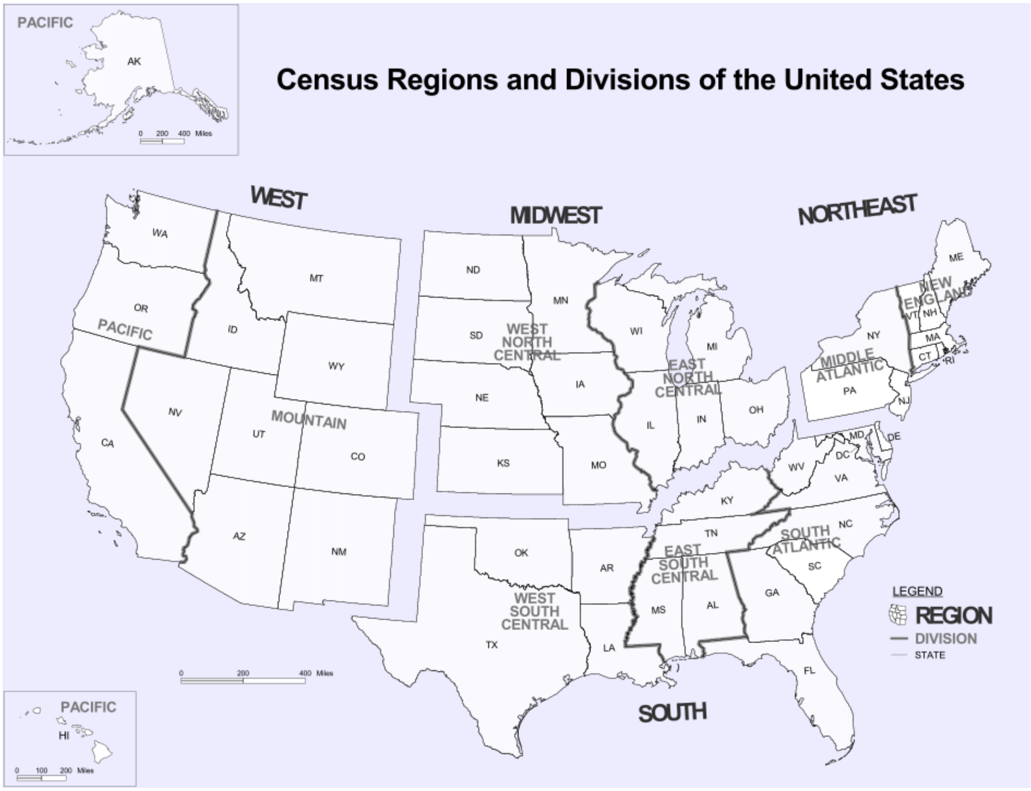

Figure 4-2: Census regions and divisions of the United States (U.S. Census Bureau)

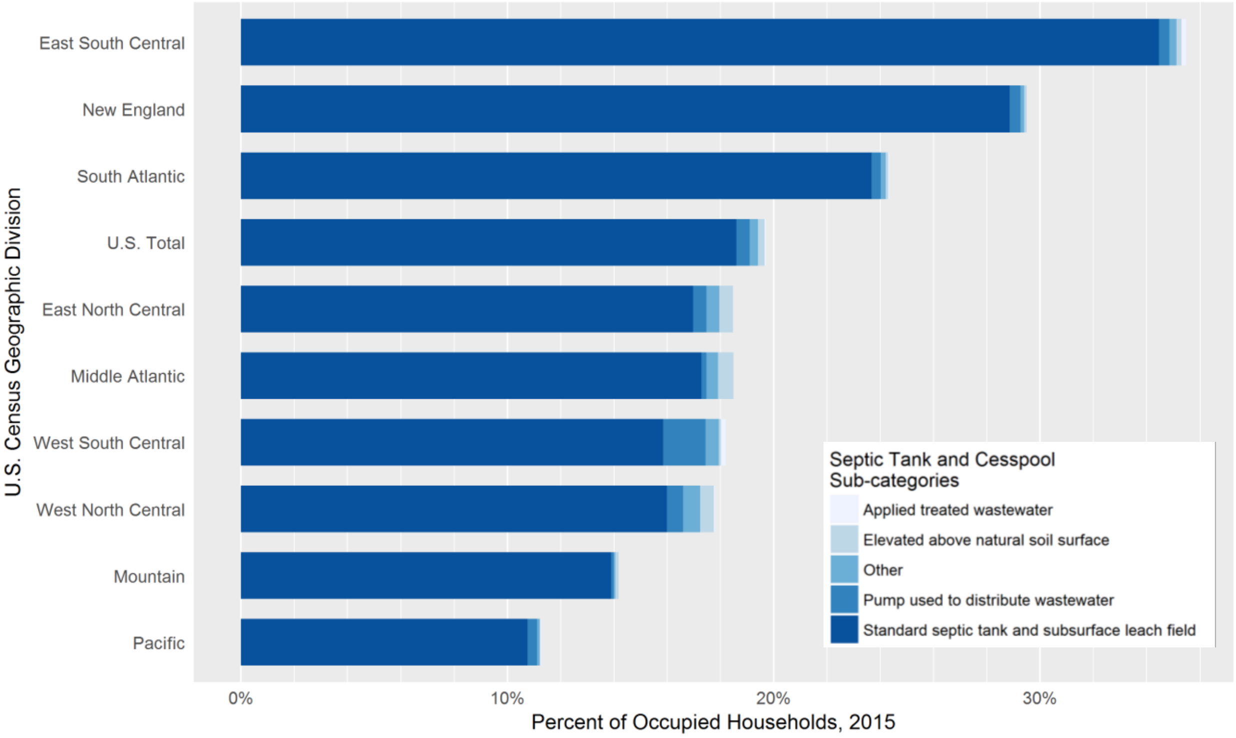

Figure 4-3: Proportion of U.S. households with septic systems, by category of septic system (American Housing Survey, U.S. Census Bureau, 2015)

Within the South Pacolet River watershed, septic system usage is far more prevalent than state or census geographical division averages. The proportion of rural vs. "urban" (U.S. Census Bureau definition) populations using septic vs. public sewer from the 1990 census (the last census that collected local sewage disposal metrics) was applied to the 2010 census estimate of watershed population and housing unit count to determine what percentage of residents use septic systems. It was found that 71% of people in the watershed are classified as "rural" and 29% as urban. Multiplying those populations by rates of septic use of 76% and 13%, it was estimated that nearly 15,000 people, or 58%, use septic sewage systems. Based on a count of household units in the watershed totaling 9,815, it was estimated that 6,555 households, or 67% of housing units, have septic systems (Figure 4-4).

Failed or poorly-functioning septic systems can pose a threat to public health or environmental quality by introducing pathogens such as *Escherichia coli*, *Salmonella*, and *Shigella* to surface waters that may be used for recreation or drinking water supplies (such as Lake Bowen, M.R.#1, and Lake Blalock). Typical septic systems discharge highly-reduced, inorganic nutrients such as ammonium, soluble reactive phosphorus (SRP), and sulfide (H_2S). In a properly functioning system, the soil and bacteria in the leachfield will oxidize these constituents. In systems that short-circuit the leachfield due to soil or topographic issues, or in systems that have structural failures in the tank itself, SRP and dissolved ammonium ions can reach surface waters (Richards, et al., 2016). These chemical constituents can create localized eutrophication conditions, which may lead to excessive algal growth, taste and odor problems with drinking water supplies, and biological integrity decline (Richards, et al., 2016).

For the purposes of estimating septic system loading, the US EPA STEPL (Spreadsheet Tool for Estimating Pollutant Loads) model was used. It was assumed that 67% of households in the watershed use a septic system, which serves 58% of the population in the watershed, which is likely true especially in the western portion of the watershed (Figure 4-4). Assuming that each household has one septic tank, it was estimated that 6,555 septic tanks are sited in the HUC-10 watershed boundary. Loading of nutrients by septic tanks was estimated using a fixed failure rate of all systems, which was supplemented by a conservative estimate of 10%, and assumed wastewater characteristics below[1]:

- Average concentration of TN from septic overcharge = 60 mg/L
- Average concentration of TP from septic overcharge = 23.5 mg/L
- Typical septic overcharge flow rate of 70 gal/person/day

Assuming that 58% of people use septic in the watershed and a 10% failure rate, which is assumed to discharge the above wastewater concentrations directly to the environment, the total nutrient load contribution from septic systems is estimated to be:

- Total load, TN = 19,336 lb/yr
- Total load, TP = 7,573 lb/yr

Based on the overall loading estimated in the watershed from monitoring data, loading from failing septic systems could represent as much as 11% and 43% of the TN and TP load from the watershed, respectively.

Aging sanitary sewer pipes can impact water quality by leaking, periodic sanitary sewer overflows caused by blockages, or other malfunctions due to deterioration. These issues release untreated sewage into the environment and therefore increase the nitrogen and phosphorus load entering water bodies. Determining the loads imparted by leaking or overflowing collection systems is very difficult in that it is entirely dependent on the source of the waste load, the volume flowing, and the frequency and duration of the event. Consequently, this load was not explicitly accounted for in the watershed analysis.

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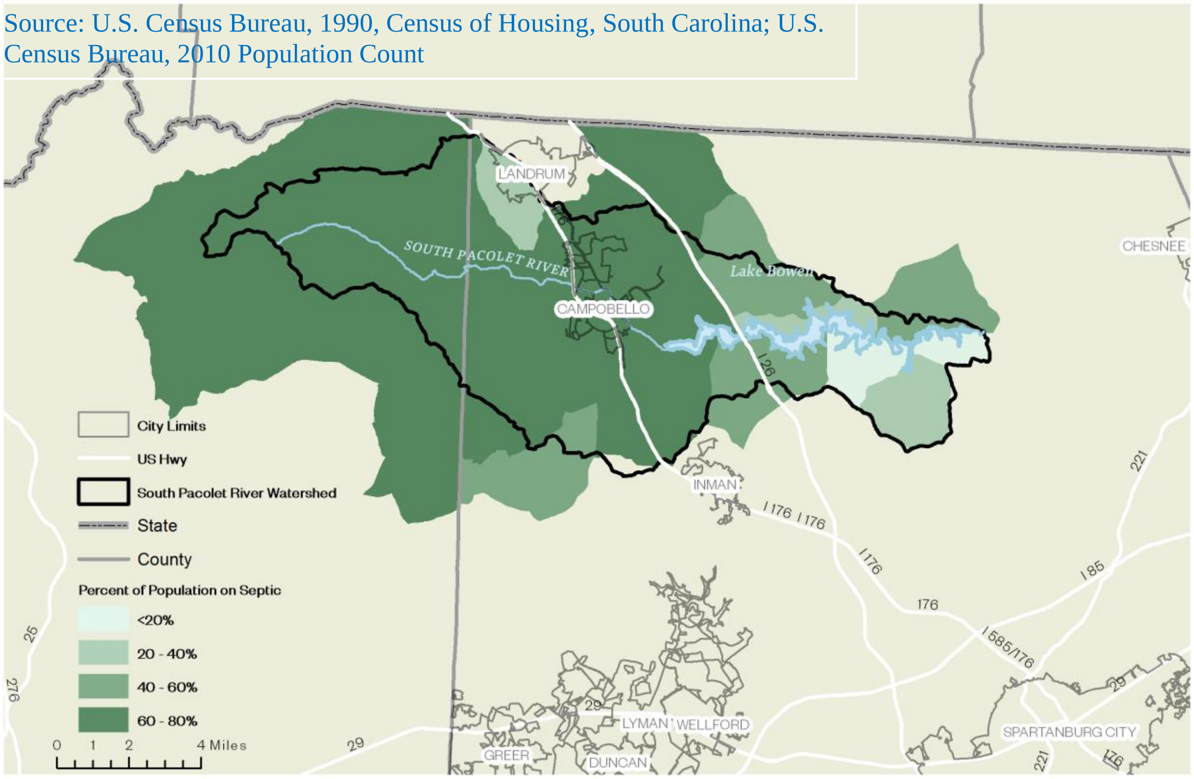
[1] STEPL v4.3 (US EPA, TetraTech), sourced from Metcalf and Eddy, Inc. 1979. Wastewater Engineering: Treatment, Disposal, Reuse. 2nd ed. McGraw-Hill, New York, NY.



Source: U.S. Census Bureau, 1990, Census of Housing, South Carolina; U.S. Census Bureau, 2010 Population Count

Figure 4-4: Percent of population using septic sewage disposal in Census block groups within and near the South Pacolet River watershed boundary

4.3.2 Non-Agricultural Fertilizer

Improper or over application of fertilizers have negative impacts on drinking water supplies. Many recreational facilities in developing watersheds use fertilizer to maintain an aesthetic and functional crop of turf grass, including golf courses, large lawns, athletic facilities, and parks. Surveys done in the literature indicate that approximately 70% of homeowners fertilize their lawns regularly whether or not additional nitrogen or phosphorus is needed (Barthe, 1995; Schueler, 2000). While highly-maintained, established lawns may provide for more rainfall retention and less runoff volume (Spence, et al., 2012), over-application of fertilizer on newly-established lawns in recently-developed neighborhoods where un-used fertilizer can be easily mobilized can be a source of phosphorus. While natural watersheds are thought to immobilize phosphorus in the soil and, thus, have a high phosphorus retention capacity, increasingly developed watersheds, or even localized areas of development, have been linked with higher levels of phosphorus export, either due to excessive inputs, low retention in the watershed, or both (Verry et al, 1982; Hobbie et al., 2017).

There is some evidence that a properly fertilized lawn may result in less phosphorus leaching than one that does not get fertilized and results in unhealthy stands of turf grass. Because roughly half of phosphorus from the developed environment results from sediment-bound phosphorus being washed away via erosion, a lawn that has exposed soil and poor soil retention can be susceptible to TP export. A study by Bierman et al (2010) looked at three years of various clipping management and fertilizer regimes on total phosphorus export. Their finding was that unfertilized turf had greater runoff phosphorus content than fertilized turf ("zero P"), but zero-P fertilized turf had less than one with a complete P-N-K mix. In soils that have adequate phosphorus levels, a determination that can be readily made by local soil offices and Clemson Cooperative Extension, zero phosphorus fertilizer, zero phosphorus fertilizer can ensure plants receive the other two essential nutrients (nitrogen and potassium, the "N" and "K" portion of the mix). Turf grasses deemed suitable to use no-P fertilizer, therefore, can draw from the reservoir of previously-available phosphorus from the soil without allowing the opportunity for excess phosphorus to runoff into streams and lakes.

A study in Wisconsin on many developed and rural watersheds found that a scenario where normal fertilizer was applied, and rainfall came a little later, resulted in annual phosphorus loads of 0.2 to 1.8 lb/ac/yr. Assuming a value of 1 lb/ac/yr within that range, and assuming the National Land Cover Dataset categories "Developed Land, Open Space" and "Developed Land, Low Density" represent managed lawns (8,826 acres), then a rough estimate of total phosphorus loading from these land uses is 8,826 lb/yr, which represents about half of the total estimated loading from the land area of the South Pacolet River watershed. (Note: it is expected in the subsequent loading reduction analyses that this land use is managed in various ways, not just with no-P fertilizer, including development stormwater BMPs).

4.3.3 Development and Impervious Cover

Land disturbing activities and impervious surfaces can lead to water quality changes in our water quality supply. The correlation between increasing watershed impervious area and loss of stream biological integrity has already been discussed in the report (3.3.1). Below, a summary of water quality constituents coming from the stormwater runoff of residential, commercial, or industrial development environment is introduced to compare to concentrations measured at the watershed sampling stations.

The International BMP Database is an online repository of research studies conducted on the performance of over 600 best management practices in the developed environment. This source provides an updated numerical data source of water quality both entering and leaving common BMPs. For the purposes of this watershed plan, pollutant concentrations in runoff leaving residential or commercial areas is assumed to be equitable to influent concentrations into stormwater BMPs listed in this database. Values in Table 4-4 below include averages over all BMP types and locations in the United States, broken up by pollutant. Note that while this table summarizes residential or commercial development runoff concentrations as a whole, it is important to note that the effects of a few of the other causes and sources introduced in this section (such as lawn fertilizer) are present within these data,

Table 4-4. Pollutant concentrations exported from developed or developing areas[1]

Pollutant	25th Percentile	Median	75th Percentile	Values in Database	Date of Query
TP (mg-P/L)	0.10	0.198	0.390	8,414	1/16/2017
Soluble reactive phosphorus (SRP) (mg-P/L)	0.021	0.056	0.150	4,692	1/16/2017
TN (mg-N/L)	0.89	1.40	2.22	3,651	1/16/2017
Nitrate + nitrite as N (mg-N/L)	0.195	0.40	0.730	4,708	5/19/2017
Total Organic Carbon (mg/L)	6.1	11.9	20.0	2,422	1/16/2017
Total suspended solids (mg/L)	17.0	49.0	123.8	8,288	1/16/2017
pH (unitless)	6.5	7.0	7.4	3,204	1/16/2017
Alkalinity (mg/L)	48.5	88.0	133.0	1,365	1/16/2017
Biological Oxygen Demand (mg/L)	4.0	6.7	11.7	1,354	5/19/2017

It may be important for future stakeholder groups in the watershed to work with pending construction project stakeholders to balance development and water quality goals. One ongoing construction project near the lake is the SC Highway 9 project, which will widen this major multi-modal corridor from 2 lanes to 5 lanes. Lane widening appears to be complete from River Oak Rd to Fagan’s Creek Drive, but future work will span Lake Bowen and expand the widening north to Rainbow Lake Rd (Spartanburg Area Transportation Study, 2017). As an NPDES permittee, South Carolina’s Department of Transportation (DOT) has been involved in stormwater program compliance, developing programs to mitigate the impacts from new impervious surfaces created through roadway construction. SC DOT has their own BMP manual, erosion control specifications, pollution prevention plan checklist, and water quality design manual available for access online at scdot.org. SC DOT is also active in working with local partners within project areas to mitigate new construction with wetlands. SC DOT and project partners use a U.S. Army Corps of Engineers tool called the “Regulatory In-lieu and Bank Information Tracking System (RIBITS) to find nearby approved stream mitigation banks or in-lieu fee programs (wetmit.org, 2015).

In the context of the South Pacolet River watershed, it may be equally important and strategic to focus on smaller tributaries with respect to existing and new impervious area impacts. A study by Furman University, presented at the Southeastern section of the Geological Society of America conference in 2008, found a statistically significant relationship between road crossings in smaller, upland tributaries of the Enoree and Saluda watersheds with erosion-based incision found in measured stream corridors (Taysom and Muthukrishnan, 2008).

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[1] Source: International Stormwater BMP Database, 2016. Database was queried on Jan 16, 2017 for all parameters except nitrate/nitrite and BOD (May 19, 2017)

4.3.4 Stream Erosion

Streams often respond to newly-constructed impervious area and land use modification through incision of the channel and bank widening (

Figure 4-5). As higher peak flows occur *more often*, there is more streambed load material that gets sheared or transported downstream. This erosion causes the down-cutting that can often result in poor stream aesthetics and loss of riparian buffer. The sediment that gets washed away, once deposited further downstream, can destroy macroinvertebrate habitat. Suspended sediment can alter the light-transmitting properties of stream or lake, and thus affect ecosystem processes dependent on photosynthesis. The sediment itself often has bound to it organic matter, nutrients, and other chemicals, which can contribute to algal growth in lakes.

Figure 4-5: Example of stream morphological changes that can occur as a result of increased peak flows, durations, and volumes (Source: Hazen and Sawyer)

4.3.5 Livestock Access to Surface Water

The South Pacolet River watershed is 21% hay/pasture agriculture by area. As a result, livestock will necessarily interact with surface waters in multiple locations throughout the watershed, which can hinder water quality by introducing nutrients and bacteria to surface waters in addition to localized stream corridor degradation. During the March 2017 meeting between Spartanburg Water and watershed stakeholders, three instances of livestock access to streams were noted, specifically in the upper tributaries of Motlow Creek and near Lake Bowen in the Walnut Hill and Turkey Creek sub-catchments. It is reasonable to assume there are additional locations with livestock access to streams throughout the watershed than those explicitly identified by stakeholders.

4.3.6 Atmospheric Deposition

Dry air contains about 78% nitrogen, making it a significant source of nitrogen that can be introduced into a waterbody by either dissolving in rainwater and falling during wet weather, or via dry deposition as nitrogen bound to particulate matter. Anthropogenic (originating from human activity) sources of atmospheric nitrogen include the transportation sector, agricultural emissions, and industrial sources. Natural sources include soil and plant nitrogen emissions, wetlands and peat bogs, natural wildfires, and even lightning.

Typically, nitrogen is measured in the atmosphere as NO_x and NH_4 (ammonium). NO_x is a collective term, comprising gaseous nitrogen oxide (NO), nitrogen dioxide (NO_2), and the nitrate ion (NO_3). These constituents can collectively be lumped into TN for the purposes of estimating total deposition. For the purposes of this watershed plan, a simple estimate was made using the last 5 years of data published by the National Atmospheric Deposition Program’s network of air concentration monitors throughout the United States. The NADP has developed annual loading chloropleth maps for nitrate, ammonium, and TN for the contiguous United States, which were used to visually estimate a 5-year average annual dry and wet deposition loading per acre. These surface area-based loading ratios were then applied to each reservoir in the watershed and the dry land portion of the watershed that drains to these water bodies. These values represent a higher-end estimate of nitrogen atmospheric loading to the South Pacolet River watershed because it is unknown how much the dry deposition of nitrogen becomes mobilized and transported from the watershed to the reservoirs (Table 4-5).

Table 4-5. Estimate of TN loading (lb/ac) by atmospheric deposition on South Pacolet River watershed

Area	Area (ac)	Nitrogen Deposition (lb-N/yr)[1]		
		Dry	Wet	Total
Lake William Bowen	1,534	6,489	4,676	11,166
Municipal Reservoir #1	271	1,146	826	1,973
Remaining Watershed	56,724	239,966	172,911	412,877
Total	58,529	247,602	178,413	426,015

[1] Visual estimation of value from wet and dry nitrogen deposition chloropleth maps (National Atmospheric Deposition Program (NADP), 2015). Values for dry and wet deposition were the average of each year, 2010 through 2015.

4.3.7 Soil Erosion

Various tools and equations exist to estimate watershed soil erosion. One that is often used on a watershed scale is the Revised Universal Soil Loss Equation (RUSLE). This equation estimates the unit mass of soil exported per year from a watershed based on factors such as watershed slope, land cover practices, soil type, rainfall patterns, and management factors. Within an EPA watershed modeling spreadsheet called STEPL, RUSLE is used to calculate sediment and nutrient loading from various land uses.

The South Pacolet River watershed has highly-varied topography, with low-lying riparian areas near the stream corridor and lakeshore, and steep, erodible piedmont and foothill soils near the western portion of the watershed in Greenville County (Figure 4-6). The amount of soil erosion is heavily-influenced by rainfall, steepness, cover management, and soil erodibility factor. These unitless values were selected based on the best possible engineering judgment and estimated for rough comparison and evaluation.

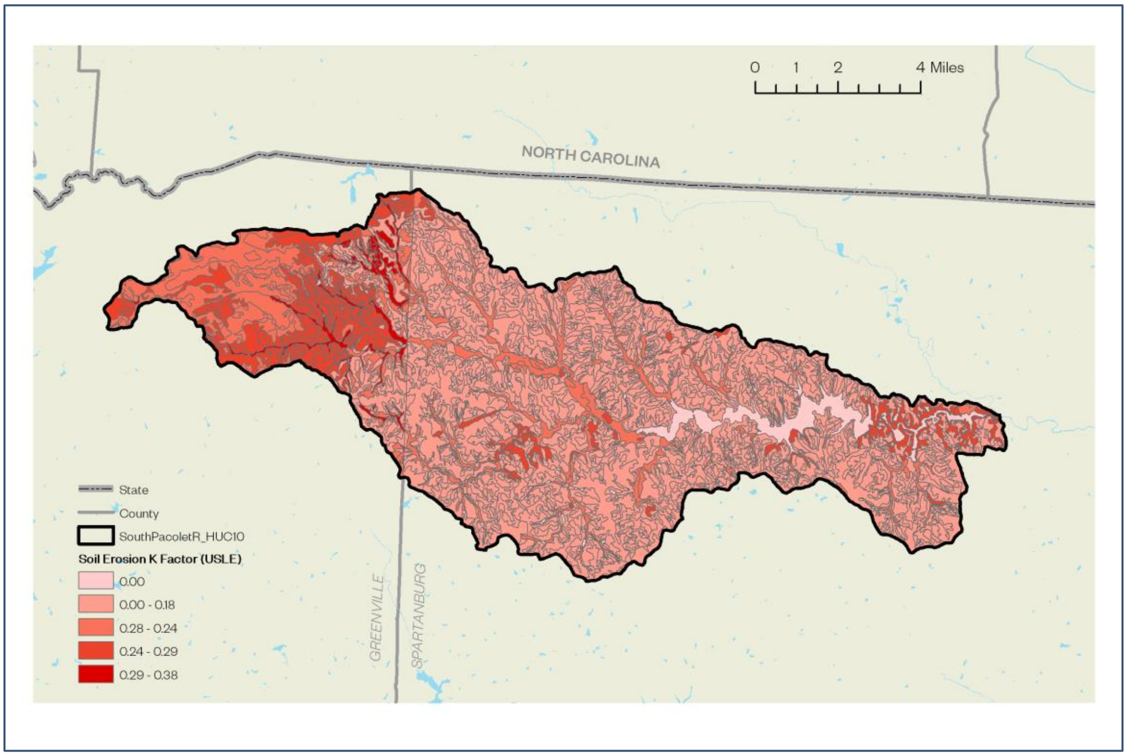


Figure 4-6. Soil erodibility factor within the HUC-10 watershed boundary used in estimating soil erosion

Based on area-averaged values of the erodibility factors (above), assumed crop cover, management factor, and precipitation values from Spartanburg and Greenville counties, it was estimated that 3,778 tons of sediment are delivered per year to Lake Bowen and Municipal Reservoir #1.

As was reported by stakeholders, there are instances of highly-turbid, sediment-laden stream stretches in the South Pacolet River watershed, including upstream of the water quality monitoring station “WS-D” on Holston Creek.

4.3.8 Lakeshore Alteration

Residential home development and the removal of natural forested and wetland land uses from the periphery of Lake Bowen and Municipal Reservoir #1 should be evaluated as a future threat to the lake’s aquatic health. In a survey of 345 lakes in the Northeast during the 1990s, the US EPA found that shoreline alteration was a more widespread problem than nutrient-caused eutrophication and acidification (United States Environmental Protection Agency, 2013). As vegetative cover is reduced along shorelines, more shallow water is exposed to algal production due to light availability, which can enhance periods of eutrophication in some lakes.

Two primary lakeshore alterations associated with Lake Bowen of particular concern are boat ramps, especially in close proximity to lawns, and drainage pipes. With residential boat ramps, lawn fertilizer can be distributed onto the concrete (typical) pad itself and then can be washed into the lake during irrigation or rain events. Drainage pipes are also direct conduits from pollutant sources to the lake. According to the EPA website relating to stormwater discharges from transportation sources, streets, roads, and highways can carry stormwater runoff pollutants from the adjacent land and from cars, trucks, and buses, including heavy metals from tires, brakes, and engine wear, and hydrocarbons from lubricating fluids, as well as chloride roadway deicers. If the pollutants are not properly controlled, they can impair waters causing them to no longer support the water's designated uses and biotic communities.

Based on the USGS National Land Cover Database 2011 satellite land cover analysis (the most recent national lad cover product created by the Multi-Resolution Land Characteristics Consortium), there are 261 acres with 10% or more impervious surface coverage within a 500 foot buffer surrounding Lake Bowen and Municipal Reservoir #1 (Figure 4-7). These areas in particular may play a critical role in maintaining and securing water quality conditions in the two reservoirs, as the runoff has less hydraulic retention time between source and destination compared to areas further up the watershed.

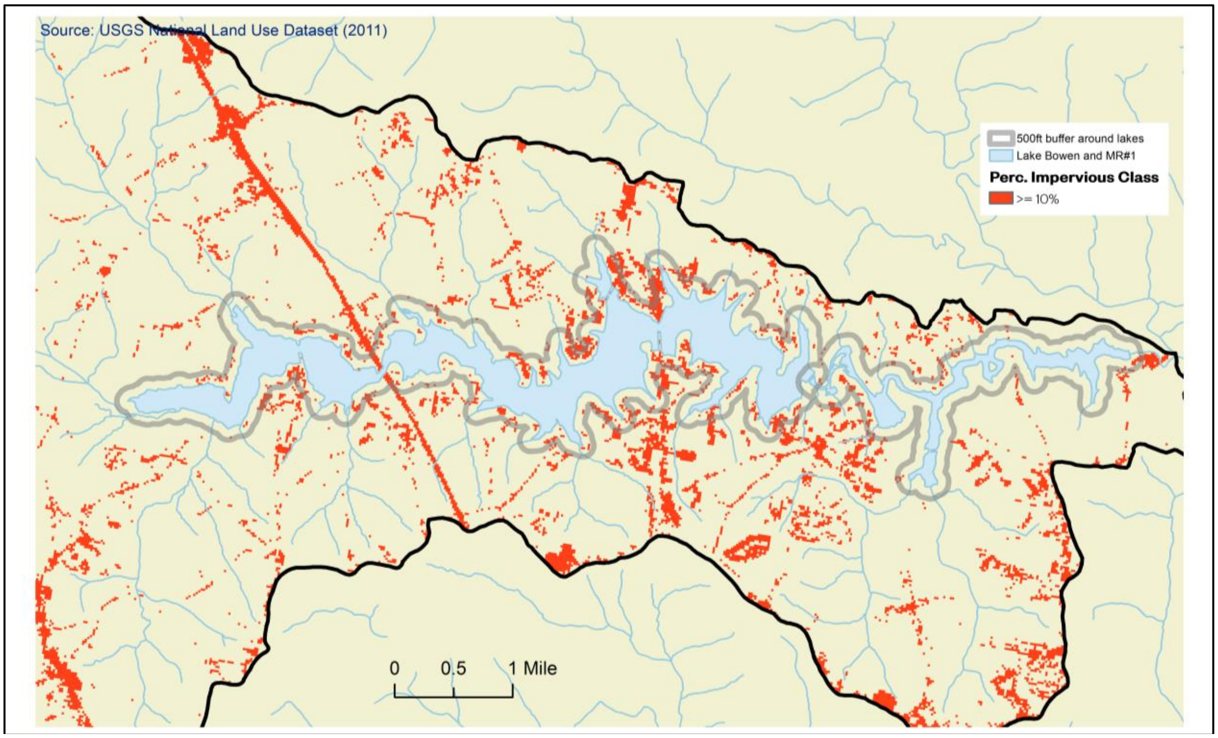

Source: USGS National Land Use Dataset (2011)

Figure 4-7: Areas of 10% or more impervious cover with 500 foot buffer around Lake Bowen and Municipal Reservoir #1

4.3.9 Construction and Land Disturbance

Stakeholders identified flows originating from areas of new development (Woodfin development and other areas south of Lake Bowen) as being problematic either due to sediment delivery or flooding concerns. New development is known to cause larger volumes of stormwater being discharged at faster rates. Existing conveyance streams near Lake Bowen may be especially susceptible to flooding downstream of construction and land disturbance. Construction close to existing streams and lakes can cause multiple environmental issues, and should be monitored closely for adverse impacts. SC DHEC's stormwater BMP handbook has guidance on sixteen sediment control BMPs, some of which may need to be implemented beyond the basic requirements for a development permit in order to safely insure little to no sediment is delivered to the lakes at these crucial locations.

4.3.10 Stakeholder Meeting

On March 23, 2017, stakeholders from within the watershed and from surrounding institutions and communities met to discuss the watershed and potential strategies to address nutrient loading concerns in Lake Bowen and Municipal Reservoir #1. The public sector, academia, and non-profits had a chance to provide first-hand indications of where potential problem areas exist in the watershed. This provided a snapshot at particular areas that could be integrated into future planning areas.

Stakeholders identified agricultural operations as the most common potential source of water quality problems in the watershed. Within that category, multiple expressions of agricultural activities were noted, including:

- Livestock near streams
- Peach farms
- Standing water
- Donkey farms
- Cattle
- Horse pastures

While livestock and cattle farms identified further west in the watershed (near Motlow Creek or Belue Creek) could be direct sources of nitrogen and phosphorus, the operations closest to the lake could impact water quality more directly due to their proximity to surface water. In such instances, there is little hydraulic retention time between the operation / point of runoff to Lake Bowen or Municipal Reservoir #1, which could leave nutrients in their most biologically-active forms longer than if they were consumed in stream ecological processes farther away.

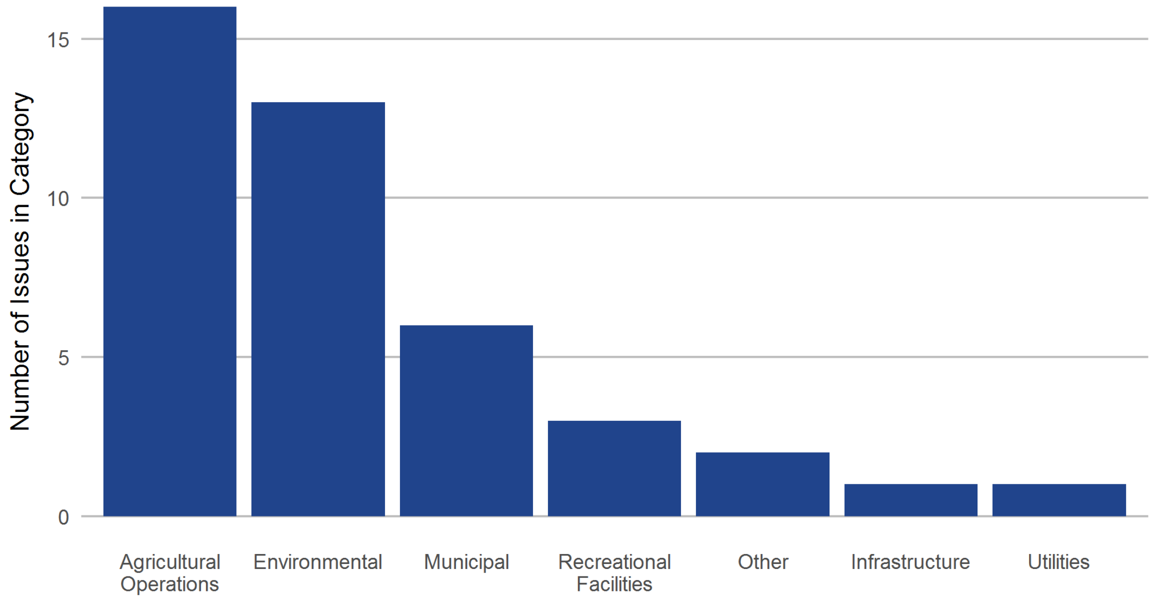


Figure 4-8: Categories of issues identified at March 23, 2017 stakeholder meeting

Another category of note was termed “Environmental” during the meeting. This included expressions of environmental degradation or pollution, including:

- Overland erosion
- Channel and stream erosion (4)
- Sediment or cloudy water
- Trash or debris in streams
- Nutrient or hyper-eutrophic hits in the lake
- Lack of vegetated stream buffer

Figure 4-9 below shows all of the issues identified by stakeholders by self-identified issue category, as well as a description of the specific issue, where applicable. As the latest EPA lake assessment shows, activities along or near the shorelines of lakes and reservoirs can be particularly impactful to the overall water quality issues facing a watershed (United States Environmental Protection Agency, 2013). In that regard, the issues that may be most prudent to address appear to be in close proximity to Lake Bowen.

The “municipal” category appears to indicate rapid residential development occurring near the Woodfin Ridge development, and on arms of Municipal Reservoir #1 further downstream, as well as pet waste (Clear Branch watershed) presence. While not directly linked to any nutrient hits, it is important to consider the overall impact of these developments in lake health by making sure the best practical technologies and practices are being implemented as the watershed develops further.

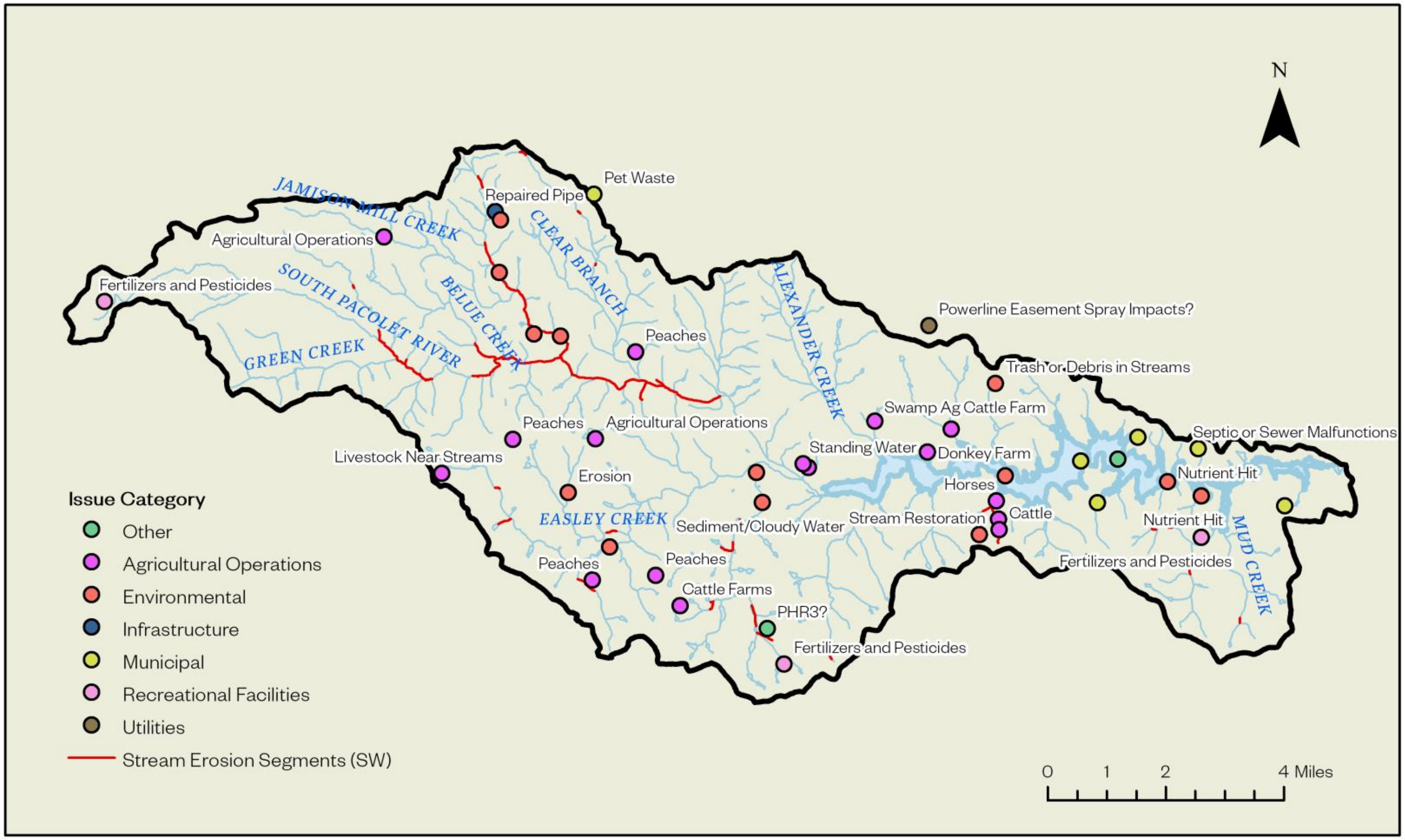


Figure 4-9: Map of issues identified by watershed stakeholders at March 23, 2017 meeting and stream erosion segments identified by Spartanburg Water

4.4 Current Water Quality Conditions

The following sections will present boxplots of water quality concentrations provided by Spartanburg Water as part of their watershed and in-lake sampling program. In order to explain the multiple plots, an example boxplot with annotations for generic data is shown in Figure 4-10.

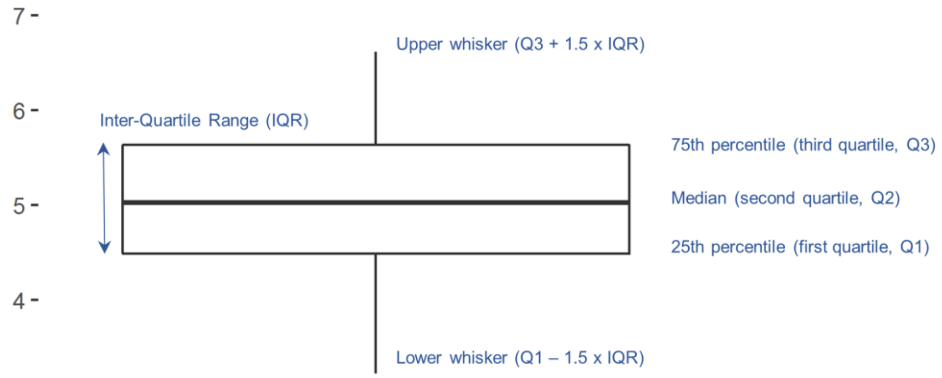
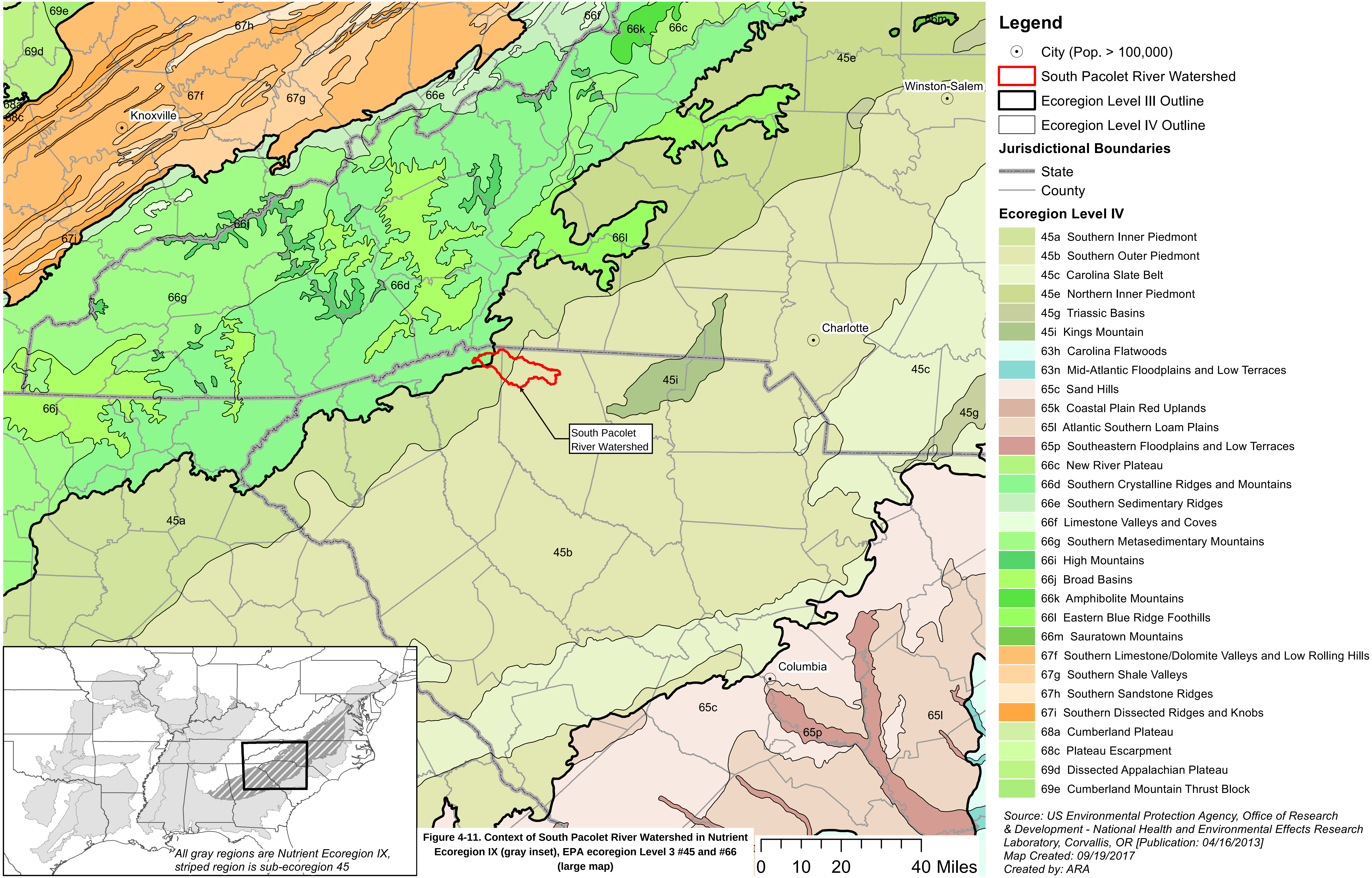


Figure 4-10: Sample boxplot with quartile and whisker labels

The U.S. EPA published national nutrient criteria for seventeen nutrient ecoregions—eight ecoregions for lakes and reservoirs, eight for rivers and streams, and one for wetlands. This data, published in 2000, are meant to establish a reference condition watershed concentration benchmark to help watersheds begin to inventory their water quality problems (United States Environmental Protection Agency, 2000). Each nutrient ecoregion is comprised of previously-derived, smaller-scale EPA Level 3 ecoregions, which, in turn, are comprised of smaller EPA Level 4 ecoregions. The South Pacolet River watershed is located in Level 3 ecoregion 45 ("Piedmont", see Figure 4-11). Three Level 4 ecoregions further comprise the watershed boundary:

- 45b - Southern Outer Piedmont (lowlands, lakeshore, and lake surface)
- 45a - Southern Inner Piedmont (middle portion of the watershed, west of Campobello)
- 66d – Southern Crystalline Ridges and Mountains (last 5 miles of the watershed on western tip)

EPA aggregated these Level 3 ecoregions into nutrient ecoregions in order to provide more specific guidance on water quality than to do so with a lump aggregation nationally. For this report, benchmarks from Level 3 ecoregion 45 will be used, since that constitutes 90% of the area of the South Pacolet River watershed.



All gray regions are Nutrient Ecoregion IX, striped region is sub-ecoregion 45

Figure 4-11. Context of South Pacolet River Watershed in Nutrient Ecoregion IX (gray inset), EPA ecoregion Level 3 #45 and #66 (large map)

Source: US Environmental Protection Agency, Office of Research & Development - National Health and Environmental Effects Research Laboratory, Corvallis, OR [Publication: 04/16/2013]
Map Created: 09/19/2017
Created by: ARA

Table 4-6 and Table 4-7 display the stream and lake benchmarks for EPA Level 45 ecoregion within Nutrient Ecoregion IX, respectively.

Table 4-6: Aggregate nutrient reference conditions for streams and rivers in EPA ecoregion IX, Level 3 ecoregion 45

Water Quality Parameter	Value
TP (mg P/L)	0.03
$NO_2 + NO_3$ (mg/L)	0.177
TKN (mg/L)	0.234
TN (mg/L)	0.615
Chlorophyll-a (µg/L) – Fluorometric	3.3
Chlorophyll-a (µg/L) – Spectrophotometric	3.493
Turbidity (NTU)	5.713
Turbidity (FTU)	7.488

Table 4-7: Aggregate nutrient reference conditions for lakes and reservoirs in EPA ecoregion IX, Level 3 ecoregion 45

Water Quality Parameter	Value
TP (mg P/L)	0.0225
$NO_2 + NO_3$ (mg/L)	0.059
TKN (mg/L)	0.245
TN (mg/L)	0.304
Chlorophyll-a (µg/L) – Fluorometric	4.513
Chlorophyll-a (µg/L) – Spectrophotometric	5.95
Secchi depth (ft)	5.30
$NO_{2/3}$-N (mg/L)	0.059

As can be noted in the tables above, lake concentrations are expected to be lower in TN and TP than in rivers, but higher in chlorophyll-*a*, a result of the dynamics and fate of those nutrients as they get used in metabolic processes Shown again for reference is a map of sampling locations in the watershed (Figure 4-12).

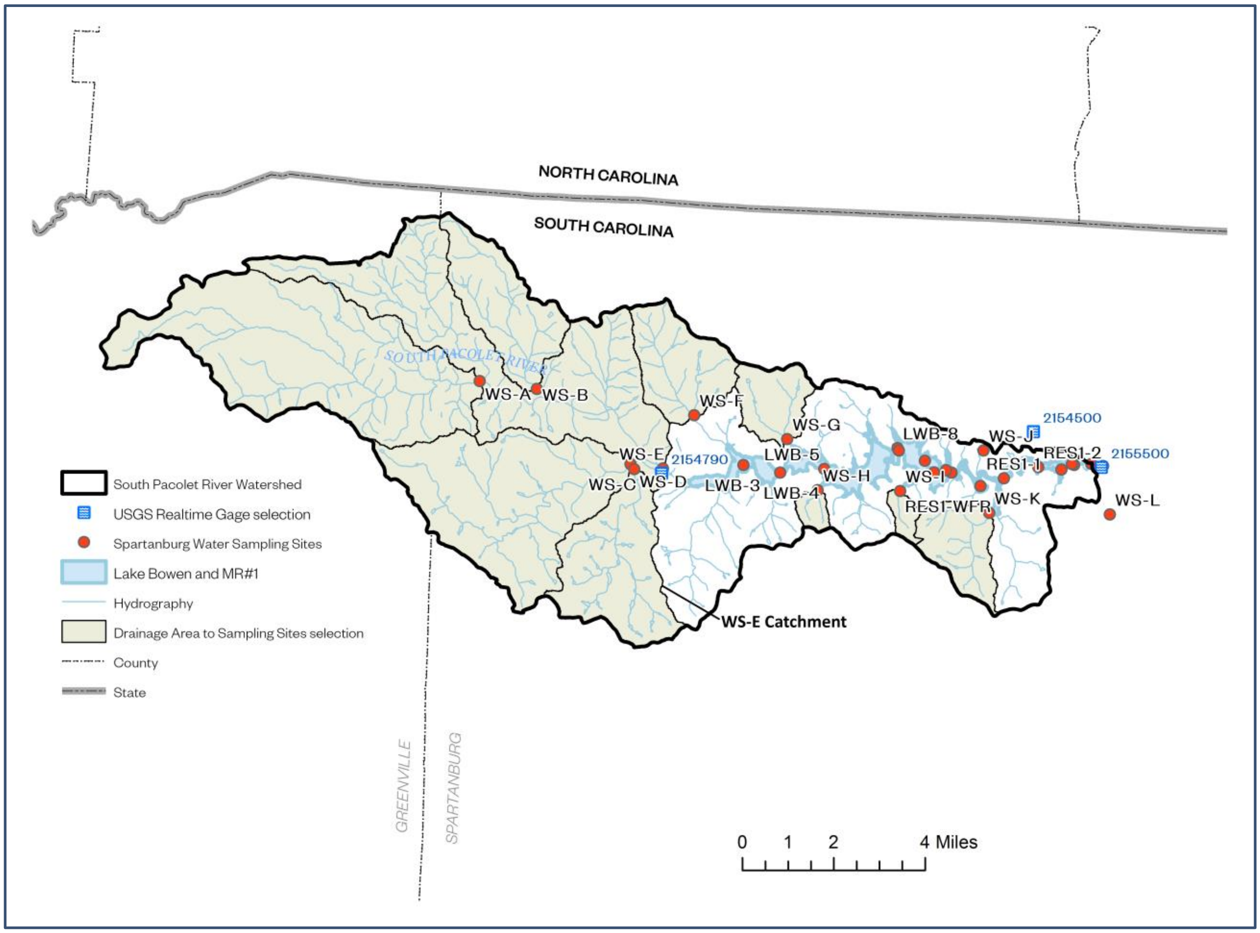


Figure 4-12: Map of Spartanburg Water sampling sites in the South Pacolet River watershed

4.4.1.1 Nitrogen Species

Below are the boxplots of TN and nitrate/nitrite concentrations for all of the non-lake (i.e. "*WS*") sites in the South Pacolet River watershed. The locations in the subsequent boxplots correspond to locations in Figure 4-12.

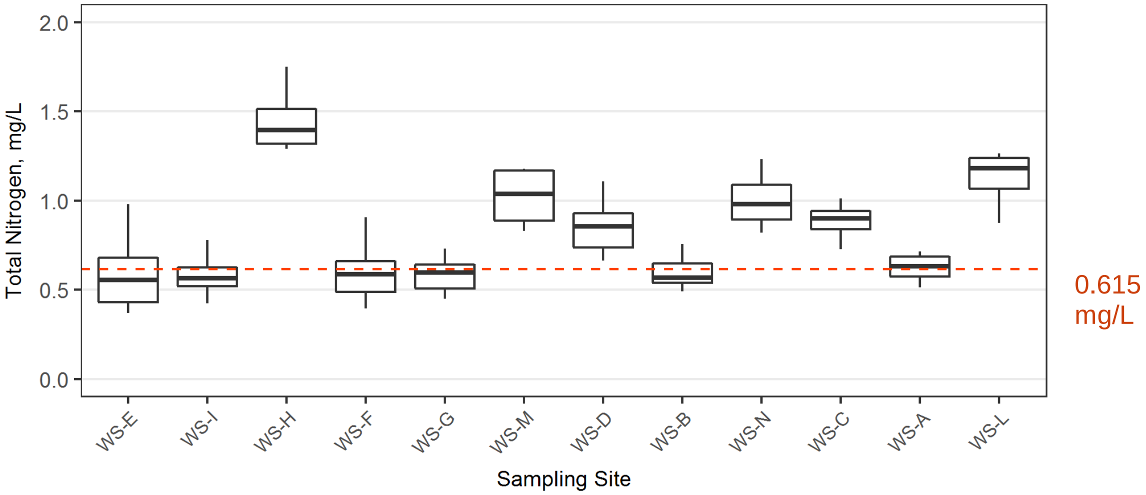


Figure 4-13: TN concentrations at stream sampling sites throughout the South Pacolet River watershed and ecoregion reference concentration (dashed line)

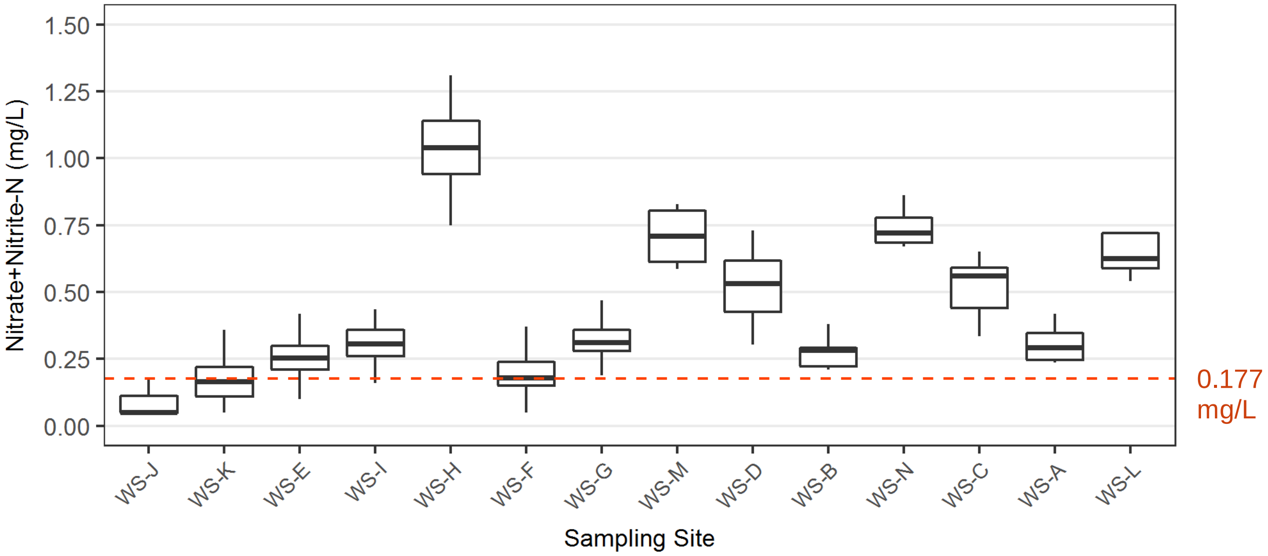


Figure 4-14: Nitrate+nitrite (as Nitrogen) concentrations at stream sampling sites throughout the South Pacolet River watershed and ecoregion reference concentration (dashed line)

Watershed sites *WS-H*, *WS-M*, and *WS-C* have median concentration values above the current ecoregional ambient water quality criteria for TN. Of note is *WS-H*, which has twice the median value of TN than the EPA benchmark. These data should be caveated by the lack of observations over the period monitored—only 16 values were measured and are included in most of these boxplots, ranging from 2009 to 2016. As a result, they are only snapshots, and cannot fully characterize the dynamics of the watershed without further monitoring and/or modeling. Given that, it does appear that *WS-H* has a higher nitrogen concentration than the rest of the sites. Looking at the stakeholder and monitoring maps, *WS-H* is located downstream from numerous cattle and horse operations, as well as an existing identified stream restoration project. The drainage area to *WS-H* does not have a particularly high percentage of impervious area (3%), and does not appear to have a large population. Given the fact that nitrate is also very high at this location compared to the EPA benchmark and the other sites, and nitrate's indicator of untreated animal or human waste, the measures discussed in Section 5 revolving around livestock exclusion, vegetated buffers, and septic tank repairs should be considered at this location. When looking at this site over time, nitrite + nitrate concentrations appear to be increasing over time at a statistically significant rate, albeit with a weak correlation (R2 = 0.368, p = 3.46×10^{-7}).

To a lesser extent, *WS-C* shows higher nitrate values than ambient benchmarks. This station drains a much larger area than *WS-H*, meaning it is harder to identify specific causes. The upper reaches of this sub-catchment include steeper topography, reported erosion, multiple peach orchards, and livestock in streams. The combination of high topography (meaning potentially large amounts of runoff and sediment for a given land use) suggest that this sub-watershed may require some attention later in the document regarding mitigation practices.

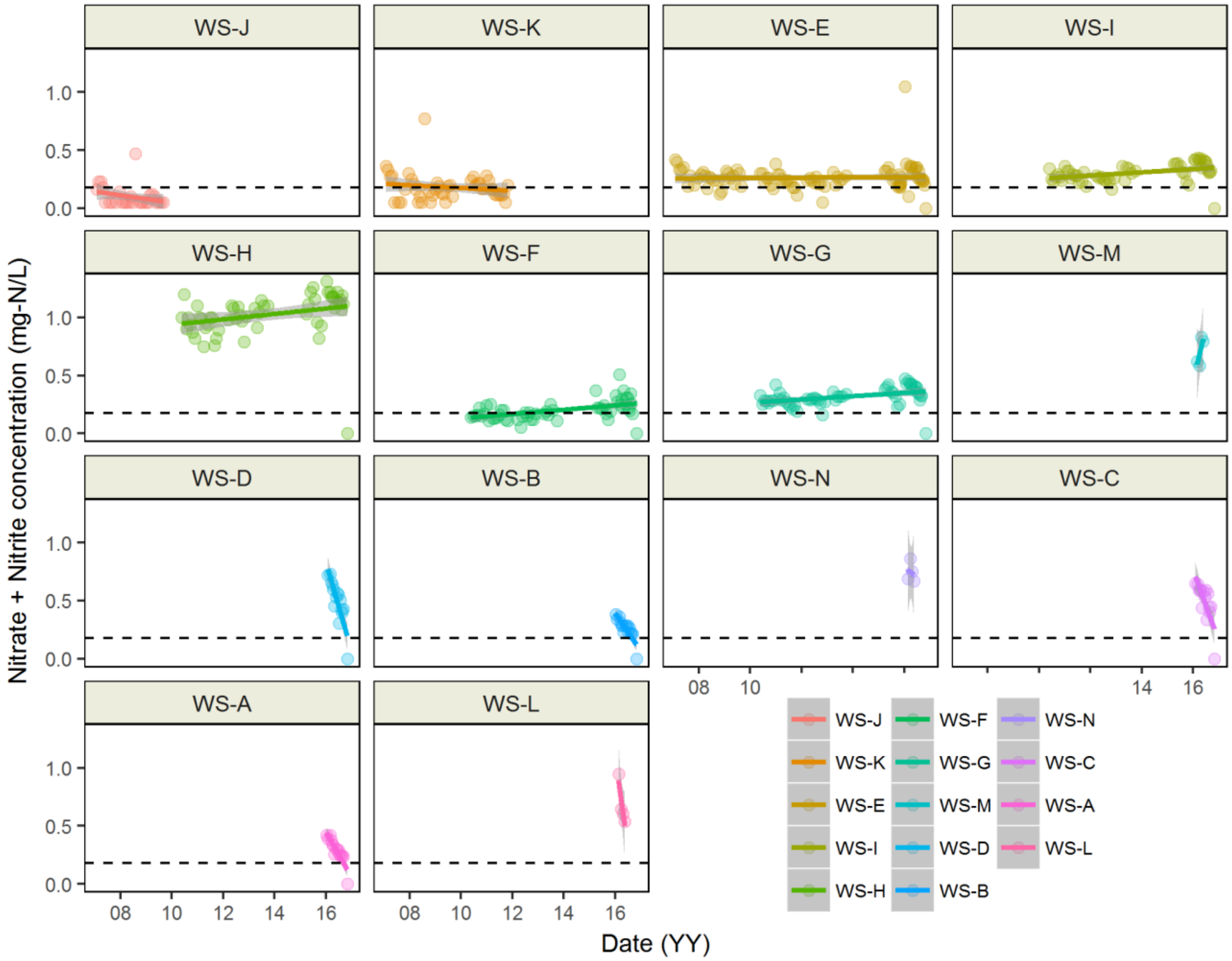


Figure 4-15: Nitrate + nitrite concentration for *WS-H* from 2010 to 2017 with overlain ecoregional reference condition shown in dashed line (0.177 mg/L)

The linear temporal trend for all *WS* sites for nitrate are shown collectively in Figure 4-15. The three sites for which data were collected only past 2016 show a high initial concentration of nitrate, followed by a decrease to the benchmark EPA reference concentration. All of the sites for which longer data sets exist except *WS-E* show statistically significant increases over time (*WS-I*, *WS-H*, *WS-F*, and *WS-G*).

4.4.1.2 Total Phosphorus

An analysis of Total Phosphorus (TP) concentrations across multiple locations in the watershed and in the lake was performed. The orange dashed line shown is the reference concentration determined by EPA for the eco-region in which the South Pacolet River watershed is located (Table 4-8).

For the purposes of this discussion, this represents the water quality benchmark for an undisturbed stream in this region. Upstream of site *WS-C* along Easley and Motley Creeks, multiple stakeholder-presented issues are present, including peach farms, agricultural operations, and noted land and stream erosion sites.

Using the map in Figure 4-12 as a location reference for the sampling sites along the x-axis, it is clear that the sampling locations just upstream of the USGS gage along Motlow Creek and Holston Creek shows a larger median TP concentration than the rest of the sites. Further downstream at the confluence of these creeks and the South Pacolet River (*WS-E*), the high phosphorus concentration is diluted to near detection limit. During the March 2017 stakeholder meeting, the presence of sediment-laden cloudy water was noted about 0.5 miles upstream of *WS-D* on Holston Creek.

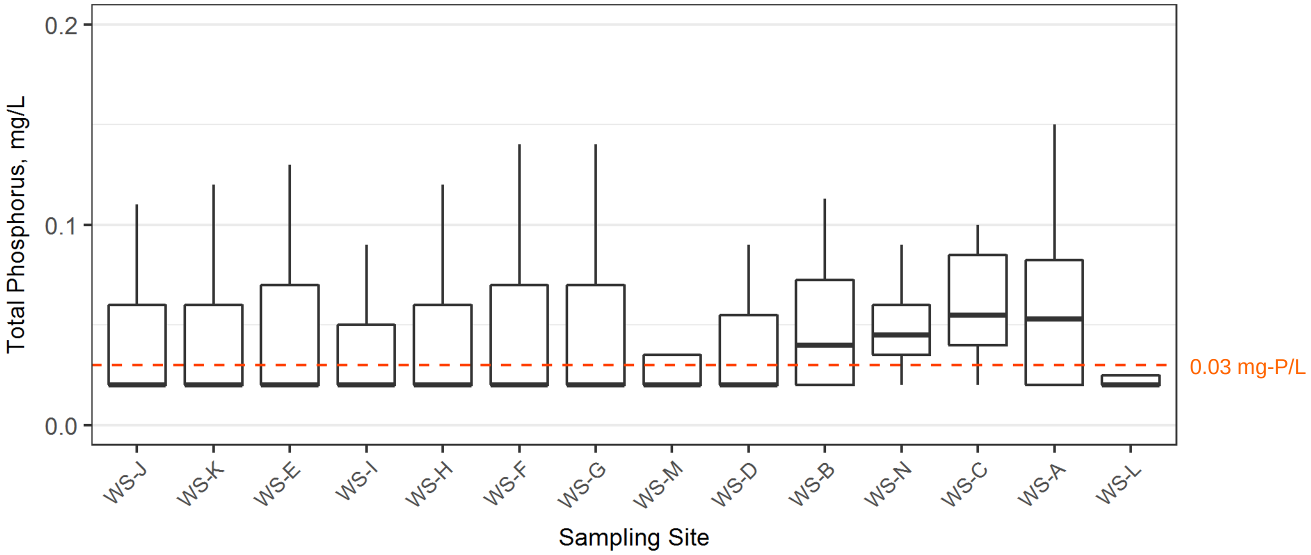


Figure 4-16: TP concentrations at stream sampling sites throughout the South Pacolet River watershed (dashed line represents TP reference condition for streams and lakes)

WS-B, located near the intersection of Spivey Creek and Horton Rd, also had a higher median TP value higher than the reference concentration of 0.03 mg/L. The caveat to this comparison is that most of the sites had a large portion of the measured TP values at or below the minimum detection limit (MDL) of

0.04 mg/L, which prevents the applicable boxplots shown above from having lower quartile “boxes” below the dark median line. In the case of TP, the minimum detection limit for the sampling was actually higher than the ambient reference TP concentrations for streams, which may be due to the nature of stream flow and phosphorus dynamics compared to the intended laboratory testing of still lenthic water columns.

Unfortunately, no monitoring points exist downstream from Woodfin Ridge Golf Club, which has been noted as a potential source of nutrients by stakeholders. Sites with median TP concentrations higher than the ambient water quality standards include:

- *WS-B*
- *WS-C*
- *WS-A*

4.4.1.3 Total Suspended Solids

There are fewer existing benchmarks for TSS concentrations appropriate for stream health on a large scale. What the data show in Figure 4-17 is that no site’s median TSS grab sample concentration exceeds 10 mg/L. For context, the median TSS value for runoff from developed lands is around 50 mg/L (see Section 4.3.4). Depending on the dynamics of the watershed, streams are often highly diluted with groundwater, which is typically very low in solids. This effect may dampen any TSS spikes that are occurring in the non-lake environment. Additionally, samples consistent mostly of baseflow (dry-weather sampling) do not reflect the drivers of sediment wash-off from various land uses during rainfall events (wet-weather effects) that can be exclusively teased out only through sampling of stormwater outfalls or ephemeral gullies/channels leading into perennial streams.

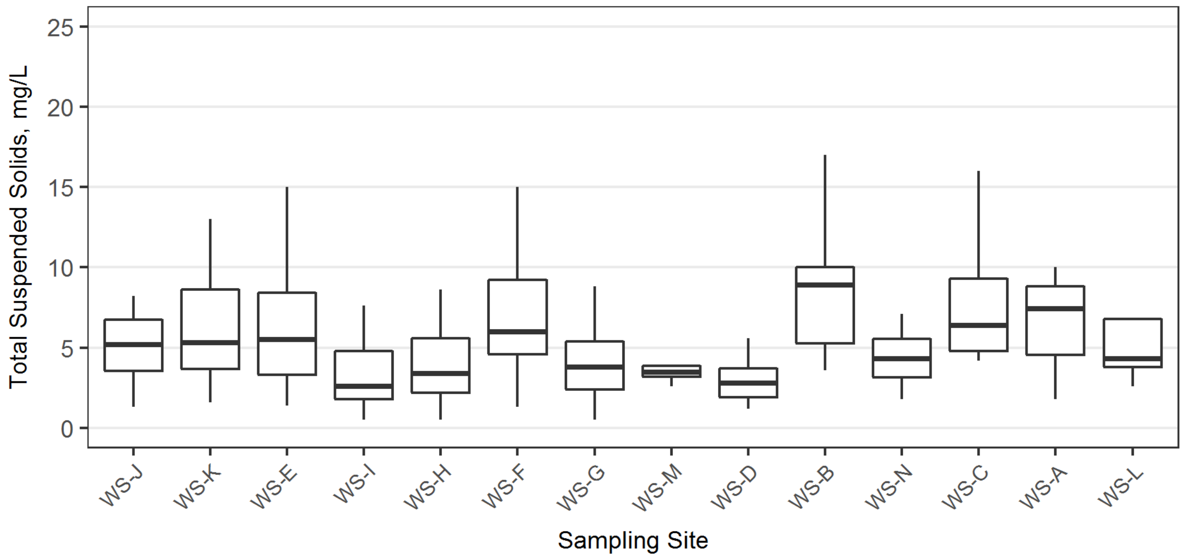


Figure 4-17: Total Suspended Solids concentrations at stream sampling sites throughout the South Pacolet River watershed

4.4.2 Lake Bowen and Municipal Reservoir #1

Data presented below are primarily from the 2009-2016 dataset made available by Spartanburg Water. Below are average water quality concentrations for TP, TN, chlorophyll, and nitrate/nitrite at multiple depths and sampling locations in Lake Bowen and Municipal Reservoir #1. Beneath each table is the EPA eco-regional reference condition for that pollutant. Samples higher than this reference value are shaded. The columns include the station names of each reservoir, and are organized from upstream to downstream (left to right).

LAKE BOWEN

Table 4-8: Average TP concentrations (mg/L) in Lake Bowen at various depths (2009-2016)

Depth	LWB-4	LWB-5	LWB-8B	LWB-9B	LWB-10	LWB-12
surface	0.026	0.024	0.024	0.032	0.024	0.026
3-ft		0.045	0.045		0.045	
9-ft					0.054	
18-ft			0.043		0.0525	
thermocline				0.02		0.020
bottom	0.028	0.044	0.024	0.043	0.040	0.0366

Reference condition, lakes and reservoirs, Ecoregion III = 0.020 mg/L (United States Environmental Protection Agency, 2000)

Table 4-9: Average TN concentrations (mg/L) in Lake Bowen at various depths (2009-2016)

Depth	LWB-4	LWB-5	LWB-8B	LWB-9B	LWB-10	LWB-12
surface	0.278	0.236	0.222	0.20	0.312	0.212
3-ft		0.616	0.599		0.566	
9-ft					0.797	
18-ft		0.673	0.648		0.711	
thermocline				0.52		0.493
bottom	0.374	0.374	1.17		0.444	0.774

Reference condition, lakes and reservoirs, Ecoregion III = 0.36 mg/L

Table 4-10: Average Chlorophyll-a concentrations (mg/m^3) in Lake Bowen at various depths (2009-2016)

Depth	LWB-4	LWB-5	LWB-8B	LWB-9B	LWB-10	LWB-12
surface	36.38	31.82	21.267	21.267	34.20	29.67
3-ft		24.39	18.242		21.63	
9-ft					32.01	
18-ft		30.925	21.59		37.68	
thermocline				23.0 (1)		27.6 (1)
bottom	41.86	42.12	51.14	16.97	41.82	13.27

Reference condition, lakes and reservoirs, Ecoregion III = 4.93 mg/L

Table 4-11: Average Nitrate/nitrite concentrations (mg/L) in Lake Bowen at various depths (2009-2016)

Depth	LWB-4	LWB-5	LWB-8B	LWB-9B	LWB-10	LWB-12
surface	0.025	0.025	0.025	0.025	0.025	0.025
3-ft		0.025	0.053		0.100	
9-ft					0.150	
18-ft		0.100	0.0525		0.100	
thermocline				0.025		0.025
bottom	0.025	0.025	0.025	0.025	0.025	0.025

Reference condition, lakes and reservoirs, Ecoregion III = 0.059 mg/L

Lake Bowen’s TP, TN, and chlorophyll-a concentrations are generally above the EPA eco-regional ambient (i.e. target) benchmarks. None of the sites’ average concentrations in this time period exceed the SCDHEC numeric criteria for the Piedmont and Southeastern Plains value of 1.50 mg TN/L. (SCDHEC R.61-68, *Water Classifications & Standards,* Section E. (11)(b)(2).

Nitrate is below this threshold for all sites except LWB-10. The high nitrate concentration value seen at *WS-H* is not reflected in the lake concentrations in Table 4-13, likely because the closest downstream station to WS-H in the lake is 1.8 miles downstream, which likely masks any effect of WS-H.

MUNICIPAL RESERVOIR #1

Table 4-12: Average TP concentrations (mg/L) in Municipal Reservoir #1 (2007-2016)

Depth	**MR1-LWBdam**	**MR1-WFR**	**MR1-Mud Creek**	**MR1-1**	**MR1-2**	**MR1-RLMS**	**MR1-100yds**	**MR1-simms**	**MR1-simms 25 yds**	**Avg, All Sites**
surface	0.035	0.027	0.039	0.053	0.052	0.036	0.047	0.028	0.022	**0.036**
1-ft						0.033				**0.033**
3-ft		0.039				0.033		0.038		**0.036**
9-ft		0.059				0.052			0.021	**0.048**
18-ft								0.075		**0.070**
thermocline							0.06			**0.060**
bottom		0.04		0.058	0.06	0.172	0.067	0.055		**0.071**
Avg, All Depths	**0.035**	**0.045**	**0.039**	**0.055**	**0.056**	**0.046**	**0.057**	**0.055**	**0.022**	**0.045**

Reference condition, lakes and reservoirs, Ecoregion III = 0.020 mg/L (United States Environmental Protection Agency, 2000)

Table 4-13: Average TN concentrations (mg/L) in Municipal Reservoir #1 (2007-2016)

Depth	**MR1-LWBdam**	**MR1-WFR**	**MR1-Mud Creek**	**MR1-1**	**MR1-2**	**MR1-RLMS**	**MR1-100yds**	**MR1-simms**	**MR1-simms 25 yds**	**Avg, All Sites**
surface	0.52	0.41	0.58	0.24	0.19	0.40	0.23	0.31	0.48	**0.46**
1-ft						0.54				**0.54**
3-ft		0.62				0.65		0.57		**0.59**
9-ft		0.72				0.59			0.53	**0.64**
18-ft								0.76		**0.76**
bottom		0.25		0.19	0.36	0.24	0.65	0.37		**0.35**
Avg, All Depths	**0.52**	**0.59**	**0.58**	**0.24**	**0.27**	**0.53**	**0.44**	**0.61**	**0.50**	**0.55**

Reference condition, lakes and reservoirs, Ecoregion III = 0.36 mg/

Table 4-14: Average Chlorophyll-a concentrations (mg/m^3) in Municipal Reservoir #1 (2007-2016)

Depth	**MR1-LWB dam**	**MR1-WFR**	**MR1-Mud Creek**	**MR1-1**	**MR1-2**	**MR1-RLMS**	**MR1-100yd**	**MR1-simms**	**MR1-simms 25 yds**	**Avg, All Sites**
surface	26.7	11.6	2.5	19.4	33.7	22.7	29.1	22.7		**23.8**
1-ft										
3-ft								22.1		**21.8**
9-ft										
12-ft								26.3		**26.3**

18-ft								47.5		**46.2**
24-ft								28.4		**28.4**
27-ft								50.6		**50.6**
thermocline							21.6			**21.6**
bottom		15.6		21.5	25.0	24.1	26.4	28.1		**26.2**
Avg, All Depths	**26.7**	**13.6**	**2.5**	**20.4**	**29.3**	**23.4**	**27.3**	**30.0**		**28.8**

Reference condition, lakes and reservoirs, Ecoregion III = 4.93 mg/L

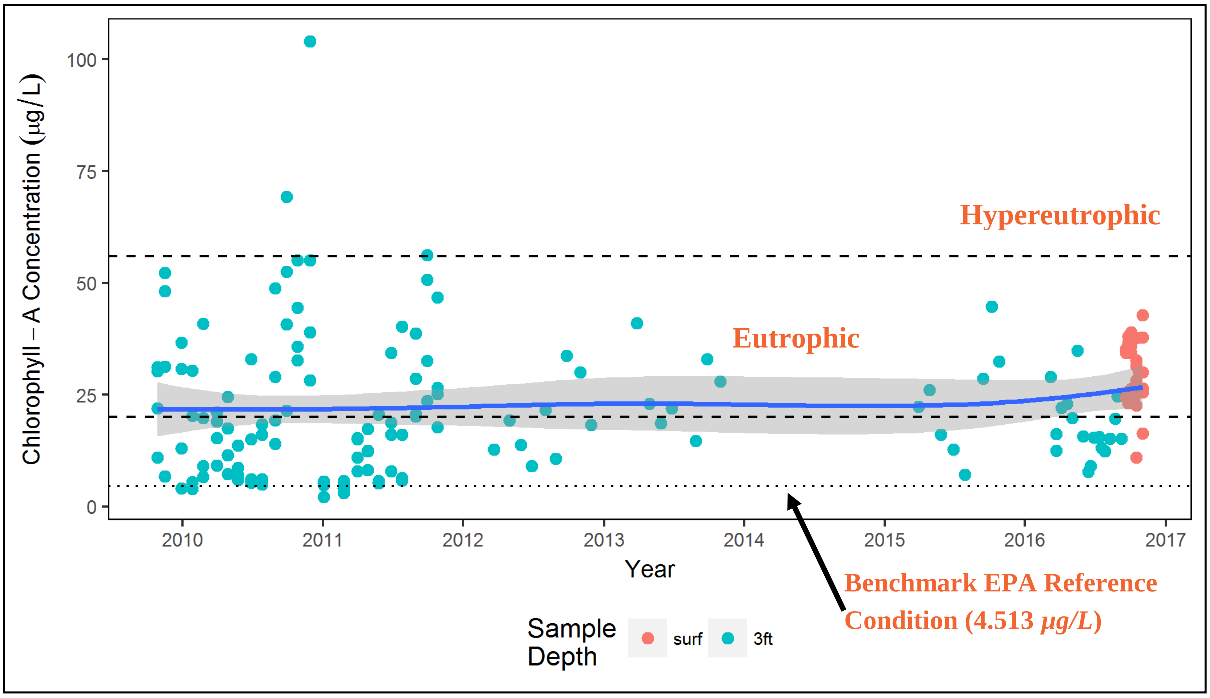
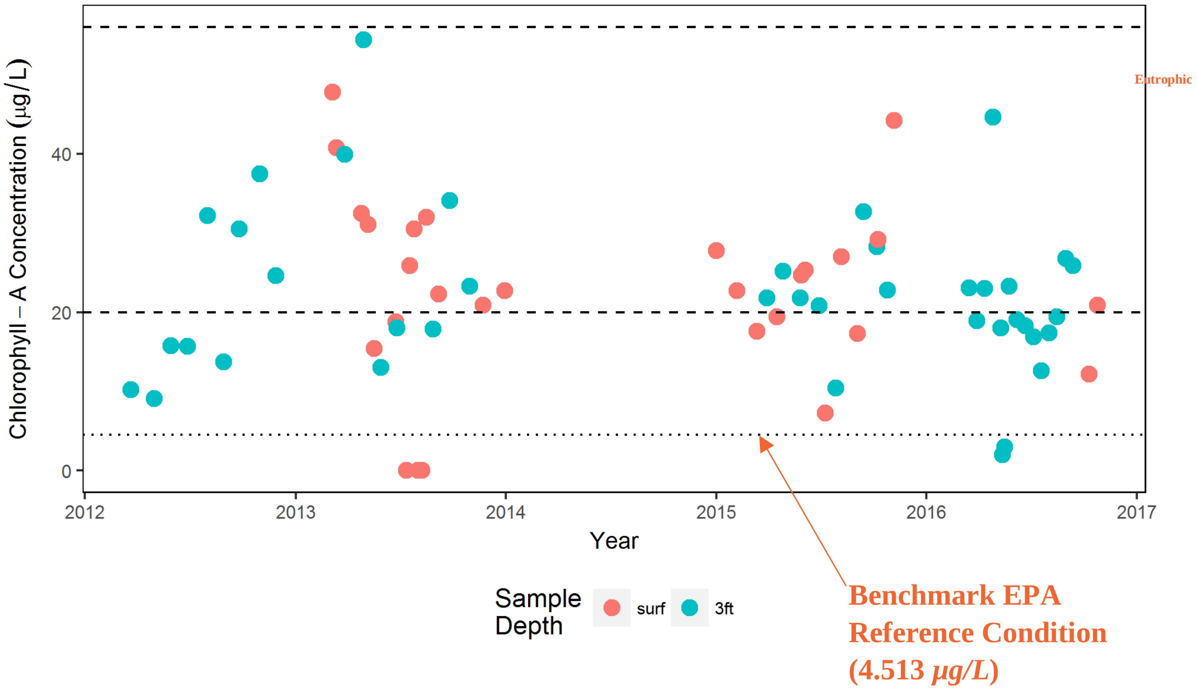


Figure 4-18: Chlorophyll-a concentration for all Lake Bowen sites, surface and 3 ft depth (gray shading represents the 95% confidence interval of the local polynomial curve fit)

Surface concentrations of TN and TP generally exceed the ambient EPA standard at the surface for most stations. None of the MR1 sites' average TN concentrations in this time period exceed the SCDHEC numeric criteria for the Piedmont and Southeastern Plains value of 1.50 mg TN/L. (SCDHEC R.61-68, *Water Classifications & Standards*, Section E. (11)(b)(2). Only a few sites, and at depths of 18ft down to the bottom, registered values higher than SCDHEC's 0.06 mg/L TP exceedance threshold for Piedmont and Southeastern Plains lakes. Chlorophyll-a concentrations in Municipal Reservoir #1 appear to be slightly lower measured at the surface for Municipal Reservoir #1 when compared to Lake Bowen. When comparing the two, it is helpful to look at chlorophyll-a over time, especially at shallow depths. The figures below show that both Lake Bowen and Municipal Reservoir #1 maintain chlorophyll-a concentrations above the EPA benchmark. Generally, the values are in the eutrophic range, with some Lake Bowen sites in 2010 and 2011 jumping into the hyper-eutrophic classification. Only LWB-4's bottom sample averaged higher than SCDHEC's exceedance threshold of 40 mg/m^3 (ug/L), while The 18-

ft and 34-ft sample sites at MR1-Simms averaged higher than 40 mg/m^3. Surface measurements of chlorophyll-a were all, on average, below the 40 mg/m^3 value.



Benchmark EPA Reference Condition (4.513 *µg/L*)

Figure 4-19: Chlorophyll-a for Municipal Reservoir #1 at Simms intake, surface and 3 ft depth

The median chlorophyll-a concentration was 23.3 and 22.05 µg/L for Lake Bowen and the Simms intake in Municipal Reservoir #1, respectively. Based on EPA water quality criteria and broad definitions of eutrophication, it is clear that there are seasonal periods of eutrophication in Lake Bowen and Municipal Reservoir #1, and instances of hyper-eutrophication in Lake Bowen during the summers of 2010 and 2011. As a reference point, the USGS limnological study of Lake Bowen and Municipal Reservoir #1 found chlorophyll-a concentrations ranging from 1.2 to 6.4 µg/L in 2005 and 5.6 to 8.2 µg/L in 2006. The report stated that surface concentrations of chlorophyll-a and TP were well below established numerical criteria for South Carolina, with final determination of the lakes being mesotrophic. Data from 2009-2016 seems to indicate that rapid increases in lake biological activity have occurred, with an order of magnitude more chlorophyll-*a* present in both reservoirs.

Another indicator of algal growth that are important to source water managers is the presence of taste and odor compounds. Spartanburg Water has been measuring 2-methylisoborneol (MIB) and trans-1, 10-dimethyl-trans-9-decalol (Geosmin) at various locations in the reservoirs. These compounds are released from algal and bacterial cells upon their decay, and are characterized by a very earthy (Geosmin) and musty (MIB) odor. Many people can detect these compounds in the 5-10 parts per trillion (ng/L) range, making them useful indicators for water distribution systems (Trojan UV, 2010). Spartanburg Water had a spike of MIB in the late summer of 2015 at the R.B. Simms intake sampling location (Figure 4-20). The dashed line below represents 5 parts per trillion, which is the value at the low end of the detectable range.

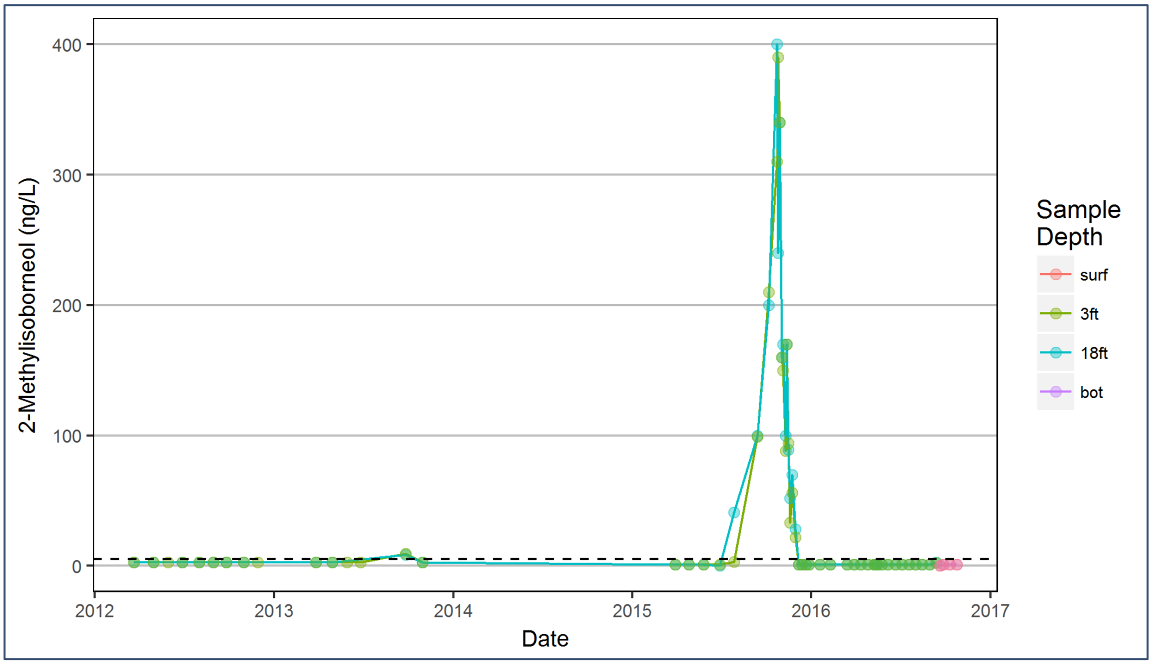


Figure 4-20: MIB concentration at the MR1-Simms sampling site for three depths sampled

In 2016, the process of oxygenation was added to potential tools at the disposal of Spartanburg Water in order to handle periods of low oxygen that may occur near Lake Bowen and Municipal Reservoir #1. This was partially in response to high MIB concentrations experienced in 2015 (Figure 4-20). The oxygenation system delivers a consistent stream of oxygen, ferric and alum through a piping system along the bottom of the lakes at certain locations.

Figure 4-21 shows the dissolved oxygen concentrations measured at the Simms intake location from 2010 to 2016. The SC DHEC standard for dissolved oxygen states that the daily average should not go below 5 mg/L and that the low value should not go below 4.0 mg/L. While we do not have data on a fine enough timescale to compare to daily minima and averages, if it is assumed that each value represents the daily averages, then there are numerous dips in the summer that result in lower dissolved oxygen near the intake.

Based on monitored data at *WS-E* (the entrance of the South Pacolet River into the lake systems), the 25th percentile, median, and 75th percentile dissolved oxygen concentrations were 7.35, 8.5, and 9.9 mg DO/L. The SCDHEC standard for FW streams is to not average less than 5.0 mg/L on a daily basis, with a low of 4.0 mg/L. Therefore, the data indicate a higher DO concentration than what is required by the state standards at this monitoring location.

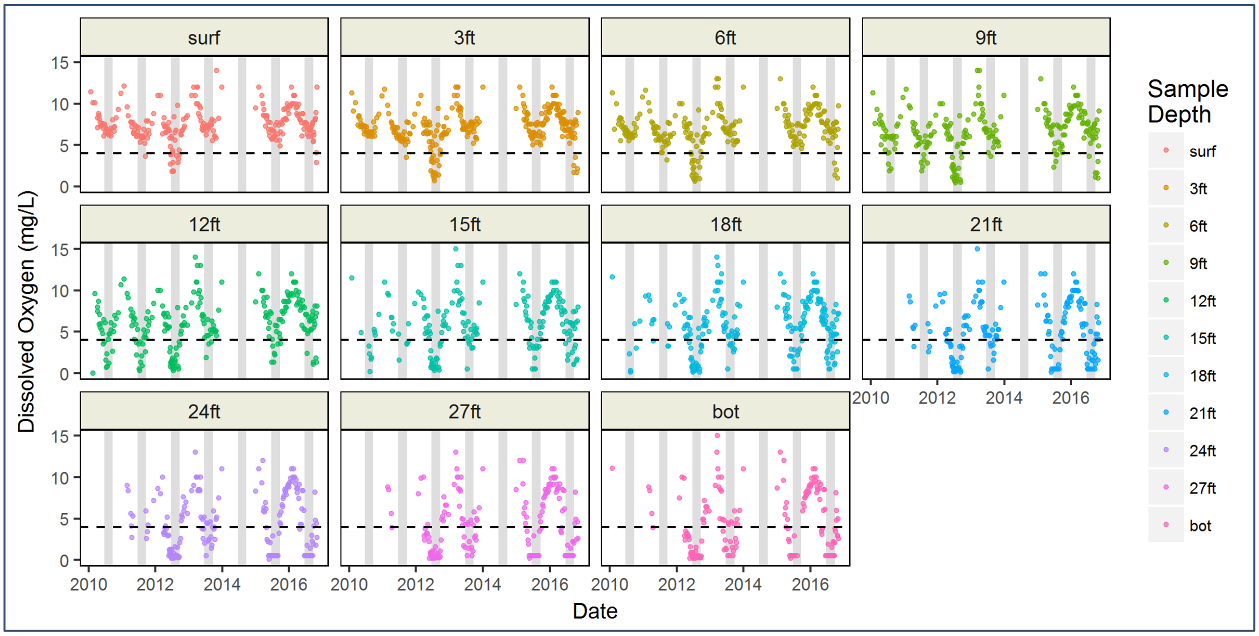


Figure 4-21: Dissolved oxygen concentrations over time for all depths at the R.B. Simms intake on Municipal Reservoir #1. Gray bars represent the summer season. Dashed line indicates SC DHEC minimum DO standard of 4.0 mg/L

5. Load Reduction Identification

5.1 Background Load Estimation

To better understand how the various BMPs described in Section 6 can be applied in the watershed, it is first imperative to estimate the current annual loading that is entering Lake Bowen and Municipal Reservoir #1. After this estimate is in place, the various practices can be applied quantitatively to begin to determine milestones of mitigation in the future.

A USGS monitoring gage exists on Alverson Rd (State Rd S-42-919), 1.08 miles upstream of the river's confluence with Lake Bowen. Spartanburg Water has maintained a water quality sampling station at this location since 2007 (*WS-E*). Grab samples of various pollutants were collected and analyzed, which are the basis for monitored load calculations into the river before entering Lake Bowen.

Three USGS stations exist in the watershed. As a result, there is no flow data associated with most of the stations sampled for water quality in Table 3-2. In order to estimate loading, which requires flow volume in addition to concentration, the USGS station coinciding with *WS-E* (USGS station 2154790) was scaled to other monitoring stations by watershed area and percent imperviousness to estimate annual flow volumes. Average annual volume for *WS-E* was calculated by taking the average value of the daily average flow values for the USGS station from 1990 to 2017, and multiplying by 365.25 days in a year, and converting that to volume in cubic feet.

Because of the strong link between sediment and nutrient inputs and the potential for eutrophication in receiving bodies, the loading for TN, TP, and TSS was desired as a metric with which to base future planning efforts. Multiple ways exist to estimate loads for a watershed. Intensive watershed and lake process modeling has been done on multiple watersheds in the Southeast (see N.C. Department of Environment and Natural Resources, 2009). These modeling efforts generally require substantial monetary and time resources to collect and analyze a large amount of data to obtain reasonable predictive accuracy. For this study, existing pollutant loads were evaluated based upon monitoring data and the use of the EPA STEPL model. The load calculated based upon monitoring data was utilized to characterize load reduction needs, while the STEPL estimation was primarily utilized to estimate the relative load contribution from different sources.

5.2 Monitored Load Estimation

For the monitored load evaluation, a baseline estimate was calculated based on existing grab-sample concentration data provided by Spartanburg Water married with the continuous real-time USGS data from the station on the South Pacolet River just upstream of Lake Bowen. Multiple years of measured concentration data exists for this site. In order to calculate load from concentration, a volume of water is needed. To estimate annual volume, the average daily flow rates for the USGS station on the South Pacolet River were converted to volume, summed on an annual basis, and averaged to obtain an average annual stream volume. This, multiplied by the *WS-E* station concentration data, allowed for the estimation of loading values in mass per time (see Figure 4-1 for locations of the stations). Because flow data was non-existent for the remainder of the watersheds with monitoring points, the flows from *WS-E* were adjusted based on the area of the other catchments in relation to *WS-E*. These area-weighted volumes were then multiplied by the average concentrations of TP, TN, and TSS at the other monitoring stations (Table 5-1).

Table 5-1: Estimated annual loading of nutrients and sediment at water quality monitoring stations in the South Pacolet River watershed

Monitoring Catchment	Catchment Area (mi^2)	Average Annual Stream Volume (millions of cf)	TP (lb/yr)	TN (lb/yr)	Sediment (tons TSS / yr)
WS-E	55.4	2,811.0	11659	98083	629
WS-I	0.5	26.7	73	917	4
WS-H	0.5	25.4	77	2289	4
WS-F	4.16	206.2	685	7237	61
WS-G	2.25	114.3	373	4075	29
WS-D	6.33	321.2	1141*	15088*	70
WS-B	4.99	253.0	783	9004	67
WS-C	12.18	618.1	3460	34062	149
WS-A	17.26	875.6	4086	33437	187
WS-K	2.77	140.4	478	6593*	36

* Concentration data is non-existent for this site and pollutant; average of all concentrations for all other sub-watersheds used as value when calculating loads

The above stations include areas that overlap each other, namely that watershed sites *WS-B*, *WS-A*, *WS-C*, and *WS-D* are contained within the entirety of *WS-E*. As a result, the data collected at *WS-E* was used instead of the sum of the four individual sites that comprise it when scaling up to the entire HUC-10 watershed scale. The above monitoring stations cover approximately 74% of the dry land contributing area of the South Pacolet River watershed. The loading for the remaining 23.3 square miles not encompassed by the above watersheds (i.e. the white space in the watershed shown in Figure 5-1) was estimated by taking the average concentrations for the various pollutants and multiplying it by the area-weighted annual volume derived by the known flow station at *WS-E*. The difference between that calculation and the calculations for the known monitoring station locations is that the latter contained site-specific concentration data through Spartanburg Water monitoring.

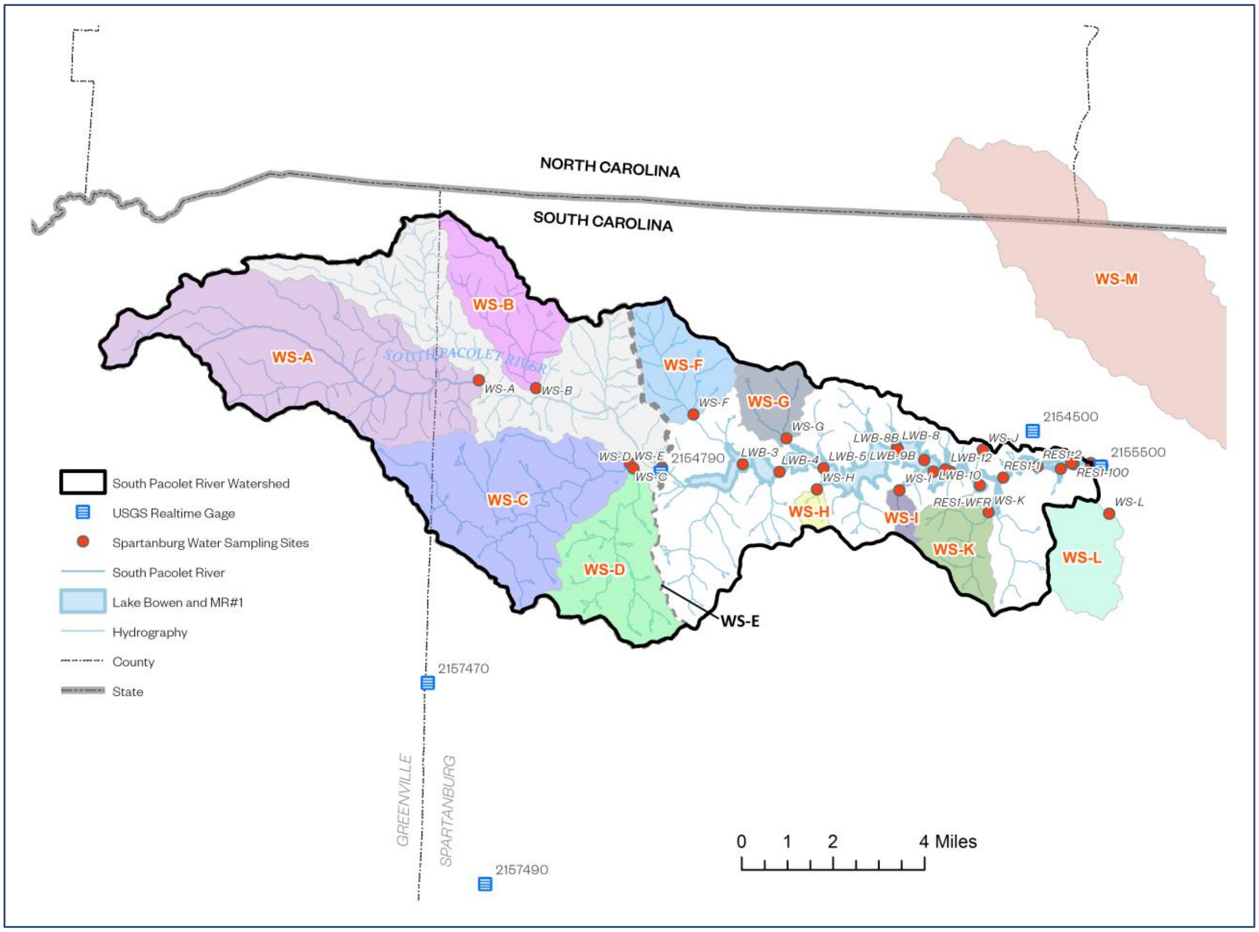


Figure 5-1: Map of monitoring catchment locations and sampling sites

The total sum of annual average monitored pollutant loads for the watershed is outlined in Table 5-2. Both the total loading in pounds per year, and the unit-weighted pounds per acre per year are presented. Due to the large differences in watershed sizes, it is useful to normalize by area in order to compare between watersheds, and allow for more site-specific load reduction calculations. This may be useful for watersheds that choose to limit new developing per acre loading in order to meet a standard, or to extrapolate loading to multiple geographical scales. The percent reduction needed was calculated as the percent difference between the current estimate per year and the loading needed to reach the lake concentrations shown under “target”.

Table 5-2: Summary of annual nutrient and sediment loading into Lake Bowen and Municipal Reservoir #1

Parameter	Estimated Current Load		Target		Percent Reduction Needed
	lb ac^{-1} yr^{-1}	lb yr^{-1}	Lake Concentration (mg L^{-1})*	Load (lb yr^{-1})**	
TN	3.05	174,704	0.36	98,100	44%
TP	0.31	17,541	0.020	5,450	69%
TSS	35.6	518,563	ND	ND	ND

*Source: Environmental Protection Agency (2000): Ecoregion IX (Southeastern Temperate Forested Plains and Hills) 25ht percentile concentrations for reference lakes and reservoirs

** Concentration multiplied by estimated annual watershed runoff / stream volume of 4.365B cubic feet

For reference, the 2008 USGS limnological study on Lake Bowen and Municipal Reservoir #1 cites loadings calculated in 1976 as 5,584 lb/yr of TP and 176,921 lb/yr of TN. The value calculated above for phosphorus is three times the 1976 value, while the TN value is roughly the same (Journey & Abrahamsen, 2008). It is important to note that different monitoring and analysis methods may account for some differences when comparing current load estimates with those from the 1976 report.

5.3 STEPL Load Estimation

The EPA Spreadsheet Tool for Estimating Pollutant Load (STEPL) calculates pollutant loads based upon input watershed characteristics. Due to the nature of STEPL calculations, the tool can be used to estimate total loads for nitrogen, phosphorus, BOD, and sediment, but can also attribute those loads to general sources within the watershed. STEPL also provides functionality to characterize the impacts of BMP implementation throughout the watershed on nutrient loads.

STEPL evaluations considered the entirety of the South Pacolet River watershed as a single basin, with watershed characteristics populated based upon existing information regarding land use, agricultural animal populations, number of septic systems and their assumed failure rate, and soil characteristics. It should be noted that limited information was available for some of these inputs and the STEPL analysis may be updated over time as watershed characteristics are better understood. For example, impaired streambanks likely contribute to nutrient loads throughout the watershed; however, impaired streambanks and gullies were not explicitly accounted for in the STEPL analysis because the information required to provide an informed assessment is not currently available. The estimated nutrient contribution from various sources is presented in Table 5-3.

Table 5-3: Existing nutrient loads estimated with STEPL

Source	TN Load (lb yr^{-1})	% of Total TN Load	TP Load (lb yr^{-1})	% of Total TP Load
Urban	31,847	17%	4,504	16%
Cropland	870	<1%	169	1%
Pastureland	123,044	66%	11,505	40%
Forest	10,485	6%	5,102	18%
Septic	19,204	10%	7,522	26%
Total	**185,451**	**100%**	**28,802**	**100%**

Pastureland was the single largest contributor of nutrient loading within the watershed, representing an estimated 66% of the watershed TN load and 40% of the watershed TP load based on the STEPL output. Of the nutrient sources considered, forest is the only contributor with limited management opportunities; however, this source represents a small portion of the overall load.

A comparison of total nutrient loads calculated from monitoring data and STEPL reveals different results. Specifically, STEPL loads for TN are 7% higher than those monitored, with TP loads 49% higher. Due to the inherent complexities in watershed characteristics and processes, as well as differences in sampling protocols and modeling assumptions, such differences are not uncommon in planning studies like the one presented herein. As discussed later in this report, these estimates provide an overall characterization of nutrient loads within the watershed and a basis to plan water quality improvement efforts. Over time, additional monitoring and analysis will support refined estimates, guiding future efforts.

6. Management Strategies

6.1 Overview of Management Approaches

This section summarizes the most likely BMPs to contribute towards protection of water quality. The focus of this report is primarily nutrient load reduction; however, many of these practices could assist in reducing bacteria loads, supporting the existing bacteria TMDL. Due to the dynamic nature of bacterial pollutants, bacterial loads and load reductions can be difficult to accurately quantify and are consequently not included herein. There are some means of approximating bacterial loads and the impact of improvement efforts that may be examined within the watershed during the course of implementation efforts to better realize comprehensive water quality improvement. Generally, practices that exclude bacterial sources from waterways, like livestock exclusion fencing, and those that incorporate elements of filtration and sunlight exposure, like bioretention, are going to be among the most effective means of reducing bacterial loads.

First, Table 6-1 is presented showing the high variety of management practices that exist. The sub-sections themselves are selected based on feasibility, experience of them in the watershed, and effectiveness given the context of the South Pacolet River.

Table 6-1: Examples of structural and nonstructural management practices (US EPA, 2008)

Class	Structural Practices	Non-Structural Practices
Agriculture	• Contour buffer strip • Grassed waterways • Herbaceous wind barriers • Mulching • Live fascines • Live staking • Livestock exclusion • Revetments • Riprap • Sediment basins • Terraces • Waste treatment lagoons	• Brush management • Conservation coverage • Conservation tillage • Educational materials • Erosion and sediment control plan • Nutrient management plan • Pesticide management plan • Prescribed grazing • Residue management • Requirement for minimum riparian buffer • Rotational grazing • Workshops/trainings for nutrient management plans
Forestry	• Broad-based dips • Culverts • Establishment of riparian buffer • Mulch • Revegetation of fire lines with adapted herbaceous species • Temporary cover crops • Windrows	• Education campaign on forestry-related nonpoint source controls • Erosion and sediment control plans • Forest chemical management • Fire management • Operation of planting machines along the contour to avoid ditch formation • Planning and proper road layout and design
Development	• Bioretention • Breakwaters • Brush layering • Infiltration basins • Green roofs • Live fascines • Wetland restoration / construction • Vegetated riparian buffers • Riprap • Stormwater ponds • Sand filters • Sediment basins • Tree revetments • Vegetated gabions • Water quality swales • Clustered wastewater treatment systems	• Reduce impervious surfaces • Ordinances • Educational materials • Erosion and sediment control plans • Fertilizer management • Pet waste programs • Pollution prevention plans • No-wake zones • Setbacks • Storm drain stenciling • Workshops on proper installation of structural practices • Zoning overlay districts • Preservation of open space • Greenway development

6.1.1 Structural BMPs

6.1.1.1 Stream Restoration

This ecological and civil engineering technique involves re-establishing the structure, function, and habitat of a stream system that existed prior to disturbance or matches a reference condition unique to the geographical area of the stream. Most commonly, it involves mass grading of an incised corridor that has lost its connection to the flood plain. This helps distribute the high forces that are involved with storms that occur roughly every 1 to 2 years or more (the “bankfull” discharge) onto a vegetated floodplain rather than concentrate them in a narrow, erodible corridor, which further exacerbates sediment transport, loss of habitat, and loss of recreational or aesthetic appeal.

Additionally, because stream erosion can result in the mobilization of sediment, which can contain phosphorus and nitrogen, it is an important tool in watershed nutrient management. There are markets in the United States that credit stream restoration on a unit basis for nutrient and sediment reduction, and even private equity markets that trade these credits as an asset. The Chesapeake Bay Program (CBP) has proposed interim credits for TN, TP, and TSS reduction on the basis of linear feet of stream restored as follows (Chesapeake Stormwater Network, 2015):

- 0.20 lb-TN/ft/yr
- 0.068 lb-TP/ft/yr
- 44.88 lb-TSS/ft/yr (for the non-coastal plain regions of the Chesapeake Bay)

The CBP does acknowledge that their derived removal rates are recommended to apply to rural stream projects, due to the lack of research on non-urban streams. However, many of the studies reviewed to determine the findings *were* from rural streams. The CBP specifically does advise not to apply removal rates they would use for crediting to riparian fencing projects to keep livestock out of streams.

Important to any program considering stream restoration is the evaluation of the progress of bank sediment loss, and the ability of stream restoration to prevent that further loss. In lieu of physically monitoring the stream corridor’s banks, many guides recommend the BANCS (“Bank Assessment for Non-point Source Consequences of Sediment”) method.

In designing a properly stabilized stream corridor, the stability of the banks necessarily leads to lowered sediment erosion rates. While this may prevent some nitrogen and phosphorus release, there are additional tools in stream restoration to reduce nitrogen through chemical and biological processes. The Chesapeake Bay has proposed building a corridor of substrate *beneath* the constructed stream bottom that relies on a process called denitrification, which converts nitrate-nitrogen into N_2 gas using nitrate-loving bacteria.

6.1.1.2 Vegetated Riparian Buffer

Development is often done in close proximity to water bodies for geographical, land value, or recreational reasons. As a result, natural riparian corridors of vegetation are susceptible to encroachment by development. Many jurisdictions, including entities near the South Pacolet River watershed, understand the value that adding vegetated riparian buffers can have for stream and water quality health. They are either expressed as vegetation stands between agricultural fields and streams, or as limits of disturbance for residential or commercial development in close proximity to surface water.

The 2009 document entitled *The Status of Natural Resources in Spartanburg County* by the Spartanburg Community Indicators Project identified buffers as an important tool to be used in the future.

- SPACE (Spartanburg Area Conservancy) procures riparian buffers in the watershed.
- Spartanburg Water is “WAIT” certified (Wildlife and Industry Together)

Buffers have been shown to remove nitrogen (particularly nitrate) from groundwater and interflow (Messer, et al., 2012; Wiseman, et al., 2014). Areas with steeper topography and less conservation practices in nearby fields are less likely to have effective buffer performance in protecting streams and removing nutrients and sediments. Higher topography often leads to flow channelizing rather than staying as a “sheet”, which reduces buffer effectiveness. In the context of this watershed, buffer effectiveness may be highest just upstream of the arms of Lake Bowen, where numerous sediment, livestock incursion, and nutrient problems have been reported by stakeholders. Additionally, areas of relatively stable, flat land that exists in the upland portions of the watershed adjacent to agriculturally facilities should be considered in developing further buffer coverage. Buffers are not always effective, however; they are best at trapping particulate pollutants and may not capture dissolved pollutants in surface flow, especially at high loading ratios (where the vegetated strip is small and the contributing area is high).

Locally, the SC DHEC BMP manual (SCDHEC, 2005) has a chapter entitled *Stream Buffers* on recommended buffer guidelines. Specifically, streams that have relatively small drainage areas of 100 acres or less (i.e. in the headwaters of the South Pacolet) are recommended to provide the following offsets:

- **Stream Side Zone (first 30 ft**) – Remains undisturbed and stable; no clear cutting, as this area is used for streambank stabilization, flood control structures, footpaths, or utility or road crossings only
- **Managed Use Zone (next 40 ft)** – Floodplain and pollutant filtration; limited number of trees removed here, with minimum of 8 healthy trees (6-inch caliper or greater) per 1,000 square feet; no fill in area; no land disturbance; some stormwater BMPs (i.e. wetlands), greenway trails, and bike paths
- **Upland zone (next 15 ft)** – Grading permitted; plant grass or other erosion-resistant cover; no fill material unless deficient soil present; can have gardens, gazebos, decks, or storage buildings less than or equal to 150 square feet

6.1.1.3 Constructed Wetlands

Constructed wetlands employ the hydric soils and ecology of natural wetlands, but do so in order to treat stormwater or agricultural runoff in an engineered manner. Constructed wetlands are designed to treat a “slug” of water entering it through biological, chemical, and physical processes. Compared to traditional detention ponds, constructed wetlands have a much higher biological and chemical treatment capacity due to the rapid uptake of nutrients common in stormwater into the plant zone in wetlands, which are often immobilized or transformed into inert forms that do not pose a major threat to water quality. Wetlands are a desirable BMP option in low-lying, high water table areas, such as locations close to surface waters. In states that award development stormwater BMPs with water quality reduction credit, stormwater wetlands often outperform traditional wet retention ponds due to the added biological and filtration capacity. An example stormwater wetland in Staten Island, NY is shown in Figure 6-1.

Figure 6-1: Constructed stormwater wetland in Staten Island, New York. Wetland design involves using biological process and high hydraulic retention times to treat stormwater runoff.

As described in Section 4.3.3, SC DOT also is active in working with local partners within project areas to mitigate new construction with wetlands. SC DOT and project partners use a U.S. Army Corps of Engineers tool called the "Regulatory In-lieu and Bank Information Tracking System (RIBITS) to find nearby approved stream mitigation banks or in-lieu fee programs. Utilizing this existing resource could help future project sites be identified more efficiently, even if they don't directly relate to SC DOT construction. The existing network of wetland mitigation efforts could be leveraged to prioritize stream and wetland restoration throughout the watershed.

Spartanburg Water recognizes the importance wetlands can play in providing source water protection per their 2010 watershed management plan document. In addition to retrofits of constructed stormwater wetlands, restoring and re-establishing wetlands that were previously lost in the watershed fits with Spartanburg Water's goal of using these ecological tools to protect Lake Bowen and Municipal Reservoir #1. Going forward, it may be possible for Spartanburg Water as a prime partner to help fund mitigation banks to keep mitigation projects in the upper reaches of the South Pacolet.

6.1.1.4 Bioretention / Rain Gardens

Rain gardens (or “bioretention” systems) are increasingly being used to capture runoff from impervious surfaces such as parking lots, roads, driveways, and rooftops. Rain gardens are vegetated depressions in the landscape that store and infiltrate runoff, sometimes into engineered soil media, which is either filtered and released by an underdrain pipe or allowed to percolate into the native soils beneath the root zone. The ponding depth and size of the system is generally related to the desired storm size to be captured, which is often an implicit annual volume reduction target (typically 80-90%). Rain gardens have become a popular, distributed treatment tool to aid in reducing the overall volume and pollutant loading of watersheds due to the secondary benefits they provide, such as landscape beautification, habitat creation, property value increase, and cost when compared to grey infrastructure.

Rain gardens have been researched extensively for their performance in removing specific pollutants. The root structure and soil in the rain garden itself is a microbial ecosystem that both filters particulate pollutants and, in some circumstances, transforms them through various biological and chemical processes. Because of their design flexibility, customization, and aesthetic value, rain gardens have become popular as retrofit BMPs in residential and commercial areas.

This BMP often comes in two forms: (1) a more engineered system that can treat more acres of impervious and often are placed in medium to high density development, often has underdrain and sub-grade rock layers, quality-controlled engineered media, and a larger footprint, and (2) homeowner-level “backyard” rain gardens that can be designed and installed by select landscape contracting companies, do not require an engineer’s approval, are usually smaller and more modest in depth, and are less expensive. Both of these systems were considered in this report as a method to reduce nutrients. Many watersheds that have undergone nutrient reduction programs, especially those as part of a TMDL process, have looked at cost-share programs of homeowner rain gardens as an option to treat runoff at its source in residential development (see Holmes Lake watershed in Lincoln, Nebraska).

6.1.1.5 Downspout Disconnection

Typical private property drainage consists of downspouts that are directed onto driveways or sidewalks that flow straight to the gutter system, and ultimately drain to surface waters through stormwater conveyance pipes. As an alternative, many municipalities are exploring voluntary outreach programs in which property owners instead direct the downspouts onto vegetated surfaces, which can ultimately be a very cost-effective stormwater volume-reducing measure on a watershed scale. Portland, Oregon’s downspouts disconnection program has resulted in 56,000 disconnections, which removes 1.3 billion gallons of stormwater from the sewer system each year (City of Portland, Oregon, 2017). This practice is especially valuable when paired with a decrease in turf grass fertilizer, that, if implemented would ultimately reduce both volume and nutrient loads to the South Pacolet River. Some jurisdictions have adopted downspout disconnection as a structural BMP with installation and crediting guidance to developers and residents (Figure 6-2). Disconnecting impervious surfaces can help reduce pollutant loading when discharged into a properly sized vegetated receiving area.

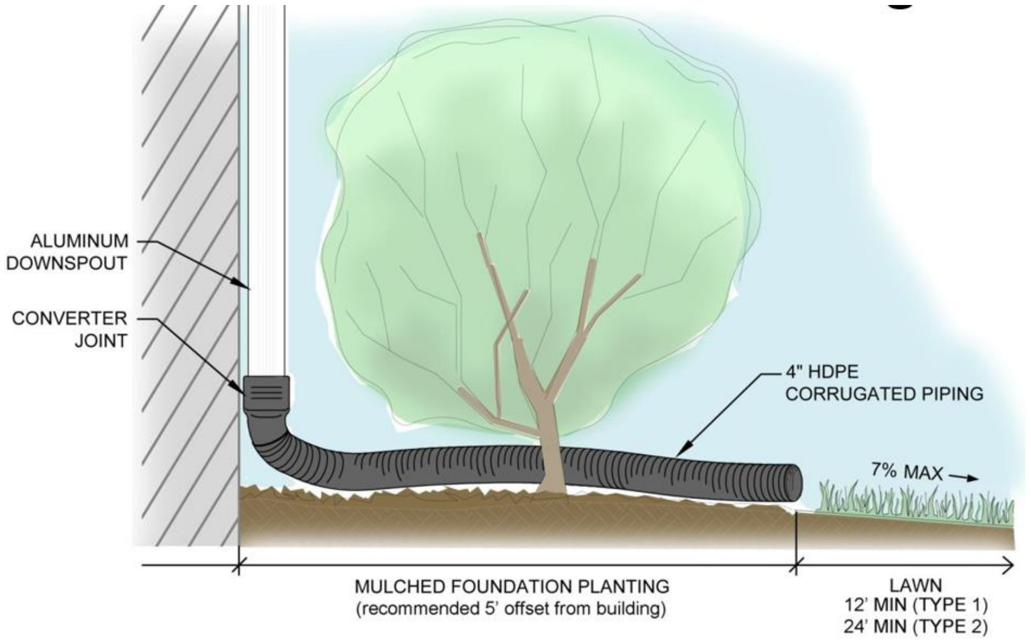


Figure 6-2: Disconnecting downspouts is one way to control and infiltrate residential runoff before it enters the storm sewer system (Source: NCDWQ Stormwater BMP Manual / North Carolina State University)

6.1.1.6 Livestock Exclusion Fencing

Exclusion Fencing is a tool that can benefit drinking water quality by preventing livestock from directly impacting the watershed. Being that the South Pacolet River watershed is located in the Upper Broad River, which completed a TMDL for fecal coliform bacteria in 2014, it follows that livestock exclusion can be an effective tool to making sure excessive bacteria do not get introduced into the South Pacolet River, and eventually, the Upper Broad River. The TMDL specifically recommends that limiting livestock access to streams is a best management practice tool that should be utilized in the Upper Broad River watershed to limit fecal coliform loading.

In 2006, a project funded by Clean Water Act Section 319 as part of the Enoree River TMDL focused on recruiting livestock farmers to implement BMPs. USDA-NRCS personnel assisted the landowners in installing 29,577 linear feet of fencing, 40,554 square feet of heavy-use area around water tanks, and engineered and reinforced select stream crossings. Clemson University Cooperative Extension worked extensively with local community organizations to educate citizens on cost-share opportunities, identified priority locations for pollution prevention practices, and educated the community, including through 4-H programming. CWA Section 319 funding contributed over $255,000, with in-kind services totaling $85,000 and private landowner contributions of $105,000. All stations re-sampled by SC DHEC in 2014 associated with the impairment showed water quality improvement. Two of the six initially impaired stream segments were below the 10% FC detection threshold to count as being “impaired”, while the remaining 4 segments showed reductions from 30-45% in 2014 compared to the 2002 303(d) assessment. (U.S. Environmental Protection Agency, 2015).

6.1.1.7 Terracing

Agricultural land management is a very important component of watershed health, as it is directly linked to the quantity and quality of the runoff that reaches the receiving water body. That is particularly true in agricultural areas that face challenges from steep topography such as is seen in the South Pacolet River watershed. Terracing of the land is a management technique characterized by broad channels, benches, or embankments constructed perpendicular to slopes in order to intercept runoff. They are usually level or only modestly sloped, with a steep grade break from terrace to terrace as the land slopes to a stream or lake (Ward & Trimble, 2003). Stakeholders have explicitly identified areas of agriculturally-based erosion in the Jamison Mill Creek sub-watershed.

6.1.1.8 Enhanced Pasture Management

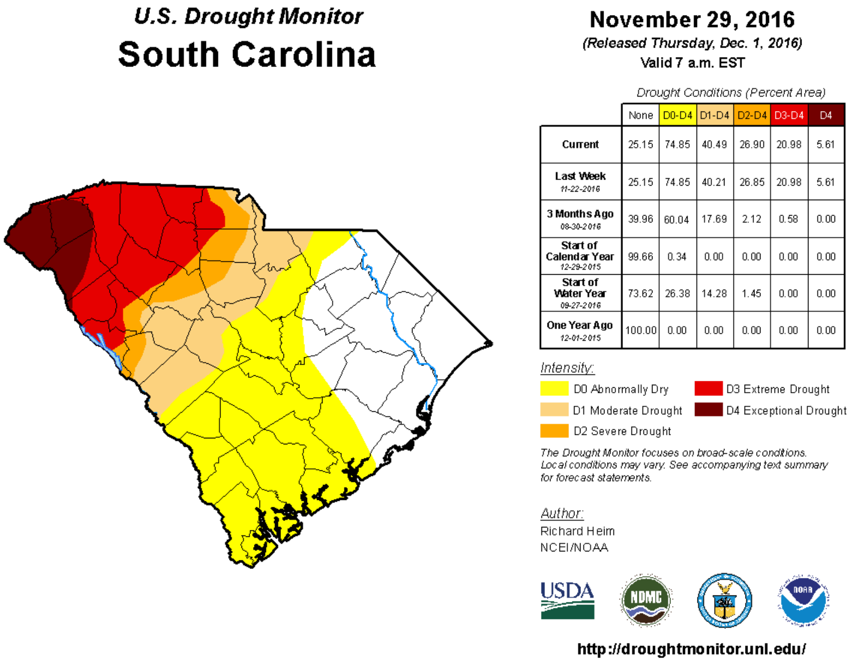
Pastured lands can reduce nitrogen and phosphorus loadings through various grazing improvement techniques, including upland prescribed grazing and intensive rotational grazing. Upland prescribed grazing includes increased management of grazing patterns to keep better forage stands and avoid degraded areas upland of streams, which can result in less runoff and erosion. Upland precision intensive rotational grazing is similar, but involves much shorter, concentrated livestock rotation schedules.

6.1.1.9 Rainwater Harvesting and Reuse

Rainwater harvesting has been used by human beings for thousands of years to capture rainfall and potentially reuse it for drinking water, irrigation, bathing, and recreation. In the context of water quality preservation, rainwater harvesting can be used in select instances to retain some of the most highly-enriched runoff before it enters streams and lakes, thus contributing to lower pollutant loading in the watershed. Capturing rainfall and runoff is most common in semi-arid climates of the world, but has gained some traction in the humid southeast in recent years due to variable rainfall patterns that can lead to water stress and drought conditions. As recently as November, Spartanburg County experienced a month of “Extreme Drought” as classified by the U.S. Drought Monitor (Figures 6-4 and 6-5). Figure 6-5 shows a daily summary of mean water surface elevations for Lake Bowen during 2016 into early 2017, which portrays the 14% water level drop that occurred during the month of November as a result.

Source: U.S. Drought Monitor, droughtmonitor.unl.edu

Figure 6-3: Drought Categories for South Carolina (top) and for the Upper Broad River Watershed (HUC-8, bottom)



U.S. Drought Monitor

South Carolina

November 29, 2016

(Released Thursday, Dec. 1, 2016)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	25.15	74.85	40.49	26.90	20.98	5.61
Last Week *11-22-2016*	25.15	74.85	40.21	26.85	20.98	5.61
3 Months Ago *08-30-2016*	39.96	60.04	17.69	2.12	0.58	0.00
Start of Calendar Year *12-29-2015*	99.66	0.34	0.00	0.00	0.00	0.00
Start of Water Year *09-27-2016*	73.62	26.38	14.28	1.45	0.00	0.00
One Year Ago *12-01-2015*	100.00	0.00	0.00	0.00	0.00	0.00

Intensity:

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Richard Heim
NCEI/NOAA

http://droughtmonitor.unl.edu/

Figure 6-4: Drought Condition map for the week of November 29, 2016 showing Extreme Drought present throughout South Pacolet River watershed

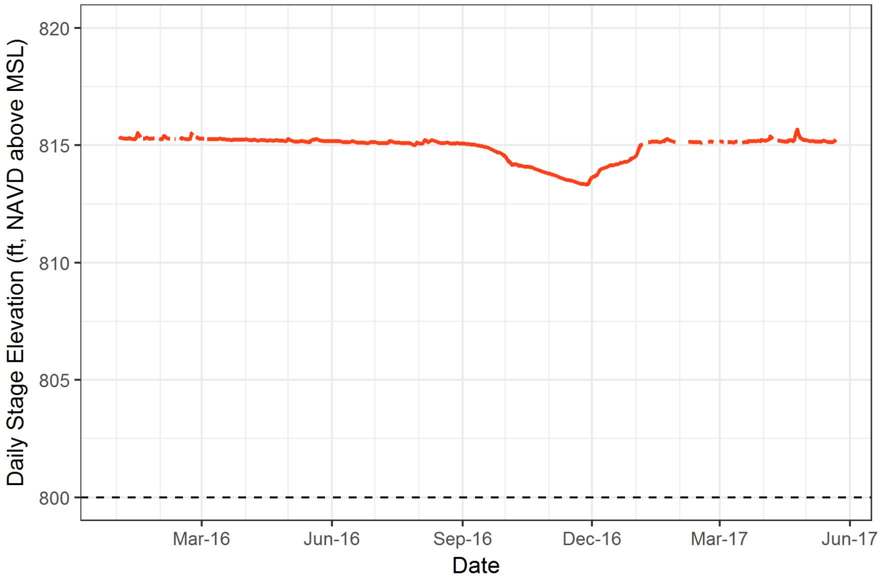


Figure 6-5: Water surface elevation of William Bowen Lake during fall 2016 drought period

While climate projections for the uplands of South Carolina generally show a slight increase in average annual rainfall, there is still a case to be made for water quality-related pursuit of rainfall capture. Rainwater harvesting can provide detention / retention of roof or parcel runoff that would otherwise flow into receiving bodies, and therefore act to trap “first flush” pollutants such as sediment and nutrients. Stormwater runoff harvesting potential is generally highest for users or property owners who have large amounts of runoff and/or demand large amounts of water, such as large-scale irrigation facilities. Research into rainwater harvesting with dual purposes—both to meet usage demand and act as a stormwater BMP (Figure 6-6)—have shown to be highly effective.

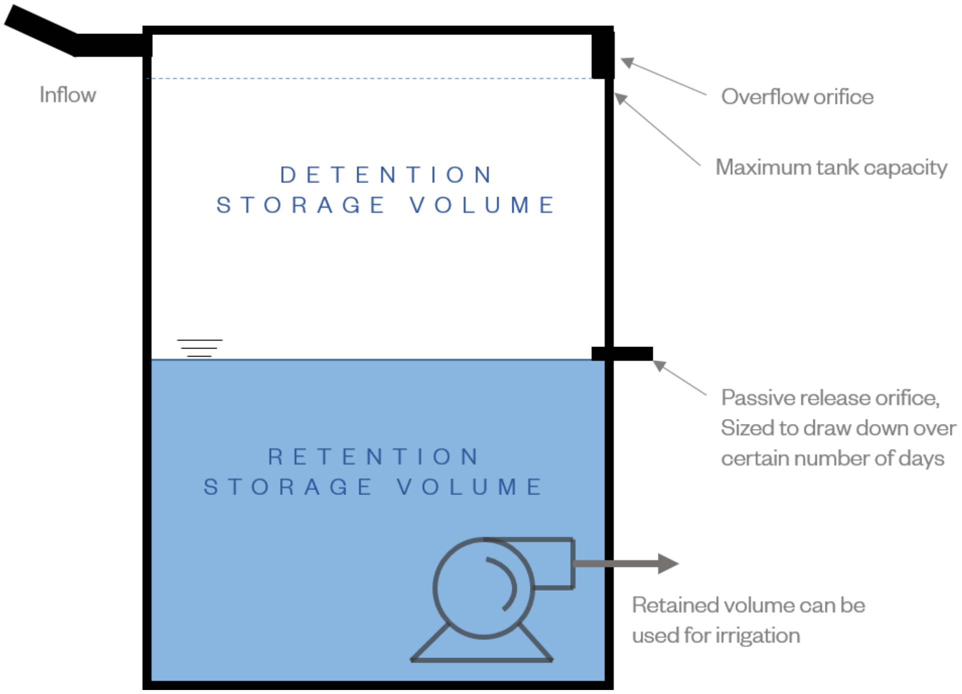


Figure 6-6: Schematic of dual-purpose rainwater harvesting tank (adapted from DeBusk, 2013)

6.1.2 Non-Structural BMPs

6.1.2.1 Residential Lawn Care

Many watersheds that have pockets of rapid development often face the challenge of balancing attractive property landscapes with environmental stewardship. Reducing residential nutrient loading is often challenging in watersheds do to the private nature of each residence, and the distributed and varied methods of lawn care exhibited by those residents. Many states have turf grass and fertilizer specialists working for their Cooperative Extension Service. Clemson University is the land grant University in South Carolina, and provides Extension information to the public that is geographically-specific. Clemson University has extension fact sheets related to proper lawn fertilization rates and techniques (Fact sheet # HGIC 1201), sustainable landscape practices in your backyard (Fact sheet # H_2O-005), and choosing native plants that require little to no fertilizer (Fact sheet # H_2O-010). Clemson discusses how an easy-to-collect yard soil sample that can be tested by Cooperative Extension can determine your exact fertilization requirements, if any, which can help reduce excess phosphorus and nitrogen washing into tributaries and lake systems.

This is emphasized through Spartanburg Water's *Healthy Lakes, Great Drinking Water* program, which cautions residents that over-irrigation can lead to nutrient wash-off, and contribute to potential periods of eutrophication in Lake Bowen. For residents along the lake shoreline, a 10-to-30 foot "no fertilizer, no pesticide" buffer zone is encouraged to assist in keeping the lake as clean as possible. Multiple fact sheets on irrigation and water conservation can be found at www.spartanburgwater.org. This can be a piece of a watershed-wide program that can be developed that help educate the public on such resources, which can ultimately promote fertilizer application only on lawns that need it, or, in sensitive areas near water bodies, exploring the use of no-phosphorus fertilizer to limit eutrophication potential from residential land uses.

One example of a watershed success story involving residential lawn care outreach is the Holmes Lake watershed in Lincoln, Nebraska. Holmes Lake was placed on the Clean Water Act 303(d) list in 1998 for nutrient, DO, and sedimentation impairments. As a result, a TMDL for sediment and phosphorus was initiated in the predominately-residential development watershed. Homeowners in the watershed received surveys on their lawn care practices. In exchange for completing the survey, homeowners were given 2 free bags of no-phosphorous fertilizer. Through a combination of lake dredging, no-phosphorous fertilizer, residential rain gardens, and homeowner awareness, the lake was removed from the 303(d) list for its chlorophyll, DO, and phosphors impairment.

6.1.2.2 Watershed Stakeholder and Homeowner Outreach

Spartanburg County discusses public education and outreach in its minimum control measures section of its Stormwater Management Plan (SWMP). To assist with outreach efforts, watershed advisory committees could be formed to develop project goals.

Multiple watersheds that have been placed on the Clean Water Act 303(d) list conduct a door-to-door outreach effort to engage with homeowners on possible septic, lawn care, or general watershed / water quality knowledge. While many watersheds work retroactively once they are on the 303(d) list, it is recommended to periodically engage in this sort of outreach proactively to catch problem sources as they arise and establish a water quality dialogue with as many customers / residents as possible.

6.1.2.3 Septic Tank Management Program

Stakeholders have identified and encouraged the increased maintenance of septic systems, within the South Pacolet Watershed. As is recommended by SC DHEC, septic tanks should be cleaned every three to five years, and should be inspected by a licensed septic contractor. For example, Spartanburg Sanitary Sewer District (SSSD) offers a $55 rebate for homeowners within the District service boundaries who dispose their septic waste at an approved facility, with proof of septic cleaning required (Spartanburg Water, 2017). This type system could be modeled by other entities elsewhere in the watershed.

Due to the Upper Broad River watershed's history with fecal coliforms as part of its TMDL, the South Pacolet River watershed is a location in which septic tank management is of high water quality importance. Modeled after the Horse Creek project, one way to implement better septic performance on a watershed scale is to improve monitoring using innovative techniques. In rural areas, it is often hard to detect systems that have failed until clear evidence exists in downstream waters, or the homeowner proactively inspects the system. Color Infrared (CIR) imagery and thermal infrared detection technology use sensors that detect different electromagnetic wavelengths either from the air or using a hand-held system on the ground. In using these technologies, thermal anomalies can be used to detect the presence of sewage. If done during the winter, and with minimal tree cover, a high-resolution, low-altitude aerial fly-over using thermal infrared imaging can possibly detect surface septic discharges, because they sometimes exhibit a larger heat signature than cold surface soil and water features.

From 2007 to 2009, the city of North Augusta and Aiken County used infrared thermographic survey imagery to spot temperature differentials that *could* indicate leaky septic tank systems of leach fields. Funding was available as part of the TMDL effort in this watershed to fix 95 septic systems after this initial data collection. Another study, funded by the Michigan Department of Environmental Quality, utilized a dual analysis approach to develop a testing protocol, which began by analyzing likely parcels for septic failure in GIS using soil, environmental, and property variables. Following a narrowing of potential candidates, a flyover with infrared and thermal technology was rendered less laborious and costly (Huron River Watershed Council, 2012). One important recommendation from this study was that the infrared imaging resulted in similar anomaly detection as thermal imaging, a more costly sensor, which led to the conclusion that infrared imaging alone may be sufficient, and allow investigators to conduct flyovers in the spring.

The watershed leveraged the existing septic contractors to educate them and raise awareness through a public outreach effort (Figure 6-8). New research has suggested that various molecules act as powerful tracers for septic tank effluent discharge, and should be evaluated as a possible monitoring component throughout sub-watersheds in the South Pacolet River watershed. Specifically, Richards et. al. (2017) found that ratios of Chloride (Cl) to compounds like artificial sweeteners and caffeine could be employed. Ultimately, a tracer program could be developed based on multiple tracers to better identify failing septic systems.

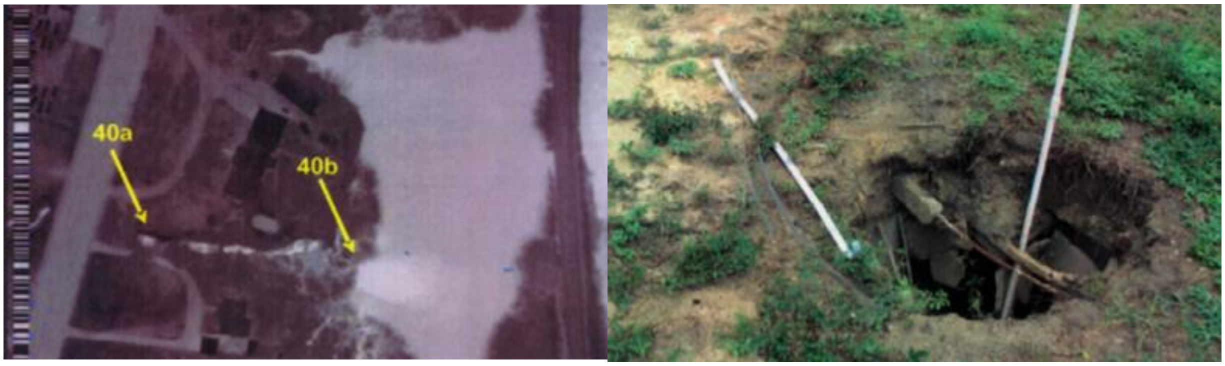


Figure 6-7: Infrared thermogeographic image showing septic illicit discharge (left) and the discovered cave-in responsible for the problem (Source: US EPA, 2016)

In this and many other implementation programs, Clean Water Act Section 319 grant funding has gone toward septic system education, outreach, and repair. This potential source of nutrients into Lake Bowen is of high importance given the large proportion of private residences in the watershed on septic sewerage. Other partners for the Horse Creek TMDL included Clemson University, NRCS, City of North Augusta, Aiken County, and the US EPA.

6.1.2.4 Land Use Planning

Many small, local governments have relatively tight budgets, and therefore have limited ability to seriously alter environmental and land issues relating to diffuse pollution. One mechanism that could produce significant gains is statutory changes via ordinances. This could include:

- Water quality amendments to community master plans
- Area performance planning for development
- Establishing critical water protection areas
- Vegetated buffer / wetlands protection

Master planning amendments as they pertain to water quality can come in the form of future designations of development, greenways, and anti-degradation policies. An example of an ordinance that could decrease stormwater volumes from developed areas is an option for curbless roadways in new developments (i.e. relying on vegetated shoulders or swales for stormwater conveyance and treatment).

Certain non-profit groups such as Upstate Forever, The Nature Conservancy and others may actively engage stakeholders in land use planning. For example, Upstate Forever, a non-profit engaged in land conservation and water quality protection in the upstate of South Carolina, can be an active stakeholder with respect to any future desire to tailor codes and ordinances toward protecting Lake Bowen and Municipal Reservoir #1. In 2007, Upstate Forever retained the Lawrence Group, an architectural and planning firm, conducted a review of pavement standards for Spartanburg County municipalities (Lawrence Group, 2007). A report for Greenville County was also issued, but none of the communities studied therein are located in the South Pacolet River watershed. In the report, various impervious surface-related regulations and minimum geometric constraints were summarized for Spartanburg County, with comparisons made to other communities or recognized standards. In general, ordinances and regulations relating to sidewalk width, vegetated swales, number of parking spots required, street widths, turning radii, and cul-de-sac radii, are explored and compared with various standards. It is important to note that ordinance changes represent just one *possible* route to implementing water quality changes, and may not be appropriate for all jurisdictions or localities.

6.1.2.5 Land Conservation

Within the United States Department of Agriculture's Natural Resource Conservation Service, there exists a program called the CRP, or conservation reserve program, where highly-erodible and sensitive farmland is rotated into conservation crop management (i.e. pasture, prairie, or forest) in exchange for a rental payment to the farmer and/or tax credits. Land conservation, especially as they related to vegetated buffers, can play a crucial role in protecting streams from wet weather surface flows, as well as reducing the overall volume of runoff being discharged from the watershed through increased infiltration and percolation. For a hypothetical acre of row crops with conservation tillage and rotation on hydrologic soil group (HSG) B converted to a grazing-protected meadow of continuous grass, the expected reduction in runoff from a two-inch rainfall is roughly 80%.[2]

States like Maryland pay farmers to cover their fields with cover crops after row crop harvest is complete, the time frame when erosion and nutrients are most liable to be washed from fields and into streams and rivers. These cover crops are not harvested, but remain in place between harvestable crop yield periods in order to hold the soil in place, improve soil water retention capacity, recycle nutrients (Clemson Cooperative Extension, 2017). Common South Carolina cover crops include monocultures or combinations of cereal oats, buckwheat, rye, crimson clover, and winter peas. For the South Pacolet River watershed, which contains more livestock foraging acreages than traditional row cropping, cover crop usage as a food source as an alternative to hay and wheat could improve cost-effectiveness (No-Till Farmer, 2017). For those farmers who do have row crops, the NCRS-USDA Cover Crop Economics Tool (v. 2.1) is available as a Microsoft Excel spreadsheet to assess the costs and benefits of incorporating cover crops into a rotation (NRCS-USDA, 2014).

In the context of the South Pacolet River watershed, it may be more important to focus on smaller tributaries with respect to existing and new impervious cover impacts. A study by Furman University, presented at the Southeastern section of the Geological Society of America conference in 2008, found a statistically significant relationship between road crossings in smaller, upland tributaries of the Enoree and Sluda watersheds with erosion-based incision found in measured stream corridors (Taysom and Muthukrishnan, 2008). It may be possible for Spartanburg Water as a prime partner to help fund mitigation banks to keep mitigation projects in the upper reaches of the South Pacolet.

6.1.2.6 Forestry Land Management

Forty-seven percent (47%) of the South Pacolet River watershed is considered “forested” (National Land Cover Database, 2011). In South Carolina, 74% of forestland is owned by private, non-industrial landowners (SFI, Inc., 2015). As a result, there are opportunities for landowners in the watershed to engage in sustainable forestry that can both ensure a profitable timber product is produced, while protecting water quality. Homeowners that do choose to engage in forestry have many resources available in the Upstate region that can assist with education on forestry issues, specifically in creating a forest management plan, which identifies goals and procedures for implementing forest management practices. Outreach efforts could be prioritized toward those landowners who may have once engaged in forestry, but no longer do, especially if the current land use is a cutover woodland. A cutover woodland site no longer has seed sources present in the soil, and thus must be regenerated by planting if it is to re-establish. Replanting trees can help reduce runoff volumes through canopy interception and improved infiltration, while improving soil health and decreasing overland soil erosion.

The South Carolina Forest Commission created a best management practice manual specifically tailored for forestry, which is intended to offer stewardship practices that protect the water quality of nearby streams, lakes, and ponds while ensuring landowners can maintain valuable acreages and produce viable products (SCFC, 2007). Of particular note, especially in the South Pacolet River, which contains many smaller tributaries to the South Pacolet in the more forested upstream portion of the watershed, is the

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[2] NRCS Curve Number method, CN = 70 compared to CN = 58, HSG = B, Q_{crop} = 0.24”, $Q_{conserv}$ = 0.04”

management of forestry operations in Streamside Management Zones (SMZs), where Non-Point Source (NPS) pollutants can most easily enter the aquatic ecosystem. The 40-ft primary SMZ (80-ft if slope is greater than 5%, which may be common in hillier portions of the watershed) and the 0-120 ft wide Secondary SMZ (depending on slope) each have specific forest management guidelines. The guidelines in the BMP manual with a forestry management plan, guidance on sediment and erosion control, and some available technical resources on forestry in the Upstate (see Section 7.2.7) can provide a basis for investigating the potential for proper forest resource management in the watershed.

6.2 Relative Load Reduction Efficiencies

An estimate of the various nutrient reduction efficiencies is presented in this section. The data were derived from multiple sources. The first table shows data from the International BMP database (see Section 5). They represent the percent reduction between paired inflow and outflow samples for the various BMPs. For instance, it is reasonable to expect a bioretention cell can achieve around 77% TSS reduction based on an aggregation of national studies.

Table 6-2: International BMP Database Summary of Removal Efficiencies by BMP

	Removal Efficiency (%) and Interquartile Range from International BMP Database (Data as of May 25, 2017)					
	TN		TP		TSS	
BMP	Median	IQR	Median	IQR	Median	IQR
Bioretention	20	-22 – 45	-25	-191 – 27	77	41 – 91
Detention basin	8	-16 – 30	20	-13 – 45	58	17 – 76
Grassed swale	-10	-49 – 12	-47	-157 – 15	21	-43 – 60
Permeable pavement	-180	-257 - -88	21	-40 – 62	57	-1.9 – 87
Retention pond	27	3 – 51	50	14 – 74	76	36 – 91
Wetland basin	0.7	-19 – 16	26	0.8 – 56	57	16 – 79
Wetland channel	21	0.2 – 39	12	-30 – 42	34	-24 – 69

Various scenarios were iterated in order to show examples of BMPs needed to achieve the TN and TP reductions stated in Table 5-2. The removal rates from Table 6-3 were applied to each BMP, which were then applied to the various land uses based on coverage area (for example, if only 50% of cropland in the watershed uses a terrace BMP, then the % Area entered is equal to 50, and the TN and TP removal rate subsequently applied to that area).

The following table illustrates values that have been vetted through the regulatory process in the largest TMDL in the United States, the Chesapeake Bay watershed, representing an area of 64,000 square miles. The process of the Chesapeake Bay loading quantification and mitigation strategy toolbox development has employed state of the art modeling tools, extensive monitoring data, peer-reviewed science, and close interaction with jurisdictional partners. While the Chesapeake Bay watershed may be more impervious and developed than the South Pacolet River watershed, the BMPs that apply to developed lands equally apply to the small, but important, pockets of imperviousness in this watershed. Additionally, there is significant agriculture in the Chesapeake Bay watershed, including livestock, that can be deemed applicable to macro-application of removal rates.

Table 6-3: Estimated removal rates for various BMPs[1]

Class	BMP	Estimated Removal Rate		
		TN	TP	Unit
Fluvial	Stream restoration	0.2	0.068	lb per linear ft per yr
Agriculture	Riparian forest buffer	56	42	% removal
	Riparian grass buffer	39	42	% removal
	Wetland restoration	14	26	% removal
	Tree planting	100	100	% removal
	Land Retirement	100	100	% removal
	Livestock exclusion	100	100	% removal
	Cover crop early drilled rye	45	15	% removal
	Continuous no-till ag	15	40	% removal
	Enhanced nutrient management	7	0	% removal
	Decision agriculture	3.5	0	% removal
	Off stream watering	5	8	% removal
	Upland prescribed grazing	10	20	% removal
	Upland precision intensive rotation grazing	11	24	% removal
Development	Dry pond	5	10	% removal
	Dry extended detention ponds	20	20	% removal
	Urban filtering practices	40	60	% removal
	Bioretention	85	85	% removal
	Wet ponds and wetlands	20	45	% removal
	Urban forest buffers	25	50	% removal
	Urban nutrient management	17	22	% removal
	Street sweeping	3	3	% removal
	Homeowner rain gardens	80	85	% removal

[1] Assumed from the Chesapeake Bay Commission nutrient trading publication: http://www.chesbay.us/Publications/Nutrient%20Trading%20Appendix/Appendix%20C%20Urban%20BMPs.pdf

SC DHEC has basic guidelines with respect to crediting Best Management Practices for stormwater runoff. Construction site BMPs must remove 80% TSS or 0.5 mL/L peak settle able concentration, whichever is less. Post-construction BMPs are required to meet various guidelines with respect to storm size retention and rate capture. Included in the manual are general ranges of average pollutant removal capabilities, although they are not enforced with the permit. There is currently no requirement in the DHEC *Standards for Stormwater Management and Sediment Reduction Regulation 72-300 thru 72-316* (2002) that requires post-construction nitrogen and phosphorus reductions, but guidance is shown in the BMP manual for engineers, and is presented in Table 6-4.

Table 6-4. SCDHEC post-construction stormwater best management practice phosphorus and nitrogen removal rates

Post-construction structural stormwater BMP	TP Removal Range	TN Removal Range
Catch basin insert	55-70%	35-55%
Separation and Filtration Device	40%	30%
Vegetated filter strips (Average)	10%	30%
Wet detention ponds	50-70%	30-45%
Dry detention ponds	14-25%	19-29%
Underground detention	55-70%	35-55%
Stormwater wetlands	42-53%	28-39%
Bioretention	55-70%	35-55%
Infiltration trench	50-60%	35-55%
Enhanced dry swales	40-60%	35-50%

6.3 Costs and Benefits of Management Practices

Of the various structural and non-structural BMPs above, the most expensive are retrofits done to developed areas such as stream corridors or developed landscapes within cities or towns. Stormwater BMP cost estimates vary widely depending on geographic region, incentive structure for new and existing development, and experience of local contractors in installing and/or maintaining them. As a point of guidance, the Chesapeake Bay Program's BMP cost per acre of drainage area treated are shown in Table 6-5.

Table 6-5: Development-related stormwater BMP costs per acre treated (in 2016 USD, CPI-adjusted)

BMP	Annualized total costs ($/acre/year) Low	Annualized total costs ($/acre/year) High	BMP Time Horizon (yr)
Dry pond	$1,699	$3,583	20
Dry extended detention pond	$678	$1,428	20
Urban filtering practices	$1,849	$6,266	20
Urban infiltration practices (no vegetation)	$1,954	$4,242	20
Urban infiltration practices (sand/vegetation)	$1,870	$4,242	20
Wet ponds and wetlands	$668	$1,407	20
Urban forest buffers	$57	$361	15
Urban nutrient management	$22		3
Street sweeping	$1,103		20

Source: Chesapeake Bay Nutrient Trading: Appendix C: Methods for Estimating Urban Stormwater BMP Costs and Load Reductions

The above category of residential/commercial nutrient management was assumed to involve public outreach and education to reduce fertilizer application on pervious developed areas. Infiltration practices with vegetation are models for bioretention, rain gardens, or tree trench systems. The table shows that there are wide ranges in costs for many BMPs, even in a region with an established industry for BMP design, installation, and maintenance. Additionally, it is clear that infiltration practices such as bioretention are more expensive than wet ponds or constructed wetlands, although experience has shown that bioretention and vegetative infiltration practices can provide many multi-disciplinary benefits that are hard to quantify monetarily, such as air quality, aesthetic and property value benefits, increased societal value, and the reduction of temperatures in stormwater. They also can remove much more phosphorus and nitrogen loading, mainly through the process of volume reduction, whereas wetlands and wet ponds rely on sedimentation, filtration, and transformation of pollutants.

Similarly, the Chesapeake Bay Program has catalogued agricultural BMP costs from US EPA or USDA Cash Rents Survey data (Chesapeake Bay Commission, 2012). Table 6-6 outlines those costs ranked from most to least expensive. The data were adjusted below to present dollars after inflation.

Table 6-6: Agricultural BMP total annualized cost by type (2017 USD)

	Annualized total costs ($/acre/year)			
BMP	**Low**	**High**	**Average**	**BMP Time Horizon (yr)**
Enhanced nutrient management	19	19	19	1
Upland prescribed grazing	9	33	21	1
Decision agriculture	13	30	22	1
Continuous no-till agriculture	20	40	30	1
Off stream watering	32	32	32	10
Cover crop early drilled rye	35	35	35	1
Upland precision intensive rotation grazing	53	93	73	1
Land retirement	19	624	322	10
Riparian grass buffer	44	632	338	15
Livestock exclusion	88	693	391	10
Tree planting	56	840	448	15
Riparian forest buffer	98	903	501	15
Wetland restoration	318	887	603	15

Based on Chesapeake Bay estimates, the cost of stream restoration is roughly $150 to $400 per linear feet restored (Chesapeake Stormwater Network, 2015). However, this number applies to “urban” streams. It is recommended to evaluate stream restoration based on a complete inventory of stream assets, with the assets categorized on a spectrum from most to least in need of restoration based on professional judgment. Methodologies which employ a decision matrix on which projects make sense from both a financial and water quality standpoint are key for smaller jurisdictions to implement this practice with success.

Costs to repair septic systems were found to range between $600 and $2,300 (HomeAdvisor, Inc., 2017). Due to the high concentration of nutrients in un-treated septic discharge, this practice may be one of the most cost-effective available on the basis of pounds of N or P removed from the environment. In many EPA 319 cost-share programs that were evaluated, this BMP was often implemented as a “low-hanging fruit”. Based on the receptions of watersheds studied, it appears that septic repair is widely accepted by residents, its benefits clearly understood by the recipients, and its benefits easily quantified and tracked programmatically.

When considering the costs of water quality improvement efforts, it is also important to recognize additional benefits these BMPs may provide. These additional benefits can be especially evident when comparing “green” (e.g. vegetative) vs. “gray” (non-vegetative or artificial infrastructure-based) practices.

The Center for Watershed Protection developed a matrix of potential benefits other than water quality associated with green practices (Table 6-7)

Table 6-7: Triple bottom line benefits of select “gray” and “green” practices for developed area stormwater runoff

	BMP	Public Health	Recreation	Neighborhood Beautification	Urban Heat Island	Wildlife Habitat	Carbon Sequestration	Flood Control
GRAY	Dry detention ponds	LOW	LOW	LOW	LOW	LOW	LOW	HIGH
	Hydrodynamic structures	LOW	LOW	LOW	LOW	LOW	LOW	LOW
	Permeable pavement	MED	LOW	MED	MED	LOW	LOW	HIGH
	Street sweeping	MED	LOW	HIGH	LOW	LOW	LOW	LOW
GREEN	Bioretention	MED	LOW	HIGH	MED	MED	LOW	MED
	Forest buffers	MED	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
	Impervious surface reduction	LOW	MED	HIGH	HIGH	MED	MED	HIGH
	Tree planting	MED	MED	HIGH	HIGH	HIGH	HIGH	MED

7. Implementation

In general, it is recommended to pursue both structural and non-structural BMPs to reduce nutrient inputs into Lake Bowen and Municipal Reservoir #1. The introduction of watershed awareness via education, outreach, programmatic updates, meetings, and advertising campaigns has the potential to boost awareness in the watershed, making the acceptance and adoption of structural measures more likely. As a starting point for structural BMPs that may be relatively new to the community, it is recommended to begin piloting practices that will be most effective at reducing nitrogen and phosphorus. In Section 7, a framework will be introduced to aid Spartanburg Water in forecasting implementation efforts, instituting benchmarks of success over time, and focusing on how to evaluate the progress being made.

7.1 Monitoring Plan

Spartanburg Water has already established a strong foundation of water quality monitoring from which to move forward. Below is a suggestive framework for the ongoing watershed and lake monitoring stations.

Increase the number of monitoring stations to include all main tributaries into Lake Bowen.

While many of the sub-watersheds are covered by the existing stations, it is clear that development is accelerating rapidly in non-monitored areas. In prioritizing the recommended monitoring locations on the map, the southern portion of Lake Bowen and Municipal Reservoir #1 would benefit from more data on annual nutrient and sediment loading.

Expand the current network of monitoring to include growing-season capability to capture flow-weighted samples.

While grab samples are often preferred due to the ease of collection and low cost, they suffer from the lack of context when looking at wet weather events. During a rainfall event, the flow rate of a storm over time (hydrograph) is often highly variable, and pollutant concentrations measured at one point in the storm could be wildly different than other parts. In order to accurately detect the difference not only on a watershed scale, but in future BMP inflow vs. outflow monitoring efforts, it is useful to install equipment that capture flow-weighted curves, meaning they activate their sampling capabilities after a programmed amount of volume has passed the sensor. This allows you to capture the entire “pollutograph” on a mass basis as the storm progresses, which results in highly-accurate loading values per storm. Note that this only applies to the gages that are directly influenced by wet-weather events (namely stream / watershed / stormwater sampling sites), and does not apply to in-lake sampling locations.

Perform wet-weather sampling of stormwater outfalls or ephemeral channels that receive predominately stormwater flow only

As discussed previously in this report, it is important to account for multiple modes of nutrient delivery, including separating wet-weather loads coming from various common land uses that stakeholders and Spartanburg Water deem as representative to the watershed. This can be done by outfitting larger stormwater pipes with various hydraulic measuring devices that can collect flow-weighted samples using, weirs, flumes, area-velocity meters, or a combination. While ultimately the health of Lake Bowen and

Municipal Reservoir #1 is the goal of the nutrient and watershed management process, wet-weather monitoring will allow for a more precise accounting of future implementation efforts without having to rely on more complex, less precise efforts at extrapolating storm runoff effects from in-stream monitoring data.

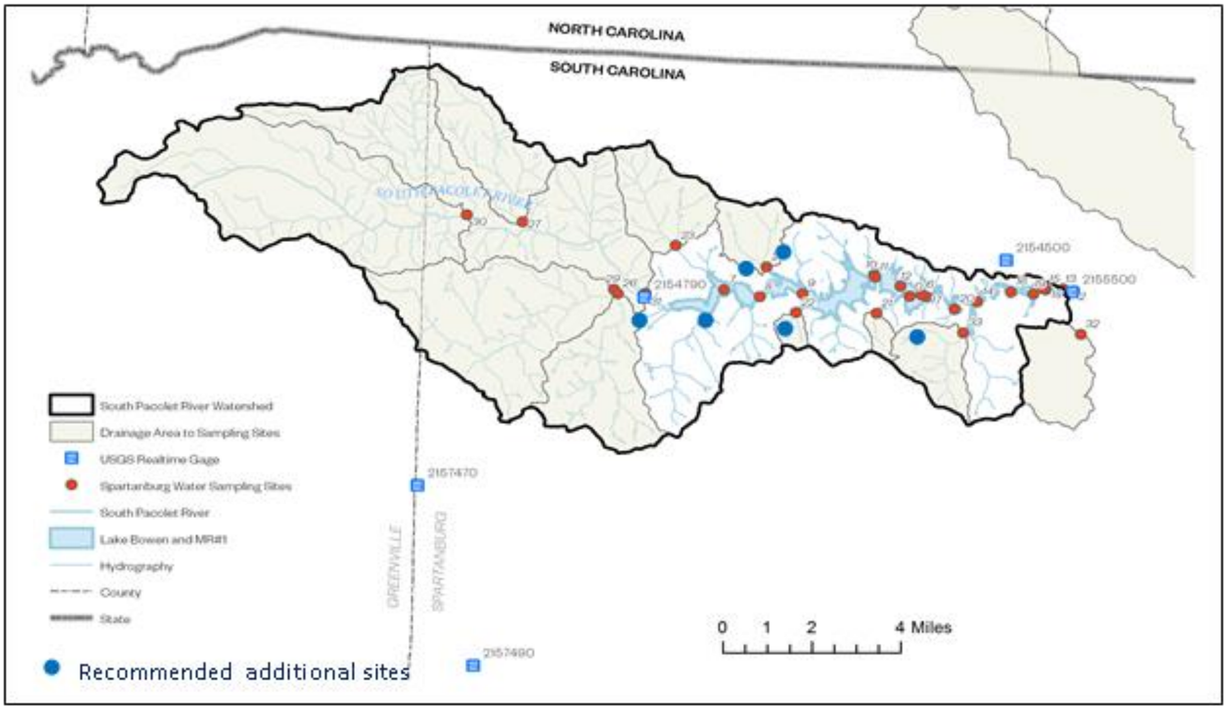


Figure 7-1: Existing monitoring stations (red) shown with 6 recommended additional stations to fill in coverage gaps

7.1.1 Overall Monitoring Schematic During Implementation

Each watershed and community has different selection criteria for appropriate BMPs based on cost, societal integration, effectiveness at the watershed goal, and applicability. The selection of BMPs should be a process which is continually fed by ongoing monitoring data (both instrumented monitoring, and personal communications or surveys with stakeholders to gage effectiveness). The figure below illustrates the process. Once BMPs are first piloted and implemented, monitoring can assess their effectiveness, as long as it is done on a frequent enough basis to still impact the continued implementation in the given fiscal or goal-driven time window. The toolbox is then altered based on results, all while transparently communicating the BMP planning and results to the public via mass outreach.

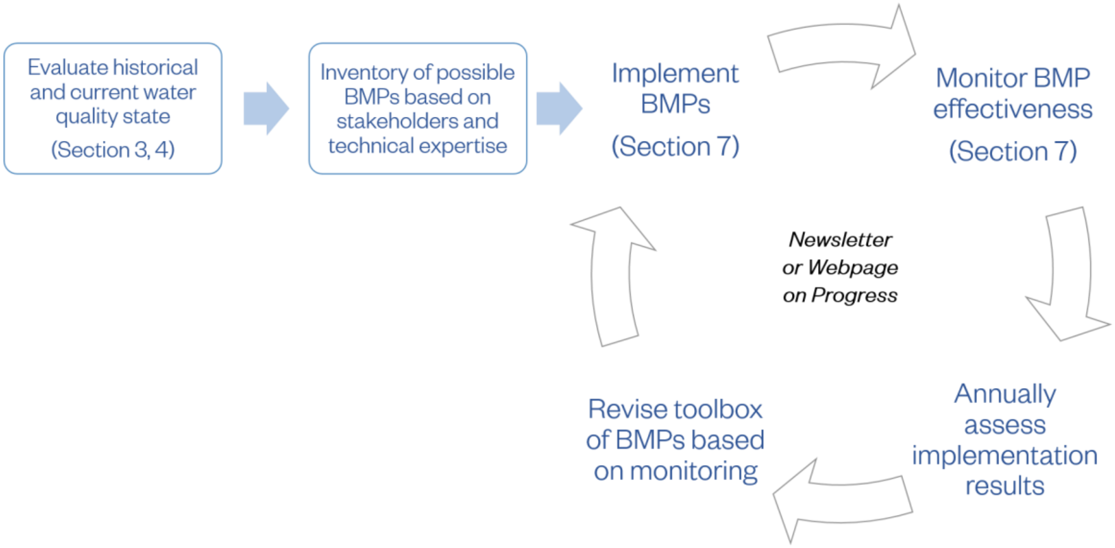


Figure 7-2: Feedback loop of implementation, monitoring, revision, and dissemination of results

7.1.2 Stream Health

It is recommended to develop quantitative measures of vulnerable stream corridors around problematic areas identified on the stakeholder map, in order to predict streambank erosion. This will allow Spartanburg Water to begin to develop an inventory of vulnerable stream assets, and create a decision-making tool to decide which projects warrant specific levels of restoration.

One tool is to combine a simple model with field measurements. In lieu of physically monitoring the stream corridor's banks, many guides recommend the BANCS ("Bank Assessment for Non-point Source Consequences of Sediment") method. The BANCS method to utilize two commonly-used bank erodibility estimation tools to predict and monitor stream erosion: Bank Erosion Hazard Index and Near Bank Stress methods. In doing so, one would install bank pins to measure stream erosion in key sites and develop a watershed inventory of sites that need the most help based on measured sediment loss.

7.1.3 Lake Sedimentation

Multiple instances of cloudy water near the upper arms of Lake Bowen have been observed by stakeholders. Additionally, there is a lot of growth occurring in the unincorporated portions of Spartanburg County, around especially vulnerable portions of Lake Bowen. As a result, a sedimentation analysis is recommended to determine the amount of lake volume being lost per year due to sediment transport from the watershed to the lake. Numerous watersheds that have undergone TMDLs often use this metric for showing reduction of sediment. While the South Pacolet River watershed does not appear to be nearing a classification on the 303(d) list, doing a sedimentation analysis ahead of time could yield large gains in understanding the balance needed between primarily sediment-reducing BMPs and those BMPs that reduce some sediment, but primarily nutrients. Spartanburg Water uses Lake Bowen and

Municipal Reservoir #1 as storage reservoirs for drinking water supply, and a sedimentation study may provide insight into long-term changes in reservoir capacity.

7.1.4 Developed Area Stormwater Runoff

Early in the program, it is recommended to install a small number of monitoring locations at major outfalls of developed drainage areas. For instance, while the WS-E gage downstream of Campobello is useful for overall watershed health, understanding the causes that come directly from residential or commercial stormwater runoff, which is driven largely by impervious surface cover, rather than groundwater, agriculture, or air deposition are useful given the cost of structural BMP retrofits.

7.2 Financial and Technical Assistance Needed

This section discusses potential funding sources with which to implement nutrient management programs and practices in the South Pacolet River watershed, along with groups that may offer technical assistance to support implementation. Some of the groups capable of offering technical assistance have contributed to the development of this plan through input at a stakeholder meeting.

7.2.1 Clean Water Act Section 319 Funding

Section 319 of the U.S. Water Act provides for grants to implement non-point source mitigation strategies described in South Carolina’s nonpoint source pollution (NPS) Management Program. This program, administered by SC DHEC since 1990, sets state water quality objectives, coordinates funding partnerships, and coordinates with federal agencies. The NPS Program’s goals include (SC DHEC, 2014):

- Assessing, prioritizing, and developing plans for watersheds affected by nonpoint source pollution
- Provide technical assistance to effectively address NPS pollution
- Strengthen partnerships and collaborative efforts to address NPS pollution
- Provide adequate funding for NPS projects and programs
- Document environmental results of NPS activities
- Administer the NPS program efficiently and effectively

The 319 funding process is a competitive grant process that is financially managed, in part, by SCDHEC each year. To be eligible, the applicant must be a public organization such as a state agency, public university, soil and water conservation district, regional planning commission, watershed organization, or non-profit organization. Due to the presence of many of these entities in the South Pacolet River watershed, it is possible a diverse team of members could satisfy the applicant requirements for 319 grants. SC DHE issues requests for proposals that vary in scope—for instance, in February 2015, 319 funding was available for the development of a watershed-based plan itself. More relevant to Spartanburg Water and the South Pacolet are the grants involved with actually conducting water pollution control measures that reduce nonpoint source loads (i.e. the *implementation* of the watershed-based plan itself).

The funding may be based on a portion or the entirety of the plan, with specific focus on BMPs that reduce nonpoint source pollution. Typically, SC DHEC gives highest priority to watersheds that have a TMDL (e.g. Upper Broad River fecal coliform TMDL), but waterbodies that show signs of impairment are also typically eligible. Additionally, priority is given to projects that can show other sources of funding (even other Federal sources) beyond the required 60% match amount.

Past RFPs by SCDHEC have provided for up to $1.2 million, which will be distributed to the various recipients based on the goals and scope of that particular year. As a result, the project are often focused in nature and intended to provide a large benefit in terms of the intended pollutant reduction. Quantifying the anticipated pollutant reduction, as well as providing for robust monitoring of the BMP or implementation efforts are key requirements for most 319 applications.

Each year, the NPS reports results and progress of all of the applicable 319-funded programs directly to the U.S. EPA, which includes measureable results and monitoring efforts showing improvements, something Spartanburg Water’s initial monitoring program sets a strong baseline from which to build. It is recommended that a large team of various stakeholders be assembled in any future 319 funding process, including non-profits such as Upstate Forever, local cooperative extension, NRCS, MS4s in the watershed, and county governmental agencies.

7.2.2 State Revolving Fund

The SC SRF is a source of low-interest loans to do, in part, stormwater improvements in a watershed. Eligible projects include green infrastructure, stormwater BMPs, and nonpoint source reduction projects, a broad umbrella that could cover many solutions the South Pacolet River watershed may employ. South Carolina engages in ranking projects that are submitted for state revolving fund receipt—projects that are eligible for 319 funding are awarded extra points and may receive a lower loan interest rate (1% as of 2014) in this application process (SC DHEC, 2014).

Lower interest rates (1%) may also be available for “green projects”. In 2012, the Clean Water State Revolving Fund provided 10% of its financing toward the Green Project Reserve. This included green stormwater infrastructure at multiple implementation scales, involving the following categories:

- Implementation of green streets (green infrastructure in the transportation right-of-way) for new development, re-development, or as retrofits
- Wet weather green infrastructure BMPs listed in Section 6 of this document
- Street tree or urban forestry programs
- Stormwater harvesting and reuse projects, including cisterns and their associated infrastructure to provide re-usable water
- Downspout disconnection
- Riparian buffer, wetland, or floodplain restoration or establishment
- Constructed stormwater wetlands
- Conservation land easement purchase

Excluded from this funding are systems not intended to mimic pre-development hydrology, such as imperviously-lined stormwater measures, stormwater ponds, in-line treatment systems that only filter, hydrodynamic separators, hardening/straightening of streams, and street sweepers (unless it supports green infrastructure projects). More information on guidance for determining eligibility can be found here: http://www.scdhec.gov/HomeAndEnvironment/Docs/srf_gpr.pdf.

7.2.3 Champions of the Environment

Champions of the Environment is an annual competition that awards K-12 environmental projects with up to $2,000 in funding. Rainbow Lake Middle School has already implemented a rain garden through cost-sharing with Spartanburg Water, Upstate Forever, and several Boiling Springs-area businesses. In addition to Rainbow Lake, Campobello-Gramling School, Landrum High School, and New Prospect Elementary School are also located near the South Pacolet confluence with Lake Bowen or the lakeshore itself. Dent Middle School in Richland County, South Carolina, was awarded funding in the 2016-2017 cycle by developing a model on how impervious surfaces can cause problems, working with local river keepers to monitor stream biology, and designing and constructing a rain garden. This funding could increase the number of pilot projects and accomplish multiple education and outreach goals in a future implementation plan.

7.2.4 Duke Energy Foundation

Since 2009, the Duke Energy Foundation has opened a funding mechanism to help lower income private residents repair septic systems in jurisdictions that have been awarded 319 grants. This funding source should be leveraged to mitigate a potential source of nutrients in the South Pacolet as 319 funding becomes available.

7.2.5 USDA – NRCS

The Natural Resources Conservation Service, part of the United States Department of Agriculture, is a program that provides local assistance on agricultural management through cooperative partnerships with state and local agencies. NRCS leads multiple efforts to assist landowners and local authorities in protecting agricultural land well-being and water quality. The Environmental Quality Incentives Program (EQIP) helps farmers financially and technically implement conservation practices or best management practices based on areas that are categorized as state priorities. Due to SC DHEC's involvement on the State Technical Committee that provides input to NRCS on funding, 319-funded projects can be leveraged.

NRCS is involved with water quality monitoring of select areas that may wish to reduce nitrogen, phosphorus, sediment, and bacteria running off from agricultural land in partnership with SC DHEC as part of the National Water Quality Initiative. Future implementation in the South Pacolet River watershed should consider working with NRCS to leverage its existing monitoring capabilities further up the watershed in predominately agricultural areas and focus on agriculturally-heavy sub-catchments near Lake Bowen and Municipal Reservoir #1.

NRCS's Conservation Innovation Grant (CIP) provides funding to single and multi-year projects to applicants who must be a government agency, non-governmental organization, or an individual. Eligible projects include:

- Demonstrating, evaluating, and verifying a conservation technology in the field with respect to soil, water, air, plants, energy, or animals
- Adapting conservation technologies, BMPs, procedures, approaches, or incentive systems to improve performance and encourage adoption
- Introduce conservation systems from another geographic area or agricultural sector

It is possible that monitored innovative agricultural practices near stream corridors, or testing of approaches done elsewhere at a scale or location that is relatively novel, may provide the South Pacolet River watershed another source of funding to reduce nutrient loading to the reservoirs. Additionally, it could provide a source of federal matching for any future 319 funding pursuits.

Additionally, NRCS's Environmental Quality Incentives Program (EQIP) provides financial and technical aid to agricultural producers to plan and implement conservation practices, especially in areas compliant with highly erodible land (see Figure 4-8) or wetland conservation requirements. Funding can be distributed directly to agricultural producers to implement various conservation practices, or to help them develop Conservation Activity Plans (CAP) to tackle various land use issues.

Projects that involve livestock exclusion and agricultural management may be best implemented with a coalition between relevant land owners, watershed managers, local soil conservation districts, and the South Carolina Department of Health and Environmental Control. NRCS's Conservation Technical Assistance Program could be leveraged in assisting decision-makers in the watershed in pursuing voluntary resource conservation. Additionally, they can provide technical assistance and assess the effectiveness of certain conservation practices in the context of the South Pacolet River watershed.

7.2.6 USDA – Farm Service Agency Programs

The Farm Service Agency (FSA) is responsible for overseeing voluntary farming initiatives that can address soil erosion and preservation of forests and wetlands, and drinking water protection. As mentioned above in the section on Land Conservation as a non-structural BMP, there are many conservation programs that can aid in keeping soil on-site, which can prevent nutrient and sediment wash-out to nearby streams and lakes.

7.2.6.1 Conservation Reserve Program (CRP)

The Conservation Reserve Program (CRP) offers general enrollment periods in which farmers can establish approved grass or tree species on their property to control soil erosion, improve water quality and/or develop wildlife habitat. The FSA, in-turn, provides rental payments and cost-share assistance. This is especially fruitful when commodity prices happen to be at a low. Contract duration for the cover crop rental is generally 10 to 15 years. For information on past CRP projects and to check on future enrollments, please check the FSA website at https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index.

The Conservation Reserve Enhancement Program (CREP), is an offshoot of the CRP, and focuses on high-priority lands that have been identified by a State. Differing from CRP, CREP is a federal/state partnership that focuses on specific problem areas, rather than in CRP, which is a federally-private landowner contract. South Carolina does not currently participate in CREP, but agencies, governments, and large landowners may be interested in checking with South Carolina's Department of Agriculture for any possible future CREP program.

7.2.6.2 Farmable Wetlands Program (FWP)

The FWP is a voluntary program of the Farm Service Agency that enlists participants to enroll their land to be restored to a wetland plant cover condition. Wetland buffers can be useful to restore water quality in some areas. Like CRP, FWP contracts last 10-15 years, and are available to anyone, regardless of state of residency. Farmland must generally have been in agricultural use 3 to 10 crop years prior, and can already have man-made wetland in all or part of it. The local FSA office in Colombia, SC can provide further details on rental rates, cost shares, and enrollment information.

7.2.6.3 Source Water Protection Program (SWPP)

The SWPP comprises a partnership between USDA's Farm Service Agency and the Natural Rural Water Association (NRWA), which is a nonprofit water/wastewater utility membership organization. South Carolina's local chapter, the SC Rural Water Association (SCWRA), counts Spartanburg Water as one of its system members. The SC source water protection effort includes assisting in grassroots, stakeholder-driven implementation of common 9-element plan mitigation strategies, including: public education and outreach, agricultural BMPs, community planning initiatives for protection of water quality, and stormwater BMPs (SCRWA, 2015).

7.2.7 South Carolina Forestry Commission Cost Share Programs and Technical Resources

Private landowners that own less than 1,000 acres of qualifying woodland that is in an abandoned or cutover state, may qualify for cost-sharing in this program. A cutover woodland site no longer has seed sources present in the soil, and thus must be regenerated by planting if it is to re-establish. Replanting trees can help reduce runoff volumes through canopy interception and improved infiltration, while improving soil health and decreasing overland soil erosion. Qualifying landowners can receive 40-90% cost share of practices that qualify. The money primarily comes from the Conservation Reserve Program (CRP, see above), Environmental Quality Incentives Program (EQIP, see above), and South Carolina's Forest Renewal Program (FRP). Interested landowners could first contact their local Forestry Commission office. The South Pacolet River watershed is located in the Piedmont Region of the commission's operational unit. Those in Greenville County should contact the Piedmont Region – West Unit office, while those in Spartanburg County are under the Piedmont Region – East Unit jurisdiction of the Forestry Commission (https://www.state.sc.us/forest/contact.htm).

On a related note, the Sustainable Forestry Initiative, a non-profit forest certification organization, has published *A Landowner's Guide to Forestry in South Carolina* (SFI, Inc., 2015) to assist private landowners in South Carolina in successfully managing land used for timber production and sales. It walks a potential private forest manager through the process of managing your investment, analyzing the economics of your harvest, and harvesting and selling the timber. Additionally, the SFI guide explores forest management BMPs. Because SFI specializes in certifying private tree farms as “sustainable”, private owners interested in pursuing this means of income could gain public recognition through their certification program.

7.2.8 South Carolina Department of Agriculture / USDA-NIFA

On May 11, 2017, South Carolina House Bill 3559 was passed and signed into law, which created a roadmap for the creation of South Carolina’s industrial hemp program. Hemp is a cultivar of Cannabis sativa that can be used to make industrial products such as rope, clothes, food, paper, textiles, plastics, insulation, and biofuel, and is not considered to be viable for recreational drug use. The SC Department of Agriculture is now implementing a pilot program that will allow 20 applications, each up to a 20 acre plot, to be grown as part of a research program. While the applicant must be a higher institute of education or be interested in research purposes, eventual expansion beyond a pilot program may be worth exploring as a means to incorporate different crop types into the watershed on private land.

The United States Department of Agriculture’s (USDA) National Institute of Food and Agriculture (NIFA) has indicated that federal grant dollars can be applied to hemp production if the applicant for money is a state that has legalized production of hemp, is a research institution or state department of agriculture, or grows industrial hemp under the auspices of a state agricultural pilot program (Statement of Principles on Industrial Hemp, 2016). While the current pilot program does not allow for private landowners to freely grow and sell hemp crop, it may be worth investigating if future opportunities could provide for a financially-beneficial crop that could play a role in conservation easements to reduce erosion and nutrient inputs.

Hemp may be a new crop in the watershed going forward, which could change the dynamics of which crops could be used as a soil cover and for agricultural production. Spartanburg Water could follow the progress of its potential introduction to see how areas in need of crop coverage that could be exporting sediment and nutrients could benefit. While it is relatively unknown how hemp may perform as a management practice to control erosion at this stage, future research grants related to USDA-NIFA could explore its potential in the agricultural runoff research field.

7.2.9 Clemson Cooperative Extension

Clemson University Cooperative Extension offers technical resources to assist individual property owners and larger entities throughout the watershed in improving water quality. Extension resources can assist in establishing agricultural best practices, as well as management of stormwater from developed areas through published guidance and direct consultation. Technical assistance provided by the Cooperative Extension service may not only cover initial implementation of water quality improvements, but also long term operation and maintenance.

Additionally, Clemson University’s Cooperative Extension program, Carolina Clear, has recently launched a new Community Grants program in Florence and Darlington Counties. It will provide downspout stormwater planter boxes to highly-visible businesses, churches, or apartment complexes in those counties, but plans are underway to expand the program to other counties that partner with Carolina Clear in the future. Spartanburg Water could potentially work with Spartanburg County’s extension office to help expand that program to applicable buildings, especially in new development near the shorelines of Lake Bowen and Municipal Reservoir #1. See http://www.clemson.edu/extension/carolinaclear/community_grants.html for more details.

7.2.10 University of South Carolina Upstate – Watershed Ecology Center

The University of South Carolina Upstate Watershed Ecology Center offers a variety of educational and outreach programs that could support water quality improvement throughout the watershed. Existing programs and initiatives include student educational programs, community outreach events, summer camps, storm drain marking, rain barrel workshops, adopt-a-stream programs, and distribution of a newsletter.

7.2.11 Spartanburg Soil and Water Conservation District

The Spartanburg Soil and Water Conservation District (SWCD) is tasked with promoting wise and responsible use of natural resources through education, demonstration, and technical services. In addition to administering NRCS programs discussed elsewhere in this section, SWCD engages in education programs with schools and County youth, can serve as a technical resource, and offers rental of no-till drill equipment.

7.2.12 Funding for Septic System Repairs

Based on resources from the U.S. EPA, the following are possible funding sources to assist in repairing septic systems in the watershed, in addition to Section 319 funds and State Revolving Funds mentioned above:

- EPA Environmental Finance Center Network

The EFC network was started as a cooperative of 10 universities that help to provide research funding for environmental projects or to initiate implementation. South Carolina, located in EPA Region 4, can leverage the Environmental Finance program that is housed at the University of North Carolina-Chapel Hill School of Government. Their mission is to enhance the ability of governmental agencies and other organizations to provide environmental services in a fair and effective way. The EFC has developed free tools that could be used by Spartanburg Water in implementation of this plan, including a water utility revenue risk assessment tool, capital finance tools for planning capital improvements, and a tool to evaluate loans and grants available to water utilities.

- U.S. Department of Agriculture, Rural Development

USDA frequently solicits applications or notices of funding through its Rural Development program that help fund various rural projects. An example grant available to Wisconsin rural residents in early 2017 consisted of the availability of 1% fixed interest loans for up to $20,000 for homeowners that require septic repair or replacement. Grants may be most applicable to low-income individuals on septic systems in the South Pacolet River watershed based on a review of existing awards.

- U.S. Department of Housing and Urban Development

HUD is responsible for administering Community Development Block Grants (CDBG) to address multiple issues within communities, which could include septic system repair and replacement. Priority for the grants is based on the extent of poverty, population in an area, housing overcrowding, age of housing, and population growth lag.

- U.S. Economic Development Administration

Multiple grant programs are run by EDA to enable local innovation, leverage public private partnerships, and environmentally sustainable development.

- Catalog of Federal Funding Sources for Watershed Protection

Spartanburg Water could utilize the catalog of federal funding sources to find a host of grants, loans, and cost-sharing mechanisms for various water resources-related projects, including septic system repair as part of a larger nutrient program.

7.2.13 Non-Profits that Support Watershed Protection

Non-profit conservation organizations that protect critical lands, waters, and provide watershed and source water protection education to the public can provide a targeted focus on specialized topics. These organizations can work with private landowners, municipalities, and other stakeholders within the South Pacolet River Watershed boundaries to champion various water quality and land protection initiatives. Certain non-profits could represent a valuable technical resource as watershed stakeholders consider implementation actions going forward, including the potential to manage nutrient-reducing Clean Water Act 319 projects within the South Pacolet River Watershed.

7.3 Public Involvement Discussion

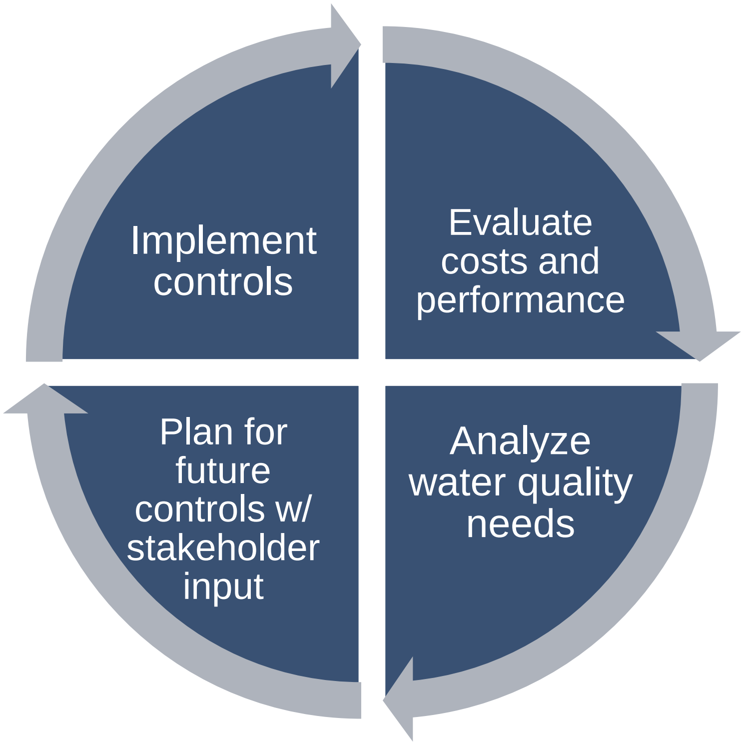
Community outreach and involvement provides value to watershed engagement. Partnerships such as those between Spartanburg Water, Non-Profits, Spartanburg County Stormwater Program, and USC Upstate’s Watershed Ecology Center are key to implementing best management practices near Lake Bowen. Key additions to this growing stakeholder group can be found in the private sector. In 2016, Coca-Cola donated 890 repurposed 55-gallon drums to be distributed to workshop attendees and used as rain barrels near Lake Bowen. Workshops such as these should continue as BMP implementation progresses and potentially expand to include topics like residential rain gardens, lawn maintenance, including proper fertilizer storage and use, as well as topics like proper disposal of household hazardous materials. These outreach efforts could build upon existing successful programs like RXcycle, which encourages residents to safely dispose of unused and expired medications. Additional public involvement activities that could benefit the watershed include a watershed festival or Paddlefest series, where public education efforts are combined with fun activities, volunteer stream cleanup events, and development of citizen engagement opportunities. These types of activities support long-term water quality objectives by directly improving existing conditions, deterring damaging activities, and facilitating the understanding of existing issues throughout the watershed. Depending upon specific characteristics, watershed partners may lead these efforts or provide funding or logistical support.

One mechanism to help oversee the interaction between BMP implementation and public perception and outreach is to coordinate an engagement process for stakeholders within the watershed. Given the development occurring near the lake, it is imperative that developers and HOA organizations be engaged and invited to take part in engagement activities, as their members and representatives ultimately will live and experience the implementation process first hand. For example, Spartanburg Water has engaged with local HOA's and the Spartanburg Homebuilders' Association, developing working relationships with these groups and other stakeholders in the watershed. These existing relationships could be leveraged and new relationships could be formed to support improvement efforts throughout the watershed, such as meeting with stakeholders to educate them on the need for improvements, listening to stakeholder input and concerns, and seeking partners for future implementation efforts.

7.4 Milestones

7.4.1 Implementation Goals

Given the substantial cost of fully achieving water quality targets, as well as the adaptive management approach to nutrient management efforts discussed later, phased implementation of watershed controls is recommended. Establishing five-year implementation milestones distributes implementation over time, while providing defined periods where progress can be evaluated. Phased implementation and evaluation is important in part due to inherent variability in water quality, which can make it challenging to evaluate the immediate impact of watershed controls. The most cost-effective watershed controls should be prioritized in early implementation phases, with more challenging controls implemented in later phases when the need for further water quality improvement is better understood.



During the course of watershed improvements, the general nature of implementation efforts may change as follows:

- Year 1-5: Identification and implementation of initial pilot projects
- Year 6-10: Implementation of refined practices based on initial pilots
- Year 11-15: Targeted scale-up throughout priority areas
- Year 16-20: Assessment of future efforts based on progress to date
- Year 21-25: Informed area-wide expansion to meet program goals

7.4.1.1 Short Term Goals

Short-term goals should include the development and implementation of pilot studies for priority BMPs to test individual practices at smaller scales and provide a localized demonstration of multiple practices. For agricultural measures such as conservation easements or vegetated buffers along the periphery of their land, small scale pilots may be effective at demonstrating a willingness to test a proof-of-concept before more wide-spread implementation. It is suggested that any pilot BMP installed in the watershed be monitored for effectiveness. Tools on monitoring such practices can be found in Section 7.1.

The South Pacolet River watershed can build off of the recently-installed rain garden at Rainbow Lake Middle School, which was made possible by Spartanburg Water’s funding of an effort by a local land conservation and advocacy organization, Upstate Forever. Leveraging this project and expanding the pilot program to other critical areas around the lake can be a next step, as Spartanburg Water and Upstate Forever have said that this project is hopefully a first of many across Spartanburg County schools.

It is recommended to phase the implementation of the potential practices such that the easiest, cost-effective projects are done first. This will require minimal investment, could provide substantial water quality improvements, and allow for a proof-of-concept that can help ease future, more complicated implementation. As the program advances, more expensive and extensive efforts can be pursued, as expertise and community buy-in grows.

The next steps for a watershed stakeholder coalition could be a three-pronged approach to initiate the implementation process:

1. Introduce low-cost programmatic controls, which may include an examination of potentially outdated or unused ordinances that hinder any water quality improvement goals. This could also include the beginnings of public outreach, especially on items like lawn management. This may include public education, IDDE, enhanced grazing practices, land development controls, urban nutrient management, forest buffers, or construction stormwater management improvements.

2. Implement pilot structural controls such as development-based bioretention, rain gardens, constructed wetlands, or stream restoration, septic system repairs, or livestock exclusion. This can build off the momentum of public outreach in #1.

3. Advance the monitoring framework to start to quantify the structural improvements and controls implemented in #1 and #2. This can supplement on-going monitoring efforts, but will allow a

smaller-scale monitoring proof-of-concept to see how a set of practices are improving water quality of a tributary or reach.

For example, Spartanburg Water and/or project partners could (1) install pilot constructed wetlands or bioretention in developed areas throughout the watershed, (2) monitor the site’s stormwater influent vs. effluent water quality and quantity for at least one year, and (3) work with state, non-profit, and cooperative extension agencies to summarize and disseminate findings.

Achievement of near-term goals is subject to a variety of factors including technical feasibility, funding availability, and general partner participation; however, the establishment of interim milestones is expected to advance watershed improvement efforts by providing a means of tracking accomplishments against proposed activities. Specific activities (that could be undertaken by watershed partners) and interim milestones proposed as targets for the first five years of improvement efforts include:

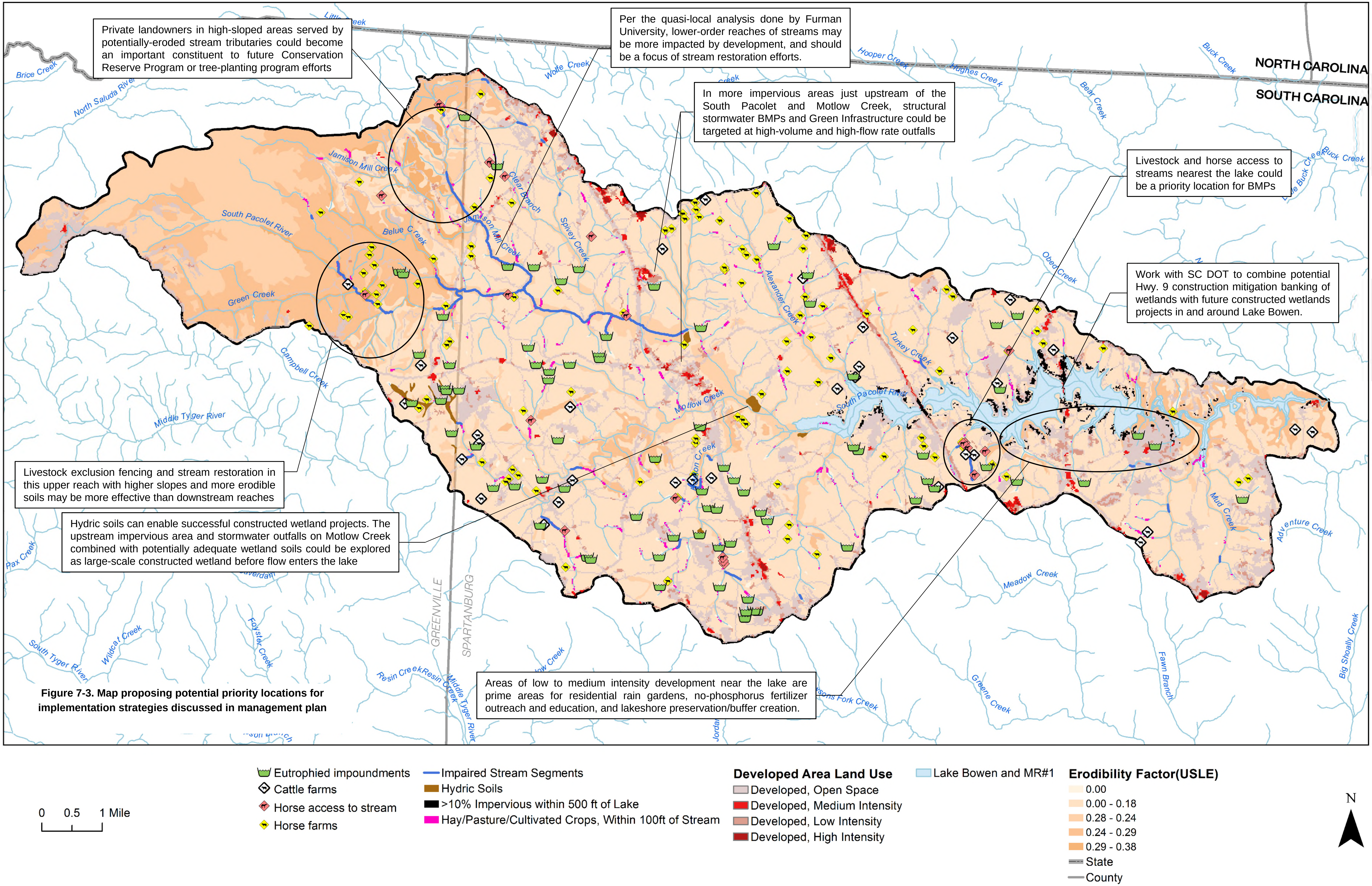
- Conduct an analysis to identify and prioritize specific improvement opportunities throughout the watershed
- Designate key partners to engage and potentially assist in implementation efforts
- Review local ordinances and identify potential revisions that would benefit water quality
- Facilitate 2 stakeholder meetings to garner input on watershed needs and potential improvement efforts
- Implement 2 streambank restoration projects
- Implement 5 septic system repairs
- Implement 2 structural controls for agricultural areas, such as livestock exclusion fencing
- Implement 2 structural controls for developed areas, such as rain gardens
- Identify (for potential elimination) point and non-point sources of pollution within watershed with a geographic focus on source water protection areas.
- Seek engagement opportunities to provide input on implementation efforts
- Host 2 workshops for watershed residents on topics like rain garden implementation and lawn maintenance practices
- Host a community watershed day event for public education and engagement
- Establish a monitoring program to evaluate the effectiveness of watershed improvements
- Outline activities to be completed during the next 5 years of improvement efforts

7.4.1.2 Long Term Goals

Long-term goals should include the widespread implementation of BMPs throughout the watershed to address water quality goals in conjunction with ongoing evaluations to determine the need for further improvements and the most cost-effective strategies. As part of this approach, lessons learned through the pilot implementation presented under short term goals should be incorporated into ongoing implementation efforts. Generally, it is anticipated that the pace of implementation efforts would increase over time given improved certainty and understanding regarding water quality needs and the cost and benefits of implemented improvements.

7.4.1.3 Potential Priority Areas

A map was compiled showing various factors that could influence which areas to implement practices first, along with an explanation explaining why the factors deem it a water quality priority (Figure 7-3). Specifically, areas where impervious surfaces (red) are located near upstream tributaries of Motlow Creek or the South Pacolet River are prime for green infrastructure demonstration practices (short term low-hanging fruit to build into long-term monitor and implementation). More upstate, multiple stream segments that were identified as having erosivity issues are located near heavy concentrations of cattle and horse farms, with noted access points into the stream prime for livestock exclusion / stream restoration combination projects. Lakeshore development, and occasion hydric soils could be investigated for constructed wetland projects, especially if Highway 9 construction by SC DOT could fit wetland offset / mitigation as part of a multi-faceted planning approach.



Private landowners in high-sloped areas served by potentially-eroded stream tributaries could become an important constituent to future Conservation Reserve Program or tree-planting program efforts

Per the quasi-local analysis done by Furman University, lower-order reaches of streams may be more impacted by development, and should be a focus of stream restoration efforts.

In more impervious areas just upstream of the South Pacolet and Motlow Creek, structural stormwater BMPs and Green Infrastructure could be targeted at high-volume and high-flow rate outfalls

Livestock and horse access to streams nearest the lake could be a priority location for BMPs

Work with SC DOT to combine potential Hwy. 9 construction mitigation banking of wetlands with future constructed wetlands projects in and around Lake Bowen.

Livestock exclusion fencing and stream restoration in this upper reach with higher slopes and more erodible soils may be more effective than downstream reaches

Hydric soils can enable successful constructed wetland projects. The upstream impervious area and stormwater outfalls on Motlow Creek combined with potentially adequate wetland soils could be explored as large-scale constructed wetland before flow enters the lake

Areas of low to medium intensity development near the lake are prime areas for residential rain gardens, no-phosphorus fertilizer outreach and education, and lakeshore preservation/buffer creation.

Figure 7-3. Map proposing potential priority locations for implementation strategies discussed in management plan

7.5 Cost and Reduction Forecast

Hazen developed a preliminary cost analysis using a combination of agricultural and development-based structural and non-structural BMPs. The approach involved determining the total reduction of nitrogen and phosphorus on a pound per year basis assuming that a select number of acres in the watershed would receive treatment from those various BMPs. These acres would then receive “credit” vis-à-vis BMP implementation through assumed load reduction efficiencies. Finally, cost estimates from various publicly-available data sources were included to quantify both cost per pound of nutrient to remove for each practice, as well as total cost of achieving the estimated 44% and 69% load reduction goals for nitrogen and phosphorus, respectively. The goal of the analysis ultimately was to implement BMPs in a reasonably feasible combination in order to get to an annual load reduction of 76,604 lbs/year and 3,117 lbs/year of nitrogen and phosphorus, respectively.

7.5.1 Cost and Performance Assumptions

Because limited local information is currently available regarding BMP costs, interim cost data from the Chesapeake Bay Program were used for each applicable BMP (Table 6-5 and Table 6-6). Except for stream restoration and septic tank removal, the costs are expressed as dollars per acre of land treated. All costs from the various public documents were adjusted to 2017 dollars for the analysis, and were summed based upon the total cost expected over the lifespan of the BMP.

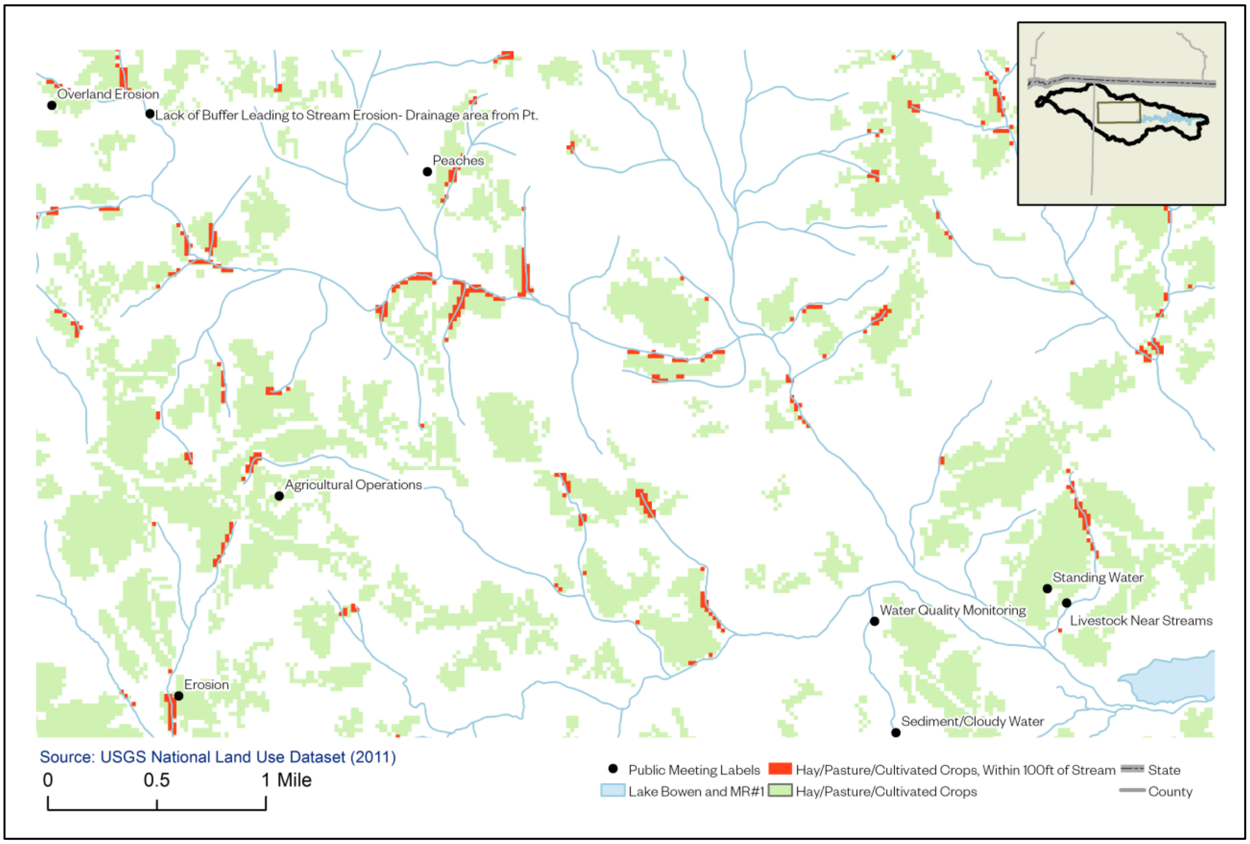
7.5.2 Load Reduction and Cost

The preliminary desktop analysis of BMP implementation over a multi-year time frame is shown below in Table 7-1.

Table 7-1: Estimated loading reduction and costs associated with agricultural and development-based BMPs in the South Pacolet River watershed

	BMP	Potential Treated Acres	Fraction of Potential Acres Treated	Treated Acres	Annual Load Reduction		Annual Cost to Remove		Lifetime BMP Cost (2017 USD)
					TN (lb/yr)	TP (lb/yr)	TN ($/lb/yr)	TP ($/lb/yr)	
Agricultural BMPs	Riparian forest buffer	379	60%	227	6,545	377	1.28	22.28	1,907,917
	Riparian grass buffer	379	20%	76	1,718	126	3.30	45.14	429,488
	Wetland restoration	379	1%	2	26	3	390.15	3,989.39	19,140
	Tree planting	0	85%	249	3,704	2,233	2.03	3.36	1,870,379
	Land Retirement	0	5%	626	5,632	626	0.64	5.74	2,248,307
	Livestock exclusion	379	90%	341	3,070	106	1.42	41.27	1,488,595
	Cover crop early drilled rye	0	0%	0	0	0	---	---	-
	Continuous no-till	31	25%	8	10	3	3.20	10.82	260
	Enhanced nutrient management	31	25%	8	5	0	4.35	---	165
	Decision agriculture	31	20%	6	2	0	12.30	---	149
	Off stream watering	379	90%	341	153	27	2.33	13.11	121,985
	Upland prescribed grazing	12515	60%	7,509	6,758	1,502	0.00	0.02	176,228
	Upland precision intensive rotation grazing	12515	60%	7,509	7,434	1,802	0.01	0.05	612,602
Development-Based BMPs	Urban filtering practices	424	0%	424	0	0.00	0.00	---	---
	Bioretention	424	0%	424	0	0.00	0.00	---	---
	Wet ponds and wetlands	124	5%	424	21	55.12	11.60	2,242.64	10,655.80
	Urban forest buffers	2,262	15%	424	64	206.70	34.80	450.43	2,675.27
	Urban nutrient management	8,826	30%	124	37	84.63	16.96	373.58	1,863.80
	Street sweeping	424	70%	2,262	1,583	2,573	722	1.24	4.41
	Homeowner rain gardens	1,579	70%	8,826	6,178	6,827	1,240	0.01	0.05

What follows is an example of how potential acreage for a BMP was evaluated in the watershed. This value represented the maximum potential area BMPs could conceivably treat. Generally, some reduction factor was applied for actual implementation (Fraction of Potential Acres Treated) to reflect prioritization of more cost-effective options and logistical and technical constraints likely to prohibit full implementation of an individual BMP. In the case of this example, a desktop analysis was performed to narrow down the land uses most applicable to riparian buffer or wetland restoration. Out of the entire watershed, 379 acres were deemed high priority for this practice due to their direct connectivity to streams (Figure 7-4). Numerous instances of agricultural land abutting streams coincided with issues such as “overland erosion”, “lack of buffer”, and “livestock near streams” identified by stakeholders in March 2017. It is from this 379 acre value that a fraction of acres to treat was selected in Table 7-1.



Source: USGS National Land Use Dataset (2011)

Figure 7-4: Land use designated as hay, pasture, or cultivated crops within 100 feet of streams and stakeholder comments of problematic issues in select area of South Pacolet River watershed

Practices such as livestock exclusion and riparian buffer protection were considered possible on the same given acre of land, and thus are drawn separately from the pool of 379 acres in the table. Land uses in the development stormwater BMP section were chosen from the pool of “developed” acreage in the National Land Use Dataset. Retrofits such as bioretention were deemed possible on “medium” and “high intensity” developed land, while residential or commercial nutrient management was focused on “developed, open space” and “developed, low intensity” land. Homeowner rain gardens were selected from “low intensity” and “medium intensity” development to strike a balance between likely connected impervious surfaces that could be treated, and low-enough density to provide for adequate economic justification for the installation of stormwater-related gardens.

There are a number of livestock operations in the watershed that could be included in the analysis as a feedlot best management practice scenario; however, limited information on the extent of these operations and the fact that the STEPL model database input for the watershed only indicated 1 acre of feedlots, the analysis was not pursued at this time pending further input.

In addition to the percent removal-based practices in Table 7-1, stream restoration and septic tank repairs were considered as part of the overall implementation strategy. In the analysis, the maximum possible stream length available for restoration efforts was estimated to be 79,238 feet (15.0 miles) based on GIS data from Spartanburg Water highlighting erosive stream sites. A fraction of this total was assumed to engage in restoration as part of this preliminary analysis. The life span of stream restoration is particularly variable, and could be examined on a case-by-case basis. The degree to which an individual project uses vegetative vs structural and hardening modifications, and the extent of stream corridor degradation, can drastically alter the longevity and cost of the project.

Table 7-2: Estimated stream restoration cost and load reduction

Parameter	Value
Cost per linear foot (2015 USD)	\$150 - \$400[a]
Assumed lifetime of practice (yr)	20
TN reduction (lb per LF)	0.2[b]
TP reduction (lb per LF)	0.068[b]
Total estimated eroded stream length (LF)	79,238
Fraction of length assumed will be restored in implementation effort	45%
Stream restoration potential (LF)	35,657
TN reduction (lb/yr)	7,131
TP reduction (lb/yr)	2,425
Cost of TN reduction (\$/lb/yr)	\$71
Cost of TP reduction (\$/lb/yr)	\$208

[a] Chesapeake Stormwater Network, 2015
[b] Schueler & Stack, 2012

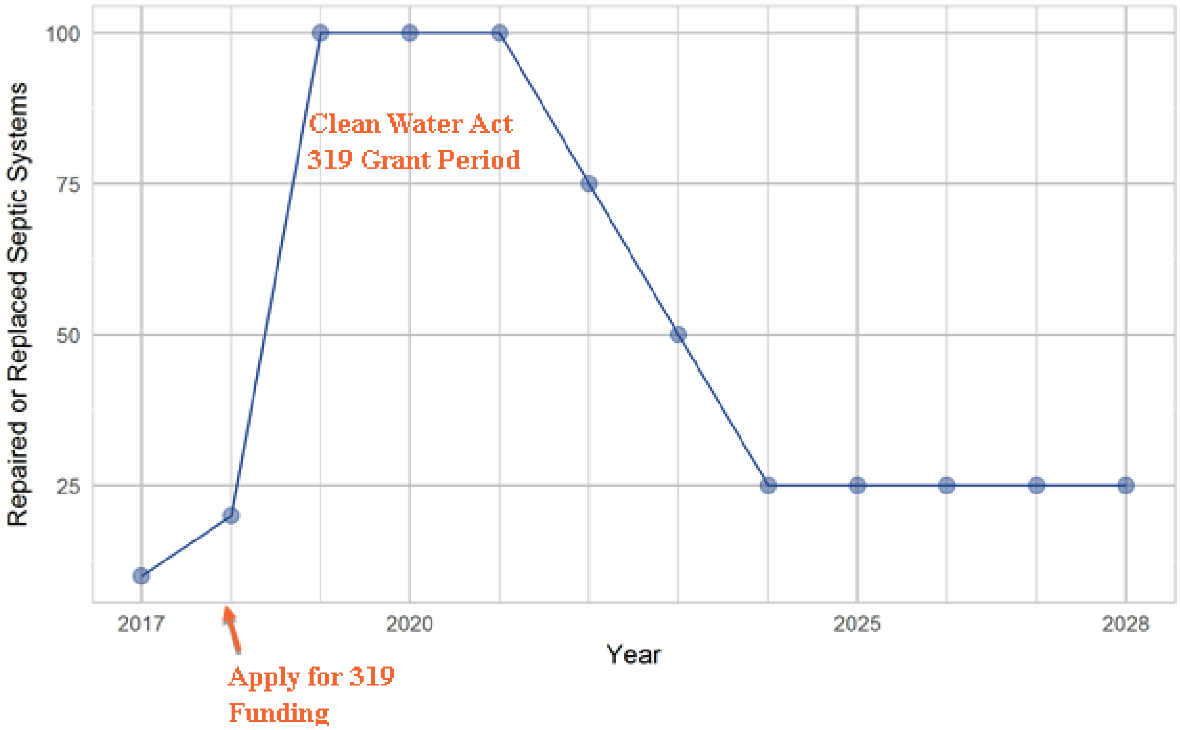


Figure 7-5: Annual septic system repair effort and potential corresponding grant time frame

Based on the discussion in Section 4.3.2 concerning on-site wastewater systems in the watershed, the above represents a total repair of 558 systems in 10 years, which is 85% of the 656 systems estimated to be in need of repair in this report, which assumed a 10% failure rate. This assumes a year of analysis to determine the most effective locations in the watershed in which to implement septic repairs, followed by a stakeholder buy-in process in preparation of potential future funding. An assumed repair cost of $1,500 per septic system was utilized. An example analysis over a 10 year time span shows how a repair program could coincide with a Section 319 grant tenure (Figure 7-5). While septic systems appear to represent a small portion of the potential load reduction practices in the watershed, they may be of high important due to the history of the Upper Broad River watershed's fecal coliform TMDL, and preventing any future 303(d) designations for biological impairment due to bacteria associated with septic leaching.

After combining the costs associated with agricultural and development-related BMPs, stream restoration, and septic tank repair, the total resulting load reductions needed to achieve the target are shown in

Table 7-3. This implementation scenario falls short of achieving the load reductions necessary to meet ecoregion TN targets, but was tailored to meet 100% of the estimated TP removal. In general, the suite of practices selected achieve a greater proportion of the TP load reduction target than the target established for TN.

Table 7-3: Estimated loading reductions and lifetime costs associated with various watershed best management practices

Class of Practice	TN reduction (lb/yr)	TP reduction (lb/yr)	Total Lifetime Cost
Agricultural	35,056	6,803	$8,875,214
Development-related	7,131	2,425	$10,081,846
Stream restoration	11,798	2,331	$26,058,352
Septic system repair	1,426	558	$870,000
Total	**55,411**	**12,117**	**$45,885,412**
Load reduction needed	*76,604*	*12,091*	
Percent achieved	*72%*	*100%*	

It is important to note that all watershed plans have some uncertainty, but the scope of watershed analysis efforts has some correlation with the certainty of improvement needs and benefit of improvement efforts. The analysis presented herein draws upon local water quality monitoring data, ecoregion targets, and common performance and costs of watershed controls to establish the foundation for water quality improvement efforts. This level of analysis differs from more advanced total maximum daily load (TMDL) development, where detailed models are often utilized to replicate physical, chemical, and biological processes throughout the watershed. As such, this implementation scenario is valuable to establish the scope of potential improvement needs and inform early watershed management efforts, but should not be perceived as a definitive list of long-term actions required to meet water quality objectives without any further analysis. The adaptive management aspect of the strategy described herein will be especially important, as the need for water quality improvement and benefits of individual controls will be better understood over time. The framework presented herein can be utilized to refine the watershed plan over time, updating cost and performance information, while also changing the balance of proposed practices to produce a path forward best suited to protecting water quality.

7.6 Schedule

This portion of the report sets a baseline for discussion in order to outline strategies that may be chosen in the future.

The amount of time required to realize pollutant load is often highly variable. Reduction of pathogens from point source leaks of sewage, for example, is often noticed much sooner than long-term nutrient loading. As a result, the aim of a nutrient management program should look at a multi-year progression.

An estimate of the time it would take to reduce TN and TP requires many input factors, including economic and social input from multiple stakeholders. A more concrete estimate of a timeline is likely to develop after stakeholder engagement begins. It is recommended that scheduling follow the proposed 5-yr implementation cycles discussed herein, with the rate of BMP implementation increasing with each 5-yr cycle as the need for further reductions and cost-benefit of individual practices is better understood. Key factors affecting the overall implementation timeline include the affordability of improvements within each 5-yr cycle and desired timeline for achievement of water quality goals. Overall implementation timelines of 25 to 30 years are typical for watershed management plans and should likely serve as the basis for coordination among Spartanburg Water and other stakeholders.

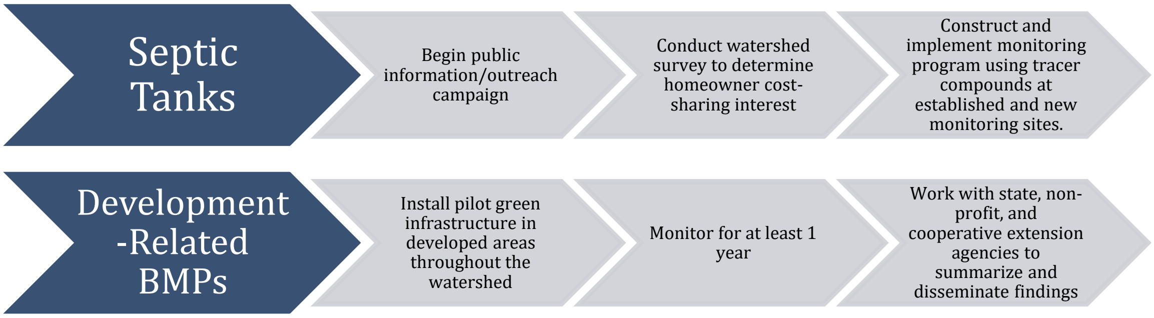


Figure 7-6: Sample scheduling and milestone implementation for two prominent BMP types recommended in the watershed

8. Future Success

8.1 Sharing Results

There are a range of options for building awareness and showcasing the success of the various components of the Watershed Based Plan. For example, Spartanburg Water currently has in-depth water quality communications with its customers via the annual drinking water quality reports. All stakeholders have other opportunities to enhance this range of options. Using the leverage of distribution networks, it is recommended to communicate with stakeholders in the watershed on issues related to this nutrient management plan. Many community organizations, non-profits, and governmental entities would benefit from forming a broad coalition to communicate the implementation and the results of the nutrient reduction plan.

8.1.1.1 Public Signage

Key to any implementation program is reminding the public exactly what practice is being used, especially in the pilot phase, via public signage. Educational signs near BMPs can insure that the monitored sites are as visible as possible.

8.1.1.2 Web Interface

With the advances in web-based technology, one relatively easy and low-cost way of engaging the public on the progress of the implementation of a nutrient plan is through metrics posted to a website. Many larger municipalities rely on this (see Philadelphia's "Green City, Clean Waters" program as an example), but it's becoming increasingly easier to establish these tools regardless of program size. A portal that shows locations of implementation BMPs on a Google map interface, monitoring stations with basic data summaries and explanations of what is being measured, and success stories of implementation thus far can be an efficient way to inform the public and garner stakeholder support.

8.1.1.3 Stakeholder Network

Utilizing the contacts established during the initial stakeholder identification process could yield itself into an effective network to disseminate findings. Once data becomes available regarding the costs and benefits of practices specific to this watershed, the findings can be circulated through this network.

8.1.1.4 Water Quality Reports

Spartanburg Water already has a data-dissemination network established to inform its customers of chemical and physical constituents in their drinking water on an annual basis. Given the section in the reports informing customers on Source Water Assessments performed by DHEC to, among other things, assess the potential for pollutants to enter the water supply, Spartanburg Water may consider adding implementation efforts to this report in order to link those detection efforts with water quality improvement efforts.

9. Summary

The South Pacolet River watershed is a 91.5 square mile watershed located in the piedmont region of South Carolina. The watershed drains to two human-made reservoirs, Lake William C. Bowen and Municipal Reservoir #1, both of which serve as drinking water supply reservoirs. Spartanburg Water owns and operates both bodies of water, providing over 50,000 residential customers with drinking water.

In years preceding this report, portions of Lake Bowen and Municipal Reservoir #1 have experienced algal blooms, which have caused low dissolved oxygen levels and triggered taste and odor issues. As a result, Spartanburg Water, as the owner and operator of these resources, is interested in exploring a strategy to reduce watershed nutrient loadings, which are thought to be contributing to periods of lake eutrophication.

Through using existing watershed monitoring stations that measure streamflow and grab samples of nutrient constituents, an area-weighted estimate of total watershed loading was calculated.

	Estimated Current Load		Target		Percent Reduction Needed
Parameter	**lb ac^{-1} yr^{-1}**	**lb yr^{-1}**	**Lake Conc. (mg/L)**	**Load (lb yr^{-1})**	
TN	3.05	174,704	0.36		44%
TP	0.31	17,541	0.020		69%
TSS	35.6	518,563	--		--

The estimated existing TN load is nearly the same value as the value estimated by USGS in 1976 (176,921 lbs-TN/yr), while the loading of TP has increased nearly threefold since 1976 (5,584 lb-TP/yr). The report suggests that, while TN loading does not appear larger than the 1976 value, an increase in nitrates over time could hint at untreated septic effluent or animal waste entering the lakes. The data are further explored and connected to Best Management Practices (BMPs) that would be the most effective in treating the nutrients entering Lake Bowen and Municipal Reservoir #1. Among them, vegetated buffer programs, conservation programs, septic tank management programs, constructed wetlands, green infrastructure, stream restoration, and residential lawn management may provide the best opportunity to aid the watershed in lowering TP, TN, and chlorophyll-a concentrations to the recommended EPA lake concentrations specific to this ecoregion (IX).

Finally, a preliminary estimate of implementation measures would result in a 76,604 lb TN load reduction and 12,117 lb TP load reduction, which is 72% and 100% of the reduction needed to achieve the targets in the table above, respectively. This estimate includes a preliminary cost estimate of $46M over the lifetime of the management practices (20-25 years).

Building on the success of the current monitoring framework will greatly enable BMP implementation and a feedback mechanism that tracks implementation year to year. This tracking, combined with building on the stakeholders already at the table through a network of subject matter experts, community leaders, and other stakeholders engaging with multiple funding sources for, implementation, can support the long-term quality of Lake Bowen and Municipal Reservoir #1 as healthy public drinking water supplies.

Appendix A: Nine Elements of a Watershed Plan (EPA Requirement)

This document intended to address a portion of the major 9 elements of an EPA watershed plan

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. E.G.:
    a. "X number of dairy cattle feedlots needing upgrading, including a rough estimate of number of cattle per facility"
    b. "Y acres of row crops needing improved nutrient management or sediment control"
    c. "Z linear miles of eroded streambank needing remediation"
    d. Need map with major causes and sources of impairment
2. Estimate of load reductions expected from management measures
    a. Incorporate TMDLs for water bodies that have TMDLs
    b. Applicable loads need to not blow up downstream water quality standards
3. Description of nonpoint source management measures that will need to be implemented to achieve load reductions, and description of critical areas in which those efforts will be needed
    a. Suggest map
4. Estimate amounts of technical and financial assistance needed, associated costs, and/or sources and authorities to be relied on to implement plan
    a. implementation + O&M
5. An information and education component used to enhance public understanding of the project and encourage early and continued participation in selecting, designing, and implementing the nonpoint source management measures to be implemented
6. Schedule for implementing nonpoint source mgmt. measures
    a. Should reflect milestones from Element 7
7. Measurable milestones for determining whether nonpoint source management measures or other control actions being implemented
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and progress is being made
9. Monitoring component to evaluate effectiveness of implementation efforts over time, measured against the criteria established under item 8.

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Appendix C: 1990 U.S. Census Table, South Carolina

	State	Urban						Rural			Rural farm
		Total	Inside urbanized area			Outside urbanized area		Total	Place of 1,000 to 2,499	Place of less than 1,000	
			Total	Central place	Urban fringe	Place of 10,000 or more	Place of 2,500 to 9,999				
Public sewer	825,754	694,635	506,743	176,389	330,354	51,976	135,916	131,119	33,046	13,253	1,342
Septic tank or cesspool	578,129	102,795	75,921	4,145	71,776	3,891	22,983	475,334	11,695	13,556	15,013
Other means	20,272	2,752	1,626	514	1,112	115	1,011	17,520	285	429	731

Source: 1990 Census of Housing, Detailed Housing Characteristics, South Carolina (TABLE 17)
(U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census)
URL: https://www2.census.gov/library/publications/decennial/1990/ch-2/ch-2-42.pdf

Appendix D: Extrapolated Loading to Subcatchments

All values below in loading are in lb/year. “Sampling watershed” refers to nearest water quality station from which pollutant average concentrations were applied to the given subcatchment. Flows were scaled from the south pacolet monitoring station WS-E to the various subctatchments proportionally by area.

Subcatchment	Area (ac)	Annual Avg Flow (cfs)	Sampling Watershed	TP	TN	TKN	NO23	NH3	SRP	TSS
Alexander Creek	3710.3	9.321	5a	977.1	10327.3	4883.1	2915.8	1033.1	890.7	174248.5
Alverson	27.4	0.069	avg	7.7	102.1	43.2	36.1	8.7	7.3	951.9
Arledge	397.8	0.999	sc	147.2	1204.4	569.8	304.7	140.3	95.5	13437.8
Arledge 2	65.3	0.164	sc	24.2	197.7	93.5	50.0	23.0	15.7	2206.4
Bascule Ridge	23.4	0.059	avg	6.6	87.2	36.9	30.8	7.5	6.3	813.4
Bascule Ridge 2	73.4	0.184	avg	20.7	273.3	115.8	96.7	23.4	19.6	2549.3
Belue Creek	1467.5	3.687	sc	543.0	4443.2	2102.0	1124.0	517.6	352.3	49575.9
Belue Mill	159.0	0.399	sc	58.8	481.4	227.7	121.8	56.1	38.2	5371.1
Bertha Burns	245.7	0.617	avg	69.2	915.3	387.8	323.8	78.3	65.6	8538.0
Big Mulberry Trace	317.5	0.798	avg	89.4	1182.7	501.1	418.3	101.2	84.8	11032.0
Blackstock	61.9	0.156	avg	17.4	230.7	97.8	81.6	19.7	16.5	2152.3
Blazing Star	25.3	0.064	sc	9.4	76.7	36.3	19.4	8.9	6.1	855.7
Branch	124.2	0.312	avg	35.0	462.8	196.1	163.7	39.6	33.2	4316.7
Brown Arrow	232.5	0.584	avg	65.5	866.1	367.0	306.4	74.1	62.1	8079.2
Caldwell	305.3	0.767	sc	113.0	924.4	437.3	233.8	107.7	73.3	10314.3
Campobello	1667.3	4.189	avg	469.6	6210.7	2631.5	2196.8	531.3	445.3	57933.1
Cane Creek	84.8	0.213	avg	23.9	315.9	133.9	111.7	27.0	22.7	2947.0
Cassidy	79.5	0.200	sp	26.1	219.8	125.5	86.2	46.3	31.7	2821.1
Catnip	198.5	0.499	sc	73.4	601.0	284.3	152.0	70.0	47.7	6705.7
Chapman	82.5	0.207	avg	23.2	307.5	130.3	108.8	26.3	22.0	2868.0
Chestnut Ridge	932.5	2.343	sc	345.0	2823.3	1335.7	714.2	328.9	223.9	31502.0
Chestnut Ridge 2	116.8	0.293	sc	43.2	353.7	167.3	89.5	41.2	28.0	3946.5
Chestnut Ridge 3	78.0	0.196	sc	28.9	236.1	111.7	59.7	27.5	18.7	2634.2
Clark Hill	77.9	0.196	avg	21.9	290.1	122.9	102.6	24.8	20.8	2706.5
Craggy Rock	492.4	1.237	sc	182.2	1490.9	705.3	377.1	173.7	118.2	16634.6
Craggy Rock 2	69.2	0.174	sc	25.6	209.6	99.2	53.0	24.4	16.6	2339.0
Crow	48.6	0.122	avg	13.7	181.0	76.7	64.0	15.5	13.0	1688.5
Depot	96.3	0.242	sp	31.7	266.4	152.1	104.5	56.1	38.5	3418.9

Dixon	1058.7	2.660	avg		298.2	3943.6	1670.9	1394.9	337.4	282.7	36785.9
Dixon Cove	85.2	0.214	avg		24.0	317.2	134.4	112.2	27.1	22.7	2959.2
E Heathland	38.2	0.096	avg		10.8	142.5	60.4	50.4	12.2	10.2	1328.8
Earlsdale	151.6	0.381	sc		56.1	458.9	217.1	116.1	53.5	36.4	5120.5
Edwards	852.9	2.143	avg		240.2	3176.8	1346.0	1123.7	271.8	227.8	29633.5
Emerald	38.2	0.096	avg		10.8	142.4	60.3	50.4	12.2	10.2	1328.1
Englewood	121.1	0.304	avg		34.1	451.2	191.2	159.6	38.6	32.4	4209.0
Fagan	516.3	1.297		2	111.8	1407.2	405.9	624.3	134.2	123.9	12172.7
Fire Pink	39.2	0.098	sc		14.5	118.6	56.1	30.0	13.8	9.4	1323.4
Foster	953.5	2.396	avg		268.5	3551.9	1504.9	1256.4	303.9	254.7	33131.8
Foster 2	34.8	0.087	avg		9.8	129.7	54.9	45.9	11.1	9.3	1209.7
Glassy Ridge	94.2	0.237	sc		34.9	285.3	135.0	72.2	33.2	22.6	3182.9
Good	79.3	0.199	sc		29.3	240.0	113.6	60.7	28.0	19.0	2678.2
Good2	344.1	0.865	sc		127.3	1042.0	492.9	263.6	121.4	82.6	11625.8
Gowensville Church	269.4	0.677	sc		99.7	815.6	385.9	206.3	95.0	64.7	9100.5
Gramling Pond 4	177.1	0.445	sp		58.2	489.9	279.7	192.1	103.2	70.7	6286.2
Green Creek	2168.8	5.448	sc		802.5	6566.5	3106.5	1661.1	764.9	520.7	73267.3
Greenhill Farms	20.4	0.051	sc		7.5	61.7	29.2	15.6	7.2	4.9	688.2
Harvey Gosnell	336.7	0.846	sc		124.6	1019.3	482.2	257.8	118.7	80.8	11373.2
Harvey Gosnell 2	24.6	0.062	sc		9.1	74.4	35.2	18.8	8.7	5.9	830.6
Highland Hills	30.1	0.076	sc		11.1	91.0	43.1	23.0	10.6	7.2	1015.6
Hillside	180.0	0.452	avg		50.7	670.6	284.1	237.2	57.4	48.1	6255.1
Hogback Base	28.2	0.071	sc		10.4	85.5	40.4	21.6	10.0	6.8	953.5
Hogback Mountain	307.9	0.773	sc		113.9	932.1	441.0	235.8	108.6	73.9	10400.1
Hoghead Mountain	131.2	0.330	sc		48.6	397.3	188.0	100.5	46.3	31.5	4433.0
Holston Creek	4068.5	10.221	hc		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Horton	169.1	0.425	sp		55.6	467.8	267.1	183.5	98.5	67.5	6003.1
Island	148.9	0.374	avg		41.9	554.7	235.0	196.2	47.5	39.8	5174.6
Island Ford	64.7	0.163	avg		18.2	241.1	102.2	85.3	20.6	17.3	2249.2
Island Ford 2	39.4	0.099	avg		11.1	146.7	62.2	51.9	12.5	10.5	1368.3
James	88.3	0.222	sp		29.0	244.2	139.4	95.8	51.4	35.3	3133.6
James2	26.6	0.067	sp		8.8	73.7	42.1	28.9	15.5	10.6	945.5
Jamison Mill Creek	4176.0	10.491	sc		1545.2	12644.1	5981.6	3198.5	1472.8	1002.5	141079.0
Jeff Woodfin	74.0	0.186	avg		20.8	275.5	116.7	97.5	23.6	19.8	2570.1
Kimbrell	134.2	0.337	avg		37.8	499.7	211.7	176.8	42.8	35.8	4661.3
Kimbrell Loop 2	32.6	0.082	avg		9.2	121.4	51.4	42.9	10.4	8.7	1132.1
Lakeview	399.4	1.003	avg		112.5	1487.6	630.3	526.2	127.3	106.7	13876.3
Lakewinds	96.5	0.243	avg		27.2	359.6	152.4	127.2	30.8	25.8	3354.7
Lanford	110.9	0.279	sp		36.5	306.8	175.2	120.3	64.6	44.3	3937.5

Laurens	32.5	0.082	sc	12.0	98.4	46.6	24.9	11.5	7.8	1097.9
Laurens 2	36.5	0.092	sc	13.5	110.5	52.3	28.0	12.9	8.8	1233.4
Little Acres	34.6	0.087	sp	11.4	95.9	54.7	37.6	20.2	13.8	1230.1
Little Chestnut Ridge	30.8	0.077	sc	11.4	93.4	44.2	23.6	10.9	7.4	1042.1
Little Hoghead	19.2	0.048	sc	7.1	58.2	27.6	14.7	6.8	4.6	649.8
Mason Road	2060.7	5.177	avg	580.4	7676.0	3252.4	2715.1	656.7	550.4	71601.9
May Apple 1	33.9	0.085	sc	12.6	102.7	48.6	26.0	12.0	8.1	1146.1
May Apple 2	22.2	0.056	sc	8.2	67.2	31.8	17.0	7.8	5.3	750.3
May Apple 3	21.6	0.054	sc	8.0	65.4	30.9	16.5	7.6	5.2	729.4
Miller Farm	499.6	1.255	avg	140.7	1861.0	788.5	658.3	159.2	133.4	17359.5
Monroe Bruce	161.1	0.405	sp	53.0	445.7	254.5	174.8	93.8	64.3	5719.2
Motlow Creek	11964.3	30.057	mo	5310.2	52277.2	21201.5	15103.7	4106.1	2895.3	458773.1
Mud Creek	3779.5	9.495	avg	1064.4	14078.3	5965.0	4979.7	1204.5	1009.4	131322.6
Narrow	36.9	0.093	avg	10.4	137.4	58.2	48.6	11.8	9.8	1281.5
Newberry	130.6	0.328	sc	48.3	395.5	187.1	100.0	46.1	31.4	4412.7
Old Mills	2637.1	6.625	avg	742.7	9822.9	4162.0	3474.5	840.4	704.3	91628.5
Old Mills 2	54.5	0.137	avg	15.3	202.9	86.0	71.8	17.4	14.6	1893.1
Old Mills 3	129.4	0.325	avg	36.4	482.1	204.3	170.5	41.2	34.6	4496.9
Oliver	27.0	0.068	avg	7.6	100.7	42.7	35.6	8.6	7.2	939.0
Open Sky Farm	205.0	0.515	sp	67.4	567.2	323.9	222.5	119.4	81.9	7278.6
Orchard	19.2	0.048	avg	5.4	71.6	30.3	25.3	6.1	5.1	667.6
Orchard 2	31.5	0.079	avg	8.9	117.4	49.7	41.5	10.0	8.4	1094.8
Outlook Ledge	71.6	0.180	sc	26.5	216.8	102.6	54.8	25.3	17.2	2419.3
Pardo	127.9	0.321	sc	47.3	387.1	183.1	97.9	45.1	30.7	4319.2
Pardo 2	89.4	0.225	sc	33.1	270.6	128.0	68.5	31.5	21.5	3019.5
Pardo 3	77.8	0.195	sc	28.8	235.6	111.5	59.6	27.4	18.7	2628.7
Pleasant Grove	114.8	0.288	sp	37.7	317.5	181.3	124.5	66.9	45.8	4073.9
Preisland	18.8	0.047	avg	5.3	70.2	29.7	24.8	6.0	5.0	654.7
Ragan	23.6	0.059	sp	7.8	65.2	37.2	25.6	13.7	9.4	836.9
Rainbow Lake	74.4	0.187	avg	21.0	277.2	117.5	98.1	23.7	19.9	2585.9
RB Simms	242.0	0.608	avg	68.2	901.5	382.0	318.9	77.1	64.6	8409.5
Riveroak	328.7	0.826	avg	92.6	1224.2	518.7	433.0	104.7	87.8	11419.6
Roberts	169.6	0.426	sp	55.8	469.4	268.0	184.1	98.8	67.8	6022.9
Rock Ridge	73.1	0.184	sp	24.1	202.4	115.5	79.4	42.6	29.2	2596.6
Rock Ridge 2	39.0	0.098	sp	12.8	108.0	61.7	42.4	22.7	15.6	1386.3
Round Rock 1	109.7	0.276	sc	40.6	332.2	157.2	84.0	38.7	26.3	3707.1
Roundrock 2	27.4	0.069	sc	10.1	82.8	39.2	21.0	9.6	6.6	924.1
Roundrock 3	128.0	0.321	sc	47.3	387.4	183.3	98.0	45.1	30.7	4322.7
Roundrock 4	90.6	0.228	sc	33.5	274.4	129.8	69.4	32.0	21.8	3061.4
Roundrock 5	41.5	0.104	sc	15.4	125.7	59.5	31.8	14.6	10.0	1402.3
Russell Watershed	575.7	1.446	avg	162.1	2144.4	908.6	758.5	183.5	153.7	20002.9

Shady Valley	41.5	0.104	sc		15.4	125.6	59.4	31.8	14.6	10.0	1401.6
Spivey Creek	3409.1	8.565	hr		836.4	9618.6	4724.9	2348.4	1181.2	912.9	142591.5
Squirrel Mountain 1	47.1	0.118	sc		17.4	142.5	67.4	36.0	16.6	11.3	1590.0
Squirrel Mountain 2	35.1	0.088	sc		13.0	106.3	50.3	26.9	12.4	8.4	1185.9
Squirrel Mountain 3	76.2	0.191	sc		28.2	230.6	109.1	58.3	26.9	18.3	2572.8
Squirrel Mountain 4	61.1	0.153	sc		22.6	184.9	87.5	46.8	21.5	14.7	2063.3
Squirrel Mountain 5	35.4	0.089	sc		13.1	107.0	50.6	27.1	12.5	8.5	1194.3
Suttles	24.8	0.062	avg		7.0	92.4	39.2	32.7	7.9	6.6	862.2
Tangleridge	31.6	0.079	avg		8.9	117.6	49.8	41.6	10.1	8.4	1097.0
Thompson Creek	3314.7	8.327	avg		933.5	12347.0	5231.5	4367.3	1056.3	885.3	115172.7
Tidewater	170.5	0.428	avg		48.0	635.0	269.1	224.6	54.3	45.5	5923.4
Timberlake	31.7	0.080	avg		8.9	118.2	50.1	41.8	10.1	8.5	1102.7
Timberlake 2	20.6	0.052	avg		5.8	76.6	32.4	27.1	6.6	5.5	714.3
Timberlake 3	62.6	0.157	avg		17.6	233.3	98.9	82.5	20.0	16.7	2176.7
Turkey Creek	1563.1	3.927		6	404.4	4417.6	1356.3	1962.7	411.0	375.3	63422.7
Wallace	116.5	0.293	sp		38.3	322.2	184.0	126.4	67.8	46.5	4134.8
Walnut Hill	18.1	0.045	avg		5.1	67.4	28.6	23.8	5.8	4.8	628.9
Watercrest	56.7	0.142	avg		16.0	211.3	89.5	74.7	18.1	15.1	1970.6
White	106.4	0.267	avg		30.0	396.3	167.9	140.2	33.9	28.4	3696.5
Wilkins	172.5	0.433	avg		48.6	642.6	272.3	227.3	55.0	46.1	5994.5
Woodfin Ridge	106.0	0.266	avg		29.8	394.7	167.3	139.6	33.8	28.3	3682.1
Zimmerman	83.1	0.209	avg		23.4	309.7	131.2	109.5	26.5	22.2	2888.8
TOTAL	62947.3				19569.5	207233.6	90072.1	64590.0	19802.0	15118.7	2149574.5
AVERAGE	484.2	1.216			150.5	1594.1	692.9	496.8	152.3	116.3	16535.2

Appendix E: STEPL Watershed Inputs

General Characteristics

- State: South Carolina
- County: Spartanburg
- Weather Station: SC GREER GREENV'L-SPART

Watershed Land Use

- Urban: 9250 ac
- Cropland: 31 ac
- Pastureland: 12515 ac
- Forest: 27696 ac
- User Defined: 0
- Feedlots: 0

Agricultural Animals

- Beef Cattle: 750
- Dairy Cattle: 52
- Swine (Hog): 46
- Sheep: 67
- Horse: 346
- Chicken: 105
- Turkey: 0
- Duck: 0
- # of months manure applied: 3

Septic Systems

- No. of Septic Systems: 6555
- Population per Septic System: 2.29
- Septic Failure Rate: 10%

- Wastewater Direct Discharge, # of People: 0
- Direct Discharge Reduction: 0%

Soil Parameters

- R: 275.0
- K: 0.182
- LS: 0.871
- C: 0.2
- P: 0.883
- Soil Hydrologic Group: B

Urban Land Use Distribution

- Urban Area: 9250 ac
- Commercial: 0.7%
- Multi-Family: 3.8%
- Single-Family: 13.2%
- Open Space: 82.2%