Cane Creek and Little Cane Creek Watershed Management Plan to Address E. Coli Impairment, Oconee County, SC

September 2018 (Rev. April 2020)

CENTER for WATERSHED EXCELLENCE
Clemson Public Service and Agriculture

FOLKS

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Acknowledgements

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EXECUTIVE SUMMARY AND OVERVIEW OF IMPLEMENTATION PLAN

E.1 Introduction

This Watershed Management Plan intends to address the seemingly consistent water use impairments of bacteria loading to the Cane and Little Cane Creek Watershed. This watershed is the largest and most urban of the drainage basins to Lake Keowee, and a priority in addressing the sustained quality of that reservoir's use for supplying drinking water and recreation.

If the water quality of this basin and that of Lake Keowee is to be sustained far beyond this plan's implementation, the most important message for residents and decision-makers is to carry out the ***BMP of Better and More Planning***. This watershed includes the popular downtown of Walhalla in Oconee County, South Carolina. The original settlers of the area were German immigrants in the 1850s, and "Walhalla" translates to Garden of the Gods. This area is the gateway to the Blue Ridge Mountains, includes historic outposts, waterfalls, and the culturally and environmentally significant Stumphouse Tunnel and Issaqueena Falls. The land is primarily used for agricultural purposes. This watershed is quintessential upstate South Carolina with ecotourism, agritourism, and rich natural resources that are a core attraction to new residents, as well as those South Carolinians who have lived and worked in Oconee County for generations. Therefore, this plan may be considered unique in that it proposes short-term solutions and long-term strategies for the protection of environmental quality and its influence on quality of life in Oconee County.

E.2 Priority Projects

The most significant project recommended in this plan is an overhaul of how water is managed in and around Sertoma Field, the most popular park site in the area. This large, multi-partner effort should include replacement of sewer infrastructure while porous pavement solutions are implemented, as well as a naturalization of the unnamed tributary that carries runoff to Cane Creek, among other projects. It is the most visible of projects to send a message to the community that ecosystem protection is vital to their quality of life, will provide opportunities to engage residents in restoration and education, and address significant shortcomings of the wastewater system to allow for more volume and less fecal pollution risk to waterways.

The plan also presents significant grassroot opportunities to engage large landowners in stabilizing their riparian corridors through tree plantings. Bank loss, sediment deposition, and less access to the floodplain is preventing the degradation of bacteria in surface waters. Most especially in the lower parts of the watershed, this is an opportunity to bring large native trees back to the river's floodplains and long-term benefit water quality, ecosystem heath, and biodiversity. An additional step is bringing back natural flow and flushing mechanism in this riparian reforestation effort.

Additional projects identified as addressing existing sources of bacteria loading to Cane Creek include:

- Repair of septic systems and sewer tie-in to those failing systems where sewer is available;
- Regional policy development to incorporate grease interceptors at the single point of discharge from buildings where this is a documented and frequent occurrence;
- Catch basin maintenance;

- Trapping of wild pigs in the area;
- Improved buffers around pastures and paddocks.
- Lot scale BMPs and stormwater conveyance retrofits.

E.3 Engaging Stakeholders in the Future of this Watershed

Finally, the natural resources of the area, widespread and much a part of the culture of the region, provide significant opportunities for outdoor and classroom education. The Best Education Practices (BEPs) that are included in this plan have been developed so as to further a movement of recognizing the critical resources of the area for all ages and motivating those involved to action. These education and involvement efforts include citizen science monitoring with SC Adopt-a-Stream; Trout in the Classroom to especially recognize the link between sediment, habitat loss, and ecotourism impacts; implementation of the Carolina Yards program to address residential runoff, buffers, and native plantings; and maintenance of septic systems with in-person education.

E.4 Website Hosting of Plan and Related Efforts

This plan will be made available long term at www.clemson.edu/watershed as a low-resolution PDF download. Additionally, the project team will announce the plan's completion through the FOLKS newsletter. A follow up meeting with the local utilities and stakeholders will be conducted to review the final plan and formulate next steps. Limited copies will also be made available at FOLKS office and the Clemson Extension office in Oconee County for free pick up.

The student project that interviewed stakeholders for their perspectives on local water resources and management of those resources will be available at www.clemson.edu/watershed, and is currently available at https://www.sarah-carter-mapc-portfolio.com/client-project/. Please view these videos showing local faces and places in the watershed.

E.5 A Call to Local Leadership

The stakeholders of the Cane Creek Watershed have the potential to ask for greater protection of their livelihood, so critically linked to healthy waterways and healthy environment. This message of Better and More Planning to those decision-makes includes mandatory changes to the handling of sewage and a mandate to tie into sewer in new homes and developments where sewer exists; planning for conservation corridors and stream buffer protection, improved maintenance of stormwater infrastructure where it exists and a requirement to consider Green Infrastructure in areas of growth.

As with all Watershed Management Plans, this Plan should be considered fluid and subject to change as land use changes occur in the watershed. Though the project team has outlined priorities for implementation, these may change, as the watershed is dynamic. The implementation of this plan is more than any one agency can do; therefore, it is recommended that Oconee County hire a full-time Watershed Planner that can work amongst the county and towns, in partnership with the utilities of the region. With more watershed plans in place, the county will be prepared to apply for more implementation funds, while overseeing the implementation of this first plan. There are significant grants available to communities who want to plan and provide healthier environments for schools, parks, and their downtowns. Money is also available for small, growing communities to update sewer and water infrastructure. Additionally, a Watershed Planner will help to prepare the area and the contractors that work in the area for the Municipal Separate Storm Sewer System

(MS4) permit that will eventually be required in urban areas of the county. These are proactive watershed management steps that will help to protect and manage the natural resources that have been the history of the area, protected for the future of the area.

1.0 INTRODUCTION

GETTING TO KNOW THE WATERSHED

Cane and Little Cane Creeks reside wholly in Oconee County in the South Carolina foothills. The county welcomes visitors and residents with its tag line of "Land Beside the Water." The Cherokee word for this phrase is Oconee. And what better way to consider watershed management as just that, managing land beside the water?

Figure 1. Oconee County welcomes visitors and residents with a tribute to the influence of its surface waters.

A watershed management plan first and foremost recognizes the land users and land uses in the watershed. The Cane Creek Watershed, with Little Cane Creek as tributary, is a 30-square mile watershed, coming together as Cane Creek, and flowing wide and slow as it enters Lake Keowee. The Cane Creek Watershed is 15 square miles. The Little Cane Creek Watershed is 14 square miles.

Figure 2. Lake Keowee, Oconee County, South Carolina

THE BACTERIA TMDL

Cane and Little Cane Creek have been on the South Carolina 303(d) list of impaired waterbodies since 1998, monitored by the SC Department of Health and Environmental Control (SC DHEC) at two stations – Cane Creek at SV-342 and Little Cane Creek at SV-343 – and not meeting standards for bacteria. Currently, bacteria and specifically, Escherichia coliform or E. coli, are the leading water quality impairment in rivers and streams of the United States (US EPA 2014).

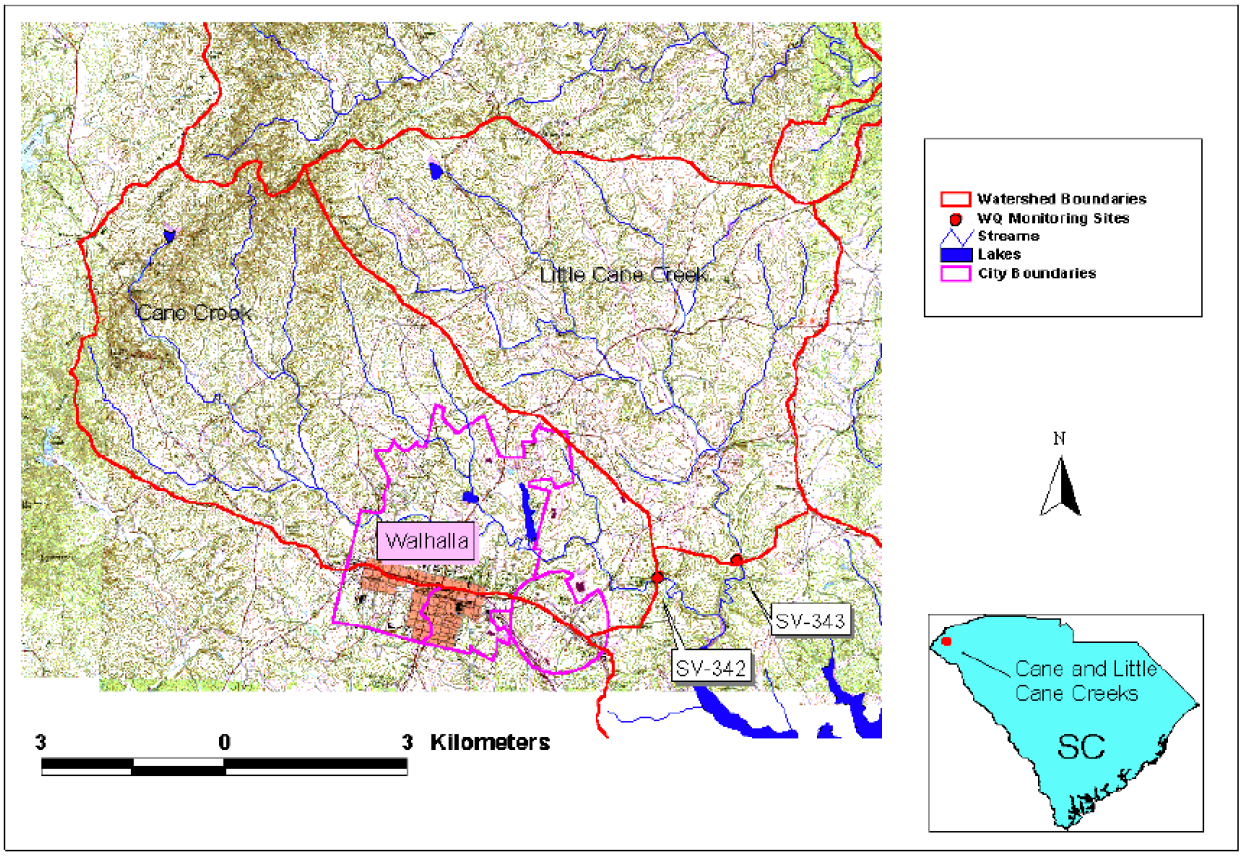


Figure 3. Map of water quality monitoring sites, excerpted from TMDL (SC DHEC, 2005).

These two systems are monitored at their crossing with Burns Mill Road, West Union, South Carolina.

From the *Total Maximum Daily Load for Fecal Coliform in Cane and Little Cane Creeks* (SC DHEC, 2005), during the assessment period of 1998-2002, **29% of samples from Cane Creek**, and **52% of samples from Little Cane Creek** violated the former fecal coliform standard for primary contact recreation in freshwater. The load duration curve methodology was used to calculate existing loads and used to estimate the percent reduction necessary for these two creeks to meet water quality standards for bacteria. Flow estimates used neighboring Coneross Creek, since there is no flow gauging station in Cane Creek. **The reductions were determined as 54% for Cane Creek (1.96E+11), and 65% for Little Cane Creek (1.79E+11).** The TMDL provides the following additional information, presented in Table 1, regarding the circumstances of the bacteria impairments in both systems.

Table 1. Details of impairment in each subwatershed, as noted by SC DHEC (2005)

Factors of Impairment	**Cane Creek Watershed**	**Little Cane Creek Watershed**
PRECIPITATION:	- Little indication of relationship between rainfall and bacteria results.	- No discernible relationship between rainfall and bacteria results.
TURBIDITY:	- Fairly strong correlation between turbidity and fecal coliform concentrations. - Little correlation between rainfall and turbidity. - Turbidity stems from events that stir up sediment from the creek bed. Or, higher turbidity and high bacteria densities are caused by the same unknown source.	- No discernible relationship between turbidity and bacteria results.

PARTNERS

This planning effort has become more multi-dimensional due to the partners who have assisted the project in providing local insights, data, stakeholder contacts, forums, and information. It is with gratitude that these partners are recognized here.

- FOLKS (Friends of Lake Keowee Society) – lead grantee on the Cane and Little Cane Creek Watershed Management Plan Development 319(h) project. It is with their support, community connections, knowledge of water resource concerns in the area, continued dedication to collecting local water quality data, and more that this project is possible.
- SC DHEC for their provision of funds and guidance during the planning effort.
- Oconee County – provided GIS data sets and consultation on project data and deliverables.
- Oconee Joint Regional Sewer Authority (OJRSA), Walhalla Water and Sewer, Seneca Light and Water – all utilities provided sewer line data and invaluable information on frequently occurring problems and geographic areas with infrastructure.
- City of Walhalla for the contributions and concerns of Mayor Danny Edwards and his participation in our student interview project, Watershed as Home.
- Clemson Extension Service of Oconee County provided connections within the community, collected data and all files from previously funded 319(h) efforts, input on stakeholders and concerns for water quality and quality of community, and field assistance.
- Oconee County Conservation District for their input throughout the process and insights on land use changes.
- Waters Edge Homeowners Association for their contributions to discussions during stakeholder meetings and awareness of riparian issues in the watershed.
- Pickens County for their sharing of ideas for watershed plan development and concern for the watersheds of Lake Keowee, that also affect their residents.

2.0 DATA REVIEW

AVAILABLE WATER QUALITY DATA

Water quality data is limited to that of SC DHEC and FOLKS. Though Walhalla Water Department collects samples at their intakes and provided these data to the watershed planning effort, these are below and outside of the TMDL watershed.

SC DHEC

The stations of significance to this watershed plan are those used in the development of the fecal coliform TMDL. SV-342 is on Cane Creek; SV-343 is on Little Cane Creek (Figs. 4 and 5). Both have been monitored since 1999 for a full suite of water quality parameters. 2009 is the only year each were monitored for E. coli and the last year of data collection at these two stations. This was a rigorous monitoring year at these two sites, as this was a special study evaluating fecal coliform and E. coli comparisons. In 2009, 49 results are available for E. coli at both monitoring locations.

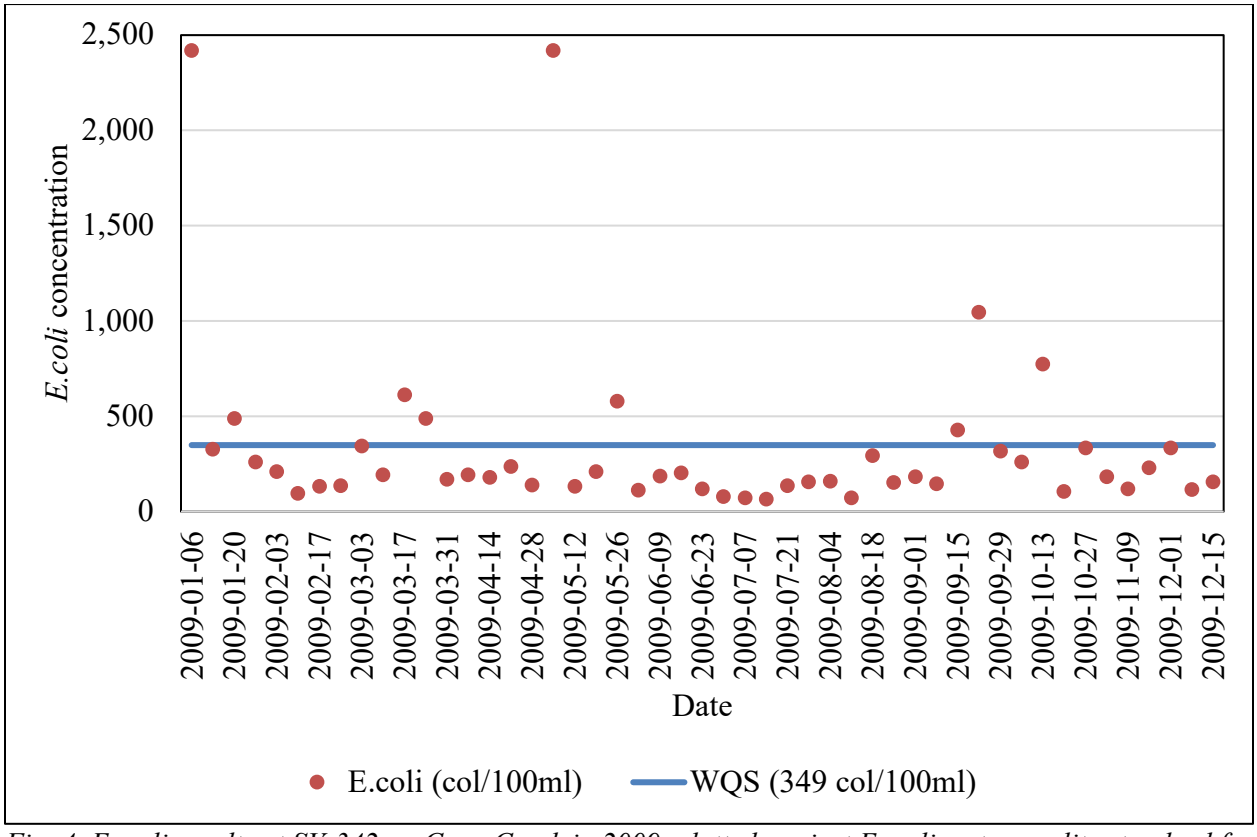


Fig. 4. E. coli results at SV-342 on Cane Creek in 2009, plotted against E. coli water quality standard for single grab samples (349 col/100mL).

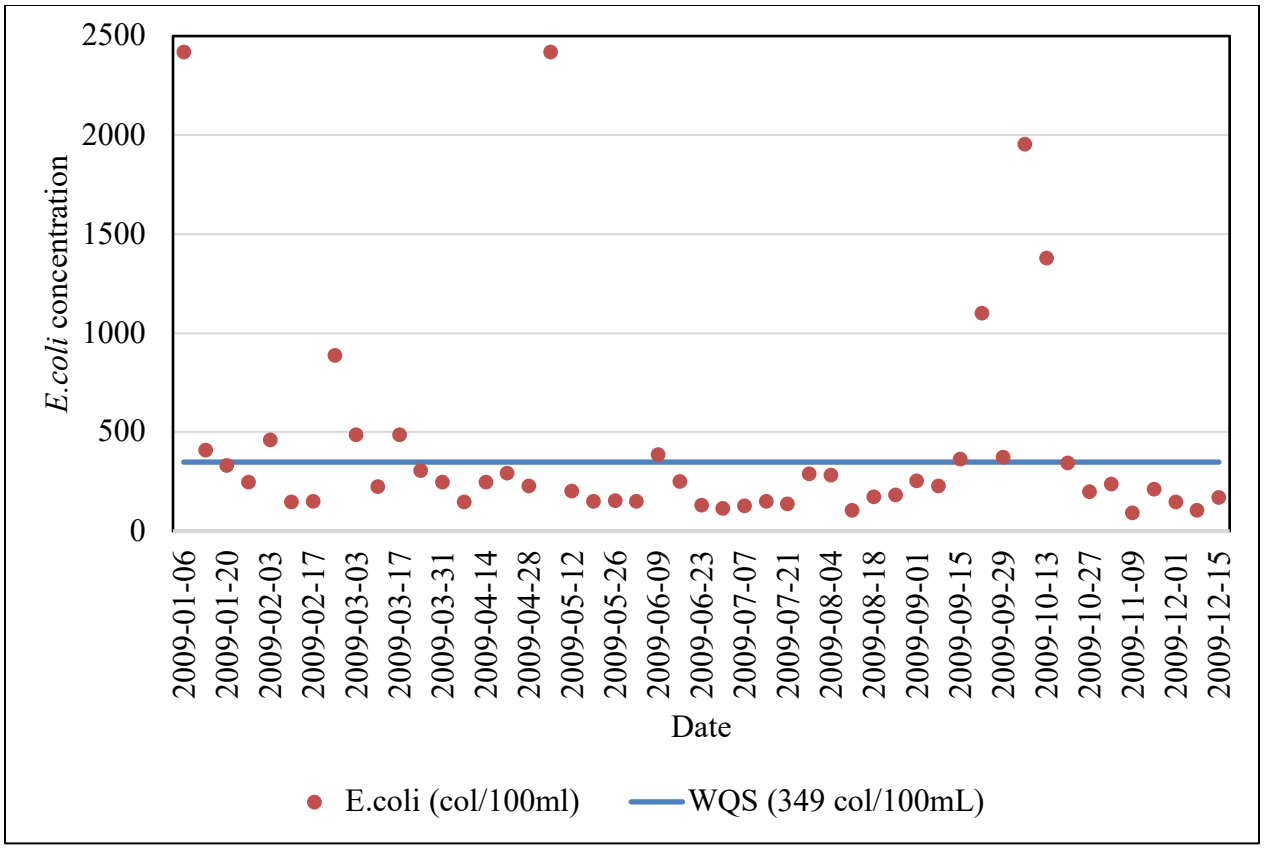


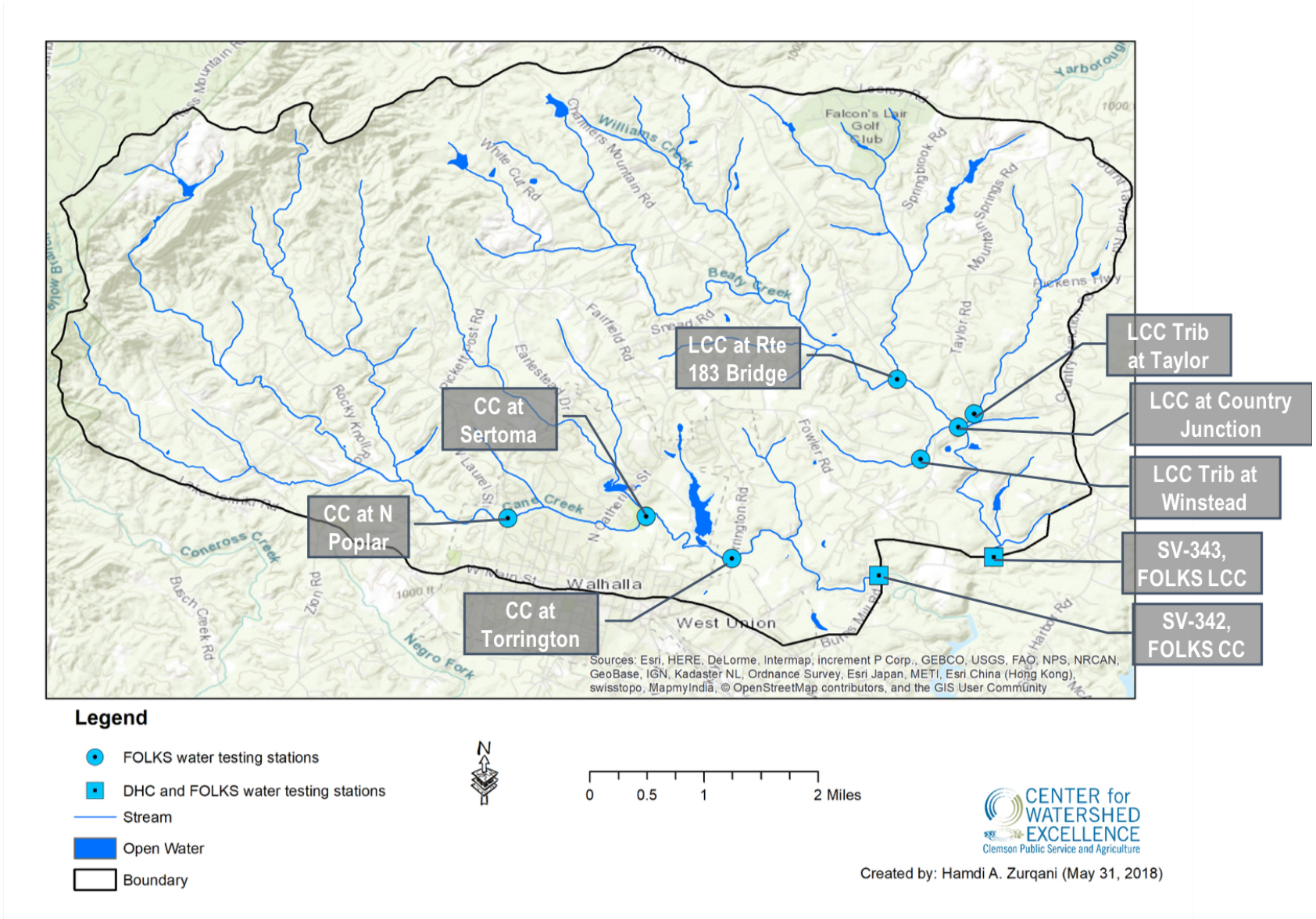
Fig. 5. E. coli results at SV-343 on Little Cane Creek in 2009, plotted against E. coli water quality standard for single grab samples (349 col/100mL).

There exists fecal coliform data from prior to 2009, collected by SC DHEC. Additionally, there are several special project stations in the upper reaches of Little Cane Creek and its tributaries that were part of a special study, with Enterococcus, fecal coliform, and E. coli all being collected over a 14-month period from 2004 to 2005. These data are being considered as too outdated for use in the development of this plan, given changes in the watershed and implementation projects undertaken in previous 319(h) work.

FOLKS

FOLKS has monitored the watershed more recently, following the Quality Assurance Project Plan that was approved in 2006 for monitoring the watersheds of Lake Keowee. Samples are collected by a volunteer Board Member and delivered to Greenville Water for analysis. E. coli has been monitored since 2015 and as recently as 2018 for the preparation of this watershed plan. Monitoring sites cover the major tributaries and are representative of both rural and urban catchments. The locations are depicted in Fig. 6. Samples collected at Sertoma Field are downstream of sewer line crossings. Samples collected at North Poplar Drive in Walhalla are above the bridge and sewer line crossing.

Fig. 6. Water quality monitoring stations from DHEC and FOLKS used in the development of this Plan.



All samples collected by FOLKS occurred at a minimum of 48 hours after a 1" storm, so as not to bias the data to only wet weather monitoring events. Table 2 provides a basic summary of E. coli results from both SC DHEC and FOLKS. For the most part, water quality measurements are not gross exceedances of the standard, and certain locations appear to have event-based high E. coli result unrelated to recent weather (though potential exists for suspended sediment to reintroduce E. coli to the water column). More data collected on Cane Creek at Sertoma Field, Torrington Road, and N. Laurel Street, as well as on Little Cane Creek at Country Junction, Winstead Road, and Route 183 Bridge would be helpful to establish any trends in these high bacteria occurrences.

Table 2. E. coli monitoring results summarized from all stations monitored after 2008.

	CANE CREEK SUBWATERSHED					
	SV-342	**FOLKS CC**	**CC at N Poplar St**	**CC at Sertoma Field**	**CC at Torrington**	**N. Laurel St (Walhalla)**
Years Represented	2009	2015, 2016, 2018	2016, 2018	2016, 2018	2016	2018
Units	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL
Max	2419	1300	490	2400	360	650
Mean	337	469	300	784	290	390
# of samples/n	49	15	5	5	2	2
# of results greater than WQS (349 col/100mL)	9	8	2	3	1	1

	LITTLE CANE CREEK SUBWATERSHED						
	SV-343	**FOLKS LCC**	**LCC 183 Bridge**	**Beaty Creek at 11 Bridge**	**LCC Tributary at Taylor Road**	**LCC Tributary at Winstead Road**	**LCC at Country Junction**
Years Represented	2009	2015, 2016, 2018	2016	2016	2016, 2018	2016, 2018	2016, 2018
Units	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL	MPN/100 mL
Max	2419	920	730	260	550	1700	580
Mean	416	285	513	260	320	794	368
# of samples/n	49	15	3	1	4	4	5
# of results greater than WQS (349 col/100mL)	13	2	2	0	1	3	3

CLEMSON UNIVERSITY AND MICROBIAL SOURCE TRACKING RESULTS

In 2015 and 2016, FOLKS worked alongside Clemson University research and faculty member, Dr. Barbara Campbell, to conduct microbial source tracking on Cane and Little Cane Creeks. Samples were collected at SV-342 and SV-343 DHEC sites at Burns Mill Road crossing, which is also the same location as FOLKS CC and FOLKS LCC.

Microbial source tracking is a suite of practices that use RNA or DNA to identify the source of bacteria. In this study, RNA and DNA were both extracted and amplified with species-specific bacteria primers. These primers target the amplified sequences in a process called polymerase chain reaction, or PCR. For this study, primers used were for human, beaver, and swine detection and present results as positive or negative for detection of that species' genetic sequence. The monitoring dates and results are shown in Table 3. Results indicate that there was a near constant input of fecal waste from human, beavers, and swine during the timeframe of this sampling effort, especially since the lifespan of the associated bacteria is expected to be less than the seven months of evaluation.

Table 3. Results of PCR on samples collected from Cane and Little Cane Creeks showing presence or absence of targeted species.

MICROBIAL SOURCE TRACKING MONITORING RESULTS - JUNE 2015 THROUGH APRIL 2016

	6/22/15	7/1/15	7/21/15	7/22/15	1/26/16	2/4/16	3/8/16
LITTLE CANE CREEK	+ Human	+ Human	+ Human	+ Human	+ Human	+ Human	- Human
	+ Beaver	+ Beaver	+ Beaver	+ Beaver	+ Beaver	+ Beaver	ND Beaver
	+ Pig	+ Pig	+ Pig	+ Pig	+ Pig	+ Pig	- Pig
CANE CREEK	ND Human	+ Human	+ Human	+ Human	+ Human	+ Human	- Human
	ND Beaver	+ Beaver	+ Beaver	+ Beaver	+ Beaver	+ Beaver	ND Beaver
	ND Pig	+ Pig	+ Pig	+ Pig	+ Pig	+ Pig	- Pig
ND = NO DATA							

One additional microbial source tracking sampling event and analysis took place in spring 2018 in partnership with Clemson University's Center for Watershed Excellence. In this analysis, qPCR was conducted, where q stands for quantitative. Thus, the results not only indicate a presence or absence of fecal associated DNA from a specific species, but also quantify the number of bacteria per species. Rather than E. coli, this qPCR method utilizes Bacteroides, which are the most predominant anaerobic bacteria in the gut of humans (Wexler 2007) and abundant in animal intestines (Scott et al. 2002). Additionally, *Bacteroides fragilis* has the advantage of being highly specific in the tracking of human fecal pollution, does not replicate in the environment, and research has shown that its presence significantly correlates to the presence of human enteric viruses (Scott et al. 2002).

The results of this single monitoring event are presented in Table 4. Swine, human, and bovine associated waste were identified in both creeks, in order of greatest to lowest total densities. Swine

had the greatest concentrations of all the identifiable bacteria, most especially in Little Cane Creek. The greatest identifiable human density was found at the SC DHEC monitoring site Cane Creek SV-342. Little Cane Creek at Winstead Road crossing, as well as Cane Creek at North Laurel Street crossing in Walhalla (above the sewer line crossing), both also showed relatively high human detection. Finally, bovine was found throughout the whole watershed. No detection of canine waste in stream was identified. Obviously, this analysis is limited to these four species, though waste related to other ruminants, wildlife, livestock, and birds could be present.

Table 4. qPCR results identifying amount of Bacteroides associated with four identifiable species and fecal waste present in surface waters of Cane and Little Cane Creeks.

Results of April 23, 2018 Microbial Source Tracking

Site ID	Bovine (CFU/100mL)	Canine (CFU/100mL)	Human (CFU/100mL)	Swine (CFU/100mL)
LCC	4E+04	-	2.5E+01	3E+05
CC	2E+04	-	1.5E+05	4E+04
CC at Sertoma Field	2E+04	-	-	8E+04
LCC Tributary at Taylor Road	4E+04	-	2E+03	5E+03
LCC Tributary at Winstead Road	3E+03	-	2E+05	8E+01
LCC at Country Junction	1E+04	-	3E+03	-
CC at N Poplar St	3E+03	-	7E+01	2.5E+04
CC above N Laurel St (Walhalla)	6E+04	-	8E+04	3.0E+05

- Indicates no detection for that species.

PAST 319(H) PROJECTS

FOLKS was previously awarded a 319(h) grant that implemented best management practices and repaired septic systems in the Cane and Little Cane Creek watershed from 2006 through 2009. Working with the Clemson Extension Service in Oconee County, the awardees accomplished much:

- Repaired 18 septic systems and provided guidance on best ways to engage stakeholders.
- Two farms participated in cost share awards to install BMPs to control bacteria-laden runoff from livestock.
- 210 storm drains were painted to alert residents that inlets drain to Cane Creek and Lake Keowee.
- Sanitary sewer overflows were identified and repaired.

DATA GAPS

The previous 319(h) monitoring and implementation effort, as well as this current Watershed Plan development process have identified data gaps in this watershed restoration process.

- Lack of digital sewer line maps of the City of Walhalla's sewer service.

- Lack of information on where septic system repairs and replacements are occurring, since this is not a requirement.
- The only two DHEC water quality monitoring stations used are at the bottom of the 30 square mile watershed. Monitoring stations that captured water quality data before and after the City of Walhalla in Cane Creek would be helpful, as well as monitoring sites on the lower tributaries before and after they enter Little Cane Creek.
- Weather data to relate water quality monitoring to dry and wet weather events would be helpful and is not widespread in the watershed.
- There exists no gauging station in this watershed. In the development of the TMDL, a gauge on Coneross Creek, a neighboring though less urbanized watershed, was used as estimate of flow. If there is to be a model developed for this watershed, especially to relate the hydromorphological conditions noted as problematic in this plan, flow gauging stations on each tributary would be beneficial.
- Many stakeholders who attended the stakeholder meetings felt disengaged in the plan and helpless to address sedimentation issues in Cane Creek, since their properties exist closer to Lake Keowee, below Burns Mill Road and the DHEC monitoring stations. They expressed concern that this watershed and all planning efforts should include the full watershed to the lake, so that sedimentation issues could be more documented and addressed through enforcement action and stabilization.

3.0 WATERSHED CHARACTERIZATION

LAND COVER

NASS DATA

The United States Department of Agriculture's National Agricultural Statistics Service (NASS) reported that the total land in farms according to use in Oconee County in 2007 was 106,729 acres, and this area decreased to 97,736 acres by the year 2012 (Table 5, Fig. 7). Major decline was seen in total cropland and pastureland.

Table 5. Land in farms in Oconee County according to use - 2012 and 2007.

Classes	2007	2012	2007	2012
	Acres (US)		Percentage (%)	
Total cropland	21,566	15,401	20.21	15.76
Total woodland	22,601	23,583	21.18	24.13
Permanent pasture and rangeland, other than cropland and woodland pastured	23,141	24,838	21.68	25.41
Land in farmsteads, homes, buildings, livestock facilities, ponds, roads, wasteland, etc	3,400	4,049	3.19	4.14
Pastureland, all types	36,021	29,865	33.75	30.56
Total	106,729	97,736	100	100

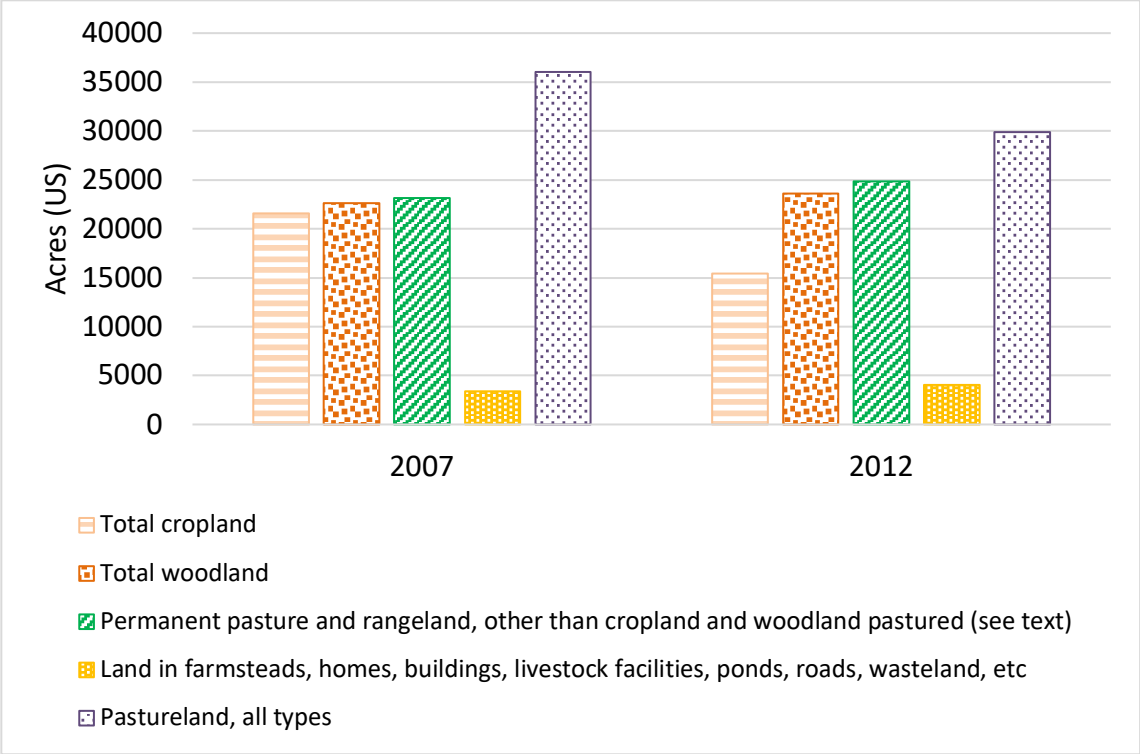


Fig. 7. Land in farms in Oconee County according to use - 2012 and 2007.

The total cropland area in Oconee County, according to the NASS report, showed a significant decline from 24,943 in 2007 to 17,755 in 2012, Table 6, Fig. 8. The dominating change was in the pasture and grazing land and cropland idle area.

Table 6. The total cropland area of Oconee County from 2007 to 2012.

Classes	2007	2012	2007	2012
	Acres (US)		Percentage (%)	
Harvested cropland	13,091	12,273	52.48	69.12
Other pasture and grazing land that could have been used for crops without additional improvements.	5,098	774	20.44	4.36
Other cropland	3,377	2,354	13.54	13.26
Cropland idle or used for cover crops or soil improvement, but not harvested and not pastured or grazed	2,656	1,955	10.65	11.01
Cropland on which all crops failed	562	188	2.25	1.06
Cropland in cultivated summer fallow	159	211	0.64	1.19
Total	24,943	17,755	100	100

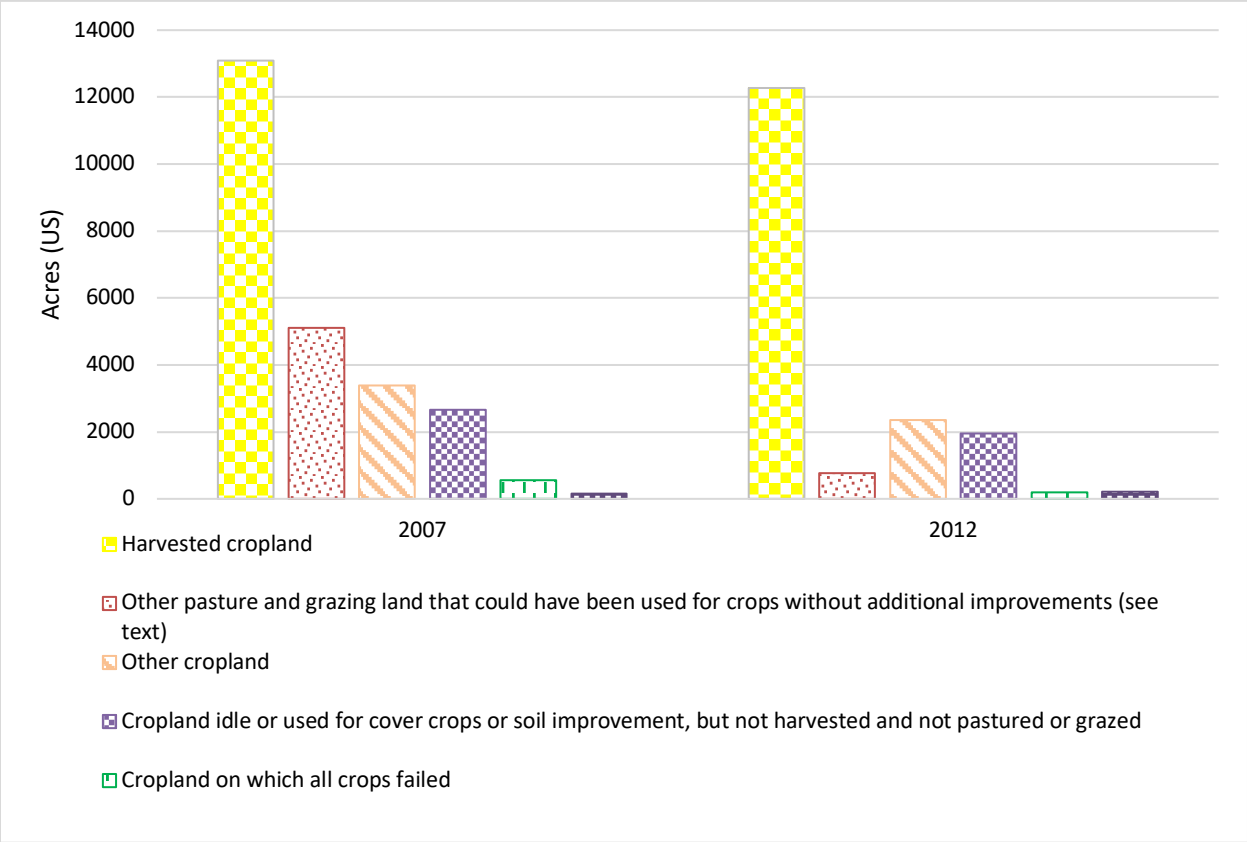


Fig. 8 The total cropland area distribution of Oconee County from 2007 to 2012.

GOOGLE EARTH ENGINE CLASSIFICATION

Land cover can significantly impact water quality, quantity, and biodiversity of an area; therefore, understanding land use and land use changes over time is a critical part of watershed planning. According to the U.S. EPA, land cover and impervious surface coverage such as roads, buildings, parking lots, and turf grass can seriously impact the biotic integrity in the streams.

In this study, land cover classification was determined based on high-resolution imagery for the years 2005, 2009, 2013, and 2015. These years were selected so that the analysis was relevant to the available water quality data, and so that regular intervals of four years could be the unit of measuring change, until the most recent imagery of 2015. Imagery used provided a one-meter resolution for higher accuracy classifications and more precise detection of change. The high-resolution imagery allows identification between the impervious surface and other types of land cover. The area was classified into five different classes:

- forested;
- non-forested (grassland/herbaceous);
- low-medium intensity urban;
- high intensity urban;
- water.

Fig. 9 depicts the results of this land cover change analysis over the selected time periods. GIS (Geographic Information System) methods are provided in Appendix 1.

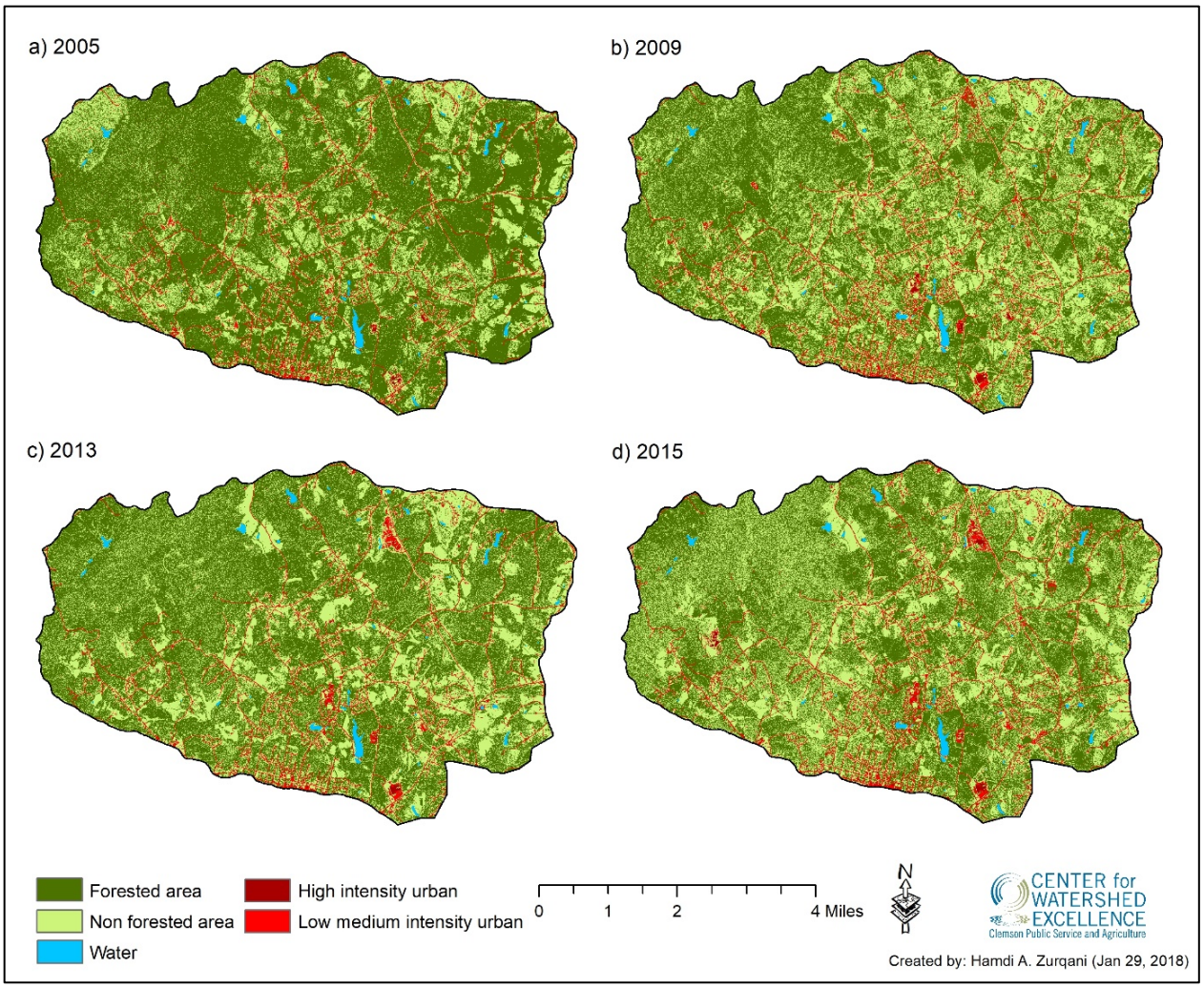


Fig.9 Land cover classification maps for the years: a) 2005, b) 2009, c) 2013, and d) 2015.

Classification results for the four-year intervals and 2015 is summarized in Table 6 and Figure 10. Results indicate that the impervious surface areas (low-medium intensity urban; high intensity urban) continuously increased over time, dominated more so by low-medium intensity urban. Forested areas of the watershed declined overall. The construction boom's halt during the 2009 recession may be the cause for increase in forested areas between 2009 and 2013; when the economy recovered, forest loss then continued from 2013 to 2015.

Table 6. Land use change in the watershed over selected years for analysis.

Land cover classes	Acres (US)			
	2005	2009	2013	2015
High intensity urban	79.46	93.91	108.06	118.68
Low Medium intensity urban	884.75	943.49	10,80.25	1,151.36
Non-forested area	5,254.74	7,630.47	6,974.16	7,954.02
Forested area	12,329.83	9,880.96	10386.11	9,324.97
Water	121.96	121.90	122.15	121.69
Total	18,670.73	18,670.73	18,670.73	18,670.73

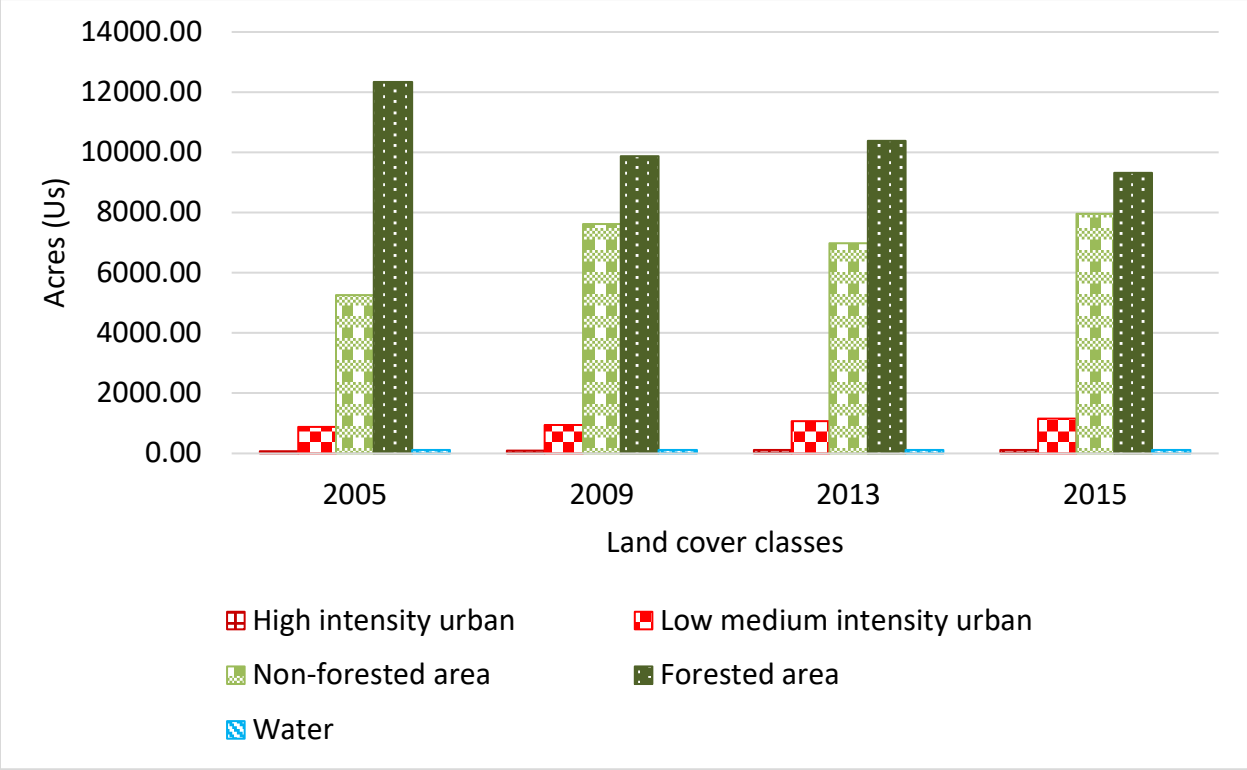


Fig. 10. Land use change depicted in the watershed.

Vegetation cover shows variable change throughout the study period. To more easily view this change, forest conversion to low-medium intensity urban and high intensity urban was grouped as "deforestation." Forest areas that stayed the same, or land cover that was converted to forest, was classified as "forestation." This simple forest gain-forest loss analysis is depicted in Fig. 11. The one-meter resolution of the images used allows a closer analysis of major changes (see Figure). It is evident that forest loss is occurring nearly everywhere in the watershed, most especially in the basin of Cane Creek.

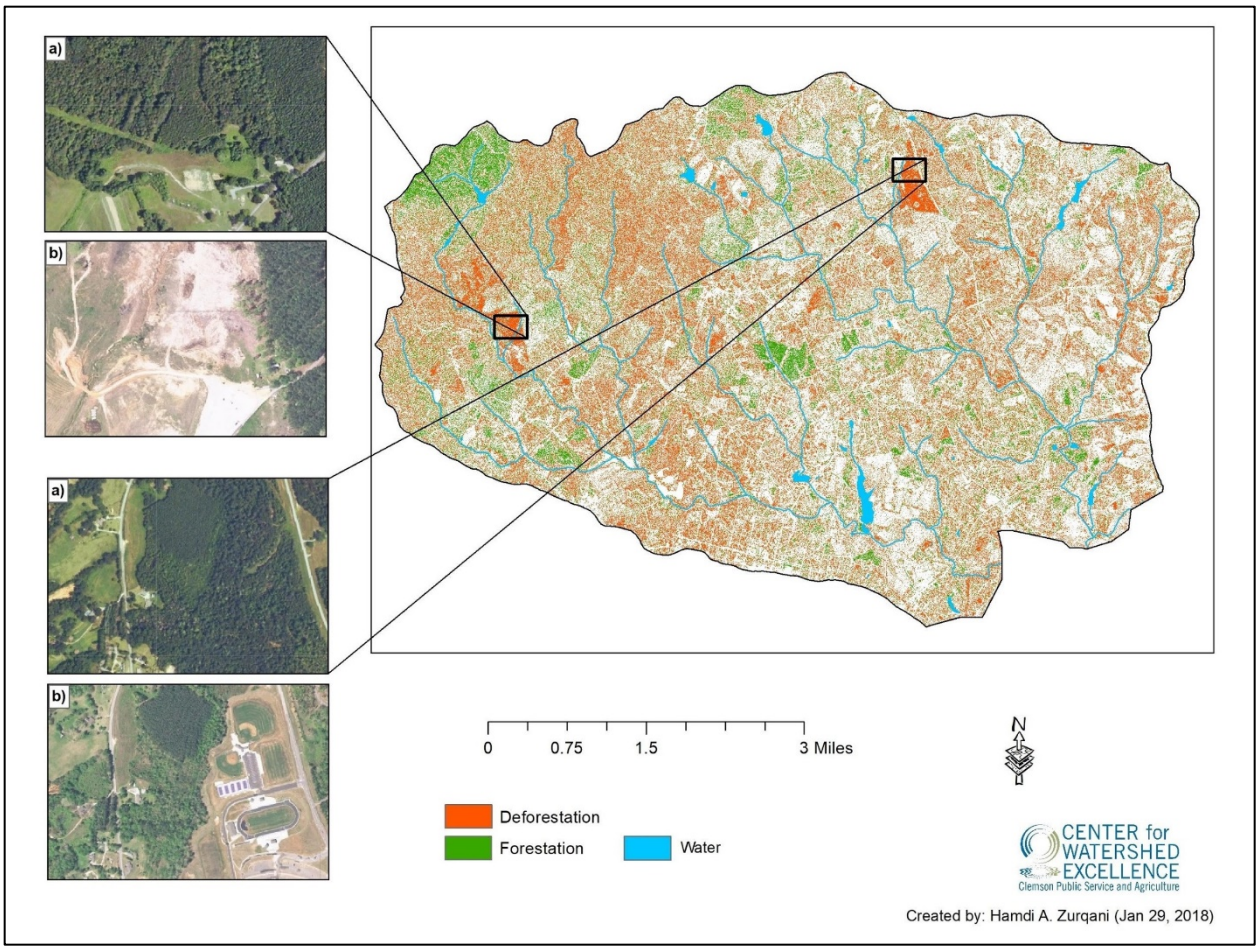


Fig. 11. Forest gain and forest loss comparison from 2005 to 2015 and examples shown.

Analysis of Land Use Change in the Riparian Corridor

Land use change is an especially important consideration when it is occurring adjacent to waterbodies, as water quality mimics its neighboring land use due to runoff and quality can be characterized by the conditions of use. Following the work of the Coastal Riparian Buffers Analysis conducted for the EPA in Connecticut (University of Connecticut NEMO 2007) the analysis of land use change in the riparian corridor was completed at two buffer widths - 150 feet, and 300 feet on each side of open water - over the selected time intervals (Fig. 12 and Fig. 13).

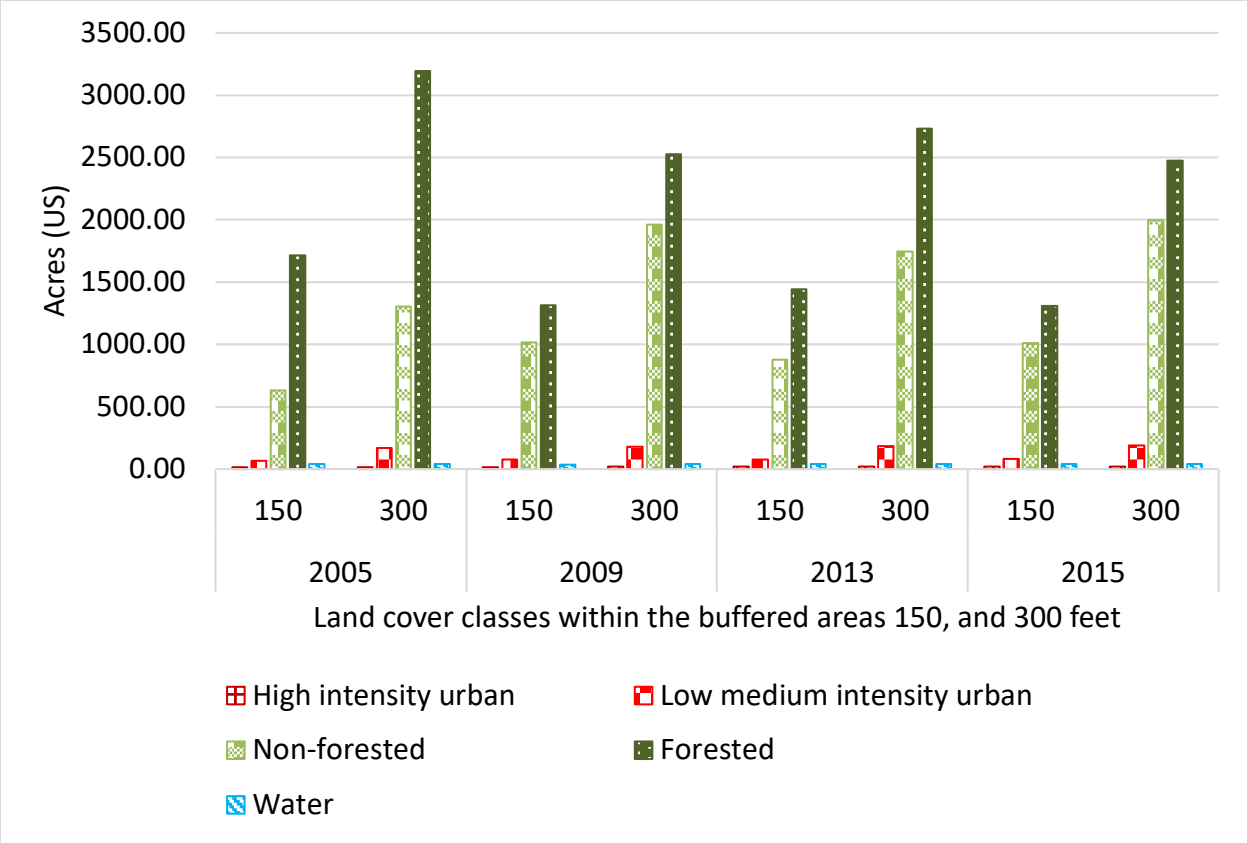


Fig. 12. Land cover classes and change within the buffered areas of 150 and 300 feet.

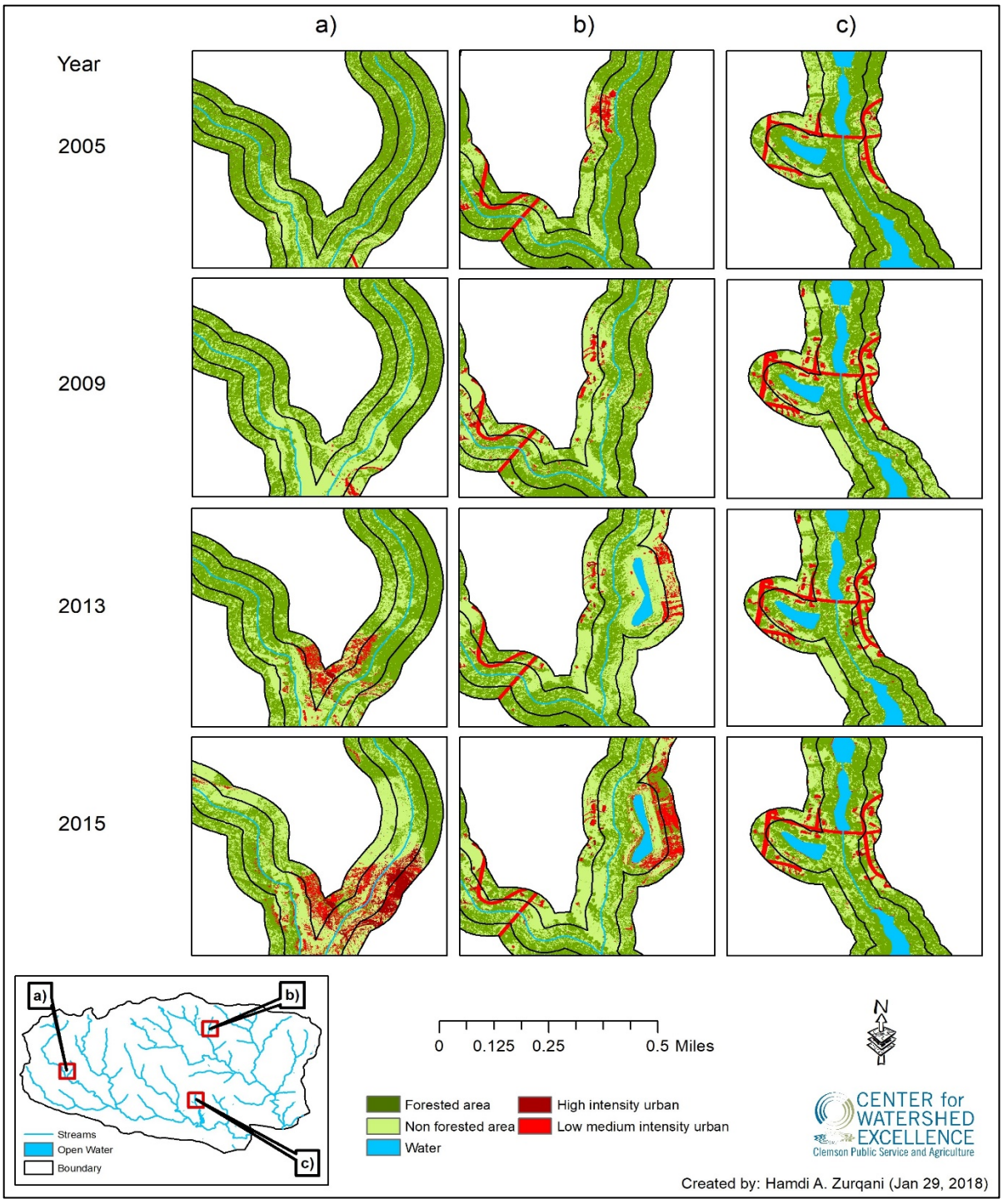


Fig. 13. Land cover classification within the buffer zone areas of 150 feet and 300 feet for each year of analysis.

Analysis of Deforestation in the Riparian Corridor

In conducting this riparian land cover change analysis, it became evident that forest loss was significant and widespread in the riparian corridors of Cane and Little Cane Creeks. This was further verified by field work conducted in the watershed, where loss of trees was obvious.

Therefore, further deforestation analysis was conducted using the high-resolution imagery in Google Earth Engine.

In 2005, forested area covers nearly 70% of the riparian zone at both 150' and 300' from the stream. Within ten years, forested area covers approximately 52% in both extents of the stream corridor. This loss of forested area is highlighted in red in Tables 7 and 8.

Table 7. Land cover of buffered area of 150 feet on each side of open waters.

Land cover classes	Acres (US)			
	2005	2009	2013	2015
High intensity urban	13.07	15.89	18.52	19.52
Low Medium intensity urban	67.04	74.44	78.69	80.07
Non-forested area	628.93	1015.05	879.96	1012.07
Forested area	1712.25	1316.08	1443.87	1309.56
Water	38.27	38.10	38.52	38.34
Total	2459.56	2459.56	2459.56	2459.56

Table 8. Land cover of buffered area of 300 feet on each side of open waters.

Land cover classes	Acres (US)			
	2005	2009	2013	2015
High intensity urban	15.09	18.16	20.23	21.70
Low Medium intensity urban	167.62	177.93	183.33	189.04
Non-forested area	1303.81	1959.97	1747.29	1998.86
Forested area	3195.78	2526.31	2731.06	2472.68
Water	41.69	41.62	42.08	41.71
Total	4723.99	4723.99	4723.99	4723.99

In order to evaluate how widespread this condition is, the project team used the one-meter resolution imagery to select sites along Cane and Little Cane Creeks for further examination of forest loss-forest gain (Fig. 14).

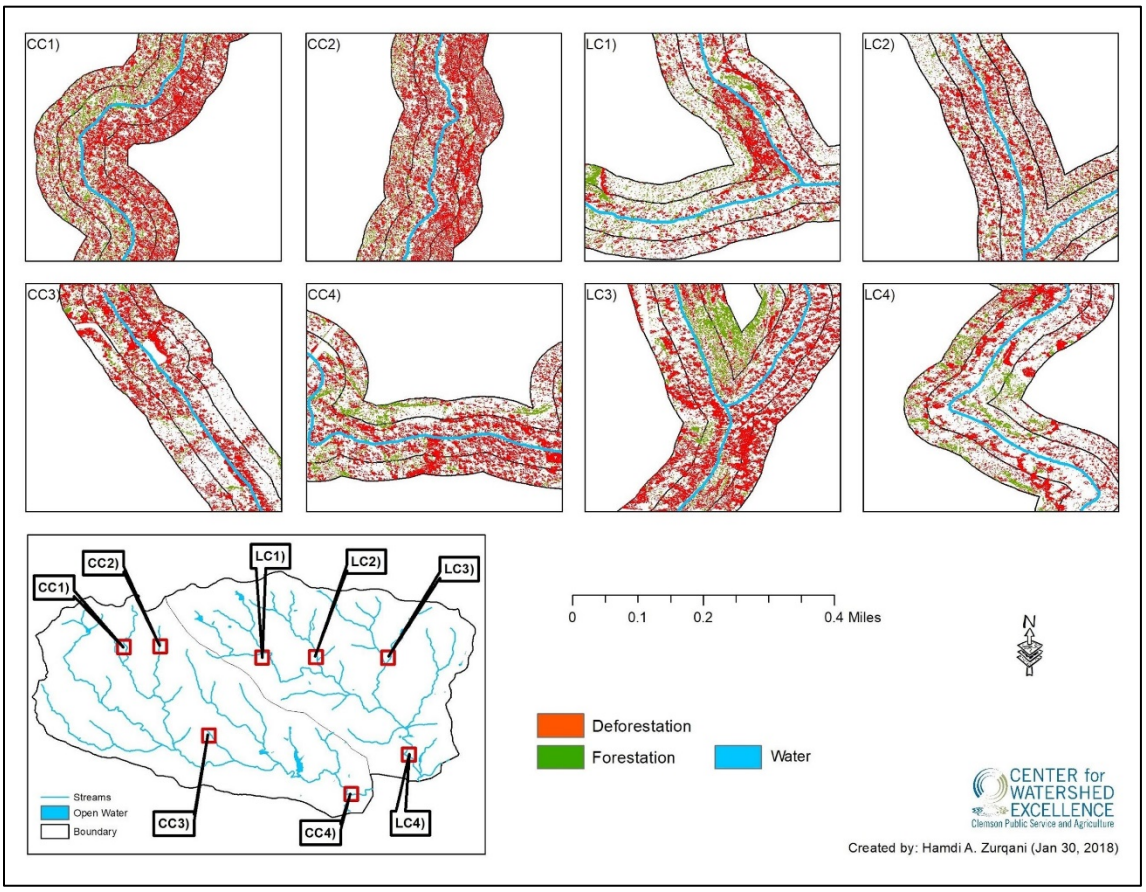


Fig. 14 The land cover/use change detection result between the years a) 2005 and b) 2015.

The result indicates that the impervious surface areas (low-medium intensity urban, high intensity urban) are continuously increasing as well as deforestation and loss of the vegetation over time. Results show that the watershed is losing three times as much forest cover as it is gaining; this result is the same within 150' of stream, where forest loss is three times as much as forest gain from 2005 to 2015 (Table 9, Fig. 15). The GIS method is provided in Appendix A.

Table 9. Forest cover change in the selected buffer widths from 2005 to 2015, in comparison to the watershed overall.

Classes	Overall area		150 feet		300 feet	
	Acres (US)	(%)	Acres (US)	(%)	Acres (US)	(%)
Deforestation	5,400.79	28.93	717.44	29.17	1,332.52	28.21
Forestation	2,093.38	11.21	227.88	9.27	476.34	10.08

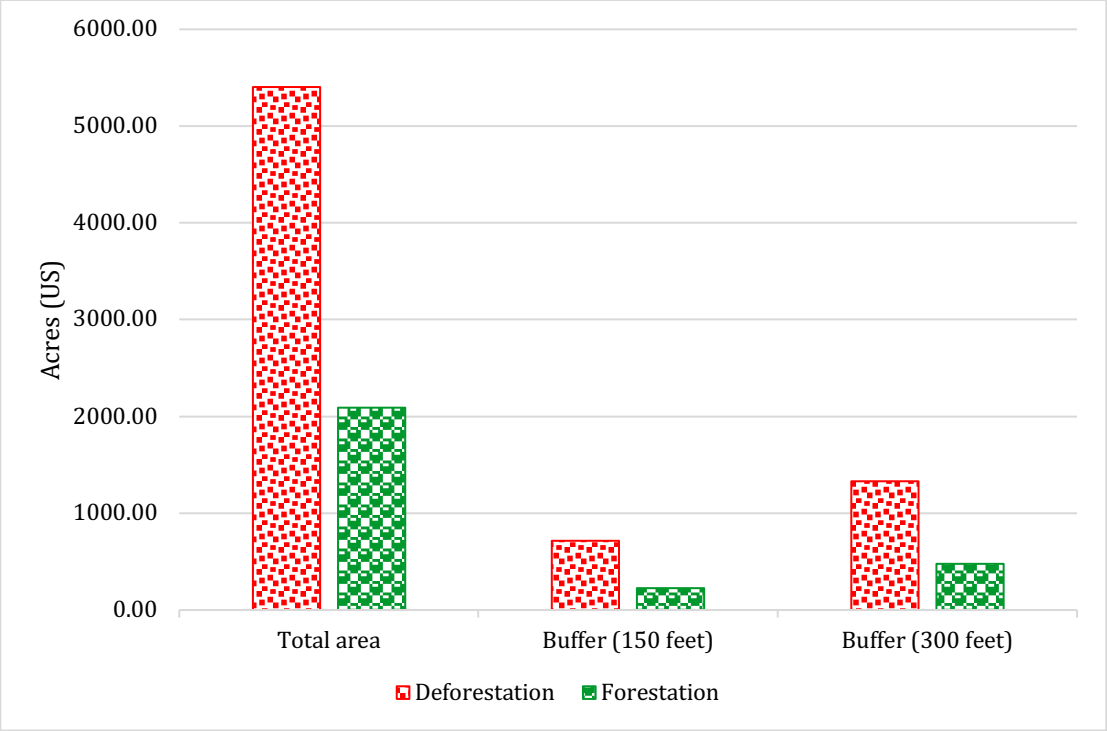


Fig. 15. Total area of deforestation in the watershed and selected buffer widths from 2005 to 2015.

WASTEWATER TREATMENT

SEWER SERVICE

The Oconee Joint Regional Sewer Commission was formed in 1971 in Oconee County and is primarily limited to the City of Walhalla downtown areas and the new Walhalla High School. The City of Seneca, City of Westminster, City of Walhalla, and Town of West Union operate their own collection systems that send wastewater to the Oconee Joint Regional Sewer Authority (OJRSA). The Authority became its own entity in 2007 and is not owned by Oconee County.

The collected wastewater is treated at the Coneross Creek Wastewater Treatment Facility. The treated wastewater (effluent) is discharged into Coneross Creek. Coneross Creek eventually enters Lake Hartwell.

In the South Cove area of Lake Keowee is the City of Seneca drinking water intake and treatment plant. Also, there is an NPDES permitted facility, Intersoll Rand/Torrington Road Groundwater Remediation site. This facility has been issued an industrial wastewater permit and resides in West Union.

Sanitary Sewer Overflows must be reported when they are in excess of 500 gallons. At the writing of this report, OJRSA has very few reported sewer overflows; the single record located is below our monitoring stations for this WBP.

SEPTIC SERVICE

Onsite wastewater treatment systems, OWTS or better known as septic systems, dominate the watershed as the primary means for wastewater treatment.

Septic systems are the mainstay of the region, and new development will often build homes on septic treatment, rather than tie into a wastewater line. There is an example in the area of a new development with individual lot septic systems, and where the sanitary sewer line is approximately one thousand feet away. The choice then to tie in to sewer line or install septic systems with new construction is the decision of the developer or builder.

Phone interviews were conducted with the most active septic system maintenance company in the area to identify common issues, reasons for failures, and geography of concentrated failures, should these exist. According to the owner's experiences over many decades, the most significant factor in failures is maintenance, and this is not limited to any specific geography or development in the watershed.

SEPTIC SYSTEM GEOSPATIAL ANALYSIS AND SOIL SUITABILITY

Septic systems are a potential source of bacteria pollution to groundwater and surface waters when the system is failing. Failure to properly treat wastewaters occurs when the system is improperly sized, not sited appropriately, not maintained, disrupted by roots and heavy items that impact the drainfield (such as driving large vehicles over the adsorption field or placement of an above ground pool), and other factors. Septic system operations are reliant on soil suitability, characterized by the soil layer's ability to infiltrate, the separation between system and high water table, and presence of bedrock.

To better evaluate the potential impact of septic systems, failures, and bacteria pollution to surface waters, a geospatial analysis was conducted. Data sources in this effort include:

- Parcel map of Oconee County.
- Sewer service lines provided by the county with feedback and details provided by the sewer utilities,
- Oconee County 911 Database which includes location of residence and age of residence,
- Natural Resource Conservation Service (NRCS) SSURGO Database.

Several assumptions were made so that a data layer of homes served by septic systems within a 300' of open water could be gained.

1. All lots within 500' of sewer line were labeled as being served by sewer.
2. Lots with more than one home were assigned the age of the oldest residence on the property.
3. All homes within 300' of open water were assumed to have the greatest potential impact on local water quality, if their system was failing.

Age of septic system was characterized as follows:

- 2001-2016
- 1971-2000
- Pre-1970
- No Information.

The results found 197 homes on septic system within 300' of surface waters. Twenty-eight of these have septic systems from this century; 112 and the majority have septic systems built between 1971 and 2000; 34 are dated as 1970 or earlier; no information was available for 23 homes (Fig. 16).

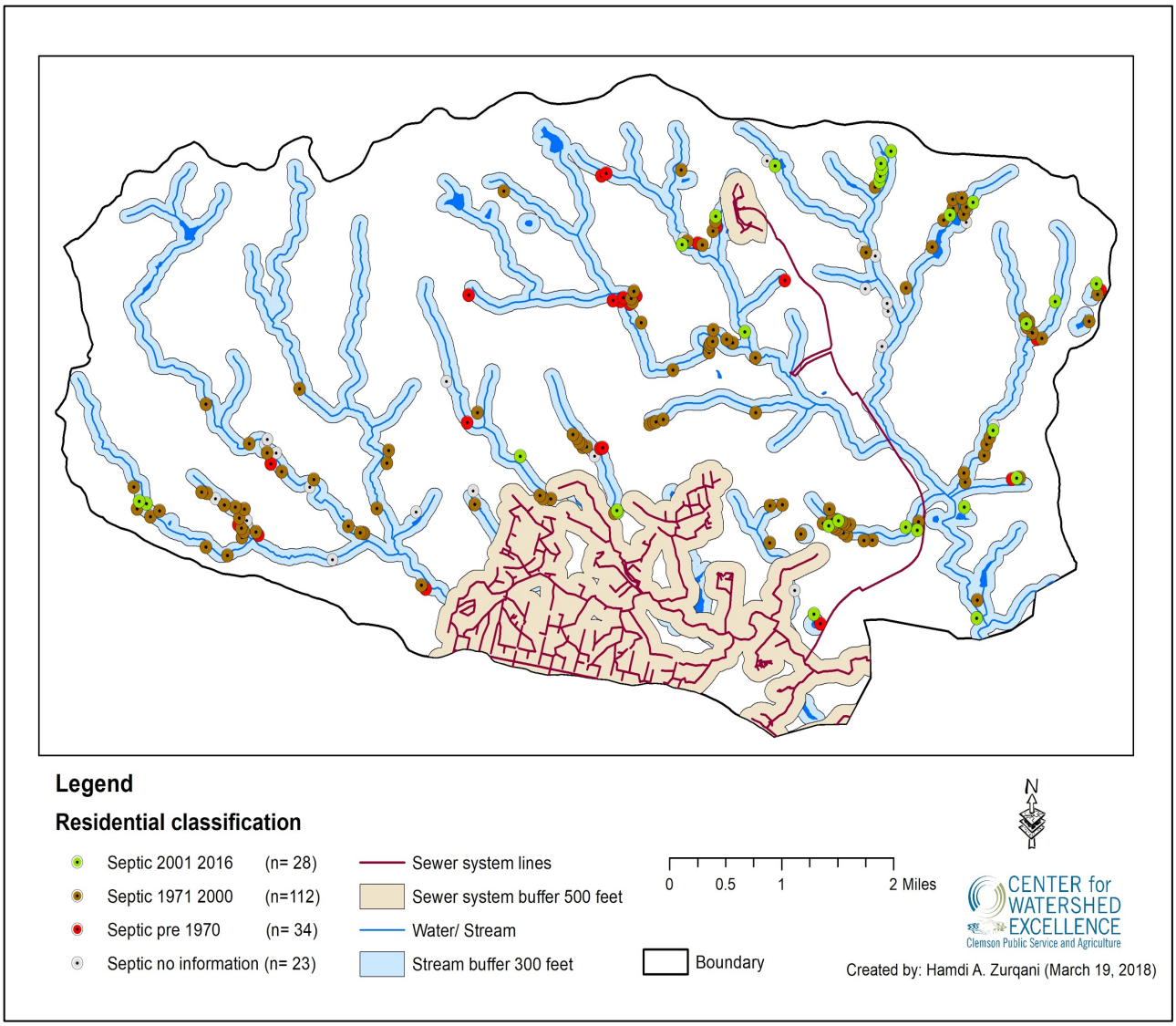


Fig. 16 The zone buffer area of the streams and the sewer system and the location of the residential with the built year.

The septic tank system consists of three components: the septic tank, a distribution device, and an absorption field. After initial treatment in the septic tank, the liquid effluent passes through the distribution device, which ensures that equal quantities of effluent go to each pipe in the absorption field. The absorption field is a subsurface leaching area within the soil that receives the liquid effluent from the distribution device and distributes it over a specified area, where it is allowed to seep into the soil.

Based on the NRCS SSURGO database, the rating classes of septic tank absorption fields are:

- *"Not limited"* - the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected.
- *"Somewhat limited"* - the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected.

- *"Very limited"* - the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected (Fig 17).

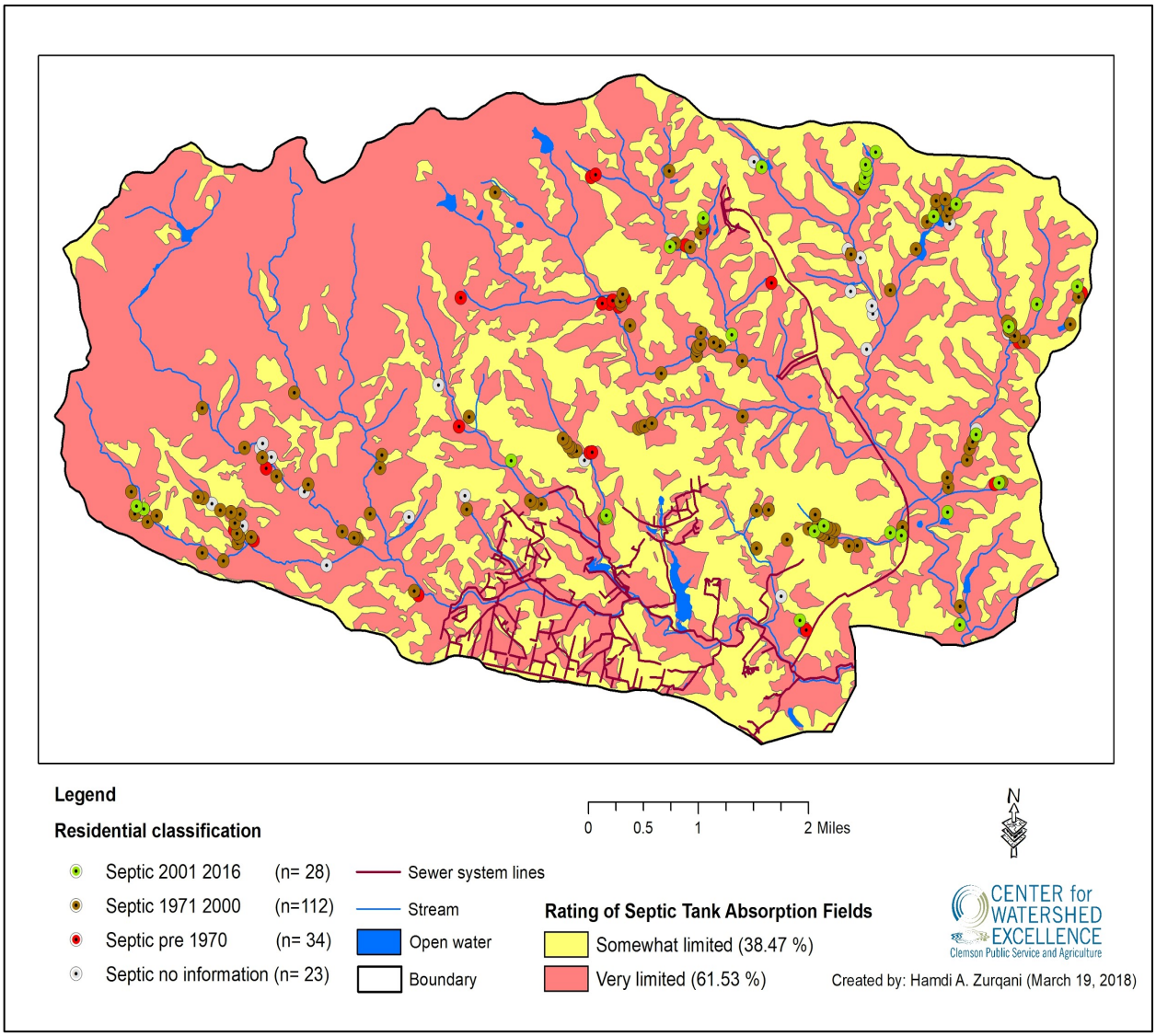


Fig. 17. The distribution area of the rating classes of septic tank absorption fields.

This analysis found that 38% of study area rated as somewhat limited; approximately 62% is considered as a very limited. In this evaluation, only the soil between depths of 24 and 60 inches is evaluated. The ratings were based on the soil properties that affect absorption of the effluent, construction, and maintenance of the system, and public health such as soil texture; stones and boulders; depth to bedrock; water movement; depth to saturated zone; flooding; slope and the maintenance needed (soil texture and elevation maps). Further information can be found in Appendix B.

4.0 ASSESSMENT OF BACTERIA SOURCES

Generally, bacteria pollution in surface waters is classified as either point or nonpoint sources. Point sources include factories, wastewater treatment facilities, and permitted multiple separate storm sewers, as examples. Point source discharges are assigned a NPDES permit by SC DHEC, with the delegated authority of the EPA to enforce the Clean Water Act. Through this permitting process, discharges are monitored for their ability to meet state water quality standards and not further degrade any receiving waterway. As stated earlier, there are no NPDES discharges in the Cane and Little Cane Creek Watershed above Burns Mill Road, the location of the two SC DHEC monitoring stations.

Nonpoint sources of pollution are diffuse in nature, spread from across the landscape, and sometimes, below it. Typically, nonpoint source pollution mirrors the land use of the area. Pathogen pollution is more difficult to address due to its nature. Sources of pathogens, such as wildlife, move across the landscape through forests and wetlands, often unseen. Livestock can be a source of bacteria pollution, better managed through healthy pastures, alternative drinking water sources, fencing livestock out of surface waters, and maintaining a healthy buffer between the farm area and the stream or lake. Underground sources exist in the form of failing septic systems and adsorption fields, as well as failing wastewater pump stations. Current methods for monitoring pathogen pollution do not include information on the source of bacteria, unless further DNA testing is conducted.

PRIORITY 1a. BACTERIA ASSOCIATED WITH WASTEWATER FAILURES

Wastewater lines, owned and operated by the previously mentioned three municipal utilities and one joint authority, do exist in the urban areas of Walhalla, as well as a single trunk line that extends from Walhalla to Walhalla High School. Wastewater lines frequently cross Cane Creek, Little Cane Creek, and its tributaries, as well as parallel sections of river. It has been documented that during very large storm events, there are sections of wastewater line that become partially submerged by high flows in Cane Creek. This poses risks for the river as well as for the infrastructure, which could be damaged by large debris carried by elevated storm flows and experience increased infiltration in the sewer infrastructure.

Illicit discharges occur when a wastewater line is incorrectly tied into a sewer line, either unknowingly or sometimes, purposefully.

Sanitary Sewer Overflows (SSOs) occur when the capacity to carry wastewater is exceeded. Manhole lids are lifted by spilling sewage, or wastewater can escape at junctions in lines. Inflow and infiltration is a leading factor in SSOs. Inflow and infiltration (I & I) is the phrase used to capture the multiple ways that liquids that are not pure wastewater are introduced into the wastewater lines. These introduced, non-wastewater liquids, include gutter downspouts and air conditioning condensate, as well as groundwater seepage into the lines. If the wastewater line is already near capacity, these introduced flows can lead to problems and spills.

I & I is occurring in the City of Walhalla's system. The wastewater line from Highway 183 to Torrington Road, Walhalla, is under siege by too much I & I, maximum capacity flow volumes, hard turns in the pipe, and other issues. This particular stretch of infrastructure has been

documented as a source of overflows to Cane Creek. These occurrences have been noted in the most frequently used public park in the area, Sertoma Field. This public park includes the main sewer line, which parallels and then crosses a tributary to Cane Creek and concrete cinder cones house risers and manholes from the sewer line. Sertoma Field is the most popular and most frequented park in the area, where baseball games, track, disc golf, and other recreational amenities are available to the public, as well as several community festivals such as Walhalla's annual Oktoberfest.

Fig.18. Previously sealed and replacement sewer lines hover just a few feet over unnamed tributary leading to Cane Creek, which runs through Sertoma Field, Walhalla, SC.

PRIORITY 1b. STORMWATER RUNOFF AND THERMAL POLLUTION AT SERTOMA FIELD

Sertoma Field in Walhalla also includes a number of site conditions and inputs that affect the water quality discharge of this area to Cane Creek. Northwest of Sertoma Field, on the other side of Pickens Highway (Highway 183), there exists a lake owned by the community living along Lakeside Drive. The dozen homes with lakefront property typically maintain turf to the lake edge. Resident Canada Geese were observed on nearly every site visit to this area of the watershed. The units are believed to all be served by sewer. The pond has no visible aeration.

The lake has two spillways, then crosses under Highway 183 where it narrows into a tributary depicted in Fig. #. This tributary is nutrient enriched and likely thermally impacted, based on observations. Aquatic vegetation covers more than 50% of the tributary's stream bed for the entire

length and for the majority of the year. The tributary is shaded by a few large trees, but predominantly has turf extending to the edge of the low bank (Fig. 19). Though not observed during the development of this watershed plan, stakeholders have stated that this park and adjacent parking lot floods several times per year. The adjacent parking lot is not curbed and is at a distance between 15 and 30 feet from the tributary for its full length. The opposing side includes utilities, walking path, and turf to the edge of the waterway (Fig. 20).

Fig. 19. Tributary to Cane Creek from neighborhood pond, after is passes under Highway 183 and enters into Sertoma Field.

Fig. 20. Unnamed tributary to Cane Creek is managed with mowed turf to the edge of the waterway, with little shading, and excessive growth of aquatic vegetation.

Across the parking lot, a relatively small neighborhood lies uphill, with an access road perpendicular to the park road (Fig. 21). Stormwater infrastructure has been observed as buried under sediment and covered with debris. There is little evidence of maintenance, and stormwater likely bypasses the pipe to flow over land and asphalt to the unnamed tributary and Cane Creek, which flows along the outer perimeter of the park. Residential stormwater can transport fecal bacteria from domestic and feral animals, trash containers, ruminants, wildlife, and septic system leachate.

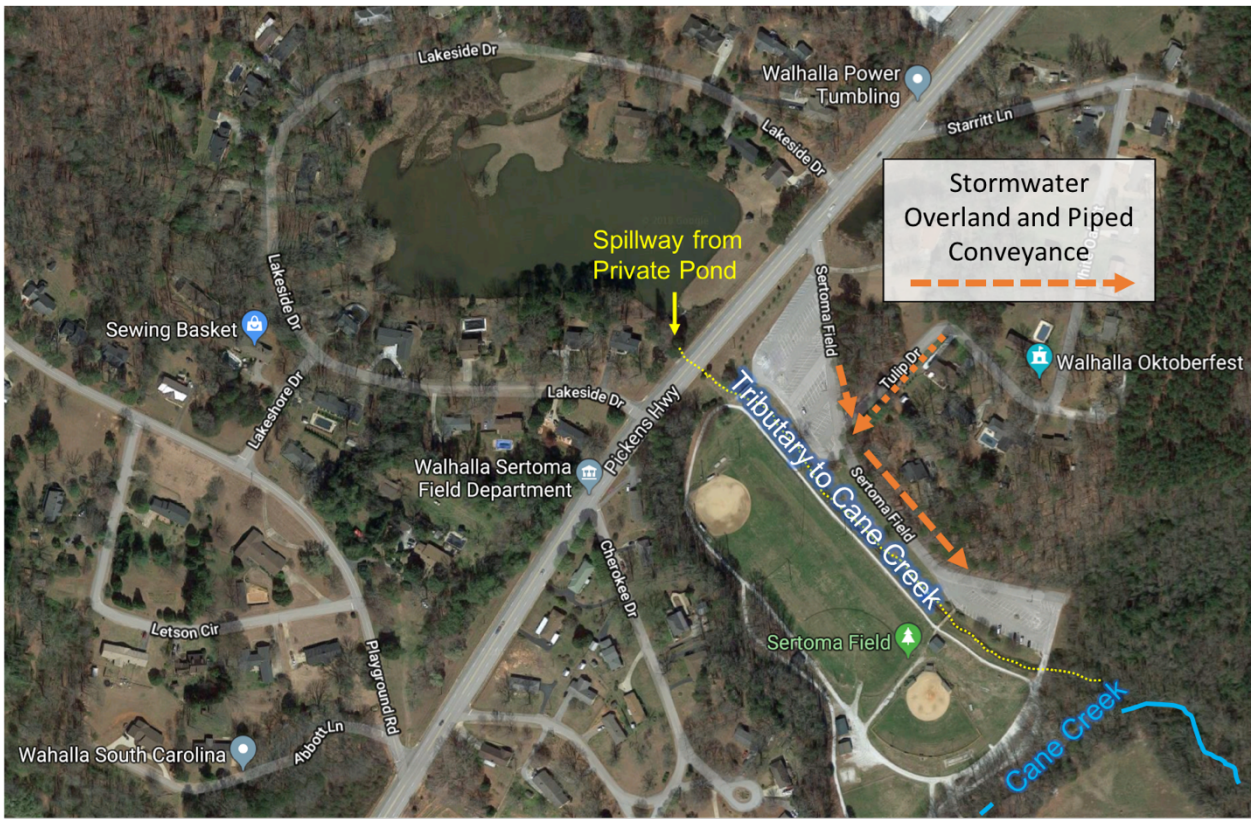


Fig. 21. Sertoma Field and conveyances of runoff and pond input to Cane Creek.

PRIORITY 2. CREEKBED SEDIMENT ACCUMULATION AND DAMMED RIVER FLOWS

Field observations showed widespread loss of large trees in the riparian corridors of Cane and Little Cane Creeks (see Fig. 22). This was further documented in the land use change analysis that revealed 28% loss of trees within 300' of stream between 2005 and 2015. With loss of large trees, comes streambank failure and streambank sediment deposition into the stream. Furthermore, the large downed trees slow stream flow and remove the natural flushing mechanism that occurs naturally during large storm events.

Fig. 22. A corridor of leaning and downed trees in the lower reaches of Cane Creek.

It has been documented that survival rates of E. coli in bottom sediments are greater than that of E. coli suspended in the water column. Researchers propose that this can be attributed to less predation in sediments and better accessibility to nutrients for survival (Kiefer et al. 2012, Schang et al. 2017). Silt concentration in sediment may be an additional factor in improved survival (Haller and Amedegnato 2009). Survival rates of indigenous E. coli in a stream are typically more prolonged that those of wildlife, geese, and bovine according to research done by Kiefer et al. (2012), and the only species of these to increase greater than indigenous E. coli was that from deer manure. While bottom sediments may allow E. coli to survive longer and even populate (Schang et al. 2017), they do not provide for survival indefinitely; therefore, continued introduction of fecal matter or fecal polluted runoff must be present to continue bacteria problems that may be associated with bottom sediments.

In addition, E. coli in sediment has different characteristics than that of E. coli suspended in surface waters, as identified by Liang et al. (2016). This research found that E. coli in sediments had greater hydrophobicity, protein content, and sugar content - factors which may affect the organism's survival rates.

Given the characteristic failing of large trees in the stream corridor, the incurred deposition of sediment due to bank loss, and the accumulation of sediments in the stream bottom, it is believed that this series of events, paired with a regular input of fecal polluted runoff or leachate is a significant cause of the observed bacteria impairment frequency in the surface waters of Cane and Little Cane Creek near their DHEC monitoring stations (see Fig. 23).

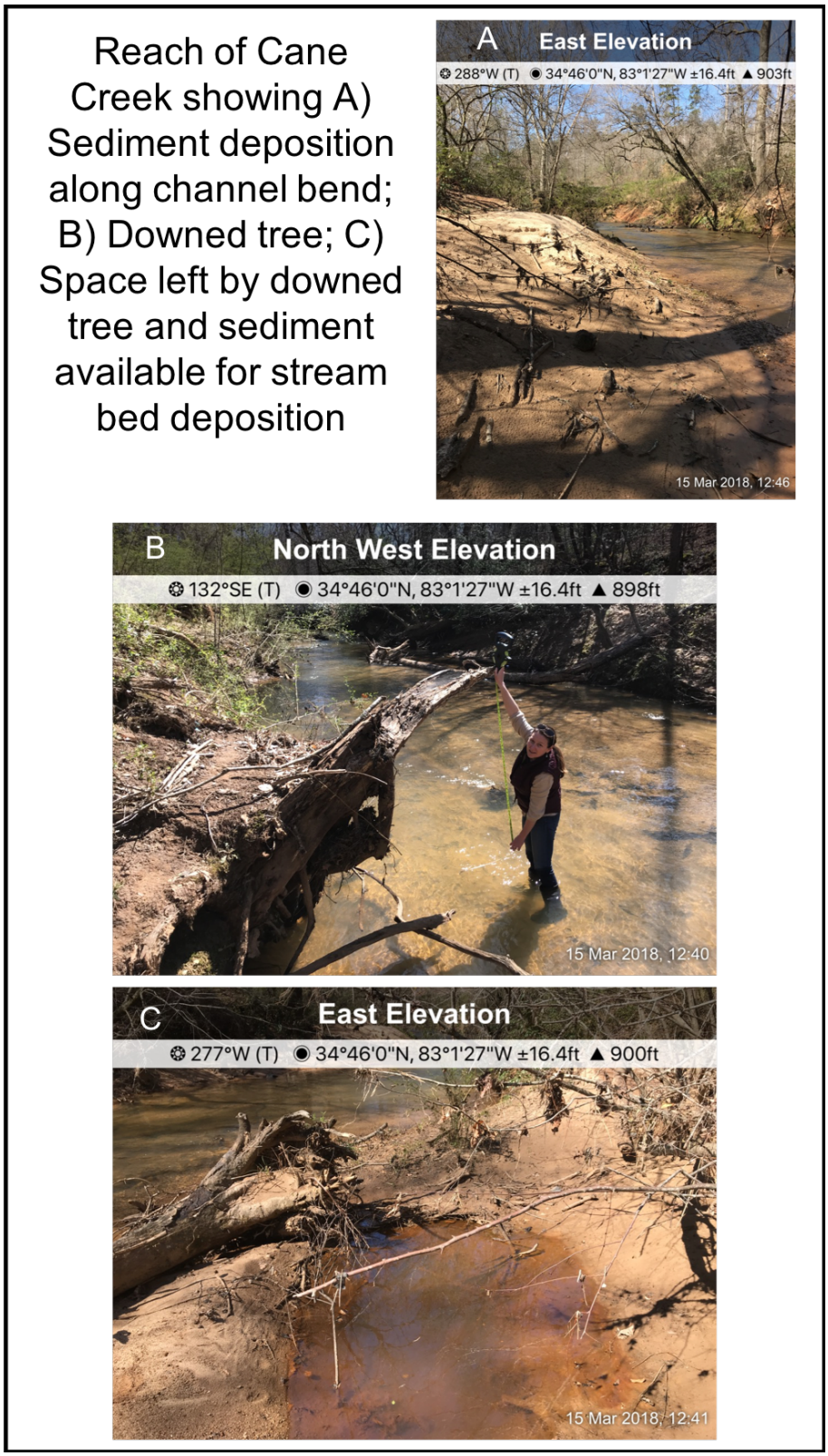


Fig. 23. Pictures of lower Cane Creek displaying the repeated cycle of trees on the cusp of collapsing into the stream, sediment accumulation, trees already have fallen into the stream, and vulnerable sediment for deposition.

Based on fieldwork, it is estimated that there exist approximately 25 downed trees per river mile in the lower reaches of Cane and Little Cane Creeks. It is therefore estimated that there is approximately 222,750 cubic feet of sediment loss to the stream bed in each river mile. To put this in perspective, this is more than 5 acres of land being covered by one foot of sediment. The calculation used to estimate this is shown below; the project team measured the space in the streambank that became void space when a tree had fallen into the stream.

Estimated Sediment Load to Stream = SE 0.5* T

SE is the cubic feet of sediments area/void space that includes (25% pores water and air, 25% trees root, and 50% soil).

0.5 is the constant number indicated that 50% of void space is sediment lost to the stream.

T is the number of trees lost to the stream per river mile.

Estimated Sediment Load = ((9*15*11) + (1*68*24) /2) * 0.5 * 25 =
= 17,820 *0.5* 25
= 222,750 cubic feet/mile

PRIORITY 3. SEPTIC SYSTEM FAILURES

Nearly 62% of the watershed is classified as very limited for septic suitability and 38% somewhat limited for septic suitability, based on a multitude of characteristics related to soil, suitability, bedrock, and saturation recorded in the SSURGO Database. Further, it was identified that the majority of septic systems with close proximity to surface waters of this watershed were installed between 1971 and 2000, making them at a minimum, 18 years old. By grouping the age of septic systems near waterways by mean, a high risk-high priority analysis was conducted (Fig. 24). Further, the microbial source tracking work completed in April 2018 shows highest human detection at N. Laurel Street on the west side of Walhalla and Winstead Road areas that are served by septic systems.

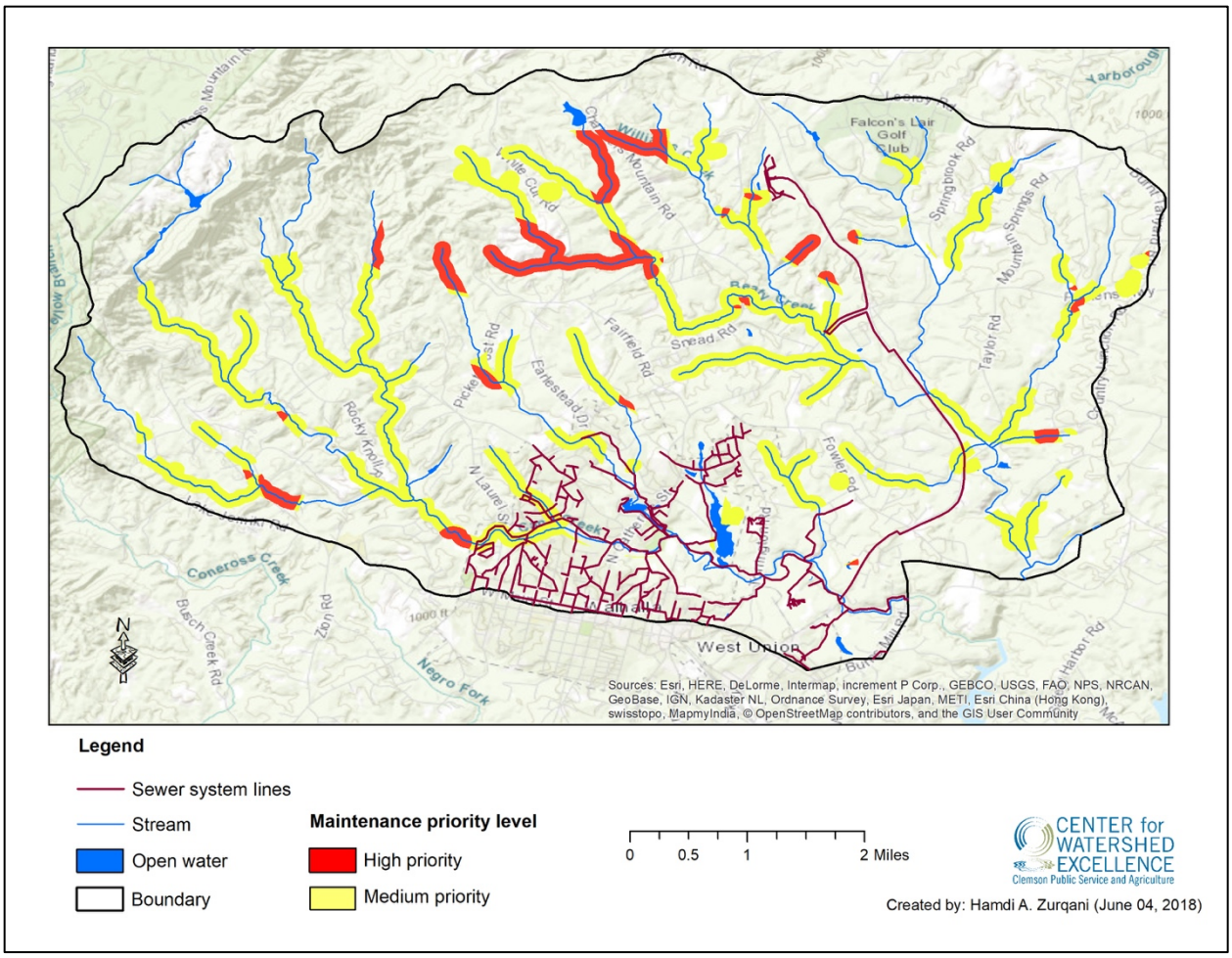


Fig. 24. High risk-high priority septic systems based on mean age and number near waterways.

Septic system replacement or discontinuation and tie-in to sewer system improved bacteria loading to Horse Creek, a watershed of the Savannah River basin. Horse Creek was identified as impaired for bacteria from 1998 through 2006. Tie in to sewer service infrastructure, septic system repairs, and education was implemented by 2009. In 2014, the waterway fully attained its use in regards and no longer was impaired for bacteria contamination (US EPA, 2016).

PRIORITY 4. CATCH BASIN ANNUAL MAINTENANCE

Catch basins are chambers, usually built into the curb line, and which receive surface runoff and funnel the runoff to the stormwater conveyance system. They are typically designed to trap a certain amount of sediment before the volume of stormwater enters the pipe network. Catch basin maintenance includes vacuuming out the accumulated debris approximately one time per year, or more frequently as needed. In this way, the catch basin can continue to effectively trap more sediment and prevent its discharge to receiving waters. In addition, catch basin maintenance removes decaying debris and highly polluted water that could draw oxygen from receiving waters (US EPA 1999).

It is especially important that catch basins can perform sediment trapping during the first flush of each storm. Street surface runoff in an urban area is highly polluted, with researchers finding total coliform counts of $4000x10^{10}$ organisms per hour of storm and 560,000 pounds per hour of storm. In addition, loading of heavy metals and high biological oxygen demand (BOD) are also associated with stormwater runoff in urban areas (Sartor and Boyd 1972).

The catch basins within the Cane Creek Watershed are predominantly in Walhalla and all are owned by the SC Department of Transportation (SC DOT). The city currently does not have capacity to vacuum or maintain the interior of these chambers, nor the ownership to do so. It would be an improvement to the quality of receiving waters for annual maintenance to occur, or a schedule developed suitable for the needs of downtown.

Fig. 25. Catch basin with landscape and natural debris in the basin.

PRIORITY 5. FATS, OILS, AND GREASE AND FLUSHABLE WIPE ISSUES IN SEWER SERVICE LINES

Fats, oils, and grease, also known as FOGs, are an especially nasty cause of failures in wastewater conveyance. Sewer lines are sized to handle typical estimated discharge of waste fluids to a wastewater treatment plant. When FOGs are introduced to the system, the substances cool in the pipes, and accumulate along the walls of the sewer line, slowly decreasing the diameter available for conveyance of waste. Over time, this can lead to total blockage of pipes, back-ups into basements and buildings, sewer spills, and overflowing manholes. It is stated that most sewer line failures can be traced back to FOGs (City of Red Wing 2018). Furthermore, FOGs leave greasy accumulations along settling basins, screens, pipes, and other units of the wastewater treatment plant, causing issues during the wastewater treatment process.

In addition, “flushable” wipes have become widespread issues in the realm of wastewater treatment. “Flushable” wipes refer to pre-moistened, woven, multi-layer towelettes used for

hygienic purposes. The patent states that the design of flushable wipes includes water dispersibility characteristics so that when flushed, it will not clog plumbing and sewage treatment in comparison to non-woven wipes (Kimberly Clark Worldwide Inc 1996).

FOGs and flushable wipes have been documented as causing significant issues in the sewer system of the Oconee Joint Regional Sewer Authority, within Cane Creek. Responses to failures relating to flushable wipes increased from 20 to nearly 70 in just one year (Fig. 26). The results of these failures have included back-ups into residences and buildings, overflowing manholes, and sewer spills. These occurrences are a source of fecal pollution to the watershed.

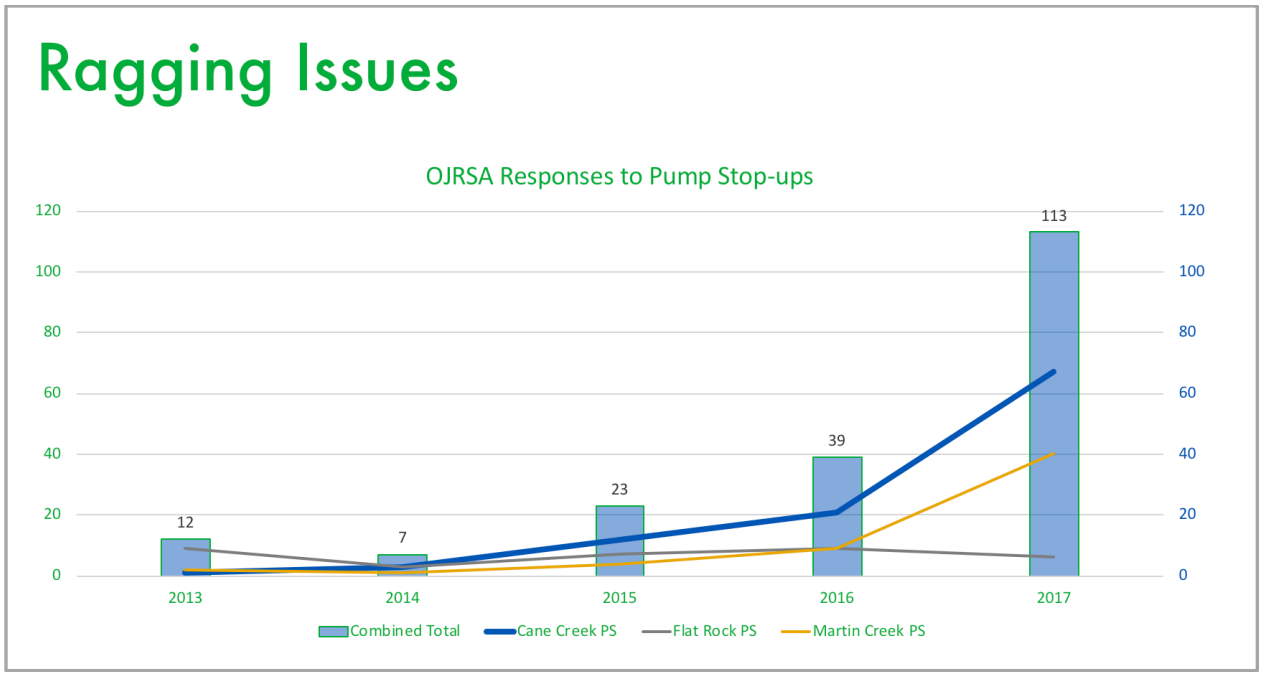


Fig.26. Increasing number of responses to "ragging issues" related to flushable wipes, with Cane Creek (shown in thick blue line) having the greatest number of failures each year recorded.

Cities across the country are dealing with these same issues. Pottstown, Pennsylvania reported in March 2018 that flushable wipes were costing their wastewater facility $100,000 to $120,000 in repairs, maintenance, and response. Upgrades to the plant to address this issue will cost the facility $500,000 (Perez 2018).

Areas of highest frequency of maintenance needs caused by FOGs and flushable wipes were identified with the assistance of the utilities of the watershed. These are depicted in Fig. 27 and are all multi-family housing units. Though not each neighborhood exists within the watershed boundary, the sewer line serves the watershed, and failures within these sewer service areas would affect the watershed. Failures associated with New Walhalla Gardens could be related to bacteria issues measured at Cane Creek at North Laurel Street and North Poplar Street monitoring locations. Standpoint Vista Apartments, Autumnwood Village, and Country Ridge Apartments could lead to failures in the system that would be detectable at the monitoring station behind Sertoma Field. Highland Glen failures could be detected by monitoring at SV-342 Cane Creek at Burns Mill Road.

Fig. 27. Highest occurrences of maintenance calls due to grease and flushable wipes impacting sewer infrastructure.

PRIORITY 6. WILD PIG POPULATION

Not far outside the boundary of the watershed, in the spring of 2018, 21 wild pigs were trapped by one farm in Oconee County. Wild pigs are an invasive species, a feral hybrid of introduced European boars and escaped domesticated swine. Wild boars and feral hogs interbreed freely. It is estimated that 130,000 to 140,000 wild pigs live in South Carolina, a 30% population increase over one decade. The impact of their population explosion was evaluated by Clemson University faculty member Dr. Shari Rodriquez in 2016. It was found that feral hogs cost the state $115 million per year in damages. This is roughly $44 million in damage to crops, and $71 million in non-crop losses and damage to streams, ponds, wetlands, unpaved road, wildlife food plots, and more (Moore 2016).

In interviewing stakeholders of the watershed, it was noted that wild pigs have been prevalent mostly in the Little Cane Creek Watershed, though they can travel through wetland and stream corridors throughout the watershed. Their large population and use of stream and wetland corridors for travel and habitat make them a considerable source of fecal pollution to surface waters. Beyond damages to crops and native plants and animals, wild pigs are hosts to many diseases and viruses that may transit to livestock, and can be transmitted to humans and dogs, as well (NWCTP 2018).

Microbial source tracking completed in April 2018 showed detection of swine at all stations except for Little Cane Creek at Country Junction. Cumulatively, swine had the highest concentration of all detected bacteria across the watershed, two-fold over human concentration.

ADDITIONAL POTENTIAL SOURCES OF BACTERIA TO WATERWAYS

The following are observations made in the watershed where improvements are needed, or further investigation is necessary, to conclude if the property is contributing to bacteria impairments.

Buffers along pastures and paddocks

MST samples widely detected fecal matter from cows. Based on field work in 2017-2018, only one farm was identified as having cattle crossing through a stream. In this case, there were little options for this passage, as it is the route for cows to get between pasture and barn without crossing a road (instead, walking Little Cane Creek as it passes below the road).

In the watershed, there exists pastures and paddocks for both horses and cows with minimal buffer between fence and top of stream bank. In some cases, in the Grant Drive and Winstead Road area of Walhalla for example, this separation is as little as 10 feet.

Diverse native buffers of shrubs and trees provide the greatest removal rates for stormwater runoff and also protect stream banks. Buffer widths of 30 feet are recommended as a minimum width to capture sediment. 100 foot wide buffers provide temperature regulation, nutrient removal, and sediment capture. Buffer widths are not the only consideration, as a diverse amount of vegetation and ability to maintain linear spreading of runoff are also crucial factors in performance (Environmental Law Institute 2003).

Identification of current wastewater service and need for improvement

There were insufficient and inconclusive evaluations of two residential areas of Walhalla where existence and type of sewer service was in question. Information was sought from the city as well as from SC DHEC, but at the time of the writing of this plan, there have been no final conclusions.

1. Springbrook Road, Walhalla, SC – This property and its buildings are reportedly occupied year-round, is a small lot, and on a steep grade directly above Little Cane Creek. The Parcel ID is 121-00-02-032 according to Oconee County tax records. The area is not serviced by sewer, and local authorities are unaware if the property has a permit for a septic system.
2. Thunder Road, Walhalla, SC – This property is at the far west reaches of Walhalla, where water is provided, but no sewer service. Based on inquiries, the property has been the site of illegal discharge of wastewater directly to Cane Creek. Whether a septic system exists, is functioning, or other means of wastewater storage (for example, a cess pool) are employed is unclear. The property is adjacent to Cane Creek.

Further investigation from local and state regulatory authorities is needed to conclude if these locations are a source of bacteria to nearby waterways.

Stormwater ditches and high-volume runoff

There exist areas of the watershed where stormwater volume exceeds the handling capacity of roadside ditches, especially in the steeper grades of the watershed along Burns Mill Road in Cane

Creek. This subwatershed should be prioritized for lot scale retrofits, green infrastructure, and re-evaluation of the street side conveyance. The area most notably impacted is Burns Mill Road and Walter Scott Lane, where curves in the river are channelized within the landscape and roadways. The objective of retrofits in this area would be capture and slow stormwater runoff, allow sediment to settle, decrease erosive forces, and infiltrate a greater volume of runoff from our most frequent storms (95th percentile). BMPs recommended for use in this subwatershed retrofit include:

- Rainwater harvesting through rain barrels and cisterns;
- Bioswales;
- Rain gardens;
- Stormwater ditches with check dams;
- Overall, disconnection of impervious areas.

Other areas of the watershed that lie within neighborhoods should pursue implementation of the above BMPs and education about stormwater management as the area continues to grow and develop.

5.0 WATERSHED RESTORATION STRATEGIES

Consistent with the priority sources of bacteria identified in the watershed, the following list the strategies for their mitigation and watershed restoration. Factors considered in the development of these strategies included proximity to water quality monitoring stations, feasibility, visibility, opportunities for public involvement, anticipated benefits to water quality and stream ecosystem, and cost.

Each strategy includes an approximate cost and timeline. These are rough estimates, given that the fine details, designs, and plans for each project are not fully developed. In addition, the timing of a project can impact its costs, as the watershed, land use, government staff and officials, and other events change the course of the watershed and its own evolution. However, the best attempt has been made within this project's timeframe to gather local estimates on costs of each strategy.

Information on each strategy is summarized in Tables 11, 12, and 13 at the end of this section.

STRATEGY 1. SEWER LINE REPAIR, RESTORATION, AND INFRASTRUCTURE PROJECT AT SERTOMA PARK

Timeline: Develop a Task Force in 2019; Complete project by 2025
Approximate Cost: Total $725,000 includes dredging ($60,000), sewer repairs ($175,000), stormwater infrastructure retrofits/removal, as well as engineering ($70,000); depaving and porous asphalt design and installation ($400,000); vegetated buffer and educational signage ($20,000)
Potential Funding Sources: SC DHEC 319(h), State Revolving Fund, USDA Water and Waste Disposal Loan and Grant (newly announced funds for rural community water and sewer improvements), EPA Five Star Challenge Grant

Due to the number of partners and the vastness of the projects proposed at Sertoma Field, several phases are suggested for implementation. It is critical to consider the order of the construction and rehabilitation efforts to best capitalize on the timing of projects, cost-savings accumulated by working in tandem, and to consider the protection and performance of practices already in place.

Phase 1 should seek to upgrade the sewer line between Highway 183 to Torrington Road in Walhalla. While this sewer line is being replaced or repaired, the 2.2 acre asphalt parking area of Sertoma Field along Highway 183 should be removed to the maximum extent allowable, given soil and water table conditions. It is suggested that this parking area be replaced with porous asphalt as much as possible and redesigned in such a way that the parking area is more than 30 feet from open waters at all times. The minimum 30 feet separation between parking area and stream will allow the minimal remaining volume of stormwater runoff to be slowed and effectively filtered for sediment. Additional green infrastructure improvements should be considered, such as curb bumpers rather than continuous curb. Due to the current demand for parking spaces at this location, efforts should be taken to minimize loss of parking spaces.

While the porous asphalt is being installed, stormwater infrastructure should be eliminated along the parking lot and collected from Tulip Drive, which is perpendicular to the park road. With the porous asphalt in place, this stormwater will be more effectively treated than traditional pipe collection (Fig. 28).

Fig. 28. This image from Aiken, SC demonstrates the ability of a porous asphalt road (right) to quickly infiltrate rain water, in comparison to standard asphalt road (left) showing puddles (Source: Calvin Sawyer, Ph.D., Clemson University).

Once this infrastructure work is complete, Phase 2 will commence to address bacteria sources upstream of this tributary at the pond on the north side of Highway 183. It is recommended that this pond be dredged to its original design depth. The pond was originally created in the 1960's and has never been dredged. Furthermore, residents of this privately-owned pond should be involved in programming and/or outreach related to "Carolina Yards" and stewardship of water resources by those living adjacent to a stream or pond. Incorporated into this homeowner outreach should include addressing resident Canada Geese. Effective signage is available from Clemson Extension's Carolina Clear program, as well as fact sheets, and information that can be provided to residents regarding a three-prong approach to encouraging these geese to not settle as residents of this pond and watershed.

Fig. 29. Signage developed by Clemson Extension Carolina Clear to discourage feeding of Canada Geese, for water quality and for the health of the animal.

Phase 3 will conclude this Sertoma Field project with the installation of a pollinator-friendly native plant buffer along the tributary to Cane Creek. This very focal park for the City of Walhalla and upstate residents includes many opportunities to demonstrate the use of a native plant buffer to protect waterways, while reducing thermal impact on the stream. This can develop as a corridor for pollinators with involvement of the community, Clemson Extension Service, and area schools, building on local programs already at work in the community. Native plant buffers with grass-shrub mix of only 8 meters has shown significant nutrient and sediment removal (Mankin et al. 2007). Therefore, this buffer should be a functioning space, for both water quality and public use, comprised of a mix of shrubs, perennials, and grasses, with a mulch walking path, connecting spaces for picnic areas or picnic tables, depending on budget allowances. Educational signage should be installed to promote practices installed at the park and buy-in from the community. These should include:

- Information on native plants for home landscaping and freshwater shorelines;
- Pollinator-friendly plantings with interactive "can you spot me" verbiage;
- Watershed "you are here" sign that informs the reader that everyone lives in a watershed with information on the Cane and Little Cane Creek Watershed;
- Information on stormwater and best management practices at the park, most especially, porous asphalt.
- Geese signage deterring feeding of geese, as this is also ongoing at the park.

STRATEGY 2A. NATURALIZING FLOWS AND REMOVAL OF LARGE TREE DEBRIS

Timeline: Apply in 2019; Complete project by 2020
Approximate Cost: $6,000
Potential Funding Sources: SC DHEC 319(h)

There are approximately 25 downed whole trees per river mile in the lower reaches of Cane and Little Cane Creeks as they approach Burns Mill Road. By cutting these trees into large logs of several feet each, the river can function more naturally, with less sediment accumulation in the bottom of the stream bed and along the banks. The logs once cut are not to be removed, as these can provide important substrate, cover, and habitat for the fish and macroinvertebrates living in the creeks, while at the same time restoring the natural flushing potential of the system. Allowing that sediment to flush out and disperse is believed to be a strategy to mitigate the regular high counts of E. coli seen across the watershed.

STRATEGY 2B. RIPARIAN REFORESTATION PROGRAM

Timeline: Apply in 2019; Complete project by 2022
Approximate Cost: $15,000
Potential Funding Sources: SC DHEC 319(h), Bring Back the Natives, USDA Water and Waste Disposal Loan and Grant (newly announced funds for rural community water and sewer improvements)

As shown previously, the loss of trees and canopy cover within the 300' buffer of the stream corridors is extensive everywhere in the watershed. As previously illustrated, the cycle of tree loss and sediment deposition includes bank failure, decreased access of the river to its floodplain, and sediment loss to the waterways. It is well documented that survival rates of E. coli in bottom sediments are greater than that of E. coli suspended in the water column. Loss of trees also presents opportunities for invasive species to dominate an area before the tree can grow back, affecting biodiversity, stream channel condition, habitat, and more.

To mitigate this continued and worsening cycle threatening stream and habitat conditions, the suggested strategy is to work with landowners to replant the stream corridor. The trees should be provided to the landowner and planted for them, if possible. In some cases, this may require the application of pesticides, hand-pulling, and removal of invasive species to improve the chances of the tree's survival. Tree options should be limited to those readily available at low cost, native to the area, deer-resistant, and pollinator-friendly.

NRCS in Vermont recommends a three-zone system for reforesting a riparian buffer for water quality and habitat protection. This strategy will follow their recommendations, implementing Zone 1 and Zone 2 buffers. Zone 1 is the area most frequently inundated at the top of the bank and extends to meet its objective of providing shade and detritus for macroinvertebrates, supporting the base of the river's food chain. Zone 2 extends landward for a minimum of 35 feet from the end of Zone 1 with the objective of slowing and filtering runoff. The combined Zone 1 and 2 should not be less than 50 feet and is recommended to extend up to 80 feet where possible (VT NRCS No Date). Since the primary goal is to restore tree density in the floodplain and along the stream, the project team recommends prioritizing a tree forested buffer for implementation, while encouraging landowners to plant native shrubs natural to the area. The density for both is provided in Fig. 30.

Plant Types/ Community	Plants per Acre	Plant-to-Plant Spacing (Feet)
Shrub Community – shrub dominated, mostly shrubs	450 to 300	10 to 12
Forest Community – tree dominated, mix of trees and shrubs	300 to 200	12 to 15

Fig. 30. Planting density and spacing for best restored floodplain establishment.

Information should be provided to the landowner regarding care and maintenance of the trees they have been provided. Accompanying information should include additional steps they may want to take to maintain a healthy riparian buffer, additional plants and shrubs to incorporate into the Zone 2 and beyond to turf, and the important role they play as a stream side landowner.

The project's success will be measured after two growing seasons, and the goal is for 75% survival. Every effort should be made to establish this survival rate and seek additional funds for replanting where necessary. This project can have immediate replication in other watersheds of Lake Keowee and in Oconee County, with lessons learned on best trees for floodplain restoration.

Long-term, it is believed that addressing bank loss is a significant strategy to sustain waters fit for recreation long after this plan has been developed. A riparian corridor is made more biodiverse from the natural flushing of flood waters across the floodplain. During flood events, seeds are deposited, soil scarified, nutrients deposited, and accelerated biogeochemical processes in soils (Zhang and Mitsch 2007). The process of downed trees and streambank failure leads to less access for the stream to spread across the floodplain during flooding events. This cycle can long-term impair the ecosystem's ability to establish a healthy, diverse, and native population of trees and shrubs.

STRATEGY 3. SEPTIC SYSTEM MAINTENANCE AND REPLACEMENT PROGRAM

Timeline: Apply in 2019; Complete project by 2021
Approximate Cost: Phase 1 ($20,000); Phase 2 estimate to be developed based on Phase 1 findings
Potential Funding Sources: SC DHEC, State Revolving Fund

It is suggested that this proposed implementation project should be carried out in two phases. Phase 1 will include offering free septic system inspections and pump-outs in priority areas of the watershed (Fig. 31).

Task 1. Procure a single contractor that will conduct this work in partnership with a project team.

Task 2. The program and its opportunities should be announced to residents in advance by way of formal communication mailed to each residence, as well as a news article regarding septic system maintenance and their impact to local waterways.

Task 3. The contractor shall begin contacting individual residences in priority areas of the watershed. At each property, the inspector should complete a survey of each household and condition of the septic system. Information to be identified includes the following:

- What is the condition of the septic system?
- What is the condition of the drain field?
- Was the septic system properly sited?
- Is the overall system the appropriate size for the household and use?
- What are key issues leading to any observed maintenance problems or failures?
- Should the septic system be replaced?

Photos of issues at the site should be collected to be used in educational purposes for the benefit of the region.

The selected inspector will also provide educational materials to the homeowner, to include a septic system file folder with maintenance tracking information and best practices for use; magnets to remind the household of what to not flush; magnets to remind the household about grease handling; other materials suggested by FOLKS.

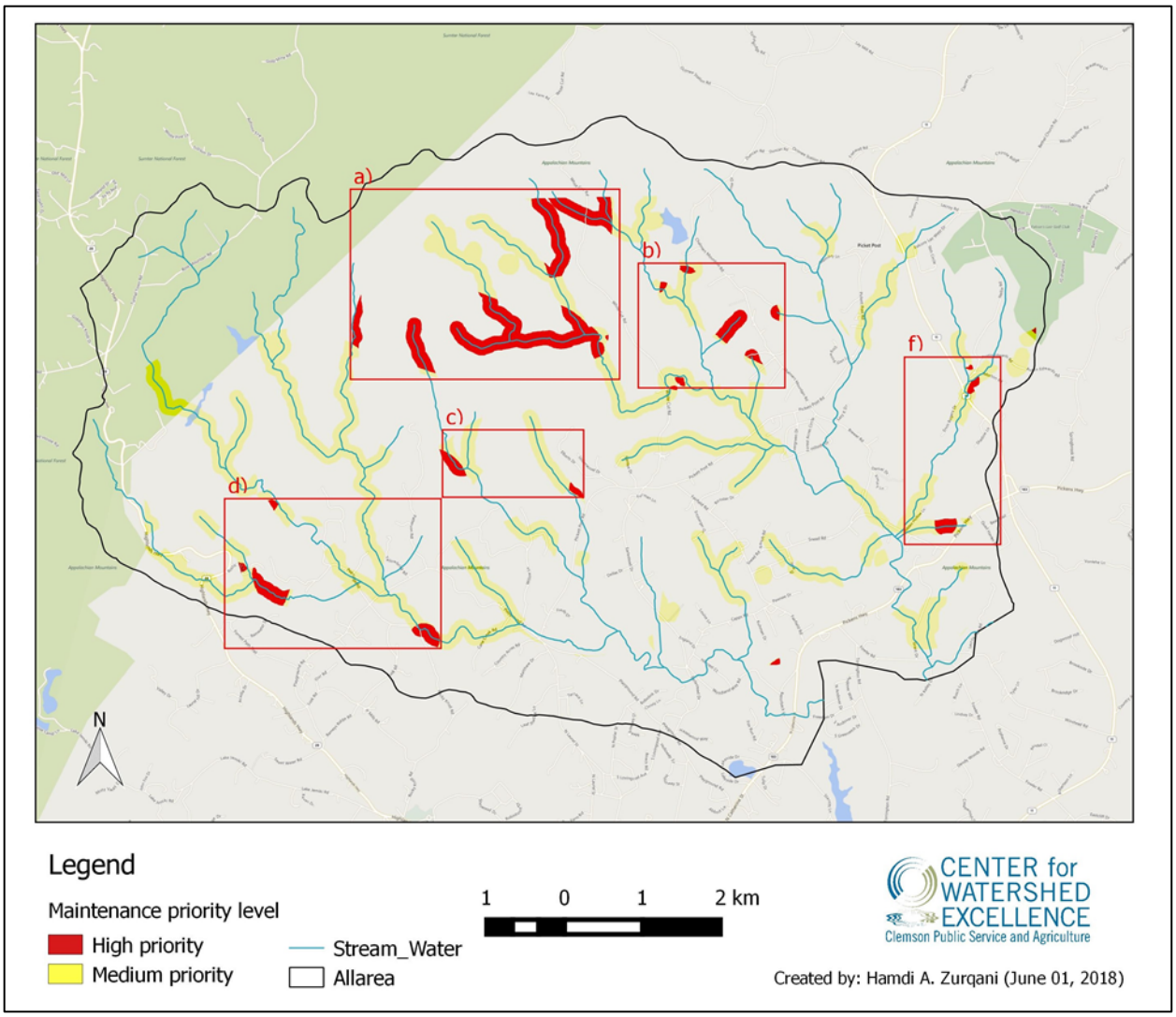


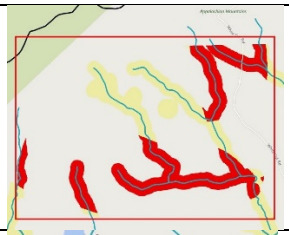
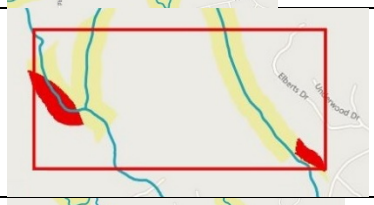
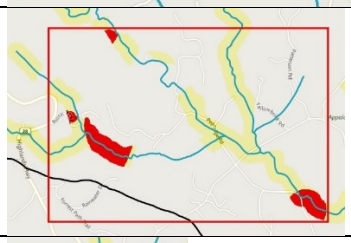
Fig. 31. Priority reaches for Septic System Repair and Replacement Program based on clusters of septic systems near streams and age of septic systems.

At the conclusion of Phase 1, the project team should then have an inventory of common issues in the watershed related to original design and installation; use and habits of the residents of the area that are leading to failures; number of households with failing septic systems that require further attention.

Phase 2 will then include cost share on replacement of those high priority septic systems or, if the option exists, tying those households directly into the sewer line. This action is supported by SC DHEC Onsite Wastewater Regulation R-61-56 Section 300.2 which reads, "Repairs or replacement of failing onsite wastewater systems shall not be allowed where a wastewater treatment facility is accessible for connection." A "wastewater treatment facility" is further defined

as "an accessible publicly or privately-owned system of structures, equipment, and related appurtenances to treat, store, or manage wastewater." There are 32 septic systems to be considered as priorities (Table 10).

Table 10. Priority areas and number of households to be included in Septic System Repair and Replacement Program.

ID	High Risk/High Priority Areas for Septic System Scheduled Maintenance	Number of Systems Included and Geographic Description
a)		N=8 Includes streets of Chalmers Mountain Road, Pickett Post Road, White Cut Road, and near Underwood Drive
b)		N= 7 Includes areas along Highway 11, Austin Edwards Road, Evin Rogers Drive, Shadow Lane, Brewer Road, and Pickett Post Road (State Road S-37-181)
c)		N= 3 Includes Woodland Way and Pickett Post Road (State Road S-37-181)
d)		N=9 Includes Tree Farm Road, Playground Road, Sweet Water Road, and Highway 28 South
f)		N=5 Includes Pickens Highway (Highway 183), Boyd Moss Road, Old Highway 11 and Country Junction (State Road S-37-24)

Given the soil characteristics and limitations of the soils to treat sewer by onsite wastewater treatment system, the on-going bacteria impairment, and the microbial source tracking results showing human bacteria detection at nearly every monitoring site in 2015 and 2018, a re-evaluation of building codes and ordinances are recommended for this area. The regional sewer authority, local water and sewer utilities, county and city governments should establish a plan

moving forward that is consistent with state regulations and mandates sewer extension to new development in this watershed, at minimum. Given the work to conform with regulation and add residences to centralized wastewater treatment, the utilities, county, and Walhalla may expand this water protecting effort countywide, since conditions are likely similar across Oconee County. Septic system education emphasizing regular maintenance of septic systems due to the area's limitations to treat septic systems not maintained should be ongoing. Cities and counties across the nation and state have enhanced regulations to permit septic systems. Where septic system permits exist, the city or county typically require proof of maintenance. Failure to comply is typically linked to penalties associated with drinking water or property taxes. In areas such as the City of Greenville, South Carolina, all residents pay a sewer fee whether served by sewer or septic. For those on septic systems, this means that the city schedules your maintenance for you, ensuring that local waterways remain protected from failing systems and high bacteria leachate. These examples of water resource management have been discussed amongst partners and will be further considered.

STRATEGY 4. CATCH BASIN CLEAN OUT PROGRAM AND CATCH BASIN REQUIREMENTS

Timeline: Implement in 2018-2019
Approximate Cost: $1500 for education component
Potential Funding Sources: N/A

SC Department of Transportation owns the City of Walhalla streets through downtown, where more than 25 catch basins collect stormwater and discharge to Cane Creek and neighboring watersheds. Based on observations, these catch basins have had very minimal maintenance. Maintenance of these catch basins is a requirement of the SC DOT's NPDES Stormwater Permit. Per the SC DOT's Stormwater Management Plan (2018), the following excerpt describes maintenance of the storm sewer system.

> *2.5 Summary of Inspection and Maintenance Program*
> *SCDOT has been providing maintenance of its storm sewer system for many years. Each district includes a maintenance department responsible for various duties, one of which includes maintenance of the roadway storm sewer system. Maintenance of the system includes routine cleaning of pipes/culverts, inlets/catch basins, and open drainage ditches. The Department utilizes an internal software program to track maintenance activities called the Highway Maintenance Management System (HMMS). This system logs maintenance/cleaning records in linear feet for roadside ditches, shoulders, and storm sewer pipe, and the total number of drainage structures cleaned.*
>
> *A structural control maintenance plan has been implemented by the Department to ensure that SCDOT-owned controls are operated in a manner to reduce the discharge of pollutants to the MEP. A consultant contracted by the Department visits and inspects all such controls quarterly. These controls are maintained annually, unless immediate need is identified in the quarterly inspection report. Required maintenance activities include removal of trash and litter, removal of excess vegetation and shrubs, removal of organic material, minor bank stabilization, seeding, and documentation of sediment level in the various BMPs. To ensure that the maintenance program is effective, the Department has*

> *developed a maintenance review program that includes periodic quality control site visits to recently maintained controls and detailed reports to document the thoroughness of the maintenance performed.*

It is suggested that the City of Walhalla review storm sewer maintenance with the SC DOT and develop a point of contact to outline continued maintenance needs and reporting of maintenance needs for this impaired watershed.

STRATEGY 5. TRAPPING FOGS AND FLUSHABLE WIPE ISSUES IN AREAS OF FREQUENT FAILURE

Timeline: Implement in 2019-2024
Approximate Cost: $8,000
Potential Funding Sources: Majority of costs – actual costs of interceptors – shall be paid for my property owners

Grease interceptors are larger units and the preferred method of trapping FOGs. These are vaults with typical minimum capacities of 750 to 1000 gallons. The large size allows hydraulic retention time, so that grease can cool and rise to the surface. The vault includes multiple chambers with flow available through a 90 degree fitting, so that grease stays up top, and wastewater flows to the next chamber, and on to the sewer line for treatment. The interceptors are serviced at some frequency by pumping out the grease and other solids related to food and food industry. The City of Red Wing, for example, mandates that interceptors be serviced four times per year at minimum (City of Red Wing 2018).

Requirements are needed that mandate the installation of grease interceptors and sewer meters at all new multi-family housing units (MFHUs). When MFHUs are documented as having frequent failures due to FOGS and flushable wipes, enforcement authority should be in place to mandate the installation of a grease interceptor. The most frequent failures that lead to back-ups, manhole spills, and direct sewer are shown in Fig.32. County ordinance and city ordinance would provide structure to support enforcement actions by the utilities that own and operate the affected sewer system.

Fig. 32. Locations of frequent maintenance due to FOG and flushable wipe disposal.

STRATEGY 6. TRAPPING WILD PIGS

Timeline: Implement in 2018-2020, over several seasons and within different areas of watershed

Approximate Cost: $5,000

Potential Funding Sources: 319(h)

According to a fact sheet produced by SC DNR, wild pigs can maintain a home range of 0.3 to 3 square miles. Habitat modification and fences do little to prevent wild hog damage or control population. Frightening devices are ineffective, while harassment may just move the population onwards. The best control to date is trapping with multiple catch traps such as corral traps. More information on control is included in Appendix C.

No wild pig may be relocated without a special permit from the SC Department of Natural Resource. Once trapped, a rifle can be used to euthanize the wild pig, starting from largest to smallest. Services exist in South Carolina to lease traps and hire a shooter. When conducting an effective trapping program, all hunting in the area should cease, especially hunting with dogs. In the watershed, several landowners could band together to implement a successful trapping program. Remote sensing technology is also available so that the trap can triggered remotely.

STRATEGY 7. EXTENDING THE WIDTH OF THE RIPARIAN ZONE ALONG PASTURES AND PADDOCKS

Timeline: Implement in 2019-2020
Approximate Cost: $15,000
Potential Funding Sources: 319(h), EQIP

For the purposes of this watershed plan, one must consider the objectives of a buffer and the risks to surface waters from lack of buffer to establish an appropriate width. Of course, land use, proximity of existing structures, slopes, condition of stream bank, and compaction are additional considerations. Our focus is of course controlling and minimizing bacteria loading to the stream. With that in mind, sediment-laden runoff should also be minimized. A minimum buffer width of 35 feet is recommended to remove suspended sediment (Wenger 1999). To maximize removal in this narrow width, the buffer should be a mix of native trees, shrubs, grasses, and perennials, rather than a grassed strip. No structures should exist within this buffer, or impervious surface, unless mandatory for utilities.

STRATEGY 8. UPDATING STORMWATER CONVEYANCE SYSTEMS AND LOT-SCALE STORMWATER CONTROLS

Timeline: Implement in 2019-2023
Approximate Cost: $45,000
Potential Funding Sources: 319(h), Five Star Challenge Grants

As one moves closer to Burns Mill Road in the Cane Creek watershed, the neighborhoods are older and some properties on steeper grades. Upgradient growth and increase in imperviousness has become burdensome on the roadside ditches and conveyance of stormwater in this lower part of the watershed. There is ample opportunity for road side improvements, following lot-scale BMPs on residential properties. Homes within this area have bare soils, worn away from roof drainage and compaction. Rainwater harvesting, overall disconnection of stormwater from impervious areas, rain gardens, and bioswales are all suitable retrofits that would mitigate impacts of stormwater runoff so close to the DHEC Cane Creek monitoring station, SV-342.

ANTICIPATED LOAD REDUCTIONS BY STRATEGY

The TMDL has set wasteload reductions for both Cane and Little Cane Creeks in the 10^{11} magnitude for fecal coliform. Tables 11 and 12 summarize the recommended strategies for each of these watersheds and the anticipated load reduction if the strategy is fully implemented. The loading estimates used were conservative, just in case the number of units (for instance, septic systems) were short of the goal established in the strategy. If fully implemented, and other changes in the watershed notwithstanding, there is high likelihood that the wasteload reductions will be achieved and water quality standards met for E. coli. Given that findings indicate a consistent source and opportunity for extended livelihoods of bacteria in streambed sediments, this achievement may be delayed while bottom sediments become flushed out of the stream, the streambank becomes sufficiently stabilized, and pathogens are degraded. This could possibly be predicated with more accuracy if weather and flow gauging data were more available in the watersheds.

Table 11. High Priority Load Reduction Strategies in Cane Creek

STRATEGY	ACTIONS AFFECTING E. COLI	ESTIMATED LOAD REDUCTION	COMMENTS
1	Sertoma retrofits, sewer repairs, dredging, riparian buffer installation, and geese control	2.94 x 10^{11} col/100mL 2.95 (Davies and Bavor 2000; LIRB 2000)	Canada goose removal provides the greatest, most regular removal of indicator bacteria from waste streams at this site.
2	Naturalizing flows and stabilizing the floodplain	100% of E. coli load in water column in high flow conditions (Soupir and Pandey 2016)	Potential to mitigate 100% of E. coli load seen during high flow events and based on particle size suspension.
4	Catch basin maintenance	2.76 x 10^{4} col/100mL (Doran et al. 1981)	Estimate based on 30 regularly maintained catch basins.
5	FOGs and grease interceptors	3.15 x 10^{7} col/100mL (Overcash and Davidson 1980)	Estimate based on removing raw sewage spills at five locations.

8	Stormwater conveyance and lot-scale BMPs	1.3 x 10^6 col/100mL (Doran et al. 1981)	Estimate based on removal of high bacteria, cumulative runoff achieved through treatment train.

Table 12. High Priority Load Reduction Strategies in Little Cane Creek

STRATEGY	ACTIONS AFFECTING E. COLI	ESTIMATED LOAD REDUCTION	COMMENTS
3	Septic system repairs and elimination through sewer service	4.84 x 10^{11} col/100mL (Horsley and Whitten 1999)	Estimate based on 20 septic systems prioritized in Little Cane Creek watershed.
4	Wild pig trapping	1.78 X 10^{11} col/100mL (Metcalf and Eddy 1991)	Estimate based on 20 pigs trapped and eliminated.
7	Riparian buffers on pastureland and paddocks	1.6 x 10^6 col/100mL (Doran et al. 1981)	Highest concentration from one site used, though best practice should be implemented at several farms and homes.

STRATEGY IMPLEMENTATION MILESTONES

Table 13. Summarized information on watershed plan implementation

STRATEGY	MILESTONES	RESOURCES REQ'D.	TECHNICAL ASSISTANCE REQ'D.	EST. BUDGET	POTENTIAL PARTNERS & *GRANTS*	TIMEFRAME
1. SERTOMA	• Development of Sertoma Field Task Force from multiple agencies and departments • Homeowner meeting • Approved construction plans and sequence of new parking area and replacement of stormwater infrastructure • Depaving • Sewer line replacement and upgrades • Installation of porous asphalt • Dredging of private pond • Establishment of buffer and recreational space along tributary • Outreach to community, neighborhood and involvement in park	Dump trucks, loaders, sewer line repair equipment, dewatering equipment, native plants, signage	Engineering to determine extent of area suitable for porous asphalt; engineering designs; engineer to determine best method to repair/replace/ enlarge sewer line; landscape design for buffer; dredging company; educator and volunteer coordinator; geese management expertise	$725,000	OJRSA, Oconee County, City of Walhalla, Walhalla Water Department, Clemson Extension Service, Appalachian Council of Governments, SC Rural Water Association; *SC DHEC 319(h), State Revolving Fund, USDA Water and Waste Disposal Loan and Grant Program, USDA Rural Utilities Service, EPA Five Star Challenge Grant*	Develop a Task Force in 2019; Complete project by 2025

STRATEGY	MILESTONES	RESOURCES REQ'D.	TECHNICAL ASSISTANCE REQ'D.	EST. BUDGET	POTENTIAL PARTNERS & *GRANTS*	TIMEFRAME
	planting and maintenance					
2A. TREE DEBRIS REMOVAL	• Procure a subcontractor • Inventory number of trees cut into several foot lengths, with GPS points and photos • Monitor outlet of Cane Creek into Lake Keowee for further sediment deposition	Chainsaws, flagging tape, GPS, camera	Contract manager, tree expertise, educator	$6,000	Oconee County, City of Walhalla, Oconee County Conservation District; *SC DHEC 319(h)*	Apply in 2019; Complete project by 2020
2B. RIPARIAN REFORESTATION	• Selection of trees available for homeowners • Media releases on project and mailers to large landowners • Response rate of homeowners • Maintenance agreement with landowner • Inventory of trees delivered by lot, parcel, and watershed • Evaluation of tree survival rate	Trees, shovels, fencing or tree tubes, mulch	Tree expert, educator	$15,000	Oconee County Soil and Water Conservation District, Clemson Extension Service, local businesses interested in tree planting community days; *SC DHEC 319(h), Bring Back the Natives, US Forest Service, Community*	Apply in 2019; Complete project by 2022

STRATEGY	MILESTONES	RESOURCES REQ'D.	TECHNICAL ASSISTANCE REQ'D.	EST. BUDGET	POTENTIAL PARTNERS & *GRANTS*	TIMEFRAME
	• Replanting where necessary				*Canopy by the Arbor Day Foundation*	
3. SEPTIC SYSTEMS	• Selection of Subcontractor • Media Releases and Contacts with Homeowners • Development of paper or online survey • Response rate of homeowners • Development of packet of educational materials and file folder • Summary of survey findings • Estimate of number of repairs, replacements, sewer extension opportunities • Implementation of Phase 2	Septic system repair company, mailers	Contract manager, septic system company, educator, utility staff and directors	$20,000	OJRSA, Oconee County, City of Walhalla, Walhalla Water Department, Appalachian Council of Governments, SC Rural Water Association; *SC DHEC 319(h), State Revolving Fund, USDA Water and Waste Disposal Loan and Grant Program, USDA Rural Utilities Service,*	Apply in 2019; Complete project by 2025
4. CATCH BASINS	• Contact SC DOT to establish point of contact	Markers and metal decals, signage, press	Educator and volunteer coordinator	$1,500	Oconee County, City of Walhalla, SC DOT	Implement in 2018-2019

STRATEGY	MILESTONES	RESOURCES REQ'D.	TECHNICAL ASSISTANCE REQ'D.	EST. BUDGET	POTENTIAL PARTNERS & *GRANTS*	TIMEFRAME
	• Meet to discuss maintenance needs of storm sewer system • Identify how to report issues through the SC DOT's Highway Maintenance Management System • Annually evaluate maintenance and catch basin performance					
5. FOGS AND WIPES	• Contact SC DOT to establish point of contact • Meet to discuss maintenance needs of storm sewer system • Identify how to report issues through the SC DOT's Highway Maintenance Management System • Annually evaluate maintenance and catch basin performance	Ordinance, building codes, utility data	Utility expertise, engineering consultation	$8,000	Utilities, city, and county	2019-2024

STRATEGY	MILESTONES	RESOURCES REQ'D.	TECHNICAL ASSISTANCE REQ'D.	EST. BUDGET	POTENTIAL PARTNERS & *GRANTS*	TIMEFRAME
6. WILD PIGS	• Newspaper article defining extent of issue and inviting participation • Organize groups of landowners to participate in exchange for a small fee (recommend $500) • Lease and establish traps with cameras • Report out on number of traps issues, number of wild pigs euthanized per region of the watershed	Venue and speakers, hunters and trappers	Technical speakers, event coordinator	$5,000	NRCS, Clemson Extension, SC Department of Natural Resources (SC DNR), USDA Field Office; *SC DHEC 319(h)*	Implement in 2018-2020
7. AGRICULTURAL BUFFERS	• Contact landowners regarding participation • Inquire • Identify how to report issues through the SC DOT's Highway Maintenance Management System • Annually evaluate maintenance and catch basin performance	Seed mix, post hole diggers, field equipment, fence and fence repair equipment	Contract manager, educator, expert in pasture productivity and agricultural best management practices, conservation planner	$15,000	Clemson Extension, NRCS; *SC DHEC 319(h), EQIP*	Implement in 2019-2020

STRATEGY	MILESTONES	RESOURCES REQ'D.	TECHNICAL ASSISTANCE REQ'D.	EST. BUDGET	POTENTIAL PARTNERS & *GRANTS*	TIMEFRAME
8. STORMWATER CONVEYANCE	• Prioritize locations and appropriate BMPs • Approach property owners regrading retrofits • Create and sign maintenance agreements • Implement BMPs • Improve roadside conveyance with use of Bioswales, check dams, and green infrastructure treatment train approach	Plants, field equipment, rainwater harvesting equipment, mulch	Contract manager, educator, engineer, landscape services company	$45,000	Clemson Extension, Oconee County, City of Walhalla, FOLKS; *SC DHEC 319(h), Five Star Challenge Grants, Captain Planet Foundation*	2019-2023

6.0 WATERSHED EDUCATION STRAGEGIES

Project partners seek to leave a legacy of outreach recommendations that are beyond specific projects, towards a greater evolution of practices, values, and behaviors that protect local water quality and habitat, so intrinsic to life in the upstate of South Carolina. These program recommendations are identified in Table 14. Activities are organized as those outreach recommendations that pair to specific strategies for watershed restoration, and those outreach recommendations that are recommended as important for long-term watershed protection.

Table 14. Outreach to be conducted in the Cane and Little Cane Creek watershed.

Outreach Program	Objective	Audiences	Methods for Implementation
WATERSHED RESTORATION PRIORITY (MEETS SPECIFIC STRATEGIES IN WBP)			
Septic System One-on-One Education	Produce and distribute septic system informational file folders for record keeping and education about septic system care and responsible ownership.	Homeowners	Distribution through contractor; available through Clemson Extension, FOLKS, and Oconee County
Riparian Forested Buffer Fact Sheet	Clemson Extension-produced fact sheet on riparian forest buffers and their importance, establishment, specifications, plant recommendations, and more.	Land owners	Online; distribution through local offices of partners in this plan
Porous Asphalt Design and Installation Workshop	Teach through demonstration the considerations, design, engineering plans, and installation best practices of porous asphalt.	Engineering community, city and county staff	Announce through professional organizations and listservs such as MASC Stormwater
Canada Goose Outreach Signage	Post signage in locations in the watershed to alert residents of the risks of feeding Canada	Park staff and visitors, neighbors	Contact Clemson Extension Carolina Clear for

Outreach Program	Objective	Audiences	Methods for Implementation
	Geese and habitat modifications to encourage migration. Accompany with neighborhood meeting or article for distribution.		signage and work with local Clemson Extension agent on outreach
Pollinator Pathways and Stream Buffer Demonstration and Planting	Involve area residents in the installation of native plant buffer on tributary to Cane Creek, provide plant lists, and post signage to educate park visitors.	Park staff and visitors, area residents	Announce workshop through local press, social media, and Master Gardener program.
Carolina Yards www.clemson.edu/carolinayards	Involve residents in the use of watershed friendly landscaping principles. This Clemson Extension-led program can be taught in person, online, and includes recognition of practices that include use of native plants, water wise landscaping, soil testing, and lot-scale stormwater management. Includes competition and program branding for long-term promotion of watershed - friendly practices.	Adult residents, HOAs, property management companies	Clemson Extension agents and news releases
County and City Councils Education Series	Hosted by the utilities, feature council educator series to address 1) septic system issues and potential permitting or easements for maintenance; 2) grease interceptors; 3) sewer planning to address growth and water quality risks by septic systems	City and county councils	Lead by utilities, host workshops with technical speakers

Outreach Program	Objective	Audiences	Methods for Implementation
Storm Drain Marking	The stenciling completed in 2007 has faded. A renewed effort to mark storm drains, most especially in downtown Walhalla is recommended. Different methods can be used to capture the public's attention and build awareness of this connection: • Downtown: metal markers at high traffic inlets. Pair with chalk art showing drainage to storm inlets. Issue invitation and press release in advance. • Side streets and residences: vinyl marker with local message paired with step stake signs that alert traffic to slow down for "volunteers marking storm drains." • Neighborhoods: provide vinyl markers and signage for interested neighborhoods.	Area residents, youth, visitors	Collaborate with local troops to implement; work with press and city to promote awareness. Try to tie into community festival.
Controls for Wild Pigs Workshop	Host a workshop that addresses the current status of wild pigs. and control options. The workshop should seek to additionally invite vendors in the area that could speak with landowners about the services they provide.	Landowners, farmers	Announce through press, social media, partnering offices, partner with SC DNR
Outreach related to agricultural buffers in pastureland and paddocks	Emphasize agricultural buffers for pastureland and paddock in ongoing outreach to farmers and hobby horse owners and stables. Offer conservation planning and EQIP match opportunities for those who quality.	Farmers, horse owners, horse stable property owners	Incorporate into existing outreach to these audiences.

Outreach Program	Objective	Audiences	Methods for Implementation
WATERSHED PROTECTION PRIORITY (TO SUSTAIN WATERSHED PROTECTION LONG-TERM)			
SC Adopt-a-Stream www.scadoptastream.org	Involve stakeholders in the collection of more data on the watershed and greater understanding in the relationships between land use, changes in land use, and impacts to the stream.	Adult residents; Girl Scouts, Boy Scouts; Master Naturalists of the Upstate; utility staff	Host training events; outreach to community through FOLKS newsletter and media
SC Adopt-a-Stream in the Classroom www.scadoptastream.org	Involve students in greater discussion, awareness, and monitoring exercises so that the next generation is better prepared to manage their watersheds. Walhalla High School has already begun monitoring the waterway on their campus with students to meet the school's natural resource science curriculum goals.	High school and middle school teachers	Contacts with Clemson 4-H and Extension Agents – organized meetings
CoCoRaHs (Community Collaborative Rain, Hail, and Snow Network) www.cocorahs.org	Weather in the mountains can be very spotty. During the development of this plan, it was found that there was a paucity of precipitation records in the watershed. FOLKS would be an ideal organization to engage members in recording weather events across the Lake Keowee watershed for use in model development. Many residents of the area have been identifying plumes of sediment coming into the lake. FOLKS and partners can serve as an information source to resource managers in connecting rain events to	Residents of the Lake Keowee Watershed	FOLKS Newsletter and FOLKS leadership and contacts with HOAs

Outreach Program	Objective	Audiences	Methods for Implementation
	sediment deposits and other related water quality concerns.		
Trout in the Classroom www.troutintheclassroom.org	Oconee County includes the state's prized trout streams, the Chattooga and Chauga Rivers. Trout demand cold, fast moving rivers, and feed from rocky river beds that are not embedded with sediment. Raising trout is an opportunity to explore habitat conditions and how land use management and planning for conservation are related and important for an area with such rivers. SC DNR operates the Walhalla State Fish Hatchery just north of the watershed, who could serve as a partner in this regional education and outreach program.	Youth, schools	Provide as a service as a partnership between Clemson Extension, SC DNR and fish hatchery
Build Your Own Flyrod Workshop	Increase awareness of the relationships between sediment, stream stabilization, and aquatic resources and fisheries through this workshop. Introduce water quality objectives for trout streams as part of the curriculum, as well as what observations to make, and how to alert proper authorities when stream conditions are in peril.	Outdoor enthusiasts of the region	Partner with local specialty fishing and outdoor suppliers, SC DNR, Trout Unlimited, and Clemson Extension.
Promote ecotourism and local interview videos	Encourage protection of local quality of life using the ideas and feedback from local leaders. Use this student-designed video in social media, local movie theaters, schools, and more to encourage personal	Residents of the area	Walhalla Facebook, local movie theaters, Walhalla High School, Community groups, Trout

Outreach Program	Objective	Audiences	Methods for Implementation
	responsibility in watershed management.		Unlimited chapter

7.0 IMPLEMENTATION MONITORING PLAN

A monitoring plan is suggested that will account for effectiveness of implementation, as well as trend monitoring. While the effectiveness monitoring should be implemented before and after installation of BMPs, trend monitoring will record conditions of the watershed as they evolve.

- *Stations dedicated to effectiveness monitoring* shall be sampled quarterly for three quarters prior to implementation and for one year following completion of project. If the stream is to be disturbed during implementation, monitoring should discontinue during that time period until all soil moving activity is complete and site stabilized. Timing of projects is based on financing, permitting, area events, engineering and design, and more. Thus, it is anticipated that there will need to be flexibility amongst the monitoring strategy to allow for delays or re-prioritization of projects based on external factors.
- *Stations dedicated to trend monitoring* shall continue throughout the project.
- It would be beneficial to add macroinvertebrate assessments at SV-342 and SV-343 since some implementation strategies, when implemented, should improve bank stability and in-stream sediment inputs to the streams over time.
- Gauging stations should be installed at these two DHEC monitoring stations as well, since the contributions of stream sediments to E. coli in the water column has been shown to positively correlate with flow velocities.
- All monitoring shall be completed during dry weather or 48 hours following wet weather, keeping consistent with the protocols guiding most extensive recent river monitoring data in the watershed, which is that of FOLKS.

Parameters recorded shall include:

- *Physical and In Situ*
    a. Active channel width, bankfull channel width, depth at bankfull to track hydrologic modifications in the rivers and how quickly conditions may be changing.
    b. Color, odor
    c. Air and water temperature
    d. Turbidity, or preferably, Total Suspended Solids (TSS)
- Chemical
    a. pH, conductivity, dissolved oxygen
    b. Nitrate, nitrite
- Bacterial
    a. E. coli

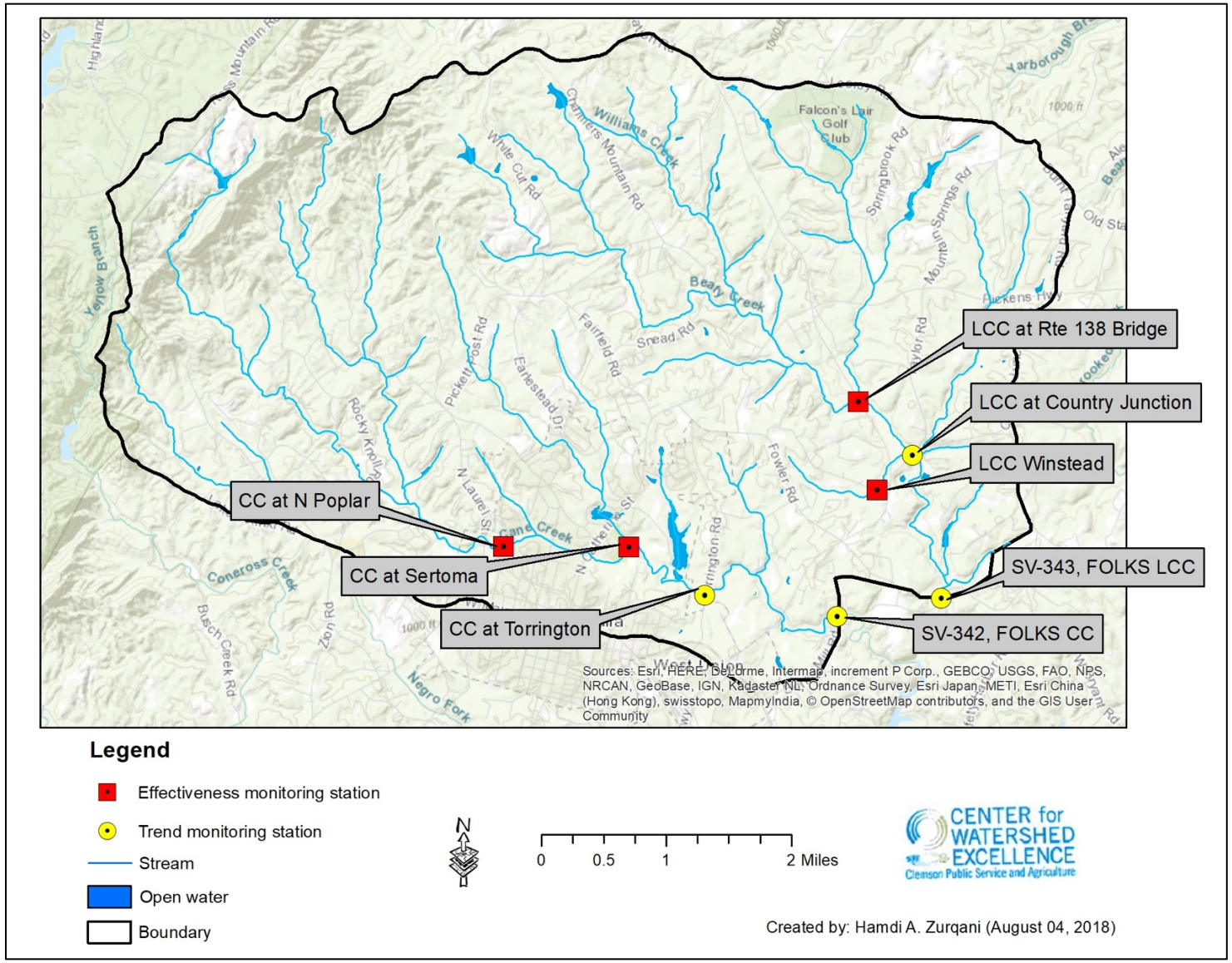


Fig. 33. Proposed water quality monitoring stations.

REFERENCES

American Society of Agricultural Engineers (ASAE). 1998. ASAE Standards, 45th Edition. Standards, Engineering, Practices, Data.

City of Red Wing. Accessed May 22, 2018. Frequently Asked Questions about Fats, Oils, and Grease. https://www.red-wing.org/media/files/departments/public_works/Utilities/Fats,%20Oils%20&%20Grease%20FAQ%20Sheet.pdf. Red Wing, MN.

Davies, C. M., and Bavor, H. J. 2000. The fate of stormwater associated bacteria in constructed wetland and water pollution control pond systems. *J. Applied Microbiology* 89: 349–360.

Doran, J.W., J.S. Schepers, and N.P. Swanson. 1981. Chemical and bacteriological quality of pasture runoff. *J. Soil and Water Conservation* May-June: 166-171.

Environmental Law Institute. 2003. Conservation Thresholds for Land Use Planners. ISBN# 1-58576-085-7. Washington, D.C.

Haller, L., Amedegnato, E., Poté, J. *et al.* 2009. Influence of Freshwater Sediment Characteristics on Persistence of Fecal Indicator Bacteria. *Water Air Soil Pollution* 203**:** 217–227. https://doi.org/10.1007/s11270-009-0005-0

Horsley and Whitten, Inc. 1996. *Identification and evaluation of nutrient and bacteria loadings to Maquoit Bay, New Brunswick and Freeport, Maine*. Final Report.

Kiefer, L.A., Shelton, D.R., Pachepsky, Y., Blaustein, R., and Santin-Duran, M. 2012. Persistence of *Eschirichia coli* introduced into streambed sediments with goose, deer and bovine animal waste. *Letters in Microbiology* ISSN 0266-8254

Kimberly Clark Worldwide Inc (1996) US Grant *US5667635A*.

Liang, X., Liao, C., Thompson, M.L., Soupir, M.L., Jarboe, L.R. and Dixon, P.M. 2016. E. coli Surface Properties Differ between Stream Water and Sediment Environments. *Frontiers in Microbiology* 7:1732

Long Island Regional Planning Board (LIRB). 1978. The Long Island Comprehensive Waste Treatment Management Plan: Volume II: Summary Documentation. Nassau-Suffolk Regional Planning Board. Hauppauge, NY.

Mankin, K.R., Ngandu, D.M., Barden, C.J., Hutchinson, S.L., and Geyer, W.A. 2007. Grass-Shrub Riparian Buffer Removal Of Sediment, Phosphorus, And Nitrogen From Simulated Runoff. *J. American Water Resources Association* **5**:1108-1116.

Metcalf and Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, Reuse*. 3rd Ed. McGraw-Hill, Inc., New York, NY.

Moore, Andrew. 2016. *From damaged crops to polluted waterways, wild hogs wreak havoc in South Carolina. Greenville News* Agriculture December 6, 2016. Greenville, SC.

Natural Resources Conservation Service of Vermont (Undated). Specification Guide Sheet for Riparian Forest Buffer (391). Retrieved from https://efotg.sc.egov.usda.gov/references/public/VT/VTSpec391-0109.pdf; accessed 9-July 2018.

Perez, W. 2018. *"Flushable" Wipes Creating Expensive Problem at Local Sewage Plant.* WPVI-TV Action News [Pottstown, PA]. March 14, 2018.

Sartor, J.D. and G.B. Boyd. 1972. Water Pollution Aspects of Street Surface Stormwater Contaminants. US EPA Office of Research and Monitoring. Washington, D.C.

Schang, C., Lintern, A., Cook, P.L., Rooney, G., Coleman, R., Murphy, H.M., Deletic, A. and D. McCarthy. 2017. Escherichia coli survival and transfer in estuarine bed sediments. *River Research and Application* **34:**606-614.

Scott, T.M., Rose, J.B., Jenkins, T.M., Farrah, S.R., and Lukasik, J. 2002. *Microbial Source Tracking: Current Methodology and Future Directions*. Applied and Environmental Microbiology **68** (12) 5796-5803.

SC Department of Health and Environmental Control. 2005. Total Maximum Daily Load for Fecal Coliform in Cane and Little Cane Creeks. Technical Report Number 017-05. Columbia, SC.

SC Department of Transportation. 2018. SC Department of Transportation Stormwater Management Plan. Columbia, SC.

Soupir, M. and P. Pandey. 2016. Sediment E. coli as a Source of Stream Impairment. Iowa State University Resource publication 23: 4-5.

Wenger, Scott. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. University of Georgia. Revised Version 5-March-1999.

United States Department of Agriculture's National Agricultural Statistics Service. 2018. Retrieved from https://quickstats.nass.usda.gov/; accessed 13-March-2018.

United States Environmental Protection Agency. 1999. *Storm Water O&M Fact Sheet: Catch Basin Cleaning 832-F-99-011*. Washington, D.C.

United States Environmental Protection Agency. 2014. *Watershed Assessment, Tracking & Environmental Results*. Washington DC: US Environmental Protection Agency Office of Water.

United States Environmental Protection Agency. 2016. *Septic System Repairs Improve Water Quality in Horse Creek* 841-F-016-001M. Washington, D.C.

University of Connecticut NEMO Program. 2007. Coastal Riparian Buffers Analysis Final Report to EPA. Hartford, CT.

Wexler, H.M. 2007. Bacteroides: the Good, the Bad, and the Nitty-Gritty. *Clinical Microbiology Reviews* **20** (4) 593-621.

Wu, J., 2008. Land Use Changes: Economic, Social, and Environmental Impacts. *Choices* 23 (4), 6-11.

Zhang, L. and W. J. Mitsch. 2007. Sediment Chemistry and Nutrient Influx in a Hydrologically Restored Bottomland hardwood Forest in Midwestern USA. *River Research Applications* **23**: 1026-1037.

Zurqani, H.A., Post, C.J., Mikhailova, E.A., Schlautman, M.A., and J.L. Sharp. 2018. Geospatial analysis of land use change in the Savannah River Basin using Google Earth Engine. Technical Contribution No. 6620. *International Journal of Applied Earth Observation and Geoinformation* (In press).

Appendix A – Google Earth Engine and GIS Methods

1. Land cover classification analysis

Table 1. Date description:

NO	Name	Data type	Source
1	National Agriculture Imagery Program: (NAIP) Imagery (2005, 2009, 2013, and 2015)	Raster	Google Earth Engine (GEE)
2	Streams data	Polyline	National Hydrography Dataset
3	TIGER: US Census Roads: Roads data (2010, and 2016)	Polyline	Google Earth Engine (GEE)
4	Parcels polygon	Polygon	Oconee County

Data and methods

In this study, a 1-meter resolution imagery NAIP were selected based on the years available that cover the study area in Google Earth Engine (GEE). All the image processing and the classification including the accuracy assessment were implemented inside the GEE platform. Unsupervised classification technique Learning Vector Quantization algorithm was used inside GEE platform to detect the land use change over time.

Image preprocessing and classification

All the NAIP imagery was conducted using the cloud-computing technology in the GEE platform (https:earthengine.googel.org/) the years of the NAIP senses were chosen for this study were 2005, 2009, 2013, and 2015 (Table 1: Fig. 2). Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) were used when the near infrared band is available to enhance the classification result (Fig. 2). Using the Learning Vector Quantization algorithm, the images were classified into 20 clusters and then reclassified into five different classes: forested; non-forested; low medium intensity urban; high intensity urban; and water. A stratified random sampling design was used to validate the classification accuracy. A total of 250 reference points were randomly delineated for each year with a consideration of no less than 50 points for each land cove class. The land use change detection in the past ten years was obtained by comparing the land cover classification of the years 2005 and 2015. The change was expresses by classifying the area into: deforestation, and forestation activities.

Table 2. The percentage of the user's and producer's, overall, kappa statistics for the land cover classification:

	2005		2009		2013		2015	
Land cover category	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy
High intensity urban	89.83	85.48	97.83	86.54	87.30	83.33	82.76	87.27
Low medium intensity urban	94.23	76.56	84.85	96.55	86.36	74.51	84.49	80.33
Non-forested	67.64	74.19	78.87	74.66	85.00	85.00	83.78	86.11
Forested	77.14	88.52	74.60	78.33	80.73	89.80	83.69	83.69
Water	100.00	100.00	100.00	98.15	100.00	98.18	100.00	94.23
Overall accuracy	84.83		85.95		86.41		85.86	
Kappa coefficient	81.06		82.37		82.43		81.89	

2. Septic tank analysis:

Table 3. Date description:

NO	Name	Data type	Source
1	Sewer system lines	Polyline	Oconee County
2	Streams data	Polyline	National Hydrography Dataset
3	911 data	Point	Oconee County
4	Parcels polygon	Polygon	Oconee County

Assumptions:

1. All homes within 500 feet of sewer system have been assigned as on sewer.
2. Lots with more than one home on them have been given the oldest date of home built.
3. Less than 300 feet to the stream is a distance that septic leachate could cover, given that this buffered area likely includes the adsorption field.

Appendix B – Watershed Septic System Suitability Investigation

Mapping the Septic Tank Absorption Fields based on SSURGO data

Description of Septic Tank Absorption Fields

Septic tank absorption fields describe the areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. In this evaluation, only the soil between depths of 24 and 60 inches is evaluated. The ratings were based on the soil properties that affect absorption of the effluent, construction, and maintenance of the system, and public health such as soil texture; stones and boulders; depth to bedrock; water movement; depth to saturated zone; flooding; slope and the maintenance needed.

The numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The ratings classes of Septic Tank Absorption Fields:

1. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected.
2. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected.
3. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Appendix C – SC DNR Wild Pig Fact Sheet

Wild Pigs

Prepared by the National Wildlife Control Training Program. http://WildlifeControlTraining.com
Researched-based, certified wildlife control training programs to solve human – wildlife conflicts.
Your source for animal handling, control methods, and wildlife species information.

Figure 1. Wild pig (*Sus scrofa*). Picture courtesy of US Fish and Wildlife Service (USFWS).

Species Overview

Conflicts

Wild pigs damage turf, crops, and landscapes by their rooting, wallows, and rubs. They also predate on native species. In addition, wild pigs vector several diseases that can infect wildlife, livestock, and humans.

Legal Status

In South Carolina, there is no closed hunting season for wild hogs on private lands with a valid hunting license during daylight hours.

Hogs can be hunted at night with certain weapon restrictions.

See the South Carolina Department of Natural Resources Rules and Regulations online for more information.

However, from the last day of February to July 1, if the landowner provides notification to the South Carolina Department of Natural Resources (SCDNR) at least 48 hours in advance, wild hogs may be hunted at night with artificial lights and nightvision devices using any legal firearm, bow, or crossbow.

Contact your local SCDNR field office or www.dnr.sc.gov for additional rules and regulations regarding night hunting for wild hogs.

Identification

Wild pigs (*Sus scrofa*) include both feral hogs (domestic swine that have escaped captivity) and wild boars (Figure 1). Wild boars are native to Eurasia but were introduced to North America to interbreed with feral hogs. Wild boars and feral hogs hybridize freely, therefore, the term wild pig is appropriate as a generic term for these animals.

Physical Description

The size and shape of wild pigs depend on the breed, degree of hybridization with wild boars, and level of nutrition during the growing period. Males tend to be larger than females. The length of adults ranges from 50 to 75 inches,

and weight ranges from 75 to 250 pounds. Pigs larger than the average tend to be the result of feeding by humans. Wild boars have longer legs and larger heads with longer snouts than feral hogs. As with domestic hogs, hybrids may be any color. The color of young boars generally is red-brown with black longitudinal "watermelon" stripes. As juveniles develop, the stripes disappear and color changes from red to brown to black. Male feral hogs and wild boars have tusks that are continuously growing.

Species Range

The first documented introduction to the US was in Florida by Hernando de Soto in 1539. Populations of unclaimed hogs increased and spread throughout the Southeast. European wild boars were released at Hooper Bald, North Carolina, in 1912.

Wild pigs currently are found throughout the southeastern US from Texas to Florida. They also are found in California, Hawaii, Puerto Rico, and the Virgin Islands. Scattered populations occur across much of the US.

Health and Safety Concerns

Wild pigs are hosts to cholera, swine brucellosis, trichinosis, bovine tuberculosis, foot and mouth disease, African swine fever, and pseudorabies. All may be transmitted to livestock from wild pigs.

Swine brucellosis is a bacterial disease that causes abortions in pigs. Humans can contract swine brucellosis by contact with infected animals. If you develop flu-like symptoms, inform medical authorities that you have worked with feral hogs.

Pseudorabies is a herpes virus that diminishes the health of swine and leads to abortions in sows. Feral hogs spread the virus through nasal and oral discharges. While not contagious to humans, pseudorabies can kill dogs, livestock, and wildlife.

Always wear disposable gloves when handling, field dressing, cleaning, and butchering a carcass of a wild pig. Avoid direct contact with blood and reproductive organs. Wash hands with soap and hot water for 20 seconds or longer immediately after dressing a wild pig. Burn or bury gloves and remains from wild pigs that have been butchered. Clean all tools and reusable gloves with disinfectant, such as dilute bleach. Thoroughly cook the meat of wild pigs.

General Biology, Reproduction, and Behavior

Reproduction

In ideal conditions, a population of wild pigs can double in just 4 months, but more typically, the annual growth rate in populations of feral hogs is about 20%. Feral hogs may begin to breed before 6 months of age if they have a high-quality diet. Sows usually have one litter per year and young may be born at any time of the year. Litter size depends upon the age of the sow, nutritional intake, and time of year. Litters of feral hogs have three to eight young, but have been as large as 13. Wild boars usually breed at 18 months.

Nesting/Denning Cover

Wild pigs seek water and dense vegetation when temperatures are high. When the weather turns cold, they pile grass and leaves high enough to bury themselves for warmth.

Behavior

Wild pigs are intelligent and adapt readily to changing conditions. They may rapidly modify their responses to humans. Wild boars have a greater capacity to invade colder and more mountainous terrain than do other wild pigs. Feral pigs are social and form family groups called "sounders." A sounder consists of one or more sows and their offspring. Male pigs tend to be solitary. The home range of wild pigs

depends on the availability of food, but typically is 0.3 to 3 square miles.

During hot weather or if hunting pressure is great, wild pigs remain in the shade in wallows during the day and feed at night. Wild pigs cool themselves in wallows by rolling in mud and then use trees or posts, called rubs, to scrape off the mud. In cold weather, they feed during the warmest parts of the day.

Habitat

A variety of habitats, from tidal marshes to mountain ranges, is suitable for wild pigs. They prefer the cover of dense brush or marsh vegetation. In general, they are restricted to areas below snowline and above freezing temperatures, although populations are expanding northward in the US. Wild pigs frequent livestock-production areas. They prefer mast-producing hardwood forests but also feed in conifer forests. In remote areas, or where human activity is minimal, they may use open range or pastures, particularly at night.

Food Habits

Wild pigs are omnivores. Types of food vary greatly depending on the location and time of year, but plants make up about 85% of their diet. Acorns or other mast, when available, make up a good portion of the diet. Wild pigs gather in oak forests when acorns fall and generally do not wander far from the forest during this period. In winters of poor mast production, wild pigs increase their range and consume greater quantities of underground plant material, herbaceous plants, and invertebrates (worms and insects). They may feed on underground vegetation during wet weather or in areas near streams and underground springs. Wild hogs eat flesh from vertebrates and will prey on bird eggs, but the extent to which animals are taken as prey or carrion is not fully known.

Voice, Sounds, Tracks, and Signs

Wild pigs vocalize with grunts and squeals.

Damage Identification

Damage to Landscapes

The most common complaint of damage from wild pigs is rooting, sometimes called grubbing. Wild pigs can cause considerable damage to lawns or golf courses when rooting for food.

Damage to Crops and Livestock

Damage to farm ponds and watering holes for livestock is common also. Damage to crops and rangeland by wild pigs is easily identified. Rooting in wet or irrigated soil generally is quite visible, but can vary from an area of several hundred square feet to only a few small spots where the ground has been turned over.

Some hogs are highly efficient predators. Depredation to calves and lambs can be difficult to identify because the small animals may be killed and completely consumed, leaving little or no evidence to determine the cause of death.

Hogs typically kill by biting and crushing the skull or neck. Hogs begin to feed on the underside of the lamb, starting at the chest and stomach. After the heart, lungs, liver, stomach, and intestines are removed, a hog will eat the ends of the ribs, break the back, and expose the muscle surrounding a leg. A pig will then consume the backbone area, approaching from the belly side and eat the muscle tissue of the leg. The brain, eyes, and tongue are consumed last. Wild pigs tend to step on the carcass while feeding. The presence of scat will help with identification. Confirmation of predation must occur shortly after death of the prey because pigs also feed on carrion.

Damage to Structures

Wild pigs can cause significant damage to fences when they use them as rub posts. They may damage fences when entering gardens.

Damage Prevention and Control Methods

Habitat Modification

In general, habitat modification is not practical for the control of wild pigs.

Pregnant ewes, nanny goats, and cows should be moved to areas less frequented by wild pigs. Ewes that have twins are particularly vulnerable, as the young are smaller and maternal protection is divided.

Exclusion

Fences are not practical except in small areas around yards and gardens. Use heavy wire mesh with holes no larger than 6 inches with posts. A single strand of electric wire about 6 inches off the ground may reduce attempts by wild pigs to breach an existing fence.

Two-strand electric fences with one wire at 8 inches and another at 18 inches have been as effective as 3-strand fences in reducing incursions by 50% in one trial. Electric fences, however, can be difficult to maintain over large areas. Hog panels 34 inches in height were very effective in containing wild pigs, even when the pigs were chased.

Frightening Devices

No frightening devices are effective for the control of wild pigs. Harassment through hunting, if legal, may move pigs from an area for limited periods of time.

Repellents

No repellents are registered for the control of wild pigs in the US.

Toxicants

No toxicants are registered for the control of wild pigs in the US.

Shooting

In South Carolina, there is no closed season on wild hogs for private landowners with a valid hunting license during daylight hours. A free depredation permit may be issued to landowners who do not possess a hunting license. Go to www.dnr.sc.gov/ for additional information.

In urban areas, shooting may not be a viable option. Consult your local ordinances before discharging a firearm.

Trapping

Where pig densities are high, use of multiple-catch traps such as corral traps, is the most effective method for control of wild pigs. Single-capture traps are available also but are not as efficient.

When conducting a trapping program, all hunting in the area should cease, especially with the use of dogs, as this may pressure the pigs to move to another area. Persistence and dedication are required for trapping program to be successful.

Check traps daily and replace bait as needed. Recent advances in remote sensing technology allow trappers to monitor traps from a distance via a computer and trigger the trap remotely. If several large pigs are in a trap, the presence of a person or vehicle will frighten them and escapes may occur, even from well-built traps. Ideally, traps should be triggered remotely and only when all members of a sounder are inside a corral-style trap.

Disposition

Relocation

It is illegal to relocate a hog from the wild unless you possess a special permit through the SCDNR. Restrictions apply.

Translocation

Translocation of wild pigs is not permitted.

Euthanasia

A well-placed shot to the head from a high-powered rifle will kill a pig instantly.

In a corral trap, shoot the largest pig first and work your way down to the smaller pigs.

Resources

Government or private agencies, universities, extension service.

Web Resources

http://dnr.sc.gov

http://wildlifecontroltraining.com

http://icwdm.org/

http://wildlifecontrol.info

Prepared by the National Wildlife Control Training Program. WildlifeControlTraining.com Certified wildlife control training programs to solve human – wildlife conflicts. The only research-based source for training, animal handling and control methods, and wildlife species information.