MARCH 2010

DRAFT Crane Creek Watershed Management Plan

PREPARED FOR:

Richland County Department of Public Works
400 Powell Road
Columbia, South Carolina 29203

PREPARED BY:

Center for Watershed Protection

8390 Main Street, 2nd Floor
Ellicott City, MD 21043
www.cwp.org

This page has intentionally been left blank.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

E.1 Introduction

Located in the sandhills region of central South Carolina, the Crane Creek Watershed is approximately 67.5 square miles in size, encompassing portions of Richland County (County), the City of Columbia (City), and the Town of Blythewood (Town). The stream network includes the Crane Creek main stem and several major tributaries: Beasley Creek, North Branch Crane Creek, and Roberts Branch. The watershed is largely forested, but facing encroaching development from neighboring jurisdictions. Currently, 33% of the watershed is considered urbanized. Crane Creek is impaired for aquatic life and recreation, due to low levels of dissolved oxygen and benthic macroinvertebrates, and high levels of fecal coliform (SCDHEC, 2008). Past impairments were caused by elevated levels of copper and zinc. The entire Crane Creek Watershed is included in the Total Maximum Daily Load (TMDL) that was developed for Lower Broad River (SCDHEC, 2005).

According to the South Carolina Department of Health and Environmental Control (SCDHEC), the probable sources of fecal coliform in the watershed are stormwater runoff from municipal separate storm sewer system (MS4) areas, MS4 point sources, failing onsite wastewater disposal (OSWD) systems, leaking sewers, pets, and wildlife. In order to meet the State recreational surface water standards and attain the targeted fecal coliform reductions for the TMDL, fecal coliform loads in Crane Creek must be reduced by 48% upstream of Lake Elizabeth and by 92% downstream of Lake Elizabeth.

It is important to note that these numbers are based off of existing water quality monitoring data. As the Crane Creek watershed continues to develop, water quality is predicted to worsen. Results of a build-out assessment projected a rapid decline in the amount of forest cover, and a substantial increase in the amount of developed land and developed open space (i.e. lawns, turf cover), and a 160% increase in watershed impervious cover (CWP, 2009a). Assuming no changes are made to current regulatory and NPDES programs in the watershed, a substantial increase in nutrient loads and fecal coliform loads is predicted as the watershed develops.

In the spring of 2009, extensive retrofit, upland, stream, and conservation area field assessments were conducted throughout the Crane Creek watershed to evaluate pollution management and watershed restoration opportunities. During these assessments, field crew teams visited over 245 locations in the watershed and used one of seven field assessment methodologies to evaluate the feasibility of implementing a management or restoration practice. Approximately 44 potential stormwater retrofit sites, 27 potential hotspot locations, 56 residential neighborhoods, 15 erosion and sedimentation control sites, 26.5 miles of stream (85 stream reaches), 11 forest sites, and 8 wetland sites were assessed in the Crane Creek Watershed. Common problems observed in the watershed included a lack of stormwater management at older development sites, inadequate stormwater treatment at recent development sites, improper outdoor material storage, erosion and sedimentation control (ESC) violations, inadequate riparian buffer areas, sanitary sewer overflows, trash and dumping sites near the stream corridor, and minor stream bank erosion. Many opportunities for restoration projects and programs were identified.

One key component of the *Crane Creek Watershed Management Plan (Plan)* was to develop specific watershed protection and restoration objectives and then rank and prioritize the proposed projects identified from the field work according to these watershed objectives. A list of ranked watershed management and restoration projects along with estimated project costs are listed in Attachment E of this *Plan.* The projects are discussed in detail by subwatershed in Section 6, and are mapped in Attachment B. Watershed projects were ranking according to the following watershed factors listed below:

- *Cost* – The cost associated with project implementation. Project costs represent only planning level estimates and were determined based on guidance provided in Schueler et al. (2007), Wright et al. (2005) and Kitchell and Schueler (2004).
- *Community Education and Involvement* – Project with potential to educate and involve the community
- *Visibility* – Project with high visibility and potential to raise the public's awareness of the watershed (visible from street or located in public park)
- *Feasibility* – Project with high potential that it will be implemented. The site has access for equipment, low maintenance burden, serves as a demonstration site and is publicly owned
- *Water Quality Improvement* – Potential for treatment or prevention of pollutants. Treats water quality volume or eliminates exposure of pollutants to stormwater runoff
- *Ecological Benefit* – Project provides an ecological, habitat, or natural resource protection benefit
- *Meeting Watershed Objectives* – Potential for project to assist in achieving watershed objectives (see Section 4 of this report)

In addition to the identification of these restoration and management practices, a green infrastructure (GI) analysis was conducted to identify strategic watershed areas for conservation and protection. As a result of the GI analysis, primary conservation areas and conservation hubs were targeted for future watershed protection efforts. The total area included in the primary conservation network and conservation hubs accounts for 37.6% of the watershed area.

E.2 Watershed Objectives and Strategies

Feedback from a stakeholder meeting, along with input by the County, was used to establish seven specific watershed objectives that meet the vision of the CCWA and the initial watershed planning goals. These specific objectives are listed below.

1. Improve the water quality and biological condition of Crane Creek by implementing stormwater retrofits and addressing sources of nonpoint source pollution.
2. Improve the water quality of Crane Creek to meet the fecal coliform reductions identified in the 2006 TMDL (48% load reduction upstream and 92% downstream of Lake Elizabeth) and reduce sediment loads by 50%.

3. Reduce flooding by minimizing the creation of future impervious cover, installing stormwater retrofit practices on existing development sites that reduce stormwater runoff (i.e. rain gardens, permeable pavement, rain barrels, infiltration practices), and by encouraging the use of these runoff reducing stormwater practices on new or re-development sites.
4. Promote recreational activities such as hiking, trail walking, fishing and swimming along the Creek. Crane Creek should serve as an environmental corridor and recreational resource for the County.
5. Reduce the impact of future growth on the Crane Creek Watershed by promoting environmentally sound development codes, retaining the existing forest canopy cover, and protecting 30% of the open space lands in the watershed.
6. Protect and restore sensitive and natural resource areas such as mature, hardwood and pine forests, isolated wetlands, environmentally sensitive areas, and intact stream buffers.
7. Increase the understanding and awareness of Crane Creek among residential, commercial, business, development, and local government communities through pollution prevention education, watershed restoration activities, trainings and workshops.

Based on these watershed objectives and the results of the watershed characterization assessment, field findings, and GI analysis, twelve key strategies were developed that are presented in order of implementation priority. These strategies focus on municipal practices and programs, natural resources protection, the treatment of polluted runoff, and source control and education.

1. **Implement programmatic changes to improve the County ESC regulations, enforcement, and inspection program**
2. **Inventory and map key resource areas**
3. **Permanently protect primary conservation areas**
4. **Adopt the Richland County Roundtable code and ordinance recommendations**
5. **Hire a Watershed Coordinator**
6. **Implement priority retrofits for water quality improvement**
7. **Explore opportunities for additional retrofits in neighborhoods**
8. **Conduct stream clean-ups and implement priority stream corridor projects**
9. **Conduct a neighborhood education campaign to educate residents about pollution prevention and source control**
10. **Develop a Green School and Institution Program**
11. **Develop a Business Stewardship Outreach Program**
12. **Promote partnership between the County, City, and Town for SSO response and repair programs, septic system education programs, and IDDE programs.**

These strategies are detailed in Section 4 of this *Plan*, and Section 5 details recommended short-term, mid-term, and long-term actions to support these strategies.

E.4. Implementation Costs and Timeline

Implementation is by far the longest and most expensive step in the watershed management process. In fact, restoration and protection costs for a single suburban subwatershed can easily range in the million dollars depending on the extent of restoration and protection activities, number of jurisdictions involved, land costs, and other factors. Section 5 of this Plan presents information on planning partners, planning level costs, and phasing and resources for implementing watershed strategies. Table E.1 below provides a draft implementation schedule and associated costs for implementing each short term, mid term and long term actions. Additional tables in Section 5 provide information on the watershed objectives met through implementation of these strategies, responsible parties, and long-term milestones for implementation of each strategy.

The cumulative estimate for implementing the 12 watershed strategies exceeds 9.8 million dollars over the next 5-10 years (Table E.1). The largest component of these cost results from the estimated cost of acquiring the conservation areas. Costs associated with watershed strategy 6 alone are estimated at 6.9 million dollars, which assume land acquisition costs for 500 acres of land along with greenway construction (Richland County, 2009a). These costs associated with the protection of conservation areas can be greatly reduced by encouraging public involvement in voluntary easement and land trust programs. Management and restoration costs for the remainder of the watershed amount to 2.9 million dollars over the next 5-10 years.

E.5 Pollutant load reductions

Table E.3 shows the pollutant load reduction estimates based on the watershed actions outlined in Section 5 as well as on-going implementation actions by the County, City and Town that include enhanced ESC measures, targeted business and residential outreach programs, and an effective IDDE program. The load reductions are based on realistic implementation scenarios over the next ten years. These numbers equate to a reduction of 19,124 lb TN, 1,489 lb TP, 655.347 lb TSS, and 754,875 billion units of bacteria per year. Overall the effect of restoration implementation would result in an 8.5% reduction in total nitrogen, close to a 5.6% reduction in total phosphorus, a 7.1% reduction in total suspended solids and a 15.9% reduction in bacteria. The recommended actions fall short of the watershed objectives for bacteria and sediment pollutant load reductions. Expanding the watershed strategies and increasing monitoring and source tracking efforts can help to better meet pollutant reduction goals.

Table E.1 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 1. Implement programmatic changes to County ESC program	• Conduct follow-up inspections at identified problem ESC sites (Attachment E) • Implement ESC recommendations from Post-Construction stormwater review • Require a 'grassing bond' at beginning of project • Improve coordination of ESC and stormwater program between the Stormwater Division and the Engineering Division	• Hire more ESC inspectors • Increase training for County ESC inspectors. • Limit the amount of development in soils with high clay content • In sandy areas where establishing vegetation is challenging, consider using turf matting to stabilize soils	• Consider County assistance with soil stabilization
Strategy 1 Costs	$40,000	$200,000	$50,000
Strategy 2. Inventory and map natural resource areas	• Conduct additional field work to supplement Crane Creek data	• Develop and adopt a watershed map of all perennial and intermittent streams • Locate, map and protect RTE species within the watershed • Complete a local wetland inventory and incorporate mapping information into local planning documents	• Incorporate the data into GIS layers and use the data during development plan reviews
Strategy 2 Costs	$35,000	$175,000	$40,000
Strategy 3. Permanently protect primary conservation areas	• Establish an Environmental Protection Overlay district in the Crane Creek Watershed • Encourage the adoption and use of the Green Code • Require protection of wetlands that appear to be isolated, especially when they have high water quality or habitat value • Promote the County's Rural Legacy program, which can support conservation easements on forested and agricultural parcels • Promote sustainable management of forests	• Direct mitigation and TDR efforts into conservation hub and primary conservation areas identified in the GI network • Consider opportunities for restoration of the native Longleaf pine ecosystem especially where they can be connected to other Longleaf pine habitat • Develop a map of watershed conservation areas	• Construct a greenway trail • Aim to preserve 30% of the watershed as open space

Table E.1 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 3 Costs	$65,000	$300,000	$6,500,000
Strategy 4. Adopt County roundtable recommendations	• Implementation committee should meet on a quarterly basis to move forward with recommendations • Enforce the 100-foot Stream Buffer Ordinance		
Strategy 4 Costs	$35,000	$40,000	$10,000
Strategy 5. Hire a Watershed Coordinator	• Hire a full-time coordinator with county and city support.		
Strategy 5 Costs	$ 35,000		
Strategy 6. Implement priority stormwater retrofits	• Identify funding sources for retrofits • Modify, repair, and/or maintain existing stormwater management facilities to improve water quality performance • Engage the public with implementation (e.g. planting, etc.)	• Disconnect downspouts to allow for treatment and volume reduction of rooftop runoff • Retrofit existing stormwater or recreational ponds in neighborhoods to improve water quality and reduce fecal coliform loads • Construct bioretention areas or rain gardens to capture stormwater runoff and provide water quality treatment	• Implement additional high priority stormwater retrofits
Strategy 6 Costs	$85,000	$144,000	$300,000
Strategy 7. Explore opportunities for additional retrofits in neighborhoods	• Explore an opportunity for pipe day-lighting at a closing school facility (L-RRI-09B).	• Evaluate opportunities for an on-site storage retrofit at Northpoint Business Park (C-RRI-101) • Further assess opportunities in neighborhoods with little or no existing stormwater management	• Where possible, remove excess or unused impervious cover • Continue to identify retrofit opportunities at schools, neighborhoods, commercial areas, and existing outfalls that do not have existing BMPs
Strategy 7 Costs	$30,000	$35,000	$100,000
Strategy 8. Conduct stream clean-ups and implement stream repair projects	• Conduct monthly stream clean-ups in the high-priority, trash impacted sites • Evaluate stream restoration opportunity at Northpoint Business Park (C-RRI-101)	• In areas of severe active erosion, repair and stabilize banks using stream restoration techniques • Implement additional high-priority stream projects	• Discourage the placement of wastewater pipes across stream channels • Discourage the placement of utilities near streams and wetlands
Strategy 8 Costs	$15,000	$68,000	$75,000

Table E.1 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 9. Conduct neighborhood education campaign	• Identify neighborhood leaders for community stewardship • Develop educational materials for pollution prevention, source control	• Expand the storm drain marking program into older neighborhood • Disconnect residential downspouts to allow for treatment and volume reduction of rooftop runoff • Develop a targeted residential education program on the proper application of fertilizer and use of alternatives to grass lawns that include native species landscaping • Conduct a trash education program that includes a residential education program that addresses proper disposal of trash and recycling • Conduct a stream buffer education program that specifically targets residential homeowners • Pilot the program in high priority neighborhoods	• Increase neighborhood tree canopy and encourage natural buffer regeneration at residences along stream corridors
Strategy 9 Costs	$50,000	$200,000	$75,000
Strategy 10. Develop a *Green School and Institution Program*	• Coordinate with institutions with priority retrofit projects (strategy 6)	• Develop a green school program that includes reforestation, stormwater retrofits and pollution prevention	• Expand the program to include additional institutions
Strategy 10 Costs	$50,000	$150,000	$100,000
Strategy 11. Develop a business stewardship outreach program	• Compile a list of hotspots on private businesses and residences and conduct a follow-up inspection to confirm the current condition of these sites • Require secondary containment for auto salvage yards where fluids are drained from vehicles • Provide the County Solid Waste Division with a list of poor trash management sites for compliance inspections	• Provide education on pollution prevention to targeted businesses and implement stormwater retrofits and pollution source control measures	• Develop a *Business Stewardship Outreach Program* that engages the business community in watershed restoration
Strategy 11 Costs	$70,000	$140,000	$50,000

Table E.1 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 12. Partnership for SSO response and repair programs, septic system education programs, and IDDE programs	• County to coordinate with City on IDDE program development	• City and County to coordinate to ensure timely repair of SSOs • Provide education on septic system maintenance	
Strategy 12 Costs	$20,000	$150,000	
Additional Recommendation		• Expand County water quality monitoring program (see Section 5.4)	
Additional Costs		$100,000	
Sub Totals	**$530,000**	**$1,937,000**	**$7,407,000**
Grand Total	**$9,874,000**		
*Note: These cost estimates include staff time, materials, supplies, and construction costs where applicable			

Table E.2. Annual Load Reductions from Recommended Practices				
Management Practice	**N (lbs/ac/year)**	**P (lbs/ac/year)**	**TSS (lbs/ac/year)**	**Bacteria (billion/ac/year)**
Lawn Care Education	0.236	0.005	0.000	0.000
Pet Waste Education	0.029	0.004	0.000	0.253
Erosion and Sediment Control	0.009	0.011	10.921	0.000
Impervious Cover Disconnection	0.009	0.001	0.248	0.393
Structural Stormwater Management Practices (including retrofits)	0.005	0.001	0.487	0.738
Riparian Buffers	0.125	0.006	9.462	0.000
Septic System Education	0.004	0.000	0.013	0.029
Illicit Connection Removal	0.022	0.006	0.158	12.909
SSO Repair/ Abatement	0.004	0.001	0.028	3.160
Channel Protection	0.000	0.000	0.218	0.000
Total Reduction per Watershed Acre	**0.44**	**0.03**	**21.54**	**17.48**
	N (lbs/year)	**P (lbs/year)**	**TSS (lbs/year)**	**Bacteria (billion/year)**
Total Reduction in the Entire Watershed	**19,124**	**1,489**	**655,347**	**754,875**
% Reduction over Existing Conditions	**8.5%**	**5.6%**	**7.1%**	**15.9%**

Long-term goals have been set to mark progress to ensure the implementation of the *Plan* adheres to a schedule to meet the defined outcomes.

- Meet interim milestones for each strategy (see Section 5)
- Meet ½ of the load reduction goals for stream restoration, downspout disconnection, stormwater retrofitting, urban turf conversion, SSO abatement, street trees. These load reduction values are presented in Section 7 of this *Plan.*
- Reduce baseflow concentrations of bacteria at monitoring stations by 20%. Although this number falls short of the targeted reductions for the TMDL, this number represents the expected load reductions that resulted from watershed modeling (Section 7). Additional monitoring is needed to better quantify bacteria loading and required watershed reductions (Section 5.4).
- Track improvements in the stream water quality and biology using the existing monitoring sites and recommended additional monitoring sites. Evaluate at five years any improvements in trends that may have occurred due to implementation efforts.

After 5 years time, this *Plan* should be updated to include recent watershed developments and monitoring results.

SECTION 1. INTRODUCTION

1.1 Process for Developing the Watershed Management Plan

The *Crane Creek Watershed Management Plan (the Plan)* is the culmination of over one year of extensive desktop analyses, field assessments, and stakeholder meetings conducted by the Center for Watershed Protection (the Center). The scope of work for the Center and Richland County (the County) consisted of three major tasks:

1. Perform a watershed baseline characterization assessment
2. Identify potential restoration and protection opportunities by conducting riparian corridor, upland pollution prevention, and stormwater retrofit assessments
3. Craft a *Watershed Management Plan* for the watershed

The initial task in developing this *Plan* was to develop an understanding of the baseline, or current, conditions of the Crane Creek watershed. To accomplish this, the Center first reviewed existing watershed data, studies, and reports. In addition, the Center analyzed extensive watershed Geographical Information System (GIS) data.

An audit of local municipal programs and policies was conducted for the County, the City of Columbia (the City), and the Town of Blythewood (the Town). The audit covered the following topic areas: land-use planning, land conservation, aquatic buffers, stormwater discharges, non-stormwater discharges, erosion and sediment control, and watershed stewardship. The information gained from the audit can be used to identify existing local tools that can be applied to watershed restoration and protection efforts, and to identify gaps and weaknesses in current programs and regulations.

The Watershed Treatment Model (WTM) was then used to estimate existing and future bacteria, sediment, and nutrient loads within the watershed. This information was used, in part, to target specific locations for more detailed and intensive field assessments.

The major outcomes of the baseline assessment task were 1) an understanding of the current conditions of the watershed; 2) knowledge about the existing codes and regulations that influence watershed management strategies; and 3) estimates of current and build-out bacteria, sediment and nutrient loading in the watershed. Work completed as part of the baseline assessment task is documented in the report, *Crane Creek Watershed Characterization Report* (CWP, 2009a), and summarized in Section 2 of this *Plan*.

The next major task in developing this *Plan* was to identify stormwater retrofit, pollution prevention, and stream restoration opportunities in the watershed. The Center conducted upland and stream field assessments in Crane Creek watershed in spring 2009. During this assessment period, field crews assessed approximately 44 potential retrofit sites, 27 potential hotspot locations, 56 residential neighborhoods, and 15 erosion and sedimentation control sites in the Crane Creek watershed. In addition, 26.5 miles of stream (85 stream reaches), 11 forest sites, and 8 wetland sites were evaluated.

Due to the large size of the watershed, field efforts targeted priority areas as identified through a desktop analysis. In addition to the field assessments, a green infrastructure (GI) analysis was conducted to identify strategic watershed areas for conservation and protection. The findings of the fieldwork and GI analysis are summarized in Section 3 of this *Plan*. The fieldwork findings are also presented in detail in a technical memorandum *Summary of Findings from the Crane Creek Watershed Field Assessments* (CWP, 2009b).

Using input from the County and watershed stakeholders, the Center developed a ranking system to prioritize identified management and restoration practice opportunities within each practice category. Using best professional judgment, each practice location was assigned points and ranked according to several factors including: cost; community education and involvement, visibility; feasibility; water quality improvement; and ecological benefit; and the ability to meet the watershed objectives.

The Center, along with input from the County and watershed stakeholders developed watershed management objectives. The Center then re-examined all data collected over the course of the project – baseline information, Watershed Treatment Model results, field observations, field assessment results, Crane Creek Watershed goals and objectives – and developed 12 key management and protection strategies for the watershed, as described in Section 4. These 12 strategies are the core of this *Plan.* They provide a framework for implementing the numerous management and restoration practices identified through field assessments as well as program and education related recommendations identified through desktop analyses, local program audit, and field assessments.

Recommended short-term, mid-term, and long-term actions to support the 12 watershed strategies are presented in Section 5. A detailed implementation plan was compiled that outlines the key watershed actions and information on individuals responsible for implementation, an implementation timeline, and summary cost information. Information on project tracking and monitoring are also provided.

The Center then developed specific management strategies for the three planning level subwatersheds: Beasley Creek, Upper Crane Creek, and Lower Crane Creek (Section 6). The subwatershed management strategies highlight potential restoration and protection opportunities and management priorities in the watershed.

Finally, pollutant load estimates were developed for two future build-out watershed scenarios using the WTM. The first build-out assesses growth assuming no implementation of the watershed strategies, whereas the second buildout assumes implementation of the 12 watershed strategies and supporting actions. The WTM results and estimated pollutant load reductions are presented in Section 7.

1.2 U.S. EPA Watershed Planning "A-I Criteria"

In 2003, the U.S. Environmental Protection Agency (EPA) began to require that all watershed restoration projects funded under Section 319 of the federal Clean Water Act to be supported by a watershed plan that includes the following nine minimum elements, known as the "a-i criteria":

a. Identification of the causes and sources that will need to be controlled to achieve the load reductions estimated in the watershed plan
b. Estimates of pollutant load reductions expected through implementation of proposed nonpoint source (NPS) management measures
c. A description of the NPS management measures that will need to be implemented
d. An estimate of the amount of technical and financial assistance needed to implement the plan
e. An information/education component that will be used to enhance public understanding and encourage participation
f. A schedule for implementing the NPS management measures
g. A description of interim, measurable milestones
h. A set of criteria to determine load reductions and track substantial progress towards attaining water quality standards
i. A monitoring component to determine whether the watershed plan is being implemented

This *Plan* meets the a-i criteria. Table 1.1 shows where these criteria are addressed throughout this document.

Table 1.1. U.S. EPA Watershed Planning "A-I" Criteria

Section of the report	A	B	C	D	E	F	G	H	I
Section 1. Introduction									
Section 2. Baseline Conditions	X								
Section 3. Watershed Assessment Protocols, General Findings, and Green Infrastructure Analysis	X								
Section 4. Watershed Goals, Objectives, and Strategies			X						
Section 5. Recommended Watershed Management Actions and Implementation Plan	X		X	X	X	X	X	X	X
Section 6. Subwatershed Management Strategies	X		X		X				
Section 7. Estimates of Pollutant Loads and Reduction Strategies		X							

1.3 Plan Organization

The *Plan* is organized as follows:

Section 1. Introduction – provides an introduction to the Crane Creek Watershed Assessment and Management Report as well as the project history.

Section 2. Baseline Conditions in the Crane Creek Watershed – describes the baseline, or current, conditions of natural features, community features, and land use and cover in the Crane Creek watershed.

Section 3. Watershed Assessment Protocols, General Findings, and Green Infrastructure Analysis – provides an overview of retrofit, stream, upland, and conservation assessment methodologies and key findings, along with the results of a green infrastructure analysis.

Section 4. Watershed Goals, Objectives, and Strategies – presents the goals and objectives for managing the Crane Creek watershed along with 12 key watershed management strategies based on watershed assessments and desktop analyses conducted by the Center.

Section 5. Recommended Watershed Management Actions and Implementation Plan – describes actions that support the 12 key strategies, along with information on planning partners, project phasing, planning level costs, and resources for implementing watershed strategies.

Section 6. Subwatershed Management Strategies – describes management strategies for each of the three subwatersheds: Beasley Creek, Upper Crane Creek, and Lower Crane Creek.

Section 7. Estimates of Pollutant Loads and Reduction Strategies– presents the pollution load reduction results of the WTM along with the results of two watershed build-out assessments.

1.4 Caveats

It is important to keep in mind that this *Plan* is limited in scope and should be updated as more information on the watershed is acquired. Recommendations are based on desktop analysis, program audit, and observations made during targeted upland and stream assessments. While representative sites from across the watershed were assessed, all stream miles and upland areas were not assessed. In the future, additional assessments should be conducted in areas of concern and this *Plan* updated to reflect watershed changes and developments.

SECTION 2. WATERSHED OVERVIEW AND BASELINE CONDITIONS

2.1 Watershed Overview

Located in the sandhills region of central South Carolina, the Crane Creek Watershed is approximately 43,177 acres (67.5 square miles) in size, encompassing portions of the County, the the City, and the Town (Figure 2.1). Crane Creek feeds into the Broad River just north of the City of Columbia at river station 14,900. The stream network includes the Crane Creek main stem and two major tributaries: Beasley Creek and North Branch. The watershed is largely forested, but facing encroaching development from neighboring jurisdictions. Currently, 33% of the watershed is considered urbanized. Crane Creek is impaired for aquatic life and recreation, due to low levels of dissolved oxygen and benthic macroinvertebrates, and high levels of fecal coliform (SCDHEC, 2008). Past impairments were caused by elevated levels of copper and zinc. The entire Crane Creek Watershed is included in the Total Maximum Daily Load (TMDL) that was developed for Lower Broad River (SCDHEC, 2005). A basic profile of the Crane Creek watershed is shown in Table 2.1.

Table 2.1. Basic Profile of the Crane Creek Watershed	
Watershed Area	43,177 acres (67.5 square miles)
Subwatersheds	Beasley Creek, Upper Crane Creek, Lower Crane Creek
Jurisdictions	Richland County, City of Columbia, Town of Blythewood
Stream Length	121.2 miles
Water Quality	- 2006 TMDL for fecal coliform - 2004 303(d) list for benthic invertebrates and fecal coliform - 2006 303(d) list for benthic invertebrates - 2008 303(d) list for benthic invertebrates and dissolved oxygen - 2010 303(d) list for benthic invertebrates and dissolved oxygen
Land Use (%) (NCLD, 2001)	Forested (48.9%), Developed (18.5%), Open Space (14.4%), Wetlands and Open Water (6.5%), Agriculture (3.9%), Other (7.7%)
Impervious Cover	8.9%
Soils (%)	
HSG A	19.0%
HSG B	50.5%
HSG C	16.6%
HSG D	9.5%
Major Transportation Routes	I-77, I-20, I-26, US 21, US 321

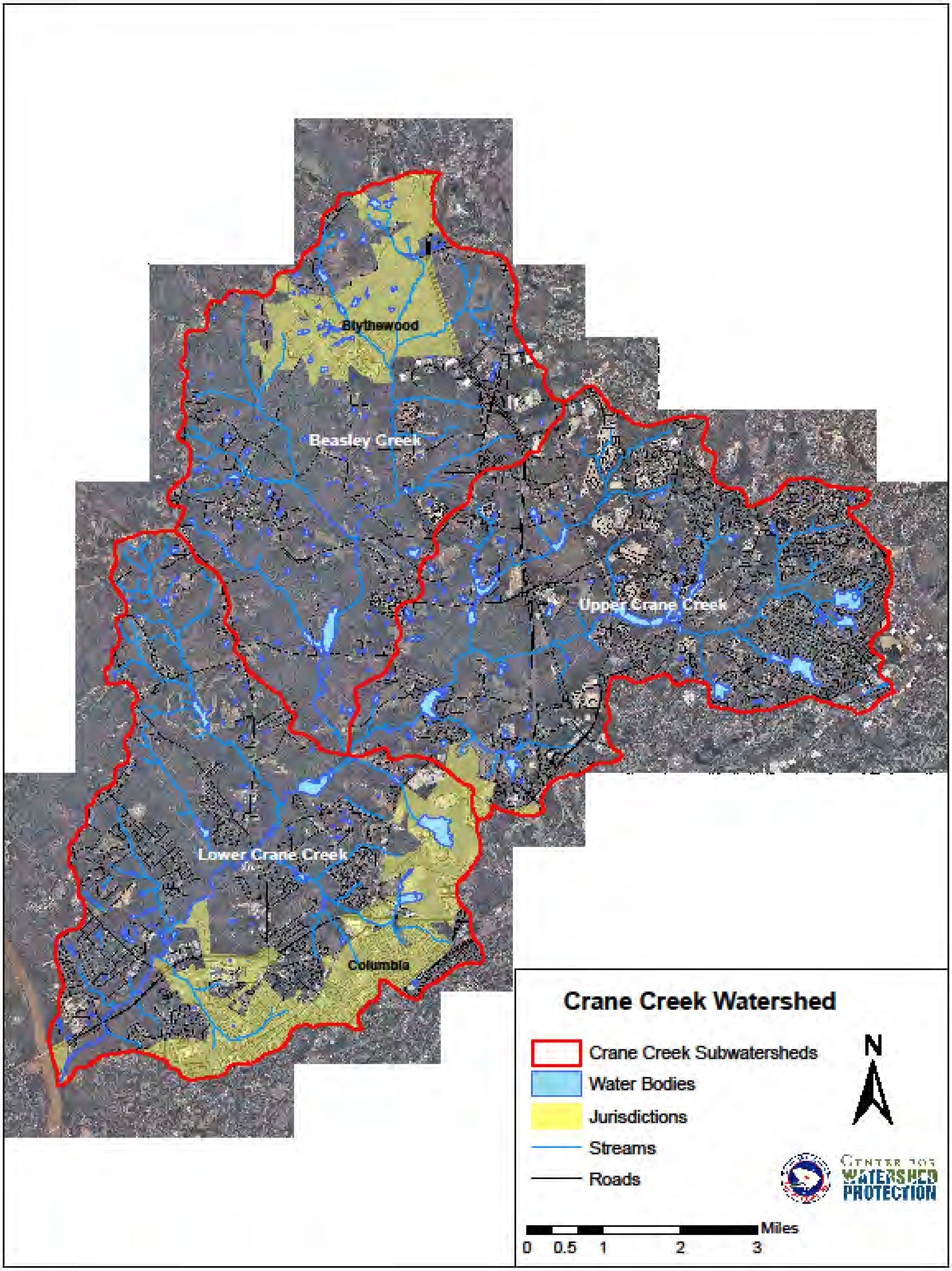


Figure 2.1. The Crane Creek Watershed

The initial task in developing the *Plan* was to develop an understanding of the baseline, or current, conditions of the watershed. To accomplish this, the Center:

- Reviewed existing watershed data, studies and reports;
- Analyzed watershed Geographical Information System (GIS) data; and
- Developed a baseline WTM for existing and future build-out watershed conditions

The results of the baseline were detailed in the *Crane Creek Watershed Characterization Report* (CWP, 2009a). The subsequent topics covered in this section provide a summary of information on the watershed hydrology, water quality, natural features, community features, and land use of the watershed. Findings on an assessment of local watershed protection programs and regulations are included, as well as the estimated pollutant loadings for the watershed based and current and projected future conditions.

2.2 Hydrology

Climate

Crane Creek is located in northern Richland County, SC. Richland County is a 756 square mile expanse of lowland, sand hills, and rolling countryside and is situated in the geographic center of SC, midway between the Appalachian Mountain chain and the Atlantic coastal area. The mean annual precipitation for the County is 47.0 inches. Precipitation is generally well distributed throughout the year, with the wettest conditions occurring from June to August, and the driest in November. Average temperatures range from a high of 80.1 °F in July, to a low of 43.0 °F in January (SC Climatology Office, Sandhill Experiment Station, Richland County, SC).

Subwatersheds

Crane Creek has three subwatersheds as previously delineated by the County: Lower Crane Creek, Upper Crane Creek, and Beasley Creek. Two subwatersheds, Lower Crane Creek and Beasley Creek, are further divided by their jurisdictional boundaries. The percent impervious cover for subwatershed area varies, with the highest impervious cover in the City portion of Lower Crane Creek (24%), followed by Upper Crane Creek (12%). Both the County and Town portion of the Beasley Creek subwatershed have the lowest percent impervious cover (3% and 2% respectively) (Table 2.2). Impervious cover data were obtained from the National Land Cover Database (NLCD) 2001 Impervious Layer. The data have a 30 meter resolution and was downloaded from the Multi-Resolution Land Characteristics Consortium (MRLC) (www.mrlc.gov/index.php).

Table 2.2. Crane Creek Subwatershed Characteristics						
Subwatershed	**% of Watershed Area**	**Jurisdiction**	**Area (acres)**	**Stream Length (miles)**	**IC (acres)**	**IC (% of target area)**
Beasley Creek	32%	County	11,583.0	30.3	385.0	3.3%
		Town	2,264.0	5.9	48.8	2.2%
Upper Crane Creek	33%	County	14,322.0	37.1	1,700.4	11.9%
Lower Crane Creek	35%	County	11,681.0	40.4	885.1	7.6%
		City	3,327.1	7.5	806.4	24.2%
Watershed Total			43,177.1	121.2	3,825.7	8.9%

2.3 Water Quality

Water Resources

The three main branches of Crane Creek traverse 121.2 miles of land through the northern part of the County. Several lakes, ponds, and swamps are present in the watershed. Although Crane Creek is an impaired urban stream, historically it was not subject to extreme channel modification. In the early 1930's, the stream was dammed and modified to create man-made lakes, most notably Lake Elizabeth and Hospital Lake on the Lower Crane Creek Branch. The Upper Crane Creek subwatershed contains several additional area ponds and lakes, including Crescent Lake, Stevenson's Lake, Elder's Pond, Sunny Acres Pond, and Hidden Acres Pond. These lakes are primarily used for recreational activities.

Lake Elizabeth is an approximately 34 acre in-stream lake located at the confluence of Crane Creek and Cumbess Creek. The watershed drainage area upstream of the lake is approximately twenty-two square miles. The lake is used as a recreational water resource by the community and as a water source for wildlife. In recent years, bank erosion of the creek and subsequent sedimentation and increased flooding in neighborhoods has occurred around the lake. Additionally, the increased sediment loads have resulted in a decline in fish and aquatic habitat. In fall 2008, Genesis Consulting Group conducted a study along a three mile stream reach from Hospital Lake to Lake Elizabeth to identify sources of sediment that ultimately drain to Lake Elizabeth. Results revealed that overall channel erosion and scour was considered minor to moderate; however inadequate erosion and sediment control practices associated with nearby development were identified as major sources of sediment to the stream. A recommendation was made for the County to increase erosion and sediment control inspections based on the identification of several construction sites with insufficient sediment and erosion control (Genesis Consulting Group, 2009).

Water Quality Monitoring

Crane Creek has been the subject of several water quality monitoring efforts over the past decade. This is primarily due to its location in the Broad River Basin, which is subject to a

TMDL for fecal coliform. Two State water quality gauging stations are located in the Crane Creek watershed; Station # B-316 , a primary station sampled year round (Crane Creek at S-40-43 under I-20 – North Columbia), and Station # B-110 a secondary station sampled May-October (Elizabeth Lake at US 21). A third station, # B-081 (Crane Creek at US 321) is used for macroinvertebrate community assessment (SCDHEC, 2008a). These stations have been in use for more than a decade to collect water quality data. Figure 2.3 shows the location of these State monitoring stations.

Additionally, the County conducts monitoring for macroinvertebrates, dissolved oxygen, sediment, ambient water quality and wet weather monitoring (Figure 2.4). Currently, monitoring data are being used to establish a baseline for water quality conditions. Initial results from wet weather monitoring in the County have detected elevated levels of total kjeldahl nitrogen (TKN), nitrite and nitrate nitrogen, dissolved phosphorus, and total phosphorus at some County outfalls, an indication that residential fertilizer application may be impacting storm water quality at these outfalls (Richland County, 2008).

Impaired Waters

Crane Creek is impaired for aquatic life and recreation, due to low levels of dissolved oxygen and benthic macroinvertebrates, and high levels of fecal coliform (SCDHEC, 2008a). Past impairments were caused by elevated levels of copper and zinc. The entire Crane Creek Watershed is included in the Total Maximum Daily Load (TMDL) that was developed for Lower Broad River (SCDHEC, 2005) (Figure 2.2). A summary of past impairments for Crane Creek is shown in Table 2.3. According to the South Carolina Department of Health and Environmental Control (SCDHEC) (2005), the probable sources of fecal coliform in the watershed are stormwater runoff from municipal separate storm sewer system (MS4) areas, MS4 point sources, failing onsite wastewater disposal systems, leaking sewers, pets, and wildlife. In order to meet the State recreational surface water standards and attain the targeted fecal coliform reductions for the TMDL, fecal coliform loads in Crane Creek must be reduced by 48% upstream of Lake Elizabeth and by 92% downstream of Lake Elizabeth.

Comparisons of 303(d) listings from 2001 to present suggest that some improvements in water quality are occurring in the watershed. As Table 2.3 shows, the stream is no longer listed for zinc or copper, constituents that had been found in past samples. According to the SCDHEC Broad River Basin Water Quality Information, aquatic life uses are now partially supported based on biological data, and there is an increasing trend in pH. Data from state water quality sampling station B-316 indicate that turbidity levels and fecal coliform levels are decreasing (SCDHEC, 2008b). However, Crane Creek still exceeds the TMDL for fecal coliform for the Broad River, and macroinvertebrate sampling still indicates impairment for biological organisms. A November 2008 study assessed benthic macroinvertebrate data at three sampling sites (Station #B-081, Station #B-316, and an additional station near Alta Vista Road in Upper Crane Creek) found that the macroinvertebrate community was stressed at all three sampling sites. The rating for the sites was either poor to fair based on the SCDHEC bioclassification system (Carnegey Biological Services, 2008). In addition, DDT and metabolites of DDT and cadmium were detected in sediment samples taken within the last five years (SCDHEC, 2008b).

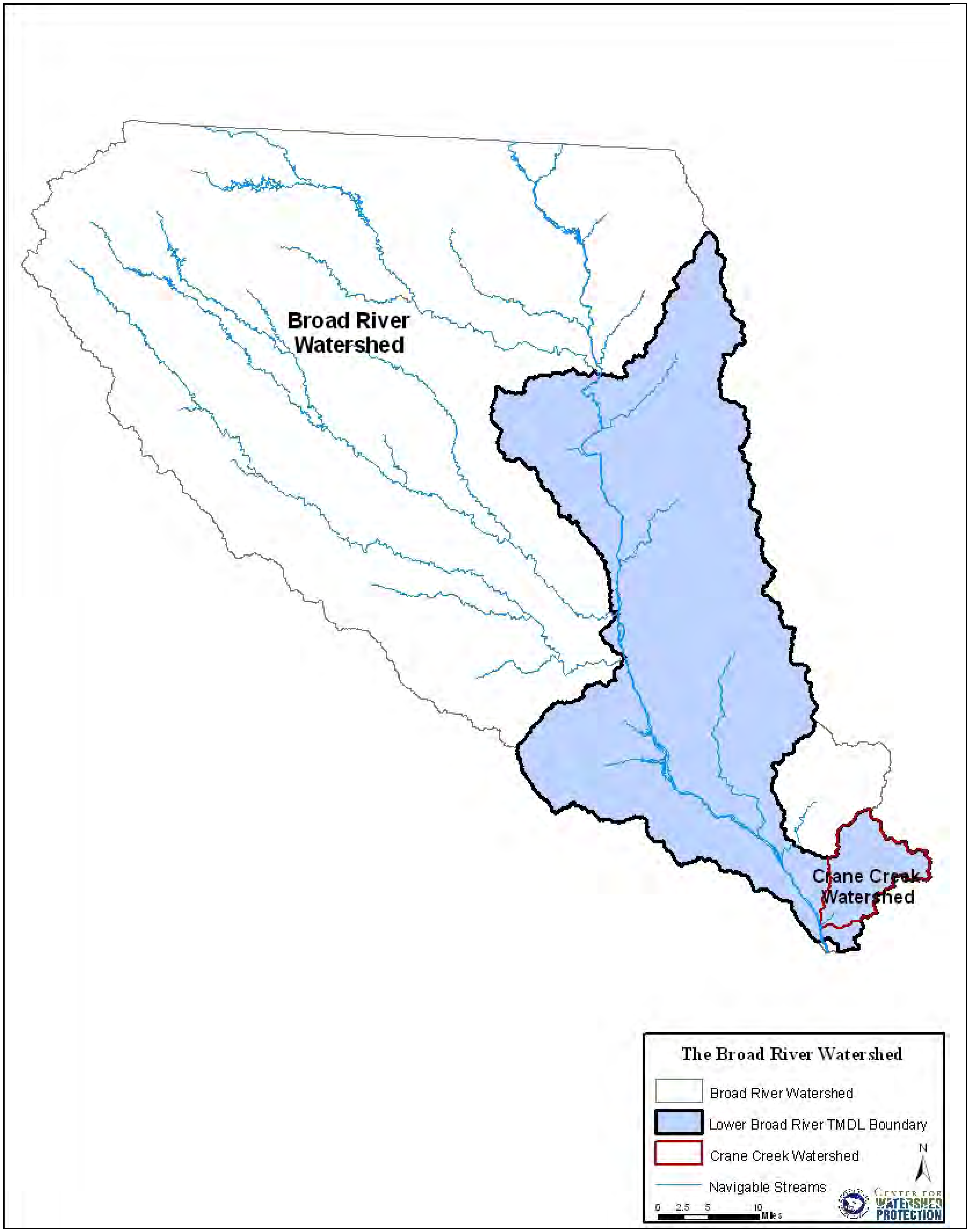


Figure 2.2. The lower Broad River TMDL

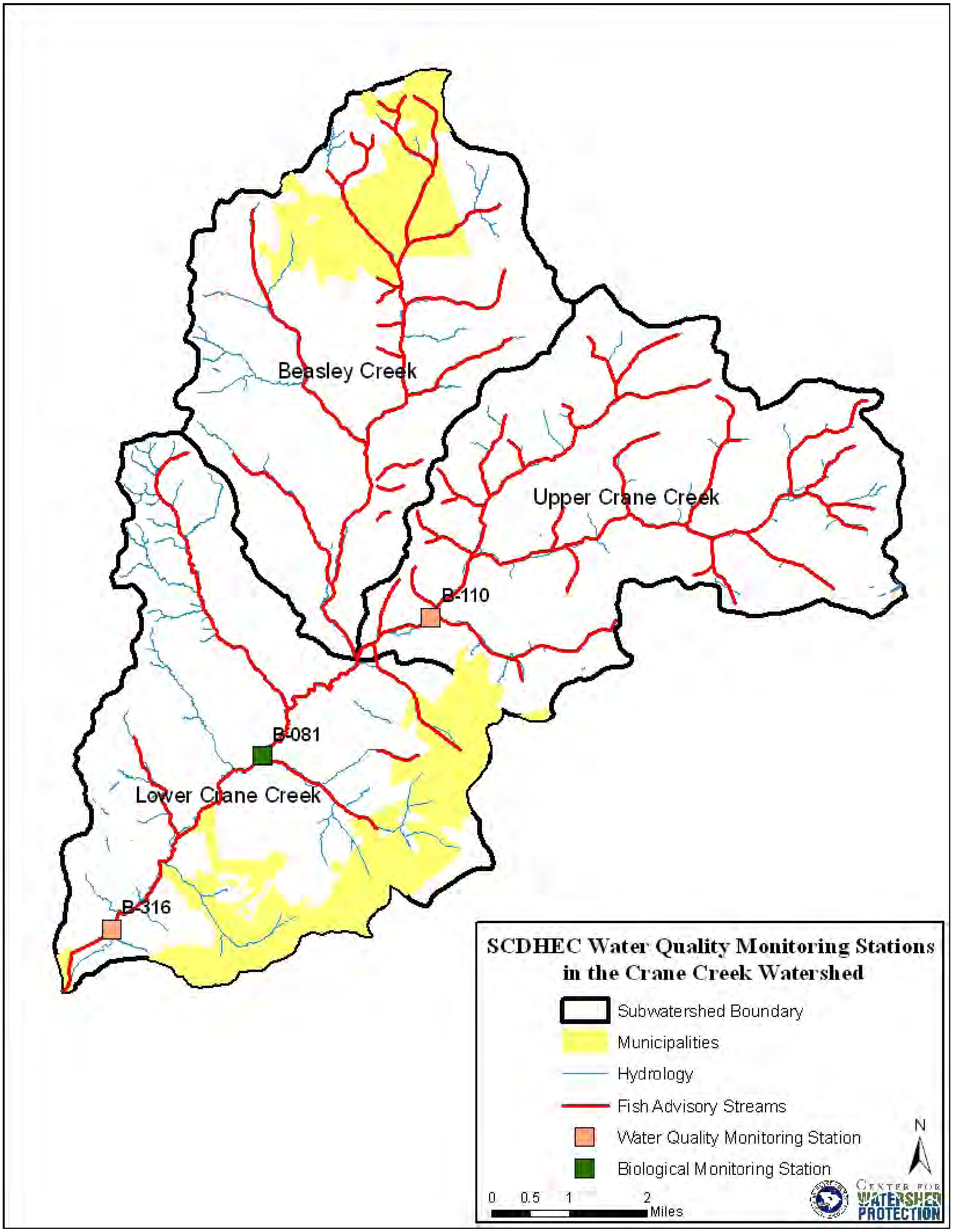
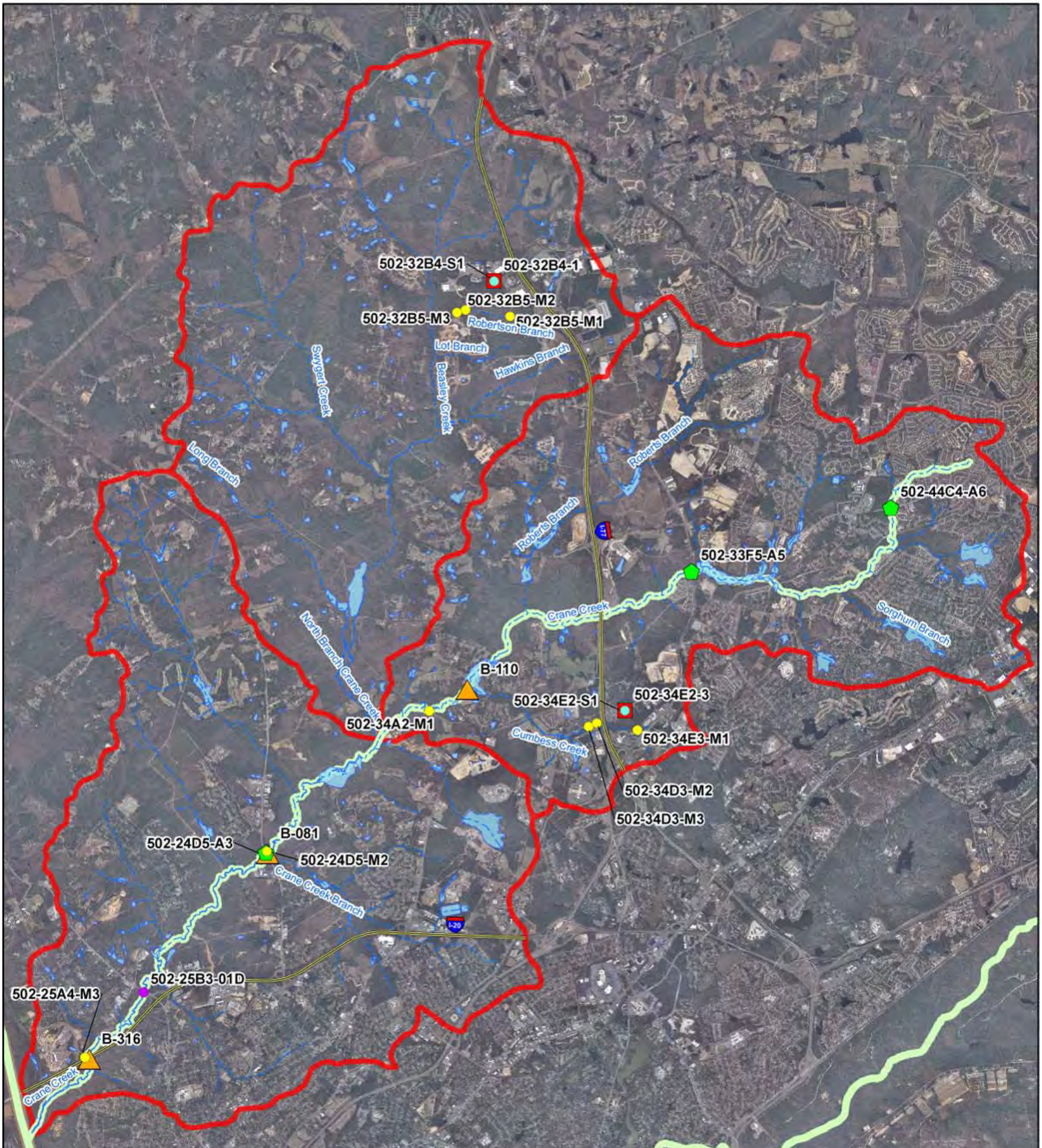


Figure 2.3. Locations of the SCDHEC water quality monitoring stations.

Crane Creek Watershed



Legend

- Macroinvertebrate Sampling - 9
- D.O. Collection Sites - 1
- Sediment Sampling - 2
- Ambient Water Quality Monitoring - 3
- Wet Weather Monitoring Stations - 2
- DHEC Sampling Sites - 3
- Interstates
- Impaired Water
- Crane Creek Watershed

DISCLAIMER: This is a product of the Richland County Public Works Department. The data depicted here have been developed with extensive cooperation from other county departments, as well as other federal, state and local governments agencies. Reasonable efforts have been made to ensure the accuracy of this map. Richland County expressly disclaims responsibility for damages or liability that may arise from the use of this map.

Table 2.3. Summary of Water Quality Impairments in the Crane Creek Watershed by Year (SCDHEC, 2008a)							
Monitoring Station ID	Monitoring Year						
	1998	2000	2002	2004	2006	2008	2010
B-081	BIO	BIO	BIO	BIO	BIO	BIO	BIO
B-110				FC	FC*	FC* Fully Supporting	FC* Fully Supporting
B-316	FC, CU, ZN	FC, CU, ZN	FC	FC	FC*, BIO	DO, FC* Not Supporting	DO, FC* Not Supporting,

BIO=macroinvertebrates (stream biology), CU=copper, DO=dissolved oxygen, FC = fecal coliform, ZN = zinc
*FC TMDL developed 2006. 2006 supporting data was not reported

Currently, there is no State water quality gauging stations located along the North Branch Crane Creek or Beasley Creek tributaries. These tributaries drain to the impaired stations B-081 and B-316 and may be a source of pollution to these stations. The monitoring section of this *Plan* (Section 7.3) presents a recommendation to establish a permanent gauging station in the Beasley Creek Subwatershed near the confluence with the Crane Creek mainstem. This station will provide data on the unknown condition of Beasley Creek.

2.4 Natural Resources

Richland County lies in two physiographic provinces: the Piedmont Plateau (1/3) and Atlantic Coastal Plain (2/3) (USDA, 1978). The two provinces join along an irregular line that runs from the City west of US Hwy 21 to the Town, bisecting the entire Crane Creek Watershed. The floodplains in the Piedmont are narrow and, in some locations, nonexistent (contrast to the Congaree – in the southern Coastal Plain – which has a floodplain 0.5-5 miles wide). Along major branches and creeks, the side slopes are strongly sloping to moderately steep, particularly along the Broad River. All of the rock in the Piedmont is grouped in a geologic belt known as Carolina Slate Belt, which is composed of shale and schist. East of the Piedmont, lies the "Sand Hills" region of the Coastal Plain. This area has many springs and the streams are fed by groundwater; that have strong flow throughout the year. The valleys are narrow in this region with few tributaries. The principal geologic formation in the Sand Hills is the Tuscaloosa that consists of unconsolidated marine deposits of light colored sands and kaolin clays.

Soils

Soil information for the watershed was based on Soil Survey Geographic Data (SSURGO) appended from the USGS 7.5 Minute Quadrangle and was provided Quality Assurance/Quality Control by the South Carolina Department of Natural Resources (SCDNR). The data originated from the U.S. Department of Agriculture, Natural Resources Conservation Service and SCDNR. The soils in the Crane Creek watershed tend to be well drained, primarily classified as hydrologic soil groups (HSG) A and B soils. Only 9.5% of the soils in the watershed are poorly-drained (HSG D), and approximately two-thirds of these soils are located in the Upper Crane Creek watershed (Table 2.4). Steep slopes (>10%) only comprise 10.7% of the watershed (Table 2.5, Figure 2.5)

Table 2.4. Crane Creek Watershed HSG Soil Classification

Subwatershed	Jurisdiction	A Soils (acres)	B Soils (acres)	C Soils (acres)	D Soils (acres)
Beasley Creek	County	1,724.9	5,837.5	2,877.1	498.5
	Town	666.8	726.3	564.1	197.4
Upper Crane Creek	County	5,104.9	5,454.4	733.3	2,698.9
Lower Crane Creek	County	293.2	7,550.1	2,766.6	318.4
	City	393.4	2,233.0	223.2	399.0
Watershed Total		8,183.2	21,801.3	7,164.3	4,112.2
% of Total Watershed Area		19.0%	50.6%	16.6%	9.5%

Table 2.5. Crane Creek Watershed Steep Slopes (10-30%) based on Soil Layer

Subwatershed	Jurisdiction	Total Area (acres)	Steep Slopes (acres)	Steep Slopes (% Target Area)
Beasley Creek	County	11,583.0	2,097.4	18.1%
	Town	2,264.0	570.3	25.2%
Upper Crane Creek	County	14,322.0	564.9	3.9%
Lower Crane Creek	County	11,681.0	1,253.3	10.7%
	City	3,327.1	116.1	3.5%
Watershed Total		43,177.1	4,601.9	10.7%

Wetlands

According to data from the 1989 National Wetland Inventory (NWI), wetlands comprise approximately 3,250 acres, or 7.5% of the Crane Creek watershed (Table 2.6). The wetland coverage includes freshwater ponds and lakes. A map of wetland coverage in the watershed is shown in Figure 2.6. More recent data from the 2001 NLCD (see Section 6) estimate wetland coverage as 6.5% of the watershed. Wetlands are regulated by the U.S. Army Corps of Engineers (USACOE) and SCDHEC. Federal wetland regulations prohibit any subdivision construction in designated wetland areas without approval prior from the U.S. Army Corps of Engineers. There are no local regulations in any of the Crane Creek jurisdictions to protect wetlands.

Descriptions of the NWI Wetland classifications found in the Crane Creek watershed are described in Cowardin et al., 1979. Regionally rare Carolina Bays, wetland depressions with a distinct shape and orientation and unknown geomorphologic origin, are found in Southeast Richland County.

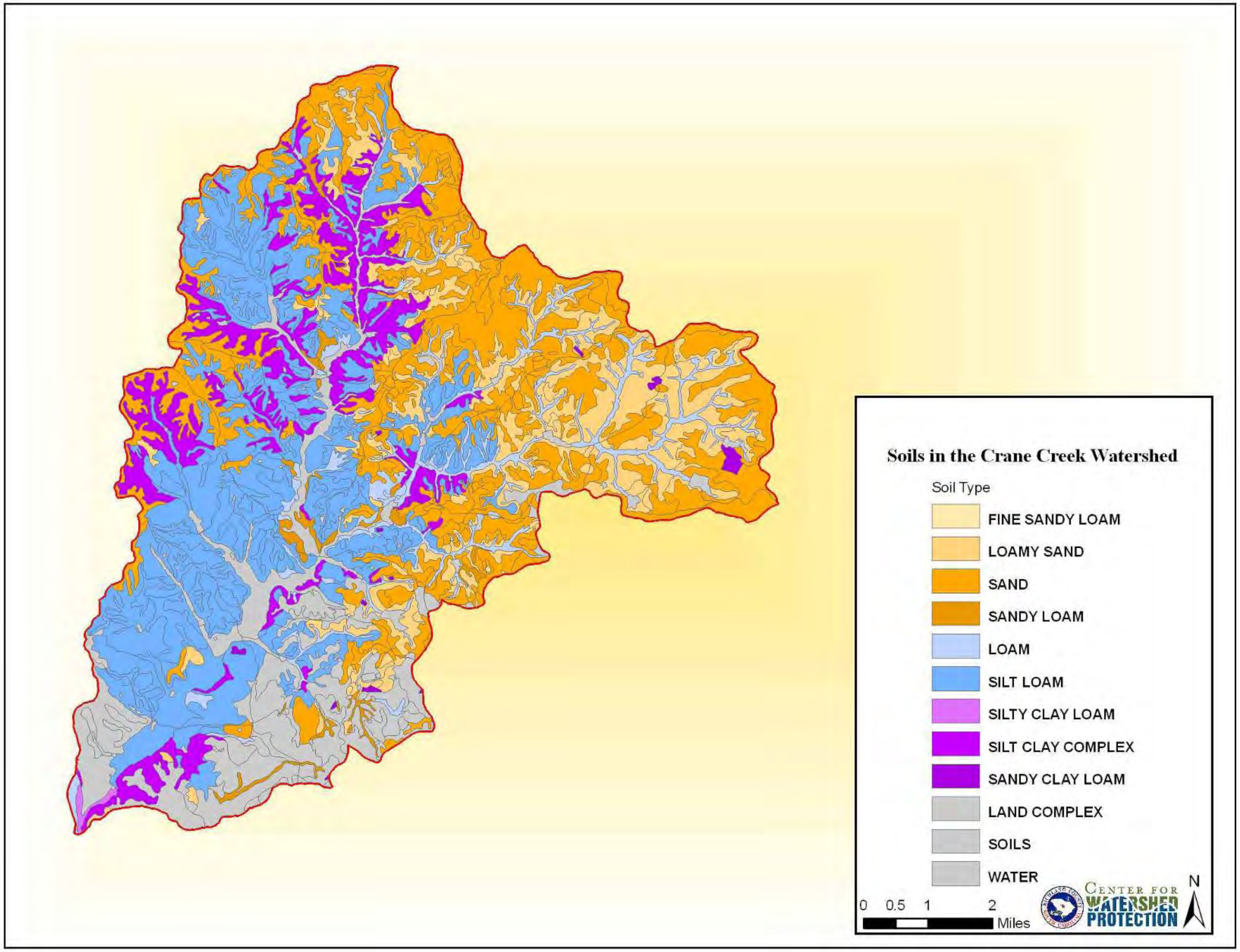


Figure 2.5. Soils in the Crane Creek Watershed.

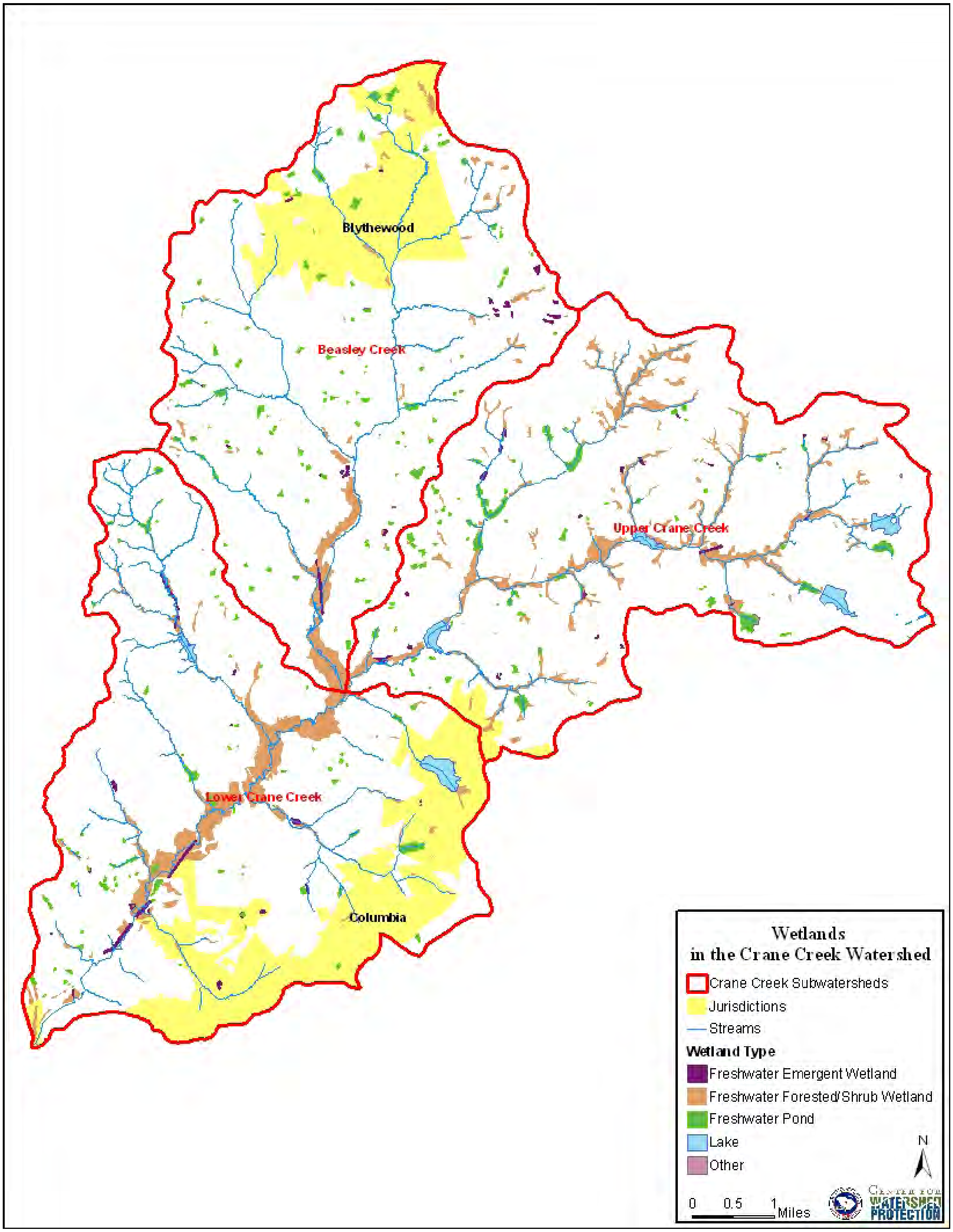


Figure 2.6. Wetlands in the Crane Creek Watershed.

Table 2.6. Crane Creek Watershed Wetland Coverage

Sub-watershed	Jurisdiction	Wetland Type					
		Freshwater Emergent Wetland (acres)	Freshwater Forested/ Shrub Wetland (acres)	Fresh-water Pond (acres)	Other (acres)	Lake (acres)	All Wetlands (acres)
Beasley Creek	County	30.6	418.3	128.7	1.5	0.0	579.1
	Town	1.2	36.9	25.5	0.0	0.0	63.6
Upper Crane Creek	County	33.2	1,085.7	193.2	5.0	146.5	1,463.6
Lower Crane Creek	County	37.0	818.2	89.9	0.0	20.0	965.1
	City	15.5	81.2	19.8	0.1	64.8	181.5
Watershed Total		117.4	2,440.3	457.2	6.6	231.3	3,252.8
% of Total Watershed Area		0.3%	5.7%	1.1%	0%	0.5%	7.5%

Forests and Canopy Cover

Priority ecological habitats in the County include bottomland hardwood forest, floodplains and longleaf pine forests. Populous tree species found in the County forests include Oak, Hickory, Pine, Red Cedar, and Poplar. The County Comprehensive Plan (Richland County, 2009) identifies three distinct forest ecosystems found in the County: Loblolly-Shortleaf Pine, Oak-Gum Cypress, and Oak-Pine Systems. Each system is characterized by specific forest coverage and unique plant and animal habitats.

Longleaf pine forests are found in several locations in the County, including Harbison State Forest, Fort Jackson and Sesquicentennial State Park. These forests are valuable in many ways. They offer diversity, visual appeal, and wildlife habitat – over 30 plant and animal species associated with longleaf pine ecosystems are threatened or endangered, including the red-cockaded woodpecker and gopher tortoise. These forests also provide excellent bobwhite quail habitat when managed properly with fire and are a significant food source for birds like the brown-headed nuthatch and other wildlife. The pine itself is resistant to many diseases, insects and other damaging agents.

Historically, the native long leaf pine forests dominated the Crane Creek landscape but now they make up just 3% of their historical range. Much of the forest has been replaced by loblolly pines that are more easily grown in plantations. Stands have also been displaced by agricultural activities and urbanization (Pers. Comm., Richland County Forester). The long leaf pine requires fire for seed regeneration as part of its lifecycle and was therefore more difficult to grow in plantations. Long leaf pine forests have been restored in several areas including Fort Jackson, SC, where prescribed burns keep the understory clear and allow for the natural regeneration of long leaf pines and suppression of understory and competitors.

Longleaf pine forests also play a key role in the succession of bird species. The understory community of wiregrass provides important feeding and nesting habitat such as Eastern Meadowlark, Eastern Bluebird, Northern Bobwhite, and Mourning Dove. With the absence or suppression of disturbance or fire, the herbaceous understory plants are replaced by shrubby species, an increase in structural complexity and subsequent corresponding changes in the avian community (NRCS, 2005). Grassland and early successional bird species such as Eastern Meadowlark and Northern Bobwhite decline, while shrub-successional species such as Indigo Bunting, Yellow-breasted Chat, Common Yellowthroat, and Prairie Warbler increase. Overtime, grassland birds disappear altogether, shrub-successional species decline, and forest birds begin to occupy the site. Total bird species diversity increases with the age of the stands, however, species diversity and abundance of grassland and early successional bird species decreases.

The Crane Creek watershed has approximately 48% canopy cover, as shown in Table 2.7. Canopy Cover data were obtained from the NLCD (2001) tree canopy layer, and determined by the per-pixel tree canopy density. The data have a 30 meter resolution and was downloaded from the MRLC. Figure 2.7 shows the percent canopy cover for the Crane Creek watershed.

Table 2.7. Crane Creek Watershed Canopy Cover

Subwatershed	Jurisdiction	Canopy Cover Area (acres)	Canopy Cover (% Target Area)
Beasley Creek	County	6,710.3	57.9 %
	Town	1,244.5	55.0 %
Upper Crane Creek	County	5,413.5	37.8 %
Lower Crane Creek	County	6,311.9	54.0 %
	City	1,075.8	32.3 %
Watershed Total		20,756.0	48.0%

Rare, Threatened, or Endangered Species

SCDNR maintains a list of rare, threatened and endangered (RTE) species within the state. The RTE species found in the Crane Creek watershed include the Pine Barrens Tree frog, Eastman's Rhododendron, and Pyramid Magnolia (Table 2.8). Over eighty species are inventoried for all of Richland County.

Table 2.8 RTE Species in Crane Creek Watershed (SCDNR, 2009)

Vertebrate Animal	Vascular Plant
Blacknose Dace	Eastman's Rhododendron
Pine Barrens Tree frog	Nestronia
Redlip Shiner	Pyramid Magnolia
	Sandhills Milkvetch
	Winter Grape-fern

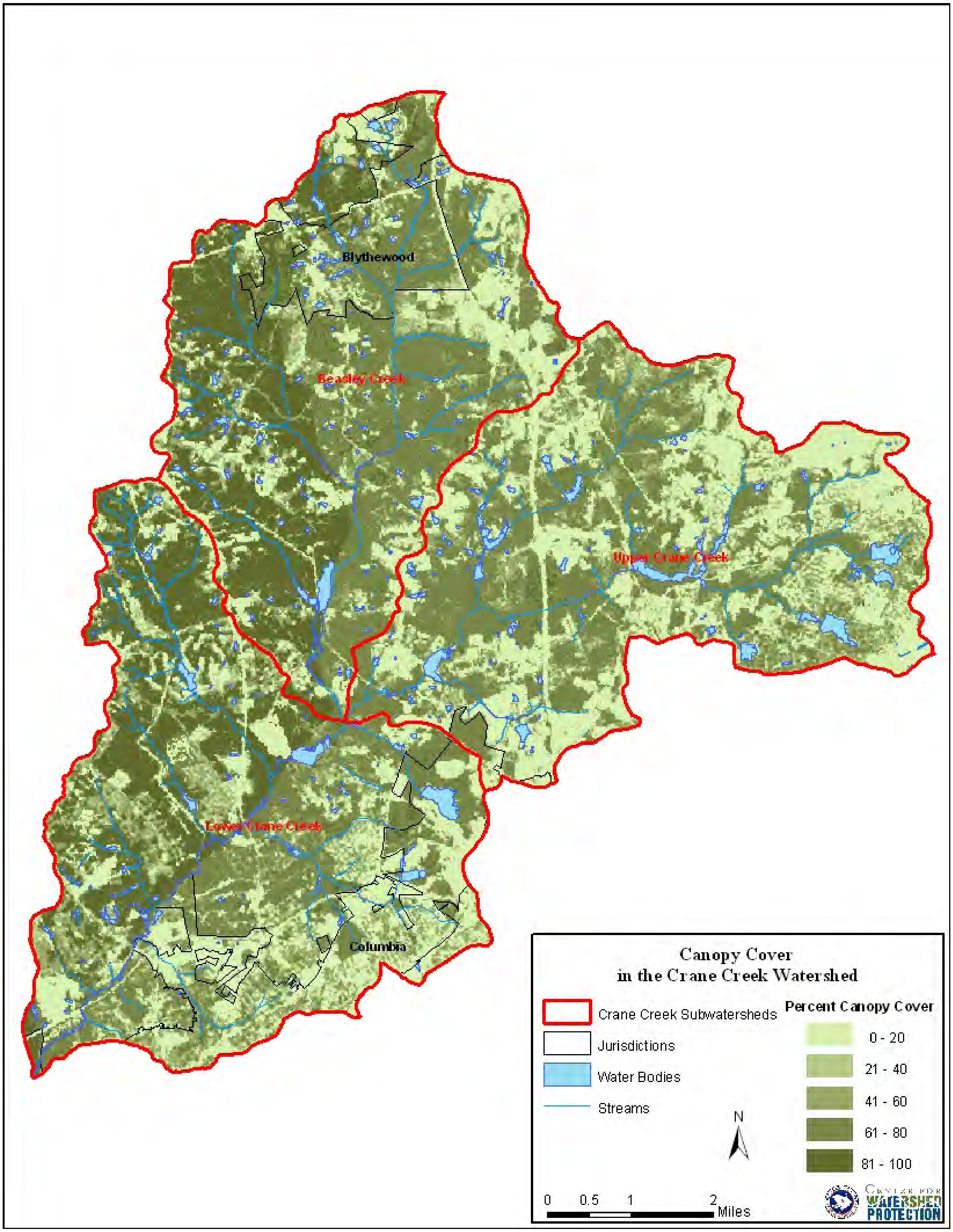


Figure 2.7. Canopy Cover in the Crane Creek Watershed.

Protected Lands

The County Legacy Program provides land conservation through voluntary easements, with a focus on land that is going to be developed and has natural resources significance (i.e. water feature, or RTE species, etc). The Congaree Land Trust is another volunteer conservation program that focuses mainly on rural lands. The volunteer program has approximately 15 private easements two of which (10 and 40 acres in size) are located in northeastern Crane Creek watershed.

2.5 Community Features

Area History

The County is reported to have received its name either for good soil found along the Congaree River (i.e., "rich land") or for a plantation of the same name owned by Thomas Taylor, who might well be considered the father of the county. The County was sparsely populated and consisted of small farms until the City was established by the state legislature in 1785 as the central seat for the state legislature. The City subsequently became not only the center of government but an important trade and manufacturing center, especially for cotton. The County itself had relatively little industrial activities and remained largely agricultural (PB, 2007).

Economic diversification in the County was spurred by a fire in 1865 that destroyed more than half of the City's blocks. The area rebounded with the establishment of the Columbia and Olympia mills that provided heavy industry to the area. Another major economic influence was the establishment of Camp Jackson during World War I. Fort Jackson was then re-established during World War II and continues to be a major economic factor in the area's economy (PB, 2007).

Current population estimates suggest that 357,734 residents call the County home, an increase of 8.4% over the 2000 U.S. Census. The County is currently the second most populous county in South Carolina. According to the County Comprehensive Plan, the County is experiencing rapid growth and is projected to increase its resident population by 40.1% by 2035, an increase of 130,793 people (Richland County, 2009).

Watershed Jurisdictions

The Crane Creek watershed encompasses three municipal entities: Richland County, the City of Columbia, and the Town of Blythewood. The watershed is primarily located in the County (87%), but encompasses smaller portions of the City (8%) and the Town (5%). The breakdown in watershed area for the three jurisdictions is provided in Table 2.9.

Table 2.9. Crane Creek watershed Jurisdictions		
Jurisdiction	**Area (acres)**	**Area (% of total watershed)**
Richland County	37,385.7	86.6%
City of Columbia	3,527.3	8.2%
Town of Blythewood	2,264.0	5.2%
Watershed Total	43,117.1	

Transportation Corridors

The Crane Creek watershed is crossed by several major transportation corridors. I-20, an east-west federal interstate highway, travels through the County portion of the Crane Creek watershed. Federal interstate I-77 also passes through the watershed in a north-south direction, from the Town to its termination at the intersection with I-26 just south of the City. Several US routes also traverse the Crane Creek watershed, including US 21 and US 321.

Parks and Schools

There are a number of park areas within the watershed, from larger community parks with many amenities to smaller neighborhood parks. There are also two golf courses within the watershed, one public (Northwoods Golf Course) and one semi-private (Oak Hills Golf Course). All together there are a total of eleven park areas of varying size that fall within the watershed boundary. Table 2.10 provides a list of the park areas in the Crane Creek watershed.

Several public and private schools are located within the watershed. Public school facilities include nine elementary schools, three middle schools, and one high school. There is also one private elementary school, and two private preschool/kindergartens. A higher education institution, Columbia College, is also located on the southern watershed boundary.

Table 2.10. Parks in the Crane Creek Watershed	
Subwatershed	**Park**
Upper Crane Creek	Northwoods Golf Course (County) Killian Park (County) North Springs Park (County) Summerhill Park (County)
Lower Crane Creek	Oak Hills Golf Course (County) Ensor Keenan House (City) Crane Forest Park (County) Sharpe Road Park (County) Greenview Park (City) Fairwold Park (City) Meadow Lake Park (County / City)

Agriculture and Forestry

The County has an abundance of rich agricultural soils; however, much of this land in the Crane Creek watershed has been developed or encroached upon. The predominant agricultural crops grown in the County include cotton, timber, wheat, and soybeans. Timber has the highest value of all agricultural crops grown in the County with several active timber farms in the Crane Creek watershed (Richland County, 2009)

Public Utilities

Wastewater treatment in the Crane Creek watershed is provided through both public sewer and onsite disposal (septic) systems. At the time this report was developed, specific data on sewer and septic coverage areas in the watershed were not available; however, a non-sewer (i.e. septic) area GIS shapefile was used to determine the area of septic system use in each of the watershed target areas. The number of homes with septic systems was then determined by intersecting the non-sewer GIS shapefile with a residential building GIS shapefile. Table 2.11 provides a summary of septic system use in the three subwatersheds that make up the Crane Creek watershed. Almost half the watershed (44%) is not sewered, with 12% of residential homes on septic systems and the rest of the land undeveloped. Septic systems are the primary treatment method in the Beasley Creek subwatershed. The Upper and Lower Crane Creek have more homes on sewer, due to proximity to the larger developed areas of the Town and the City.

Table 2.11. Septic System Use in the Crane Creek Watershed

Sub-watershed	Jurisdiction	Septic Area (acres)	Septic Area (% Target Area)	# Houses	# Houses on Septic	Houses on Septic (% Target Area)
Beasley Creek	County	8,625.0	74.5%	1628	1,104	67.8%
	Town	1,907.8	84.3%	257	108	42.0%
Upper Crane Creek	County	3,594.4	25.1%	10,578	571	5.4%
Lower Crane Creek	County	4,016.0	34.4%	5463	686	12.6%
	City	854.2	25.7%	3314	13	0.4%
Watershed Total		18,997.4	44.0%	21,240	2,482	11.7%

The Department of Utilities and Engineering at the City operates and maintains the drinking water and public waste water treatment, distribution, and storage systems for locations inside the City and in major portions of the County, including the Town. Lake Murray, created by a dam on the Saluda River, provides drinking water to the County. The Columbia Metro Wastewater Treatment Plan services the County and is the largest plant in the state. The plant has a permit to discharge treated wastewater to the Congaree River (SCDHEC, 2008c).

Stormwater

Stormwater facility information provided by the County for the Crane Creek watershed was limited in its availability. A stormwater best management practice (BMP) pond layer was provided to the Center that had 5 ponds listed for Upper Crane Creek. The ponds were located at the following locations (addresses were not provided):

- Department of Public Works
- Twin Eagles
- Salusbury Lane
- Gateway Business Park
- Harrington Court

GIS data provided by the County suggest that much of the stormwater infrastructure in the watershed consists of pipes, channels and culverts associated with roadway systems. Tables 2.12 and 2.13 provide some summary information on the stormwater conveyance infrastructure found in the watershed. The majority of drainage channels in the watershed occur as natural channels. Most of the stormwater pipes and culverts are located in the Upper Crane Creek subwatershed, likely due to recent development in this area that is subject to stormwater conveyance regulations.

Table 2.12. Length (in Feet) of Stormwater Channels by Subwatershed and Lining Type

Subwatershed	Jurisdiction	Asphalt (ft)	Natural (ft)	Concrete (ft)	Grass (ft)	Rip-Rap (ft)	Other (ft)
Beasley Creek	County	611	1,078	0	0	0	0
	Town	0	2,622	0	0	0	0
Upper Crane Creek	County	37	13,868	515	559	924	93
Lower Crane Creek	County	55	19,078	738	1,365	0	692
	City	0	379	0	0	0	0
Watershed Total		703	37,024	1253	1,924	924	785

Table 2.13. Length of Stormwater Pipes and Culverts by Subwatershed

Subwatershed	Jurisdiction	Culvert Length (ft)	Pipe length (miles)
Beasley Creek	County	163.4	1.7
	Town	98.6	1.2
Upper Crane Creek	County	1,928.1	46.5
Lower Crane Creek	County	299.4	13.1
	City	0	1.0
Watershed Total		2,489.6	63.4

Greenways

There are three major shared-use pathways within the County: the Three Rivers Greenway, the Palmetto Trail, and the Harbison Pathways. Lower Crane Creek has slightly less than 1 mile of the Palmetto Trail at the southern end of its boundary. These trail systems provide a multitude of recreational opportunities from walking, running, cycling, to skating. Other trail systems exist within the County as well, with smaller pathways within municipalities and parks, such as the Blythewood Explorer bike trail. The Three Rivers Greenway and Palmetto Trail are still in development with future sections in the planning stages that may potentially include parts of the Crane Creek watershed (Matthews, 2004).

2.6 Land Cover

Current Land Cover

Land cover and impervious cover data were obtained from the 2001 NLCD with a 30 meter resolution. A list of all the land use descriptions included in this layer, as well as documentation on how this data were derived from satellite imagery, is included in Homer et al. (2004).

Fifteen different types of land use and land cover categories were identified in the watershed, which were further grouped into 6 general land uses, as shown in Figure 2.8. A listing of the land use descriptions is found in Attachment C and the *Crane Creek Watershed Characterization Report* (CWP, 2009a). A break down of land use by watershed target areas is shown in Table 2.14. Developed Open Space (14.4%) is defined as lawns from large lot single family housing, parks, and golf courses. The forested lands (48.9%) were comprised of approximately half deciduous and half evergreen forests. A map of the watershed land cover data is shown in Figure 2.9 and a map of impervious cover is shown in Figure 2.10.

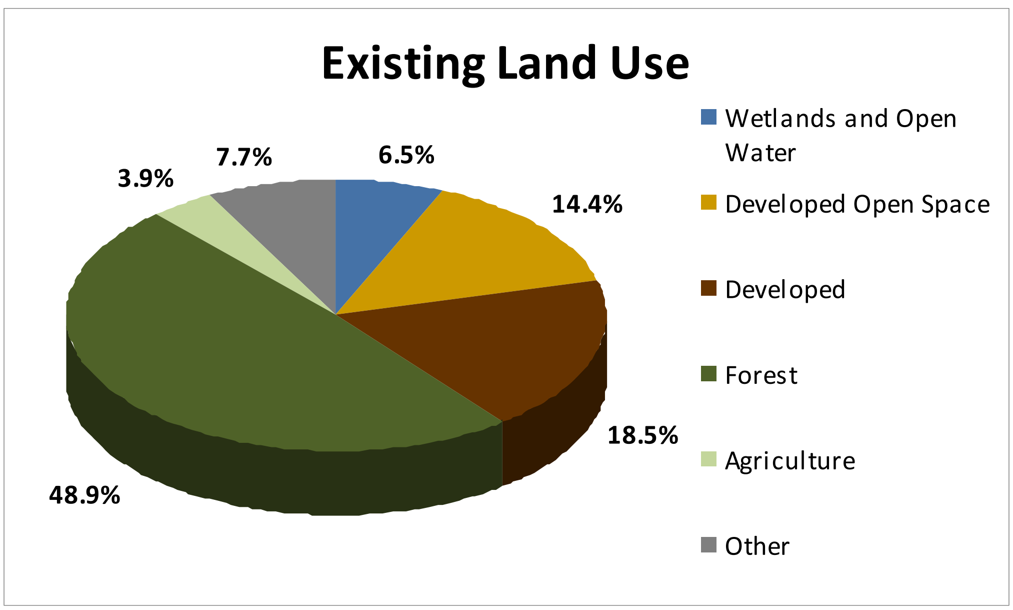


Figure 2.8. Existing Land Cover in the Crane Creek Watershed.

Table 2.14 Land Use by Target Area in the Crane Creek Watershed							
Subwatershed	**Jurisdiction**	**Wetlands and Open Water (acres)**	**Developed Open Space (acres)**	**Developed (acres)**	**Forest (acres)**	**Agriculture (acres)**	**Other (acres)**
Beasley Creek	County	462	1,060	739	7,824	562	935
	Town	81	186	131	1,591	98	177
Upper Crane Creek	County	1,311	2,190	3,621	5,395	485	1,321
Lower Crane Creek	County	801	2,107	1,858	5,656	452	807
	City	161	693.8	1,639	666	92	76
Watershed total		2,816	6,237	7,989	21,131	1,688	3,317
% of Total Watershed Area		6.5%	14.4%	18.5%	48.9%	3.9%	7.7%

2.7 Municipal Policies and Programs

Eight Tools Audit

The Center conducted interviews with municipal officials and consultants in the three jurisdictions within the Crane Creek watershed to identify programmatic strengths and gaps in watershed protection strategies in each jurisdiction. The inquiry explored eight categories of programmatic and regulatory tools that local governments can apply to watershed management: land use planning, land conservation, aquatic buffers, better site design (BSD) (i.e. environmentally sensitive design), erosion and sedimentation control (ESC), stormwater management, non-stormwater discharges, and watershed stewardship. The tools correspond to the stages of the development cycle from initial land use planning and land conservation, through site design and construction, to post-construction stormwater controls, stewardship and home ownership. The Center recommends that comprehensive watershed plans apply elements of each of the eight tools.

The Eight Tools Audit (CWP, 2007) was used as a basis for exploring programmatic and regulatory tools in the County, the Town, and the City. Detailed results of the review are provided in the *Crane Creek Watershed Characterization Report* (CWP, 2009a) and a summary is provided in Table 2.15.

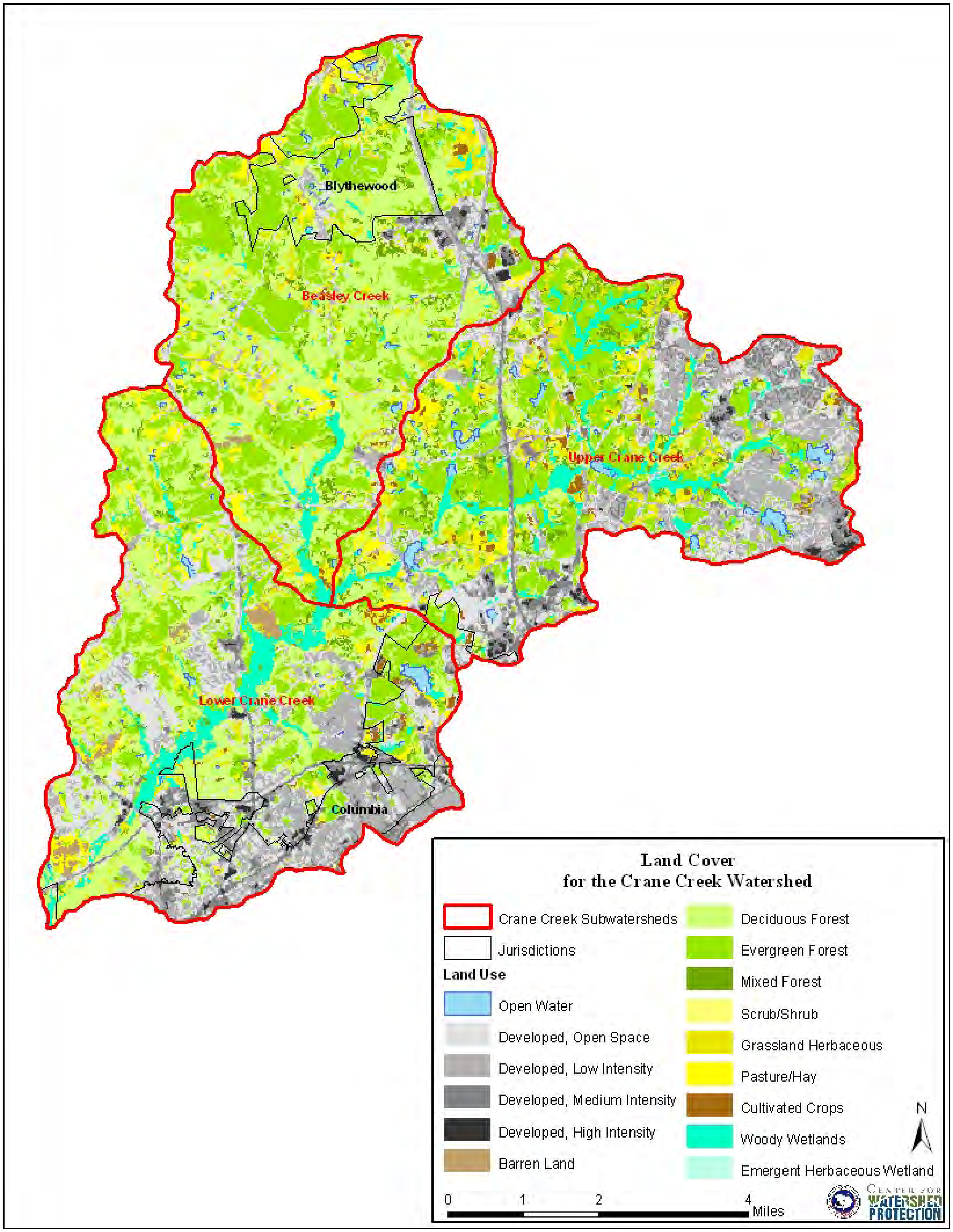


Figure 2.9. Land Use in the Crane Creek Watershed.

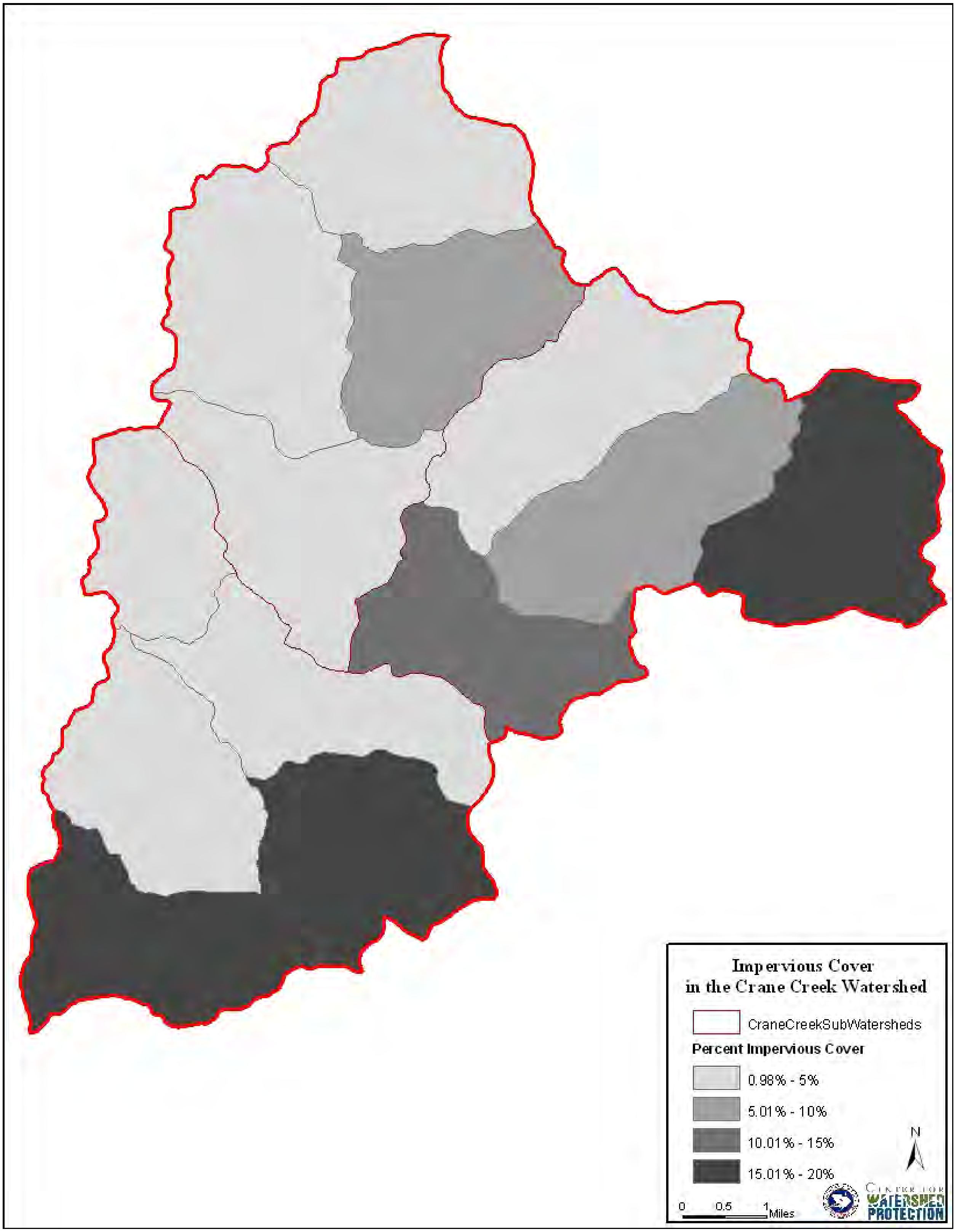


Figure 2.10. Impervious Cover in the Crane Creek Watershed.

Table 2.15. Summary of Findings from the Eight Tools Audit			
Watershed Management Tool	**Jurisdiction**		
	City of Columbia	**Richland County**	**Town of Blythewood**
Land Use Planning	• Comprehensive Plan includes recommendations for natural resources protection and conservation	• No regulations of wetlands or steep slopes • Green Code has overlay districts and density bonuses to encourage BSD	• Master Plan being developed that includes sustainability guidelines • No regulations of wetlands or steep slopes
Land Conservation	• Included in Richland County Legacy Program • Tree preservation ordinance	• Richland County Legacy Program • COWASEE basin partnership	• Included in Richland County Legacy Program • Tree protection under Tree Preservation Ordinance
Aquatic Buffers	• No current stream buffer regulation but recommended in Comprehensive Plan	• Recently passed stream buffer regulation of 50-100 ft.	• Stream buffer of 20 feet on each side of the stream
Better Site Design (BSD)	• City is mostly built-out • Cluster housing is allowed but mostly infill or redevelopment	• Existing 'green code' that encourages BSD but not being used • Roundtable project provided code recommendations to achieve BSD (see Sec. 5.5)	• Optional Conservation Subdivision Code that is rarely implemented
Erosion and Sediment Control	• ESC plan must be approved prior to site grading permit • Require ESC sites inspected by City engineer	• Provide ESC oversight for Town of Acadia Lakes and City of Forest Acres • SWPPP required	• Plans are reviewed by consultant, HPG and Company • SCDHEC provide permitting and plan review
Stormwater Management	• Phase 1 NPDES community • No water quality, peak flow or volume regulations for stormwater • Existing stormwater management utility	• Phase 1 NPDES community • Stormwater Drainage Design Manual is being updated • Require BMPs for water quantity and quality • Most practices are stormwater ponds	• Permitting done by DHEC • Most practices are stormwater ponds • No requirements for runoff volume or water quality

Table 2.15. Summary of Findings from the Eight Tools Audit			
Watershed Management Tool	**Jurisdiction**		
	City of Columbia	**City of Columbia**	**City of Columbia**
Non-Stormwater Discharges	• Operates Columbia Metro WWTP • Proposed stormwater outfall monitoring program • Street sweeping program • Currently mapping stormwater outfalls and waterways	• Separate stormwater and sanitary sewer system • Established IDDE program • Wastewater service is provided by City of Columbia	• Separate stormwater and sanitary sewer system • Wastewater service is provided by City of Columbia
Watershed Stewardship Programs	• Limited education and outreach efforts • Volunteer Climate Protection Action Committee (CPAC) • New Riverkeeper on the Saluda, Broad and Congaree rivers	• Public education and outreach program through partnership with Carolina Clear, called Richland Countywide Stormwater Consortium • Pesticide, Herbicide and Fertilizer Program Industrial and High Risk Runoff Program • Wet and dry weather monitoring program	• No education and outreach programs, water quality monitoring, or watershed associations

Richland County Roundtable

In the fall of 2009, a Richland County Site Planning Roundtable (Roundtable) was convened. The process involved a diverse group of participants that represented the County government, local developers, engineers and environmental groups. The goal of this process was to develop recommendations for changes to the existing county development codes in order to achieve more environmentally friendly development in Richland County. This process resulted in over 100 recommendations to existing development codes that were approved by the county council. Key recommendations included conducting a natural resources inventory, promoting the preservation of open space and other natural areas, and minimizing impervious cover associated with development through multiple better site design principles. A final report on the process and recommendations is available at http://www.cwp.org/Resource_Library/Better_Site_Design/

Post-Construction Review

In 2008, Richland County's Department of Public Works requested a third-party assessment of its post-construction stormwater management program along with a set of recommendations for improving the program. In early 2009, the Center as part of an existing scope of work to review the county's development codes, conducted this assessment using the post-construction manual, *A Guide for Building an Effective Post-Construction Program* (Hirschman et al., 2008), as a framework. Much of the information garnered for this program review is based on a self-assessment survey (Tool 1 of manual) completed by several Richland County Stormwater Management Division staff members and a follow-up interview. This information was then used to provide specific recommendations for filling program gaps and making improvements for the future of the program. These recommendations are found in Attachment K. Key recommendations include adopting the proposed stormwater ordinance, providing more frequent inspection and better enforcement of ESC practices on new development sites, and encouraging use of stormwater practices other than ponds.

SECTION 3. WATERSHED ASSESSMENT PROTOCOLS, GENERAL FINDINGS, AND GREEN INFRASTUCTURE ANALYSIS

3.1 Introduction to the Watershed Assessments

In March, 2009, field work was conducted in the 67.5 square mile Crane Creek Watershed. For purposes of the field effort, the three planning level subwatersheds; Beasley Creek, Lower Crane Creek and Upper Crane Creek were further divided into smaller subwatersheds. These subwatersheds (A-M) are referenced in this document and identified in Figure 3.1.

The watershed field assessment strategy aimed to meet initial watershed restoration and protection goals outlined by the Center and the County, based on stakeholder input. These general watershed goals were to:

- Improve water quality
- Decrease stream erosion and sedimentation
- Reduce localized flooding
- Protect in-stream and upland habitat

During these field assessments, the field crew teams, consisting of at least one Center staff and volunteers from the County and other groups, visited over 245 locations in the watershed and used one of seven field assessment methodologies to evaluate the feasibility of implementing a management or restoration practice. Approximately 44 potential stormwater retrofit sites, 27 potential hotspot locations, 56 residential neighborhoods, 15 erosion and sedimentation control sites, 26.5 miles of stream (85 stream reaches), 11 forest sites, and 8 wetland sites were assessed in the Crane Creek Watershed. Table 3.1 provides a summary of general findings from the field assessments.

Table 3.1. General Findings from Field Assessments

Task	General Findings
Stormwater Retrofit Inventory	• 44 sites visited • 41 potential stormwater retrofits identified for 33 sites • Focus on water quality treatment and channel protection • Identified 14 high priority sites • Types of retrofits include pond modifications, bioretention, rain gardens, downspout disconnection, and water quality inlets
Hotspot Site Investigation	• 27 potential hotspot sites investigated • 10 sites confirmed as hotspots, and 3 sites are potential hotspots • Biggest offenders include auto salvage, maintenance, and repair facilities • Poor trash storage and illegal dumping observed in several locations • Types of projects recommended are pollution prevention education including dumpster management, vehicle activities, and outdoor material storage
Neighborhood Source Assessment	• 56 neighborhoods assessed • Pollution severity index: 33 moderate, 21 low • Neighborhood restoration potential: 15 moderate, 41 low • Neighborhoods were mix of older and newer single family homes, most without

Table 3.1. General Findings from Field Assessments	
Task	**General Findings**
	downspouts or disconnected • Types of recommendations include education on lawn care, stream buffers, storm drain stenciling, trash in streams, tree plantings, and demonstration rain gardens
Erosion and Sedimentation Control Sites	• 15 sites identified having erosion and sedimentation control (ESC) problems • ESC violations appear to be an on-going problem • Follow-up inspections recommended for all sites • Programmatic changes to the County ESC program are recommended
Unified Stream Assessment	• Walked over 26.5 miles of stream • Evaluated 85 stream reaches • Completed site impact evaluations at 23 stream and utility crossings, 2 modified channels, 3 erosion sites, 7 outfalls, 12 impacted buffers, 13 trash site, and 3 miscellaneous impacts (algae and drained wetlands) • Identified 23 high priority riparian corridor projects • Major findings include reaches with abundant trash and dumping, poor stream buffers, areas of stream bank erosion in neighborhoods and near utilities, infrastructure problems, and excessive algal growth
Contiguous Forest Assessment	• Assessed 11 forest sites • Majority of forest stands were managed forest for timber harvest • Mature forest identified near riparian corridor should be targeted for protection
Wetland Function Assessment	• 8 wetland sites assessed for habitat and water quality function • High function scores were determined for most wetland sites • Wetlands mapped as isolated were found to be hydrologically connected, and should be protected by federal and state laws • County should consider protection of additional isolated wetlands

After the field assessments were completed, a ranking system was developed to prioritize identified management and restoration practices within each practice group. Using best professional judgment, each practice location was assigned points and ranked according to the factors listed below:

- *Cost* – The cost associated with project implementation. Project costs represent only planning level estimates and were determined based on guidance provided in Schueler et al. (2007), Wright et al. (2005) and Kitchell and Schueler (2004).
- *Community Education and Involvement* – Project with potential to educate and involve the community
- *Visibility* – Project with high visibility and potential to raise the public's awareness of the watershed (visible from street or located in public park)
- *Feasibility* – Project with high potential that it will be implemented. The site has access for equipment, low maintenance burden, serves as a demonstration site and is publicly owned
- *Water Quality Improvement* – Potential for treatment or prevention of pollutants. Treats water quality volume or eliminates exposure of pollutants to stormwater runoff
- *Ecological Benefit* – Project provides an ecological, habitat, or natural resource protection benefit
- *Meeting Watershed Objectives* – Potential for project to assist in achieving watershed objectives (see Section 4 of this report)

The ranking system was based on 100 points. The ranking factors and criteria are described in more detail in Attachment F. A list of all the sites visited along with their ranked priority and planning level cost estimates is included in Attachment E. The estimated costs are preliminary and should be used to guide the County, Town and City in establishing implementation budgets. These estimates should be adapted to include more appropriate local cost estimates where available. Additional information on project costs can be found in Section 5.

A key to the nomenclature used by field teams during the assessment work is provided in Table 3.2. The naming convention was designed to be flexible for multiple field teams and to immediately impart key information about the site. Identifiers consist of three parts: 1) the abbreviation of the subwatershed in which the site or reach is located, 2) the type of assessment conducted, and 3) a unique identifier that is employed as a team evaluates a subwatershed or reach (e.g. the first three retrofits identified in one subwatershed reach would be numbered R1, R2, R3…). This nomenclature was carried through the project and is used elsewhere in this *Plan*.

Table 3.2. Field Assessment Nomenclature Key				
Watershed	**Subwatershed**		**Assessment Type**	**Abbreviation**
Beasley Creek	A		Retrofit	RRI
	B		Hotspot	HIS
	C		Neighborhood	NSA
	D		Erosion and Sedimentation Control	ESC
Upper Crane Creek	E		Stream Reach	RCH
	F		Outfall	OT
	G		Stream Crossing	SC
	H		Trash and Debris	TR
Lower Crane Creek	I		Impacted Buffer	IB
	J		Eroded Bank	ER
	K		Utility Impact	UT
	L		Channel Modification	CM
	M		Miscellaneous	MI

A summary of observations made by field crews during the stream and upland assessments of the Crane Creek watershed are discussed below. The locations of assessed sites are shown in Attachment A and a list of all the sites and identified projects are listed in Attachment E.

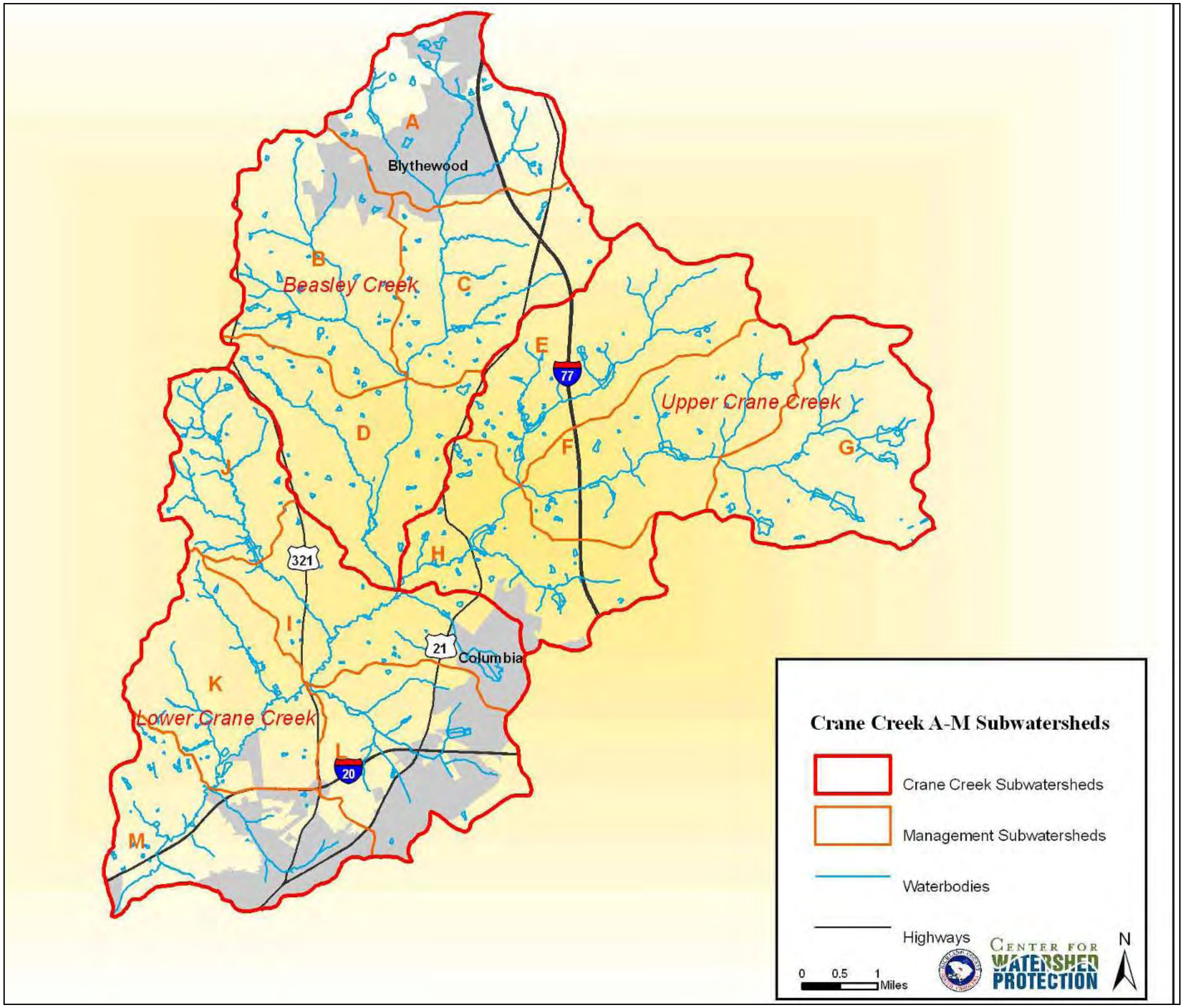


Figure 3.1. Crane Creek A-M subwatersheds.

3.2 Stormwater Retrofit Inventory

Stormwater retrofits are structural stormwater management practices that can be used to address existing stormwater management problems within a watershed. These practices are installed in upland areas to capture and treat stormwater runoff before it is delivered to the storm drainage system, and ultimately, Crane Creek. They are an essential element of a holistic watershed restoration program because they can help improve water quality, increase groundwater recharge, provide channel protection, and control overbank flooding. Without using stormwater retrofits to address existing problems and to help establish a stable, predictable hydrologic regime by regulating the volume, duration, frequency, and rate of stormwater runoff, the success of many other watershed restoration strategies -- such as stream stabilization, reduced erosion, and aquatic habitat enhancement -- cannot be guaranteed. In addition to the stormwater management benefits they offer, stormwater retrofits can be used as demonstration projects, forming visual centerpieces that can be used to help educate residents and build additional interest in watershed restoration.

Stormwater retrofits can be broken into three general categories: offsite storage, onsite nonresidential, and onsite residential. Offsite storage retrofits, such as ponds and wetlands, generally provide the widest range of watershed restoration benefits because of their ability to treat relatively large drainage areas. However, onsite retrofit practices, such as bioretention and filtration practices, can provide a substantial benefit when applied to a large number of sites within a subwatershed.

Assessment Protocol

Potential stormwater retrofit opportunities at a number of candidate project sites in the Crane Creek watershed were assessed during the retrofit inventory. A Retrofit Inventory field form was used to evaluate retrofit opportunities at candidate sites. Field crews look specifically at drainage patterns, the amount of impervious cover, available space, and other site constraints when developing concepts for a site. In the Crane Creek watershed, 39 candidate project sites were identified prior to field work using aerial photography, stakeholder input, and information gathered during earlier watershed site visits in the months prior to field work. Candidate retrofit sites identified for the assessment generally had one or more of the following characteristics:

- Located adjacent to headwater streams
- Located at existing stormwater management facilities,
- Situated on publicly-owned or publically-operated lands or open spaces (e.g. school sites, parks)
- Located on commercial and industrial sites with large areas of impervious cover
- Could serve as a demonstration project

Summary of Sites Assessed

A total of 44 stormwater retrofit sites were visited by field crews throughout the Crane Creek watershed and a total of 41 preliminary retrofit concepts were developed at 33 of the sites

(Attachment E). Multiple concepts were developed for several of the sites and are indicated by a letter after the site number (i.e. C-RRI-19B). There were no concepts developed for 11 sites that either had adequate stormwater management or site constraints such as access or feasibility. A map of the RRI sites visited is found in Attachment A.

Fourteen high priority retrofit opportunities were identified. Details on these 14 sites are included in Attachment H. The proposed stormwater management practices included bioretention areas, downspout disconnection, pond modification, site stabilization, permeable pavement, water quality inlets, and pipe daylighting. The majority of stormwater retrofit opportunities identified in the watershed were on publicly-owned land in highly visible locations, such as public schools and parks. Some retrofit opportunities were identified on privately-owned land, primarily on private school grounds, in existing stormwater management facilities, and commercial parking lots. General profile sheets for retrofit concepts can be found in Attachment I.

A water quality volume (WQ_v), or the volume that will capture runoff from most rainfall events and a substantial portion of runoff from larger events, was calculated for each retrofit drainage area. This volume captures high pollutant loads in the "first-flush" of stormwater runoff from all rainfall events. WQ_v was calculated for each proposed retrofit as follows:

$$WQ_v = [(P)(R_v)(A)] / 12$$

Where WQ_v = water quality volume (acre-feet)
P = design storm runoff depth (inches)
$R_v = 0.05 + 0.009(I)$, where (I) is the percent impervious cover of the site
A = site drainage area (acres)

The runoff depth of the design storm (P) varied according to the type of retrofit practice proposed. This was defined as 1.5 inches for ponds, and 1 inch for infiltration practices, including rain gardens, bioretention areas, swales, and downspout disconnection. This volume reflects the water quality design volume defined in the Richland County Drainage Design Standards Manual (Richland County, 2001).

General Findings

The following are general findings that the stormwater retrofit field crews encountered throughout the Crane Creek watershed. Site IDs for specific retrofit concepts are listed after the field findings.

<u>1. Inadequate stormwater treatment</u>
At several field sites, inadequate or poor treatment of stormwater through stormwater dry and wet ponds was observed (Figure 3.2). Common problems included stormwater by-pass of the treatment mechanism, lack of water quality treatment, pond erosion, and pond sedimentation. These problems often appeared to be a result of poor design, lack of maintenance, or poor stabilization of the pond area or contributing drainage area.

Related sites: I-RRI-17C, C-RRI-19A, C-RRI-19B, A-RRI-21A, F-RRI-28, F-RRI-30, E-RRI-31A, E-RRI-33, E-RRI-34B, F-RRI-35, H-RRI-200

2. Lack of stormwater treatment

Throughout the watershed, a lack of stormwater treatment was observed for many older development sites, as well as several recent development sites (Figure 3.3 (a, b, & c)). At many of these sites, untreated stormwater discharges directly to wetlands, stream channels, or the stormdrain system. Unmanaged stormwater can contribute high pollutant loads to the receiving waterbodies, and can also result in high stormwater runoff flow rates that cause streambank erosion and degrade stream habitat.

Related sites: M-RRI-01, M-RRI-02, M-RRI-03, K-RRI-04, I-RRI-07, L-RRI-08, L-RRI-09, L-RRI-10, L-RRI-11, I-RRI-17, H-RRI-23, H-RRI-24A, H-RRI-24B, E-RRI-32, G-RRI-38, L-RRI-100, C-RRI-101, G-RRI-201, G-RRI-202

3. Schools and Parks

Many of the older schools and parks visited during field work had no stormwater management practices. At newer schools, there were often large areas of turf grass or bare soils with very little or no trees. Despite the presence of sandy native soils, downspouts were often directly connected to the stormwater conveyance system. Schools and parks are great places for stormwater retrofits because of the educational and demonstration component associated with projects. An understanding of stormwater and the environment can be incorporated into school science curriculums. Students can learn about the connection between stormwater, Crane Creek, and how they can play a part in improving water quality. Additionally, these sites can serve as good community demonstration projects (Figure 3.3 (d, e, & f)).

Related sites: M-RRI-01, M-RRI-02, M-RRI-03, K-RRI-06, I-RRI-07, L-RRI-09, L-RRI-10, L-RRI-11, L-RRI-12, I-RRI-17, F-RRI-29, E-RRI-31, E-RRI-32, G-RRI-38, G-RRI-39

(a)

(b)

(c) (d)

Figure 3.2. Poor functioning stormwater management practices. (a) erosion in a neighborhood dry pond (F-RRI-35); (b) stormwater pond with unstable drainage area (C-RRI-19B); (c) flood-control pond at business park with no water quality control (H-RRI-200); and (d) undersized neighborhood dry pond (A-RRI-21A).


(a)


(b)


(c)


(d)


(e)

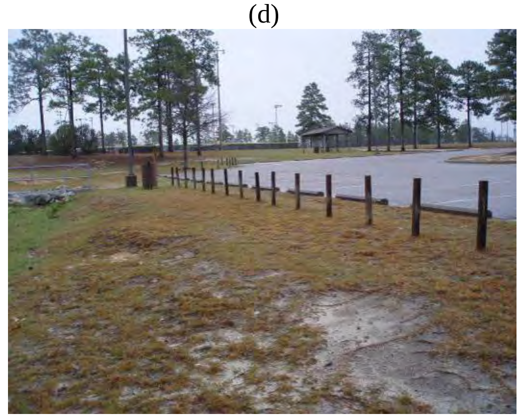

(f)

Figure 3.3. Stormwater retrofit opportunities. (a) Untreated business park parking lot runoff travelling directly to stream (H-RRI-24B); (b) untreated school parking lot runoff travelling into forested area (I-RRI-17); (c) opportunity for a roadway retrofit in a residential neighborhood (G-RRI-201); (d) proposed location for a bioretention area at a school (E-RRI-34); (e) downspout disconnection opportunity at a school (K-RRI-06); and (f) proposed location for a bioretention area to capture parking lot runoff from a park (G-RRI-38).

3.3 Unified Subwatershed and Site Reconnaissance

The Center conducted the Unified Subwatershed and Site Reconnaissance (USSR) to evaluate pollution-producing behaviors and restoration potential in upland areas of the Crane Creek Watershed. The USSR is a "windshield survey" where field crews drive watershed roads to determine specific pollution sources and identify areas outside the stream corridor where pollution prevention possibilities exist. The USSR can be a powerful tool in shaping initial subwatershed restoration strategies and locating potential stormwater retrofit or restoration opportunities. The goal of the USSR is to quickly identify source areas that are contributing pollutants to the stream, and reduce these pollutant loads through source controls, outreach and change in current practice, and improved municipal maintenance operations. Additional information on the USSR is found in Wright et al. (2005).

Field crews assessed more than 27 potential hotspots and 56 residential neighborhood locations within the Crane Creek watershed using the USSR methodology (Attachment E). In addition, several ESC problems in the watershed were identified and noted. Identification of hotspots (HSI), residential pollution-producing behaviors (NSA), and ESC problems that contribute to nutrient and sediment loading was the primary focus of this effort. Maps of the HSI, NSA, and ESC sites visited are found in Attachment A. General profile sheets for pollution prevention and source control practices can be found in Attachment J.

3.3.1 Hotspot Investigations

Pollution source control includes the management of potential "hotspots" which are certain commercial, industrial, institutional, municipal, and transport-related operations in the watershed. These hotspots tend to produce higher concentrations of polluted stormwater runoff than other land uses and also have a higher risk for spills. They include auto repair shops, department of public works yards, restaurants, etc. Specific on-site operations and maintenance combined with pollution prevention practices can significantly reduce the occurrence of "hotspot" pollution problems.

Assessment Protocol

The Hotspot Site Investigation (HSI) is used to evaluate commercial, industrial, municipal or transport-related sites that have a high potential to contribute contaminated runoff to the storm drain system or directly to receiving waters. At hotspot sites, field crews look specifically at vehicle operations, outdoor materials storage, waste management, building conditions, turf and landscaping, and stormwater infrastructure to evaluate potential pollution sources (Table 3.3). Based on observations at the site, field crews may recommend enforcement measures, follow-up inspections, illicit discharge investigations, retrofits, or pollution prevention control and education.

The overall pollution prevention potential for each hotspot site is assessed based on observed sources of pollution and the potential of the site to generate pollutants that would likely enter the storm drain network. A hotspot designation criterion set forth in Wright et al. (2005) was used to determine the status of each site based on field crew observations. Sites are classified into four initial hotspot status categories:

- Not a hotspot – no observed pollutant; few to no potential sources
- Potential hotspot – no observed pollution; some potential sources present
- Confirmed hotspot – pollution observed; many potential sources
- Severe hotspot – multiple polluting activities directly observed

Table 3.3. Potential Hotspot Pollution Sources

Type	Description	Examples
Vehicle Operations	Routine vehicle maintenance and storage practices, as well as vehicle fueling and washing operations	• Vehicle storage and repair • Fueling areas • Vehicle washing practices
Outdoor Materials	Exposure of outdoor materials stored at the site	• Loading and unloading • Outdoor materials • Secondary containment
Waste Management	Housekeeping practices for waste materials generated at the site	• Dumpster practices
Stormwater Infrastructure	Practices used to convey or treat stormwater, including the curb and gutter, catch basins, and any stormwater treatment practices	• Catch basins • Stormwater treatment practices

Summary of Sites Assessed

A total of 27 hotspot sites were assessed in the Crane Creek Watershed. Ten sites were identified as confirmed hotspots, and three sites were identified as potential hotspots. An additional 14 locations were assessed and not determined to be hotspots using the USSR criteria; however, some pollution producing behaviors were noted at these locations. The majority of hotspot project identified were low cost projects such as adding secondary containment for small areas, trash clean ups or maintenance activities (e.g. adding a dumpster lid). Other hotspot projects, although expensive, would provide a tremendous amount of water quality benefit, such as adding a water quality filter at the County bus maintenance facility (I-HSI-16). A complete list of all evaluated hotspot sites can be found in Attachment E.

General Findings

The following are general findings from the hotspot assessment that field crews encountered throughout the Crane Creek watershed. Figure 3.4 illustrates some of the field findings.

1. <u>Storage of outdoor materials and parts without containment</u>

This was the most common observation made during the hotspot assessment. Outdoor materials noted included 55 gallon drums, grease barrels, fuel tank, paint, and storage tanks. In addition, problems were observed at auto salvage locations that include vehicles and parts being stored outside with no containment. Many of the sites were fenced and had no access to allow proper inspection.

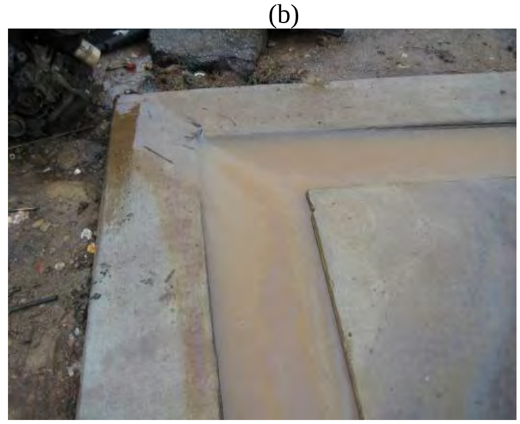
2. Poor trash storage practices and illegal dumping

Some illegal dumping was observed in the stream buffer (see Section 3.4) and open space areas. In addition, overflowing dumpsters were noted.


(a)


(b)


(c)


(d)


(e)


(f)

Figure 3.4. Pollution producing behaviors found during the HSI. (a, b, & c) outdoor materials without secondary containment at sites I-HSI-1, E-HSI-2, and K-HSI-4, respectively; (d) automobile oil leaking from an auto salvage yard at site I-HSI-2; (e) dumping site next to a gas station at site M-HSI-1; (f) an automotive salvage site adjacent to a stormwater channel at site H-HSI-22.

3.3.2 Neighborhood Source Assessment

Residents engage in behaviors and activities that can influence water quality. Some behaviors that negatively influence water quality include over-fertilizing lawns, using excessive amounts of pesticides, and poor housekeeping practices such as inappropriate trash disposal or storage. Alternatively, positive behaviors such as tree planting and native plants, disconnecting rooftops, and picking up pet waste can help improve water quality.

Assessment Protocol

The Neighborhood Source Assessment (NSA) was conducted to evaluate pollution source areas, stewardship behaviors, and restoration opportunities within individual residential areas. The assessment looks specifically at yards and lawns, rooftops, driveways and sidewalks, curbs, and common areas. Table 3.4 provides examples of the types of restoration opportunities that were evaluated for each site.

An NSA field form was used to assess neighborhoods in terms of age, lot size, tree cover, drainage, lawn size, general upkeep, and evidence of resident stewardship (i.e., storm drain stenciling, pet waste management signage, etc.). Each site was assigned a pollution severity rating of "severe," "high," "moderate," or "low," using a set of benchmarks set forth in Wright et al. (2005). Pollution severity is an index of the amount of non-point source pollution a neighborhood is likely generating based on easily observable features (i.e. lawn care practices, drainage patterns, oil stains, etc.). A restoration potential rating of high, moderate or low was also assigned to each neighborhood. Restoration potential is a measure of how feasible onsite retrofits or behavior changes would be based on space, number of opportunities, presence of a strong homeowner association (HOA), and similar factors.

Table 3.4. Types of Projects Identified During Neighborhood Source Assessment

Type	Description	Examples
On-site Retrofits	Homeowners reduce stormwater runoff generated by their lots	• Rain gardens • Rain barrels • Other rooftop disconnection
Lawn and Landscaping Practices	Better lawn and landscaping practices minimize the use of chemicals and encourage the use of native landscaping. These types of projects are generally needed in neighborhoods where high input lawns and extensive turf cover are prevalent	• Improved buffer protection • Native plantings • Turf reduction • Proper fertilizer and pesticide application
Open Space Management	Management of neighborhood common areas or courtyards	• Landscaping • Pet waste education • Stream buffer restoration • Trash removal

Summary of Sites Assessed

A total of 56 neighborhoods were visited by the field crews. A list of the assessed neighborhoods can be found in Attachment E. The assessed neighborhoods were predominantly a mix of older and newer single family homes. Older neighborhoods were concentrated in the Lower Crane Creek subwatershed near the City. Many of the newer developments were located in the Beasley Creek subwatershed near the Town, and in the Upper Crane Creek subwatershed (Subwatersheds F, G, H, I, J). Many neighborhoods were observed to have little or poorly functioning stormwater management practices. A large majority of all the homes observed had no downspouts or they were disconnected.

The Crane Creek neighborhoods assessed tended to rate as moderate or none in terms of pollution severity. Only two neighborhoods received a rating of “High” for pollution severity, mostly due to inadequate protection of bare soil spots in the sandhills region that are likely contributing sediment to the stream. A total of 33 neighborhoods received a rating of moderate pollutant severity, and 21 rated as low for pollution severity.

Restoration opportunities in the neighborhoods were also limited since 41 neighborhoods rated “Low” for restoration potential. This is likely due to the nature of the rooftop drainage, since guttering and downspouts were rarely found in many neighborhoods. Downspout disconnection typically offers the best chance to reduce runoff volumes, and the absence of downspout drainage systems also limited the use of residential rain gardens to capture and treat rooftop runoff. The existing restoration opportunities identified were focused on tree planting and conversion of turf to native landscaping, since a predominant amount of the neighborhoods assessed had lots that were covered with 50% or more of turf. In the sandhills region, it was observed that there were frequent bare spots in the lawns as grass is difficult to establish in these soils. In contrast, there were residential neighborhoods in the sandhills region that had more extensive landscaping and no exposed soil.

General Findings

The following are general findings that the field crew encountered throughout the watershed. Figure 3.5 illustrates some of the field findings. A map in Attachment A provides the location of specific sites..

<u>1. Lawn and Landscaping Practices</u>
High amounts of fertilization were observed in the common areas and lawns of many neighborhoods, as evidenced by strong odors and green, highly manicured lawns. Field crews also noted several instances of irrigation occurring during rainfall events. In several neighborhoods, particularly newer ones, a lack of tree canopy was observed.

<u>2. Pollution Prevention Practices</u>
Although storm drain markers were observed in several neighborhoods, lots of trash was still observed in nearby streams (see Section 3.4). Conversations with County staff indicate that the storm drain markers are installed by youth groups with little engagement of residents.

<u>3. Residential Retrofit Opportunities</u>
As noted in Section 3.2 of this report, many neighborhoods were observed to have little or poorly functioning stormwater management practices. Several opportunities for improved stormwater management noted include bioretention in cul-de-sacs, parking lot retrofits, repair of existing stormwater dry ponds, and incorporating stormwater treatment into wide residential roadways.

(a) (b) (c) (d)

Figure 3.5. Field findings from NSA. (a) bare soils in neighborhood G-NSA-2; (b) over-fertilization in neighborhood I-NSA-3; (c) Stormdrain marker in neighborhood F-NSA-2; and (d) pond modification at neighborhood F-NSA-2 (F-RRI-30).

3.3.3 Erosion and Sedimentation Control Observations

Overview

Field teams also noted erosion and sedimentation control (ESC) practices at current construction sites as part of the upland assessments. Construction sites that do not have functional ESC controls can be a significant source of sediment to receiving waters. It has been reported that erosion associated with construction activities can be 200 times greater than that from cropland and 2,000 times greater than that naturally occurring in woodlands (USEPA, N.D.). Construction activities also result in the most concentrated form of erosion - the rate of erosion from construction sites can exceed that from agricultural land by 10 to 20 times (USEPA, N.D.). In addition, sediment can carry other pollutants (heavy metals, nutrients, chemicals) which may also contribute to water quality problems. ESC is particularly challenging in the Crane Creek watershed due to the soils that consist of sandy soils and areas with high clay content (Figure 2.5). Soils with high clay content have very fine particles that are difficult to contain with standard ESC practices. While, in the sandhill region, establishing a grass cover is challenging.

Summary of Sites Assessed

Field teams identified numerous instances of poor or nonexistent ESC controls at active construction sites. A total of 15 incidences of failing or poorly maintained ESC practices were documented during the week of field work. A list of these sites is found in Attachment E. It should also be noted that additional sites were identified during previous trips to the watershed by the Center, so this is an ongoing problem. Figure 3.6 provides examples of some of the problems encountered by the field crews during the week of field work.

(a) (b) (c) (d) (e) (f)

Figure 3.6. Erosion and sediment control problems found during field work. (a) Poor ESC at a subdivision construction site (E-ESC-2); (b) failing ESC at an inactive construction site (H-ESC-1); (c&d) sediment export from an abandoned sediment pond (F-ESC-2); and (e&d) poor ESC along utility line construction (B-ESC-2) and (B-ESC-1).

3.4 Unified Stream Assessment

Assessment Protocol

The primary assessment protocol used to assess stream corridors in the Crane Creek Watershed was the Unified Stream Assessment (USA), which is a comprehensive stream walk protocol developed by the Center for evaluating the physical riparian and floodplain conditions in small urban watersheds. The USA integrates qualitative and quantitative components of various stream survey and habitat assessment methods and is used to identify locations of severely eroded stream banks, utility crossings, stormwater outfalls, impacted riparian buffers, excessive trash accumulation and dumping, stream crossings, and channel modifications within the stream corridor. Restoration opportunities for discharge prevention, stream restoration, stormwater retrofits, and riparian reforestation are also identified. More detail on conducting the USA protocol can be obtained directly from Kitchell and Schueler (2004).

Summary of Reaches Assessed

Eighty-five stream reaches were evaluated in the Crane Creek watershed using the USA. The portion of Crane Creek between Hospital Lake at SC 555 (Farrow Rd) and Lake Elizabeth (Nina Lee Drive) was assessed by Genesis Consulting Group in October and November of 2008 (GCG, 2009) and was not included as part of this stream assessment. An overall quantitative score for each reach was assigned based on average physical condition of various in-stream and riparian parameters (i.e. diversity of instream habitat, floodplain connectivity, vegetative buffer width, etc.). These scores were used to classify stream reaches into condition categories ranging from *excellent* to *very poor* (Table 3.5).

The best reach score in the study area was I-RCH-3, which scored 148 points. This can be considered a representative score for the best attainable condition for a reach within the watershed. A score of at least 89% or greater than this number (≥131) is considered comparable to the reference condition and represents excellent stream conditions for the watershed. A score less than 19% (≤68 pts) of the reference score is considered very poor. Between these two extremes, 46% of the reference score (103≥68 pts) represents poor stream conditions, 71% of the reference score (120≥103 pts) represents fair stream conditions, and 81% of the reference score (131≥120 pts) represents good stream conditions.

Table 3.5. Stream Reach Scoring Criteria		
Classification	**Percentile**	**Point Threshold**
Excellent	89%	≥131
Good	81%	131 ≥120
Fair	71%	120 ≥103
Poor	46%	103 ≥ 68
Very Poor	19%	≤ 68

While these criteria serve to place the assessed reaches in context, they are somewhat subjective. A reach scoring a few points higher than another may be placed in a higher category, but the qualitative aspects of the method make differences of a few points insignificant.

Reaches scoring fair often had better quality riparian buffer areas than reaches scoring in the poor and very poor ranges. Maps of the stream reaches assessed and the observed impacts can be found in Attachment A.

Summary of Reach Impacts

A summary of notable restoration opportunities and stream impacts observed in the stream reaches are presented in Table 3.6. A complete list of the stream reaches assessed and the stream impacts observed can be found in Attachment E. Figure 3.7 provides examples of stream impacts. Twenty-three high priority opportunities to restore the riparian corridor in the Crane Creek watershed were identified. Specific techniques prescribed to these twenty-three locations include stream clean-up, invasive plant removal, riparian reforestation, natural regeneration, residential education, and discharge inspection.

Table 3.6. Summary of Noted Stream Improvement Opportunities and Impacts

Impact Type	Site Description
Discharge Investigation	• Outfalls with algae growth associated with a drained wetland and residential lawn fertilizer, respectively (F-OT-2, G-OT-1, G-MI-1, K-MI-1) • Potential illicit discharges found in stream (M-UT-1, L-RCH-3) • Sewer pipe leaks reported to the City of Columbia Department of Public Works. Crew started repairs (M-RCH-2, M-RCH-10)
Stream Buffer Restoration	• Impacted buffer identified along 5,754 linear feet of stream (1.1 miles) • Residential stream encroachment through the form of mowing to the edge of the stream (F-IB-1, G-IB-2, G-IB-3, L-RCH-5, M-RCH-2, L-RCH-8, K-RCH-13, L-RCH-2, L-RCH-3, L-RCH-5, M-RCH-20) • Lack of stream buffer at Oak Hills Golf Course (G-IB-2, I-IB-11). • Overall, narrow stream buffer along most streams (5 ft-30 ft)
Infrastructure Problems and Stream Crossings	• Several utility lines cross the stream acting as a trash rack and altering hydrology (K-RCH-12, L-RCH -5, L-RCH -6, L-RCH-8, M-RCH -1) • Utility corridors crossing streams were common (J-RCH-2, M-RCH-3, K-RCH-11, J-RCH-11, J-RCH-12) causing bank erosion and cleared stream buffer. • Several stream impacts from utilities were noted with associated impacts from trucks crossing the stream

Table 3.6. Summary of Noted Stream Improvement Opportunities and Impacts	
Impact Type	**Site Description**
Trash Removal and Education	• Dumping of old appliances, fertilizer bags, clothes, car parts, garbage, etc in floodplain and adjacent upland areas (G-TR-4, I-TR-1, J-TR-1, K-TR-1, L-RCH-3). • Residential trash found in stream and floodplain including plastic, paper, glass, tires (F-TR-1, G-TR-1, G-TR-2). • Dumping of Vehicles (D-TR-1) • Trash in stream reaches L-RCH -1, L-RCH-7, M-RCH-2, L-RCH-2, G-RCH -10, E-RCH -20, L-RCH -3, M-RCH-1, I-RCH-1, G-RCH -7, J-RCH-5, G-RCH-1, G-RCH-8, J-RCH-3, F-RCH-5, I-RCH-2, H-RCH-31, K-RCH-1, M-RCH -20
Bank Erosion	• Steep stream banks eroding behind residential neighborhood (F-ER-1) • Severe bank erosion occurring at an industrial park (C-RCH-2) • Utility crossings with soil erosion (J-ER-11, J-ER-12, J-RCH-2, M-RCH-3, K-RCH-11, K-RCH-13)

General Findings

The following are general findings that the field crew observed throughout the watershed. Figure 3.7 illustrates some of the field findings. Attachment E provides a list of specific site locations.

1. Stream Buffer Encroachment
   In the more developed parts of the watershed, Upper Crane Creek and Lower Crane Creek, stream buffers ranged from 5 feet to approximately 30 feet wide. Larger, forested stream buffers were noted in the less developed Beasley Creek. Stream buffer impacts were noted associated with residential homeowner encroachment on the stream including mowing to the edge of the stream. A total length of 5,754 linear feet of the stream corridor was recorded as having an impacted buffer.

2. Trash
   Trash (e.g. plastic, paper, etc.) was identified in most of the streams that flow through residential neighborhoods. A large percentage of the trash consisted of recyclable materials including plastic and glass bottles. While these neighborhoods often had stormdrain markers, they did not seem to be effective at preventing dumping or littering near-by.

   There was also several trash sites found along the stream corridor throughout the more rural areas of the watershed. Trash at these sites included larger items including large appliances, clothing, tires, and car parts.

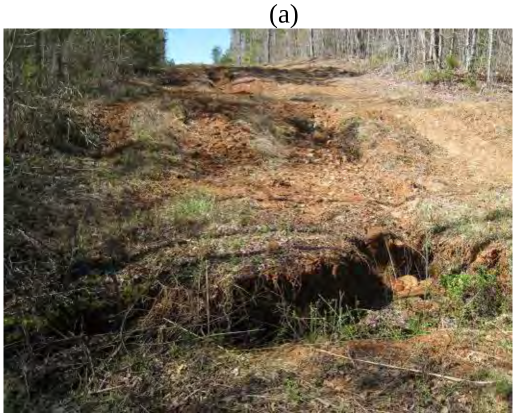
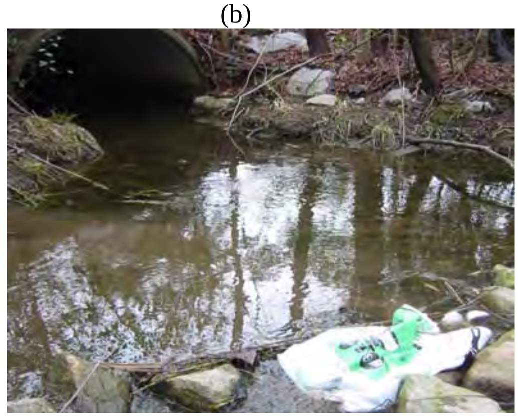
3. <u>Utility Impacts</u>
   Several impacts from utilities were noted that include stream bank erosion and clearing of stream buffers.

4. <u>Residential Fertilizers</u>
   Excessive algal growth was seen at several outfalls along the stream and in the ponds. In fact, at one outfall a fertilizer bag was found in the stream. In the sandhill region it appears that establishing grass is challenging and excess fertilizers are used to combat this problem. Also, the excessive use of fertilizers in the neighborhood common areas was noted as evidenced by excessively green grass and an odor of chemicals.

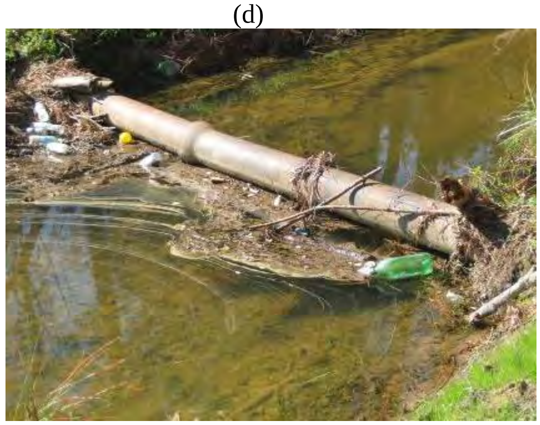
5. <u>Bank Erosion</u>
   Bank erosion was frequently noted along utility corridors near streams (see Utility Impacts) and also in high density residential areas and an industrial area. In most of these areas stream buffers were either cleared or lacking vegetation. Other areas had large quantities of unmanaged stormwater that discharged directly to the stream reach. In utility areas, vehicle access lanes often impacted the stream.

6. <u>Illicit Discharges</u>
   Elevated sewer pipes were frequently noted across stream reaches. These pipes cause alterations to the stream hydrology, act as trash racks and are potential sources of sewage to the stream. During field work, illicit discharges were identified and reported to the City (M-RCH-2, M-RCH-10). Repair crews responded to repair the problems.


(a) (b)

(c) (d)

(e) (f)

Figure 3.7 Stream restoration opportunities. (a) mowed and fertilized stream edge (L-RCH-5) located in neighborhood L-NSA-3; (b) trash including plastic bottles, wrappers and cups in G-RCH-10; (c) erosion impacts associated with utility crossing (J-ER-11); (d) fertilizer bag in stream in neighborhood G-NSA-2 (G-TR-2); (e) utility corridor located above stream reach K-RCH-13 contributing to bank erosion and impacted buffers; (f) sewer utility across stream acting as trash barrier (L-RCH-5).

3.5 Conservation Area Assessment

Although the Crane Creek watershed has obvious, identified impacts from human activities throughout, many opportunities exist to implement protection and restoration strategies. The watershed is expected to become a hotspot for future development, so it is critical to protect valuable natural areas now.

The goal of conservation area planning is to identify and prioritize areas for protection based on their ability to protect habitat, biological integrity, and water quality. Ecological factors such as the size and quality of the forest, the presence of rare, threatened or endangered species (RTEs), the connectedness of the floodplain, the presence of wetlands, in-stream habitat, and the preservation of aquatic corridors and historic areas are all considered when identifying potential conservation areas. Prioritizing conservation areas also requires consideration of non-ecological parameters such as easement/acquisition costs, parcel ownership, development potential, and public priorities. Effective conservation area planning should, at a minimum, protect the natural areas critical to biological diversity and overall watershed function, as well as protecting unique historical areas. During the Crane Creek Watershed assessment, field crews evaluated two primary types of conservation areas; forest and wetlands. Rare, threatened and endangered (RTE) species information was also accessed through the South Carolina Department of Natural Resources and used to develop a profile of species likely located in the watershed (SCDNR, 2009).

3.5.1 Contiguous Forest Assessment

Several Crane Creek forest areas were surveyed to identify existing blocks of mature contiguous forest and to generally characterize the species and conditions in the forests. Contiguous forests are defined as forestland without significant breaks such as roads, power lines or other clearings. The larger and more round a tract of contiguous forest, the greater the amount of interior forest created. Interior forest is commonly defined as forest that is at least 100 meters (330 ft) from the forest edge (Wilcove, 1985), and is important for many species of birds, wildlife and plants (Wenger, 1999). Large contiguous forests make it difficult for crows, cowbirds, feral cats, starlings and other species associated with the forest edge to predate or disrupt breeding and foraging behaviors of interior bird species. In contrast, fragmented forest allows entry points for crows and feral cats to prey on eggs and nesting birds, and allows easier access for cowbirds to parasitize nests and for starlings to take over cavity nests used by native species. Both cowbird parasitism and nest predation decrease considerably in contiguous forests. Many species of migratory songbirds that breed in the County rely on large tracts of contiguous forest that have declined both locally and in the eastern United States (USGS, 2000).

Historically, the native long leaf pine forests dominated the Crane Creek landscape but now they make up just 3% of their historical range (Figure 3.13). Much of the forest has been replaced by loblolly pines that are more easily grown in plantations, agricultural land, and urbanization (Pers. Comm., Richland County Forester). The long leaf pine requires fire for seed regeneration as part of its lifecycle and was therefore more difficult to grow in plantations. Long leaf pine forests have been restored in several areas including Fort Jackson, SC, where prescribed burns keep the understory clear and allow for the natural regeneration of long leaf pines and suppression of understory and competitors.

Figure 3.13. Longleaf Pine forest with its characteristic open understory from Santee Coastal Reserve.

Assessment Protocol

The evaluation of Crane Creek's forests involved two steps: (1) 2007 land cover digital orthophotographs provided by the County were analyzed to identify potential contiguous tracts to visit in the field, and (2) a field evaluation of forest community, structure, and condition was conducted using a Contiguous Forest Assessment (CFA) developed by the Center.

Information collected during the CFA included the dominant tree species, the percent canopy cover, forest structure, understory conditions, and site impact conditions. Invasive species and diseases were also noted. Multiple locations within a forested tract were often surveyed to generate average forest conditions for the tract. The highest quality tracts are identified in the *Plan* as conservation priorities.

Summary of Sites Assessed

A total of 11 forest sites were assessed in the Crane Creek watershed (Table 12). A map of the forest survey points is found in Attachment A and details about these points is found in Attachment E.

General Findings

During field visits, teams recognized that the majority of forest stands were managed forest stands for timber harvest and therefore very few intact mature contiguous forest areas were located in the watershed. Most of the mature forest that was identified was located within the riparian corridor or within wetland areas (Figure 3.14).

The upland forests were dominated by active timber management, though according to the local foresters, much of the forestland has since been sold by the large timber companies. It is still subject to cutting and management by private landowners and contractors. Bottomland hardwood forest was often found associated with streams and wetlands and appears to receive less active cutting which is beneficial since riparian stream buffer areas are important for water quality.

Figure 3.14. Representative forest conditions in Crane Creek. (a) A specimen white oak tree located adjacent to a stream in Subwatershed B (B-RCH-6); (b) a bottomland hardwood forest located in Subwatershed A (A-FP-5); (c) a representative pine forest that has undergone thinning in Subwatershed B; and (d) a clear cut pine forest during regeneration (B-FP-2).

3.5.2 Wetland Function Assessment

Assessment Protocol

An effort was made to characterize the wetland wildlife habitat and water quality functions in the Crane Creek watershed. Isolated wetland areas, as identified using National Wetlands Inventory (NWI) data, were targeted for assessment since these wetlands are not protected by federal, state, or local regulations. These wetlands, however, can often provide numerous ecological and water quality benefits to the stream (Cappiella et al. 2007).

Wetland sites identified from the NWI data were evaluated in the Crane Creek watershed and verified in the field. They were assessed for wildlife habitat function and water quality function using the Evaluation for Planned Wetlands (EPW) assessment (Bartoldus et al. 1994). Information was collected on the hydrologic condition, size, vegetation, cover types, and geometry of the wetlands. The functional capacity for each wetland was calculated using a numeric functional capacity index (FCI) with score ranges from 0 (no functional capacity) to 1 (optimal functional capacity).

Summary of Sites Assessed

A total of 8 wetland assessments were completed in the Crane Creek watershed. The functional wildlife and water quality capacity for each of these wetlands was calculated using a numeric functional capacity index (FCI) score that ranges from 0 (no functional capacity) to 1 (optimal functional capacity). The FCI scores for each evaluated wetland are listed in Attachment E. A map of the locations for each wetland surveyed is found in Attachment A. It is important to note that several additional wetland sites were visited (sites listed in Attachment E), but no field form was filled out, due to similarities with other wetlands. These sites are important because they provide good habitat, water quality and are clearly "hydrologically connected" to down stream areas. It is important to note that these streams were not present on the existing USGS quadrangle maps often used to indicate the location of streams.

General Findings

Wetlands assessed in the watershed generally showed very good scores for both water quality and habitat (Figure 3.15). A few wetlands were deemed to have relatively low value due to size or disruption by clearing for power lines or impacts from nearby construction. At site C-WP-2, large quantities of sediment were observed in the wetland bottom due to poor ESC at a nearby site (Figure 3.16).

In the field the majority of the flagged NWI isolated wetlands were determined to be hydrologically connected to streams or other surface waters. This reflects the importance for protecting wetlands in this watershed, particularly ones that were identified as isolated according to the NWI layer but in the field were determined to be hydrologically connected. It is important to note that these streams connected to wetlands were not present on the existing USGS quadrangle maps often used to indicate the location of streams. Man-induced wetlands were observed in sporadic areas in the field reviewed areas (upgradient of road culverts and scattered areas along the sanitary sewer/underground gas pipeline in

Subwatershed D and within the abandoned brick clay pits in Subwatershed M). It is anticipated that the upper headland valley seeps without ponds would dry out in the late summer and fall seasons. Well developed sloughs form the majority of the Broad River floodplain with some sloughs, despite being impacted by floodplain encroachment and sanitary sewer pipes, evident along the lower reach of Crane Creek.

(a) (b) (c)

Figure 3.15. Wetland habitats from Crane Creek. (a) constructed pond formed by creating an embankment on a small headwater stream (B-WP-1); (b) headwater stream wetland with nearby development (C-WP-7); and (c) wetland with tulip poplars and a small ephemeral stream (A-WP-4).

Figure 3.16. A wetland impacted by sediment from a poorly controlled construction site (C-WP-2).

3.6 Green Infrastructure Analysis

Green infrastructure (GI) planning is a form of strategic conservation planning whereby a core of interconnected networks of green and open space areas is defined, in this case, through a Geographic Information System (GIS) analysis with field verification. The concept underlying GI protection is to link large, contiguous blocks of ecologically significant natural areas (hubs) with natural corridors. Such connections can help to offset the functional losses caused by fragmentation from development. GI planning is currently being utilized by the County at multiple levels:

- The County, in conjunction with the Central Midlands Council of Governments, has a conceptual GI Network of protected lands, sites and river/stream corridors.

- The County has a draft Greenway Plan that identifies the Crane Creek Watershed floodplains as a priority segment for preservation and recreation in a GI network. The Greenway Plan seeks to create a network from the Broad River to the Town.

- The County's Comprehensive Plan (Richland County, 2009) identifies several natural resource goals with a GI focus including: 1) within 2 years, establish a protected greenway corridor/trail system and to connect existing parks and trails; 2) within 3 years, establish an Environmental Protection Overlay District limiting land use activities that increase the risk of water pollution; and 3) on a continuous basis, consider innovative land use mechanisms for protecting natural resources, such as Transfer of Development Rights (TDR), clustering, density bonuses, wetland and stream mitigation, Low Impact Development (LID), best management practices (BMPs) and conservation easements.

The Crane Creek GI analysis can assist the County in meeting the objectives identified in the planning documents above as well as additional conservation recommendations discussed in this *Plan*. The GI assessment emphasizes strategic areas for basing conservation efforts. These areas can be targeted for actions such as: 1) developing a trail system; 2) forming the basis for an Environmental Protection Overlay District; 3) targeting acquisition and conservation easement efforts; and 4) directing TDR, LID and other initiatives in ways that are the most beneficial and strategic for natural resources protection. The methodology and criteria used to construct the GI network can be found in Attachment G.

General Findings

Areas were classified in GIS and categorized based on a ranking value into one of the following categories for their suitability or unsuitability into the GI network: high priority conservation area, priority conservation area, conservation area, potential conservation area, not suitable, and very not suitable. In general, the primary GI network is composed of the stream corridor and floodplain (green, light green and yellow areas in Figure 3.17). These high priority conservation areas, priority conservation areas and conservation areas, when summed together, account for approximately 18% of the watershed and represent the primary

GI network. Approximately 28% of the watershed has potential for inclusion in the GI network and should be field evaluated to make any further determination (Table 3.7). Roads and areas dominated by impervious cover were considered not suitable for inclusion in the network as they are considered to be barriers to the movement of plant and animal species as well as hydrology (orange areas in Figure 3.17). This area amounted to over 50% of the watershed and includes areas composed largely of urban and residential development and areas of high road density.

Table 3.7. Classification of the GI Analysis.

Suitability for Inclusion in GI Network	Percent of Watershed
High priority conservation area (value 351-475)	3.35%
Priority conservation area (value 276-350)	4.47%
Conservation area (value 221-275)	10.00%
Potential conservation area (value 151-220)	27.9%
Not suitable (value 51-150)	34.35%
Very not suitable (value 0-50)	19.92%

Primary Conservation Network (18% of Watershed)

Conservation hubs were identified based on high values resulting from the GI analysis and also from findings from the field-based conservation assessments (Figure 3.18). The total area of all conservation hubs was about 8,440 acres (~19.5% of the watershed) and the mean individual hub size is approximately 560 acres. The largest hubs were located primarily in the Beasley Creek subwatershed. The Upper and Lower Crane Creek subwatersheds contain smaller hubs (~189 acre average size) located primarily in headwater areas. Corridors, totaling 25.6 miles, link the hubs, primarily through the stream and floodplain network. A potential recreational greenway corridor was mapped within the primary conservation network.

Figure 3.19 clearly presents the primary conservation areas and hubs and highlights features of the assessed natural areas in the Crane Creek Watershed. The total area included in the primary conservation network and conservation hubs accounts for 37.6% of the total watershed area.

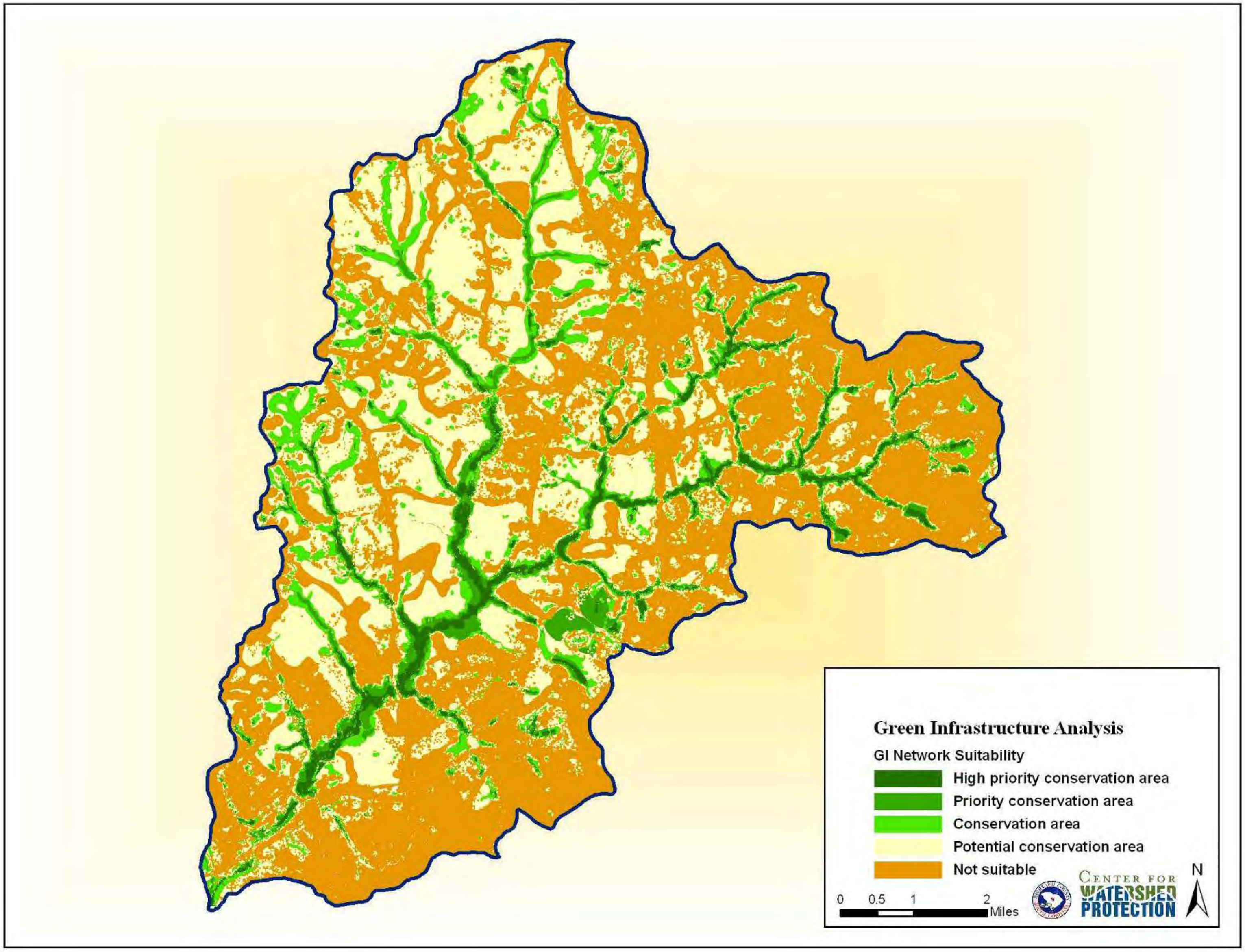


Figure 3.17. GI Suitability Analysis.

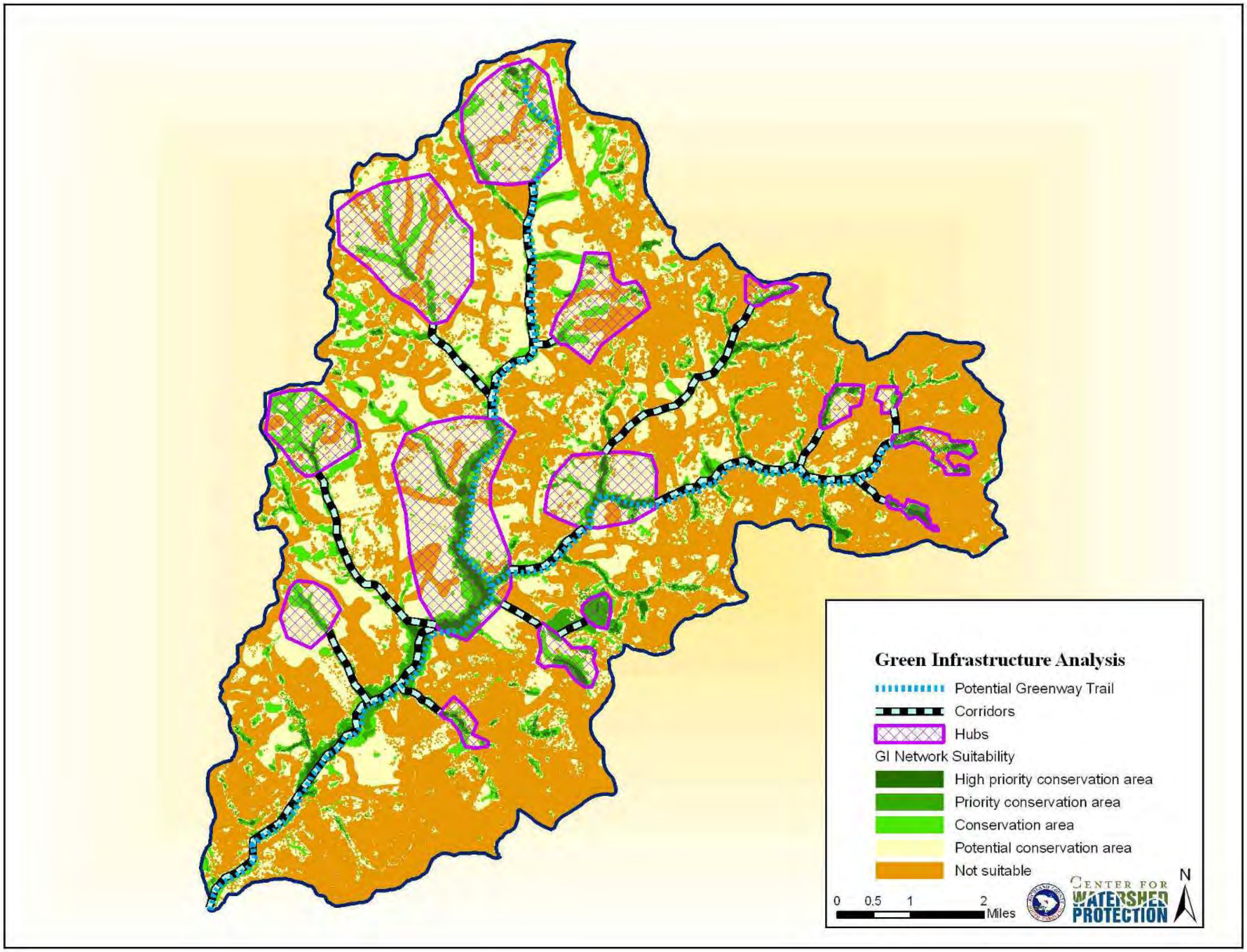


Figure 3.18. Proposed GI Network and Greenway.

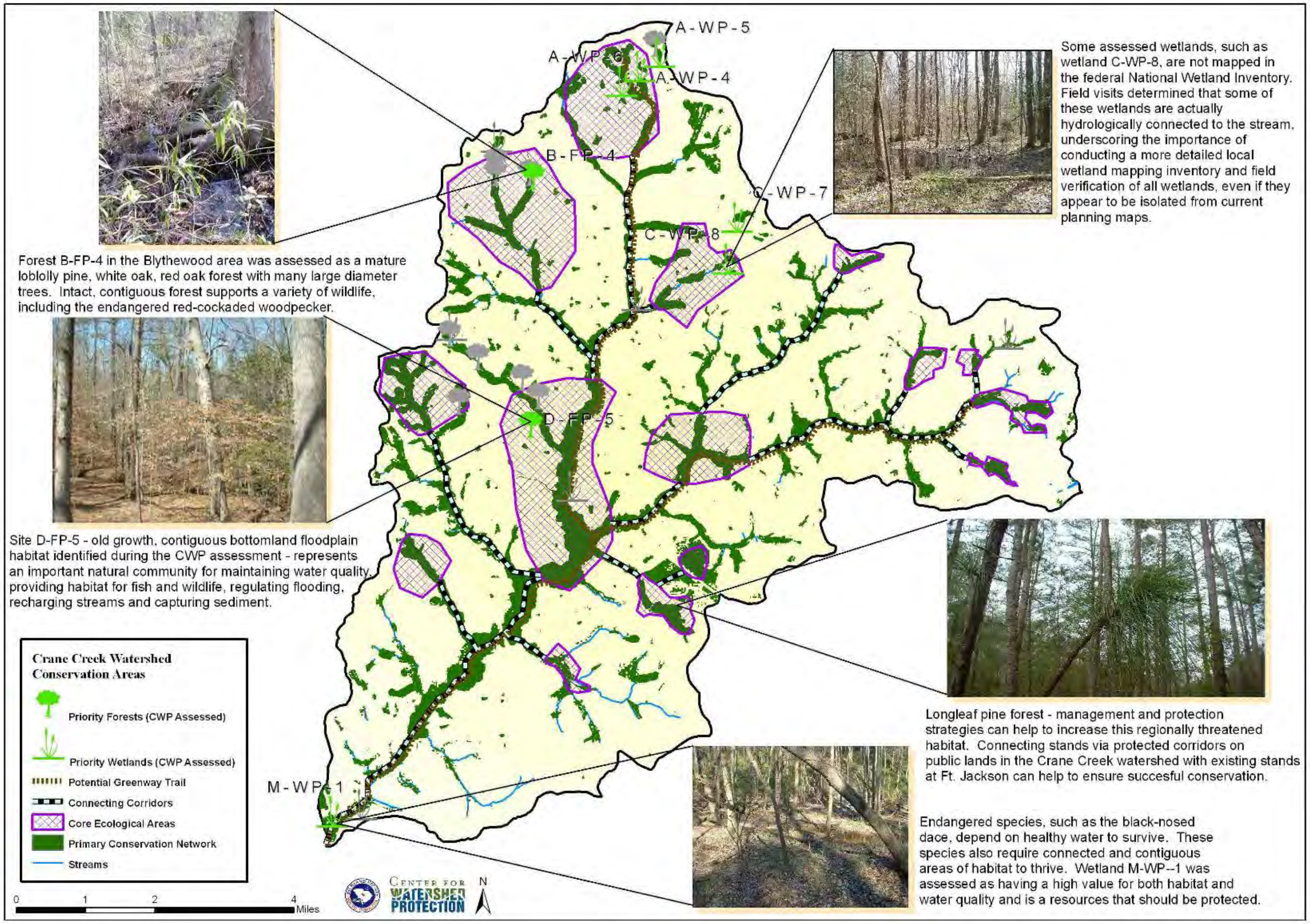


Figure 3.19. Conservation Priorities in the Crane Creek Watershed.

SECTION 4. WATERSHED GOALS, OBJECTIVES AND STRATEGIES

Strategies for managing the County portion of the Crane Creek Watershed are guided by the vision of the Crane Creek Watershed Association (CCWA), preliminary planning goals, and supporting objectives identified by stakeholders in the Crane Creek Watershed. The objectives are geared towards improving impaired conditions of Crane Creek. This section presents the vision, goals, objectives, and 12 key strategies for managing and protecting the Crane Creek watershed. Section 5 details recommended actions to support these key watershed strategies. Section 6 presents more specific subwatershed management strategies.

4.1 Crane Creek Watershed Vision, Goals, and Objectives

The CCWA was formed in Fall 2008 by the County, in partnership with the University of South Carolina and watershed stakeholders (watershed residents, local environmental groups, and County, City and Town staff). The CCWA has established the following vision statement:

> "*The Crane Creek Watershed Association is a citizen-based group united for and working to maintain, protect, and further improve the natural environment within the Crane Creek Watershed. Our vision for the watershed is to be a place where people enjoy hiking trails, scenic parks, and fishing and swimming in the creeks and ponds within the watershed, and where environmentally-sound development codes protect the health of the watershed by taking into account impacts on water quality, water quantity, and wildlife habitat. The Association will achieve this vision by providing a unified voice to the appropriate governmental agencies to enforce existing laws and discourage actions that will be harmful to the watershed. The association will foster partnerships to improve knowledge of existing conditions, take action to correct identified problems, and educate citizens and public officials on the state of Crane Creek Watershed.*"

In addition to the watershed vision established by the CCWA, the Center developed initial planning goals at the onset of this project to guide the baseline assessment and field assessments. These general watershed goals are to:

- Improve water quality
- Decrease stream erosion and sedimentation
- Reduce localized flooding
- Protect in-stream and upland habitat

Feedback from a stakeholder meeting, along with input by the County, was used to establish seven specific watershed objectives that meet the vision of the CCWA and the initial watershed planning goals. These specific objectives are listed below.

1. Improve the water quality and biological condition of Crane Creek by implementing stormwater retrofits and addressing sources of nonpoint source pollution.

2. Improve the water quality of Crane Creek to meet the fecal coliform reductions identified in the 2006 TMDL (48% load reduction upstream and 92% downstream of Lake Elizabeth) and reduce sediment loads by 50%.

3. Reduce flooding by minimizing the creation of future impervious cover, installing stormwater retrofit practices on existing development sites that reduce stormwater runoff (i.e. rain gardens, permeable pavement, rain barrels, infiltration practices), and by encouraging the use of these runoff reducing stormwater practices on new or re-development sites.

4. Promote recreational activities such as hiking, trail walking, fishing and swimming along the Creek. Crane Creek should serve as an environmental corridor and recreational resource for the County.

5. Reduce the impact of future growth on the Crane Creek Watershed by promoting environmentally sound development codes, retaining the existing forest canopy cover, and protecting 30% of the open space lands in the watershed.

6. Protect and restore sensitive and natural resource areas such as mature, hardwood and pine forests, isolated wetlands, environmentally sensitive areas, and intact stream buffers.

7. Increase the understanding and awareness of Crane Creek among residential, commercial, business, development, and local government communities through pollution prevention education, watershed restoration activities, trainings and workshops.

4.2 Watershed Strategies

To meet these objectives, twelve key strategies are recommended for the Crane Creek watershed. They are based on the results of the watershed baseline assessment, field findings, and watershed objectives. These strategies focus on municipal practices and programs, natural resources protection, the treatment of polluted runoff, and source control and education.
These strategies are presented in order of implementation priority, and are intended to be implemented watershed-wide, regardless of jurisdiction. The County, City, and Town should work together to achieve these strategies and use the Crane Creek watershed as a model for other watersheds in those jurisdictions. Section 5 details recommended short-term, mid-term, and long-term actions to support these key watershed strategies along with a detailed implementation plan for addressing these strategies.

1. **Implement programmatic changes to improve the County ESC regulations, enforcement, and inspection program.**
   In order to address sediment loads to Crane Creek, the County should work to establish improved ESC enforcement with more frequent site inspections. The County should conduct immediate and follow-up inspections at all observed ESC sites, which are listed in Attachment E. In problem areas, the County should assist in the stabilization of site

soils, particularly in areas where soil is sandy and grass establishment is difficult. Additionally, the County should work to increase the number of ESC field inspectors, frequency of inspections and enforcement measures. A “grassing bond” (similar to an ESC performance bond) should be required at the beginning of a development project for all new and re-development sites to provide financial incentive for the developer to not abandon the site and provide financial means for the County to fix the site if it is abandoned. The County currently requires a “grassing bond” if a site isn’t stabilized upon final inspection. Additional recommendations to improve the ESC program are provided in the Richland County Roundtable document and the Post-construction audit (Attachment K).

2. **Inventory and map key natural resource areas.**
   A local wetland, RTE species, contiguous forests and stream inventory should be completed for the Crane Creek watershed to identify prime habitat and valuable natural resource areas. The inventory should build upon the field work conducted for this *Plan*. This information should be mapped and incorporated into local planning and resource protection regulations. It was noted during field work that several intermittent streams and wetlands were not identified on the existing mapped stream or wetland data layers. Having updated information on primary natural resources would ensure adequate protection of these areas.

3. **Permanently protect primary conservation areas.**
   Over the long-term, protection strategies should be implemented to ensure the preservation of the rural integrity, character, and health of the watershed into the future. The County should work to permanently protect 18% of the watershed identified as primary conservation areas, and an additional 19.5% of the watershed encompassed in conservation hubs. These areas are mapped and discussed in Section 3.6 of this report. Protected of these lands can be achieved through acquisition, conservation easements, and by establishing a watershed Environmental Protection Overlay district to limiting development activity within the identified primary conservation areas and conservation hubs. Any development within this overlay district should be limited. A greenway trail system can be constructed to connect residential neighborhoods with the primary Crane Creek conservation network. The overlay district should be expanded to encompass additional natural resource areas identified by strategy 2.

4. **Adopt County Roundtable code and ordinance recommendations.**
   The County Roundtable developed recommendations for changes to the existing county development codes in order to achieve more environmentally friendly development in the County (see Section 2.7 and Section 5.2). Specifically, the recommendations encourage the use of more effective stormwater practices, increased protection of natural resources and enhanced preservation of open space. The recommendations have been approved by County Council and a committee was formed to incorporate these recommendations into the County Code. At the time of this report, two of the recommendations have been formally adopted, stream buffers (principle 17) and stormwater outfalls (principle 22).

The committee should continue work on the additional recommendations to have these adopted and codified. The adoption of these recommendations will provide considerable water quality improvements as the County continues to develop. Additionally, similar recommendations should be adopted by the Town and City to ensure enhanced and adequate natural resource protection throughout the entire watershed.

As a result of the adopted stream buffer principle, County Council approved a stream buffer ordinance that requires a minimum 50-foot stream buffer County-wide, and a 100-foot buffer along impaired waters. Since the entire Crane Creek watershed falls under a TMDL, a 100-foot stream buffer should be enforced throughout the entire watershed. In order to fully protect the health of Crane Creek, this ordinance should also be adopted by the Town and City.

5. **Hire a Watershed Coordinator.**
   The CCWA is currently being formed through a coordinated effort by the County and University of South Carolina. The vision statement for the association is provided in Section 4.1. As the focus moves toward implementation, the County should hire a watershed coordinator to oversee implementation of this plan, coordinate CCWA activities, and promote watershed stewardship into the future.

6. **Implement priority retrofits for water quality improvement.**
   Over 40 potential stormwater retrofits were identified throughout the watershed, which included both larger storage and smaller on-site retrofits. A complete list of identified stormwater retrofits is listed in Attachment E. The construction of priority stormwater retrofits is critical because there are many developed areas in the watershed with little or no existing stormwater management. Numerous retrofit opportunities were identified in residential developments, at schools and parks, and on public land. These projects include bioretention, rain gardens, downspout disconnection, and pond modification. These sites provide good opportunities for community education and outreach, and efforts should be made to involve the public in the design and construction of these retrofits.

7. **Explore opportunities for additional retrofits in neighborhoods.**
   Little or no existing stormwater management was observed in many neighborhoods, particularly in the Upper Crane Creek subwatershed. In developments with no existing stormwater management, opportunities for additional retrofit practices to treat roadway and driveway runoff should be further investigated. Many of the homes in these developments were observed to have disconnected downspouts that likely provide partial treatment of the rooftop runoff via filtration and infiltration, particularly on sites with sandy soils.

8. **Conduct stream clean-ups and implement stream corridor projects.**

Residential neighborhood trash clean-ups should be organized for identified stream segments. Trash and dumping sites were noted in stream reaches and areas throughout the watershed. Trash ranged from larger items such as old appliances and car parts, to plastic and glass bottles, and paper. A complete list of stream projects is in Attachment E.

9. **Conduct a neighborhood education campaign to educate residents about pollution prevention and source control.**
   Using the restoration information that was collected for each neighborhood, target neighborhoods for proper lawn care, trash awareness, trash clean-ups, native landscaping, tree planting, buffer programs, storm drain stenciling, downspout disconnection, and watershed education. Excessive algal growth was noted at several stormwater outfalls along stream reaches and in ponds near residential neighborhoods. Develop a targeted residential education program on the proper application of fertilizer and pesticides and the use of alternatives to grass lawns that include native species landscaping. Also, provide education to homeowners about the value and functions of stream buffers and their benefits to water quality. Homeowner encroachment into the stream buffer (e.g. mowing to the edge of the stream) was observed throughout the watershed. Identify and train a neighborhood captain to lead the restoration effort. Project partners can provide education and training to neighborhood captains and provide technical and program assistance as needed. In addition, project partners would provide materials needed for restoration practices such as trees and other materials as necessary. Information on the neighborhood assessments and opportunities is found in Attachment E.

10. **Develop a Green School and Institution Program.**
    A Green School and Institution program should be developed to provide watershed education and incorporate watershed restoration projects into an environmental curriculum that has an emphasis on the Crane Creek Watershed. Institutions include schools, places of worship and hospitals that generally contain large amounts of impervious cover and green space, ideal areas to treat stormwater runoff. During a Crane Creek stakeholder meeting, construction of schools was discussed as a particular problem and potential source of pollution due to poor ESC practices. Many pollution prevention, tree planting, downspout disconnection, rain garden, and pond retrofit opportunities were identified on school properties. These retrofits can be implemented at schools and used as a teaching tool and as an outdoor classroom for students.

11. **Develop a Business Stewardship Outreach Program.**
    A Business Stewardship Outreach program should be developed to engage the business community in watershed restoration. Many businesses were identified during field investigations as hotspots that contain known or potential sources of pollution such as improper storage of outside materials such as food waste or grease traps. Partners can work with businesses to implement pollution prevention practices on-site and in return become recognized as a “green business.”

1. **Promote partnership between the County, City, and Town on SSO response and repair programs, septic system education programs, and IDDE programs.**
   In order to reduce bacteria loads watershed-wide, attention to sewer and septic management is critical. Aging infrastructure and illicit connections contribute to sewer overflows throughout regions of the watershed. These problems, along with failing septic systems, result in high bacteria loads to Crane Creek. Several sewer overflows were observed during field assessments, which were reported and immediately fixed by authorities. The City is responsible for maintaining sanitary sewer lines and responding to overflows. The County should coordinate with the City to make sure overflows are immediately reported and repaired. Both the County and City should partner on efforts and share information on mapping sewer infrastructure, develop a database to document discharges and overflows, track maintenance activities and costs, and estimate discharge impacts. Problem areas should be carefully tracked and the County should work with the City to provide necessary repairs and upgrades to the sewer infrastructure. Further, as part of the neighborhood stewardship program (strategy 9), information on proper septic system care and maintenance should be provided to residents on septic systems. By mapping the sewered regions of the County as previously recommended, the County will be able to easily identify non-sewered areas to target for septic system education. Incentives for septic system pump-outs should be provided. Additionally, more stringent system inspections should be enacted for any new septic systems.

SECTION 5. RECOMMENDED WATERSHED MANAGEMENT ACTIONS AND IMPLEMENTATION PLAN

This section presents recommended actions to help achieve the 12 watershed strategies presented in Section 4 along with information on planning partners, planning level costs, and phasing and resources for the implementation of these actions.

5.1 Recommended Actions for Achieving Watershed Strategies

Recommended actions for each of the 12 management strategies are broken down into short-term, mid-term, and long-term actions.

- *Short-term* actions are initial actions to be carried out within the next year that set the framework for executing remaining watershed recommended actions. In general, these are time-sensitive activities to protect the watershed from future degradation and are considered highest priorities for implementation. Such actions include adoption of local ordinances and the identification of parcels for land conservation. Follow-up site inspections for ESC sites and hotspots and the development of a comprehensive watershed education program to target stewardship priorities and pollution source control projects should begin during this stage. Small, inexpensive demonstration projects (i.e. rain gardens, trash cleanup, tree planting) can be done to generate support for continued action. Construction of large retrofit practices is not included in this phase in order to accommodate required design, engineering, and permitting.
- *Mid-term* actions, which should occur over the next 2-4 years, involve continued programmatic and operational measures, distribution of educational materials, and construction of one or two large retrofit and/or stream stabilization projects. Securing funding for stormwater retrofit and educational projects during this phase is crucial. Progress on land conservation, continued enforcement and inspection, and establishment of a monitoring and tracking plan should occur during this period.
- *Long-term* actions mark continued implementation of any additional projects necessary to meet watershed objectives, as well as an evaluation of progress, accounting of successes and lessons learned, and an update of the watershed plan. L*ong-term* actions should be implemented in 5 or more years.

1. Implement programmatic changes to improve the County ESC regulations, enforcement, and inspection program.

Short-Term Actions

1. *Conduct follow-up inspections at identified ESC sites.* Fifteen problem ESC sites were identified at new and abandoned development sites (Section 3.3.3 and Attachment E).

2. *Implement ESC recommendations from the County Post-Construction Review.* This action will help ensure that the County regulations require adequate ESC practices. During the field assessments, numerous development sites were noted without adequate ESC practices, several of which were located adjacent to the stream corridor or at utility

crossings. In addition, several abandoned development sites were noted without adequate ESC practices. Unstable or improperly stabilized development sites were identified as the largest source of sediment to the creek. The recommendations from the Post-Construction Review are found in Attachment K.

3. *Require an ESC 'grassing bond' at the beginning of a development project.* Based on conversations with County staff during the Roundtable, it was noted that there was a systemic problem with abandoned development sites. This occurs when a developer completes the clearing and grading on a site but doesn't stabilize the site before the site is abandoned. In these situations, the County has no recourse to make the developer fix the problem and is left without funding to fix the problem themselves. The County currently requires a "grassing bond" if a site isn't stabilized upon final inspection. The "grassing bond" (similar to an ESC performance bond) should be required at the beginning of a project for all new and re-development sites to provide financial incentive for the developer to not abandon the site and provide financial means for the County to fix the site if it is abandoned.

4. *Improve coordination of the ESC and stormwater program between the County's Stormwater Management Division and Engineering Division.* The Engineering Division is responsible for reviewing site plans for new development and the Stormwater Division personnel are not involved in the review process nor are provided an opportunity to visit stormwater BMPs before construction of a site is complete. Only when final site stabilization is completed does the Stormwater Division become involved in a site's stormwater management issues. In general, the stormwater personnel do not seem to have the opportunity to provide input on the design, design features, or types of BMPs that are installed in new developments. This system indicates a lack of coordination between these two divisions and has likely led to several lost opportunities to prevent foreseeable future stormwater BMP maintenance problems.

Mid-Term Actions

5. *Increase the number of ESC field inspectors, frequency of inspections and enforcement measures.* The Engineering Division is charged with conducting the inspections of development sites during construction to enforce the use of proper ESC methods. The Division has several inspectors that are Certified Professionals in Erosion and Sediment Control (CPESC) and conduct ESC inspections in the field. Unfortunately, based on the state of some construction sites in certain parts of the County and from anecdotal evidence, in many cases ESC practices in the County are not well implemented and/or maintained (Attachment E). According to the post construction review, (Attachment K) this is partly due to the fact that the group of ESC inspectors is under-staffed in comparison to the amount of new development that has occurred in the County in recent years.

6. *Increase training for County ESC inspectors.* In order to ensure that personnel within the Division have a diverse set of skills and knowledge, they should be provided the opportunity to receive training in such topics as:
    - Hydrology

- Water quality and biology
- Construction, inspections, facilities maintenance
- Land use planning

7. *Limit the amount of development in soils with high clay content.* Consider developing different development and ESC design standards in these areas. Soils with high clay content have very fine particles that are difficult to contain with standard ESC practices. Without proper ESC, the soils can enter the stream and alter stream habitat.

8. *In sandy areas where establishing vegetation is challenging, consider using turf matting to stabilize soils.* In the sandhill region, it appears that establishing grass is challenging due to the sandy nature of the soils. In response, excessive fertilizer application is used to encourage the grass to establish faster. The excess fertilizer often runs off the lawn into the stream without successfully establishing vegetation. In addition, mixing rye grass with the permanent grass can be used to help prevent erosion on new lawns as it establishes faster than most grasses.

Long-Term Actions

9. *Consider County assistance with soil stabilization in sandy soil sites.* Since ESC problems related to poor site stabilization were observed to be a major source of sediment, it is in the County's best interest to assist with these efforts. Revenue generated through the enforced "grassing bond" can be used to supplement these efforts.

2. Inventory and map natural resource areas.

Short-Term Actions.

1. *Conduct additional field work to supplement Crane Creek conservation data.* Evaluate in more detail ~28% of the watershed identified as potential conservation areas in the GI analysis (see Section 3.6). These areas should be field verified for inclusion in the GI network.

Mid-Term Actions

2. *Develop and adopt a watershed map of all perennial and intermittent streams.* It was noted during field work that several intermittent streams were not identified on the mapped stream layers. Having an updated stream map would ensure adequate protection of county streams. The map would be used as a more accurate replacement of the USGS 'blue lines' for reviewing proposed site development plans.

3. *Locate, map and protect RTE species within the watershed.* Precise RTE species location information was unable to be determined through this watershed planning process, however, it is recommended that the County obtain RTE species location information.

4. *Complete a local wetland inventory*. The County currently relies on NWI data from 1989, which is out-dated and typically does not include wetlands smaller than one to three acres, ephemeral wetlands, farmed wetlands, and certain wetland types that are difficult

to identify from interpretation of orthoimagery. During the field assessments, several wetlands that appeared to be isolated on the NWI layer were identified as in fact being hydrologically connected to Crane Creek and its tributaries. Performing a local wetland inventory will help identify these areas and promote better protection of wetlands.

Long-Term Actions

5. *Incorporate updated natural resource data into GIS layers and use the data during development plan reviews.*

3. Permanently protect primary conservation areas.

Short-Term Actions

1. *Establish an Environmental Protection Overlay district in the Crane Creek Watershed similar to the existing overlay in the Gills Creek Watershed (*Sec.26-108 Land Development Code*).* This overlay district should encompass the 37.6% of the watershed identified as primary conservation area and conservation hubs. Development within this overlay district should be limited.

2. *Encourage the use of the Green Code on new development parcels in the watershed* (Sec. 26-186. Green Code Standards).

3. *Require protection of wetlands that appear to be isolated, especially when they have high water quality or habitat value.*

4. *Promote the County's Rural Legacy program, which can support conservation easements on forested and agricultural parcels.* This program can be used to target land parcels within the Environmental Protection Overlay district for acquisition or easement. The Congaree Land Trust is another potential partner in conservation and protection efforts within the Crane Creek watershed (to date, the Congaree Land Trust has acquired only one parcel in the northeast section of the Crane Creek watershed).

5. *Promote sustainable management of forests.* Partner with local Stewardship Foresters to educate small forest landowners on sustainable forest management principles.

Mid-Term Actions

6. *Direct mitigation and TDR efforts into the Crane Creek Environmental Protection Overlay district.*

7. *Consider opportunities for restoration of the native Longleaf pine ecosystem especially where they can be connected to other Longleaf pine habitat*. Encourage reforestation efforts, particularly in conservation hubs identified within the GI network.

8. *Develop a map of protected watershed open space and conservation areas.* This can help map will help track conservation progress and be a useful planning tool in directing future conservation and greenway planning efforts.

Long-Term Actions

9. *Develop a greenway trail system to connect residential neighborhoods with the primary Crane Creek conservation network.* A 21 mile trail is suggested that will also function to connect the Broad River Greenway to the Town (Figures 3.18 and 3.19).

10. *Aim to preserve 30% of the watershed as open space in the watershed.* Some smaller recommendations to achieve this goal include:
    - *Permanently protect 18% of the watershed identified as primary conservation areas.* As was shown in section 3.6, this 18% comprises the high priority conservation areas, priority, and conservation areas.
    - *Expand the Environmental Protection Overlay district to include resource areas with high water quality and habitat function as identified in strategy 2.*
    - *Promote restoration and acquisition activities in identified hubs and corridors.*
    - *Protect headwater areas and intermittent streams.* Valleys without ponds coalesce into intermittent streams then evolve into perennial stream channels. These headwater areas can be significant sources of sediment into a watershed and should also be protected from future impacts. In addition, with their associated corridors, they provide opportunities for recreational links of urban and suburban area residents to access the Crane Creek core network.
    - *Protect watershed ponds.* Ponds appear to attenuate stormwater flow and thereby protect in-stream conditions. As such, ponds should be a protected resource along with wetlands.
    - *Prioritize protection of lands in areas with sandy subsoils* (see Figure 2.5). Soils in the Sandhills region may perform a similar function as that listed in the previous bullet due to high infiltration rates in these areas.

4. Adopt the County Roundtable code and ordinance recommendations

Short-Term Actions

1. *Adopt the County Roundtable code and ordinance recommendations.* As noted in Section 2.7, the County Roundtable developed recommendations for changes to the existing county development codes in order to achieve more environmentally friendly development in the County. Specifically, the recommendations encourage the use of more effective stormwater practices, increased protection of natural resources, enhanced preservation of open space, and reduction of impervious cover. An implementation committee was formed to work towards implementation of the recommendations and should continue to meet on a quarterly basis. The adoption of these recommendations will provide considerable water quality improvements as the County continues to develop.

2. *Enforce the newly adopted 100-foot stream buffer ordinance*. Stream buffers function to reduce the impacts from land development including stabilizing banks, providing organic matter for aquatic life, filtering nutrients, providing habitat and attenuating flood waters

(Wenger, 1999). At the start of this project, the County had a 40-foot stream buffer regulation that was not currently enforced. More recently, County Council approved a stream buffer ordinance that would require a minimum 50-foot stream buffer County-wide, and a 100-foot buffer along impaired waters. Since the entire Crane Creek watershed falls under a TMDL, a 100-foot stream buffer should be enforced throughout the entire watershed. In order to fully protect the health of Crane Creek, this ordinance should also be adopted by the Town and City.

5. Hire a Watershed Coordinator.

Short-Term Actions

1. *Hire a Watershed Coordinator.* The CCWA is currently being formed through a coordinated effort by the County and USC. The vision statement for the association is provided in Section 4.1. As the focus moves toward implementation, the County should hire a full time watershed coordinator to oversee implementation of the plan, coordinate CCWA activities, and promote watershed stewardship.

6. Implement priority stormwater retrofits for water quality improvement.

Short-Term Actions

1. *Identify funding sources for retrofits.* Grant opportunities and other sources should be explored.

2. *Modify, repair, and/or maintain existing stormwater management facilities to improve water quality performance* During the field assessment, it was noted that the performance of several existing stormwater ponds, on both public and private lands, could be improved by performing maintenance, modifying pond designs to provide better water quality treatment, planting vegetation along the pond banks and bottoms of eroding ponds, stabilizing sites with unstable contributing drainage areas or pond banks, and performing structural repair on failing ponds. Also, geese were observed in some stormwater wet ponds that lacked vegetation, which can contribute high loads of fecal coliform in the watershed. Planting an aquatic plant bench and establishing a no-mow zone around the pond edge can deter geese and help to reduce fecal coliform loads in the watershed.

3. *Engage the public in implementation of retrofits on public lands or in neighborhoods.* Construct demonstration rain gardens or bioretention areas and promote native tree and shrub plantings throughout these sites.

Mid-Term Actions

4. *Disconnect downspouts to allow for treatment and volume reduction of rooftop runoff.* Disconnecting downspouts to pervious areas can allow for a portion of the runoff to infiltrate into the ground rather than being conveyed directly to the stormdrain system. Many areas of the watershed, particularly in Upper and Lower Crane Creek, contain

sandy soils with high permeably which have the potential to reduce greater volumes of rooftop runoff. In areas with clay soils, such as portions of Beasley Creek, rooftop runoff can still be reduced via downspout disconnection, but likely to a lower extent. In several locations, opportunities exist to further improve water quality and reduce runoff by disconnecting downspouts to rain gardens or bioretention areas.

5. *Retrofit existing stormwater or recreational ponds in neighborhoods to improve water quality and reduce fecal coliform loads.* Many of these ponds were observed to have high numbers of geese around them. Strategies to discourage geese include discouraging the feeding of geese, creating a "no-mow" zone around ponds and lakes, planting a buffer of cattails, reeds or other native – and non-turf – thick and dense vegetation around ponds, installing fencing around ponds and lakes, and allowing ponds to freeze in the winter.

6. *Construct bioretention areas or rain gardens to capture stormwater runoff and provide water quality treatment.* At sites with adequate space available, these practices can effectively improve water quality of stormwater runoff. In areas of the watershed with permeable soils, infiltration of stormwater through these practices will be possible. In areas of poorly drained soils, an underdrain pipe should be included in the retrofit design, or the design can be modified to a constructed wetland.

Long-Term Actions

7. *Implement the additional high priority stormwater retrofits.* Fourteen high priority sites were identified in the watershed. A list of sites and concept descriptions of the high priority sites can be found in Attachments E and H, respectively. If implemented, these stormwater retrofits will improve stormwater runoff quality and recharge, mitigate localized channel erosion areas, and serve as demonstration and education sites.

7. Explore opportunities for additional retrofits in neighborhoods.

Short-Term Actions

1. *Explore the opportunity for pipe day-lighting at a closing school facility (L-RRI-09B).* This potential project would allow for treatment of a large volume of stormwater. Information about this site is included in Section 6.3.4. and Attachment H.

Mid-Term Actions

2. *Evaluate the opportunity for an on-site storage retrofit at Northpoint Business Park (C-RRI-101).* The downstream reach should also be evaluated for potential stream restoration. Information about this site is included in Section 6.1.3. and Attachment H.

3. *In neighborhoods with little or no existing stormwater management, explore opportunities for treatment of driveway and street runoff through neighborhood retrofits.* Examples include bioretention practices along the roadway curb and gutter, cul-de-sacs and at storm drain inlets. In addition to providing water quality treatment, these projects can serve as neighborhood demonstration projects.

Long-Term Actions

4. *Where possible, remove excess or unused impervious cover*. Several large and under utilized commercial and office parking lots were observed. Reducing site impervious cover and replacing it with pervious areas will result in a reduction of site runoff volumes.

5. *Continue to identify retrofit opportunities at schools, neighborhoods, commercial areas, and existing outfalls that do not have existing BMPs.* In developments with no existing stormwater management, design retrofit practices to treat roadway and driveway runoff. Many of the homes in these developments were observed to have disconnected downspouts that likely provide partial treatment of the rooftop runoff via filtration and infiltration, particularly on sites with sandy soils.

8. Conduct stream clean-ups and implement stream corridor projects.

Short-Term Actions

1. *Conduct monthly stream clean-ups in the high-priority, trash impacted sites.* Trash was noted in stream reaches throughout the watershed ranging from larger items such as old appliances and car parts to plastic and glass bottles and paper. Organize residential neighborhood trash clean-ups for identified stream segments. Community groups such as boy scout troops would be excellent partners to engage in this effort. A Neighborhood Stream Watch program can be developed to help prevent future dumping.

2. *Evaluate a stream restoration opportunity observed at the outfall of Northpoint Business Park (C-RRI-101).* Information about this site is included in Section 6.1.3. of this *Plan.*

Mid-Term Actions

3. *In areas of severe active erosion, repair and stabilize banks using stream restoration techniques*. Depending on the severity of the site, a combination of soft and hard stabilization techniques may be required.

4. *Implement additional high priority stream projects.* A list of these projects, which include stream clean-up, invasive plant removal, riparian reforestation, natural regeneration, residential education, and discharge inspection can be found in Attachment E. If implemented, these riparian corridor restoration projects will result in enhanced riparian habitat and improved stream quality.

Long Term Actions

5. *Discourage the placement of wastewater pipes across stream channels.*
Elevated sewer pipes were frequently noted across stream reaches. These pipes cause alterations to the stream hydrology, act as trash racks, and, if damaged, can be direct sources of fecal coliform and bacteria to the stream. Relocate existing pipes that are acting as barriers.

6. *Discourage the placement of utilities near streams and wetlands*. Several impacts from utilities were noted that include stream bank erosion and clearing of stream buffers.

9. Conduct a neighborhood education campaign to educate residents about pollution prevention and source control.

Short-Term Actions

1. *Identify neighborhood residents who can become leaders in community stewardship.* These individuals can help coordinate neighborhood activities, programs, and assist with watershed educational efforts.

2. *Develop educational materials focused around key pollution prevention and source control educational topics.*

Mid-Term Actions

3. *Expand the storm drain marking program into older neighborhoods*. Work with the residential homeowners to conduct the storm drain marking program. This should be accompanied by an outreach effort to neighborhood residents to explain the purpose of the storm drain markers and the link between the storm drain and Crane Creek.

4. *Disconnect residential downspouts to allow for treatment and volume reduction of rooftop runoff.* In several locations, opportunities for disconnection to rain gardens or rain barrels were identified. In addition to providing water quality benefits, these opportunities can be engaging and educational to residents.

5. *Develop a targeted residential education program on the proper application of fertilizer and use of alternatives to grass lawns that include native species landscaping.* Excessive algal growth was noted at several stormwater outfalls along stream reaches and in ponds. In fact, at one outfall a fertilizer bag was found in the stream. Encourage residents to conduct a soil test before applying fertilizers to lawns. Sanction a “Green Certification” program specifically for landscape companies that promote less resource intensive lawn care practices.

6. *Conduct a trash education program that includes a residential education program that addresses proper disposal of trash and recycling*. A large percentage of the trash found in streams consisted of recyclable materials including plastic and glass bottles. Many of the adjacent neighborhoods had stormdrain markers, but these did not seem to be effective at preventing dumping or littering.

7. *Conduct a stream buffer education program that specifically targets residential homeowners.* The majority of stream buffer impacts noted were associated with residential homeowner encroachment on the stream (e.g. mowing to the edge of the stream). Homeowners should be educated on the functions that stream buffers provide for water quality and the stabilization benefits for their property.

8. *Pilot the developed educational programs in high priority neighborhoods. These neighborhoods are listed in Attachment E.*

Long-Term Actions

9. *Increase tree canopy in residential neighborhoods, and encourage natural buffer regeneration along buffer impacted stream corridors.* Target tree planting on private lots and in common areas, possibly through a cooperative program with the Forest Service.

10. Develop a Green School and Institution Program

Short-Term Actions

1. *Begin coordination with institutions where priority retrofit projects were identified* (strategy 6). Outreach to schools and explore partnership opportunities. Begin to develop the framework for the program, along with educational material that focused around watershed educational topics.

Mid Term Actions

2. *Develop a green school program that includes reforestation, stormwater retrofits and pollution prevention.* Many downspout disconnection, rain garden, and pond retrofit opportunities were identified on school properties. These retrofits can be implemented at schools and used as a teaching tool and as an outdoor classroom for students. Retrofit projects can be incorporated into an environmental curriculum that has an emphasis on the Crane Creek Watershed.

Long-Term Actions

3. *Expand the program to include additional institutions.* Institutions include schools, places of worship and hospitals that generally contain large amounts of impervious cover and green space, ideal areas to treat stormwater runoff. Several opportunities at churches were also identified.

11. Develop a Business Stewardship Outreach Program

Short-Term Actions

1. *Compile a list of hotspots for private businesses and residences and conduct a follow-up inspection to confirm the current condition of these sites.* Immediate follow-up inspections should be conducted for the 10 confirmed hotspot sites.

2. *Require secondary containment for auto salvage yards where fluids are drained from vehicles.* Work with auto salvage businesses to train owners on proper outdoor storage.

3. *Provide the County Solid Waste Division with a list of poor trash management sites for compliance inspections.*

Mid-Term Actions

4. *Provide education on pollution prevention to targeted businesses and implement stormwater retrofits and pollution source control measures.* A list of hotspot opportunities is found in Attachment E.

Long-Term Actions

5. *Develop a Business Stewardship Outreach Program that engages the business community in watershed restoration*. Many businesses were identified during field investigations as hotspots that contain known or potential sources of pollution such as improper storage of outside materials such as food waste or grease traps. Partners can work with businesses to implement pollution prevention practices on-site and in return become recognized as a "green business."

12. Promote partnership between the County, City, and Town on SSO response and repair programs, septic system education programs, and IDDE programs.

Short-Term Actions

1. *County to coordinate with City and Town on IDDE program development.* The establishment of a watershed-wide IDDE program should be considered, where municipalities in the watershed can cost-share equipment, overflow response staff, educational materials, discharge investigations, and possibly repairs. The County should investigate the legality of establishing a shared program, particularly as it relates to water/sewer service fees and taxes collected by each jurisdiction. If sharing is not feasible, then the City and Town should adopt the existing County IDDE program.

Mid-Term Actions

2. *County and City to coordinate to ensure timely repair of SSOs.* The County should coordinate and partner with the City to make sure overflows are immediately reported and repaired. Both the County and City should collaborate to map sewer infrastructure, develop a shared database to document discharges and overflows, track maintenance activities and costs, and estimate discharge impacts. Problem areas should be carefully tracked and the County should work with the City to provide necessary repairs and upgrades to the sewer infrastructure.

3. *Provide education on septic system maintenance.* As part of the neighborhood stewardship program (strategy 9), information on proper septic system care and maintenance should be provided to residents on septic systems. By mapping the sewered regions of the County as recommended in action 2 above, the County will be able to easily identify these areas to target. Incentives for septic system pump-outs should be provided. Additionally, more stringent system inspections should be enacted for any new septic systems.

Additional Recommended Action

Expand County water quality monitoring program (see Section 5.4)

5.2 Implementation Planning and Costs

Implementation is by far the longest and most expensive step in the watershed management process. In fact, restoration and protection costs for a single suburban subwatershed can easily range in the million dollars depending on the extent of restoration and protection activities, number of jurisdictions involved, land costs, and other factors. Salaries, land acquisition and construction of projects often account for a majority of these costs. A minimum of ten years is usually needed to design and construct all the necessary projects, which are normally handled in several annual "batches." Sustaining progress over time and adopting the plan as more experience is gained are vital aspects of implementation.

Presented below are planning partners, planning level costs, and phasing and resources for implementing watershed strategies. Preliminary cost estimates and responsible partners have been identified so that financial resources can be allocated and staff roles can be defined. Table 5.1 provides the objectives met, location, responsible parties, and long-term milestones for implementation of each strategy. Table 5.2 provides a draft implementation schedule and associated costs for implementing each short term, mid term and long term action.

The cumulative estimate for implementing the 12 strategies presented in Section 4 exceeds 9.8 million dollars over the next 5-10 years (Table 7.1). The largest component of these cost results from the estimated cost of acquiring the conservation areas. Costs associated with watershed strategy 6 alone are estimated at 6.9 million dollars, which assume land acquisition costs for 500 acres of land along with greenway construction (Richland County, 2009a). These costs associated with the protection of conservation areas can be greatly reduced by encouraging public involvement in voluntary easement and land trust programs. Management and restoration costs for the remainder of the watershed amount to 2.9 million dollars over the next 5-10 years.

Project costs represent only planning level estimates and were determined based on guidance provided in Schueler et al. (2007), Wright et al. (2005), Kitchell and Schueler (2004), the County Post-Construction Review (Attachment K), and the Richland County Greenways Plan (Richland County, 2009a). These estimates should be adapted to include more appropriate local cost estimates where available. These cost estimates should be used to guide the County, the Town, the City, and other project partners in estimating annual operation and implementation budgets for the Crane Creek Watershed. The implementation costs should be distributed across implementation partners, existing programs, and responsible property owners (i.e., the County, Town, City, institutions, businesses, and landowners). Project costs for individual watershed projects can be found in Attachment E.

Table 5.1. Crane Creek Implementation Strategy

Objectives Met	Strategy	Location	Responsible Parties	Interim Milestones
1	1. Implement programmatic changes to County ESC program	Watershed wide	• County Engineering Department	• Delisting of 303d listed stream • Increases # of field inspectors, frequency of inspection and enforcement measures • Enforcement of 'grassing bond'
5, 6	2. Inventory and map natural resource areas	Watershed wide	• County Planning Department	• Use of natural resource data during plan review • Complete natural resources mapping in Crane Creek Watershed in Year 1. Continue to map natural resources at the rate of 1 watershed/year.
4, 5, 6	3. Permanently protect primary conservation areas	Watershed wide	• County Conservation Commission	• Permanent protection of 18% of the watershed • Establishment of an Environmental Protection Overlay district • Completion of 10 miles of a greenway trail system
5, 6	4. Adopt County roundtable recommendations	County wide	• County Planning Department • County Engineering Department • County Stormwater Department • Roundtable Implementation Committee	• Adoption of all 22 recommendations • First year implement ESC recommendations (as corresponds to strategy 1) • Develop a residential and commercial LID development
7	5. Hire a Watershed Coordinator	Watershed wide	• County Stormwater Department • USC • CCWA	• Assist in coordination of strategies 6-11. • Build partnerships between County, City, Town departments to implement other strategies
1, 2, 3	6. Implement priority stormwater retrofits	Watershed wide (specifically Upper Crane Creek at schools and parks)	• County Stormwater Department • County Engineering Department • RCSC • CCWA	• Install 4 retrofits at schools (see strategy 10) • Retrofit 4 stormwater ponds to provide water quality treatment
1	7. Explore opportunities for additional retrofits in neighborhoods	Watershed wide (specifically Upper Crane Creek)	• County Stormwater Department	• Assess 10 neighborhoods (see strategy 9) • Implement 5 roadway retrofits

Table 5.1. Crane Creek Implementation Strategy				
Objectives Met	**Strategy**	**Location**	**Responsible Parties**	**Interim Milestones**
1	8. Conduct stream clean-ups and implement stream projects	Watershed wide	• RCSC • CCWA • County Stormwater Department • Keep Midlands Beautiful	• Clean-up all high priority trash sites
1, 2, 7	9. Conduct neighborhood education campaign	Watershed wide	• RCSC • County Stormwater Department • CCWA	• Educate and train 5 neighborhood captains • Conduct training workshops on pollution prevention in at least 10 high priority neighborhoods • Work with one neighborhood as a demonstration project that has native plantings instead of lawn, etc.
1, 7	10. Develop a Green School and Institution Program	Watershed wide	• RCSC	• Develop program and install retrofits at 2 schools (see strategy 6) • Change lawn care policies of institutions to a low nutrient input strategy
1, 7	11. Develop a Business Stewardship Outreach Program	Watershed Wide	• County Stormwater Department	• Investigate all high priority hotspots • Develop a 'green business' program • Establish two 'green businesses'
1, 2	12. Partnership for SSO response and repair programs, septic system education programs, and IDDE programs	Watershed Wide (specifically in Lower Crane Creek)	• County Stormwater Department • City Stormwater Department	• Establish better County/City communication regarding SSO's • City to develop a SSO tracking database • Conduct quarterly septic system education (see strategy 9) • County to assist City in IDDE program development
CCWA = Crane Creek Watershed Association & Watershed coordinator; RCSC=Richland County Stormwater Consortium				

Table 5.2 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 1. Implement programmatic changes to County ESC program	• Conduct follow-up inspections at identified problem ESC sites (Attachment E) • Implement ESC recommendations from Post-Construction stormwater review • Require a 'grassing bond' at beginning of project • Improve coordination of ESC and stormwater program between the Stormwater Division and the Engineering Division	• Hire more ESC inspectors • Increase training for County ESC inspectors. • Limit the amount of development in soils with high clay content • In sandy areas where establishing vegetation is challenging, consider using turf matting to stabilize soils	• Consider County assistance with soil stabilization
Strategy 1 Costs	$40,000	$200,000	$50,000
Strategy 2. Inventory and map natural resource areas	• Conduct additional field work to supplement Crane Creek data	• Develop and adopt a watershed map of all perennial and intermittent streams • Locate, map and protect RTE species within the watershed • Complete a local wetland inventory and incorporate mapping information into local planning documents	• Incorporate the data into GIS layers and use the data during development plan reviews
Strategy 2 Costs	$35,000	$175,000	$40,000
Strategy 3. Permanently protect primary conservation areas	• Establish an Environmental Protection Overlay district in the Crane Creek Watershed • Encourage the adoption and use of the Green Code • Require protection of wetlands that appear to be isolated, especially when they have high water quality or habitat value • Promote the County's Rural Legacy program, which can support conservation easements on forested and agricultural parcels • Promote sustainable management of forests	• Direct mitigation and TDR efforts into conservation hub and primary conservation areas identified in the GI network • Consider opportunities for restoration of the native Longleaf pine ecosystem especially where they can be connected to other Longleaf pine habitat • Develop a map of watershed conservation areas	• Construct a greenway trail • Aim to preserve 30% of the watershed as open space
Strategy 3 Costs	$65,000	$300,000	$6,500,000

Table 5.2 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 4. Adopt County roundtable recommendations	• Implementation committee should meet on a quarterly basis to move forward with recommendations • Enforce the 100-foot Stream Buffer Ordinance		
Strategy 4 Costs	$35,000		
Strategy 5. Hire a Watershed Coordinator	• Hire a full-time coordinator with county and city support.		
Strategy 5 Costs	$ 35,000	$40,000	$10,000
Strategy 6. Implement priority stormwater retrofits	• Identify funding sources for retrofits • Modify, repair, and/or maintain existing stormwater management facilities to improve water quality performance • Engage the public with implementation (e.g. planting, etc.)	• Disconnect downspouts to allow for treatment and volume reduction of rooftop runoff • Retrofit existing stormwater or recreational ponds in neighborhoods to improve water quality and reduce fecal coliform loads • Construct bioretention areas or rain gardens to capture stormwater runoff and provide water quality treatment	• Implement additional high priority stormwater retrofits
Strategy 6 Costs	$85,000	$144,000	$300,000
Strategy 7. Explore opportunities for additional retrofits in neighborhoods	• Explore an opportunity for pipe day-lighting at a closing school facility (L-RRI-09B).	• Evaluate opportunities for an on-site storage retrofit at Northpoint Business Park (C-RRI-101) • Further assess opportunities in neighborhoods with little or no existing stormwater management	• Where possible, remove excess or unused impervious cover • Continue to identify retrofit opportunities at schools, neighborhoods, commercial areas, and existing outfalls that do not have existing BMPs
Strategy 7 Costs	$30,000	$35,000	$100,000
Strategy 8. Conduct stream clean-ups and implement stream repair projects	• Conduct monthly stream clean-ups in the high-priority, trash impacted sites • Evaluate stream restoration opportunity at Northpoint Business Park (C-RRI-101)	• In areas of severe active erosion, repair and stabilize banks using stream restoration techniques • Implement additional high-priority stream projects	• Discourage the placement of wastewater pipes across stream channels • Discourage the placement of utilities near streams and wetlands
Strategy 8 Costs	$15,000	$68,000	$75,000

Table 5.2 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 9. Conduct neighborhood education campaign	• Identify neighborhood leaders for community stewardship • Develop educational materials for pollution prevention, source control	• Expand the storm drain marking program into older neighborhood • Disconnect residential downspouts to allow for treatment and volume reduction of rooftop runoff • Develop a targeted residential education program on the proper application of fertilizer and use of alternatives to grass lawns that include native species landscaping • Conduct a trash education program that includes a residential education program that addresses proper disposal of trash and recycling • Conduct a stream buffer education program that specifically targets residential homeowners • Pilot the program in high priority neighborhoods	• Increase neighborhood tree canopy and encourage natural buffer regeneration at residences along stream corridors
Strategy 9 Costs	$50,000	$200,000	$75,000
Strategy 10. Develop a *Green School and Institution Program*	• Coordinate with institutions with priority retrofit projects (strategy 6)	• Develop a green school program that includes reforestation, stormwater retrofits and pollution prevention	• Expand the program to include additional institutions
Strategy 10 Costs	$50,000	$150,000	$100,000
Strategy 11. Develop a business stewardship outreach program	• Compile a list of hotspots on private businesses and residences and conduct a follow-up inspection to confirm the current condition of these sites • Require secondary containment for auto salvage yards where fluids are drained from vehicles • Provide the County Solid Waste Division with a list of poor trash management sites for compliance inspections	• Provide education on pollution prevention to targeted businesses and implement stormwater retrofits and pollution source control measures	• Develop a *Business Stewardship Outreach Program* that engages the business community in watershed restoration
Strategy 11 Costs	$70,000	$140,000	$50,000

Table 5.2 Implementation Actions and Costs*			
Strategy	**Short-Term Action (year 1)**	**Mid-Term Action (year 2-4)**	**Long-Term Action (year 5+)**
Strategy 12. Partnership for SSO response and repair programs, septic system education programs, and IDDE programs	• County to coordinate with City on IDDE program development	• City and County to coordinate to ensure timely repair of SSOs • Provide education on septic system maintenance	
Strategy 12 Costs	$20,000	$150,000	
Additional Recommendation		• Expand County water quality monitoring program (see Section 5.4)	
Additional Costs		$100,000	
Sub Totals	**$530,000**	**$1,937,000**	**$7,407,000**
Grand Total	**$9,874,000**		
*Note: These cost estimates include staff time, materials, supplies, and construction costs where applicable			

5.3 Implementation Guidance and Resources

It is important to remember that real watershed restoration requires a multi-faceted approach, which combines land use decisions with on-the-ground implementation, education and protection of watershed functions. Each strategy is provided below with a brief discussion of how it relates to existing county programs and other watershed strategies. Helpful resources for meeting these strategies are provided where applicable.

2. **Implement programmatic changes to improve the County ESC regulations, enforcement, and inspection program.**
   The Richland County Roundtable document (see strategy 4) and County Post Construction Review (Attachment K) both identify several recommended improvements to the existing ESC program. In addition, recently the County passed stormwater regulations that should help improve the program.

   Site stabilization can be achieved through a variety of approaches. Information on the rye grass seeding can be found through the Clemson Cooperative Extension at: http://www.clemson.edu/extension/hgic/plants/landscape/lawns/hgic1206.html.

3. **Inventory and map natural resource areas.**
   One of the recommendations from the Richland County Roundtable is to require a natural resource inventory before a sketch plan is submitted for development (p.25-26 in consensus document – see strategy 4). The natural resource inventory should be based on a GIS desktop assessment followed by a field visit. Providing an accurate inventory and map of County natural resources will enhance the protection of natural resources during the development review process. The green infrastructure network and environmental protection overlay district (strategy 3) should be integrated into the County GIS layers.

4. **Permanently protect primary conservation areas.**
   These efforts can be led by the County and supported by local partners such as the Congaree Land Trust (http://www.congareelt.org/), private stewardship foresters, local watershed champions, and other groups. Lands should be protected through the *Richland County Legacy Program* that is administered by the County Conservation Commission. The program provides land conservation through easements, purchase of property, or land donations. The program focuses on protecting land that is going to be developed and has to have natural resources significance (i.e. water feature or RTE species, etc).

   Resources for forestry programs that promote sustainable forest management and restoration of long leaf pine are provided below:
   - Forest Stewardship Council's Forest Certification Standards for the Southeastern United States: (http://www.fscus.org/images/documents/2006_standards/se_10.0_NTC.pdf)

- Sustainable forest management principles: (http://www.state.sc.us/forest/ric.htm)
- A potential funding source for a longleaf pine forest restoration program may be available from the U.S. Fish and Wildlife Service – Partners for Fish and Wildlife Program http://www.fws.gov/southeast/es/partners/. Ft. Jackson has implemented an active restoration program.

5. **Adopt the County Roundtable code and ordinance recommendations.**
The Richland County Roundtable recommendations are available at www.cwp.org/Resource_Library/Center_Docs/BSD/richlandcountyconsensusdocument.pdf. Since the completion of the roundtable, a committee was formed to work towards implementing the recommendations. This committee has succeeded in passing two of the recommendations that pertain to stream buffers and stormwater management. The committee should continue to meet on a monthly basis to work towards implementation of the remaining recommendations. One approach to take is to identify recommendations that can be implemented in the short term and long term time frame. The ESC recommendations from strategy 1 should be implemented as part of this strategy.

6. **Hire a Watershed Coordinator.**
As was done for the first County watershed plan in Gills Creek, a watershed coordinator should be hired for crane creek to provide leadership for implementation of the watershed plan and coordination of the CCWA. The watershed coordinator should provide assistance with implementing strategies 6-11. After year 1, the County should expected to support only half the salary of this coordinator. Additional salary support can be brought in through grant dollars.

7. **Implement priority stormwater retrofits for water quality improvement.**
Implementation of priority stormwater retrofits in neighborhoods should be coordinated with strategy 8, at schools and institutions (strategy 10) and businesses (strategy 11). As a result of the stream studies conducted by Genesis Consulting Group (2009), several retrofits projects other than those identified in this plan are already underway in the watershed

8. **Explore opportunities for additional retrofits in neighborhoods.**
This strategy should be conducted as part of the neighborhood education campaign (strategy 9).

9. **Conduct stream clean-ups and implement stream corridor projects.**
The County should work with Keep Midlands Beautiful and the Adopt-A-Waterway Program to conduct trash clean-ups (http://www.keepthemidlandsbeautiful.org). Also, regularly scheduled stream clean-ups should conducted as part of the County public education and outreach program, Richland County Stormwater Consortium. This strategy should be conducted as part of the neighborhood education campaign (strategy 9).

10. **Conduct a neighborhood education campaign to educate residents about pollution prevention and source control.**
The County should implement this strategy through the existing Richland County Stormwater Consortium. The implementation of this strategy should be coordinated with neighborhood retrofits (strategy 7), stream clean-ups (strategy 8), and septic system programs (strategy 12). As part of this strategy, the County should expand the *Pesticide, Herbicide and Fertilizer Program* to work with residential homeowner associations to reduce the use of fertilizers and pesticides in residential neighborhoods.

11. **Develop a Green School and Institution Program**
This program can also be implemented through the existing Richland County Stormwater Consortium and Keep the Midlands Beautiful Green Steps Schools. Additionally, there are several examples of successful green school programs nationwide that are provided below. These can also be used as models for the program in Crane Creek. Implementation of high priority stormwater retrofits should be coordinated with the program (strategy 6).
    - Green Steps Schools (http://www.greenstepschools.com/)
    - Maryland Green School Program: http://www.dnr.state.md.us/education/greenschools.html
    - Oregon Green School Program: http://www.oregongreenschools.org

12. **Develop a Business Stewardship Outreach Program**
The establishment of a 'green business' program would expand on the County *Industrial and High Risk Runoff Program* that focuses on industrial facilities and facilities that are determined to be high risks for contributing substantial pollutant loadings to the stormwater system. Developing a green business program engages the private sector in pollution prevention efforts. Implementation of high priority stormwater retrofits should be coordinated with this program (strategy 6). Throughout the Country there are numerous examples of successful green business programs. Several programs are listed below that the County can use as models to establish a program.
    - Stony Brook-Millstone Watershed Association, River-Friendly Certification Program: http://www.thewatershed.org/river_friendly_program.php
    - Corsica River Watershed Restoration and Enhancement Project, Certified Green Business: http://www.corsicariver.org/WhatsNew.html

13. **Promote partnership between the County, City, and Town on SSO response and repair programs, septic system education programs, and IDDE programs.**
The City and Town should each adopt an IDDE program using the County program as an example. For example, the City is currently expanding their IDDE program and should look to the County for guidance. An educational guide from the EPA, A Homeowners Guide to Septic Systems: http://www.epa.gov/owm/septic/pubs/homeowner_guide_long.pdf, can be used to help educate homeowners on septic system maintenance.

5.4 Monitoring Plan

The County, City, Town, CCWA, and other watershed partners have a vested interest in measuring whether the projects they implement are successful. Success can be measured in a number of ways including direct improvements in watershed indicators (e.g. reduced pollutant loading or improved aquatic insect communities) or indirectly (e.g. number of rain gardens installed, number of volunteers, acres preserved).

The load reduction goals established in the Crane Creek TMDL (48% upstream of Lake Elizabeth and by 92% downstream of Lake Elizabeth) are based on data from the two SCDHEC sentinel monitoring stations in the watershed. In order to better estimate existing steam quality, targeted pollutant load reductions, and measure water quality improvements, more sampling sites are needed.

The monitoring plan includes the assessment of individual watershed projects, the monitoring of stream indicators at sentinel monitoring stations, expanding the County water quality monitoring program, and sanitary sewer overflow monitoring and tracking. Guidance on developing monitoring studies is provided in Law et al. (2008). Information can be input to a tracking system and then used to revise or improve the watershed plan over a five to ten year cycle. Each part of the monitoring plan is described below:

- *Project monitoring* at a small scale (reach or smaller) to illustrate benefits of individual restoration efforts. As stormwater retrofits, neighborhood and business pollution prevention and education strategies are implemented monitoring should be conducted to show effectiveness.

- *Sentinel station monitoring* to track long-term health and water quality trends. Sentinel monitoring stations are fixed, long-term monitoring stations which are established to measure trends in key indicators over many years. Sentinel monitoring is perhaps the best way to determine if conditions are changing in a subwatershed or watershed. Two SCDHEC water quality gauging stations are located in the Crane Creek watershed; Station # B-316, a primary station sampled year round, and Station # B-110 a secondary station sampled May-October (see Figure 2.3). It is recommended that an additional sentinel monitoring station is installed in the Beasley Creek subwatershed along near the confluence of North Branch Crane Creek and Crane Creek mainstem. Installation of this station will enable the County to determine if water quality impairments exist in this region of the watershed.

- *Expand County water quality monitoring program*. Two major water quality concerns in the Crane Creek watershed, total suspended solids and fecal coliform, should be monitored. Total suspended solids are an indicator of sediment and fecal coliform is an indicator of bacteria. Based on field observations, sediment is likely from poor ESC practices, and would be different in the areas with sandy soils as opposed to the areas with clay soils. Fecal coliform should be sampled on the lakes as wildlife is likely a major source of bacteria.

- *Sanitary Sewer Overflow monitoring and tracking* should be coordinated between the City and County in order to reduce bacteria loads to Crane Creek. Both the County and City should collaborate to map sewer infrastructure, develop a database to document discharges and overflows, track maintenance activities and costs, and estimate discharge impacts. Problem areas should be carefully tracked and the County should work with the City to provide necessary repairs and upgrades to the sewer infrastructure.

- *Source Tracking* to better identify watershed pollutant loads. To date, no detailed sourcing studies have been completed in the watershed, so it is difficult to quantify load reductions that should be targeted. The county should conduct research to better identify sources of watershed impairment and target future watershed actions to address these sources.

5.5 Project Tracking

Managing the delivery of a large group of restoration projects within a subwatershed can be a complex task. Creating a master project spreadsheet linked to a GIS system can help track the status of individual projects through final design, permitting, construction, inspection, maintenance and any performance monitoring. For non-structural efforts, tracking systems will include measures such as number of stream clean-ups, residents educated, green schools and businesses created, acres of natural resources preserved, or number of dedicated volunteers. By tracking the delivery of watershed projects, implementation progress can be assessed over time, which in turn, helps explain future changes in stream quality. Project tracking can also improve the delivery of future projects, and creates reports that can document implementation progress for key funders and stakeholders.

The watershed coordinator will manage implementation tracking. This person will setup project information in spreadsheet/GIS format, and report on the status of implementation quarterly to the County. The tracking system will account for all watershed practices undertaken in the subwatershed plan regardless of their type or size, and track the progress of outlined milestones.

5.6 Long-term Goals

Long-term goals have been set to mark progress to ensure the implementation of the *Plan* adheres to a schedule to meet the defined outcomes.

- Meet interim milestones from Table 5.1 for each strategy
- Meet ½ of the load reduction goals for stream restoration, downspout disconnection, stormwater retrofitting, urban turf conversion, SSO abatement, street trees. These load reduction values are presented in Section 7 of this *Plan.*
- Reduce baseflow concentrations of bacteria at monitoring stations by 20%. Although this number falls short of the targeted reductions for the TMDL, this number represents the expected load reductions that resulted from watershed modeling (Section 7). Additional

monitoring is needed to better quantify bacteria loading and required watershed reductions (Section 5.4).

- Track improvements in the stream water quality and biology using the existing monitoring sites and recommended additional monitoring sites. Evaluate at five years any improvements in trends that may have occurred due to implementation efforts.

After 5 years time, this *Plan* should be updated to include recent watershed developments and monitoring results.

SECTION 6. SUBWATERSHED MANAGEMENT STRATEGIES

This section describes the subwatershed management strategies, conservation and restoration opportunities for the three Crane Creek subwatersheds: Beasley Creek, Upper Crane Creek, and Lower Crane Creek. Maps of the subwatersheds are found in Attachment B.

6.1 Beasley Creek Subwatershed

Subwatershed Description

The Beasley Creek subwatershed encompasses the entire portion of the Town located within the Crane Creek watershed. This subwatershed is mostly forested and relatively undeveloped and contains small agricultural areas, but the Town is actively annexing portions of the watershed. Recently, new residential development and in-fill development have occurred throughout the subwatershed. In addition, utility construction associated with connecting the City sewer and water services to the Town was observed. Due to the close proximity of the utility construction to the Town and to I-77, it is predicted that this subwatershed will become a hotspot for development in the near future.

The soils in the subwatershed consist mainly of silty loam and sandy clay loam soils (Figure 2.5). Numerous ESC problems were observed in the subwatershed, which were particularly problematic in areas of heavier clay soils. Sediment from these sites was observed entering streams and wetland areas. The streams in the subwatershed were in relatively good condition, except where impacted by construction. This subwatershed also had areas of high functional wetlands and mature forests. Beasley Creek has the highest amount of intact habitat of all three subwatersheds. Because it also contains many headwater streams for the entire Crane Creek watershed, protection strategies should be employed throughout the subwatershed. This subwatershed was identified as a large hub area for conservation. It is important to protect the vital natural resources in this area before future development accelerates and properly manage construction and stormwater runoff.

Subwatershed Management Strategy

The subwatershed management strategies listed below provide a framework for implementing the numerous conservation, management, and restoration practices identified through field assessments as well as program and education-related recommendations identified through both desktop analyses and field assessments. Management strategies for the Beasley Creek subwatershed are as follows:

1. *Address ongoing ESC problems and better protect streams from high sediment loads.* In order to address sediment loads to Crane Creek and subsequently the Broad River, and also to help improve the health of the headwater streams, the County should work to improve construction and utility site stabilization. The County should conduct immediate and follow-up inspections at all observed ESC sites. In problem areas, the

County should assist in stabilization of site soils. Effort should be undertaken to limit the area of disturbance in clay soil development sites.

2. *Establish conservation hubs and protect valuable resource areas.* This can be done by incorporating the conservation analysis into the Environmental Protection Overlay District established by the County (Sec.26-108 Land Development Code). Any development within this overlay district should be limited.

3. *Direct protection, mitigation and TDR efforts to primary conservation areas.* This subwatershed has a tremendous amount of intact habitat and opportunities for developing and targeting protection strategies should be encouraged.

4. *Promote sustainable management of forests and reforestation of parcels within the conservation area hubs and corridors.* Consider restoration of native long-leaf pine forests where possible.

5. *Enforce the 100-foot stream buffer ordinance recently adopted by the County for impaired waters.*

6. *Permanently protect intact forest areas (B-FP-4) and old-growth floodplain forest (D-FP-5) identified during the field assessment.*

7. *Permanently protect high functioning wetlands identified through the field assessment.* Wetlands that appear to be isolated from mapping resources may, in fact, be hydrologically connected to the stream corridor. These wetlands also serve to recharge groundwater resources.

8. *Target lawn care education, native landscaping, rain gardens, and tree planting to neighborhoods with large areas of high maintenance turf.* The Ashley Oaks (A-NSA-1&2) and Wren Creek (C-NSA-4) neighborhoods should be targeted for outreach and education due to the identified restoration opportunities and the neighborhood's close proximity to Crane Creek.

9. *Identify residential areas having septic systems and educate residents on proper septic system maintenance, inspection, and repair.*

10. *Implement the high priority retrofit project identified in the Ashley Oaks neighborhood (A-RRI-21A&B).*

11. *Repair the stream channel and relocate the sewer pipe located downstream of the Koyo Industries outfall at the Northpoint Business Park (C-RRI-101).* Explore on-site retrofit opportunities at this industrial site.

Conservation Opportunities in the Subwatershed

As growth pressure increases in the Beasley Creek subwatershed, the conservation and preservation of existing natural resources becomes more imperative. Strategic placement of development *and* conservation areas can help to ameliorate the deleterious effects that increased impervious cover plays on aquatic systems.

The subwatershed is largely intact ecologically with areas over 5,700 acres in total size that may be considered as hubs in the GI network (Figure 6.1). The northernmost hub contains a wetland assessed by Center staff and was determined to have the highest functional value of any that were assessed (Table 6.1). Likewise, the hub contains several large parcels over 230 acres in size. This is advantageous from a protection perspective as large swaths of land can be protected. The County has expressed interest in purchasing large (300-600 acre) green recreational hubs as green spaces, particularly in the Town. Purchasing property within this identified hub would fulfill multiple objectives: 1) protection of significant stream corridor and floodplain areas as well as the headwaters of the Crane Creek watershed; 2) protection of an area that can serve as a recreational hub for residents of the County, providing them with an opportunity to preserve an important piece of rural and natural integrity; and 3) directing growth away from ecologically significant areas to areas where development is already occurring, thereby alleviating stress on natural resources.

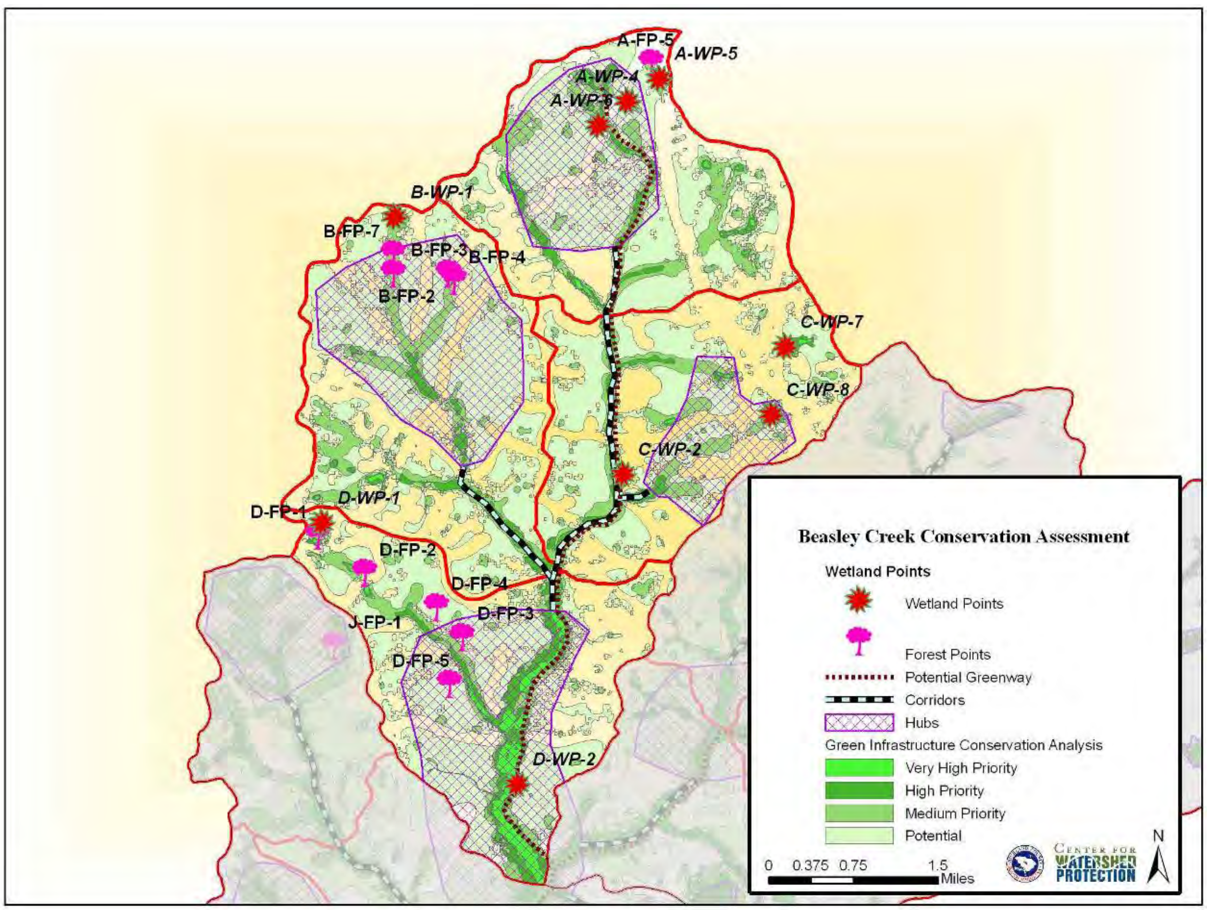


Figure 6.1. Beasley Creek conservation areas.

Table 6.1. Wetlands Assessed in the Beasley Creek Subwatershed			
Site ID	**Wildlife Habitat FCI**	**Water Quality FCI**	**Description**
A-WP-4	0.90	0.86	Upland wetland hydrologically connected
A-WP-5	Not assessed, similar to A-WP-4		Large upland wetland hydrologically connected, mature forest (A-FP-5)
A-WP-6	Not assessed, similar to A-WP-4		Upland wetland hydrologically connected
B-WP-1	0.79	0.75	Upland wetland hydrologically connected
C-WP-2	0.68	0.90	Upland wetland hydrologically connected
C-WP-7	Not assessed, similar to A-WP-4		Upland wetland hydrologically connected, adjacent to commercial development
C-WP-8	Not assessed, similar to A-WP-4		Upland wetland hydrologically connected, adjacent to new residential development – some sedimentation noted in wetland
D-WP-1	0.71	0.74	Upland wetland hydrologically connected
D-WP-2	0.81	0.79	Floodplain wetland associated with the stream corridor

The southernmost hub is composed almost entirely of three parcels. This area is prime for conservation as the area is dominated by bottomland floodplain forest and occurs just below the confluence of two major tributaries in the Upper Crane Creek watershed. West of this hub, teams conducted several forest assessments and determined that very few intact mature contiguous forest areas were located in the subwatershed (Table 6.2). Most of the mature forest that was identified was located within the riparian corridor or within wetland areas. One old-growth forest was identified in this hub and should receive priority for protection (D-FP-5). The upland forests in the area were dominated by active timber management, though according to the local foresters, much of the forestland has since been sold by the large timber companies. It is still subject to cutting and management by private landowners and contractors. Bottomland hardwood forest was often found associated with streams and wetlands and appears to receive less active cutting which is beneficial since riparian stream buffer areas are important for water quality. Areas east of this hub should be targeted for reforestation efforts, including long leaf pine restoration.

Table 6.2. Forest Assessment Points in the Beasley Creek Subwatershed					
Site ID	**Average Densiometer**	**75th Percentile** (dbh)	**Dominant Tree Species**	**Understory Characterization**	**Forbes**
A-FP-5	24	18	Tulip Poplar, Red Maple, Water Oak	Medium	Medium
B-FP-2	10	4.4	Loblolly Pine, Sweet Gum	Dense	Sparse
B-FP-3	19	11	Red Maple, Loblolly Pine, White Oak	Dense	Sparse
B-FP-4	24	26	Loblolly Pine, Red Oak, White Oak	Medium	Sparse
B-FP-7	22	17	Loblolly Pine, Red Oak, White Oak	Sparse	Medium
D-FP-1	23	13	Loblolly Pine	Medium	Sparse
D-FP-2	21	13	White Oak, Water Oak	Medium	Sparse
D-FP-3	23	14	Loblolly Pine	Dense	Sparse
D-FP-4	24	11	Loblolly Pine	Dense	Sparse
D-FP-5	24	26	White Oak, Beech, Southern Red Oak	Medium	Sparse

According to the County NWI layer, many of the wetlands assessed in Beasley Creek appeared to be isolated but, upon closer inspection, were hydrologically connected to the stream corridor (Figure 6.2). These wetlands serve an important function in attenuation of stormflows and therefore serve to protect the stream corridor from erosive forces. These wetland areas should be protected from disturbance or development. In addition, improvements should be made to ESC practices to decrease sediment loads to the stream as impacts from poor ESC practices were assessed during the field inventory (B-ESC-2 & B-ESC-3).

Restoration Opportunities in the Subwatershed

Several restoration opportunities in Beasley Creek were identified during the field assessments. Many ESC impacts associated with development or utility construction were observed along the stream corridor. Additionally, several neighborhood restoration and educational opportunities were noted. Individual restoration projects and opportunities are discussed below by the smaller planning level subwatershed (A-D) identified during the field work.

(a) (b)

Figure 6.2. (a & b) Wetlands A-WP-4 and C-WP-2, high quality wetlands hydrologically connected to the stream corridor.

6.1.1. Subwatershed A

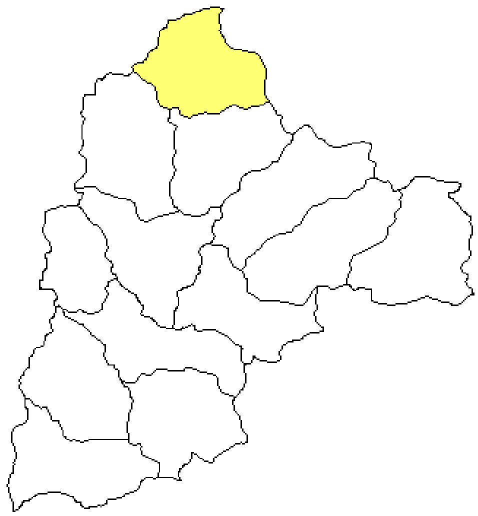


Table 6.3. Subwatershed A Characteristics		
Subwatershed		A, Beasley Creek
Drainage Area		3295 acres
Existing Impervious Cover		97 acres (2.9%)
Stream Miles		10.10 miles
2001 Land Use	Developed	6%
	Forested	63%
	Developed Open Space	10%
	Wetlands and Open water	4%
	Agriculture	6%
	Other	11%
Jurisdictions as Percent of Subwatershed A		47 % Richland County 53% Town of Blythewood 0% City of Columbia

Subwatershed Description

Subwatershed A is located in the most northern part of the Beasley Creek subwatershed. The subwatershed area falls almost evenly between the Town (53%) and the County (47%) (Table 6.3). Land use is primarily forested (63%), but also contains some developed open space and other (i.e. grasslands). The developed land in the subwatershed is only 6%, and the existing impervious cover is less than 3%. The subwatershed is bisected on its eastern side by Interstate 77. Soils in the headwaters of the subwatershed are primarily sand; riparian soils are a mixture of sand, loam, and silt complexes. During the field assessments, some areas of heavy clay soils were observed. The subwatershed has 4% wetlands and open water, which are primarily small isolated freshwater forested/shrub wetlands as well as freshwater ponds.

Although the subwatershed is mostly forested and undeveloped, active development is occurring, particularly in the Town jurisdictional area, and poor ESC practices associated with this development were observed during the fieldwork. Several subwatershed restoration opportunities were observed. High priority restoration projects included a pond retrofit opportunity in the Ashley Oaks Neighborhood (A-RRI-21A&B), and an observed ESC site associated with new development and a public water-line extension along Locklier Rd (A-ESC-1). Two areas of the Ashley Oaks neighborhood were assessed and assigned a moderate pollution severity and restoration potential. This neighborhood would be a good candidate for targeted watershed education and outreach due to the identified restoration opportunities and the neighborhood's close proximity to Crane Creek. These opportunities are discussed in detail below.

Management and Restoration Practice Opportunities in the Subwatershed

In subwatershed A, two retrofit opportunities were identified in the Ashley Oaks subdivision (Table 6.4). The first retrofit concept involves the repair of a stormwater pond located immediately adjacent to the stream channel (A-RRI-21A). The pond is undersized and unstable, and is experiencing severe erosion at the pond outfall, which is located directly on a stream bank (Figure 6.3). Erosion was observed along the banks of the adjacent stream, and the deposition of sediment was present in the stream bottom. It is recommended that the stormwater pond be repaired and stabilized. A smaller bioretention project (A-RRI-21B) in the neighborhood was identified and can serve as a good community demonstration and educational project. One additional retrofit site was evaluated at the Fairfield Electric Facility (A-RRI-22) but no opportunities were identified.

Table 6.4. Stormwater Retrofit Opportunities in Subwatershed A

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
High	A-RRI-21A	Ashley Oaks	Pond Repair	32.2	20	40326	100%	$71,810
Low	A-RRI-21B	Ashley Oaks	Bioretention area	0.3	100	1035	48%	$5,250

(a) (b) (c)

Figure 6.3. (a & b) Pond retrofit opportunities at site A-RRI-21A and (c) portion of creek adjacent to residential development at A-RRI-21A.

One stream reach was assessed in subwatershed A (A-RCH-1), and was found to be in good condition, and no stream impacts were noted. A portion of the stream through the Ashley Oaks neighborhood (near site A-RRI-21A) was not formally assessed; however, ESC problems were observed (A-ER-1). Further, portions of the stream that abutted residential property lines were lacking a riparian buffer zone (Figure 6.3).

One privately-owned hotspot opportunity for improved pollution prevention was observed at the Accutech Industrial Facility (Table 6.5). Barrels were stored outdoors lacking cover, and several barrels were missing lids and proper labels. Although this facility was classified as 'not a hotspot,' there should be a follow-up visit to this site to review the site's pollution prevention plan. Opportunities at this site include adding lids and proper labeling to barrels and storing the barrels under coverage.

Table 6.5. Hotspot Management Opportunities in Subwatershed A					
Priority	**Site ID**	**Location**	**Opportunity**	**Hotspot Status**	**Cost**
Medium	A-HSI-1	Accutech Industrial Facility	Secondary containment, Material storage, proper labeling	Not	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					

Two neighborhood source control opportunities were identified and are shown in Table 6.6. Residential rain gardens, storm drain stenciling, and cul-de-sac retrofit opportunities were observed in the field and are considered the most important areas for improvement (Figure 6.4). Additionally, the Ashley Oaks neighborhood should be a targeted area for neighborhood outreach and education. Portions of Crane Creek run through the Ashley Oaks Neighborhood and a neighborhood walking trail provides connection between the residents and the stream. The trail currently provides neighborhood recreational benefits, but can be adapted into an educational tool to inform residents about the Crane Creek Watershed and promote awareness about residential behaviors that affect the quality and health of the stream.

Table 6.6. Neighborhood Source Control Opportunities in Subwatershed A						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Medium	A-NSA-2	Ashley Oaks 2	Moderate	Moderate	Rain gardens, storm drain stenciling, ESC for infill, cul-de-sac retrofits, neighborhood education and outreach	$$$
Low	A-NSA-1	Ashley Oaks 1	Moderate	Moderate	Rain gardens, bioretention in turf cul-de-sacs, storm drain stenciling, neighborhood education and outreach	$$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

Table 6.7 lists the ESC problems that were observed during field work. The Ashley Oaks neighborhood (A-ESC-2) had areas actively under construction, and a need for more stringent ESC practices was noted (Figure 6.5). In addition, an observed ESC site associated with new development and a public water-line extension along Locklier Road near the Ashley Oaks development was identified as a high priority ESC site. Large amounts of sediment were entering the stream channel. The County should conduct immediate and regular inspections

at these sites to ensure that ESC problems have been properly addressed, and that the sites have been stabilized to prevent further erosion.

(a) (b)

Figure 6.4. (a) Cul-de-sacs with landscaping island at A-NSA-1 and (b) large cul-de-sac at A-NSA-2.

Table 6.7. Erosion and Sedimentation Control Sites in Subwatershed A			
Priority	**Site ID**	**Location**	**Description of Problem**
High	A-ESC-1	Locklier Rd near Ashley Oaks	New development occurring with no ESC practices, large amount of sediment directly entering the stream
Low	A-ESC-2	Ashley Oaks	Development is ongoing throughout neighborhood with little to no ESC

(a) (b) (c)

Figure 6.5. ESC problems observed at sites (a) A-ESC-2 and (b & c) A-ESC-1.

6.1.2. Subwatershed B

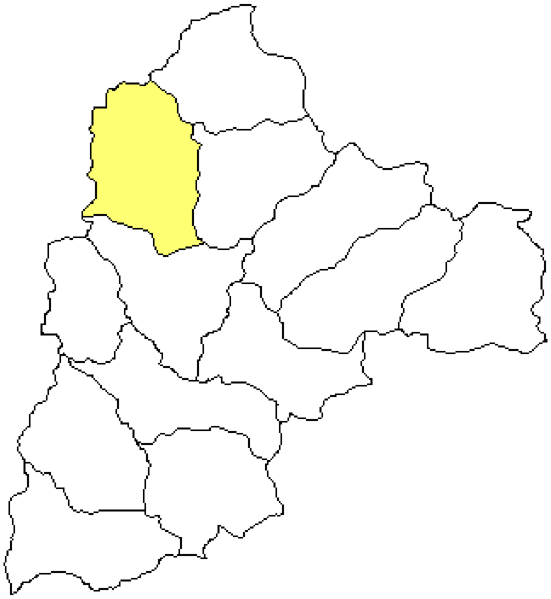


Table 6.8. Subwatershed B Characteristics		
Subwatershed		B, Beasley Creek
Drainage Area		3825 acres
Existing Impervious Cover		42 acres (1.1%)
Stream Miles		9.73 miles
2001 Land Use	Developed	2%
	Forested	75%
	Developed Open Space	8%
	Wetlands and Open water	1.7%
	Agriculture	5%
	Other	7%
Jurisdictions as Percent of Subwatershed B		89% Richland County 11% Town of Blythewood 0% City of Columbia

Subwatershed Description

Located in the northwestern part of the Crane Creek Watershed, subwatershed B is also located within Beasley Creek. It falls mostly within the jurisdiction of the County (89%), with 11% of the subwatershed within the Town (Table 6.8). Land use is primarily forested (75%) with developed open space and other (i.e. grasslands) comprises 8% and 7% of the land use, respectively. Only 2% of the subwatershed is developed and current impervious cover is around 1%. Soils in subwatershed B are primarily silty loam and sandy clay loam (hydrologic soil groups B and C respectively). During the field assessments, some areas of heavy clay soils were observed. Freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up 1.7% of the subwatershed.

Subwatershed B, although mostly undeveloped, does contain several pocket areas of rural development. During the field work, field crews observed significant construction associated with a utility line and City water line extension to the Town. Severe ESC issues associated with the installation of these lines were observed, and the impact to nearby streams was evident. Many of the assessed stream reaches had turbid water, bank erosion, and sedimentation. The subwatershed opportunities are discussed in detail below.

Management and Restoration Practice Opportunities in the Subwatershed

In subwatershed B, no retrofit opportunities or hotspots were identified. Six stream reaches were evaluated, and classified as good (1 reach), fair (2 reaches), and poor (3 reaches). The biggest problem noted in these reaches was high amounts of sediment in the streams, often associated with disturbance from adjacent development construction sites or utility construction. The effect of sediment on the receiving waters was particularly detrimental in this area of the watershed, since the soils consisted predominately of heavy clays and soil particles remained suspended in runoff. Stream flow was turbid and colored, and stream sedimentation was observed. Areas of isolated bank erosion were observed at B-RCH-4 (Figures 6.6 & 6.7). No specific stream impacts were identified.

(a) (b)

Figure 6.6. (a & b) Bank erosion and sedimentation in B-RCH-4.

(a) (b) (c)

Figure 6.7. Stream reaches in subwatershed B. (a) an undisturbed reach at B-RCH-3; (b) historic channelization in B-RCH-6; and (c) sediment from an adjacent construction site at B-RCH-1.

A neighborhood off Lorick Road (B-NSA-9) was observed to have a high pollution severity and low restoration potential (Table 6.9). The neighborhood was an older development that consisted of mixed sewer and septic lots, and lots with high amounts of grass, bare soil areas, few trees, and few landscaping areas. Trash and litter were also observed on some properties. Landscaping and tree planting opportunities are considered the most important for improvement in this neighborhood. The neighborhood is also a good candidate for a residential trash cleanup.

Table 6.9. Neighborhood Source Control Opportunities in Subwatershed B						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
High	B-NSA-9	Lorick Rd	High	Low	Landscaping/tree planting, neighborhood cleanup	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

Several severe ESC problems were observed in Subwatershed B. The ESC problems in this area were especially pronounced due to the presence of the heavy clay soils. Table 6.10 lists the ESC problems that were observed during field work. An observed ESC site associated with the public water-line extension along Mount Valley Road (B-ESC-1&2) was identified as high priority (Figure 6.8). In addition, the construction of a utility line crossing did not appear to have any ESC controls and was resulting in sediment flow to the creek. A neighborhood site (B-ESC-3) had some failure of ESC practices and the site was lacking vegetation. The County should conduct immediate and regular inspections at these sites to ensure that ESC problems have been properly addressed, and that the sites have been stabilized to prevent further erosion.

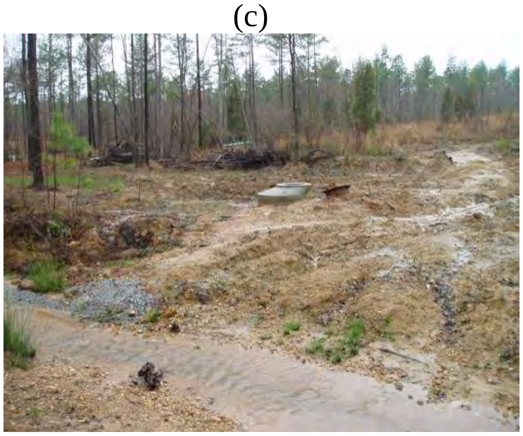
Table 6.10. Erosion and Sedimentation Control Sites in Subwatershed B			
Priority	**Site ID**	**Location**	**Description of Problem**
High	B-ESC-1	Mount Valley Rd	Appears to be a new sewer line installation with limited ESC practices
High	B-ESC-2	Mount Valley Rd	Utility line construction – no ESC controls, in-stream construction and pumping sediment laden water to downstream reaches
Medium	B-ESC-3	Neighborhood	Some failure of ESC practices – silt fence etc – lack of vegetative stabilization of the site

(a)

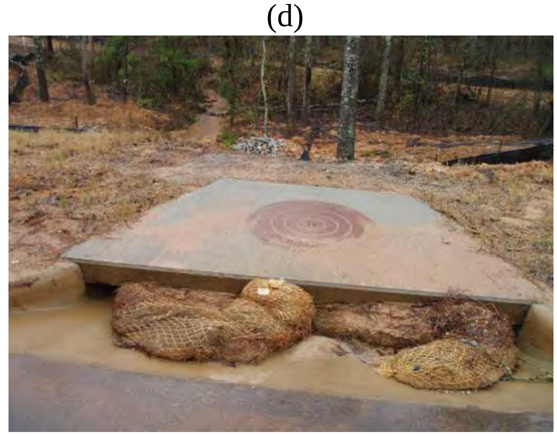
(b)

(c)

(d)



(e)



(f)

Figure 6.8. Erosion sites in subwatershed E. (a, b & c) B-ESC-1; (d) B-ESC-2; and (e & f) B-ESC-3 adjacent to B-RCH 1.

6.1.3. Subwatershed C

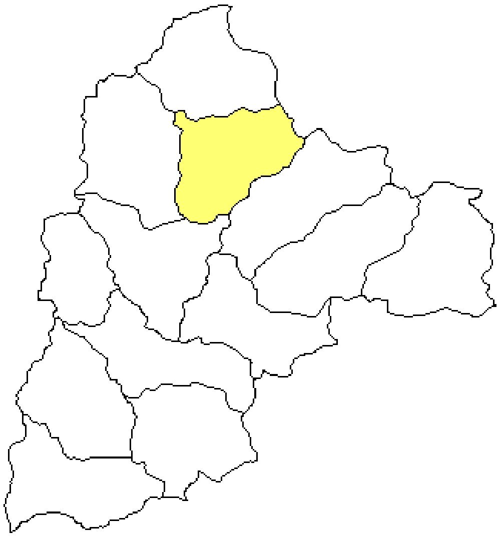


Table 6.11. Subwatershed C Characteristics		
Subwatershed		C, Beasley Creek
Drainage Area		3261 acres
Existing Impervious Cover		238 acres (7.3%)
Stream Miles		7.93 miles
2001 Land Use	Developed	14%
	Forested	66%
	Developed Open Space	10%
	Wetlands and Open water	2%
	Agriculture	2%
	Other	6%
Jurisdictions as Percent of Subwatershed C		97% Richland County 3% Town of Blythewood 0% City of Columbia

Subwatershed Description

Located in the northern part of the Crane Creek Watershed, subwatershed C is part of the Beasley Creek subwatershed. The subwatershed is mostly located within the County (97%) but 3% falls within the Town. Land use is primarily forested (66%), while development and developed open space comprise 14% and 10% of the land use, respectively (Table 6.11). The current impervious cover for the subwatershed is 7.3%. The subwatershed is bisected on its eastern side by Interstate 77. Soils in subwatershed C are primarily silty loam and sandy clay loam (hydrologic soil groups B and C respectively). Freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up 2% of the subwatershed.

Of all the areas in Beasely Creek, subwatershed C contains the highest amount of developed land; however, most of the subwatershed area is still forested and undeveloped. Some active development is occurring, and poor ESC practices associated with this development were repeatedly observed during the fieldwork. Several subwatershed restoration opportunities were observed. The high priority restoration projects include addressing ESC problems associated with residential development. Additionally, an important stream restoration and retrofit opportunity was identified at Koyo Industries (C-RRI-101) where very large quantities of stormwater were being discharged, untreated, directly to a stream channel. These opportunities are discussed in detail below.

Management and Restoration Practice Opportunities in the Subwatershed

There were several retrofit opportunities noted in this subwatershed (Table 6.12). Perhaps the most important opportunity was at Koyo industries (C-RRI-101) where very large amounts of stormwater runoff were being discharged, untreated, to a 72-inch stormwater outfall along the Creek. The stream reach was experiencing severe erosion and downcutting, and an exposed sewer line crossed the stream channel (Figure 6.9). At a minimum, a stream restoration project is needed to stabilize this section of stream. Banks should be stabilized and check dams installed to slow down the runoff. The sewer line needs to be re-routed away from the stream. Field crews did not complete an upland assessment at this site, so the County should explore opportunities to treat stormwater and reduce runoff volumes in the upland industrial area. Opportunities likely exist to disconnect rooftop runoff, install grass swales, and install additional on-site and storage retrofits. The contributing drainage area is industrial with several large rooftop, paved lot, and grassed areas. Treating stormwater on-site would reduce runoff volumes and peak flows to the 72-inch outfall, and help to reduce erosion in the stream channel.

(a) (b)

Figure 6.9. (a & b) Retrofit opportunity at site C-RRI-101.

Opportunities for two pond repair retrofits were also identified in the Wren Creek Neighborhood. A smaller bioretention project (C-RRI-19C) in the neighborhood was identified and can serve as a good community demonstration and educational project. One additional site was evaluated (C-RRI-20) along Northpoint Road, but no retrofit opportunities were identified.

Table 6.12. Stormwater Retrofit Opportunities in Subwatershed C

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
Medium	C-RRI-101	Koyo Industries	Stream restoration/ stabilization, upstream treatment	43.7	40	97,558	100%	$375,000
Medium	C-RRI-19A	Wren Creek	Pond Repair	7.24	20	9,067	100%	$5,000
Medium	C-RRI-19B	Wren Creek	Pond Repair	18.8	5	9,725	100%	$10,000

Table 6.12. Upland Retrofit Opportunities in Subwatershed C								
Priority	**Site ID**	**Location**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/ WQv**	**Cost**
Low	C-RRI-19C	Wren Creek Community Center	Bioretention area	0.25	100	862	35%	$3,150

Five stream reaches were assessed in subwatershed C and classified as good (1 reach), fair (3 reaches), and poor (1 reach). Bank scour and sedimentation were noted in the fair and poor reaches (Figure 6.10). Many of the degraded stream reaches were associated with uncontrolled stormwater and sediment. The stream reach near Koyo industries was indentified as a stream restoration project (C-RCH-2).

(a) (b)

Figure 6.10. (a) Erosion at C-RCH-3 and (b) turbid water at C-RCH-5.

One privately-owned, potential hotspot was identified at Royson's Blythewood Automotive Center (Table 6.13). Vehicle and automotive parts were stored outdoors without cover, and discoloration and staining of the storage areas were evident. Opportunities at this site include providing secondary containment and storing vehicles and parts under cover or in material storage areas.

Table 6.13. Hotspot Management Opportunities in Subwatershed C					
Priority	**Site ID**	**Location**	**Opportunity**	**Hotspot Status**	**Cost**
Medium	C-HSI-2	Royson's Blythewood Automotive	Secondary containment	Potential	$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					

Four neighborhood source control opportunities in subwatershed C were identified and are shown in Table 6.14. Better ESC practices for development were the highest priority opportunities (Figure 6.11). Many of these developments were built within the last 5 years, and construction for many of the lots was on-going or stalled. As a result, high levels of sediment were entering the stormdrain system, overwhelming stormwater management facilities that may have existed and ultimately flowing into Crane Creek. In some cases, ESC practices were lacking, and in other cases, practices were failing. One ESC site identified was located in the Stonington Neighborhood (site C-ESC-1, Table 6.14). Other opportunities include stormdrain stenciling, and landscaping/tree planting. An opportunity for a demonstration retrofit project was identified at the Wren Creek Community Center (C-RRI-19C). The Wren Creek neighborhood (C-NSA-4) would be a good candidate for targeted watershed education and outreach due to the identified restoration opportunities and the neighborhood's close proximity to Crane Creek. Portions of Crane Creek run through the Wren Creek Neighborhood and a neighborhood walking trail provides connection between the residents and the stream. The trail appears intended to provide neighborhood recreational benefits, but can be adapted into an educational tool to inform residents about the Crane Creek Watershed and promote awareness about residential behaviors that affect the quality and health of the stream.

Table 6.14. Neighborhood Source Control Opportunities in Subwatershed C

Priority	Site ID	Location	Pollution Severity	Restoration Potential	Opportunity	Cost
High	C-NSA-3	Beasley	High	Moderate	ESC, storm drain stenciling, increased landscaping/tree planting	$
High	C-NSA-5	Enclave	Moderate	Low	Pet waste education, tree planting	$
High	C-NSA-6	Stonington	Moderate	Moderate	Landscaping/tree planting in common space, storm drain stenciling, tree planting throughout neighborhood, ESC	$
Low	C-NSA-4	Wren Creek	Moderate	Moderate	Rain barrels, storm drain stenciling, retrofit potential at community center	$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

(a) (b)

Figure 6.11. ESC problems at (a) C-NSA-3 and (b) C-ESC-1.

Table 6.15. Erosion and Sedimentation Control Sites in Subwatershed C			
Priority	**Site ID**	**Location**	**Description of Problem**
Low	C-ESC-1	Stonington Neighborhood	Some failure of ESC practices including silt fence, etc.; and lack of vegetative stabilization of the site

6.1.4. Subwatershed D

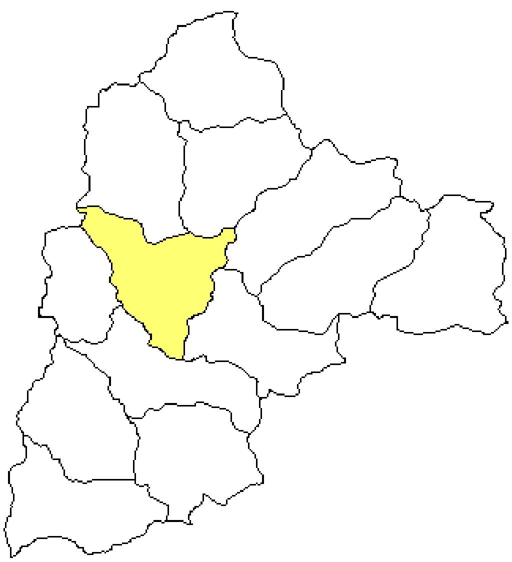


Table 6.16. Subwatershed D Characteristics		
Subwatershed		D, Beasley Creek
Drainage Area		3466 acres
Existing Impervious Cover		54 acres (1.6%)
Stream Miles		8.39 miles
2001 Land Use	Developed	4%
	Forested	67%
	Developed Open Space	8%
	Wetlands and Open water	8%
	Agriculture	6%
	Other	8%
Jurisdictions as Percent of Subwatershed D		100% Richland County 0% Town of Blythewood 0% City of Columbia

Subwatershed Description

Subwatershed D is the fourth subwatershed of the Beasley Creek subwatershed. It is located in the central, western part of the Crane Creek Watershed and is entirely within the jurisdiction of the County. Land use is primarily forested (67%) with the remaining land uses being somewhat evenly distributed (Table 6.16). Developed land comprises only 4% of the subwatershed, and current impervious cover is relatively small, less than 2%. Soils in Subwatershed D are primarily silty loam and sandy clay loam (hydrologic soil groups B and C respectively). According to the NWI map, freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up about 8% of the subwatershed.

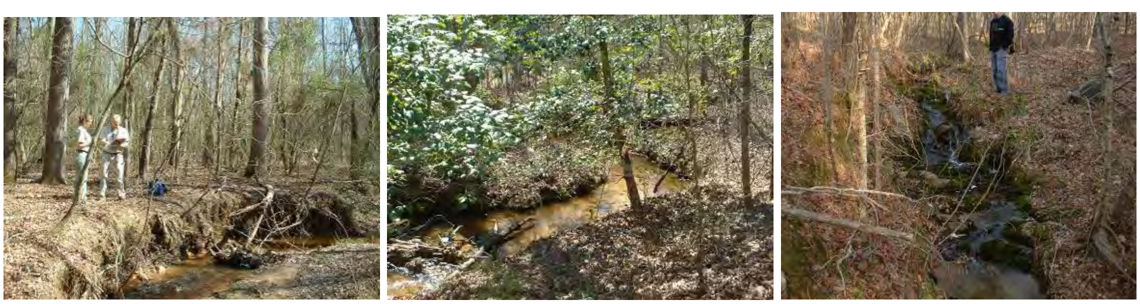
Similar to the other areas in the Beasley Creek Subwatershed, subwatershed D is mostly forested and undeveloped. No high priority projects were identified in this area. The subwatershed had very few problem areas identified, and stream reaches were in good condition. Some medium priority opportunities were identified at two neighborhoods. These opportunities are discussed below.

Management and Restoration Practice Opportunities in the Subwatershed

Five stream reaches were assessed in Subwatershed C and classified as excellent (2 reaches), good (1 reach), and fair (2 reaches). Most of the streams were stable, however some minor areas of sediment deposition were observed in D-RCH-2 and D-RCH-3 (Figure 6.12). Many of the streams were entrenched, apparently from historic channelization related to agricultural practices. High priority stream impacts are listed in Table 6.17.

Table 6.17. High Priority Stream Impacts in Subwatershed D

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
Medium	D-TR-1	D-RCH-1	Wetland	Trash	Stream Cleanup	$$
$: Estimated Planning Level Cost < $2,000 $$: Estimated Planning Level Cost $2,000-$8,000 $$$: Estimated Planning Level Cost > $8,000						



(a) (b) (c)

Figure 6.12. (a) D-RCH-3, a “fair” stream reach; (b) D-RCH-2, a “good” stream reach; and (c) D-RCH-4, an “excellent” stream reach.

Two neighborhood source control opportunities were identified and are shown in Table 6.18. Residential rain gardens, storm drain stenciling, tree-plantings and cul-de-sac retrofit opportunities were observed in the field and are considered the most important areas for improvement (Figure 6.13).

Table 6.18. Neighborhood Source Control Opportunities in Subwatershed D						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Medium	D-NSA-7	Heritage Hills	Moderate	Moderate	Rain gardens, cul-de-sac retrofits, storm drain stenciling	$$$
Medium	D-NSA-8	Palmetto Palms	Moderate	Low	Landscaping/tree planting	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

(a) (b)

Figure 6.13. Residential neighborhood opportunities include (a) cul-de-sac retrofit at D-NSA-7 and (b) landscaping at D-NSA-8.

6.2 Upper Crane Creek Subwatershed

Subwatershed Description

The Upper Crane Creek Subwatershed has seen rapid growth in the form of residential development over the past 10 to 15 years with none or very little stormwater management. Despite this development, field assessments reveal overall good stream health. This good stream quality is due to the numerous recreational man made ponds that detain the increased volume and velocity of stormwater before being discharged to the streams. Many stream reaches run through residential areas and stream impacts, including trash, lack of a stream buffer, and increased algae, were evident. In addition, it was noted that establishing grass lawns in the residential neighborhoods is a challenge due to the sandy soils. This challenge, combined with the numerous sites noted for failing or lack of ESC provides evidence of several major sources of sediment to the Crane Creek.

Subwatershed Management Strategy

The subwatershed management strategies listed below provide a framework for implementing the numerous conservation, management, and restoration practices identified through field assessments as well as program and education-related recommendations identified through both desktop analyses and field assessments. Management strategies for Upper Crane Creek subwatershed are as follows:

1. *Develop a residential education program to target neighborhoods for trash clean-up, reduced application of fertilizers, native landscaping and on-site stormwater retrofits.* The neighborhoods in close proximity to Crane Creek should be targeted for outreach and education. Specific locations include the Commons of Winchester (G-NSA-2).

2. *Enforce the 100-foot stream buffer ordinance recently adopted by the County for impaired waters. Additionally, several identified buffer restoration projects should be implemented.* This will help maintain the condition of streams in good condition during future development.

3. *Address ongoing ESC problems and reduce high sediment loads to streams.* In order to address sediment loads to Crane Creek, the County should work to establish improved ESC enforcement with more frequent site inspections. The County should conduct immediate and follow-up inspections at all observed ESC development sites. In problem areas, the County should assist in stabilization of soils, particularly in areas where soil is sandy and grass establishment is difficult.

4. *In sandy areas where establishing vegetation is challenging, consider using turf matting to stabilize soils. In addition, mixing rye grass with the permanent grass can help prevent erosion on new lawns as it establishes faster than most grasses.* This will help prevent erosion with future development.

5. *As opportunities arise, implement demonstration and residential upland stormwater retrofits.* The installation of stormwater retrofits is critical due to the fact that there is little or no stormwater treatment associated with most of the development in this subwatershed. Numerous retrofit opportunities were identified in residential developments, at schools and parks. These include bioretention, rain gardens, downspout disconnection and pond modification. Opportunities at schools and parks provide additional educational benefits for the students and are good sites for demonstration projects for the community.

6. *Establish a greenway trail system to connect residential neighborhoods with the primary Crane Creek conservation network.* A greenway trail system that connects the many residential neighborhoods in this subwatershed with the primary conservation network will provide opportunities for residents to actively interact with this important natural resource.

7. *Protect smaller headwater hubs in the eastern portion of the subwatershed.* Some high quality wetland areas were identified in this area. In addition, headwater areas have the potential to contribute large amounts of sediment to the stream network; buffering these areas through protection strategies can help to mitigate this problem.

8. *Manage nutrient input to ponds.* Ponds should be managed to control the algae inputs through a targeted neighborhood fertilizer education program, control of geese population, and planting shoreline buffers to filter nutrients.

Conservation Opportunities in the Subwatershed

Upper Crane Creek is an impacted subwatershed with a large amount of residential development and numerous constrained floodplain areas. Several neighborhoods have been identified as having moderate pollutant generating potential. Likewise, a series of stream impacts were identified as well as potential hotspots. Despite these impacts in the uplands and stream corridor, several excellent stream reaches were identified along with one wetland that was assessed as highly functional (G-WP-3; Table 6.19). Because habitat was so constrained in this subwatershed, protecting the 9.5 mile corridor network and small hubs that were identified is very important to alleviate the stresses from impervious cover (Figure 6.14). A greenway trail system that connects the many residential neighborhoods in this subwatershed with the core conservation network will provide opportunities for residents to actively interact with important natural resources.

A significant hub was identified at the intersection of three of the smaller planning level subwatersheds (subwatersheds E, F, and H). This hub is over 2,300 acres and is primarily composed with approximately 6 large parcels. Acquisition of these six parcels by the County or other land trust organizations would preserve the majority of this hub that is rapidly being encroached upon by residential subdivisions.

Table 6.19. Wetlands Assessed in the Upper Crane Creek Subwatershed			
Site ID	Wildlife Habitat FCI	Water Quality FCI	Description
G-WP-3	NA	0.85	Natural wetland providing as stormwater management

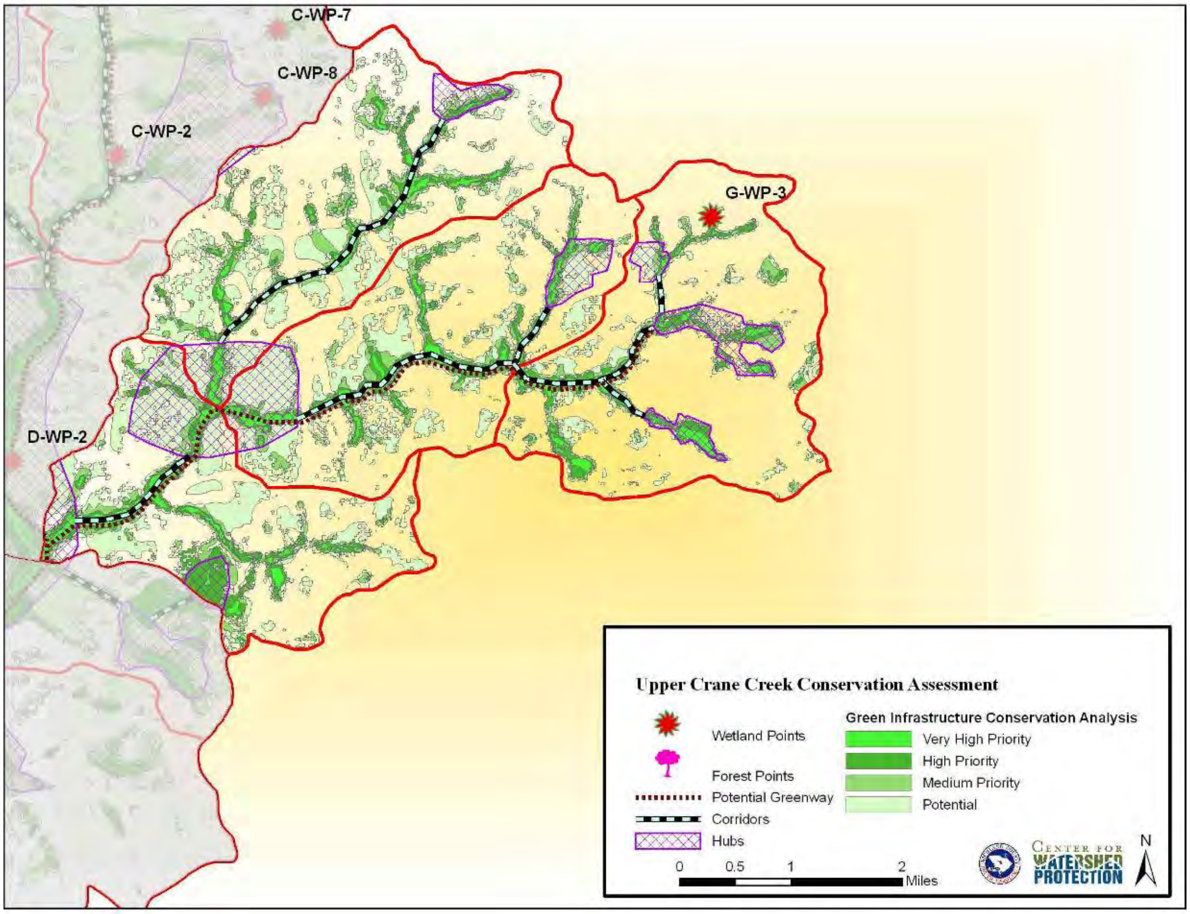


Figure 6.14. Upper Crane Creek conservation areas.

Restoration Opportunities in the Subwatershed

Numerous restoration opportunities in Upper Crane Creek were identified during the field assessments. Numerous retrofit opportunities were identified at schools, parks, neighborhoods, and existing stormwater management facilities. Although the streams were in relatively good condition, many buffer and development encroachment impacts were observed along the stream corridor. Additionally, several neighborhood restoration and educational opportunities were noted. Individual restoration projects and opportunities are discussed below by the smaller planning level subwatershed (E-H) identified during the field work.

6.2.1. Subwatershed E

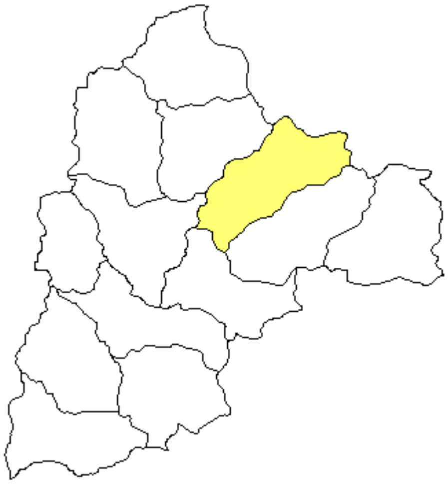


Table 6.20. Subwatershed E Characteristics		
Subwatershed		E, Upper Crane Creek
Drainage Area		3,785 acres
Existing Impervious Cover		188 acres (5.0%)
Stream Miles		10.31 miles
2001 Land Use	Developed	10%
	Forested	52%
	Developed Open Space	12%
	Wetlands and Open water	9%
	Agriculture	4%
	Other	13%
Jurisdictions as Percent of Subwatershed E		100% Richland County 0% Town of Blythewood 0% City of Columbia

Subwatershed Description

Subwatershed E is located in the eastern part of the Crane Creek Watershed. It is bisected by Interstate 77 and it falls entirely within the jurisdiction of the County. Land use is primarily forested (52%). Ten percent of the subwatershed is developed and current impervious cover is about 5% (Table 6.20). Soils in Subwatershed E are primarily sand and silty loam (hydrologic soil groups A and B respectively). Freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up 9% of the subwatershed.

The majority of the streams were in good condition with minimal impacts. Two locations for trash clean-up were identified. In order to maintain this high stream quality, several high priority stormwater retrofit opportunities involving downspout disconnection, bioretention and planting of stormwater ponds were identified at schools and parks, locations which offer good opportunities for demonstration, education, and community outreach. In addition, several pollution prevention opportunities were identified in the neighborhoods along with several ESC violations and hotspots. Two high priority hotspots were noted with recommendations of secondary containment and proper storage of materials. These opportunities are discussed in detail below.

Management and Restoration Practice Opportunities in the Subwatershed

Seven retrofit opportunities were identified in subwatershed E, three of which were ranked as high priority and four as medium priority (Table 6.21). Several schools and parks were identified for projects that are great opportunities for stormwater retrofits because of the educational and demonstration component associated with these projects. Projects identified at Longleaf Middle School (E-RRI-31A, E-RRI-31B) and Sandlapper Elementary School (E-RRI-34A, E-RRI-34B) include redirecting the building downspouts into demonstration rain gardens, installing a bioretention islands, tree planting and site stabilization, and planting of existing stormwater ponds (Figure 6.15). In addition, a bioretention project at Killian Park (E-RRI-32) to treat the stormwater runoff from a parking lot was identified as a good demonstration site.

Table 6.21. Upland Retrofit Opportunities in Subwatershed E

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
High	E-RRI-31A	Longleaf Middle School	Pond repair, site stabilization	14.6	35	19,334	100%	$15,000
High	E-RRI-31B	Longleaf Middle School	Rain gardens	0.46	100	1,586	100%	$16,653
High	E-RRI-32	Killian Park	Bioretention area	0.5	100	1,724	91%	$16,391
Medium	E-RRI-34A	Sandlapper Elementary School	Bioretention area, downspout disconnection to rain gardens	0.56	50	1,016	100%	$26,250
Medium	E-RRI-34B	Sandlapper Elementary School	Pond repair	14.5	45	35,923	100%	$5,000
Medium	E-RRI-26	Walmart Shopping Center	BMP design modification	0.35	100	1,207	100%	$5,000
Medium	E-RRI-33	Westmoreland and Robins Egg Rd (E-NSA-3)	Pond Repair	Unknown	30	Unknown	N/A	$15,000

Nine stream reaches were assessed in subwatershed E and classified as excellent (4 reaches), good (4 reaches), and poor (1 reach). The stream reach (E-RCH-20) was rated in poor condition due to floodplain encroachment and minimal stream buffer. In several other stream reaches, sediment deposition was observed. Since the subwatershed was mostly forested and undeveloped, there were few stream impact projects identified (Table 6.22). Those that were identified include a trash clean-up at sites E-SC-1, E-SC-3, and E-TR-20 (Figure 6.16). Trash at these sites ranges from old appliances, tires and bags of fertilizer that would need to be cleaned up by a combination of volunteers and County staff. Other projects include bank stabilization (E-SC-2), removal of a fish barrier (E-SC-5), and conducting a discharge inspection (E-SC-22).

(a) (b)

Figure 6.15. (a) Potential for downspout disconnection at E-RRI-31B and (b) creation of a bioretention in the existing traffic roundabout at E-RRI-34.

Table 6.22. High Priority Stream Impacts in Subwatershed E						
Priority	**Site ID**	**Stream Reach**	**Location**	**Impact**	**Opportunity**	**Cost**
High	E-SC-1	E-RCH-1	Cogburn Rd.	Trash	Stream Cleanup	$
Medium	E-SC-2	E-RCH-3	Spring Park Rd. near Longreen intersection	Water Quality	Bank stabilization	$
Medium	E-SC-3	E-RCH-4	Longreen Rd.	Trash, Water Quality	Stream Cleanup	$
Medium	E-SC-6	E-RCH-5	Pines Rd.	Stream Crossing	Encourage utility company to minimize impact of vegetation clearing near stream banks	$
Medium	E-TR-20	E-RCH-20	Killian Arch	Trash	Stream Cleanup	$
Low	E-SC-5	E-RCH-5	Farrow Rd just downstream of significant wetland	Stream Crossing	Fish barrier removal	$$$
Low	E-SC-22	E-RCH-21	Intersection of Davis Smith and Killian Arch	Stream Crossing	Discharge inspection	$
$: Estimated Planning Level Cost < $2,000 $$: Estimated Planning Level Cost $2,000-$8,000 $$$: Estimated Planning Level Cost > $8,000						

(a) (b)

(c) (d)

Figure 6.16. (a) Excellent Stream Reach (E-RCH-2); (b) poor stream reach cleared for utility lines; and (c & d) trash identified at site E-TR-20.

Three sites were visited during the hotspot assessment; two were considered potential hotspots and one was not a hotspot (Table 6.23). At the Sandlapper Elementary School (E-HSI-2) grease barrels were stored outside uncovered. Recommendations at this site include adding lids to the barrels and storing the barrels under coverage with secondary containment. At Walmart (E-HSI-1), a storage area draining directly to a stormwater pond was observed. Secondary containment should be installed in conjunction with the recommended retrofit E-RRI-26. At the Dollar General (E-HSI-3) large amounts of trash were observed piled next to the dumpster (Figure 6.17). While not a high priority project, a trash clean-up should be conducted by the store. To prevent future dumping, the number of weekly trash pick-ups should be investigated to ensure they are adequate for the amount of trash generated, and no dumping signs should be displayed.

Table 6.23. Hotspot Management Opportunities in Subwatershed E

Priority	Site ID	Location	Opportunity	Hotspot Status	Cost
High	E-HSI-1	Walmart	Secondary containment	Potential	$
High	E-HSI-2	Sandlapper Elementary	Material storage	Potential	$
Medium	E-HSI-3	Dollar General	Trash clean up	Not	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					

(a) (b)

Figure 6.17. (a) Uncovered grease containers at Sandlapper Elementary School (E-HSI-2) and (b) dumping of trash at Dollar General (E-HSI-3).

Seven neighborhood source control opportunities were identified and are shown in Table 6.24. None of these sites were ranked as high priority. Landscaping and tree planting, storm drain marker repair, and downspout disconnection opportunities were observed in the field and are considered the most important areas for improvement. In addition, in neighborhood E-NSA-3, a stormwater retrofit was identified site for pond repair (E-RRI-33).

Table 6.24. Neighborhood Source Control Opportunities in Subwatershed E

Priority	Site ID	Location	Pollution Severity	Restoration Potential	Opportunity	Cost
Medium	E-NSA-1	Traditions	Moderate	Low	Landscaping/tree planting, storm drain marker repair	$
Medium	E-NSA-2	Vineyard Crossings/ Rivendale	Moderate	Low	Landscaping/tree planting, storm drain marker repair, ESC problems	$$
Medium	E-NSA-4	Brook Haven	Moderate	Low	Landscaping/tree planting, storm drain marker repair	$
Medium	E-NSA-6	Holly Ridge	Moderate	Low	Landscaping/tree planting, downspout redirection	$
Low	E-NSA-3	Mason Ridge/ Thomaston	None	Low	Landscaping/tree planting, storm drain marker repair, sediment in some curb & gutter systems, storm water pond maintenance	$$
Low	E-NSA-5	Ashley Ridge	Low	Low	Landscaping/tree planting, storm drain markers/stenciling	$

Table 6.24. Neighborhood Source Control Opportunities in Subwatershed E						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Low	E-NSA-7	Landon Place	None	Low	Some areas still under construction, landscaping/tree planting, storm drain stenciling	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

Two sites with uncontrolled ESC practices were identified (Figure 6.18). Poor storm drain inlet protection and silt fence failure was observed at both sites (Table 6.25). The County should conduct inspections at these sites to ensure that ESC problems have been properly addressed, and that the sites have been stabilized to prevent further erosion.

Table 6.25. Erosion and Sedimentation Control Sites in Subwatershed E			
Priority	**Site ID**	**Location**	**Description of Problem**
Medium	E-ESC-1	Rivendale Dr and Sepia Ct	Silt fence failure, poor inlet protection
Medium	E-ESC-2	Heather Green	Silt fence failure, poor inlet protection

(a)

(b)

Figure 6.18. (a & b) Failing silt fence at E-ESC-2 allowing silt to enter the storm drain inlet and discharge to the creek.

6.2.2. Subwatershed F

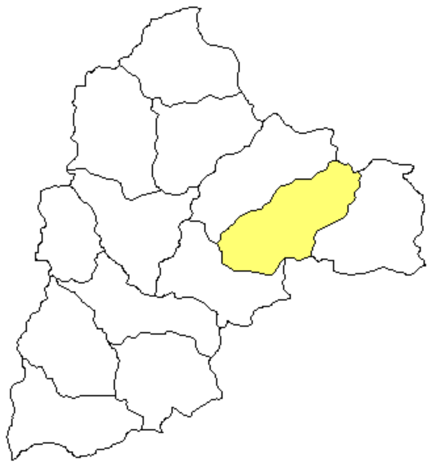


Table 6.26. Subwatershed F Characteristics		
Subwatershed		F, Upper Crane Creek
Drainage Area		3695 acres
Existing Impervious Cover		343 acres (9.3%)
Stream Miles		8.72 miles
2001 Land Use	Developed	21%
	Forested	44%
	Developed Open Space	11%
	Wetlands and Open water	10.5%
	Agriculture	4%
	Other	10%
Jurisdictions as Percent of Subwatershed F		100% Richland County 0% Town of Blythewood 0% City of Columbia

Subwatershed Description

Located in the Upper Crane Creek subsection, subwatershed F falls completely within the jurisdiction of the County and is transected by Interstate 77. Subwatershed F is 44% forested and 21% developed, and the current impervious cover is 9.3% (Table 6.26). Freshwater ponds, freshwater forested/shrub wetland, freshwater emergent wetland and a lake make up 10.5% of the subwatershed, and soils consist primarily of silty loam and sand (hydrologic soil groups B and A respectively).

Stream reach conditions ranged from very poor to excellent conditions, and appear to be correlated to the presence of a wide stream buffer. Residential stream impacts were apparent, and included mowed stream buffer and trash in the stream. The residential neighborhoods in the subwatershed presented several opportunities for pollution prevention activities ranging from tree planting and buffer reforestation to stormdrain marking. Three sites were identified with a lack of ESC practices with the high priority site F-ESC-1 containing no ESC practices. Field work also revealed extensive wetland draining at site F-MI-1. These opportunities are discussed in detail below.

Management and Restoration Practice Opportunities in the Subwatershed

Four medium priority stormwater retrofit opportunities were identified in subwatershed F (Table 6.27). Although none of the sites were ranked as high priority, the projects were noted as sources of sediment to nearby streams. Sediment impacts were most evident at Longtown Commons (F-RRI-28) (Figure 6.19). This large site area had been cleared for construction, but was since abandoned. During the field assessments, the site had been recently fertilized and seeded, but due to the sandy nature of the soils, vegetation had not been established at the site. Fertilizer and sediment from the site drained to a sediment pond that was full of algae and experiencing bank erosion. Stormwater discharge from the pond was very turbid and contained algae. Stabilizing this site and repairing the pond can result in water quality improvements. This site was also identified as a medium priority ESC site to address (F-ESC-2, Table 6.31). A bioretention area project at Killian Elementary School (F-RRI-29) was identified that presents a good educational opportunity. Two additional retrofit sites at Heron Lake Apartments (F-RRI-25) and Lowes (F-RRI-27) were investigated but no projects were identified.

Table 6.27. Stormwater Retrofit Opportunities in Subwatershed F

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
Medium	F-RRI-28	Longtown Commons	Pond Modification, Site Stabilization	27.6	5	14277	100%	$25,387
Medium	F-RRI-29	Killian Elementary School	Bioretention area	1.38	50	2505	100%	$26,303
Medium	F-RRI-30	Killian Station	Pond Modification	4.8	40	10716	100%	$21,408
Medium	F-RRI-35	Timberview	Pond repair	11.65	30	20299	100%	$15,000

(a) (b)

Figure 6.19. Site F-RRI-28 (a) soil needs to be stabilized and (b) sediment laden outflow from the stormwater pond.

Five stream reaches were assessed and their classification ranged from excellent to very poor. Sediment deposition was observed in several of the stream reaches. The sediment deposition can be attributed to severe bank erosion (F-ER-1) from uncontrolled stormwater in the neighborhoods. In addition, large sources of sediment are likely from several uncontrolled erosion sites and Killian Station (F-MI-1) where wetlands were ditched and drained and sediment needs to be contained at the site.

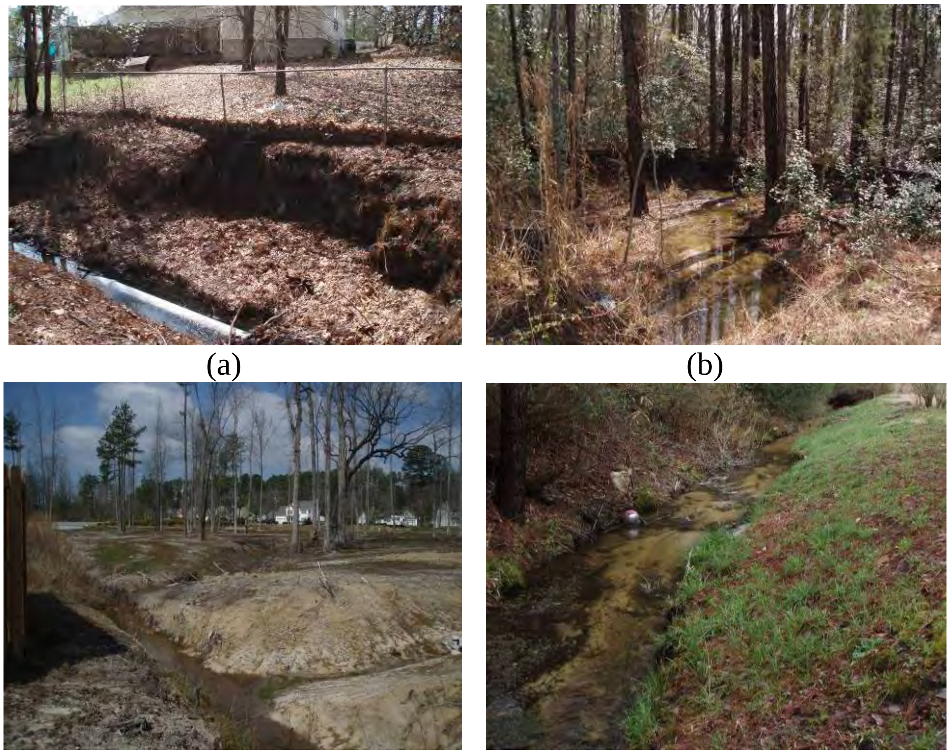
The excellent and good rated stream reaches were located in areas with wide stream buffers while the more degraded stream reaches (fair to very poor) were located closer to residential development with stream buffer encroachment resulting in a narrower stream buffer. In the very poor stream reach (F-RCH-4), bank scour, bank failure, and channelization were noted. Several stream impacts were noted in this subwatershed, as noted in Table 6.28, including evidence of extensive wetland draining (F-MI-1), steep eroding banks (F-ER-1), an impacted stream buffer due to homeowners mowing directly to the edge of the stream (F-IB-1), and trash accumulation associated with a storm drain outfall (F-TR-1) (Figure 6.20). In addition, several stream crossings were noted with associated erosion impacts. Two high priority projects were identified along F-RCH-2 for a stream cleanup and riparian reforestation.

Table 6.28. High Priority Stream Impacts in Subwatershed F

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
High	F-TR-1	F-RCH-2	Just upstream of Clemson Rd	Trash	Stream Cleanup	$
High	F-IB-1		Northern portion of Winslow Rd near the channel	Buffer	Riparian reforestation	$
Medium	F-MI-1	F-RCH-3	Entrance to Killian Station development (F-NSA-2)	Miscellaneous	Stream restoration; E&S control; plantings	$$
Medium	F-SC-4	F-RCH-5	Intersection of Farrow Rd and Longtown	Stream Crossing	Culvert replacement	$$
Medium	F-SC-3		Crossings Community Church	Stream Crossing	Stream restoration; bank stabilization at outfall; ESC at Lowe's	$$$
Low	F-ER-1	F-RCH-4	Just upstream of Winslow Rd intersection with RCH-4	Erosion	Bank stabilization/ Follow up on exposed sewer pipe	$$$

$: Estimated Planning Level Cost < $2,000
$$: Estimated Planning Level Cost $2,000-$8,000
$$$: Estimated Planning Level Cost > $8,000

In addition to the streams assessed by the Center field crews, the three mile stream reach from Hospital Lake to Lake Elizabeth was assessed by the Genesis Consulting Group (2009) under a separate contract with the County. This stream assessment focused on identifying sources of sediment that ultimately drain to Lake Elizabeth. Results revealed that overall channel erosion and scour was considered minor to moderate. In addition, a recommendation was made for the County to increase ESC inspections based on the identification of several construction sites with insufficient ESC.



(a) (b) (c) (d)

Figure 6.20. Stream reaches and impacts in subwatershed F. (a) a very poor stream reach at F-RCH-4; (b) good stream reach at F-RCH-3; (c) Wetlands drained at Killian Station at F-MI-1; (d) stream buffer mowed to the edge (F-IB-1).

One hotspot site was assessed at a residential storage location in this subwatershed (Table 6.29). The site was not identified as a hotspot, but paint and building materials were observed within close proximity (less than 10 feet) of stream reach F-RCH-2. Opportunities for clean up or homeowner education can be pursued.

Table 6.29. Hotspot Management Opportunities in Subwatershed F

Priority	Site ID	Location	Opportunity	Hotspot Status	Cost
Medium	F-HSI-30	Residential Near F-RCH-2	Clean up	Not	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					

Eight residential neighborhoods were assessed. Although no neighborhoods were identified as high priority projects, several locations had moderate pollution severity or restoration potential. Pollution prevention opportunities included landscaping and tree planting, storm drain stenciling, downspout disconnection and bioretention (Table 6.30). Although not a high priority neighborhood, Killian Station (F-NSA-2) had extensive ditching and draining of wetlands and exposed soils that need to be stabilized.

Table 6.30. Neighborhood Source Control Opportunities in Subwatershed F						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Medium	F-NSA-8	Ashley Hall Rd	None	Moderate	Minimal downspout disconnection	$
Medium	F-NSA-2	Killian Station (F-MI-1)	Moderate	Low	Landscaping/tree planting, better ESC for infill	$
Medium	F-NSA-3	Hester Woods	Moderate	Low	Landscaping/tree planting	$
Low	F-NSA-1	Killian Green / Villages at Lakeshore	Moderate	Low	Landscaping/tree planting, bioretention in open space island	$$$
Low	F-NSA-4	Timbervale	Moderate	Moderate	Bioretention in cul-de-sacs, tree planting, dry pond outfall repair	$$$
Low	F-NSA-5	Ashley Ridge Rd/Winslow	None	Low	Landscaping/tree planting, storm drain markers/stenciling	$
Low	F-NSA-6	Heathergreen	None	Low	Some areas still under construction, landscaping/tree planting, storm drain markers/stenciling	$
Low	F-NSA-7	Whitehurst Way	None	Low	Landscaping/tree planting, storm drain markers/stenciling	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

Three ESC sites were identified in subwatershed F. The Killian Lake Apartments (F-ESC-1) were identified as a high priority site as the site was developed with no ESC practices. It is interesting to note that this site was also noted for failed ESC practices in the 2009 Genesis Consulting Group report. Additionally, problems were noted at an inactive construction site with unstable soils at Longtown Commons (F-ESC-2) and at a development site with poor ESC at construction entrances (E-ESC-3) (Table 6.31 and Figure 6.21). Each ESC site should be field investigated and remediated.

Table 6.31. Erosion and Sedimentation Control Sites in Subwatershed F			
Priority	**Site ID**	**Location**	**Description of Problem**
High	F-ESC-1	Killian Lake 9559 Farrow Rd	New apartment/condo complex being developed with no ESC practices. Lots of sediment entering stormdrains, erosion at sediment pond. Site soils are not stabilized.
Medium	F-ESC-2	Longtown Commons	Inactive construction site with unstable soils. Sediment is washing into stormwater pond. Lots of erosion from pond into stream.
Medium	F-ESC-3	Diesel Drive and Killian Commons	Poor ESC at construction entrances

(a) (b)

Figure 6.21. ESC problems identified in Subwatershed F. (a) lack of ESC at site F-ESC-1 and (b) failing ESC at site F-ESC-3.

6.2.3. Subwatershed G

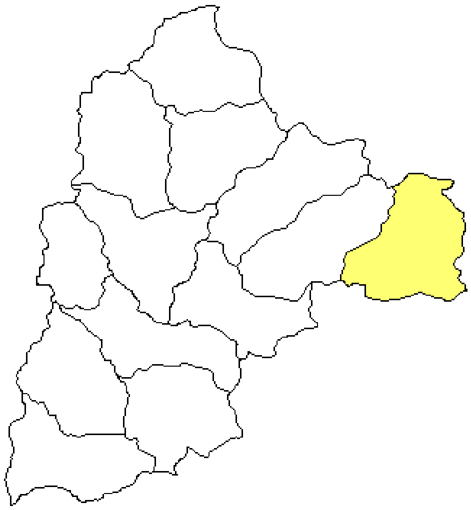


Table 6.32. Subwatershed G Characteristics		
Subwatershed		G, Upper Crane Creek
Drainage Area		3820 acres
Existing Impervious Cover		796 acres (20.8%)
Stream Miles		10.81 miles
2001 Land Use	Developed	46%
	Forested	17%
	Developed Open Space	20%
	Wetlands and Open water	9.3%
	Agriculture	2%
	Other	6%
Jurisdictions as Percent of Subwatershed G		100% Richland County 0% Town of Blythewood 0% City of Columbia

Subwatershed Description

Located in the easternmost part of the Crane Creek Watershed, subwatershed G falls completely within the County jurisdiction. With approximately half of the land use devoted to development (46%), current impervious cover falls just above 20% (Table 6.32); the highest in the Upper Crane Creek subwatershed. Freshwater ponds, freshwater forested/shrub wetland, freshwater emergent wetland and lakes make up about 9.3% of the subwatershed and soils are primarily sand and silty loam (hydrologic soil groups A and B respectively).

This subwatershed is mostly developed with residential neighborhoods constructed in the past 10 to 15 years with minimal stormwater treatment. The stream reaches were in generally good condition despite the residential developed nature of the subwatershed. This is mainly due to the numerous ponds located in this subwatershed that retain the additional stormwater generated from the surrounding development. The stormwater retention alleviates the erosive forces that could degrade in-stream conditions and remove pollutants. The major high priority stream project is trash clean-up. Algae were also noted in several streams that were attributed to high nutrient management in the residential neighborhoods. This observation led to the high priority neighborhood projects that include a targeted residential education program on trash clean-up and nutrient lawn management. Due to the presence of sandy soils, establishing grass cover on residential lawns is challenging. Lawns with exposed soils were noted as sources of sediment to the streams. The County should provide a native grass mix to use for soil stabilization. Several on-site stormwater retrofits were identified including bioretention at a school, park, and a neighborhood. The two high priority stormwater retrofit sites identified will serve as good demonstration and educational projects. There were no identified hotspots or ESC sites. These opportunities are discussed in detail below.

Management and Restoration Practice Opportunities in the Subwatershed

Four stormwater retrofit sites were identified in a neighborhood, a school and a park (Table 6.33). A relatively simple and low cost project was identified at the North Springs Elementary School (G-RRI-39) and included planting vegetation around the existing stormwater pond. Also, at North Spring Park (G-RRI-38) a bioretention cell was proposed to treat stormwater from the parking lot (Figure 6.22). Both projects were ranked as high priority and would serve as a good demonstration and educational projects. Two locations for treatment of roadway runoff through bioretention systems were also identified in the Commons of Winchester neighborhood (G-RRI-201 and G-RRI-202). Runoff from this neighborhood flowed directly into Crane Creek without receiving any treatment. No stormwater management practices were present in this recent development. Implementation of the bioretention systems would provide some treatment of roadway, driveway, and residential lawn runoff. In addition, two other sites were evaluated (G-RRI-36 and G-RRI-37) but no retrofit opportunities were identified.

Table 6.33. Stormwater Retrofit Opportunities in Subwatershed G

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
High	G-RRI-38	North Spring Park	Bioretention area	2.7	100	9311	100%	$97,755
High	G-RRI-39	North Springs Elementary	Pond vegetation	N/A	N/A	N/A	N/A	$5,000
Medium	G-RRI-201	Commons of Winchester (G-NSA-2)	Roadway bioretention retrofit	3.82	25	3813	52%	$21,000
Low	G-RRI-202	Commons of Winchester (G-NSA-2)	Bioretention	3.08	25	3075	15%	$4,725

Twelve stream reaches were assessed and were classified as excellent (4 reaches), good (2 reaches), fair (3 reaches), poor (2 reaches) and very poor (1 reach) (Table 6.34). The most notable impact to the stream was buffer encroachment and mowing to the edge of the buffer (G-IB-3) by homeowners as well as trash in the stream (Figure 6.23). The very poor stream reach (G-RCH-6) is a riprap stream with a mowed buffer (G-IB-3) located in a residential park (G-NSA-14). The neighborhood and the County should work together to plant vegetation along the stream that would help stabilize the stream banks, provide habitat, and aesthetic benefits. In addition, the County should organize neighborhood stream clean-up events at sites G-TR-1, G-TR-2, and G-TR-4 (Figure 6.23). Trash found in the stream ranged from litter items (e.g. plastic bottles, wrappers) to large bulk items (e.g. tires, etc.). At one site (G-TR-2) a fertilizer bag was found in the stream that was evidence of the highly manicured lawns in the adjacent neighborhood (G-NSA-2). As noted in the neighborhood assessment section, a targeted residential lawn fertilizer education program is recommended.

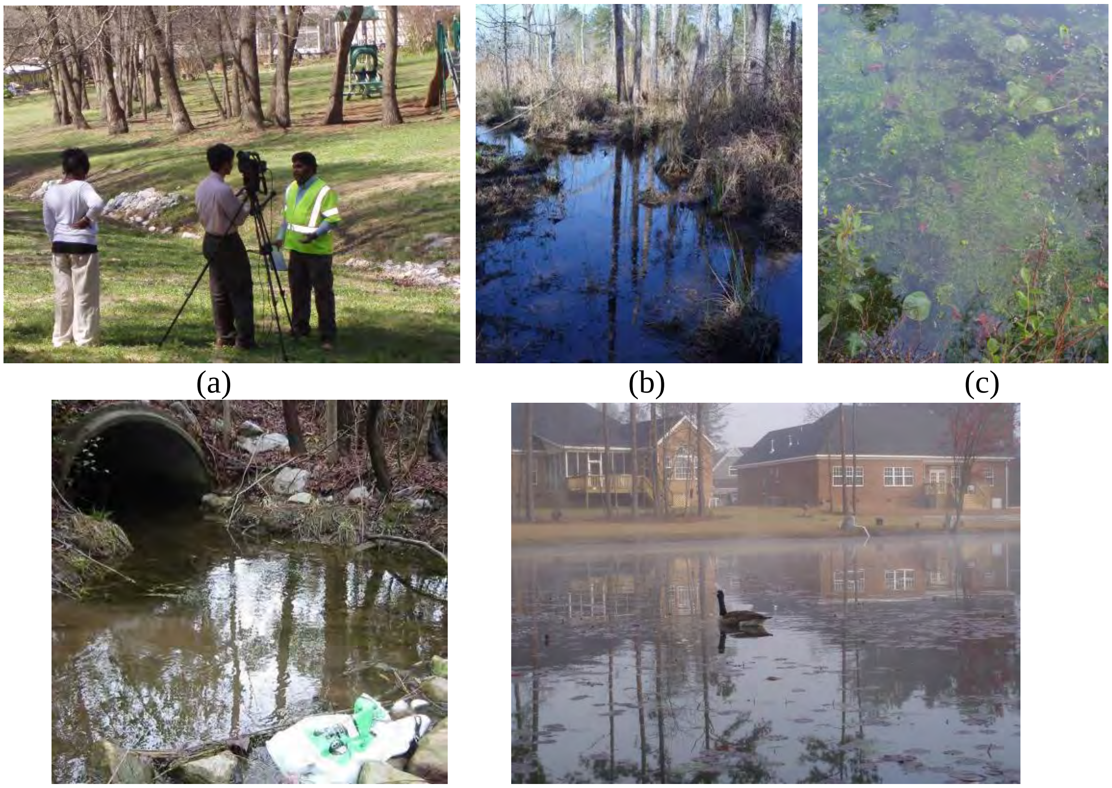
Last, it is recommended that the ponds in this subwatershed are managed to control the algae inputs through a targeted neighborhood fertilizer education program, control of geese population, and planting shoreline buffers to filter nutrients.


(a)


(b)

Figure 6.22. (a) Location for a potential bioretention (G-RRI-38) and (b) Location for vegetation planting at an existing stormwater pond.

Table 6.34. High Priority Stream Impacts in Subwatershed G						
Priority	**Site ID**	**Stream Reach**	**Location**	**Impact**	**Opportunity**	**Cost**
High	G-OT-1	G-RCH-1	Kinrose	Outfall	Discharge inspection; residential education	$
High	G-TR-1		Kinrose	Trash	Stream Cleanup	$
High	G-TR-2		Kinrose	Trash	Stream Cleanup	$
High	G-IB-3	G-RCH -6	Lightwood Knot	Buffer	Riparian reforestation	$
High	G-TR-4	G-RCH -10	Sloan Road	Trash	Stream Cleanup	$
Medium	G-MI-1	G-RCH -9	Cane Brake	Miscellaneous-algae	Discharge inspection	$
N/A	G-IB-2	G-RCH -4	Chancery	Buffer	No Action	N/A
$: Estimated Planning Level Cost < $2,000 $$: Estimated Planning Level Cost $2,000-$8,000 $$$: Estimated Planning Level Cost > $8,000						



(a) (b) (c)

(d) (e)

Figure 6.23. (a) Very poor stream reach G-RCH-6 and impacted buffer G-IB-3 in G-NSA-14; (b) wetland associated with excellent rated stream reach G-RCH-12; (c) algae in pond; (d) fertilizer bag found in stream (G-TR-2) in G-NSA-2; and (e) representative pond with geese and algae (G-RCH-7 in G-NSA-2).

Thirteen neighborhoods were assessed for sources of pollution and restoration potential (Table 6.35). One neighborhood was identified as high priority, three medium priority and nine as low priority. All of the neighborhoods except G-NSA-3, G-NSA-1, G-NSA-7, and G-NSA-10 have portions of Crane Creek running through the residential backyards. These neighborhoods present good opportunities for residential education and outreach on stream protection. It should be noted that high lawn care maintenance was observed in G-NSA-2, G-NSA-7, G-NSA-8, and was associated with high algae levels in nearby stream reaches G-RCH-1, G-RCH-7, G-RCH-9 (Figure 6.24). Nutrient management and fertilizer education opportunities for pollution control were noted in these neighborhoods. Residential lawns were also found to be a source of sediment throughout the subwatershed due to the presence of sandy soils. It is recommended that turf matting and/or mixing rye grass with permanent grass is used for stabilization in areas with sandy soils. Also, opportunities for residential restoration projects included planting trees, installing rain gardens and street retrofits, and planting stream buffers.

(a) (b)

Figure 6.24. (a) High fertilizer use G-NSA-8 and (b) spots of bare soil at G-NSA-2.

Table 6.35. Neighborhood Source Control Opportunities in Subwatershed G						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
High	G-NSA-13	Fishers Shore Rd	Moderate	Low	Potential rain gardens	$
Medium	G-NSA-2	Commons of Winchester	Moderate	Moderate	Nutrient management, rain gardens, limited downspout disconnection, wide street retrofits	$$
Medium	G-NSA-5	Elders Pond Dr	Moderate	Low	Plant trees	$
Medium	G-NSA-14	Lightwood Knot Rd	None	Low	Buffer planting along eroded stream	$
Low	G-NSA-1	Gatewood Way	None	Low	Plant trees in common area and lots, retrofit of common area parking lot, wide street retrofits	$$
Low	G-NSA-3	Ridge Trail Dr	Moderate	Moderate	Non-target irrigation in common area	$
Low	G-NSA-4	Brookfield Rd	None	Low	Minimal downspout disconnection, wide road retrofits	$$
Low	G-NSA-6	Markham Rd	None	Moderate	Rain gardens	$
Low	G-NSA-7	Parsons Mill Ln	None	Low	Nutrient management	$
Low	G-NSA-8	Rainsborough Way	None	Low	Wide road retrofits, rain gardens, stormdrain stenciling, Nutrient management	$$

Table 6.35. Neighborhood Source Control Opportunities in Subwatershed G						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Low	G-NSA-10	Lockleven Dr	None	Low	Retrofit stormwater pond, trash in drainage ditch, disconnection of garage downspouts	$$
Low	G-NSA-11	Seton Hall Dr	None	Low	Stormdrain stenciling	$
Low	G-NSA-12	Green Springs Dr	None	Moderate	Lawn alternatives, plant more trees	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

6.2.4. Subwatershed H

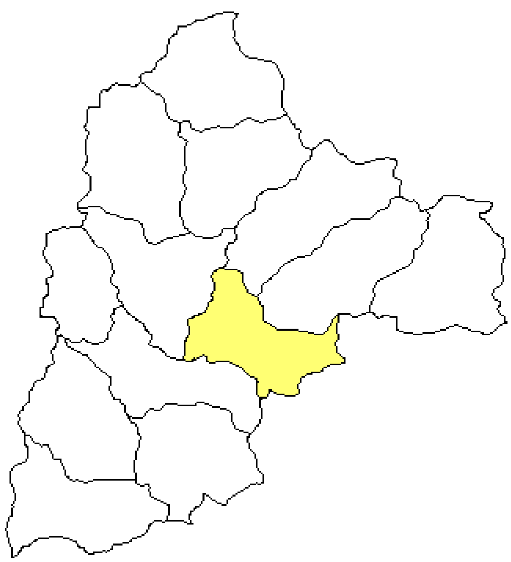


Table 6.36. Subwatershed H Characteristics		
Subwatershed		H, Upper Crane Creek
Drainage Area		3023 acres
Existing Impervious Cover		378 acres (12.5%)
Stream Miles		7.30 miles
2001 Land Use	Developed	24%
	Forested	38%
	Developed Open Space	19%
	Wetlands and Open water	7.4%
	Agriculture	5%
	Other	7%
Jurisdictions as Percent of Subwatershed H		93% Richland County 0% Town of Blythewood 7% City of Columbia

Subwatershed Description

The last subwatershed in the Upper Crane Creek subsection, subwatershed H is located in the central, eastern part of the Crane Creek Watershed. The subwatershed falls mostly within the jurisdiction of the County, but 7% of the subwatershed is located in the City (Table 6.36). Interstate 77 crosses the southwestern portion of the subwatershed. Development comprises 24% of the land use, and current impervious cover is 12.5%. The subwatershed is 38% forested and 19% developed open space. Freshwater ponds, freshwater forested/shrub wetland, freshwater emergent wetland and lakes make up about 7.4% of the subwatershed and soils are primarily silty loam and sand (hydrologic soil groups B and A respectively).

One of the major concerns in this subwatershed is the sediment loadings to Lake Elizabeth. These loadings were investigated by the Genesis Consulting Group (2009) by walking the stream to identify sediment 'hotspots'. This report revealed that overall channel erosion and scour was considered minor to moderate while identified inadequate ESC practices were noted as major sources of sediment to the stream. While none of the neighborhoods were ranked high priority, opportunities for pollution prevention include landscaping, downspout disconnection and stormdrain stenciling. Two hotspot locations were identified, both in need of secondary containment. In addition, four stormwater retrofit opportunities were identified for bioretention and modification of an existing stormwater pond. One failing ESC site was identified.

Management and Restoration Practice Opportunities in the Subwatershed

Four stormwater retrofit projects were identified in subwatershed H (Table 6.37). Three potential projects involve creating a bioretention area to treat parking lot stormwater runoff (Figure 6.25). Sites H-RRI-24A and H-RRI-24B involve the conversion of existing parking spaces to bioretention and/or permeable pavement. The proposed concept at site H-RRI-200 involves enhancing an existing stormwater pond to provide water quality treatment of the SC DHEC office building and parking lot. Currently, runoff from the parking lot by-passes an existing water quantity pond. The pond outlet can be modified and the pond converted to a wetland system for enhanced water quality treatment and pollutant removal. In addition, a swale can be constructed to direct parking lot runoff into the existing stormwater pond. The projects located on SCDHEC and the HealthPort properties (H-RRI-24A and H-RRI-200, respectively) may provide good opportunities for demonstration projects and education and outreach.

Table 6.37. Stormwater Retrofit Opportunities in Subwatershed H

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
Medium	H-RRI-24A	SC DHEC	Bioretention Area	1.55	100	5,345	13%	$9,530
Medium	H-RRI-24B	HealthPort Building	Bioretention Area, Permeable Pavement	0.69	100	2,379	100%	$34,450
Medium	H-RRI-200	SC DHEC/ Enterprise	Pond Modification, Swale	5.16	80	21,634	100%	$20,000
Low	H-RRI-23	Nationwide Insurance Building	Bioretention Area	1.5	90	4,683	80%	$39,375

(a) (b) (c)

Figure 6.25. (a) Potential location of a bioretention cell at site H-RRI-23. (b) pond retrofit opportunity at H-RRI-200. (c) treatment opportunity at site H-RRI-24A.

Streams in this subwatershed were assessed by the Genesis Consulting Group (2009). In the fall of 2008, Richland County hired the Genesis Consulting Group to perform a field assessment of the tributary located between Hospital Lake at Farrow Rd and Lake Elizabeth (near Nina Lee Drive). This stream assessment focused on identifying sources of sediment that ultimately drained to Lake Elizabeth. According to the report findings, major sources of sediment to the stream included unstabilized development sites and stormwater runoff. The other tributary to Lake Elizabeth is currently being evaluated by the Genesis Consulting Group.

The Center assessed three stream reaches west of Interstate 21. These were classified as excellent (1 reach) and good (2 reaches). Immediately downstream of the dam at Lake Elizabeth, H-RCH-30 was rated in good condition, while the other two located off Alta Vista Road were rated as good (H-RCH-31) and excellent (H-RCH-32) (Figure 6.26).

(a) (b)

Figure 6.26. (a) Good stream reach H-RCH-30 and (b) excellent stream reach H-RCH-32.

Five sites were visited during the hotspot assessment; two were considered potential hotspots and three were not a hotspot (Table 6.38). Secondary containment is recommended for all sites except H-HSI-4 where a trash clean-up is needed. Outdoor storage of old cars and car parts were identified at site H-HSI-22 (Figure 6.27). Additionally, outdoor storage of construction materials was noted at site H-HSI-20. These sites should develop a pollution prevention plan to address the potential contaminants from the vehicles.

(a) (b)

Figure 6.27. (a) Uncovered storage of construction material (H-HSI-20) and (b) auto salvage yard (H-HSI-22).

Table 6.38. Hotspot Management Opportunities in Subwatershed H					
Priority	**Site ID**	**Location**	**Opportunity**	**Hotspot Status**	**Cost**
Medium	H-HSI-3	Exxon Quick Stop	Secondary containment	Not	$
Medium	H-HSI-4	Enterprise Car Rental	Trash clean up	Not	$
Medium	H-HSI-20	M.B. Kahn	Secondary containment, Material storage	Potential	$$
Medium	H-HSI-22	Auto Salvage Yard next to Richland County DPW	Secondary containment, Material storage	Potential	$$
Low	H-HSI-21	Richland County DPW	Secondary containment, wash area	Not	$$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					

Seven neighborhoods source control opportunities were identified and are shown in Table 6.39. Landscaping, storm drain stenciling and potential rain gardens opportunities were observed in the field and are considered the most important areas for improvement (Figure 6.28). In addition, native landscaping on residential lawns should be investigated to improve soil stability on sandy soils.

Table 6.39. Neighborhood Source Control Opportunities in Subwatershed H						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Medium	H-NSA-22	Jasmine Place	Moderate	Moderate	Landscaping/tree planting, storm drain stenciling, rain gardens	$$

Table 6.39. Neighborhood Source Control Opportunities in Subwatershed H						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Medium	H-NSA-23	Ida Rd	Moderate	Low	Landscaping	$
Medium	H-NSA-24	Nina Lee/Boyleston/Ted	Moderate	Low	Landscaping	$
Medium	H-NSA-25	Fairlawn	Moderate	Low	Landscaping, storm drain stenciling	$
Medium	H-NSA-26	Summerhill	Moderate	Moderate	Landscaping, storm drain stenciling	$
Low	H-NSA-20	Twin Eagle	None	Low	Rain barrels, storm drain stenciling	$$
Low	H-NSA-21	The Fairways	None	Moderate	Parking lot retrofit, storm drain stenciling	$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

(a)

(b)

Figure 6.28. Representative neighborhood photos from (a) H-NSA-22 and (b) H-NSA-26.

An inactive/abandoned construction site with failing ESC was noted near the Gateway Corporate Park (Table 6.40, Figure 6.29). The site should be stabilized to prevent further sediment from leaving the site and entering the stream.

Table 6.40. Erosion and Sedimentation Control Sites in Subwatershed H			
Priority	**Site ID**	**Location**	**Description of Problem**
Low	H-ESC-1	Near Gateway Corporate Park	In-active/abandoned construction site with failing ESC controls. Sediment travelling from site under ESC fencing into stream

(a) (b)

Figure 6.29. (a & b) Failing ESC at site H-ESC-1.

6.3 Lower Crane Creek Subwatershed

Subwatershed Description

The Lower Crane Creek subwatershed is a mixture of urban and rural land uses. The City lies partially within this subwatershed so urban impacts on the streams are still very relevant. Many high priority hotspots and retrofit opportunities were identified throughout the subwatershed. Many neighborhood dumping locations were also identified and stream impacts from utilities (notably sewer lines and power lines) were evident. Despite these urban land use impacts, the Lower Crane Creek subwatershed still contains large swaths of intact, undeveloped land as well as key hubs and corridors. Conservation opportunities are located mostly within the northwest portion of the subwatershed. Key corridors could also be protected to link the Crane Creek conservation network to the Broad River greenway as well as to Sesquicentennial State Park and potentially to Fort Jackson. A greenway trail corridor could begin at the mouth of Crane Creek and provide the City residents with opportunities to enjoy the watershed in its natural setting.

Subwatershed Management Strategy

The subwatershed management strategies listed below provide a framework for implementing the numerous conservation, management, and restoration practices identified through field assessments as well as program and education-related recommendations identified through both the desktop analyses and field assessments. Management strategies for the Lower Crane Creek subwatershed are as follows:

1. *Implement the high priority retrofit projects.* Two notable projects were called out that would provide water quality as well as education benefits located at the Forest Hills Elementary School (K-RRI-6) and W.G. Sanders Elementary School (L-RRI-9A and L-RRI-9B). The project at Forest Hills Elementary School (K-RRI-6) was identified as an excellent demonstration opportunity. The W.G. Sanders Elementary School is a facility that was due to close in the summer, 2009, providing an opportunity to implement the proposed concepts, including downspout disconnection, bioretention, and daylighting an underground pipe which runs through an open field at the site.

2. *The numerous hotspot areas that were identified throughout the subwatershed should be addressed immediately.* The County bus maintenance shop (I-HSI-16) and the Flying J Gas Station (M-HSI-1) had severe problems that should be addressed immediately.

3. *Target educational programs in residential areas for trash clean-ups, trash awareness, buffer programs, and native landscaping.* Where possible, restore residential buffers where mowing to the stream edge is common practice. Education can be employed to encourage homeowners to discontinue this practice and allow for natural regeneration of the stream buffer. Non-native species that emerge should be controlled to allow native species an opportunity to develop. The local Soil and Water Conservation

District will be able to assist with identification and control of non-native species control.

4. *Begin implementation of stream clean-ups where dumping is a notable problem in the stream corridor.* An adopt-a-stream program can be developed to encourage regular stream corridor clean-up and maintenance.

5. *Protect remaining high priority habitat areas, especially. identified hubs and corridors.* Contain development within the existing urban footprint and provide access to protected natural areas.

6. *Encourage reforestation efforts in the northwestern portion of the subwatershed.* Consider promoting sustainable forest management practices in this area.

7. *Create a greenway trail corridor* along the mainstem of Crane Creek; connect this to the Broad River Greenway.

8. *Connect the primary conservation network with corridors to adjacent ecological hubs outside the Crane Creek Watershed* (Sesquicentennial State Park, Fort Jackson, and Harbison State Forest).

9. *Assess sewer lines that cross or parallel the stream corridor for risk of damage* from 5, 10, 50, and 100 year storm events. The sewer service provider may also perform this analysis. Local neighborhood associations may also be made aware of the potential problem and monitor the situation.

10. *Identify residential areas having septic systems and educate residents on proper septic system maintenance, inspection, and repair.*

11. *Work with local utility companies to address severe erosion areas under powerlines.* A significant amount of erosion was found in K-RCH-13.

Conservation Opportunities in the Subwatershed

Conservation opportunities in the Lower Crane Creek subwatershed are a mix of protection and habitat restoration strategies. The region northwest of the Crane Creek mainstem offers opportunities for protection and reforestation efforts. One forest site was visited (J-FP-1) and was composed of a bottomland hardwood mix (Table 6.41). Two wetlands that were assessed near the mouth of Crane Creek (M-WP-1 & M-WP-2) were determined to have overall high functional values (Table 6.42 & Figure 6.30). These areas, along with the mainstem corridor, are high priority for protection strategies such as acquisition, TDR and easements.

The northernmost hub in the subwatershed is at the junction of the three major subwatersheds, Beasley Creek, Upper Crane Creek and Lower Crane Creek (Figure 6.31). The hub is approximately 2,300 acres and is dominated by bottomland floodplain forest, along with evergreen forest, woodland and mesic deciduous forest. The hub is composed of a number of parcels so acquisition in this area could be challenging; however, conservation actions on the larger parcels would be very beneficial for the subwatershed as a whole.

Nearly 1/3 of the Lower Crane Creek subwatershed is dominated by the City, which is densely populated and built-out by existing development. Therefore, the GI Network is limited primarily to the mainstem of Crane Creek itself. Despite this limitation, important connections can be made to green spaces outside of the watershed. Approximately 1.2 miles upstream on the Broad River is Harbison State Forest, a recreational and ecological hub connected to Crane Creek through the Broad River itself. Harbison State Forest is managed primarily to serve as an educational and recreational greenspace for City as well as the State. The forest mix is roughly forty percent loblolly and shortleaf pine, forty percent natural longleaf pine, twenty percent bottomland flood plain hardwoods and hardwood drains.

On the east side of the Lower Crane Creek, a hub has been identified that is adjacent to Sesquicentennial State Park. This hub contains a large area of suitable habitat for the pine barren treefrog as well as patches of habitat suitable for the red-cockaded woodpecker. Likewise, longleaf pine forests are also known to occur at this park so protecting a connected network system to this hub will help to preserve biodiversity. Nearby to Sesquicentennial State Park is Fort Jackson where successful longleaf pine restoration efforts have already been undertaken. Exploring a green network between these two hubs outside of the watershed could be instrumental in preserving this declining ecosystem as well as declining bird species. Longleaf pine fields are important for a variety of early successional and grassland species that likely use the areas for nesting and foraging (USDA, 2005). Studies suggest that an early successional longleaf pine community that is managed properly creates valuable habitat for declining breeding bird species and could potentially assist in slowing or halting population declines. Planting or promoting native grasses and forbs, as well as controlling invasive species such as bermudagrass, can assist in restoring longleaf pine forests that maximizes early successional wildlife habitat.

Table 6.41. Forest Assessment Points in the Lower Crane Creek Subwatershed

Site ID	Average Densiometer	75th Percentile (dbh)	Dominant Tree Species	Understory Characterization	Forbes
J-FP-1	Did not assess using CFA		White Oak, Loblolly Pine, Poplar	Did not assess using CFA	

Table 6.42. Wetlands Assessed in the Lower Crane Creek Subwatershed

Site ID	Wildlife Habitat FCI	Water Quality FCI	Description
M-WP-1	0.87	0.77	Lower Crane Creek bottomland wetlands
M-WP-2	0.16	0.98	Slough wetlands associated with the Broad River near the outlet of Crane Creek

(a) (b)

Figure 6.30. (a) High functioning wetland near the mouth of Crane Creek (M-WP-1) and (b) bottomland hardwood forest in Lower Crane Creek (J-FP-1).

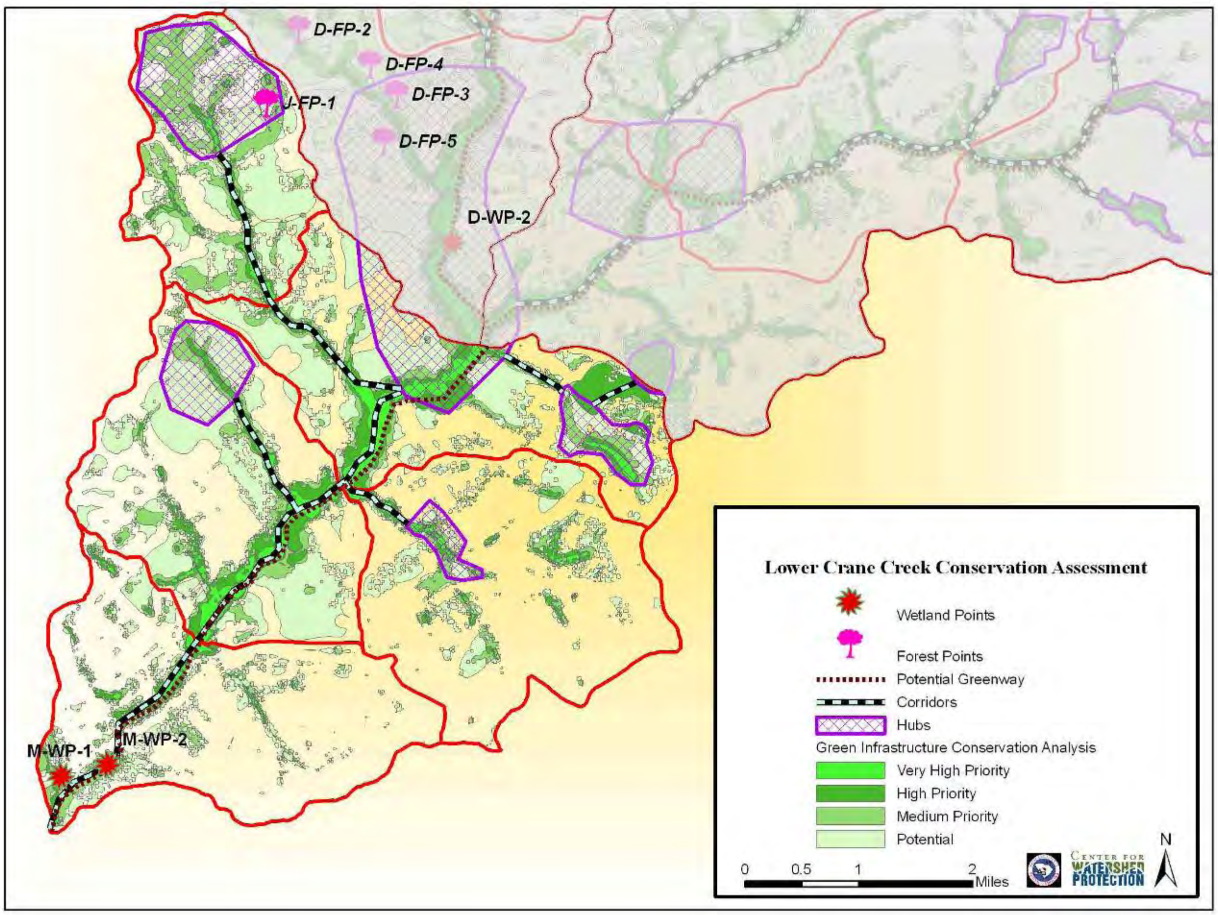


Figure 6.31. Lower Crane Creek conservation areas.

Restoration Opportunities in the Subwatershed

Several restoration opportunities in Lower Crane Creek were identified during the field assessments. Numerous high priority retrofit projects were identified, many of which offered opportunities for education, outreach, and community involvement. Several stream impacts and confirmed hotspot areas were also observed. Man-made ponds, particularly in subwatersheds I and J, should be managed to reduce the amount of nutrients and sediment that enter them and, subsequently, the stream corridor. Individual restoration projects and opportunities are discussed below by the smaller planning level subwatersheds (I-M) identified during the field work.

6.3.1. Subwatershed I

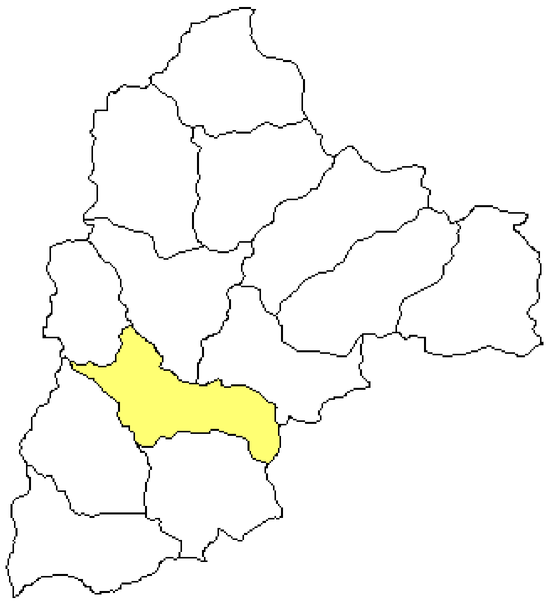


Table 6.43. Subwatershed I Characteristics		
Subwatershed		I, Lower Crane Creek
Drainage Area		3091 acres
Existing Impervious Cover		173 acres (5.6%)
Stream Miles		7.75 miles
2001 Land Use	Developed	11%
	Forested	48%
	Developed Open Space	17%
	Wetlands and Open water	12.7%
	Agriculture	4%
	Other	8%
Jurisdictions as Percent of Subwatershed I		81% Richland County 0% Town of Blythewood 19% City of Columbia

Subwatershed Description

Subwatershed I is located in the south-central part of the Crane Creek Watershed at the northern-most part of Lower Crane Creek. Nineteen percent of the subwatershed falls within the City with the remaining 81% contained within the County (Table 6.43). Land use is primarily forested (48%) and developed open space (17%). The developed land use is 11% and current impervious cover is 5.6%. Freshwater ponds, freshwater forested/shrub wetland, freshwater emergent wetland and lakes make up 12.7% of the subwatershed and soils are primarily silty loam and sandy clay loam (hydrologic soil groups B and C respectively).

A number of restoration opportunities are available in subwatershed I. Two high priority retrofit projects were identified at W.J. Keenan High School (I-RRI-17A and C), a site that also offers opportunities for student engagement. Potential exists to treat this entire site through downspout disconnection and construction of bioretention areas. Minor modification to an existing stormwater pond would greatly reduce the amount of sediment entering a nearby forested area. Four priority and confirmed hotspots were identified in the subwatershed. Practices that were recommended for these sites included adding secondary containment and storage of materials as well as retrofit of a catch basin and adding a water quality filter at a bus maintenance facility (I-RRI-16 and I-HSI-16). Three streams were assessed as fair in this subwatershed; projects identified include stream clean-up, buffer enhancement and upland retrofits.

Management and Restoration Practice Opportunities in the Subwatershed

In subwatershed I, two retrofit opportunities were identified at the W.J. Keenan High School (I-RRI-17A and C) (Table 6.44). Existing conditions at the site (I-RRI-17) are such that downspouts are directly connected to the stormdrain system (Figure 6.32). The stormdrain network then directs all stormwater to the southwest corner of the site into a rip-rapped basin before being discharged into a nearby forest. Potential opportunities at the site are to treat the entire site through downspout disconnection and construction of bioretention areas in turf areas. Minor modification to an existing stormwater pond would greatly reduce the amount of sediment entering a nearby forested area. Two sites at the Prison/Mental Health Center (I-RRI-14 and I-RRI-15) were identified for potential retrofits, however, these sites were not fully assessed.

Table 6.44. Stormwater Retrofit Opportunities in Subwatershed I

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
High	I-RRI-17A	W.J. Keenan High School	Downspout disconnection, bioretention areas	5.89	100	20,312	81%	$94,786
High	I-RRI-17C	W.J. Keenan High School	Pond modification	9.64	80	40,417	100%	$5,000
Medium	I-RRI-7	School of Inquiry/Community Center	Step pools and bioretention area	1.51	77	4,096	92%	$41,539
Medium	I-RRI-16	Richland Bus Maintenance	O/W Separators	6.36	90	19,907	100%	$200,000

(a) (b) (c)

Figure 6.32. (a) Downspouts at site I-RRI-17; (b) southwest corner of lot drains most site; and (c) rip-rapped stilling basin discharging stormwater into nearby forested area.

A total of five stream reaches were assessed in subwatershed I. One reach was assessed as excellent, one was assessed as poor and three were assessed as fair. Stream reaches scored generally lower scores in this subwatershed due to problems with sediment deposition, bank scour and downcutting. New development was in process surrounding one of the reaches (I-RCH-1). This same reach flowed through an identified hotspot (I-HSI-20) and was impacted by construction equipment at a stream crossing. Two high priority stream impacts were observed during the assessment (Table 6.45). An opportunity at the Oak Hills Golf Course (I-IB-11) was assessed. Passive restoration techniques can be utilized at this site by discontinuing current mowing practices in the buffer and allowing natural regeneration of native plants to occur. A dumping location was identified in I-RCH-2. This site (I-TR-1) was documented as having trash scattered throughout the reach; trash included car parts, clothes, appliances, garbage and more. It is recommended that local government lead a stream clean-up effort in this reach as it may be more material than volunteers could handle (Figure 6.33). Man-made ponds should be managed to reduce the amount of nutrients and sediment that enter them and, subsequently, the stream corridor. This can be accomplished by buffer establishment or enhancement, management of geese and reduction of fertilizers in adjacent neighborhoods.

Table 6.45. High Priority Stream Impacts in Subwatershed I

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
Medium	I-SC-1	I-RCH-1	Marob Ct	Stream Crossing	Temporary stream crossing	$
High	I-TR-1	I-RCH-2	Highland Forest Dr	Trash	Stream Cleanup	$
High	I-IB-11	I-RCH-11	Oak Hills Golf Course	Buffer	Riparian reforestation	$

$: Estimated Planning Level Cost < $2,000
$$: Estimated Planning Level Cost $2,000-$8,000
$$$: Estimated Planning Level Cost > $8,000

(a) (b) (c)

Figure 6.33. (a) Poor stream reach with no buffer and algae in the stream (I-RCH-11); (b) sediment deposition in fair stream reach (I-RCH-1); and (c) dumping location in Reach I-2 (I-TR-1) is a priority stream clean-up opportunity.

Several confirmed hotspots were identified in subwatershed I, three of these were privately owned businesses and one was a County bus maintenance facility (Table 6.46). Capitol City Towing (I-HSI-1) and North Columbia Auto Salvage (I-HSI-2) were both noted as hotspots due to the manner in which vehicles and parts were stored at the site. It is recommended for these sites that on-site inspection be conducted immediately. The Midlands Honda dealer (I-HSI-3) was assessed as a confirmed hotspot due to car washing activities that were observed occurring out in the open with soap suds draining directly into the storm drain system. Also, unlabeled metal drums were stored outside without secondary containment (Figure 6.34). On-site inspection is recommended for this site as well. The County bus maintenance shop (I-HSI-16) was assessed as a severe hotspot including pollution sources related to vehicle operations, storage of outdoor materials, waste management and poor housekeeping practices. Recommended actions at this site are follow-up site inspection, installation of floor drains in the maintenance areas, installation of an oil/water separator, and education with regards to good housekeeping practices.

Table 6.46. Hotspot Management Opportunities in Subwatershed I

Priority	Site ID	Location	Opportunity	Hotspot Status	Cost
High	I-HSI-1	Capitol City Towing	Secondary containment, Material storage	Confirmed	$$
High	I-HSI-2	North Columbia Auto Salvage	Secondary containment, Material storage	Confirmed	$$
High	I-HSI-3	Midlands Honda	Catch basin retrofit (washing area)	Confirmed	$$$
High	I-HSI-16	Richland County School Bus Maintenance	Retrofit (WQ filter), clean up	Confirmed	$$$
Medium	I-HSI-20	Hastings Pt	Material storage	Not	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					

(a) (b) (c) (d)

Figure 6.34. (a) Improperly stored metal drums at Capitol City Towing (I-HSI-1); (b) oil sheen in stormwater at North Columbia Auto Salvage (I-HSI-2); (c) improperly stored metal drums at Richland County bus maintenance facility (I-HSI-16); and (d) wash water from bus cleaning drains directly to the stormdrain network at the County bus maintenance facility (I-HSI-16).

Several neighborhoods were identified in subwatershed I with moderate pollution severity and low restoration potential (Table 6.47). Restoration opportunities at these sites include tree planting to increase forest canopy, storm drain markers or stenciling and landscaping with native materials. Two neighborhoods were also assessed for having improperly stored materials – batteries at Northgate (I-NSA-1) and sand piles at Hastings Point (I-NSA-3). Evidence of a past sewage overflow (Figure 6.35) was observed in one neighborhood (I-NSA-4) and likely contributed bacteria to waterways at the time of overflow. County staff was present when the observation was made and addressed the issue promptly.

Table 6.47. Neighborhood Source Control Opportunities in Subwatershed I

Priority	Site ID	Location	Pollution Severity	Restoration Potential	Opportunity	Cost
Medium	I-NSA-1	Northgate	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling, battery stored in front yard	$
Medium	I-NSA-2	Crane Crossing	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling	$
Medium	I-NSA-3	Hastings Point	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling, Uncovered sand piles	$

Table 6.47. Neighborhood Source Control Opportunities in Subwatershed I						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Low	I-NSA-4	Highland Forest	None	Low	Landscaping/tree planting, storm drain stenciling	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

Figure 6.35. Evidence of sewage overflow in the Highland Forest neighborhood.

Table 6.48 lists the ESC problems that were observed during field work. Two of these were in assessed neighborhoods (Hastings Point, I-NSA-3 and Highland Forest, I-NSA-4) and one was a new development site for the Whitaker Container Service on Wessinger Road (I-ESC-1) (Figure 6.36). The County should conduct regular inspections at these sites to ensure that ESC problems have been properly addressed, and that the sites have been stabilized to prevent further erosion. In addition, the grading permit for Whitaker Container Service (I-ESC-1) should be checked.

Table 6.48. Erosion and Sedimentation Control Sites in Subwatershed I			
Priority	**Site ID**	**Location**	**Description of Problem**
Medium	I-ESC-2	Hastings Point	Failing ESC, uncovered stock piles
Low	I-ESC-1	Wessinger Road	New site for Whitaker Container Service
Low	I-ESC-3	Highland Forest	Infill with no ESC

(a) (b)

Figure 6.36. (a) Poor ESC practices at Hastings Point development (I-ESC-2) and (b) new development without ESC at Whitaker Container Service (I-ESC-1).

6.3.2. Subwatershed J

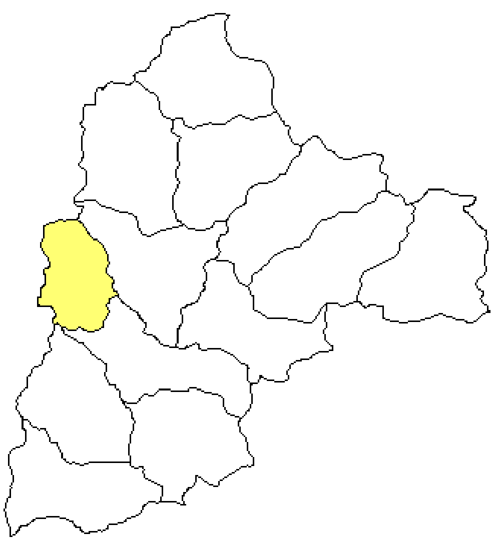


Table 6.49. Subwatershed J Characteristics		
Subwatershed		J, Lower Crane Creek
Drainage Area		2092 acres
Existing Impervious Cover		33 acres (1.6%)
Stream Miles		13.15 miles
2001 Land Use	Developed	3%
	Forested	69%
	Developed Open Space	9%
	Wetlands and Open water	3.3%
	Agriculture	10%
	Other	5%
Jurisdictions as Percent of Subwatershed J		100% Richland County 0% Town of Blythewood 0% City of Columbia

Subwatershed Description

Also part of the Lower Crane creek subsection, Subwatershed J is located in the western part of the Crane Creek Watershed. It falls entirely within the County's jurisdiction. Primarily forested (69%), development only accounts for 3% of the subwatershed and impervious cover is less than 2% (Table 6.49). Freshwater ponds, freshwater forested/shrub wetland, freshwater emergent wetland and a lake make up 3.3% of the subwatershed and soils are primarily sandy clay loam and silty loam (hydrologic soil groups C and B respectively).

Restoration opportunities in this subwatershed are primarily within the stream corridor itself. Two ESC sites were noted, as well as an opportunity for buffer restoration and a stream clean-up. No retrofit opportunities were assessed or ESC sites observed in this subwatershed.

Management and Restoration Practice Opportunities in the Subwatershed

Nine stream reaches were assessed in subwatershed J. Four of these were ranked as excellent, one was ranked as good and four were ranked as fair. The excellent reaches were generally located in headwater areas. The fair reaches exhibited historic impacts, perhaps from forest clearing – the streams were incised, with steep banks; however, the banks were stable as indicated by the moss growing on them. A dumping location was assessed in reach J-RCH-3 in the Heron Ridge neighborhood (Table 6.50). At this location, the stream flows through the back of the neighborhood. Household materials, including appliances and other trash are blocking flow and causing a head cut to form.

In this same neighborhood, impacted buffers were also documented due to mowing by homeowners up to the stream's edge (Figure 6.37). This neighborhood would benefit from a targeted education program related to buffers and their benefits and the effects of dumping in the stream corridor. Mobilizing neighbors through an organized stream clean-up would be very beneficial. Additionally, a gas pipeline in this subwatershed is creating multiple problems where it crosses the stream. Several erosion areas were noted related to the pipeline, with no vegetation in place to hold the stream banks in place. Since these impacted areas are contributing significant amounts of sediment to the stream, bank stabilization should be pursued at these locations. Man-made ponds should be managed to reduce the amount of nutrients and sediment that enter them and, subsequently, the stream corridor. Recommendations include buffer establishment or enhancement, management of geese and reduction of fertilizers in adjacent neighborhoods.

The Heron Ridge neighborhood (J-NSA-1), discussed above, could benefit from additional restoration opportunities (Table 6.51). Tree planting to increase forest cover, planting with native materials, and storm drain markers or stenciling along with a targeted educational campaign would help to improve water quality in the stream that flows through this neighborhood.

Table 6.50. High Priority Stream Impacts in Subwatershed J

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
High	J-TR-1	J-RCH-3	Heron Ridge Neighborhood	Trash	Stream Cleanup	$
Medium	J-IB-1		Heron Ridge Neighborhood	Buffer	Riparian reforestation	$
Medium	J-ER-11	J-RCH-11	Owens Rd. (gas pipeline)	Erosion	Bank stabilization	$
Medium	J-ER-12	J-RCH-12	Owens Rd. (gas pipeline)	Erosion	Bank stabilization	$

$: Estimated Planning Level Cost < $2,000
$$: Estimated Planning Level Cost $2,000-$8,000
$$$: Estimated Planning Level Cost > $8,000

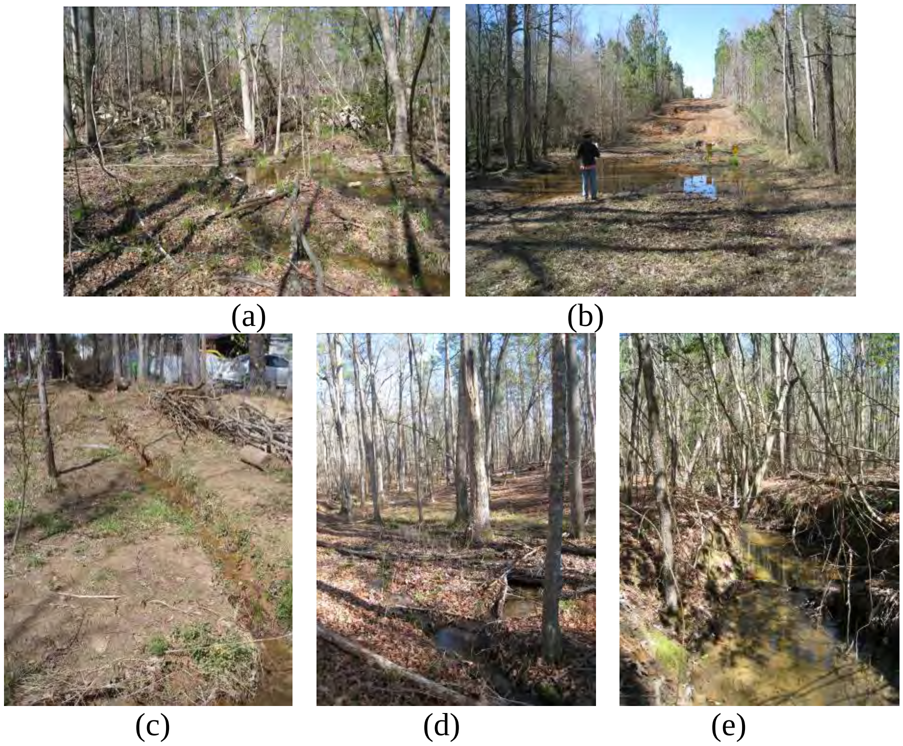


Figure 6.37. (a)Trash dumping in J-RCH-3 (J-TR-1); (b) erosion impacting J-RCH-12 from a gas pipeline crossing (J-ER-12); (c) impacted buffer in J-RCH-3 (J-IB-1); (d) excellent reach (J-RCH-11) and (e) fair reach (J-RCH-13) downstream from excellent reach shown in (d) – legacy impacts evident by steep banks and historic channel incision.

Table 6.51. Neighborhood Source Control Opportunities in Subwatershed J						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Low	J-NSA-1	Heron Ridge	None	Low	Landscaping/tree planting, storm drain markers/stenciling	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

6.3.3. Subwatershed K

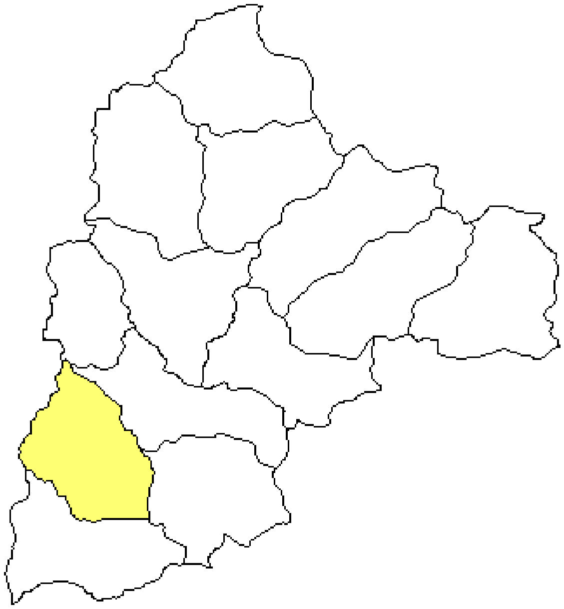


Table 6.52. Subwatershed K Characteristics		
Subwatershed		K, Lower Crane Creek
Drainage Area		3297 acres
Existing Impervious Cover		160 acres (4.8%)
Stream Miles		9.26 miles
2001 Land Use	Developed	9%
	Forested	50%
	Developed Open Space	21%
	Wetlands and Open water	9.6%
	Agriculture	2%
	Other	9%
Jurisdictions as Percent of Subwatershed K		96% Richland County 0% Town of Blythewood 4% City of Columbia

Subwatershed Description

Subwatershed K is located in the south-western part of the Crane Creek Watershed, within the Lower Crane Creek subwatershed. The subwatershed is mostly within the jurisdiction of the County, with 4% falling within the City. Interstate 20 runs along the southernmost border of the subwatershed. Primarily consisting of forest (50%) and developed open space (21%), developed land use is 9% and existing impervious cover is slightly less than 5% (Table 6.52). Freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up about 9.6% of the subwatershed and soils are primarily silty loam and sandy clay loam (hydrologic soil groups B and C respectively).

Numerous opportunities for restoration are available in subwatershed K. Two retrofit opportunities were identified with the potential to treat over half of the water quality volume from about 11.5 acres of impervious cover at the Forest Hills Elementary School (K-RRI-6) and the Sunbelt Industrial Site (K-RRI-4) through downspout disconnection and bioretention practices. Priority stream corridor projects in the subwatershed include stream clean-ups, riparian restoration and mitigating impacts from a utility crossing. Two confirmed hotspots were identified in the southern portion of the subwatershed. These are both privately maintained sites and field crews noted improper storage of materials at these locations. Pollution source control opportunities in neighborhoods include tree planting and native landscaping, storm drain markers or stenciling and, in one neighborhood, installation of rain gardens. There were no ESC sites observed in the subwatershed.

Management and Restoration Practice Opportunities in the Subwatershed

Three potential retrofit sites were assessed in subwatershed K. One of these, the SC DOT facility did not present any opportunities for stormwater retrofits. An excellent opportunity for a demonstration project was documented at the Forest Hills Elementary School (K-RRI-6)

(Table 6.53). Currently, rooftops at the school drain to an underground storage system, however, two locations were identified on-site for installation of bioretention practices for demonstration purposes (Figure 6.38). School administrative staff met with field crews during the site investigation and was excited about restoration opportunities. At the Sunbelt Industrial Site (K-RRI-4), four opportunities were identified to treat over half of the water quality volume at the site. Opportunities available at the site include downspout disconnection and directing flow to a bioretention facility, connecting an existing ditch to a bioretention, installation of a dry or wet swale with underground permeable pipe and creating a berm around an existing catch basin to attenuate flow.

Table 6.53. Stormwater Retrofit Opportunities in Subwatershed K

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
High	K-RRI-6	Forest Hills Elementary School	Downspout disconnection, bioretention areas	0.6	100	2,069	100%	$21,725
Low	K-RRI-4	Sunbelt Industrial Site	Downspout disconnection, bioretention areas, dry swales	10.91	100	37,623	54%	$222,486

Six stream reaches were assessed in subwatershed K. Four of these were assessed as good, one was assessed as fair and one was assessed as very poor. Numerous stream impacts were also documented, three of which were in K-RCH-1, a reach assessed as good (Table 6.54). Two stream clean-up opportunities were identified in this reach, one on Swan Lane and Blue Ridge Terrace (K-TR-1) where construction materials, clothes and tires were being dumped and one on Peachwood Dr. where trash was being dumped at a stream crossing (K-SC-2) (Figure 6.39). K-RCH-1 was also assessed as good, however, a significant amount of dumping was found at the pond at the top of this reach. The nearby neighborhood, K-NSA-2, was assessed as a high priority for restoration and should be targeted for educational efforts related to trash dumping in addition to other efforts pursued in this neighborhood. Utility corridors were also identified as impacting the stream in two different locations (K-SC-3 and K-IB-1), creating multiple problems including erosion, acting as a fish barrier, and affecting riparian buffer function.

(a) (b) (c)

Figure 6.38. (a) Opportunity for restoration at Forest Hills Elementary School (K-RRI-6) by disconnecting downspout and directing to a bioretention facility for treatment; (b) staining of pavement indicates stormwater tends to sit in this proposed location for a bioretention practice at Sunbelt Industrial Site (K-RRI-4); and (c) a dry swale at Sunbelt Industrial Site (K-RRI-4) could be enhanced for more effective treatment of stormwater before it enters the stormwater system.

Table 6.54. High Priority Stream Impacts in Subwatershed K

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
High	K-TR-1	K-RCH-1	Swan Ln and Blue Ridge Ter	Trash	Stream Cleanup	$
Medium	K-SC-2		Peachwood Dr	Trash	Stream Cleanup	$
Low	K-OT-1		Sandpiper Lane	Outfall	Outlet stilling pond	$
Medium	K-SC-3	K-RCH-11	Utility corridor off Crane Church road	Erosion, fish barrier	Remove fish barrier	$$$
Medium	K-IB-1	K-RCH-13	Utility corridor off Club House road	Buffer	Riparian reforestation	$
$: Estimated Planning Level Cost < $2,000 $$: Estimated Planning Level Cost $2,000-$8,000 $$$: Estimated Planning Level Cost > $8,000						

Two confirmed hotspots were identified in subwatershed K (Table 6.55). Plinkington Advanced Technologies (K-HSI-3) and 1 Sunbelt Ct (K-HSI-4) both exhibited improper storage of outdoor materials (Figure 6.40). Follow-up inspection should be conducted at these sites and education about storage of materials conducted. Practices to be employed at these sites include storing materials under cover, with secondary containment and in labeled containers. When these practices are not employed, then the chance of hazardous materials entering the storm drain network is increased. Two others sites were assessed but were not identified as hotspots (K-HSI-5 and K-HSI-6), however, these sites should be included in future education efforts.

(a)

(b)

(c)

(d)

Figure 6.39. (a) Stream erosion in K-RCH-13 due to impacts from a utility right-of-way; access road for utility maintenance runs directly adjacent to the stream impacting the riparian buffer (K-IB-1); (b) trash in K-RCH-1 (K-TR-1); (c) outfall with algae denoting heavy nutrient input into K-RCH-1; and (d) trash at a stream crossing in K-RCH-2 (K-SC-2).

Table 6.55. Hotspot Management Opportunities in Subwatershed K

Priority	Site ID	Location	Opportunity	Hotspot Status	Cost
High	K-HSI-3	Plinkington Advanced Technologies	Secondary containment, Material storage	Confirmed	$
High	K-HSI-4	1 Sunbelt Court	Material storage	Confirmed	$
Medium	K-HSI-5	Dougherty Equipment Rental	Material storage	Not	$
Medium	K-HSI-6	GTG	Secondary containment	Not	$

$: Estimated Planning Level Cost < $5,000
$$: Estimated Planning Level Cost $5,000-$10,000
$$$: Estimated Planning Level Cost > $10,000

(a) (b)

Figure 6.40. (a) Storage of 55 gallon drums at Plinkington Advanced Technologies (K-HSI-3) without cover or secondary containment and (b) leakage and spilling from paint containers at 1 Sunblet Ct. (K-HSI-4).

Neighborhood pollution source control opportunities in subwatershed K are limited to the minimal pollution severity and low restoration potential observed at the two neighborhoods that were assessed (Table 6.56). Storm drain markers and stenciling were identified as opportunities available in both neighborhoods. Tree planting should also be encouraged due to overall low forest canopy in the neighborhoods (Figure 6.41). Rain gardens were also identified as a restoration opportunity, particularly in the Lincolnshire neighborhood (K-NSA-2).

Table 6.56. Neighborhood Source Control Opportunities in Subwatershed K

Priority	Site ID	Location	Pollution Severity	Restoration Potential	Opportunity	Cost
High	K-NSA-2	Lincolnshire	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling, rain gardens	$
Low	K-NSA-1	Rockgate	None	Low	Landscaping/tree planting, storm drain markers/stenciling	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

Figure 6.41. Typical dwelling in the Lincolnshire neighborhood (K-NSA-2).

6.3.4. Subwatershed L

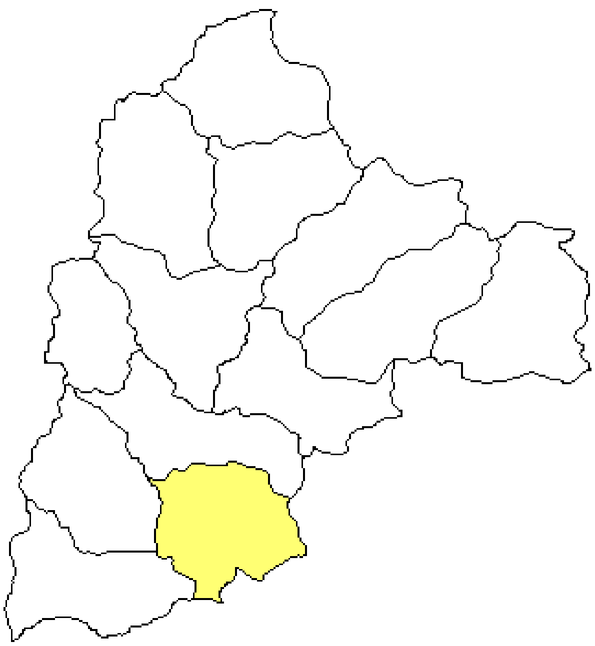


Table 6.57. Subwatershed L Characteristics		
Subwatershed		L, Lower Crane Creek
Drainage Area		3263 acres
Existing Impervious Cover		736 acres (22.6%)
Stream Miles		9.07 miles
2001 Land Use	Developed	50%
	Forested	28%
	Developed Open Space	16%
	Wetlands and Open water	2.4%
	Agriculture	2%
	Other	2%
Jurisdictions as Percent of Subwatershed L		58% Richland County 0% Town of Blythewood 42% City of Columbia

Subwatershed Description

Also located within the Lower Crane Creek subsection, subwatershed L is located in the south-eastern part of the Crane Creek Watershed. It is divided almost evenly between the jurisdictions of the County (58%) and the City (42%) (Table 6.57). As a result, 50% of the subwatershed is developed with the remaining half mostly forested (28%) and developed open space (16%). It is horizontally bisected by Interstate 20 and existing impervious cover is 22.6%, the highest in the entire watershed. Freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up less than 2.5% of the subwatershed and soils are primarily silty loam and sand (hydrologic soil groups B and A respectively).

Subwatershed L contains numerous high priority stormwater retrofit and stream impact projects. Several of the stormwater retrofit projects that were identified are on public land –

either at schools, parkland or at a County recreation facility. The majority of the stream impacts that were assessed were impacted buffer sites. Three hotspots assessments were conducted, however, none of the sites were determined to be hotspots. All of the neighborhood assessments indicated a moderate amount of pollution severity in this subwatershed. There were no ESC sites observed in this subwatershed.

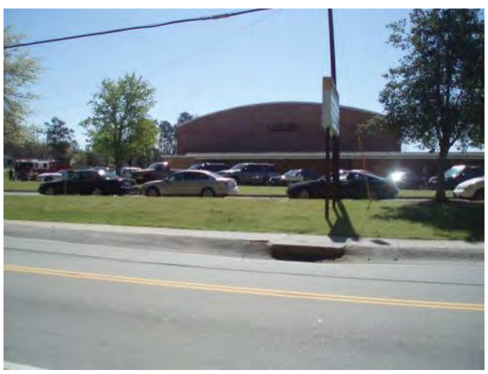
Management and Restoration Practice Opportunities in the Subwatershed

Nine retrofit assessments were conducted in subwatershed L. Five priority concepts that were developed have the potential to treat nearly 100% of the water quality volume from more than 7 impervious acres (Table 6.58). Several restoration opportunities were identified at W.G. Sanders Elementary School (L-RRI-9A and B)(Figure 6.42), a facility that was due to close in the summer of 2009, providing an opportunity to implement the proposed concepts. Numerous places for downspout disconnection and installation of bioretention practices were called out that could treat the entire site (L-RRI-9A). In addition, a 72" underground storm sewer pipe could be daylighted in an open field (L-RRI-9B). The pipe, which ran under the facility, may have been contaminated with sewage as reflected in the turbidity of the water at the outfall (Figure 6.42). Nearly 100% of the water quality volume at the Greenview Elementary School could also be treated (L-RRI-10). The proposed concept at this site was the construction of multiple rain gardens throughout the site. No underdrains or soil replacement would be needed as the site has good infiltration capacity with sandy soils. In addition, this site would also provide educational and student involvement opportunities. At the Northminster Presbyterian Church (L-RRI-100), current stormwater conveyance is sheetflow to grass, which then flows to Gavilan Ave. The proposed concept for this site would catch the existing sheetflow in a 9" deep bioretention facility placed in the grass to capture stormwater before it reaches the road. Three retrofit concepts were developed at Greenview Park (L-RRI-11). Curb cuts would be used to direct water into bioretention areas. Two catch basins would be bypassed and a catch basin within the facility would be raised and used for overflow. For two retrofit sites, no concepts were developed (L-RRI-13 & L-RRI-18).

Table 6.58. Stormwater Retrofit Opportunities in Subwatershed L

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
High	L-RRI-9A	W.G. Sanders Elementary School	Downspout disconnection, bioretention areas	4.36	85	12,899	100%	$12,899
High	L-RRI-9B	W.G. Sanders Elementary School	Pipe daylighting	Unknown	Unknown	Unknown	N/A	$100,000

Table 6.58. Upland Retrofit Opportunities in Subwatershed L								
Priority	**Site ID**	**Location**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/ WQv**	**Cost**
High	L-RRI-10	Greenview Elementary School	Downspout disconnection, bioretention areas	1.41	100	4,862	100%	$50,957
High	L-RRI-12	Meadowlakes Recreation Center	Bioretention area and swales	0.5	100	1,724	100%	$20,602
High	L-RRI-100	Northminster Presbyterian Church	Bioretention area	0.79	100	2,724	100%	$28,602
Medium	L-RRI-11	Greenview Park	Bioretention area and swales	1.54	100	5,311	80%	$44,499
Low	L-RRI-8	Pepsi Plant	Downspout disconnection	1.33	100	4,587	100%	$4,587



(a)

(b)

(c)

(d)

Figure 6.42. (a) W.G. Sanders Elementary School (L-RRI-9) was due to close in summer, 2009; which may present opportunities for stormwater retrofits at this location; (b) turbid water at the stormwater outfall from the W.G. Sanders Elementary School (L-RRI-9) may indicate sewage contamination; (c) potential location of bioretention facility at Greenview Park (L-RRI-10); and (d) 80% of the water quality volume produced from 1.5 acres of impervious cover at Greenview Park (L-RRI-10) could be treated with three stormwater retrofit concepts that were developed for the site.

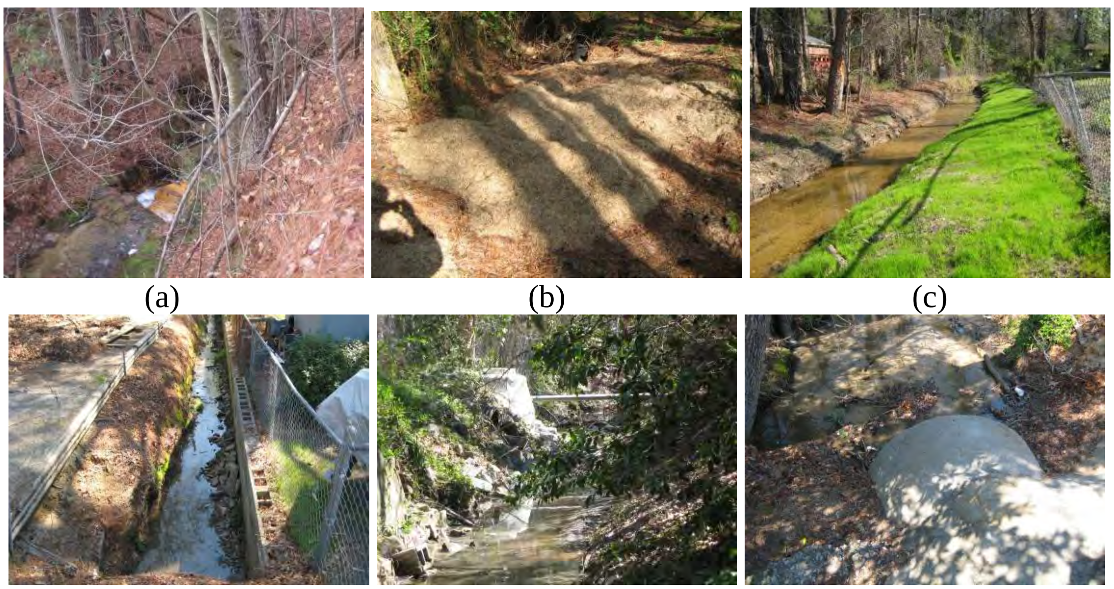
Nine stream reaches were assessed in subwatershed L. Three of these were determined to be in fair condition and six were determined to be in poor condition. Due to the generally low quality of streams in this subwatershed, a targeted education and outreach program to nearby neighborhoods, all of which were assessed as medium priority, is warranted. Six high priority stream corridor projects were identified through the stream assessment; four of these were to remedy impacted buffers and two were to remedy impacts from trash (Table 6.59). In residential settings, where mowing to the stream edge is common practice (Figure 6.43), education can be employed to encourage homeowners to discontinue this practice and allow for natural regeneration of the stream buffer. In another instance (L-IB-3), riparian reforestation as an active restoration process was identified during the stream assessment. In addition, lawn fertilization adjacent to the stream should be discontinued as this practice contributes excessive nutrient loading into the stream.

Table 6.59. High Priority Stream Impacts in Subwatershed L

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
High	L-IB-2	L-RCH-2	Torwood Dr	Buffer	Natural regeneration	$
High	L-IB-1	L-RCH-3	Torwood Dr	Buffer	Natural regeneration	$
High	L-TR-1		Torwood Dr	Trash	Stream Cleanup	$
High	L-TR-2	L-RCH-4	Torwood Dr	Illegal Dumping	Stream Cleanup	$
High	L-IB-3	L-RCH-5	Meadowlake Dr	Buffer	Riparian reforestation	$
High	L-IB-4	L-RCH-8	Sinclair Dr	Buffer	Invasive plant removal	$
Medium	L-SC-1	L-RCH-5	Near Leaf Cir	Stream Crossing	Culvert repair	$$$
$: Estimated Planning Level Cost < $2,000 $$: Estimated Planning Level Cost $2,000-$8,000 $$$: Estimated Planning Level Cost > $8,000						

Three hotspots were assessed in subwatershed L (Table 6.60). All three were determined to not be a hotspot, however, each site should be included in future education efforts. Poor dumpster management was identified as a problem at the Piggly Wiggly (L-HSI-10) (Figure 6.44). Likewise, at the Dollar General Shopping Center (L-HSI-11), material was being stored outside without a cover. Because impervious cover is directly connected to the storm drain system at this location, proper storage of materials can help to avoid accidental inputs of pollutants into the stream system.

Table 6.60. Hotspot Management Opportunities in Subwatershed L					
Priority	**Site ID**	**Location**	**Opportunity**	**Hotspot Status**	**Cost**
Medium	L-HSI-10	Piggly Wiggly	Trash clean up	Not	$
Medium	L-HSI-11	Dollar Store Shopping Center	Tarp coverage	Not	$
Low	L-HSI-20	B&B Enterprises	Secondary containment, material storage	Not	$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					



(a) (b) (c) (d) (e) (f)

Figure 6.43. (a) Headcut in L-RCH-2; (b) illegal dumping (L-TR-2) of yard waste in stream corridor; (c) impacted buffer (L-IB-3) and over-fertilized lawn contribute excess nutrients to the stream; (d) constrained stream without buffer (L-IB-4) in a residential neighborhood; (e) sewer line crossing stream corridor in L-RCH-8, a poor reach; and (f) sediment accretion at culvert outlet in L-RCH-8.

Neighborhoods assessed in subwatershed L would benefit from a broad educational campaign to encourage residents to plant trees and landscape lawns with native materials (Table 6.61). Neighborhoods had generally low tree canopy coverage and some had accumulations of trash (Figure 6.45). In addition, none of the neighborhoods that were assessed had storm drains marked or stenciled, a practice which can help to raise awareness of stormwater in neighborhoods. A potential retrofit opportunity was identified in the Westmore/Gavilan neighborhood (L-NSA-20). Road-side ditches could be retrofitted to biowswales to provide treatment of stormwater before it enters the storm drain network.

(a) (b)

Figure 6.44. (a) Trash collecting outside of a dumpster at the Piggly Wiggly (L-HSI-10) and (b) material stored without cover or tarp at the Dollar General Shopping Center (L-HSI-11).

Table 6.61. Neighborhood Source Control Opportunities in Subwatershed L						
Priority	**Site ID**	**Location**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost**
Medium	L-NSA-1	Hollywood Hills	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling	$
Medium	L-NSA-2	Hollywood Hills	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling	$
Medium	L-NSA-3	Meadowlake Hills	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling	$
Medium	L-NSA-20	Westmore/Gavilan	Moderate	Low	Bioswale in road ditches	$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

(a) (b)

Figure 6.45. Trash accumulation at abandoned house in Hollywood Hills (L-NSA-1 & L-NSA-2) and (b) potential location of retrofit opportunity in the Westmore /Gavilan neighborhood where road ditches could be converted to bioswales (L-NSA-20).

6.3.5. Subwatershed M

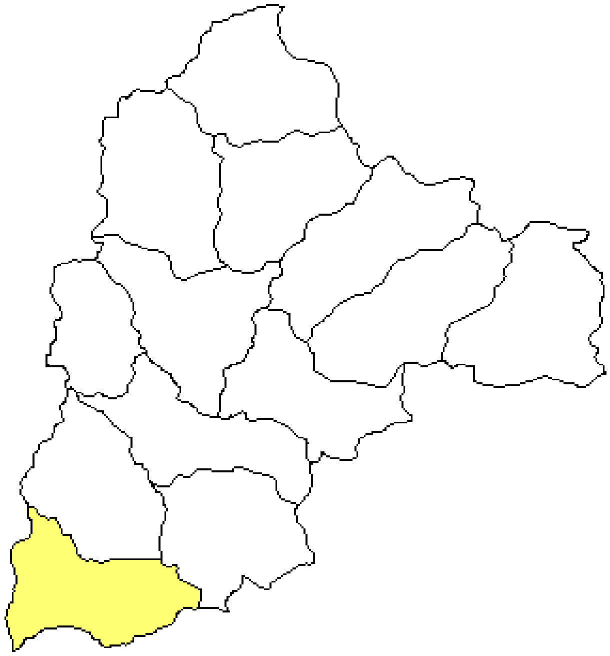


Table 6.62. Subwatershed M Characteristics		
Subwatershed		M, Lower Crane Creek
Drainage Area		3265 acres
Existing Impervious Cover		584 acres (17.9%)
Stream Miles		8.67 miles
2001 Land Use	Developed	36%
	Forested	26%
	Developed Open Space	27%
	Wetlands and Open water	3.2%
	Agriculture	3%
	Other	5%
Jurisdictions as Percent of Subwatershed M		62% Richland County 0% Town of Blythewood 38% City of Columbia

Subwatershed Description

Subwatershed M is located within the Lower Crane Creek subsection and it makes up the southernmost and most downstream portion of the Crane Creek Watershed. It is primarily within the County's jurisdiction (62%) however a significant portion of the subwatershed falls within the City (38%) and Interstate 20 runs through it. Land use is primarily developed (36%), followed by developed open space (27%) and forested (26%). The existing impervious cover in the subwatershed is almost 18% (Table 6.62). Freshwater ponds, freshwater forested/shrub wetland and freshwater emergent wetland make up 3.2% of the subwatershed and soils are primarily silty and loam and sandy clay loam (hydrologic soil groups B and C respectively).

Numerous restoration opportunities were identified in subwatershed M. Three retrofit projects, all in institutional settings, were called out during the field assessment. These projects would provide ample opportunity for student involvement and serve as ideal demonstration locations for watershed restoration. Stream assessments revealed a range of conditions from excellent to poor quality streams. Several restoration opportunities were identified - trash and impacted buffers were the most frequently identified impact. A sewage leak was discovered off Carola Rd. during one stream assessment – the City was notified immediately and promptly responded. Four confirmed hotspots were identified during the assessment. The most common problem identified was lack of secondary containment in the storage of outdoor materials. There were no ESC sites observed in this subwatershed.

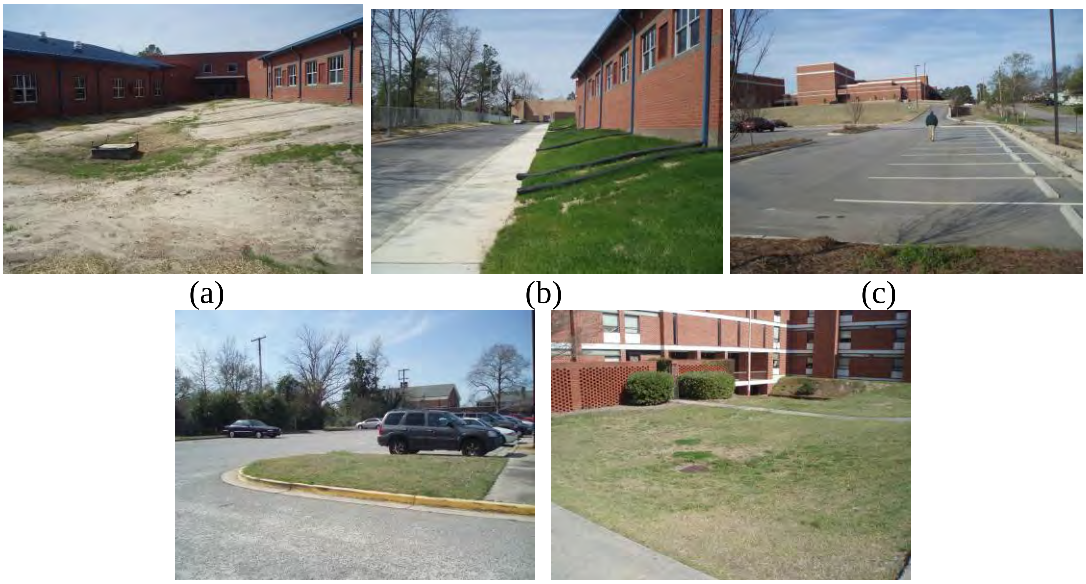
Management and Restoration Practice Opportunities in the Subwatershed

Three retrofit opportunities were identified at high school and college property in subwatershed M (Table 6.63). All three projects offer opportunities for student involvement and engagement in watershed restoration activities. At the Eau Claire High School (M-RRI-1), field surveyors noted that several areas on the south side of the property were eroding and should be stabilized with hay, straw and grass seed. The existing soil at this site is very sandy and so any plantings that are implemented from the proposed concept should be planted with drought-tolerant species. Portions of the Columbia College campus (M-RRI-2) drained outside of the watershed and were not assessed. Opportunities were identified at the site including a parking lot which was noted as being overly wide. Asphalt could therefore be removed from some of the lot without impacting parking and could be constructed into a bioretention facility. At Alcorn Middle School (M-RRI-3), it was noted that an underground stormwater detention system was in the process of being installed to provide stormwater treatment. Since this new system is being installed, the site was listed as low priority. Although the system will provide water quality treatment though infiltration, the site was still ranked as low priority due to the outreach and education potentials through a demonstration project at the site. Proposed projects include disconnecting existing downspouts and directing half of the rooftop area to a bioretention facility in the middle of the school facility (Figure 6.46). The remaining rooftop area currently drains directly to the sidewalk. The retrofit concept proposes directing each of the downspouts into a 3’ wide, 2’ deep channel that would be surrounded with #57 stone.

Table 6.63. Stormwater Retrofit Opportunities in Subwatershed M

Priority	Site ID	Location	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/ WQv	Cost
Medium	M-RRI-1	Eau Claire High School	Bioretention and slope stabilization	0.82	100	2,828	27%	$8,159
Medium	M-RRI-2	Columbia College	Bioretention areas	2.15	100	7,414	69%	$53,834
Low	M-RRI-3	Alcorn Middle School	Bioretention areas and dry well	0.24	100	828	100%	$20,511

A total of ten stream reaches were assessed in subwatershed M and were classified as excellent (2 reaches), good (3 reaches), fair (1 reach), poor (3 reaches) and very poor (1 reach). An illicit discharge that was detected during field work was reported and the City responded within 3 hours. Continued reconnaissance for other potential problems is warranted given the number of sewer line crossings that were encountered in this subwatershed (Figure 6.47). The responsible sewer authority should ensure that all areas with exposed pipes are mapped and collected in a database for frequent monitoring. Impacts from residential development were commonly noted on many of the assessed reaches (Table 6.64) and as such, a broad educational campaign to homeowners is recommended. Neighbors should be encouraged to engage in stream clean-ups in their neighborhoods where trash dumping is common such as along Pinner Road (M-TR-2 and M-TR-1). In some instances, stream clean-ups may be paired with buffer restoration along with an educational effort.



(a) (b) (c)

(d) (e)

Figure 6.46. (a) An opportunity for implementing a bioretention demonstration project was identified at the Alcorn Middle School (M-RRI-3); (b) at the same site, downspouts could be individually retrofitted rather than directing rooftop runoff to the sidewalk and then storm drain network; (c) large parking lot to be retrofitted at the Eau Claire High School (M-RRI-1); (d) asphalt could be removed from this over-sized parking lot at Columbia College (M-RRI-2) and retrofitted for stormwater treatment; and (e) many opportunities for treating rooftop runoff were identified at site M-RRI-2.

Table 6.64. High Priority Stream Impacts in Subwatershed M

Priority	Site ID	Stream Reach	Location	Impact	Opportunity	Cost
Medium	M-UT-1	M-RCH-1	Carola Rd	Illicit Discharge	Discharge inspection	$
High	M-IB-1	M-RCH-2	Pinner Rd	Buffer	Invasive plant removal; riparian reforestation	$
High	M-TR-2		Pinner Rd	Trash	Stream Cleanup	$
High	M-IB-2	M-RCH-20	Brickyard Rd	Buffer	Invasive plant removal	$
High	M-TR-1	No reach	Hodges Dr	Trash	Stream Cleanup	$
Low	M-SC-1	No reach	Denny Rd	Stream Crossing	Culvert removal	$$$

$: Estimated Planning Level Cost < $2,000
$$: Estimated Planning Level Cost $2,000-$8,000
$$$: Estimated Planning Level Cost > $8,000

(a) (b) (c)

(d) (e) (f)

Figure 6.47. (a) Multiple sewer line crossings were found in M-RCH-1; (b) turbid water and toilet paper indicated a sewage leak (M-UT-1), which was called in to authorities during the field assessment; (c) trash and an impacted buffer (M-IB-1 & M-TR-2) were found in a stream off Pinner Road; (d) very poor stream reach (M-RCH-20); (e) sewer stack in M-RCH-6; and (f) fair reach (M-RCH-3).

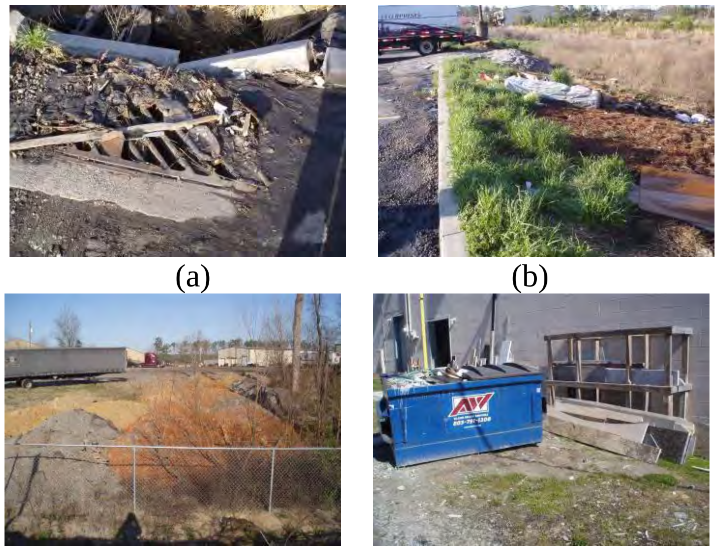
Four confirmed hotspots were identified in subwatershed M (Table 6.65). At the Flying J Gas Station (M-HSI-1), problems including trash dumped into the stream, storm drain inlets collapsed in with trash (Figure 6.48), and piles of sediment without cover and storm drains generally accumulated with sediment, organic material and litter. Authorities should follow-up with this site for immediate enforcement and schedule a review of the owner's storm water pollution prevention plan. Dumpsters overflowing with garbage and with broken lids were found at Solito Marble & Tile (M-HSI-3). This observed pollution source is cheap and easy to fix and therefore a priority. Storage of material was identified as a problem at Truck Supply of SC (M-HSI-2). Piles of sediment and gravel were stored without cover and 55 gallon drums were stored without cover or secondary containment. This site is recommended for immediate enforcement and a follow-up site inspection. Similar to the Flying J, a review of the owner's storrmwater pollution prevention plan is necessary and would also help to educate the owner about good housekeeping practices.

Table 6.65. Hotspot Management Opportunities in Subwatershed M

Priority	Site ID	Location	Opportunity	Hotspot Status	Cost
High	M-HSI-1	Flying J Gas Station	Trash clean up, secondary containment, stabilization (pond repair)	Confirmed	$
High	M-HSI-2	Truck Supply of SC	Secondary containment, tarp coverage	Confirmed	$
High	M-HSI-3	Solito Marble & Tile Monticello Industrial Park	Add dumpster lid	Confirmed	$

Table 6.65. Hotspot Management Opportunities in Subwatershed M

Priority	Site ID	Location	Opportunity	Hotspot Status	Cost
High	M-HSI-4	Junk Yard on Peebles	Secondary containment, Material storage	Confirmed	$$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$10,000 $$$: Estimated Planning Level Cost > $10,000					



(a) (b) (c) (d)

Figure 6.48. (a) Collapsed storm drain inlet at the Flying J Gas Station (M-HSI-1); (b) improperly stored trash and sediment at site (M-HSI-1); (c) piles of sediment should be covered at Truck Supply of SC (M-HSI-2); and (d) a new dumpster lid is an easy fix for an observed pollution source at Solito Marble & Tile (M-HSI-3).

Only one neighborhood was assessed in subwatershed M (Table 6.66). Pollution severity in the neighborhood was moderate due to exposed soil. Planting these areas with native landscaping or trees would reduce the impact of the erosion to stream quality.

Table 6.66. Neighborhood Source Control Opportunities in Subwatershed M

Priority	Site ID	Location	Pollution Severity	Restoration Potential	Opportunity	Cost
Medium	M-NSA-10	Dorchester St.	Moderate	Low	Plant bare patches in lawn	$
$: Estimated Planning Level Cost < $5,000 $$: Estimated Planning Level Cost $5,000-$20,000 $$$: Estimated Planning Level Cost >$20,000						

SECTION 7. ESTIMATE OF POLLUTANT LOADS AND REDUCTION STRATEGIES

This section reports watershed pollutant load estimates that were derived using the Watershed Treatment Model (WTM) (Caraco, 2002). Estimates were developed for existing watershed conditions and two future build-out watershed scenarios using the WTM. The first build-out estimates growth assuming no implementation of the watershed strategies, whereas the second build-out assumes implementation of the 12 watershed strategies and supporting actions. The effect of watershed strategies and actions themselves are also quantified. A description of the assessment methods and the results of the WTM modeling are provided below. WTM model inputs and model assumptions are described in Attachment D. Assumptions for the build-out analysis are presented in Attachment C.

7.1 Watershed Treatment Model

The WTM was used to estimate the nutrient, total suspended solid, and bacteria loads for the Crane Creek watershed, for the existing watershed conditions and two estimated future build-out conditions: one that assumes no restoration and protection measures in the watershed (build-out: status-quo) and another that assumes the implementation of the 12 watershed strategies (build-out: with strategies). Five different models were created, tailored to the unique characteristics of each of the 5 watershed target areas: Upper Crane Creek – Richland County, Lower Crane Creek – Richland County, Lower Crane Creek – Columbia, Beasley Creek – Richland County, and Beasley Creek – Blythewood.

The WTM, version 3.1 (Caraco, 2002), is a simple spreadsheet model used to:

- Estimate pollutant loading under current watershed conditions
- Determine the effects of current management practices
- Estimate load reductions associated with implementation of structural and non-structural management practices
- Evaluate the effects of future development

The model has two basic components: Pollutant Sources and Treatment Options. The *Pollutant Sources* component of the WTM estimated the load from primary land uses (i.e. residential, commercial, forest land) and secondary sources (i.e. active construction, managed turf, channel erosion, illicit connections) in a watershed without treatment measures in place. The *Treatment Options* (or "Management Practices") component of the model estimates the potential reduction in the uncontrolled load if various treatment measures are used (both structural and nonstructural).

Several caveats should be considered while reviewing the results of the model:

- The WTM is a planning level model primarily for urban/suburban applications. There are many simplifying assumptions made by the WTM and the model results are not calibrated. Therefore, the results of the model simulations should be compared on a relative basis rather than used as absolute values.

- The WTM does not account for all watershed pollutant sources. For example, the WTM does not measure the effect of wildlife on watershed pollutants, which was identified as a main contributor to watershed fecal coliform loads (SCDHEC, 2005).
- The application of existing treatment practices in the Crane Creek watershed is based on limited GIS data, data provided from the three municipalities within the Crane Creek watershed, conversations with their staff, best professional judgment, and default values associated with the WTM.
- A series of modeling assumptions were made on loading rates and existing and current practice application that may or may not be valid throughout the Crane Creek watershed.
- Bacteria, which is of special interest in the Crane Creek Watershed, is a highly variable pollutant, dominated by unpredictable sources such as illicit discharges and failing septic systems. Since no detailed sourcing study has been completed in the watershed, the WTM uses conservative estimates of the potential load from these sources, and may overstate the importance of some particular sources. The model results should be viewed as a "first cut" approach that can later be modified with more detailed information from field surveys, particularly from illicit discharges and septic systems.

7.2 Existing Conditions and Load Reductions from Future Practices

The WTM results estimate current watershed TN, TP, TSS, and FC loads as 5.2 lb/ac/yr, 0.6 lb/ac/yr, 305 lb/ac/yr, and 110 billion units/ac/yr, respectively. The results of the WTM model match closely to a 2007 evaluation of Crane Creek in which a HSPF model was used to simulate the water quality in the creek from 1998 to 2004 (Wagner, 2007). According to the 2007 report, average annual loadings over that time period estimated TN, TP, TSS, and bacteria loads as 4.9 lb/ac/yr, 0.63 lb/ac/yr, 109 lb/ac/yr, and 170 billion units/ac/yr, respectively. The higher TSS loads generated in the WTM model are primarily a result of two assumed factors: sediment loads from active construction due to poor ESC practices and enforcement, and stream channel erosion due to minimal stormwater management and lack of stream buffer enforcement.

Assuming implementation of 12 watershed strategies and supporting short-term, mid-term, and long-term actions, Table 7.1 below presents load reductions that would be realized in the Crane Creek watershed. Expected load reductions for TN, TP, TSS, and FC loads are 0.44 lb/ac/yr, 0.03 lb/ac/yr, 21.54 lb/ac/yr, and 17.48 billion units/ac/yr, respectively. These numbers equate to a reduction of 19,124 lb TN, 1,489 lb TP, 655.347 lb TSS, and 754,875 billion units of bacteria per year.

Table 7.1. Annual Load Reductions from Recommended Practices				
Management Practice	**TN (lbs/ac/year)**	**TP (lbs/ac/year)**	**TSS (lbs/ac/year)**	**Bacteria (billion/ac/year)**
Lawn Care Education	0.236	0.005	0.000	0.000
Pet Waste Education	0.029	0.004	0.000	0.253
Erosion and Sediment Control	0.009	0.011	10.921	0.000
Impervious Cover Disconnection	0.009	0.001	0.248	0.393
Structural Stormwater Management Practices (including retrofits)	0.005	0.001	0.487	0.738
Riparian Buffers	0.125	0.006	9.462	0.000
Septic System Education	0.004	0.000	0.013	0.029
Illicit Connection Removal	0.022	0.006	0.158	12.909
SSO Repair/ Abatement	0.004	0.001	0.028	3.160
Channel Protection	0.000	0.000	0.218	0.000
Total Reduction per Watershed Acre	**0.44**	**0.03**	**21.54**	**17.48**
	TN (lbs/year)	**TP (lbs/year)**	**TSS (lbs/year)**	**Bacteria (billion/year)**
Total Reduction in the Entire Watershed	**19,124**	**1,489**	**655,347**	**754,875**

This table shows that Lawn Care Education and Riparian Buffers would provide the largest reductions of nitrogen in the Crane Creek watershed, providing 0.24 and 0.13 lbs/ac/year reductions, respectively. For phosphorus, Erosion and Sediment Control would provide about a third of the reductions (.011 lbs/ac/year), while Riparian Buffers and Illicit Connection Removal combined would provide another third of the reductions (both remove 0.006 lbs/ac/year). Erosion and Sediment Control and Riparian Buffers are shown as the top practices for reducing TSS in the Crane Creek watershed (10.9 and 9.5 lbs/ac/year, respectively). Based on the model assumptions (of relatively high illicit connection rates), Illicit Connection Removal would by far have the highest effect in reducing bacteria levels in the watershed, with a removal of 12.9 billion/ac/year. Sanitary Sewer Overflow Repair/Abatement would also provide a significant level of bacteria reduction (3.2 billion/ac/year) in the Crane Creek watershed.

Table 7.2 compares the existing conditions with the predicted load reductions. Implementation of the watershed strategies and actions is predicted to result in TN, TP, TSS, and bacteria loads of 8.5%, 5.6%, 7.1%, and 15.9%, respectively.

Table 7.2. WTM Load Estimates for the Crane Creek Watershed				
Modeled Conditions	**TN (lb/acre/year)**	**TP (lb/acre/year)**	**TSS (lb/acre/year)**	**Bacteria (billion/acre/yr)**
Existing	5.2	0.6	304.5	110.2
Future Reductions	0.44	0.03	21.54	17.48
% Reduction	**8.5%**	**5.6%**	**7.1%**	**15.9%**

7.3 Build-out Assessment

In order to meet the State recreational surface water standards and attain the targeted fecal coliform reductions for the TMDL, fecal coliform loads in Crane Creek must be reduced by 48% upstream of Lake Elizabeth and by 92% downstream of Lake Elizabeth. It is important to note that these numbers are based on existing water quality monitoring data. As the Crane Creek watershed continues to develop, water quality is predicted to degrade.

A build-out assessment is a GIS analysis that estimates future land cover in a watershed. The results are useful for predicting future health of streams and developing watershed protection recommendations.

The Crane Creek build-out: status-quo assessment made the following assumptions:

- Full build-out of the watershed will occur based on allowable zoning (e.g., no rezoning)
- Current land cover on developed land will remain the same in future build-out scenario
- Protected land will remain the same in future build-out scenario
- Buildable land will be converted to impervious cover, as dictated by land use coefficients

The Crane Creek build-out: with strategies assessment, a protected land GIS shapefile was created for the Crane Creek watershed that included the following data:

- Stream buffers – 100 ft on both sides of the stream channel
- Wetlands – obtained from the NWI and added a 50 ft buffer around each wetland
- Water bodies – obtained from Richland County and added a 50 ft buffer around each water body
- Parks – obtained from Richland County
- The primary conservation network derived from the green infrastructure analysis. The green infrastructure assessment described in Section 3.6 of this report.

The protected land layer was then subtracted from the developable land layer used in the build-out: status-quo assessment.

Detailed methodology for conducting the build-out assessment is presented in the *Crane Creek Watershed Characterization Report* (CWP, 2009a) and can also be found in Attachment C of this report. The basic steps of the build-out assessment include:

1. Identify developed and undeveloped land
2. Identify and subtract protected land from undeveloped land to determine "buildable land"
3. Calculate the area of each zoning category for the potentially buildable land
4. Multiply the potentially buildable land in each zoning category by the corresponding impervious cover coefficients
5. Align the zoning categories to the land cover categories in the NLCD to determine the future land cover in the watershed

When compared to the existing watershed land cover in Figure 7.1, both of the build-out conditions project a rapid decline in the amount of forest cover, and a substantial increase in the amount of developed land and developed open space (i.e. lawns, turf cover) (Figures 7.2 and 7.3). Also, a substantial increase in watershed impervious cover is predicted (Table 7.5). It is important to note that the build-out analysis does not account for any future land rezoning, a practice that is common with rural lands in the County, according to County officials. Therefore, the future land cover estimate is conservative, as rezoning would likely increase the future impervious cover and amount of developed land.

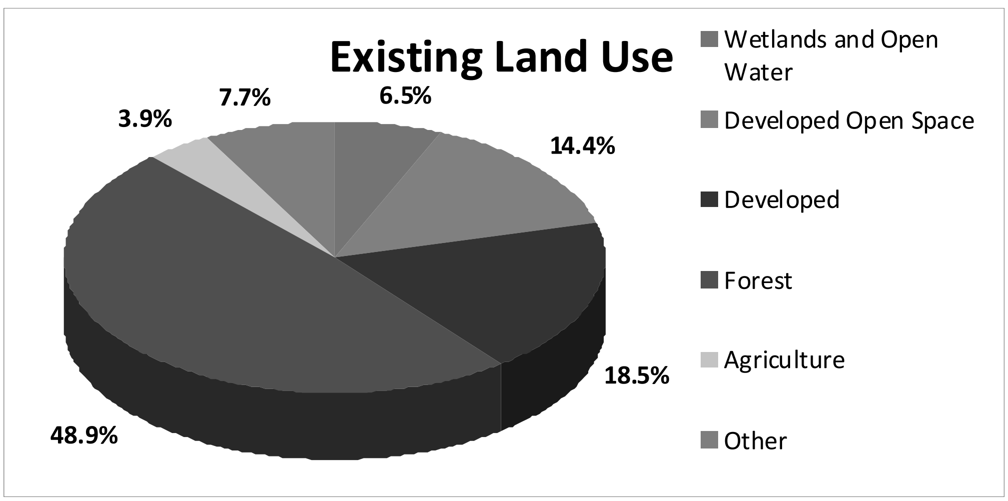


Figure 7.1. Existing land use coverage in the Crane Creek watershed.

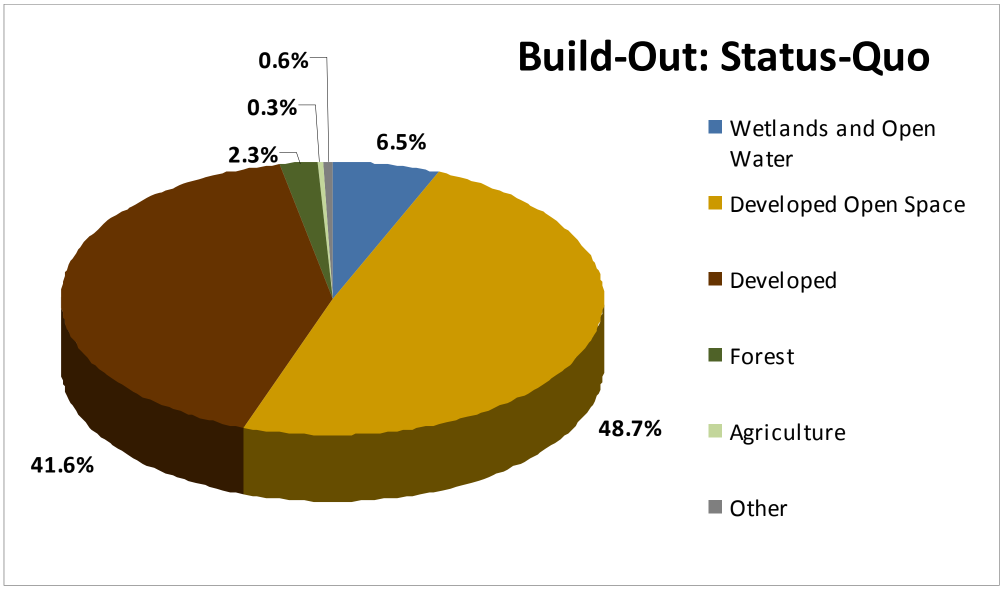


Figure 7.2. Projected build-out land use coverage in the Crane Creek watershed for future conditions: status-quo.

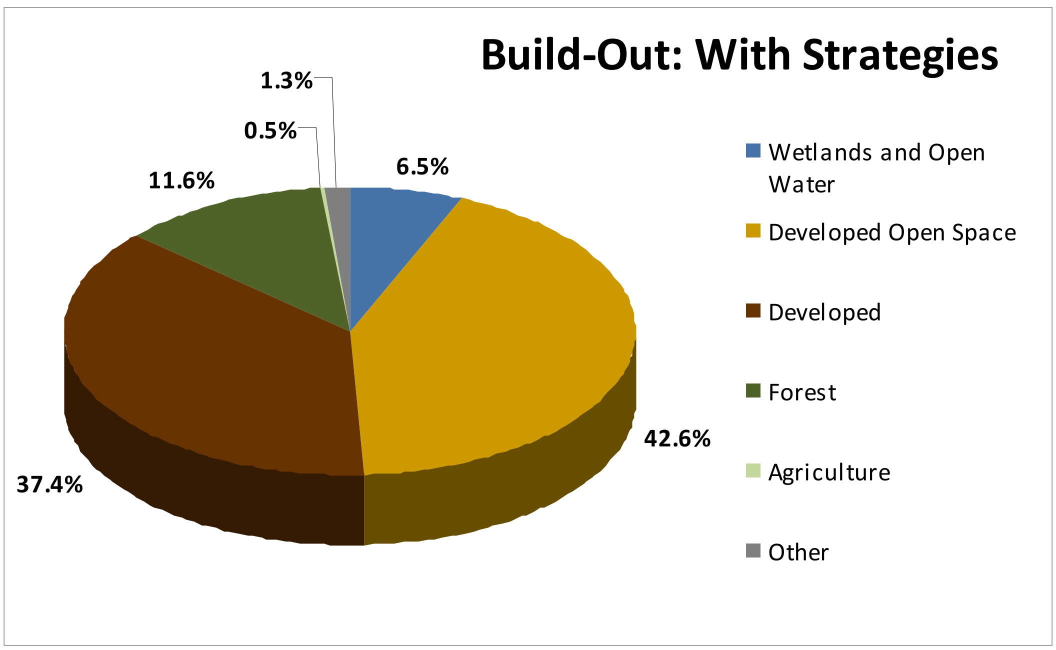


Figure 7.3. Projected build-out land use coverage in the Crane Creek watershed for future conditions: with watershed strategies.

Table 7.3. Impervious Cover Build-out Assessment in the Crane Creek Watershed				
Subwatershed	**Jurisdiction**	**Existing IC (ac)**	**Future IC (ac) from Build-out: Status-Quo**	**Future IC (ac) from Build-out: with Strategies**
Beasley Creek	County	385.0	1,934.1	1,637.9
	Town	48.4	241.9	212.6
Upper Crane Creek	County	1,700.4	4,040.9	3,691.9
Lower Crane Creek	County	885.1	2,466.2	2,129.4
	City	806.4	1,098.4	1,036.4
Watershed total		3,825.3	9,781.4	8,708.2
% of Total Watershed Area		8.9%	22.7%	20.2%

WTM results are presented for total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and fecal coliform (FC) loads for the existing and two future build-out conditions. Table 7.3 shows the pollutant load and Table 7.4 summarizes the net increase in imperviousness and the percent increase in pollutant loads from existing to the two future land use conditions.

Table 7.3. WTM Load Estimates for the Crane Creek Watershed					
Modeled Conditions	**Imperviousness (%)**	**TN (lb/acre/year)**	**TP (lb/acre/year)**	**TSS (lb/acre/year)**	**Bacteria (billion/acre/yr)**
Existing	**8.5%**	**5.2**	**0.6**	**304.5**	**110.2**
Build-out: Status-Quo	**22.7%**	**7.8**	**0.8**	**305.0**	**229.4**
Build-out: With Management Strategies	**20.2%**	**6.6**	**0.7**	**250.5**	**150.0**

Table 7.4. Percent increase in future scenario loads over existing watershed conditions for the Crane Creek Watershed					
Modeled Conditions	**Imperviousness (%)**	**TN (lb/acre/year)**	**TP (lb/acre/year)**	**TSS (lb/acre/year)**	**Bacteria (billion/acre/yr)**
Build-out: Status-Quo	**14.2%**	**50.7%**	**37.3%**	**0.2%**	**108.1%**
Build-out: With Management Strategies	**14%**	**27.1%**	**14.4%**	**-17.7%**	**36.1%**

Based on the results from both build-out analyses, a substantial increase in nutrient loads and fecal coliform loads is predicted as the watershed develops, as shown in Table 7.4. For the build-out: status-quo scenario, which assumes that development occurs at a steady rate, with no changes made to current regulatory and NPDES programs in the watershed, the WTM predicts a 51% increase in TN loads, 37% increase in TP loads, 0.2% increase in TSS loads, and a 108% increase in bacteria loads. In addition, a 14% increase in impervious cover is predicted. The low TSS increase seen in the future scenario can be attributed to a lower active construction rate resulting upon build-out. When build-out conditions are reached, the rate of active construction will occur only as redevelopment or infill development. The high bacteria loading rate is largely attributed to an assumed high rate of septic system failure in the future (consistent with the assumption for existing conditions).

On the other hand, the build-out: with strategies scenario, which assumes steady rate development with implementation of the 12 watershed strategies, the WTM predicts a 27% increase in TN loads, 14% increase in TP loads, 18% decrease in TSS loads, and a 36% increase in bacteria loads. A 14% increase in impervious cover is still predicted, the same result as in the status-quo build-out scenario.

The increase in TN, TP, and bacteria loading for both future build-out scenarios can be attributed to the large amount of projected watershed development. In its current state, Crane Creek is relatively undeveloped. Comparatively, the amount of land that is projected to be converted from forest to development far outweighs the number of restoration practices identified for implementation on existing development. Therefore, it is no surprise that after implementation of all the watershed management strategies, build-out of the entire watershed will still result in increases in pollutant loadings. However, it is important to note that the build-out scenario with strategies predicts far lower future pollutant loads than the status-quo scenario. Instead of a 108% increase in bacteria loads, only a 36% increase is predicted.

The build-out: with strategies model represents a conservative estimate of benefits that could be realized by implementing a majority of the watershed strategies. This model was based on a full build-out scenario, will not occur in the near future. Despite the long planning horizon, several measures can be recommended to further reduce these estimated loads:

- Protect additional lands: A goal of the Crane Creek watershed was to protect 30% of the land as open space. The build-out: with strategies scenario only assumed protection of 18% of the watershed. By increasing the amount of protected land to include conservation hubs and further limiting development in priority natural resources areas, the expected pollutant load reductions will decrease.
- Explore additional stormwater retrofit opportunities and incorporate the treated areas into the model.
- Continue to enact more outreach and educational programs aimed at source control and pollution prevention.
- Improve installation and maintenance of erosion and sediment control measures with better enforcement of standards.
- Conduct regular illicit discharge investigations of both commercial and residential properties and enforce repair of any illicit connections found.
- Replace leaking and undersized sewer infrastructure to reduce bacteria loads

- Enforce stream buffer protection rules for new and existing development in order to reduce channel erosion and sediment loads.
- Implement mandatory or incentive-based measures to improve septic system performance. While the build-out: with strategies scenario assumed a low (5%) failure rate for septic systems in the future, it also only used education to replace or improve existing failing systems.

As previously mentioned, watershed pollutants (i.e. bacteria, which is of particular concern due to the fecal coliform TMDL) are highly variable and dominated by unpredictable sources. To date, no detailed sourcing studies have been completed in the watershed, the WTM uses conservative estimates of the potential load from these sources, and may overstate the importance of some particular sources. The model results should be viewed as a "first cut" approach that can later be modified with more detailed information from monitoring data and field surveys, particularly from illicit discharges and septic systems. As new watershed information and data are obtained, modeling inputs should be updated to reflect this information.

SECTION 8. REFERENCES

Bartoldus, C.C., E.W. Garbisch, M.L. Kraus. 1994. *Evaluation for planned wetlands* (EPW). Environmental Concern Inc., St. Michaels, MD.

Carnegey Biological Services. 2008. *Macroinvertebrate Assessment of Crane Creek Richland County, South Carolina.* Submitted to Richland County Department of Public Works. Carnegey Biological Services. Lexington, SC. November, 2008.

Cappiella, K. and K. Brown. 2001. *Impervious Cover and Land Use in the Chesapeake Bay Watershed.* Prepared for the Chesapeake Research Consortium. Center for Watershed Protection. Ellicott City, MD.

Cappiella, K. and L. Fraley-McNeal. 2007. *The Importance of Protecting Vulnerable Streams and Wetlands at the Local Level.* Article 6 in the Wetlands and Watershed Article Series. Center for Watershed Protection. Ellicott City, MD.

Caraco, D. 2002. *The Watershed Treatment Model: Version 3.1*. U.S. Environmental Protection Agency, Region V. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection (CWP). 2009a. Crane Creek Watershed Characterization Report. Prepared for Richland County, SC. Ellicott City, MD.

Center for Watershed Protection, 2009b (CWP). Summary of Findings from the Crane Creek Watershed Field Assessments. Prepared for Richland County, SC. Ellicott City, MD.

Center for Watershed Protection (CWP). 2007. The Eight Tools Audit. Center for Watershed Protection. Ellicott City, MD.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Department of the Interior Fish and Wildlife Service. Report # FWS/OBS-79/31.

Genesis Consulting Group (GCG). 2009. Stream Assessment Report: Lake Elizabeth – Phase II Crane Creek. Submitted to Richland County Public Works, Stormwater Services Division. Columbia, SC.

Heraty, M. 1993. *Riparian Buffer Programs: A Guide to Developing and Implementing a Riparian Buffer Program as an Urban Stormwater Best Management Practice.* Metropolitan Washington Council of Governments. Produced for US EPA Office of Wetlands, Oceans, and Watershed. Washington, DC.

Hirschman, D. and J. Kosco. 2008. Managing Stormwater in Your Community: A Guide for Building an Effective Post Construction Program.

Kitchell, A. and T. Schueler. 2004. *Unified Stream Assessment: A User's manual. Manual 10 in the Urban Subwatershed Restoration Manual Series.* Center for Watershed Protection. Ellicott City, MD.

Law, N., L. Fraley-McNeal, K. Cappiella and R. Pitt. 2008. Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs. Prepared for EPA Grant CP-83282201-0. Ellicott City, MD.

Matthews, R. 2004. A&F Agenda Item D: Greenways for Richland County : A Countywide Master Plan. Memo to Richland County Council Members. Office of the County Administrator. Nov. 19, 2004.

National Land Cover Database (NLCD). 2001. Available online: www.mrlc.gov/index.php.

PB. 2007. Technical Memorandum No. 1- Existing Conditions. Transportation Study Commission. Richland on the move. Submitted to Richland County. August 2007.

Richland County Forester. Personal Communication to Paul Sturm. March 18, 2009.

Richland County. 2001. *Stormwater Drainage Design Standards*. Richland County, SC.

Richland County Geodatabase [Soils feature class] (2001-2002). Richland County Government, 2020 Hampton St., Columbia, SC 29204.

Richland County. 2008. NPDES Annual Report. Submitted to South Carolina Department of Health and Environmental Control (SCDHEC). NPDES SCS400001.

Richland County. 2009. Richland County Comprehensive Plan: Looking Forward to Future Growth. Richland County Planning Department. Columbia, SC.

Richland County. (2009a). Richland County Greenways. Power-point presentation. Richland County Conservation Commission, Richland County, SC.

SC Climatology Office, Sandhill Experiment Station, Richland County, SC.
SC State Climatology Office.
http://www.dnr.sc.gov/climate/sco/ClimateData/cli_sc_climate.php#precipitation

Schueler, T., Hirschman, D., Novotney, M., and J. Zielinski. 2007. *Urban Stormwater Retrofit Practices Version 1.0. Manual 3 in the Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

South Carolina Department of Health and Environmental Control (SCDHEC). 2005. Total Maximum Daily Loads for Fecal Coliform – Upper Broad River Basin. SCDHEC Technical Report Number: 028-05. September 2005.

South Carolina Department of Health and Environmental Control (SCDHEC). 2008a. *303(d) & Total Maximum Daily Loads.* SCDHEC Bureau of Water. http://www.scdhec.net/environment/water/tmdl/index.htm#303d

South Carolina Department of Health and Environmental Control (SCDHEC). 2008b. Watersheds and TMDLS, Broad River Basin. Broad River Watershed Evaluation SCDHEC Bureau of Water. http://www.scdhec.net/environment/water/shed/bd_bd.htm

South Carolina Department of Health and Environmental Control (SCDHEC). 2008c. Watersheds and Planning, Saluda River Basin. Congaree River Watershed Evaluation. SCDHEC Bureau of Water. http://www.scdhec.net/environment/water/shed/congaree.htm.

South Carolina Department of Natural Resources (SCDNR). 2009. *Rare, Threatened and Endangered Species Inventory at the SC DNR's Heritage Trust Program.* File created January 13, 2009.

United States Department of Agriculture, Natural Resources Conservation Service. 2005. Bird Use of Longleaf Pine Restoration. Warnell School of Forest Resources, University of Georgia. ftp://ftp-fc.sc.egov.usda.gov/WHMI/WEB/pdf/LongleafPine.pdf

United States Department of Agriculture Soil Conservation Service. 1978. Soil Survey of Richland County, South Carolina.

United States Environmental Protection Agency (USEPA). No Date. *United States et al v. M.D.C. Holdings, Inc.* (Richmond American Homes Information Sheet. US Environmental Protection Agency (EPA), Office of Enforcement and Compliance Assurance. http://www.epa.gov/compliance/resources/cases/civil/cwa/richmondamericanhomes-infosht.html

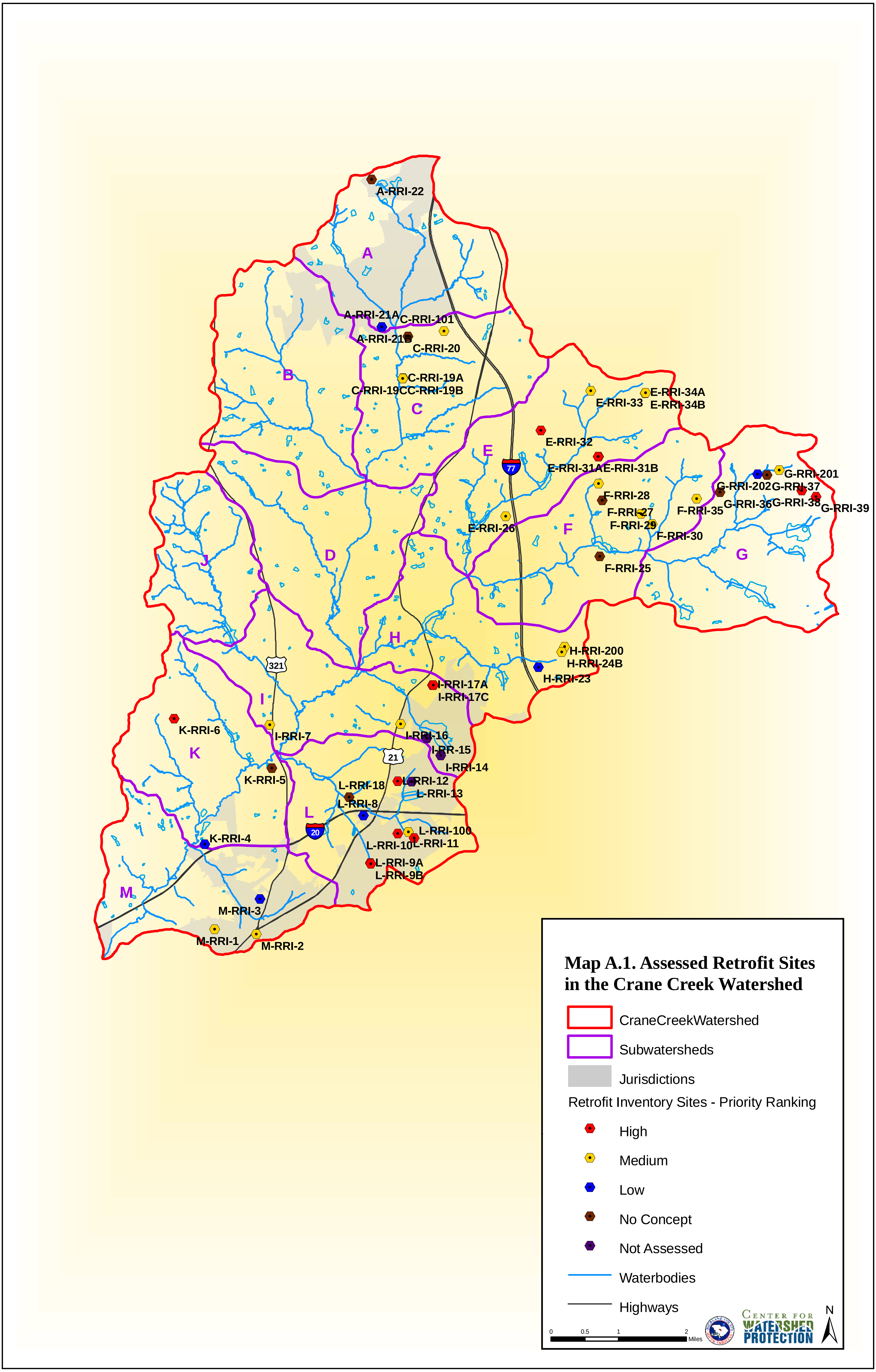
United States Geological Survey Patuxent Wildlife Research Center (USGS). 2000. *North American Breeding Bird Survey Internet data set.* Available online: http://www.mp2-pwrc.usgs.gov/bbs/retrieval/

Wenger, S. 1999. *A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation.* Office of Public Service and Outreach. Institute for Ecology. University of Georgia. Athens, GA.

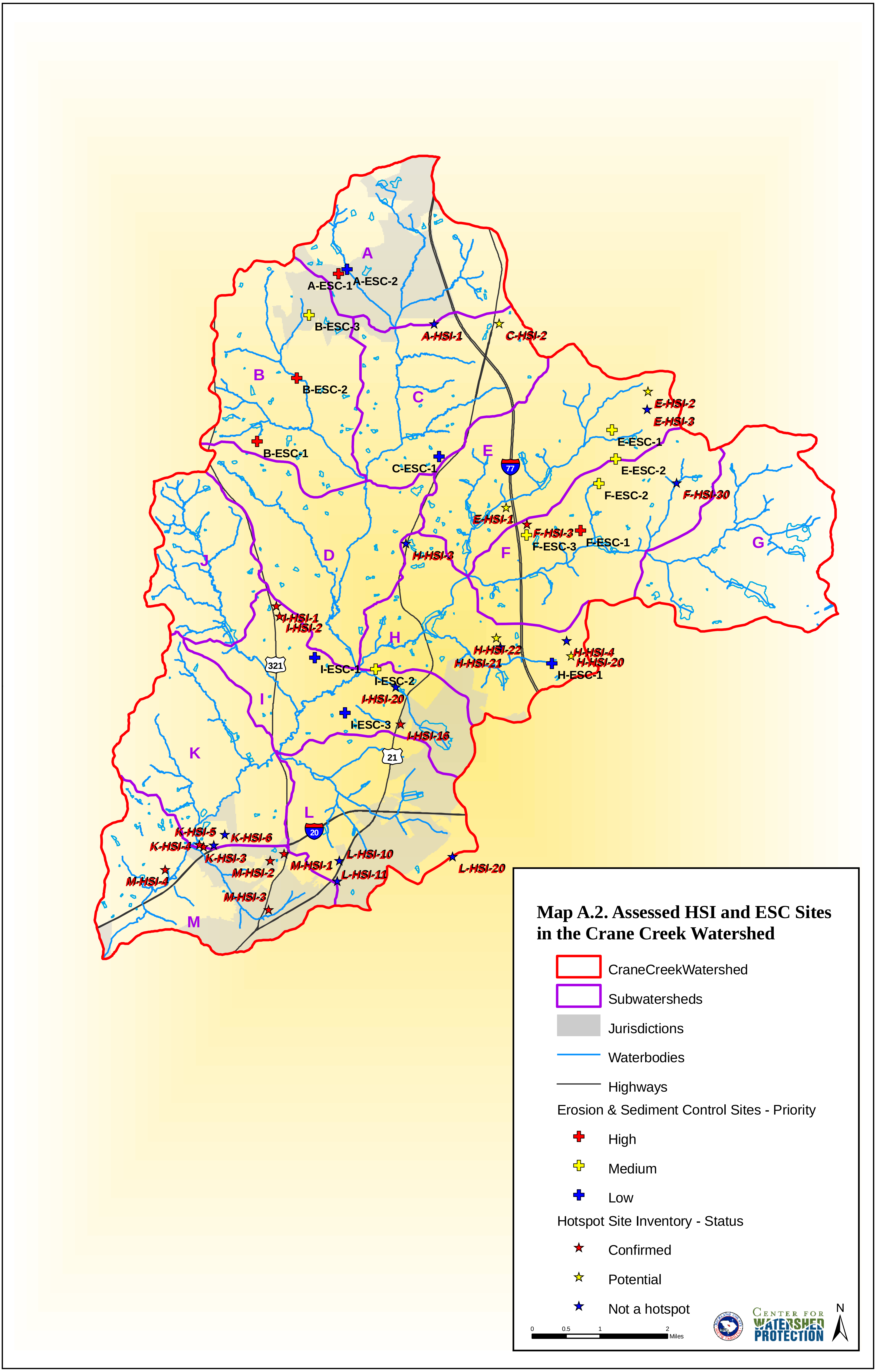
Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66: 1211-1214.

Wright, T., C. Swann, K. Cappiella, T. Schueler. 2005. *Unified Subwatershed and Site Reconnaissance: A User's Manual-Version 2.0. Manual 11 in the Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

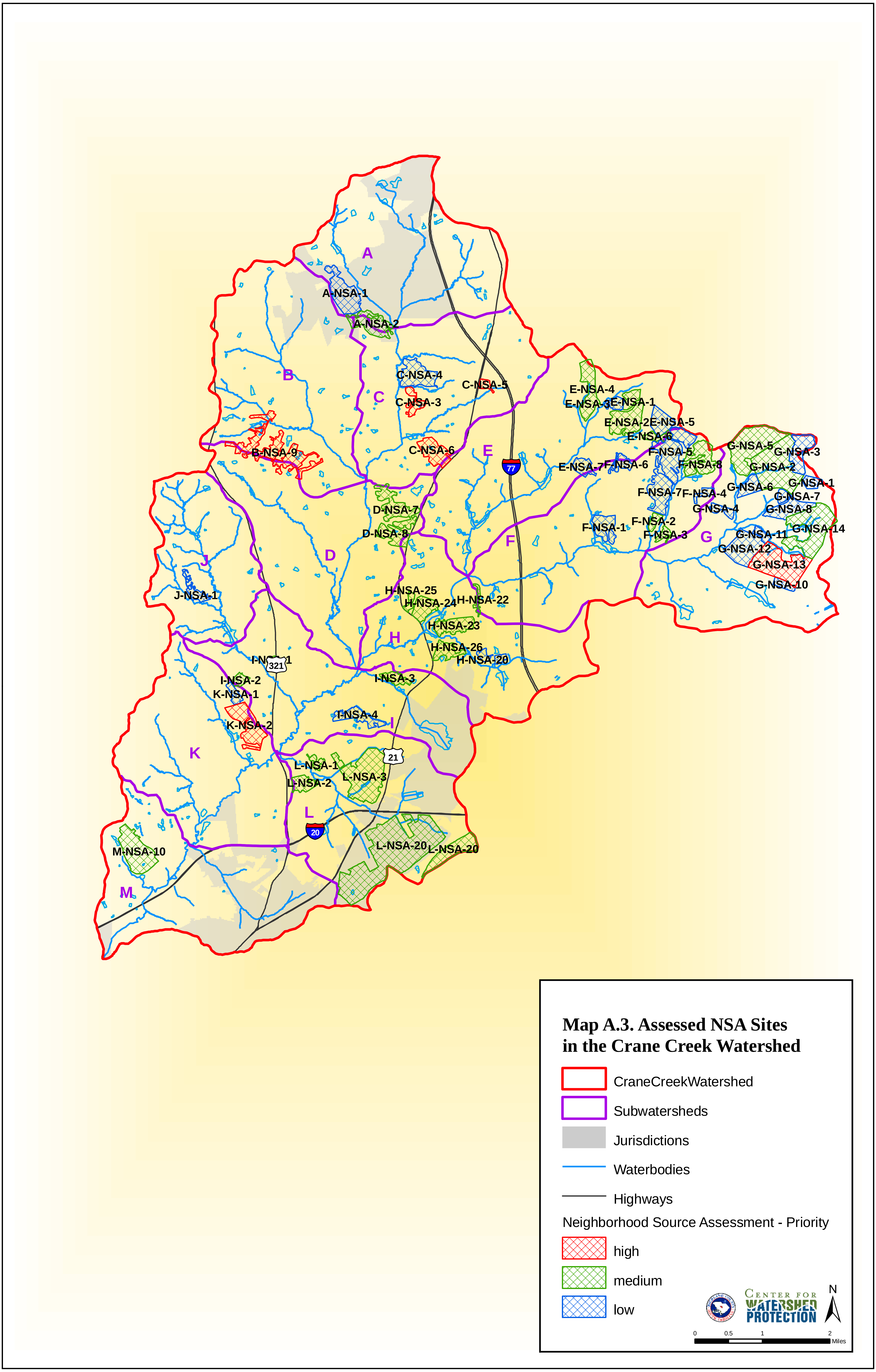
Attachment A. Crane Creek Watershed Maps



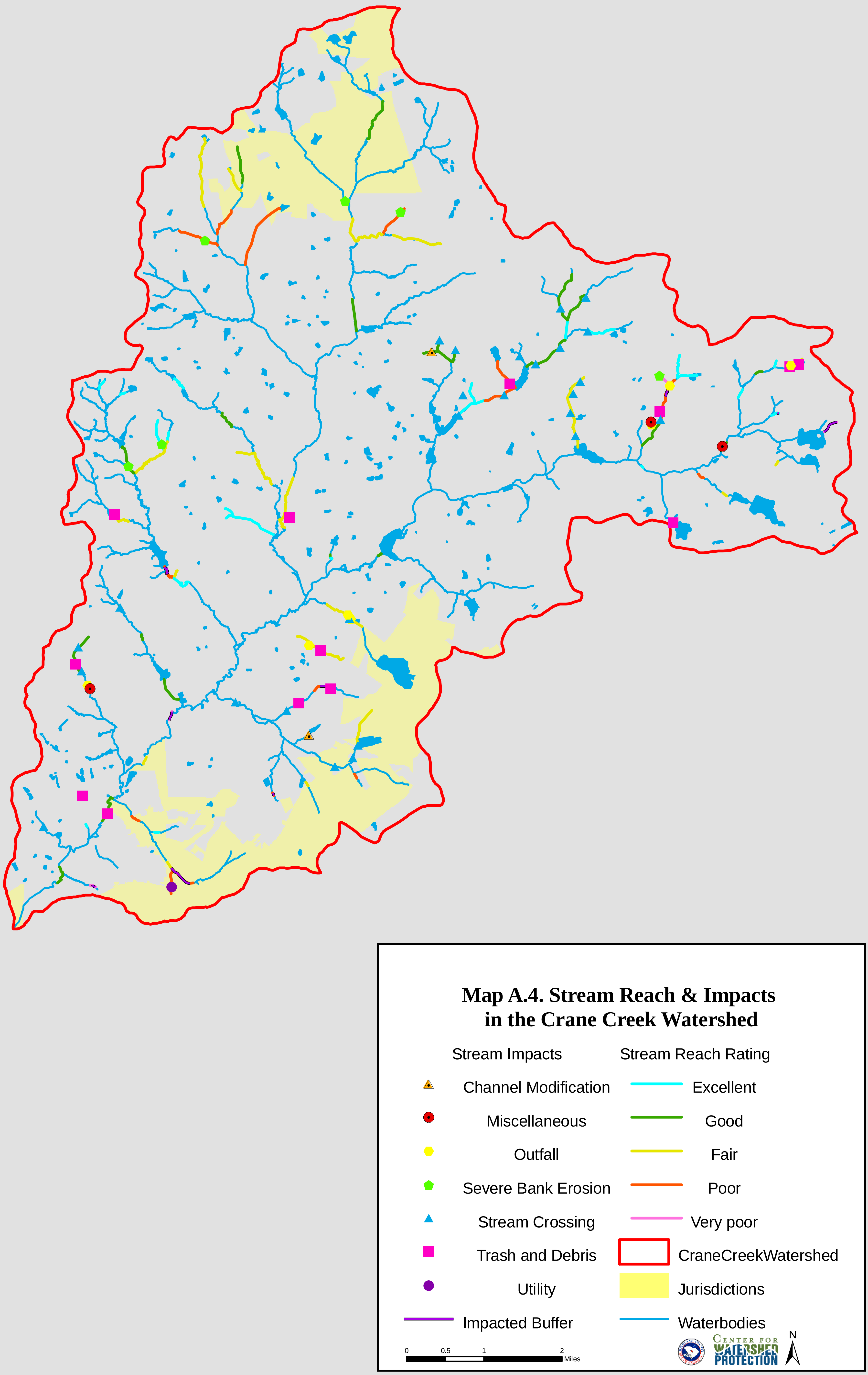
Map A.1. Assessed Retrofit Sites in the Crane Creek Watershed



Map A.2. Assessed HSI and ESC Sites in the Crane Creek Watershed



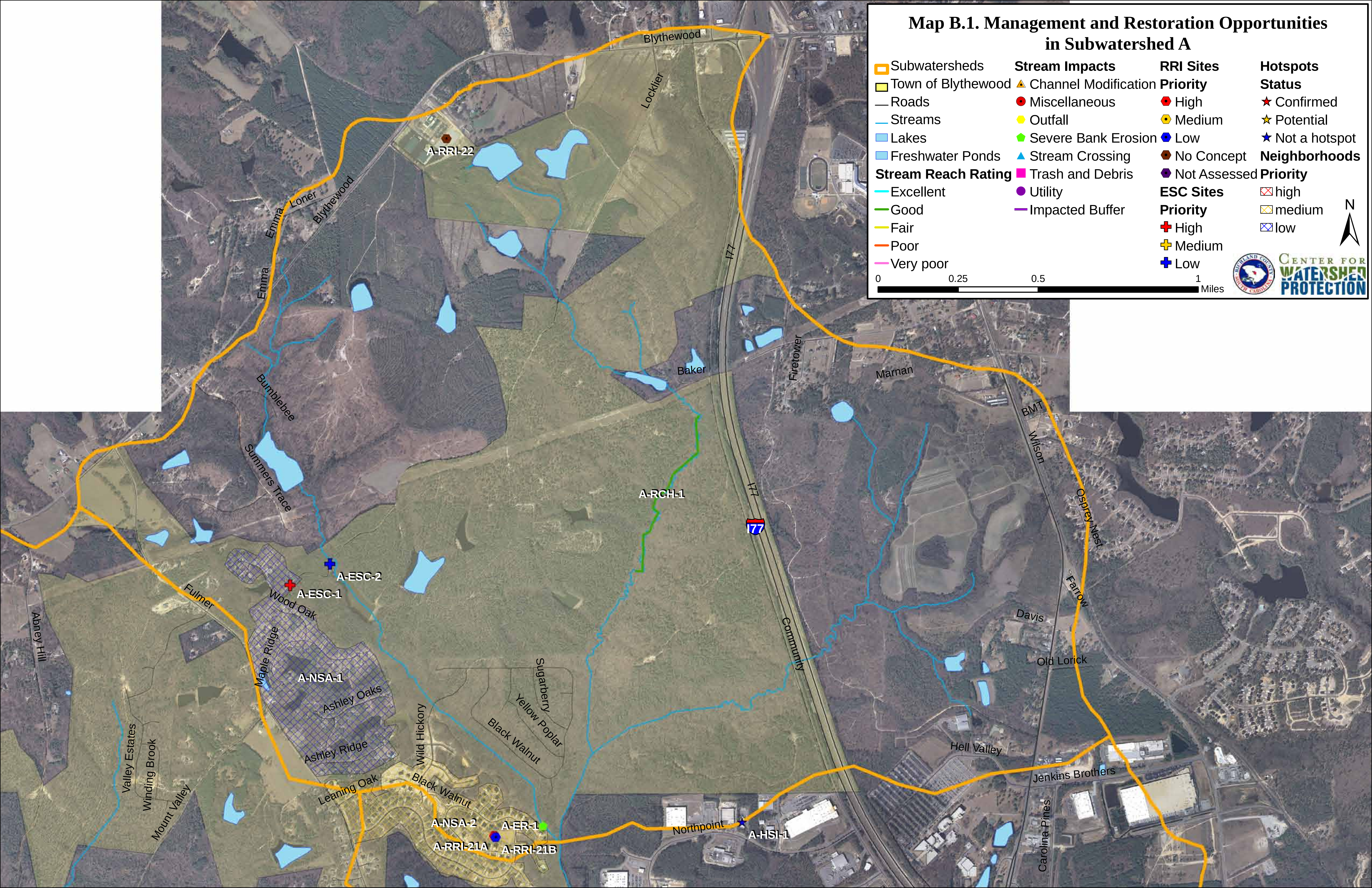
Map A.3. Assessed NSA Sites in the Crane Creek Watershed

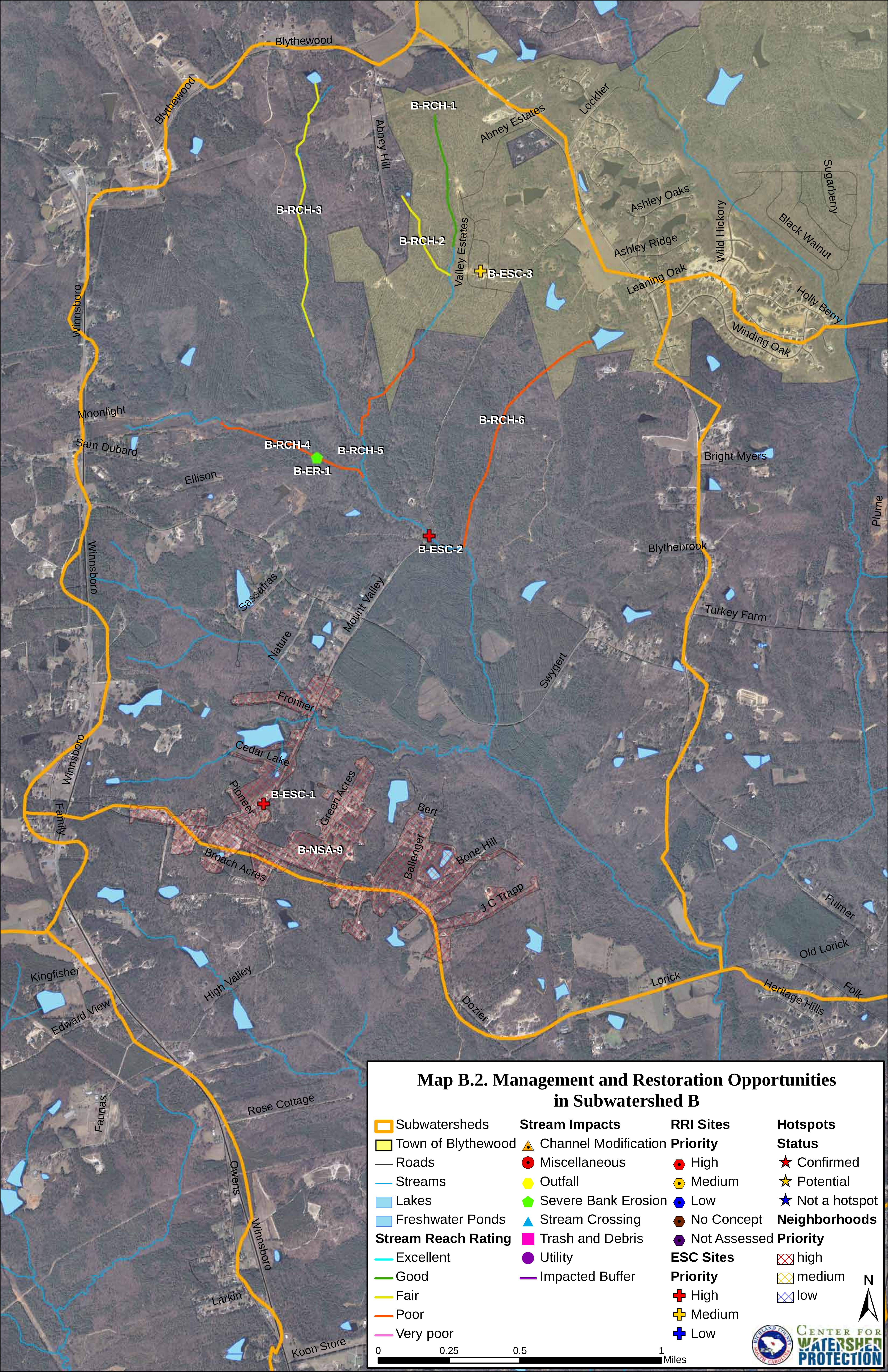


Map A.4. Stream Reach & Impacts in the Crane Creek Watershed

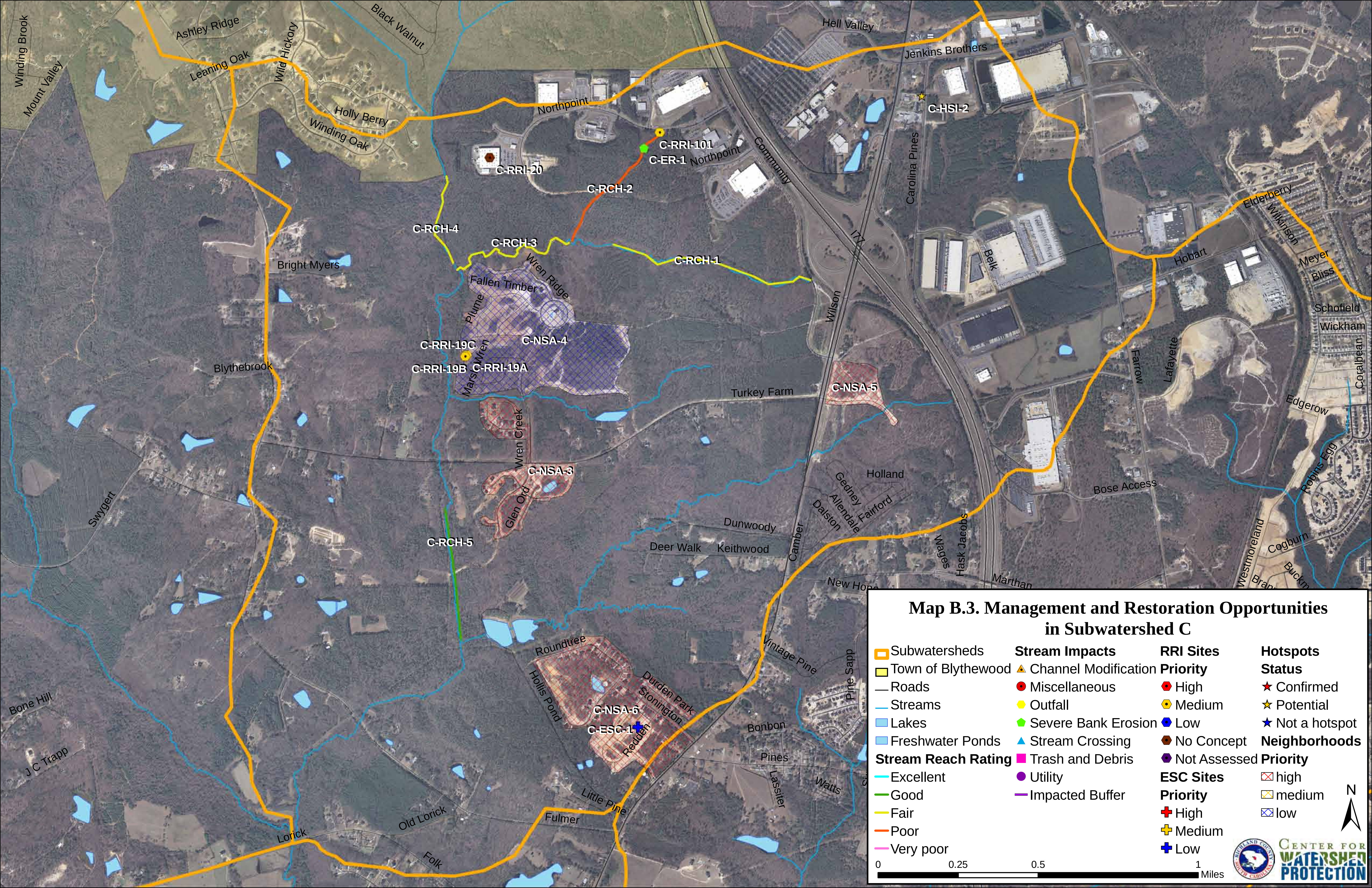
Attachment B. Crane Creek Subwatershed Maps

Map B.1. Management and Restoration Opportunities in Subwatershed A

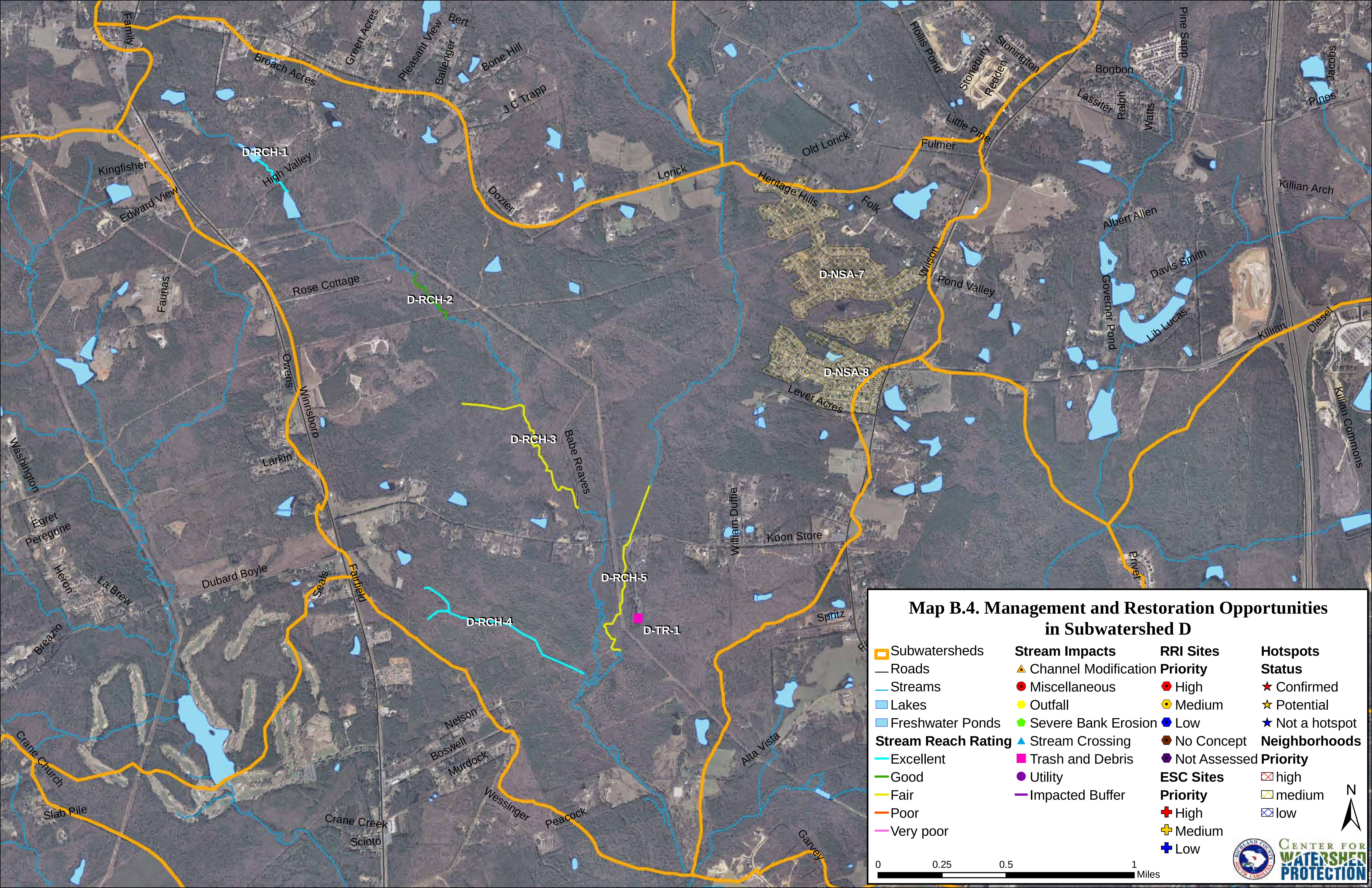




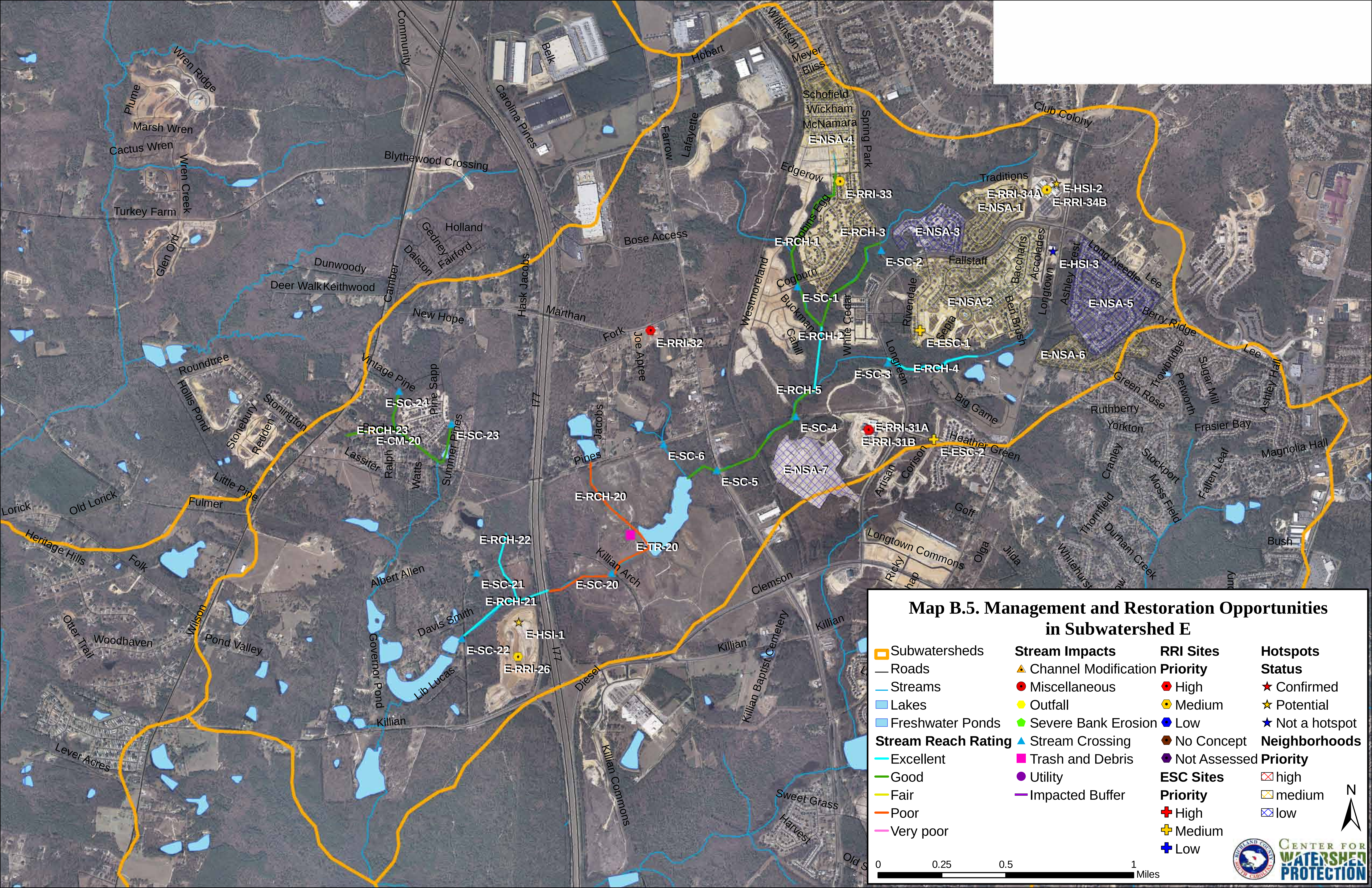
Map B.2. Management and Restoration Opportunities in Subwatershed B



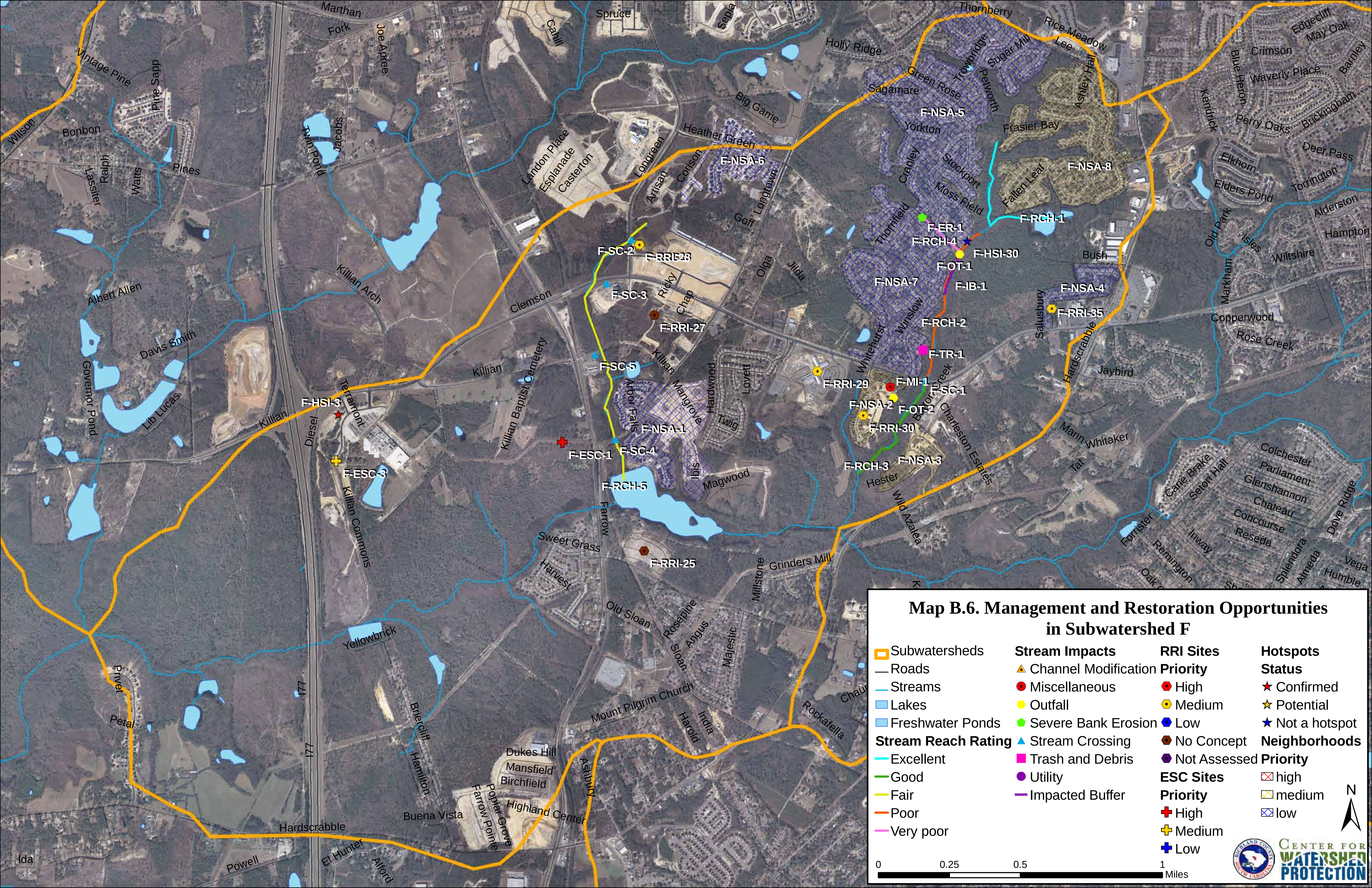
Map B.3. Management and Restoration Opportunities in Subwatershed C



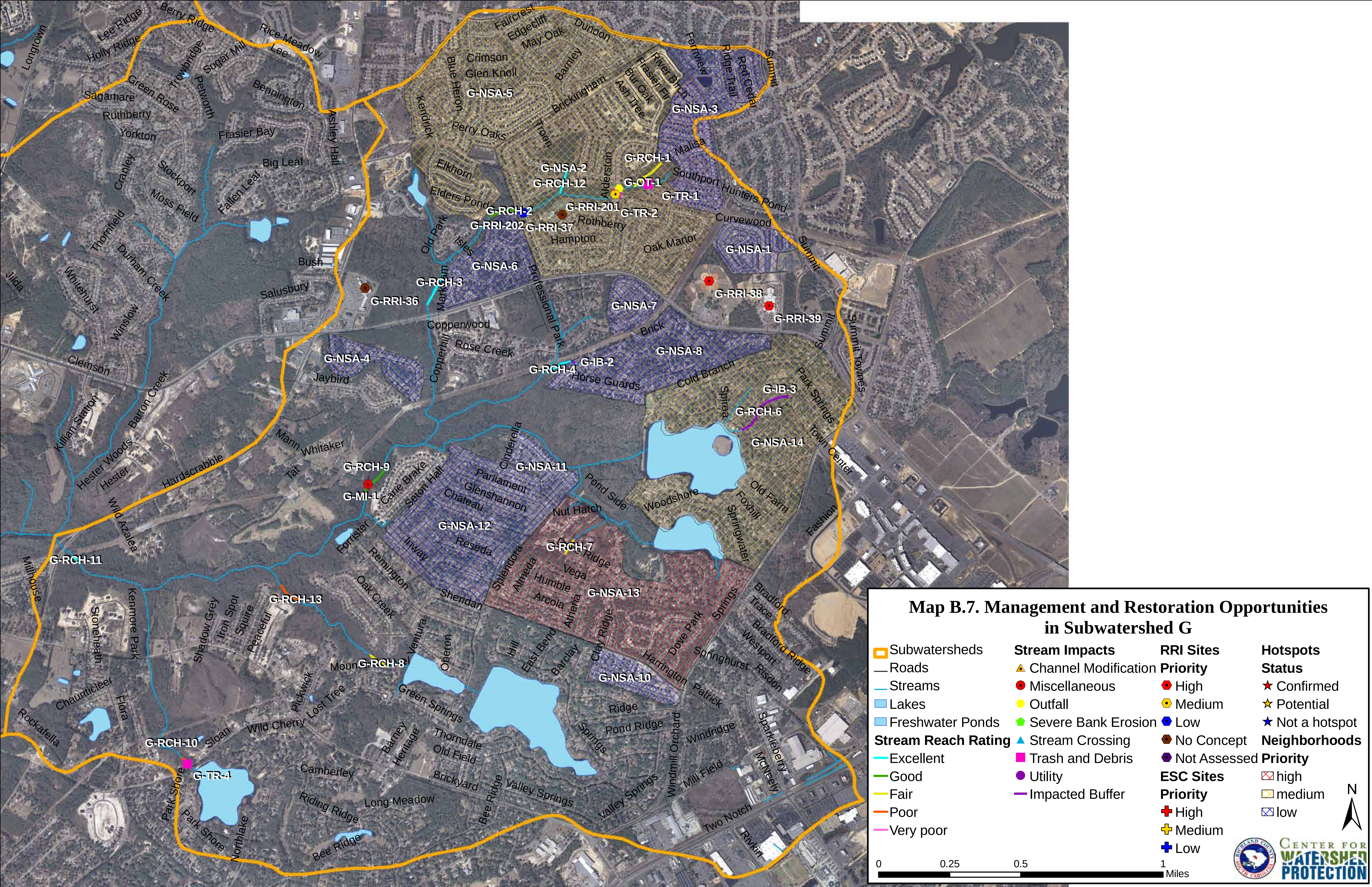
Map B.4. Management and Restoration Opportunities in Subwatershed D



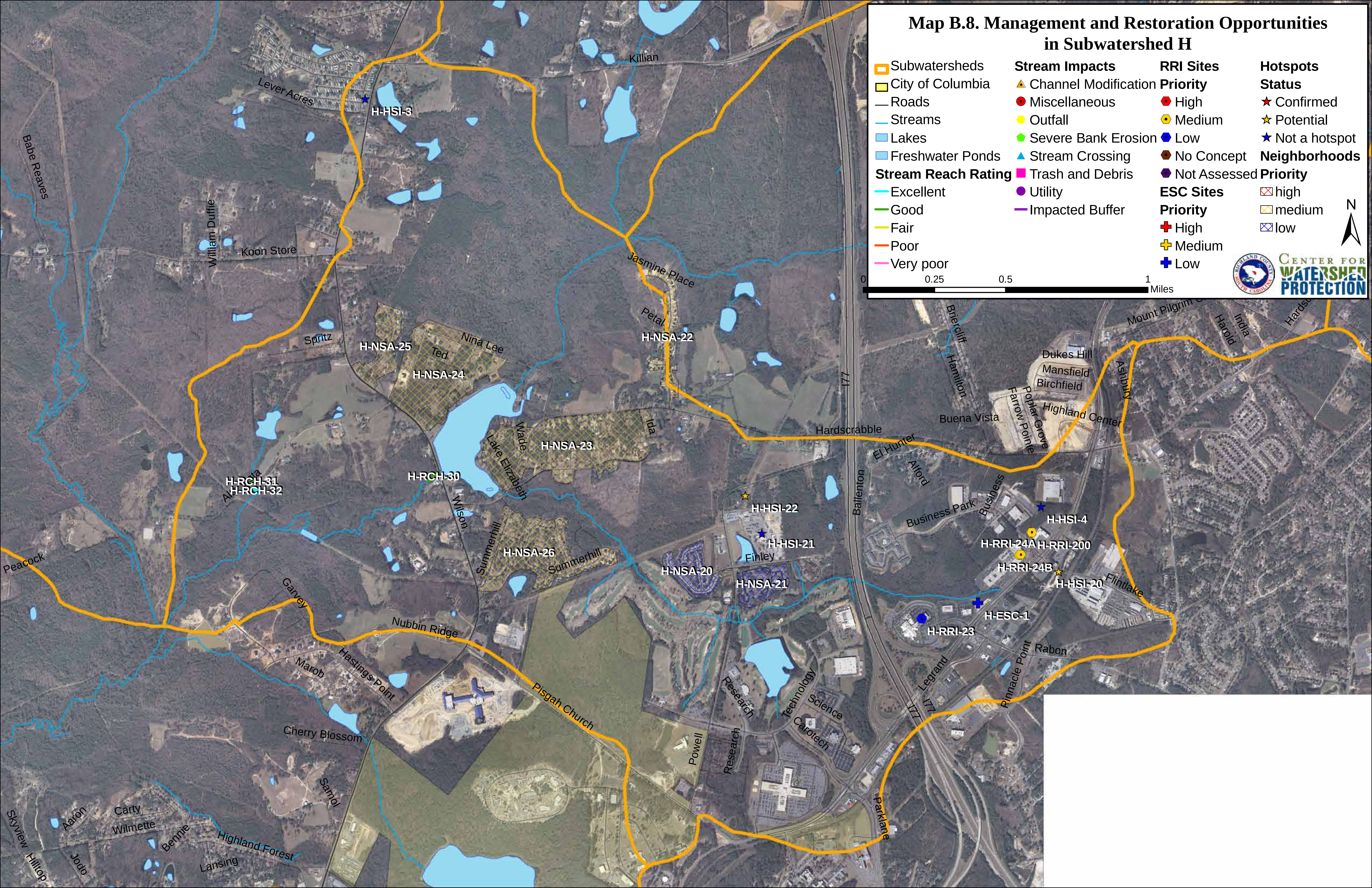
Map B.5. Management and Restoration Opportunities in Subwatershed E



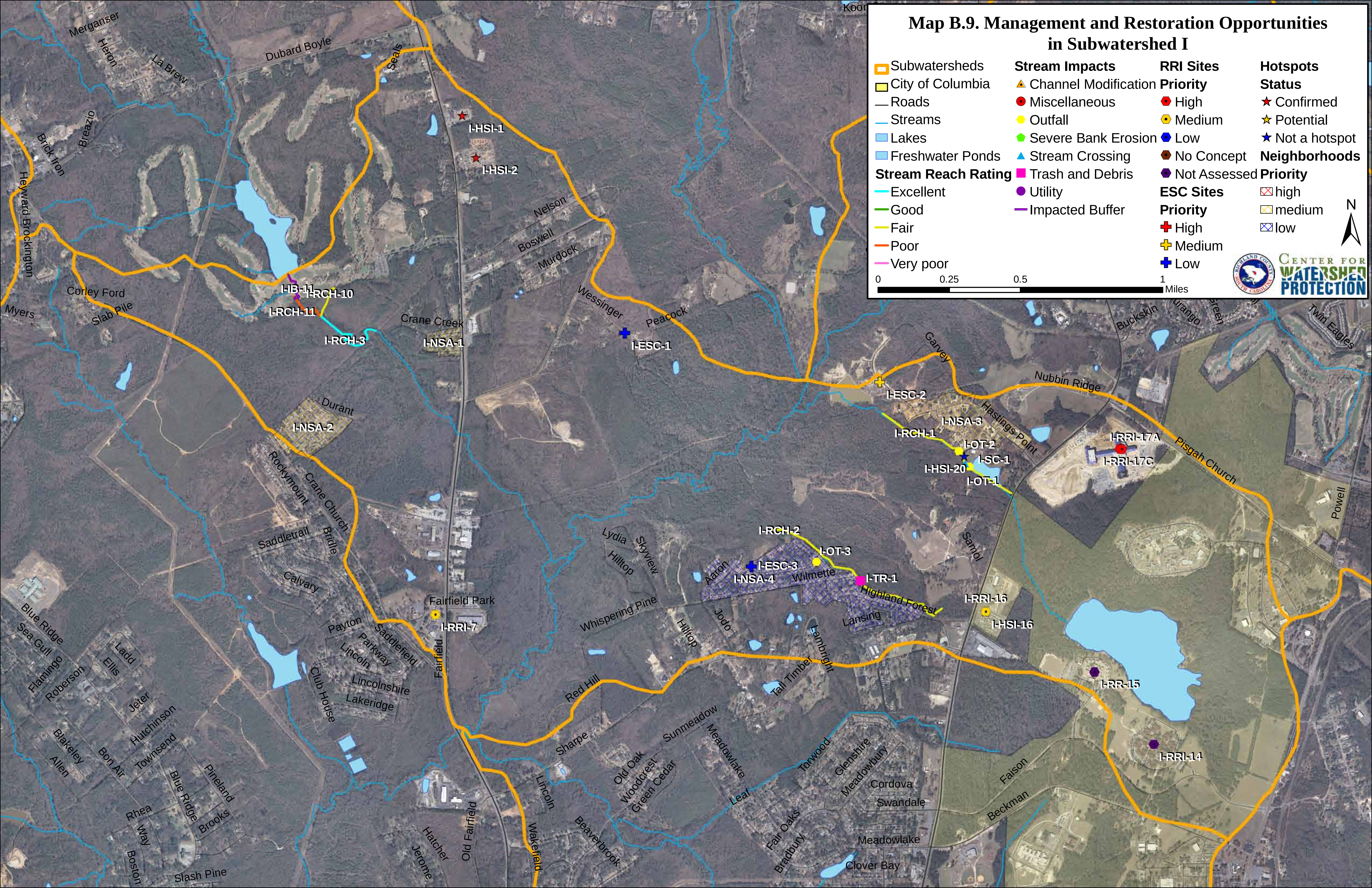
Map B.6. Management and Restoration Opportunities in Subwatershed F

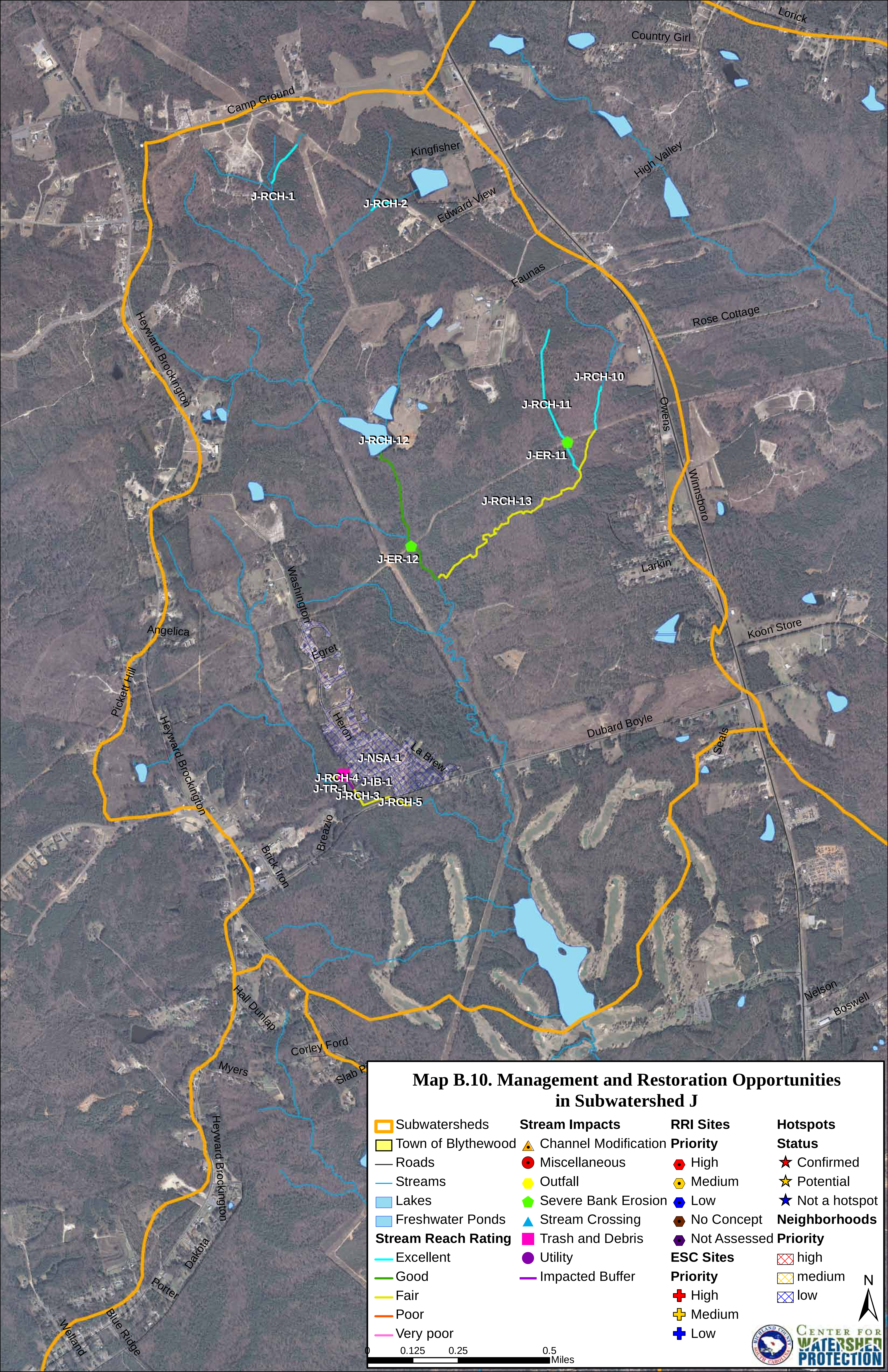


Map B.7. Management and Restoration Opportunities in Subwatershed G

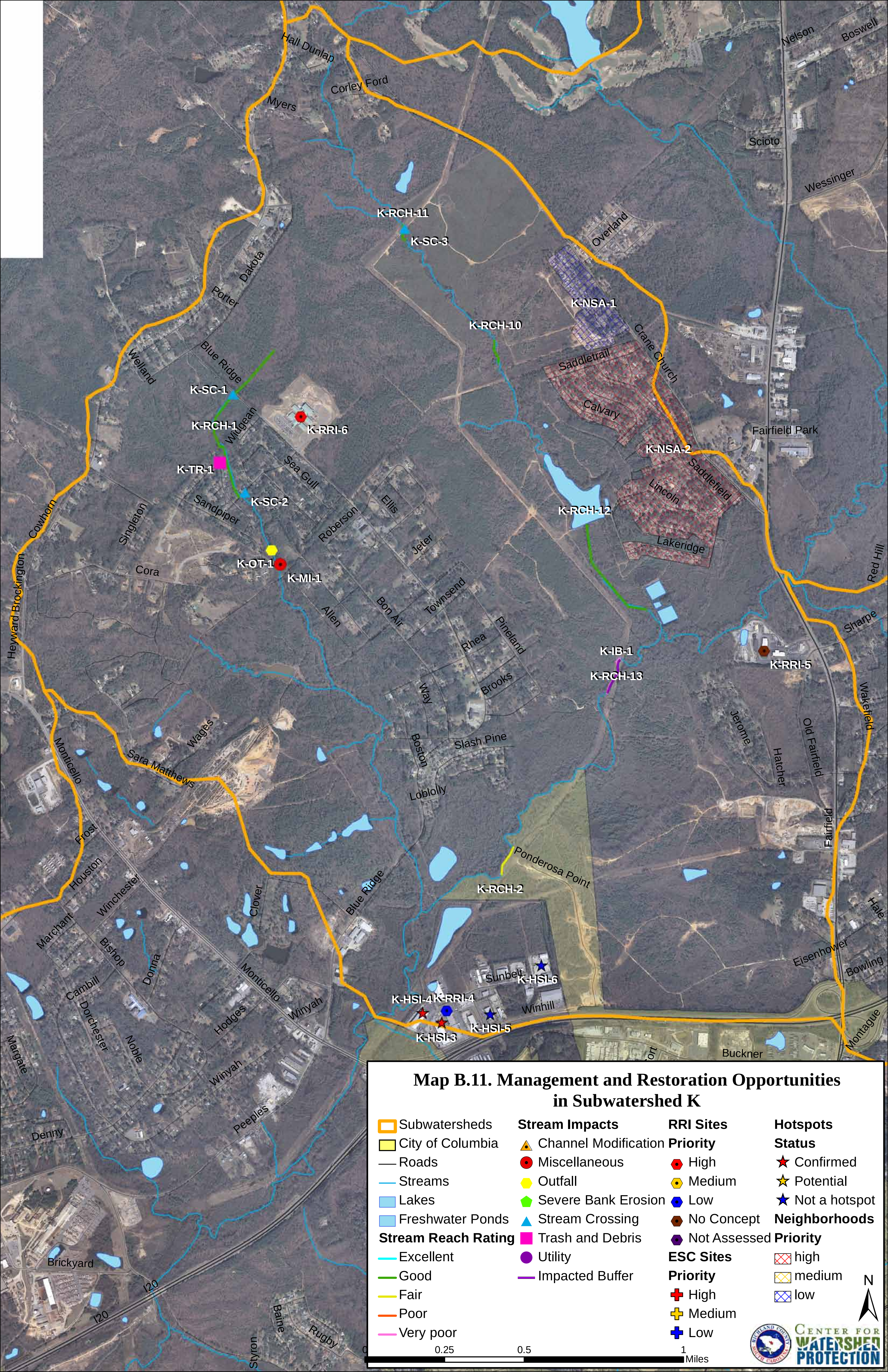


Map B.8. Management and Restoration Opportunities in Subwatershed H

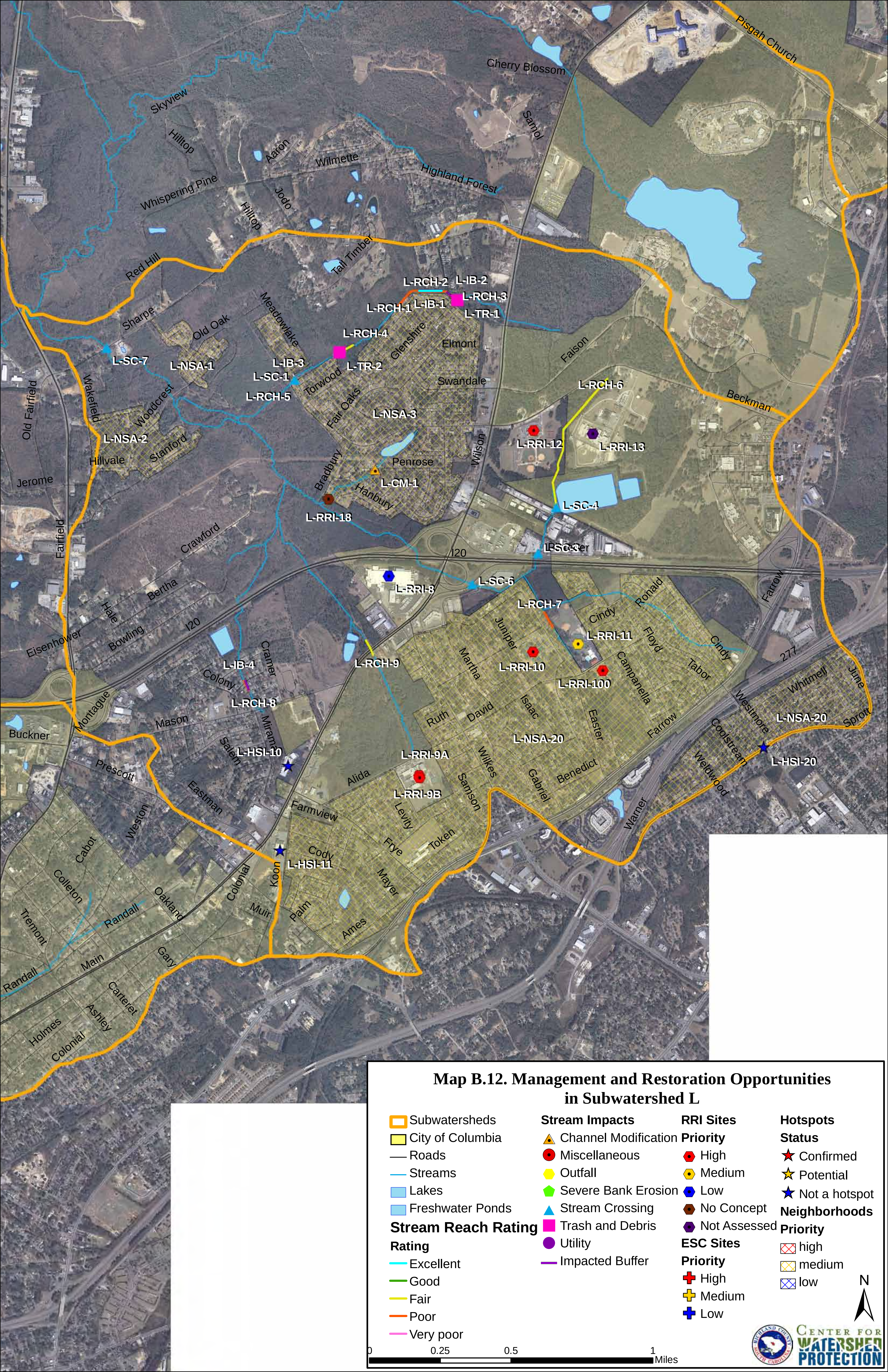

Map B.9. Management and Restoration Opportunities in Subwatershed I
Subwatersheds
City of Columbia
Roads
Streams
Lakes
Freshwater Ponds
Stream Reach Rating
Excellent
Good
Fair
Poor
Very poor
Stream Impacts
Channel Modification
Miscellaneous
Outfall
Severe Bank Erosion
Stream Crossing
Trash and Debris
Utility
Impacted Buffer
RRI Sites
Priority
High
Medium
Low
No Concept
Not Assessed
ESC Sites
Priority
High
Medium
Low
Hotspots
Status
Confirmed
Potential
Not a hotspot
Neighborhoods
Priority
high
medium
low
N
0
0.25
0.5
1
Miles
Center for Watershed Protection
I-HSI-1
I-HSI-2
I-IB-11
I-RCH-10
I-RCH-11
I-RCH-3
I-NSA-1
I-ESC-1
I-NSA-2
I-ESC-2
I-NSA-3
I-RCH-1
I-OT-2
I-SC-1
I-HSI-20
I-OT-1
I-RRI-17A
I-RRI-17C
I-RCH-2
I-OT-3
I-ESC-3
I-NSA-4
I-TR-1
I-RRI-16
I-HSI-16
I-RRI-7
I-RR-15
I-RRI-14
Merganser
Heron
La Brew
Dubard Boyle
Seals
Breazio
Brick Iron
Heyward Brockington
Corley Ford
Slab Pile
Myers
Crane Creek
Nelson
Boswell
Murdock
Wessinger
Peacock
Garvey
Nubbin Ridge
Hastings Point
Pisgah Church
Buckskin
Twin Eagles
Powell
Durant
Rockymount
Crane Church
Saddletrail
Bridle
Calvary
Fairfield Park
Lydia
Hilltop
Skyview
Aaron
Wilmette
Highland Forest
Lansing
Whispering Pine
Jodo
Lambright
Tall Timber
Red Hill
Samol
Blue Ridge
Sea Gull
Flamingo
Roberson
Ladd
Ellis
Payton
Saddlefield
Parkway
Lincoln
Lincolnshire
Lakeridge
Club House
Fairfield
Jeter
Hutchinson
Blakeley
Bon Air
Townsend
Allen
Pineland
Rhea
Way
Brooks
Boston
Slash Pine
Hatcher
Jerome
Old Fairfield
Wakefield
Beaverbrook
Sharpe
Sunmeadow
Meadowlake
Old Oak
Woodcrest
Green Cedar
Leaf
Torwood
Glenshire
Meadowbury
Cordova
Swandale
Fair Oaks
Bradbury
Clover Bay
Faison
Beckman



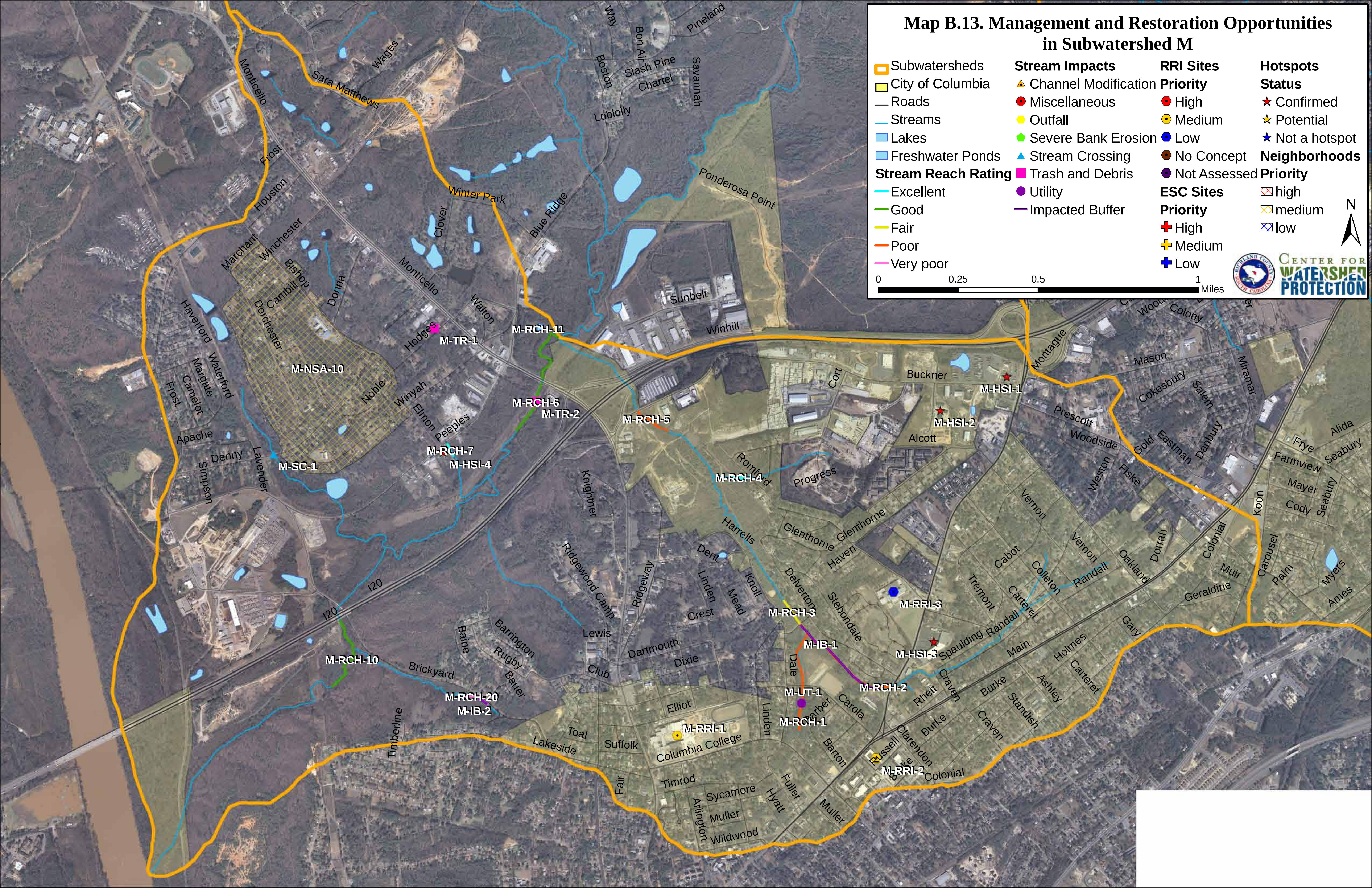
Map B.10. Management and Restoration Opportunities in Subwatershed J



Map B.11. Management and Restoration Opportunities in Subwatershed K



Map B.12. Management and Restoration Opportunities in Subwatershed L



Map B.13. Management and Restoration Opportunities in Subwatershed M

Attachment C. Supplemental Information for Land Cover and Development and the Buildout Assessments

2001 National Land Cover Database (NLCD) Land Cover Descriptions

Land cover descriptions for the 2001 NLCD are described in Homer et al. (2004) and are shown in Table C.1.

Table C.1.. Land Cover Descriptions

Land Use	Land cover categories	Description
Wetlands and Open Water	Open Water	All areas of open water, generally with less than 25% cover or vegetation or soil. Open water comprised 1.3% of the total watershed area.
	Woody wetlands	Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water. Woody wetlands comprised 5.1% of the total watershed area.
	Emergent Herbaceous Wetlands	Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water. Emergent wetlands comprised 0.1% of the total watershed area.
Open Space	Developed, Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total area. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. Developed, open space comprised 14.4% of the total watershed area.
Developed Land	Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units. Low intensity development comprised 13.2 % of the total watershed area.
	Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units. Medium intensity development comprised 4.7 % of the total watershed area.
	Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover. High intensity development comprised 0.7 % of the total watershed area.
Forested Land	Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change. Deciduous forest comprised 23.0 % of the total watershed area.
	Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage. Evergreen forest comprised 23.3 % of the total watershed area.
	Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover. Mixed forest comprised 2.7% of the total watershed area.
Agriculture	Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation. Pasture/Hay comprised 3.1% of the total watershed area.

Table C.1.. Land Cover Descriptions		
Land Use	**Land cover categories**	**Description**
	Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled. Cultivated crops comprised 0.8% of the total watershed area.
Other	Barren Land	Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover. Barren lands comprised 0.7% of the total watershed area.
	Scrub/Shrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions. Scrub lands comprised 0.3% of the total watershed area.
	Grassland/ Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. Grasslands comprised 6.7% of the total watershed area.

Build-out Assessment Methodology

The build-out assessment is a GIS analysis that estimates future land cover in a watershed. The results are useful for predicting future health of streams and developing watershed protection recommendations. The Crane Creek build-out assessment made the following assumptions:

- Full build-out of the watershed will occur based on allowable zoning (e.g., no rezoning)
- Current land cover on developed land will remain the same in future build-out scenario
- Protected land will remain the same in future build-out scenario
- Buildable land will be converted to impervious cover, as dictated by land use coefficients

The following steps were followed in order to conduct the build-out assessment:

Step 1. Identify developed and undeveloped land

The 2001 land cover raster dataset from the NLCD was converted to a polygon shapefile to allow for ease of analysis. A new shapefile for undeveloped land was created by removing the following land cover categories from the NLCD dataset:

- 21 – developed, open space
- 22 – developed, low intensity
- 23 – developed, medium intensity
- 24 – developed, high intensity

Step 2. Identify and subtract protected land from undeveloped land

For build-out: status quo scenario, a protected land shapefile was created the Crane Creek watershed that included the following data:

- Stream buffers – 0 ft in Columbia, 0 ft in Richland County, and 20 ft in Blythewood (see Section 7 for more information).
- Wetlands – obtained from the NWI
- Water bodies – obtained from Richland County
- Parks – obtained from Richland County

The Crane Creek build-out: with strategies assessment, a protected land GIS shapefile was created for the Crane Creek watershed that included the following data:

- Stream buffers – 100 ft on both sides of the stream channel
- Wetlands – obtained from the NWI and added a 50 ft buffer around each wetland
- Water bodies – obtained from Richland County and added a 50 ft buffer around each water body
- Parks – obtained from Richland County
- The primary conservation network derived from the green infrastructure analysis. The green infrastructure assessment described in Section 3.6 of this report.

These shapefiles of protected lands were then subtracted from the undeveloped land shapefile. Wetlands and water bodies identified in the NLCD land cover dataset were also subtracted from the undeveloped land shapefile, resulting in a new shapefile of land that is potentially buildable.

Step 3. Calculate the area of each zoning category for the potentially buildable land
The zoning layer was intersected with the potentially buildable land layer. The result was a new GIS layer of potentially buildable land classified according to zoning. From this layer, a data table was generated that includes the calculated area of each zoning category for potentially buildable land in the watershed.

Step 4. Multiply the potentially buildable land in each zoning category by the corresponding impervious cover coefficients
Impervious cover coefficients represent the fraction of a land use parcel that is impervious cover. The coefficients vary by land use type and intensity. Coefficients from Cappiella and Brown (2001) were utilized in this build-out assessment and were developed by sampling more than 200 land use polygons within four Chesapeake Bay communities to calculate an average impervious cover for 12 land use categories. The impervious cover coefficients from Cappiella and Brown (2001) were aligned with the zoning categories within the Crane Creek watershed as shown in Table C.2. The potentially buildable land within each zoning category was multiplied by these coefficients to obtain the future impervious cover estimate.

Table C.2. Impervious Cover Coefficients Correlated to Richland County Zoning

Richland Co. Zoning Code	Description	Impervious Cover Coefficient*
RU, D-1	Rural - 33,000/120	9.5
RR	Rural Residential - 33,000/100	9.5
RS-1, RS-LD	Residential, Single-Family, Low Density - 12,000/75	36
RS-2, RS-MD	Residential, Single-Family, Medium Density - 8,500/60	36
RS-3, RS-HD	Residential, Single-Family, High Density - 5,000/50	42
MH	Manufactured Home - 7,260/60	36
RG-1, RM-MD	Residential, Multi-Family, Medium Density - Max Density 8 units/acre/50	42
RG-2, RM-HD	Residential, Multi-Family, High Density - Max Density 16 units/acre/50	66
C-1, OI	Office and Institutional	42
C-2, NC	Neighborhood Commercial	66
C-3, GC	General Commercial	66
M-1, LI	Light Industrial District	42
M-2, HI	Heavy Industrial	66
PUD-R	Residential Planned Unit Dev - 1	42
PUD-C	Commercial Planned Unit Dev - 1	66
PUD-2, PDD	Planned Unit Dev - 2	42
Unidentified	Planned Development District	42

* Source: Cappiella and Brown, 2001

Step 5. Align the zoning categories to the land cover categories in the NLCD to determine the future land cover in the watershed.
Based on best professional judgment, the zoning categories (land use) were aligned with the land cover categories in the NLCD dataset as shown in Table C.3. By doing so, the amount of land in

each land cover category of potentially buildable land was calculated for future conditions. This amount was added to the existing land cover of developed land within the watershed to obtain the future land cover.

Table C.3. Zoning Categories and Corresponding Land Cover Categories

Zoning Code	Zoning Description	Land Cover Code	Land Cover Description
RU, D-1	Rural - 33,000/120	21	Developed, Open Space
RR	Rural Residential - 33,000/100	21	Developed, Open Space
RS-1, RS-LD	Residential, Single-Family, Low Density - 12,000/75	22	Developed, Low Intensity
RS-2, RS-MD	Residential, Single-Family, Medium Density - 8,500/60	23	Developed, Low Intensity
RS-3, RS-HD	Residential, Single-Family, High Density - 5,000/50	24	Developed, Medium Intensity
MH	Manufactured Home - 7,260/60	23	Developed, Low Intensity
RG-1, RM-MD	Residential, Multi-Family, Medium Density - Max Density 8 units/acre/50	23	Developed, Medium Intensity
RG-2, RM-HD	Residential, Multi-Family, High Density - Max Density 16 units/acre/50	24	Developed, High Intensity
C-1, OI	Office and Institutional	23	Developed, Medium Intensity
C-2, NC	Neighborhood Commercial	23	Developed, High Intensity
C-3, GC	General Commercial	24	Developed, High Intensity
M-1, LI	Light Industrial District	23	Developed, Medium Intensity
M-2, HI	Heavy Industrial	24	Developed, High Intensity
PUD-R	Residential Planned Unit Dev - 1	23	Developed, Medium Intensity
PUD-C	Commercial Planned Unit Dev - 1	24	Developed, High Intensity
PUD-2, PDD	Planned Unit Dev - 2	23	Developed, Medium Intensity
Unidentified	Planned Development District	23	Developed, Medium Intensity

Buildout Results

Table C.4. lists the land use for the existing watershed conditions and the estimated future land use based on the results of the build-out analysis.

Table C.4. Existing Land Use and Results of the Build-out Analyses

Land Use	Wetlands and Open Water	Developed Open Space	Developed	Forest	Agriculture	Other
EXISTING CONDITIONS						
	Acres	Acres	Acres	Acres	Acres	Acres
Beasley Creek - County	462.0	1060.0	739.3	7824.1	562.1	935.4
Beasley Creek - County	80.8	186.4	131.3	1590.7	97.6	177.2
Upper Crane - County	1310.9	2189.7	3620.7	5395.0	484.8	1320.9
Lower Crane - County	801.3	2107.4	1858.1	5655.6	451.7	806.9
Lower Crane - City	160.7	693.8	1639.0	665.5	91.9	76.1
Total	2816	6237	7988	21131	1688	3316
% of Watershed	**6.5%**	**14.4%**	**18.5%**	**48.9%**	**3.9%**	**7.7%**
FUTURE CONDITIONS: STATUS-QUO						
Beasley Creek - County	462	8159	2626	238	37	62
Beasley Creek - County	81	1895	216	58	6	8
Upper Crane - County	1311	4451	8062	366	33	100
Lower Crane - County	801	5760	4708	298	38	76
Lower Crane - City	161	780	2339	38	3	7
Total	2816	21045	17950	998	116	253
% of Watershed	**6.5%**	**48.7%**	**41.6%**	**2.3%**	**0.3%**	**0.6%**
FUTURE CONDITIONS: WITH STRATEGIES						
Beasley Creek - County	462	7000	2238	1665	68	151
Beasley Creek - County	81	1578	215	349	17	24
Upper Crane - County	1311	4142	7408	1229	54	178
Lower Crane - County	801	4928	4110	1587	78	177
Lower Crane - City	161	753	2192	194	11	16
Total	2816	18401	16163	5024	228	546
% of Watershed	**6.5%**	**42.6%**	**37.4%**	**11.6%**	**0.5%**	**1.3%**

Attachment D – Watershed Treatment Model

Estimate of Pollutant Loads and Reduction Strategies

A description of the assessment methods and the results of the Watershed Treatment Model for existing and future build-out conditions in the Crane Creek watershed are provided below. Five different models were created, tailored to the subwatersheds and three jurisdictions in the Crane Creek watershed: Upper Crane Creek – Richland County, Lower Crane Creek – Richland County, Lower Crane Creek – Columbia, Beasley Creek – Richland County, and Beasley Creek – Blythewood.

D.1 Model Inputs and Assumptions

Pollutant Sources
The WTM land use primary source estimates are based on land cover data for the Crane Creek watershed provided by the 2001 NLCD. The database divides the entire watershed area into 15 different land cover categories, as described in Attachment C. Impervious cover factors were assigned to each land cover category based on a combination of impervious cover estimates made within the NLCD and guidance reported in "Impervious Cover and Land Use in the Chesapeake Bay Watershed" (Cappiella and Brown, 2001). The final impervious cover value percentages were adjusted where reasonable, to align more closely with the directly measured impervious cover values generated from GIS data layers. The following impervious cover values were used for all of the five models:

- Developed, Open Space – 9.5%
- Developed, Low Intensity – 36%
- Developed, Medium Intensity – 42%
- Developed, High Intensity – 66%

Additional assumptions for primary sources included:

- An annual average precipitation of 47 inches (SC Climatology Office, Sandhill Experiment Stn, Richland County, SC).
- Roadways were not treated as a separate land cover category, but rather, were assumed to be integrated into other categories.
- Vacant lots were assumed to be minimal in area compared to other land cover categories in the watershed; therefore, they were not considered as a separate category.
- 50% of TN, 70% of TP, 90% of TSS, and 100% of fecal coliform loads from rural and forest areas are from storm versus non-storm flow.
- A different planning horizon was calculated for each watershed target area, based on the time it would take to reach total build-out of current buildable zoning districts. A constant construction rate equal to the current rate observed in each watershed target areas was applied as the development rate.

Secondary loads are basically calculated as a product of flow and concentration. Caraco (2002) details how loads are specifically calculated for each type of secondary pollutant source. Secondary sources that were present in the watershed were quantifiable based on existing data and information provided by local government staff. Table D.1 describes input data and assumptions for secondary sources.

Table D.1. Secondary Sources and Assumptions.	
Secondary Source	**Assumption**
Nutrients in Urban Soil	Phosphorus and nitrogen values in urban soils in this part of the country were taken from a study by Haith *et al.* (1992).
General Sewage Use and Septic System Data	Data on residential septic systems was derived from the residential building and non-sewer area shapefiles (Section 5.7)
Active Construction	Active Construction values were calculated by looking at 2007 aerial photography of the Crane Creek watershed. Construction site acreage values were subtracted from the land cover categories in which the construction was occurring.
SSOs	The number of total sewer miles in the Crane Creek watershed, estimated as 114.6 miles, was obtained from the City Engineering Department. Sewer length in each of the five sub-watersheds was estimated by dividing up this total proportionally, based on the number of homes in each sub-watershed area. *Note: The wastewater treatment plant that services the Crane Creek watershed discharges effluent outside the watershed. This model does not include pollutant loads exported out of the watershed.*
CSOs	No Combined Sewer Overflow structures are present in the Crane Creek watershed.
Illicit Connections	0.1% of residential units and 10% of businesses (including 9% discharging wash water) were assumed to have illicit connections.
Channel Erosion	Because no data was available quantifying channel erosion rates specifically in the Crane Creek watershed, the WTM's default sediment loading rate from channel erosion of 500 lbs/acre/year was used. This value was derived from results of various studies of urban stream erosion (Caraco, 2002).
Lawns (Subsurface Flow)	The GIS soils layer was combined with Hydrologic Soil Group (HSG) information and used to estimate the percentage of HSG A, B, C, or D soils located within each treatment area.
Hobby Farms / Livestock / Marinas	No livestock operations, confined animal feeding operations, or marinas are known to exist in the Crane Creek watershed.
Road Sanding	Due to the mild winter climate in this part of South Carolina, road sanding is rare, thus road sanding values in the WTM model were left at 0.
Non-Stormwater Point Sources	Only one active permitted point-source discharge exists in the Crane Creek watershed, within the County portion of the Lower Crane Creek sub-watershed. Pollutant discharge values for this facility were found on EPA's Enforcement and Compliance History Online website (www.echo.gov).
Vacant Lots	Vacant lots were assumed to be minimal in area compared to other land cover categories in the watershed, therefore were not considered as a separate category.

Management Practices
The WTM models load reduction from primary and secondary sources associated with the application of treatment practices. Existing practices and future reductions associated with potential practice implementation can both be modeled. The WTM was specifically used to estimate the nitrogen, phosphorus, total suspended solid, and bacteria loads for the Crane Creek watershed, for existing watershed conditions and two estimated future build-out conditions:

1. Build-out: Status Quo - Assumes no new restoration and protection measures in the watershed (Future Management Practices equal to Existing Management Practices).
2. Build-out: with Strategies - Assumes the implementation of the 12 watershed strategies (Future Management Practices improved).

Existing Conditions
Information and data about existing management practices was provided by local government staff and through research and used to model the existing conditions in the Crane Creek watershed. Table D.2 summarizes the inputs and assumptions used for applying the existing management practices to the WTM. The "County" refers to Richland County, the "City" refers to Columbia, and the "Town" refers to Blythewood.

Table D.2. Existing Management Practices and Assumptions.

Input	Assumption
Lawn Care/Pet Waste Education	The County is the only municipality within the Crane Creek watershed that has a Pet Waste and/or Lawn Care education program. Since these education programs use outreach tools that currently reach a relatively low number of citizens (e.g., brochures and workshops), it is assumed that their effect on changing lawn care and pet waste cleanup behavior throughout the County is moderate to low.
Erosion and Sediment Control	ESC programs exist throughout the watershed with an approximate 70% program efficiency, minus various discount factors. A program efficiency of 70% is a best-case scenario of a sediment control program that emphasizes erosion control measures, including practices that limit clearing and grading or promote phased construction methods, and requires advanced erosion and sediment control measures to reduce the concentration of sediment in runoff leaving the site (Caraco, 2002). Each municipality within the watershed has varying degrees of ability to enforce good erosion and sediment control practices, therefore discount factors for the treatment areas in each municipality are slightly different.
Street Sweeping	The City is the only municipality within the Crane Creek watershed that conducts street sweeping. According to City staff, residential streets and other roadways are swept approximately monthly with a mechanical sweeper. Additionally, it is understood that no parking restrictions or special operator training are required.
Impervious Cover Disconnection	It is assumed that approximately 70% of residential homes and 25% of businesses in the entire Crane Creek watershed have roof downspouts that are not directly connected to the storm drain system.
Structural Stormwater Management Practices	Based on the Center field visits and discussions with municipality staff, it is assumed that stormwater practices within Richland County portions of the watershed treat 40% of the impervious cover, stormwater practices within the Columbia portion treat 5% of the impervious cover, and practices within Blythewood treat about 30% of the impervious cover.
Riparian Buffers	The Town and County have buffer setback requirements, but no design

Table D.2. Existing Management Practices and Assumptions.	
Input	**Assumption**
	guidance is provided and activities within the buffer are not very restrictive. The City has no riparian buffer regulations. The actual, on-the-ground riparian buffer length in each target area was calculated with aerial photography and GIS. Stream lengths within forested land cover areas were excluded from the calculations.
Catch Basin Cleanouts	None of the municipalities within the Crane Creek watershed routinely clean out catch basins on any significant level.

Future Development: Build-out: Status Quo

For the Build-out: Status Quo scenario, the WTM estimates loads assuming that all buildable areas were built out to their maximum potential, and no programmatic or pollutant management changes occur. Thus, for this run of model, future management practices were set equal to the existing management practices. Future land cover data at build-out conditions were estimated for the Crane Creek watershed as described in Attachment C, and entered into WTM. The model assumes that current zoning districts will not change over time, neither increasing nor decreasing development density permitted by current zoning.

In addition to management practices, several assumptions must be made in the WTM to characterize future new development in the watershed Table D.3 summarizes the inputs and assumptions made about new development in the WTM to model Build-out: Status Quo conditions.

Table D.3. New Development Input Data and Assumptions – Build-out: Status Quo.	
Input	**Assumption**
New Wastewater Treatment Customers	It was assumed that the ratio of buildings per acre in each unique zoning category will remain constant throughout time, thus the number of new units that will be built at build-out conditions was estimated using these ratios. All target areas in Crane Creek are at least partially serviced by sewage lines. For all the new development within the County and Town, it was therefore assumed that 5% would be serviced by septic fields and 95% would be serviced by the sewage system. In the City, it was assumed that 100% of new development would be serviced by the sewage system.
New Roads; Street Sweeping	The City is the only jurisdiction that conducts street sweeping efforts in the Crane Creek watershed. It is assumed that future development in the City will largely consist of infill/redevelopment and thus will not result in a significant increase in new roads within the city. Therefore, it is assumed that there will be no significant increase in street sweeping.
Stormwater Controls on New Development	The controls on new development inputs were based on the current stormwater programs of each of the three municipalities, which vary in water quality treatment requirements. It was assumed that in the County portions of the Crane Creek watershed, 50% of the new stormwater facilities constructed would be wet ponds and 50% would be dry extended detention ponds. In the Town, 50% would be wet ponds, 30% would be dry water quantity ponds, and 20% would be dry extended detention ponds. In the City, 60% would be dry water quantity ponds and 40% wet ponds. Each municipality also varies in terms of the percentage of new developments that will require stormwater controls and the percentage of those that will also require channel protection controls for small storms.

Future Development: Build-out: with Strategies

Assumptions about future management practices for the Build-out: with Strategies scenario are based on the implementation of watershed restoration and protection strategies outlined in this report. Table D.4 lists the future management practices and assumptions made in modeling this scenario in the WTM. Note that a greater diversity of management practices was included in this run of the model (e.g., illicit connection removal, channel protection/stabilization projects)

Table D.4. Future Management Practices and Assumptions – Build-out: with Strategies.

Input	Assumption
Lawn Care/Pet Waste Education	It was assumed that each of the three jurisdictions would implement a lawn care education program and pet waste education program. The model assumes that 25% of the population in each of these jurisdictions will be reached by these programs, through a variety of outreach methods and media outlets.
Erosion and Sediment Control	This run of the model assumed that, across all three jurisdictions, improvements would be made to E &S control inspections, installation, and maintenance. Specifically, it was assumed that 70% of development would be in compliance with E&S standards and 60% would properly install and maintain the practices.
Street Sweeping	Assumed no increase in street sweeping activity in the future.
Impervious Cover Disconnection	Assumed a 10% increase in downspout disconnections, through an education campaign for residents and a targeted campaign for businesses. Effectively, this resulted in an assumption that a total of 80% of residential homes and 35% of businesses in the entire Crane Creek watershed would have roof downspouts not directly connected to the storm drain system.
Structural Stormwater Management Practices	Several specific stormwater management retrofits to existing development in the Crane Creek watershed are proposed for the future, as described in this report. This run of the model calculated the load-reduction effect of incorporating these structural stormwater management practices in the landscape.
Riparian Buffers	It was assumed that, with the implementation of ordinances, a 100-ft. riparian buffer would be protected in future development throughout the watershed and strictly enforced by local government staff. Education of developers and citizens about activities allowed in the stream buffer would also be incorporated in the future.
Catch Basin Cleanouts	Assumed no increase in catch basin cleanout activity in the future.
Channel Protection	Several stream channel erosion control projects were identified during the Crane Creek field surveys. The length of stream channel that would be stabilized by implementing these projects in the future was input into this run of the model.
Illicit Connection Removal	It was assumed that in each of the three jurisdictions, a rigorous illicit discharge detection program would be implemented. The assumption was that 50% of the watershed would surveyed, and 100% of any illicit connections identified would be repaired.
Septic System Education	It was assumed that each of the three jurisdictions would implement a septic system education program to encourage septic users to properly maintain their septic tanks and septic fields. Simple outreach methods, such as distribution of brochures, would be used.
SSO Repair/Abatement	It was assumed that, a goal of reducing 50% sanitary sewer overflows would be *half* achieved, resulting in a 25% reduction of SSOs at any one time.

In the Build-out: with Strategies scenario, a few of the assumptions about new development were different from the status quo scenario. Table D.5 outlines those assumptions.

Table D.5. New Development Input Data and Assumptions – Build-out: with Strategies.	
Input	**Assumption**
New Wastewater Treatment Customers	Same assumptions as in Build-out: Status Quo scenario.
Septic Failure Rate	It was assumed that the failure rate of septic systems built for new development would have a much lower failure rate than for past developments. Thus, the septic failure rate was reduced from 30% to 5% of septic systems.
New Roads; Street Sweeping	Same assumptions as in Build-out: Status Quo scenario.
Stormwater Controls on New Development	Assumed that throughout the Crane Creek watershed there would be a slight shift away from using only wet and dry ponds for stormwater management. This run of the model assumes, 40% of the new stormwater facilities constructed would be wet ponds 40% would be dry extended detention ponds, and 20% bioretention. Also assumed that 90% of developments in Blythewood and Richland County will require stormwater controls and 50% of developments in Columbia will require stormwater controls in the future. And 100% of those will also require channel protection controls for small storms.

D.2. Results

Results are presented for total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and fecal coliform (FC) loads for existing and future build-out conditions.

Existing Conditions

Table D.6 shows the pollutant load estimates for existing conditions in the Crane Creek watershed and each of its five target areas. The WTM results estimate current watershed TN, TP, TSS, and FC loads as 5.2 lb/ac/yr, 0.6 lb/ac/yr, 305 lb/ac/yr, and 110 billion units/ac/yr, respectively. The results of the WTM model match closely to a 2007 evaluation of Crane Creek in which a HSPF model was used to simulate the water quality in the creek from 1998 to 2004 (Wagner, 2007). According to the 2007 report, average annual loadings over that time period estimated TN, TP, TSS, and bacteria loads as 4.9 lb/ac/yr, 0.63 lb/ac/yr, 109 lb/ac/yr, and 170 billion units/ac/yr, respectively. The higher TSS loads generated in the WTM model are primarily a result of two assumed factors: sediment loads from active construction due to poor ESC practices and enforcement, and stream channel erosion due to minimal stormwater management and lack of stream buffer enforcement.

Table D.6. WTM Existing Load Estimates for the Crane Creek Watershed.

Name	Existing Imperviousness (%)	TN (lb/acre/year)	TP (lb/acre/year)	TSS (lb/acre/year)	FC (billion/acre/yr)
Upper Crane - Richland	11.1	5.5	0.7	382.5	139.3
Lower Crane – Richland	7.7	4.8	0.5	269.8	98.8
Lower Crane - Columbia	21.2	6.7	0.9	414.4	266.8
Beasley Creek - Richland	3.4	4.8	0.5	227.1	52.9
Beasley Creek - Blythewood	2.9	4.2	0.4	223.4	48.8
Crane Creek Watershed	**8.5%**	**5.2**	**0.6**	**304.5**	**110.2**

Build-out: Status Quo

Pollutant loads for future conditions with no change in management practices are summarized for the Crane Creek watershed and each of its five target areas in Table D.7. The WTM results predict future TN, TP, TSS, and FC loads as 7.8 lb/ac/yr, 0.8 lb/ac/yr, 305.0 lb/ac/yr, and 229.4 billion units/ac/yr, respectively.

Table D.7. WTM Future Load Estimates for the Crane Creek Watershed – Build-out: Status Quo.

Name	Future Imperviousness (%)	TN (lb/acre/year)	TP (lb/acre/year)	TSS (lb/acre/year)	FC (billion/acre/yr)
Upper Crane - Richland	28.2	8.2	0.9	314.4	350.8
Lower Crane – Richland	21.1	7.5	0.8	277.7	171.0
Lower Crane - Columbia	33	8.3	1.2	522.8	340.0
Beasley Creek - Richland	16.7	7.7	0.7	253.1	126.1
Beasley Creek - Blythewood	10.7	7.2	0.8	330.5	128.6
Crane Creek Watershed	**22.7%**	**7.8**	**0.8**	**305.0**	**229.4**

Build-out: with Strategies

Pollutant loads for future build-out conditions with the implementation of improved watershed strategies recommended in this report are summarized for the Crane Creek watershed and each of its five target areas in Table D.8. The WTM results predict future TN, TP, TSS, and FC loads as 6.6 lb/ac/yr, 0.7 lb/ac/yr, 251 lb/ac/yr, and 150 billion units/ac/yr, respectively.

Table D.8. WTM Future Load Estimates for the Crane Creek Watershed – Build-out: with Strategies.

Name	Future Imperviousness (%)	TN (lb/acre/year)	TP (lb/acre/year)	TSS (lb/acre/year)	FC (billion/acre/yr)
Upper Crane - Richland	25.8	7.0	0.8	266.1	192.7
Lower Crane – Richland	18.2	6.2	0.7	234.3	128.5
Lower Crane – Columbia	31.1	7.0	1.0	431.0	273.5
Beasley Creek - Richland	14.1	6.5	0.6	208.4	92.7
Beasley Creek - Blythewood	9.4	5.8	0.6	184.9	103.1
Crane Creek Watershed	**20.2**	**6.6**	**0.7**	**250.5**	**150.0**

<u>Load Increases</u>

Tables D.9 and D.10 summarize the net increase in imperviousness and the percent increase in pollutant loads from existing to future land use conditions.

Assuming that development occurs at a steady rate, with no changes to the programmatic or watershed management practices, the WTM predicts a 51% increase in TN loads, 37% increase in TP loads, 0.2% increase in TSS loads, and a 108% increase in bacteria loads at buildout. In addition, a 14% *net* increase in impervious cover is predicted. The low TSS increase seen in the future scenario can be attributed to a lower active construction rate resulting upon build-out. When build-out conditions are reached, the rate of active construction will occur only as redevelopment or infill development. The high bacteria loading rate is largely attributed to an assumed high rate of septic system failure in the future (consistent with the assumption for existing conditions).

On the other hand, assuming that development occurs at the same steady rate and the watershed strategies recommended in this report are implemented, the WTM predicts a 27% increase in TN loads, 14% increase in TP loads, 17% decrease in TSS loads, and a 36% increase in bacteria loads at buildout. A 14% *net* increase in impervious cover is still predicted.

Table 8.9. WTM Net IC and Percent Pollutant Load Increase – Existing Conditions vs. Build-out: Status Quo.

Name	Net Increase in Imperviousness (%)	% Increase in TN	% Increase in TP	% Increase in TSS	% Increase in FC
Upper Crane - Richland	17.1	47.6%	22.9%	-17.8%	151.9%
Lower Crane – Richland	13.4	55.2%	45.7%	2.9%	73.2%
Lower Crane - Columbia	11.8	23.5%	25.5%	26.2%	27.5%
Beasley Creek - Richland	13.3	58.1%	55.1%	11.4%	138.3%
Beasley Creek - Blythewood	7.8	71.2%	76.0%	47.9%	163.7%
Crane Creek Watershed	**14.2%**	**50.7%**	**37.3%**	**0.2%**	**108.1%**

Table D.10. WTM Net IC and Percent Pollutant Load Increase – Existing Conditions vs. Build-out: with Strategies.

Name	Net Increase in Imperviousness (%)	% Increase in TN	% Increase in TP	% Increase in TSS	% Increase in FC
Upper Crane - Richland	17.1	26.6%	5.1%	-30.4%	38.3%
Lower Crane – Richland	13.4	28.6%	19.8%	-13.1%	30.2%
Lower Crane - Columbia	11.8	3.9%	7.1%	4.0%	2.5%
Beasley Creek - Richland	13.3	33.6%	27.2%	-8.2%	75.1%
Beasley Creek - Blythewood	7.8	38.1%	31.5%	-17.3%	111.5%
Crane Creek Watershed	**14.2%**	**27.1%**	**14.4%**	**-17.7%**	**36.1%**

Discussion of these results is provided in Section 7 of the main body of this report.

Attachment E – Summary of Projects

Table 1. Stormwater Retrofit Opportunities in the Crane Creek Watershed									
Site ID	**Ranked Priority**	**Location**	**Jurisdiction**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/WQv**	**Cost**
A-RRI-21A	High	Ashley Oaks	Town	Pond Repair	32.2	20	40326	100%	$71,810
E-RRI-31A	High	Longleaf Middle School	County	Pond repair, site stabilization	14.6	35	19344	100%	$15,000
E-RRI-31B	High	Longleaf Middle School	County	rain gardens	0.46	100	1586	100%	$16,653
E-RRI-32	High	Killian Park	County	Bioretention area	0.5	100	1724	91%	$16,391
G-RRI-38	High	North Spring Park	County	Bioretention area	2.7	100	9311	100%	$97,755
G-RRI-39	High	North Springs Elementary	County	Pond vegetation	N/A	N/A	N/A	N/A	$5,000
I-RRI-17A	High	W.J. Keenan High School	County	Downspout disconnection, bioretention areas	5.89	100	20312	81%	$94,786
I-RRI-17C	High	W.J. Keenan High School	County	pond modification	9.64	80	40417	100%	$5,000
K-RRI-6	High	Forst Hills Elementary School	County	Downspout disconnection, bioretentation areas	0.6	100	2069	100%	$21,725

Table 1. Stormwater Retrofit Opportunities in the Crane Creek Watershed									
Site ID	**Ranked Priority**	**Location**	**Jurisdiction**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/WQv**	**Cost**
L-RRI-9A	High	W.G. Sanders Elementary School	City	Downspout disconnection, bioretention areas	4.36	85	12899	100%	$12,899
L-RRI-9B	High	W.G. Sanders Elementary School	City	Pipe daylighting	Unknown	Unknown	Unknown	N/A	$100,000
L-RRI-10	High	Greenview Elementary School	City	Downspout disconnection, bioretention areas	1.41	100	4862	100%	$50,957
L-RRI-12	High	Meadowlakes Recreation Center	City	Bioretention area and swales	0.5	100	1724	100%	$20,602
L-RRI-100	High	Northminster Presbyterian Church	City	Bioretention area	0.79	100	2724	100%	$28,602
C-RRI-19A	Medium	Wren Creek	County	Pond Repair	7.24	20	9067	100%	$5,000
C-RRI-19B	Medium	Wren Creek	County	Pond Repair	18.8	5	9725	100%	$10,000
C-RRI-101	Medium	Koyo Industries	County	Stream restoration/stabilization, upstream treatment	43.7	40	97558	100%	$375,000
E-RRI-26	Medium	Walmart Shopping Center	County	BMP design modification	N/A	N/A	1207	100%	$5,000
E-RRI-33	Medium	Westmoreland and Robins Egg Rd	County	Pond Repair	Unknown	30	Unknown	N/A	$15,000

Table 1. Stormwater Retrofit Opportunities in the Crane Creek Watershed									
Site ID	**Ranked Priority**	**Location**	**Jurisdiction**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/WQv**	**Cost**
E-RRI-34A	Medium	Sandlapper Elementary	County	Bioretention area, downspout disconnection to rain gardens	0.56	50	1016	100%	$26,250
E-RRI-34B	Medium	Sandlapper Elementary	County	Pond repair	14.5	45	35923	100%	$5,000
F-RRI-28	Medium	Longtown Commons	County	Pond Modification, Site Stabilization	27.6	5	14277	100%	$25,387
F-RRI-29	Medium	Killian Elementary School	County	Bioretention area	1.38	50	2505	100%	$26,303
F-RRI-30	Medium	Killlian Station	County	Pond Modification	4.8	40	10716	100%	$21,408
F-RRI-35	Medium	Timberview	County	Pond repair	11.65	30	20299	100%	$15,000
G-RRI-201	Medium	The Commons of Winchester	County	Roadway bioretention retrofit	3.82	25	3813	52%	$21,000
H-RRI-24A	Medium	SC DHEC	County	Bioretention area, permeable pavement	1.55	100	5345	13%	$9,530
H-RRI-24B	Medium	HealthPort Building	County	Impervious cover removal, Bioretention area	0.69	100	2379	100%	$34,450

Table 1. Stormwater Retrofit Opportunities in the Crane Creek Watershed

Site ID	Ranked Priority	Location	Jurisdiction	Retrofit Concept	Drainage Area (ac)	Impervious Cover (%)	WQv (cf)	Tv/WQv	Cost
H-RRI-200	Medium	SC DHEC/Enterprise	County	Pond Modification, Swale	5.16	80	21634	100%	$20,000
I-RRI-7	Medium	School of Inquiry/Community Center	County	Step pools and bioretention area	1.51	77	4096	92%	$41,539
I-RRI-16	Medium	Richland Bus Maintenance	City	O/W Separators	6.36	90	19907	100%	$200,000
L-RRI-11	Medium	Greenview Park	City	Bioretention area and swales	1.54	100	5311	80%	$44,499
M-RRI-1	Medium	Eau Claire High School	City	Bioretention and slope stabilization	0.82	100	2828	27%	$8,159
M-RRI-2	Medium	Columbia College	City	Bioretention areas	2.15	100	7414	69%	$53,834
A-RRI-21B	Low	Ashley Oaks	Town	Bioretention area	0.3	100	1035	48%	$5,250
C-RRI-19C	Low	Wren Creek Community Center	County	Bioretention area	0.25	100	862	35%	$3,150
G-RRI-202	Low	The Commons of Winchester	County	Bioretention	3.08	25	3075	15%	$4,725
H-RRI-23	Low	Nationwide Insurance Building	County	Bioretention area	1.5	90	4683	80%	$39,375

Table 1. Stormwater Retrofit Opportunities in the Crane Creek Watershed									
Site ID	**Ranked Priority**	**Location**	**Jurisdiction**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/WQv**	**Cost**
K-RRI-4	Low	Sunbelt Industrial Site	County	Downspout disconnection, bioretention areas, dry swales	10.91	100	37623	54%	$222,486
L-RRI-8	Low	Pepsi Plant	County	Downspout disconnection	1.33	100	4587	100%	$4,587
M-RRI-3	Low	Alcorn Middle School	City	Bioretention areas and dry well	0.24	100	828	100%	$20,511
A-RRI-22	No Concept	Fairfield Electrical Facility	Town	None	N/A	N/A	N/A	N/A	N/A
C-RRI-20	No Concept	Northpoint Rd	County	None	N/A	N/A	N/A	N/A	N/A
F-RRI-25	No Concept	Heron Lake Apartments	County	None	N/A	N/A	N/A	N/A	N/A
F-RRI-27	No Concept	Lowes Shopping Center (clemson and longtown rd)	County	None	N/A	N/A	N/A	N/A	N/A
G-RRI-36	No Concept	Piggly Wiggly Shopping Center (clemson and Hardscrabble Rd)	County	None	N/A	N/A	N/A	N/A	N/A
G-RRI-37	No Concept	The Commons of Winchester	County	None - see R200, R201	N/A	N/A	N/A	N/A	N/A
K-RRI-5	No Concept	SCDOT Facility	County	None	N/A	N/A	N/A	N/A	N/A
L-RRI-18	No Concept	Bedford Road culvert	County	None	N/A	N/A	N/A	N/A	N/A

Table 1. Stormwater Retrofit Opportunities in the Crane Creek Watershed									
Site ID	**Ranked Priority**	**Location**	**Jurisdiction**	**Retrofit Concept**	**Drainage Area (ac)**	**Impervious Cover (%)**	**WQv (cf)**	**Tv/WQv**	**Cost**
I-RRI-14	Not Assessed	Prison/Mental Health Center	City	None - Restricted Access	N/A	N/A	N/A	N/A	N/A
I-RRI-15	Not Assessed	Prison/Mental Health Center	City	None - Restricted Access	N/A	N/A	N/A	N/A	N/A
L-RRI-13	Not Assessed	Prison/Mental Health Center	City	None - Restricted Access	N/A	N/A	N/A	N/A	N/A

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
D-RCH-1	Excellent		County		67	70	137
D-RCH-4	Excellent		County		67	70	137
E-RCH-2	Excellent	Between Cogburn Rd. and confluence of reaches 2 & 4	County	Braided stream leading into wetland patches with water lilies present; thick woods; nearby is poor storm drain inlet protection at cul-de-sac.	73	67	140
E-RCH-4	Excellent	Behind Longtown Dr. to SC-3 at Longreen	County	Braided stream; hydric soils; silt deposition; mature forest.	74	64	138
E-RCH-21	Excellent	North of Walmart on Killian Rd	County	Stream is north of the recently developed Walmart. Good floodplain and stream condition, especially in light of the new Walmart development. Good stream buffer as well. Some foam in the channel - unsure of the source.	77	68	145
E-RCH-22	Excellent	Intersection of Killian Arch and I77	County	Stream through forested area with wetland patches. Good floodplain and stream condition.	76	72	148

Table 2. Stream Reach Ratings in the Crane Creek Watershed

Site ID	Rating	Location	Jurisdiction	Description	Overall Stream Condition Score	Overall Buffer/ floodplain Score	Total Score (out of 160)
F-RCH-1	Excellent	Upstream of Clemson Rd near Fallen Leaf	County	Stable 1st order stream with wetland patches. Nice forested buffer.	77	71	148
G-RCH-3	Excellent	Markham	County	Some backyards close to stream, otherwise good buffer and floodplain.	70	65	135
G-RCH-4	Excellent	Chancery	County	Some backyards close to stream, otherwise good buffer and floodplain.	70	65	135
G-RCH-11	Excellent	Hardscrab-ble Rd	County	Expansive wetland complex	63	70	133
G-RCH-12	Excellent	Shamley Green	County	Stream has nice wetland complex.	69	69	138
H-RCH-32	Excellent	Alta Vista	County	Nice wetland, floodplain area	66	71	137
I-RCH-3	Excellent	Down-stream of gulf course	County	Stream flows through steep forested valley, bedrock and clams present, good stream and buffer/floodplain condition.	71	77	148
J-RCH-1	Excellent	Headwaters at Camp-ground Rd	County	Headwater stream that is in good condition. Stream tributary was recently dammed to create a pond. Evidence of some erosion, sedimentation, discoloration immediately downstream of pond.	76	60	136

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
J-RCH-2	Excellent	Kingfisher Rd	County	Nice headwater stream with wetlands. Utility line crosses stream, but impacts are quickly mitigated downstream.	72	69	141
J-RCH-10	Excellent	Owens Rd	County	Small stream, shallow & stable banks, wetlands along streams; gas pipeline crosses; mature woods.	73	74	147
J-RCH-11	Excellent	Owens Rd	County	Small stream, shallow & stable banks, wetlands along streams; gas pipeline crosses; mature woods.	74	76	147
M-RCH-4	Excellent	Romford Road	City	Sediment deposition. No stream visible upstream of road crossing. Kudzu present in large quantities. Downstream of road crossing is nice floodplain area with some standing water visible.	65	67	132
M-RCH-7	Excellent	Peebles Road	County	Located off Peebles road, some industrial nearby. Good buffer, no visible impacts to stream from nearby land use.	72	69	141
A-RCH-1	Good		Town	Fear of development	68	61	129
B-RCH-1	Good		Town	Adjacent sewer	68	55	123
C-RCH-5	Good		County	At sewer crossing	64	67	131

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
D-RCH-2	Good		County		56	70	126
E-RCH-1	Good	Brookhaven subdivision off Robins Egg Dr. beginning at stormwater pond	County	Headwaters buried under subdivision; very developed drainage area; new construction; stream buffer very overgrown.	68	62	130
E-RCH-3	Good	Behind elementary school and Traditions developmen t ends at confluence with Rch-2	County	Very thick undergrowth; could not access much of the reach; characterization of reach is based on SC-2; braided channels and wetlands; lots of surrounding development.	67	60	127
E-RCH-5	Good	Below confluence of reaches 2 & 4 to upstream of lake	County	Stream becomes deeper and faster flowing; powerline and gas pipeline run through start of reach; pools and riffles, point bars present; stream becoming more channelized and less braided; NICE wetland in this reach upstream of road crossing (Farrow Rd).	62	60	122

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
E-RCH-23	Good	Pines Rd and Summer Pines	County	Stream has minor sediment deposition, but is in overall decent condition. Main impact is a portion that is piped underground (CM-20).	67	64	131
F-RCH-3	Good	On the east side of Killian Station develop-ment	County	Nice stream with forested buffer and wetland patches. Evidence of sediment deposition within the channel. Good condition considering the Killian Station development and upstreamd developments.	65	66	131
G-RCH-2	Good	Kinrose	County	Some backyards close to stream. Otherwise good buffer and floodplain.	65	59	124
G-RCH-9	Good	Cane Brake	County	Storm drain outfall from residential area with brown flocculent. Large beaver wetland.	64	64	128
H-RCH-30	Good	Wilson and Hard-scrabble	County	Sewer line parallel to stream, higher flows.	63	62	125
H-RCH-31	Good	Alta Vista	County	Old trash along stream bank, aquatic mollusk shells.	63	60	123
J-RCH-12	Good	Owens Rd	County	Deeper banks with some scour; deep in woods; downstream from lake - water tannic; bad erosion at gas pipeline crossing.	61	65	126

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
K-RCH-1	Good	Peachwood Dr	County	Stream through neighborhood with trash problem (TR-1). Nice stream with good habitat, slight downcutting.	68	55	123
K-RCH-10	Good	Rockyview	County	Nice stream. Accessed via dirt road near habitat for humanity development.	67	59	126
K-RCH-11	Good	Crane Church	County	Utility access road includes stream channel. Sediment deposition from road into forest area evident. Upstream area is nice stream habitat.	65	59	124
K-RCH-12	Good	Club House Road	County	Stream channel good, utility crossing. Good buffer.	66	65	131
M-RCH-6	Good	Monticello	City	Reach off Monticello near I-20. Stream wide, with signs of bank erosion. Excessive number of tires dumped in tree area. Some sanitary sewer adjacent to stream now due to erosion.	61	67	128
M-RCH-10	Good		County		65	60	125
M-RCH-11	Good		County		61	65	126
B-RCH-2	Fair		Town	Sediment deposition in channel; turbidity.	56	50	106
B-RCH-3	Fair		County	Downcut and little algae	58	54	112
C-RCH-1	Fair	Adjacent to Hwy 77	County	Little bit of scour	57	63	120

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
C-RCH-3	Fair		County	Algae; E & S pond below confluence is under-sized; some sedimentation but not too high; pools & riffles; banks not too high.	63	54	117
C-RCH-4	Fair		County	Sedimentation; outfall from constructed wetland.	58	51	109
D-RCH-3	Fair		County		41	70	111
D-RCH-5	Fair		County		41	64	105
F-RCH-5	Fair	Intersection of Killian and Farrow	County	Stream is near the construction of a large shopping center and is receiving some suspended sediment, wetland patches, some trash, erosion downstream of Killian Rd (SC-3), and eroding dry ponds in adjacent development.	57	63	120
G-RCH-1	Fair	Kinrose	County	Stream connected to the floodplain, trash in stream from stormdrain inlets.	57	56	113
G-RCH-7	Fair	Osprey Pond	County	Small drainage that leads to lake, lots of trash in the stream (bottles, wrappers), lots of algae in the lake.	55	56	111
G-RCH-8	Fair	Mountain Laurel	County	Some trash in the stream	65	53	118

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
I-RCH-1	Fair	Wilson and Cherry Blossom Ln	County	Stream goes through area of land clearing for potential development, bank scouring, trash, 55 gal drum storage (HSI-20), stream crossing from construction equipment (SC-1), bedrock is present, sediment deposition.	52	53	105
I-RCH-2	Fair	Highland Forest Dr	County	Stream flows through back of neighborhood, downcutting, sediment deposition, bank scour, lots of trash (TR-1), bedrock present, good buffer on right bank but limited buffer on left bank.	63	57	120
I-RCH-10	Fair	Oak Hills Golf Course	County	Nutrient-rich water, but stable banks; minnows & frogs.	62	51	113
J-RCH-3	Fair	Dubard Boyle Rd (upstream)	County	Lots of trash along stream reach, and dumping site at top of reach. Stream bottom is sand, then bedrock, then cobble, then sand/silt. Buffer impacts along left bank. Homeowner ditches convey stormwater to stream at lower reach. Lots of Crayfish observed in reach.	67	51	118

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
J-RCH-4	Fair	Dubard Boyle Rd (upstream)	County	Lots of erosion in channel, past downcutting evident, particularly near confluence with RCH-J3.	56	50	106
J-RCH-5	Fair	Dubard Boyle Rd (downstream)	County	Some scattered trash, erosion along RCH. Stream is slightly entrenched.	52	59	111
J-RCH-13	Fair	Owens Rd	County	Steep banks - from legacy land use; sandy and gravel bottom; sinuous; pine plantations.	51	63	114
K-RCH-2	Fair		County	Sedimentation	55	56	111
L-RCH-4	Fair	Torwood	County	Illegal dumping from homes - large mounds of grass and organic matter.	60	45	105
L-RCH-6	Fair	Meadow-lake Park	City	Stream flows through park and by correctional facility. Invasives present in buffer. Dumping in park, including sand and dirt piles, as well as barrels and barrel lids. Elevated sewer line crossing.	59	49	108

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
L-RCH-9	Fair	Location off of Route 21	County	Opaque color possibly due to construction at church and uncovered material piles. However, opaque color was noted even at beginning headwaters near school on David Road. Opaque color found across road and flowing through wetland area.	62	53	115
M-RCH-3	Fair	Pinner (downstream)	City	Light residential adjacent. Buffer has some invasives. Utility corridor on right bank about 12 foot from stream edge.	50	55	105
B-RCH-4	Poor		County	Steep erodible banks; some turbidity.	45	53	98
B-RCH-5	Poor		County	More siltation than other streams in area.	44	53	97
B-RCH-6	Poor		County		50	53	103
C-RCH-2	Poor	Koyo Industries	County	Industrial Park; bad erosion; uncontrolled stormwater.	26	48	74

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
E-RCH-20	Poor	Killian Arch	County	Nice streams and wetland patches throughout what appears to be an abandoned development site (Killian's Crossing). Would make an nice greenspace if it wasn't going to be developed. Main problem is trash throughout site (TR-20).	61	37	98
F-RCH-2	Poor	Upstream of Clemson Rd and downstream of RCH-1	County	Forested land on the left bank and housing development at the right bank. Evidence of high flows with several foot bridges turned sideways. Moderate sediment deposition within the channel. Homeowners mow to the edge of the right bank (IB-1). Paint storage next to channel in one of the backyards (F-HSI30).	59	43	102
G-RCH-10	Poor	Sloan Road	County	Trash in stream	53	44	97
G-RCH-13	Poor	Yellow Flag	County	Nice floodplain	54	46	100
I-RCH-11	Poor	Oak Hills Golf Course	County	Downstream from big lake - tannic water; some bank scour; 1/2 of reach is on golf course - no vegetation, significant algae.	44	37	81

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
L-RCH-1	Poor	Torwood	County	Found suds in stream, traced back to possible source at auto shop. Small buffer area on left bank with backyards within short distance to stream. Trash found in locations along stream, each site small in size but overall trash removal (stream walk) may result in several pick-up bed loads.	50	40	90
L-RCH-2	Poor	Torwood	County	Found suds in stream, traced back to possible source at auto shop. Small buffer area on left bank with backyards within short distance to stream. Trash found in locations along stream, each site small in size but overall trash removal (stream walk) may result in several pick-up bed loads.	55	41	96
L-RCH-3	Poor	Torwood	County	Found suds in stream, traced back to possible source at auto shop. Trash found in locations along stream, including several automobiles found in the buffer adjacent to the stream. Autos assumed to be part of auto shop that is also likely suds source.	57	42	99

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
L-RCH-5	Poor	Meadowlake	County	Sewer pipe crosses stream below road crossing and barely above water level. Likely acting as trash rack in large storms. Downstream side of road crossing has failing wall with cracks (see photo). Lareg amount of sediment deposited at crossing. Mowed buffer down to channel edge on left bank.	50	30	80
L-RCH-7	Poor	Greenview Park	City	Stream flows through park. Invasives present in buffer. Small buffer present where park and adjacent neighborhood meet. Some trash material in stream.	57	38	95

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
L-RCH-8	Poor	Sinclair	County	Stream flows through backyards. No much buffer, and occasionally fencing on banks failing due to erosion. Several pipes (likely yard drainage) entering stream. Sediment deposition at several road crossings. Interesting sewer line crossing where hole punched into pipe to allow sewer line to cross. Line now acting as trash rack that catches large debris and could result in culvert clog.	50	33	83
M-RCH-1	Poor	Carola Drive	City	Typical urban stream. 2 shopping carts, large amounts of trash. Appears to be some kind of gauging stations at road crossing on Carola. 12" sanitary line leaking into stream. Large number of utility line crossings.	42	60	102

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
M-RCH-2	Poor	Pinner (upstream)	City	Part of stream buffer slated for park development. Stream will be riprapped on right bank to prevent further loss of backyards and fencing. Possible illicit discharge detected, but could be flowing groundwater. Residential trash throughout reach suggest a stream cleanup. Residential encroachment into buffer.	43	52	95
M-RCH-5	Poor	Buckner Road	City	Reach off buckner road near I-20. Banks extremely deep. Stream accessible by utility access road.	51	49	100
F-RCH-4	Very Poor	Intersects Winslow Rd	County	Channel is impacted from surrounding development - sediment deposition, channel erosion (ER-1), steep banks, minimal buffer.	35	33	68
G-RCH-6	Very Poor	Lightwood Knot	County	Stream through a residential park. No stream buffer. Evidence of past erosion problems due to heavy riprap. Stream drains to a lake.	17	11	28

Table 2. Stream Reach Ratings in the Crane Creek Watershed							
Site ID	**Rating**	**Location**	**Jurisdiction**	**Description**	**Overall Stream Condition Score**	**Overall Buffer/ floodplain Score**	**Total Score (out of 160)**
K-RCH-13	Very Poor	Utility Line	County	Utility access road includes stream channel. Active bank erosion, lots of sediment deposition.	22	19	41
M-RCH-20	Very Poor	Brickyard	County	Numerous invasives, trash, no buffer on right bank due to road.	36	32	68

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
C-ER-1	C-RCH-2	High	Koyo Industries	County	Erosion	Not formally assessed	Stream restoration	$$$
E-SC-1	E-RCH-1	High	Cogburn Rd.	County	Trash	Tires and trash in stream; silt fence still in place - should be removed.	Stream cleanup	$
F-IB-1	F-RCH-2	High	Northern portion of Winslow Rd near the channel	County	Buffer	Homeowners mow to the edge of the channel.	Riparian reforesta-tion	$
F-TR-1	F-RCH-2	High	Just upstream of Clemson Rd	County	Trash	Small amount of illegal dumping and trash accumulation at outfall, including plastic, paper, and metal equipment.	Stream cleanup	$
G-IB-2	G-RCH-6	High	Lightwood Knot	County	Buffer	Stream through a residential park. No stream buffer. Evidence of past erosion problems due to heavy riprap. Stream drains to a lake.	Riparian reforesta-tion	$
G-IB-3	G-RCH-3	High	Chancery	County	Buffer	Residential stream encroachment.	Riparian reforestati on	$
G-OT-1	G-RCH-1	High	Kinrose	County	Outfall	Outfall has excessive algal growth in pipe and discharge potentially from fertilizers.	Discharge inspection; residential education	$
G-TR-1	G-RCH-1	High	Kinrose	County	Trash	Large amount of trash in stream and floodplain.	Stream cleanup	$
G-TR-2	G-RCH-1	High	Kinrose	County	Trash	Fertilizer bag in stream.	Stream cleanup	$

[1] $: Estimated Planning Level Cost < $2,000
$$: Estimated Planning Level Cost $2,000-$8,000
$$$: Estimated Planning Level Cost > $8,000

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
G-TR-4	G-RCH-10	High	Sloan Road	County	Trash	Large amount of trash in floodplain and upland of stream.	Stream cleanup	$
I-IB-11	I-RCH-11	High	Oak Hills Golf Course	County	Buffer	Oak Hills Golf Course does not have any buffer (not even tall grass) on this stream (or other streams?) on course.	Riparian reforesta-tion	$
I-TR-1	I-RCH-2	High	Highland Forest Dr	County	Trash	Stream flows through back of a neighborhood, lots of dumping of car parts, clothes, appliances, garbage, etc throughout the entire RCH2.	Stream cleanup	$
J-TR-1	J-RCH-3	High	Heron Ridge Neighbor-hood	County	Trash	Stream flows through back of a neighborhood, lots of dumping of household materials, appliances. Trash in stream is backing up water and causing a head cut to form. Downstream RCH is scattered with trash including automotive, tires.	Stream cleanup	$
K-TR-1	K-RCH-1	High	Swan Ln. and Blue Ridge Ter.	County	Trash	Trash scattered throughout reach, clothes, plastic, tires, paper, glass, mattresses, construction materials (filled bags of concrete).	Stream cleanup	$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
L-IB-1	L-RCH-3	High	Torwood	County	Buffer	Residential stream encroachment. Buffer area inadequate due to backyards within 10 feet of stream.	Natural regenera-tion	$
L-IB-2	L-RCH-2	High	Torwood	County	Buffer	Residential stream encroachment. Buffer area inadequate due to backyards within 10 feet of stream.	Natural regenera-tion	$
L-IB-3	L-RCH-5	High	Meadow-lake	County	Buffer	Mowing from homeowner property is encroaching on stream reach.	Riparian reforesta-tion	$
L-IB-4	L-RCH-8	High	Sinclair	County	Buffer	Residential stream encroachment. Buffer area inadequate due to backyards within 10 feet of stream.	Invasive plant removal	$
L-TR-1	L-RCH-3	High	Torwood	County	Trash	Stream flows through back of a neighborhood, lots of dumping of household materials, appliances. Trash scattered throughout reach.	Stream cleanup	$
L-TR-2	L-RCH-4	High	Torwood	County	Illegal Dumping	Yard waste dumping location. Reported to county solid waste division through Richland County SW personnel .	Stream cleanup	$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
M-IB-1	M-RCH-2	High	Pinner Road	City	Buffer	Residential stream encroachment. Buffer area inadequate due to backyards within 10 feet of stream.	Invasive plant removal; riparian reforesta-tion	$
M-IB-2	M-RCH-20	High	Brickyard Road	County	Buffer	Residential stream encroachment. Buffer area inadequate due to backyards within 10 feet of stream.	Invasive plant removal	$
M-TR-1	None	High	Hodges Drive	County	Trash	Accumulation of residential garbage from illegal dumping.	Stream cleanup	$
M-TR-2	M-RCH-2	High	Pinner Road	County	Trash	Residential trash from neighborhood dumped in stream. Some trash due to erosion of backyards into stream.	Stream cleanup	$
A-ER-1	None	Medium	Ashley Oaks	Town	Erosion	Not formally assessed	Bank Stabilization, Natural regenera-tion	$$
B-ER-1	B-RCH-4	Medium		County	Erosion	Not formally assessed	Bank stabiliza-tion	$$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
D-TR-1	D-RCH-1	Medium	Wetland	County	Trash	Vehicles dumped on wetlands slew/small tribs. Wetland is less than 200 ft from Beasley creek. Easily accessible by dirt road. Parts extracted and strong automotive fluid smell. Likely owned by adjacent private residence/commercial property.	Stream cleanup	$$
E-SC-2	E-RCH-3	Medium	Spring Park Rd. near Longreen intersection	County	Water Quality	Algae; slight erosion on embankments.	Bank stabilization	$
E-SC-3	E-RCH-4	Medium	Longreen Rd.	County	Trash, Water Quality	Silt fence is still in place and should be removed; tires in stream on upstream side; flow constricted by culverts; algae present.	Stream cleanup	$
E-SC-6	E-RCH-5	Medium	Pines Rd.	County	Stream Crossing	Gas pipeline on downstream side of culvert; trucks have been going through stream and creating ruts.	Use hand labor instead of mechanical	$
E-TR-20	E-RCH-20	Medium	Killian Arch	County	Trash	Illegal dumping from homes - old appliances, decorations, etc; several filled bags of turf fertilizer.	Stream cleanup	$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
F-MI-1	F-RCH-3	Medium	Entrance to Killian Station develop-ment	County	Miscell-aneous; wetland ditching	Appears that wetland was drained using several ditches and vegetation was cleared to make way for the development. Banks of the ditches are eroding badly, with significant sedimentation downstream.	Stream restoration E & S control; plantings	$$
F-SC-3	F-RCH-5	Medium	Crossings Commun-ity Church	County	Stream Crossing	Erosion at downstream side of road crossing - bank scour, downcutting, steep channel slope; construction site upstream (in front of Lowes) contributing significant amounts of clay to the ditch; fish barrier.	Stream restoration bank stabiliza-tion at outfall; E & S control at Lowe's	$$$
F-SC-4	F-RCH-5	Medium	Intersec-tion of Farrow Rd and Longtown	County	Stream Crossing	Road crossing with erosion problems around culvert; consider reconstructing wetland upstream of culvert or replacing culvert.	Culvert replaceme nt	$$
G-MI-1	G-RCH-9	Medium	Cane Brake	County	Miscella neous-algae	Brown algal flocculant discharging to stream from residential outfall.	Discharge inspection	$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
I-SC-1	I-RCH-1	Medium	Marob Ct	County	Stream Crossing	Path directly through the channel where trucks cross for construction purposes.	Temporary stream crossing	$
J-ER-11	J-RCH-11	Medium	Owens Rd. (gas pipeline)	County	Erosion	Gas pipeline crosses several streams without any protection for stream crossing and no vegetation to hold banks.	Bank stabiliza-tion	$
J-ER-12	J-RCH-12	Medium	Owens Rd. (gas pipeline)	County	Erosion	Gas pipeline crosses several streams without any protection for stream crossing and no vegetation to hold banks.	Bank stabiliza-tion	$
J-IB-1	J-RCH-3	Medium	Heron Ridge Neighbor-hood	County	Buffer	Mowing from homeowner property is encroaching on stream reach.	Riparian reforesta-tion	$
K-IB-1	K-RCH-13	Medium	Utility corridor off Club House road	County	Buffer	No buffer due to utility access road. Heavy erosion.	Riparian reforesta-tion	$
K-SC-2	K-RCH-1	Medium	Peach-wood Dr	County	Trash	Road crossing with minimal impacts, except for trash; road inlets clogged with organics.	Stream cleanup	$
K-SC-3	K-RCH-11	Medium	Utility corridor off Crane Church road	County	Erosion, fish barrier	Utility access road crosses stream and prevents stream flow. Sediment present in downstream channel after road crossing.	Remove fish barrier	$$$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
L-SC-1	L-RCH-5	Medium		County	Utility	Road crossing - utility crossing. Downstream sewer pipe is acting as a trash collector.	Culvert repair / Replace-ment	$$$
M-UT-1	M-RCH-1	Medium	Carola Road	City	Illicit Dis-charge	Pipe leaking to stream. Reported to City Public Works. Repairs started same day.	Discharge inspection	$
E-SC-22	E-RCH-21	Low	Intersec-ion of Davis Smith and Killian Arch	County	Stream Crossing	Road crossing culvert is almost completely submerged and has an unknown foam on the water surface.	Discharge inspection	$
E-SC-5	E-RCH-5	Low	Farrow Rd just down-stream of significant wetland	County	Stream Crossing	Sediment deposition just downstream of culvert; partial fish barrier.	Fish barrier removal	$$$
F-ER-1	F-RCH-4	Low	Just upstream of Winslow Rd inter-section with RCH-4	County	Erosion	Approximately 10ft high steep banks that are eroding - starting to scour at backyards, under fences, and exposed PVC sewer pipe is exposed on bottom of stream.	Bank stabiliza-tion	$$$
K-OT-1	K-RCH-1	Low	Sandpiper Lane	County	Outfall	Outfall is draining a road cul-de-sac, erosion down a steep slope to the stream, looks like flow bypasses the road inlet and goes down the hill.	Outlet stilling pond	$

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
M-SC-1	None	Low	Denny Road	County	Stream Crossing	Invasives, small buffer, plunge pool acting as fish barrier.	Culvert removal	$$$
E-CM-20	E-RCH-23	N/A	Bonbon Rd	County	Channel Modifi-cation	Channel is underground in utility easement with inlets in backyards. Appears to be minor flooding issues. Discharges to a small stretch of rip-rap channel and then back into natural stream.	Not a restoration project	N/A
E-SC-20	E-RCH-20	N/A	Killian Arch	County	Stream Crossing	Road crossing through abandoned development site (Killian's Crossing).	Not a restoration project	N/A
E-SC-21	E-RCH-22	N/A	Intersection of Killian Arch and I77	County	Stream Crossing	Road crossing with minimal stream impacts.	Not a restoration project	N/A
E-SC-23	E-RCH-22	N/A	Summer Pines Rd	County	Stream Crossing	Road crossing with no apparent impacts, downstream discharges to a pond with algal growth.	Not a restoration project	N/A
E-SC-24	E-RCH-23	N/A	Vintage Pine Rd	County	Stream Crossing	Road crossing in new development, good ESC at inlets, nice wetland area.	Not a restoration project	N/A

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
E-SC-4	E-RCH-5	N/A	Powerline near Landon Place subdivision	County	Stream Crossing	Powerline crossing directly through stream; no infrastructure present.	Not a restoration project	N/A
F-OT-1	F-RCH-2	N/A	Upstream portion of RCH-2 near Moss Field Rd	County	Outfall	Moderate sedimentation in the channel, but no specific sedimentation or erosion coming from outfall.	Not a restoration project	N/A
F-OT-2	F-RCH-3	N/A	Entrance to Killian Station development	County	Outfall	Red algae or iron bacteria stains at outfall - probably due to drainage from a previous wetland area (MI-1).	Not a restoration project	N/A
F-SC-1	F-RCH-2, F-RCH-3	N/A	Clemson Rd	County	Stream Crossing	Some sediment deposition at road crossing.	Not a restoration project	N/A
F-SC-2	F-RCH-5	N/A	Inter-section of Longtown Commons and Longreen	County	Stream Crossing	Road crossing through wetland area, lots of algae, receives water from detention pond at construction site and wetland area.	Not a restoration project	N/A
F-SC-5	F-RCH-5	N/A	Intersection of Killian and Farrow	County	Stream Crossing	Road crossing with culvert over halfway submerged; wetland areas present (especially on downstream side)	Not a restoration project	N/A
I-OT-1	I-RCH-1	N/A	Cherry Blossom Ln	County	Outfall	12" pvc discharge pipe from the pond. Stream does not enter pond - it collects drainage from another small channel.	Not a restoration project	N/A

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
I-OT-2	I-RCH-1	N/A	Marob Ct	County	Outfall	Plastic pipe draining part of the development, moderate sediment deposition within the pipe, sediment deposition continues downstream.	Not a restoration project	N/A
I-OT-3	I-RCH-2	N/A	Highland Forest Dr	County	Outfall	Metal pipe that appears to have past erosion problems, but has since been stabilized with rip-rap.	Not a restoration project	N/A
K-MI-1	K-RCH-1	N/A	LMK 36	County	Miscell-aneous (algae)	Pipe standing high out of the bank, flow is a trickle and causing algae growth, potentially an old pond drain at the top of the hill.	Not a restoration project	N/A
K-SC-1	K-RCH-1	N/A	Blue Ridge Ter	County	Stream Crossing	Road crossing - downstream pipe is almost completely submerged.	Not a restoration project	N/A
L-CM-1	L-RCH-1	N/A	Penrose	County	Channel Modifi-cation	Concrete channel leading to outfall where riprap of channel has occurred. Concrete channel appears to be old infrastructure, since storm drain inlet is located at beginning of channel.	Not a restoration project	N/A
L-SC-3	None	N/A		City	Stream Crossing	Road crossing - no impacts	Not a restoration project	N/A

Table 3. Stream Impacts in the Crane Creek Watershed								
Site ID	**Stream Reach**	**Ranking Priority**	**Location**	**Jurisdiction**	**Impact**	**Description**	**Proposed Practice**	**Cost[1]**
L-SC-4	None	N/A		City	Stream Crossing	Road crossing - no impacts	Not a restoration project	N/A
L-SC-6	None	N/A		City	Stream Crossing	Road crossing - turbid water	Not a restoration project	N/A
L-SC-7	None	N/A		County	Stream Crossing	Road crossing - no impacts	Not a restoration project	N/A

Table 4. Hotspot Management Opportunities in the Crane Creek Watershed

Site ID	Ranking Priority	Location	Jurisdiction	Type of Hotspot	Description	Opportunity	Status (Confirmed, Potential, Not)	Estimated Cost[2]
E-HSI-1	High	Walmart	County	Outdoor storage	Storage area directly connected and draining to storm water pond.	Secondary containment	Potential	$
E-HSI-3	High	Dollar General	County	Outdoor storage	Trash piled next to dumpster, likely source is neighborhood dumping.	Trash clean up	Not	$
F-HSI-3	High	Midlands Honda	County	Vehicle Operations, Outdoor Material Storage	Vehicles washed, soap suds evident, some outdoor material storage 55 gallon drums, evidence of oil leaks from stored vehicles.	Catch basin retrofit (washing area)	Confirmed	$$$
I-HSI-1	High	Capitol City Towing	County	Vehicle Operations, Outdoor Material Storage	Vehicles and parts stored outside and uncovered, no secondary containment.	Secondary containment, material storage	Confirmed	$$

[2] $: Estimated Planning Level Cost < $5,000
$$: Estimated Planning Level Cost $5,000-$10,000
$$$: Estimated Planning Level Cost > $10,000

Table 4. Hotspot Management Opportunities in the Crane Creek Watershed

Site ID	Ranking Priority	Location	Jurisdiction	Type of Hotspot	Description	Opportunity	Status (Confirmed, Potential, Not)	Estimated Cost[2]
I-HSI-2	High	North Columbia Auto Salvage	County	Vehicle Operations, Outdoor Material Storage	Vehicles and parts stored outside and uncovered, no secondary containment.	Secondary containment, material storage	Confirmed	$$
I-HSI-20	High	Hastings Pt	County	Outdoor Material Storage	55 gallon drums stored outside next to stream in residential area without labels. Drums are full and closed, but are rusting.	Secondary containment, coverage	Not	$
K-HSI-3	High	Plinkington Advanced Technologies	County	Waste Management/ Outdoor materials	construction materials stored outside, rusted 55 gallon drums.	Secondary containment, material storage	confirmed	$
K-HSI-4	High	1 Sunbelt Court	County	Outdoor Materials	Paint stored outside without secondary containment, leaking from containers.	Material storage	confirmed	$

Table 4. Hotspot Management Opportunities in the Crane Creek Watershed								
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Type of Hotspot**	**Description**	**Opportunity**	**Status (Confirmed, Potential, Not)**	**Estimated Cost[2]**
M-HSI-1	High	Flying J Gas Station	City	Vehicle Operations, Waste Management	Vehicles stored and repaired onsite. Garbage dumped into ditch at end of parking lot. Large eroded pit with trash that leads to the stormwater pond.	Trash clean up, secondary containment, stabilization (pond repair)	confirmed	$
M-HSI-2	High	Truck Supply of SC	City	Outdoor Materials	Construction materials (gravel, stone) stored on site without secondary containment or cover and directly connected to storm drain.	Secondary containment, tarp coverage	confirmed	$
M-HSI-3	High	Solito Marble & Tile Monticello Industrial Park	City	Waste Management	Dumpster with no lid, overflowing.	Add dumpster lid	Confirmed	$
M-HSI-4	High	Junk Yard on Peebles	County	Vehicle Operations	Cars repaired and stored, located near a stream.	Secondary containment, material storage	Confirmed	$$

Table 4. Hotspot Management Opportunities in the Crane Creek Watershed								
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Type of Hotspot**	**Description**	**Opportunity**	**Status (Confirmed, Potential, Not)**	**Estimated Cost[2]**
A-HSI-1	Medium	Accutech	County	Outdoor Material Storage	55 gallon drums stored outside without labels and some missing lids.	Secondary containment, coverage	Not	$
C-HSI-2	Medium	Roysons Blythewood Automotive	County	Vehicle Operations, Outdoor Material Storage	Vehicles and parts stored outside and uncovered.	Secondary containment, material storage	Potential	$$
E-HSI-2	Medium	Sandlapper Elementary	County	Outdoor storage	Grease barrel is stored uncovered.	Material storage	Potential	$
F-HSI-30	Medium	Residential Property	County	Outdoor Material Storage	Homeowner storage of paint and building materials next to stream.	Clean up	Not	$
H-HSI-3	Medium	Exxon Quick Stop	County	Outdoor Material Storage	Grease bin is open and overflowing, wash water stored outside.		Not	$
H-HSI-4	Medium	Enterprise Car Rental	County	Outdoor storage	Trash piled next to fence.	Trash clean up	Not	$
H-HSI-21	Medium	Richland County DPW	County	Vehicle Operations, Outdoor Material Storage	Large dirt piles lacking containment, uncertain vehicle wash discharge.	Secondary containment, wash area	Not	$$$

Site ID	Ranking Priority	Location	Jurisdiction	Type of Hotspot	Description	Opportunity	Status (Confirmed, Potential, Not)	Estimated Cost[2]
H-HSI-22	Medium	Auto Salvage Yard next to DPW	County	Vehicle Operations, Outdoor Material Storage	Major outside storage of vehicles and parts.	Secondary containment, material storage	Potential	$$
I-HSI-16	Medium	Richland County School Bus Maintenance	City	Vehicle Operations, Outdoor Material Storage, Waste Management, Physical Plant	Old buses and 55 gallon drums stored outside; liquids from vehicle maintenance flow from building to parking lot oil leakage from both new and old buses evident.	Retrofit (WQ filter), clean up	Confirmed	$$$
K-HSI-5	Medium	Industrial Equipment Rental	County	Outdoor Materials	Batteries and 55 gallon drums stored outside with no cover.	Partial storage	Not	$
K-HSI-6	Medium	GTG	County	Outdoor Materials	Fuel tank with no secondary containment or labels.	Secondary containment	Not	$
L-HSI-10	Medium	Piggly Wiggly	City	Waste Management	Overflowing dumpster with trash on the ground.	Trash clean up	Not	$

Table 4. Hotspot Management Opportunities in the Crane Creek Watershed

Table 4. Hotspot Management Opportunities in the Crane Creek Watershed								
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Type of Hotspot**	**Description**	**Opportunity**	**Status (Confirmed, Potential, Not)**	**Estimated Cost[2]**
L-HSI-11	Medium	Dollar Store Shopping Center	City	Outdoor Materials	Construction equipment and materials stored on site with no cover.	Tarp coverage	Not	$
H-HSI-20	Low	M.B. Kahn	County	Outdoor Material Storage	Construction equipment and machinery stored outside, as well as materials - storage tanks, diesel fuel tank, 55 gallon drums, etc.	Secondary containment, material storage	Potential	$$
L-HSI-20	Low	B&B Enterprises	County	Vehicle Operations, Outdoor Material Storage	Vehicles and parts stored outside and uncovered.	Secondary containment, material storage	Not	$$

Table 5. Neighborhood Source Control Opportunities in the Crane Creek Watershed							
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost [3]**
B-NSA-9	High	Lorick Rd	County	High	Low	Landscaping/tree planting	$
C-NSA-3	High	Beasley	County	High	Moderate	ESC for infill, storm drain stenciling, increased landscaping/tree planting	$
C-NSA-5	High	Enclave	County	Moderate	Low	Pet waste education, tree planting	$
C-NSA-6	High	Stonington	County	Moderate	Moderate	Landscaping/tree planting in common space, storm drain stenciling, tree planting throughout neighborhood, better ESC for infill	$
G-NSA-13	High	Fishers Shore	County	Moderate	Low	Potential rain gardens,	$
K-NSA-2	High	Lincoln-shire	County	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling rain gardens	$
A-NSA-2	Medium	Ashley Oakes 2	Town	Moderate	Moderate	Rain gardens, storm drain stenciling, ESC for infill, cul-de-sac retrofits	$$$
D-NSA-7	Medium	Heritage Hills	County	Moderate	Moderate	Rain gardens, cul-da-sac retrofits, storm drain stenciling	$$$
D-NSA-8	Medium	Palmetto Palms	County	Moderate	Low	Landscaping/tree planting	$

[3] $: Estimated Planning Level Cost < $5,000
$$: Estimated Planning Level Cost $5,000-$20,000
$$$: Estimated Planning Level Cost >$20,000

Table 5. Neighborhood Source Control Opportunities in the Crane Creek Watershed							
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost [3]**
E-NSA-1	Medium	Traditions	County	Moderate	Low	Landscaping/tree planting, storm drain marker repair	$
E-NSA-2	Medium	Vineyard Crossings/ Rivendale	County	Moderate	Low	Landscaping/tree planting, storm drain marker repair, ESC problems	$$
E-NSA-4	Medium	Brook Haven	County	Moderate	Low	Landscaping/tree planting, storm drain marker repair	$
E-NSA-6	Medium	Holly Ridge	County	Moderate	Low	Landscaping/tree planting, downspout redirection	$
F-NSA-2	Medium	Killian Station	County	Moderate	Low	Landscaping/tree planting, better ESC for infill	$
F-NSA-3	Medium	Hester Woods	County	Moderate	Low	Landscaping/tree planting	$
F-NSA-8	Medium	Ashley Hall	County	None	Moderate	Minimal downspout disconnection	$
G-NSA-2	Medium	Carriage Oaks	County	Moderate	Moderate	Nutrient management, rain gardens, limited downspout disconnection, wide street retrofits	$$
G-NSA-5	Medium	Elders Pond	County	Moderate	Low	Plant trees	$
G-NSA-14	Medium	Lightwood Knot	County	None	Low	Buffer planting along eroded stream	$
H-NSA-22	Medium	Jasmine Place	County	Moderate	Moderate	Landscaping/tree planting, storm drain stenciling, rain gardens	$$
H-NSA-23	Medium	Ida Rd	County	Moderate	Low	Landscaping	$

Table 5. Neighborhood Source Control Opportunities in the Crane Creek Watershed							
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost [3]**
H-NSA-24	Medium	Nina Lee/ Boyleston/ Ted	County	Moderate	Low	Landscaping	$
H-NSA-25	Medium	Fairlawn	County	Moderate	Low	Landscaping, storm drain stenciling	$
H-NSA-26	Medium	Summer-hill	County	Moderate	Moderate	Landscaping, storm drain stenciling	$
I-NSA-1	Medium	Northgate	County	Moderate	Low	Landscaping/tree planting, storm drain markers / stenciling battery stored in front yard	$
I-NSA-2	Medium	Crane Crossing	County	Moderate	Low	Landscaping/tree planting, storm drain markers / stenciling	$
I-NSA-3	Medium	Hastings Point	County	Moderate	Low	Landscaping/tree planting, storm drain markers / stenciling, cover sand piles	$
L-NSA-1	Medium	Hollywood Hills	County	Moderate	Low	Landscaping/tree planting, storm drain markers/stenciling	$
L-NSA-2	Medium	Hollywood Hills	County	Moderate	Low	Landscaping/tree planting, storm drain markers / stenciling	$
L-NSA-20	Medium	Westmore/ Gavilan	City	Moderate	Low	Bioswale in road ditches	$$
L-NSA-3	Medium	Meadow-lake Hills	County	Moderate	Low	Landscaping/tree planting, storm drain markers / stenciling	$
M-NSA-10	Medium	Dorcester	County	Moderate	Low	Plant bare patches in lawn	$

Table 5. Neighborhood Source Control Opportunities in the Crane Creek Watershed							
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost [3]**
A-NSA-1	Low	Ashley Oakes 1	Town	Moderate	Moderate	Rain gardens, bioretention in turf cul-da-sacs, storm drain stenciling	$$$
C-NSA-4	Low	Wren Creek	County	Moderate	Moderate	Rain barrels, storm drain stenciling, retrofit potential at community center	$$
E-NSA-3	Low	Mason Ridge / Thomaston	County	None	Low	Landscaping/tree planting, storm drain marker repair, sediment in some curb & gutter systems, storm water pond maintenance	$$
E-NSA-5	Low	Ashley Ridge	County	Low	Low	landscaping/tree planting, storm drain markers / stenciling	$
E-NSA-7	Low	Landon Place	County	None	Low	Some areas still under construction, landscaping/tree planting, storm drain stenciling	$
F-NSA-1	Low	Killian Green / Villages at Lakeshore	County	Moderate	Low	Landscaping/tree planting, bioretention in open space island	$$$
F-NSA-4	Low	Timber-vale	County	Moderate	Moderate	Bioretention in cul-da-sacs, tree planting, dry pond outfall repair	$$$
F-NSA-5	Low	Ashley Ridge/Win slow	County	None	Low	landscaping/tree planting, storm drain markers / stenciling	$

Table 5. Neighborhood Source Control Opportunities in the Crane Creek Watershed							
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost [3]**
F-NSA-6	Low	Heather-green	County	None	Low	Some areas still under construction, landscaping/tree planting, storm drain markers / stenciling	$
F-NSA-7	Low	Whitehurst	County	None	Low	Landscaping/tree planting, storm drain markers / stenciling	$
G-NSA-1	Low	Gatewood	County	None	Low	Plant trees in common area and lots, retrofit of common area parking lot, wide street retrofits	$$
G-NSA-10	Low	Lockleven	County	None	Low	Retrofit stormwater pond, trash in drainage ditch, disconnection of garage downspouts	$$
G-NSA-11	Low	Seton Hall	County	None	Low	Storm drain stenciling	$
G-NSA-12	Low	Green Springs Drive	County	None	Moderate	Lawn alternatives, plant more trees	$
G-NSA-3	Low	Ridge Trail	County	Moderate	Moderate	Non-target irrigation in common area	$
G-NSA-4	Low	Brookfield	County	None	Low	Minimal downspout disconnection, wide road retrofits	$$
G-NSA-6	Low	Markham	County	None	Moderate	Rain gardens	$
G-NSA-7	Low	Parsons Mill	County	None	Low	Fertilizer education	$
G-NSA-8	Low	Rains-borough	County	None	Low	Wide road retrofits, rain gardens, storm drain stenciling	$$

Table 5. Neighborhood Source Control Opportunities in the Crane Creek Watershed							
Site ID	**Ranking Priority**	**Location**	**Jurisdiction**	**Pollution Severity**	**Restoration Potential**	**Opportunity**	**Cost** [3]
H-NSA-20	Low	Twin Eagle	County	None	Low	Rain barrels, storm drain stenciling	$
H-NSA-21	Low	The Fairways	County	None	Moderate	Parking lot retrofit, storm drain stenciling	$$
I-NSA-4	Low	Highland Forest	County	None	Low	Landscaping/tree planting, storm drain stenciling	$
J-NSA-1	Low	Heron Ridge	County	None	Low	Landscaping/tree planting, storm drain markers / stenciling	$
K-NSA-1	Low	Rockgate	County	None	Low	Landscaping/tree planting, storm drain markers / stenciling	$

Table 6. Erosion and Sedimentation Control Sites in the Crane Creek Watershed					
Site ID	**Priority for Further Action**	**Location**	**Jurisdiction**	**Description**	**Status of Development**
A-ESC-1	High	Locklier Rd near Ashley Oaks	Town	New development occurring with no ESC practices, large amount of sediment directly entering the stream.	Active development
B-ESC-1	High	Mount Valley Rd	City	Appears to be a new sewer line installation with limited ESC practices.	Active development
B-ESC-2	High	Mount Valley Rd	County	Utility line construction – no ESC controls, instream construction and pumping sediment laden water to downstream reaches.	Active development
F-ESC-1	High	9559 Farrow Rd	County	new apartment/condo complex being developed with no ESC practices. Lots of sediment entering stormdrains, erosion at sediment pond. Site soils are not stabilized.	Active development
B-ESC-3	Medium	Neighbor-hood	Town	Some failure of ESC practices – silt fence etc – lack of vegetative stabilization of the site.	Active development
E-ESC-1	Medium	Rivendale and Sepia	County	Silt fence failure, poor inlet protection.	Active development
E-ESC-2	Medium	Heather Green	County	Poor inlet protection, silt fence failure.	Active development
F-ESC-2	Medium	Longtown Commons	County	Inactive construction site with unstable soils. Sediment is washing into stormwater pond. Lots of erosion from pond into stream.	In-active construction
F-ESC-3	Medium	Diesel Drive and Killian Commons	County	Poor ESC at construction entrances.	Active development
I-ESC-2	Medium	Hastings Point	County	Failing ESC, uncovered stock piles.	In-active construction

Table 6. Erosion and Sedimentation Control Sites in the Crane Creek Watershed					
Site ID	**Priority for Further Action**	**Location**	**Jurisdiction**	**Description**	**Status of Development**
A-ESC-2	Low	Ashley Oaks 2	Town	Development is ongoing throughout neighborhood with little to no ESC.	Active development
C-ESC-1	Low	Stoning-ton Neighbor-hood	County	Some failure of ESC practices (i.e. silt fences) in development. Lack of vegetative stabilization of the site.	Active development
H-ESC-1	Low		County	In-active/abandoned construction site with failing ESC controls. Sediment travelling from site under ESC fencing, into stream.	In-active construction
I-ESC-1	Low	Wessin-ger Rd	County	New site for Whitaker Container Service.	Check grading permit
I-ESC-3	Low	Highland Forest	County	Infill with no ESC	Active development

Table 7. Wetlands Assessed in the Crane Creek Watershed					
ID	**Latitude**	**Longitude**	**Wildlife Habitat FCI**	**Water Quality FCI**	**Description**
A-WP-4	34° 20' 51"	80° 99' 15"	0.90	0.86	Upland wetland hydrologically connected
A-WP-5	34° 20' 85"	80° 98' 62"	Not assessed, similar to A-WP-4		Large upland wetland hydrologically connected, mature forest (A-FP-5)
A-WP-6	34° 20' 27"	80° 99' 54"	Not assessed, similar to A-WP-4		Upland wetland hydrologically connected
B-WP-1	34° 19' 03"	81° 02' 75"	0.79	0.75	Upland wetland hydrologically connected
C-WP-2	34° 15' 72"	80° 99' 22"	0.68	0.90	Upland wetland hydrologically connected
C-WP-7	34° 17' 33"	80° 96' 74"	Not assessed, similar to A-WP-4		Upland wetland hydrologically connected, adjacent to commercial
C-WP-8	34° 16' 47"	80° 96' 90"	Not assessed, similar to A-WP-4		Upland wetland hydrologically connected, adjacent to new residential development – some sedimentation noted in wetland
D-WP-1	34° 15' 09"	81° 03' 88"	0.71	0.74	Upland wetland hydrologically connected
D-WP-2	34° 11' 73"	81° 00' 86"	0.81	0.79	Floodplain wetland associated with the stream
G-WP-3	34° 14' 91"	80° 89' 90"	NA	0.85	Natural wetland serving as stormwater
M-WP-1	34° 04' 91"	81° 06' 86"	0.87	0.77	Lower Crane Creek bottomland wetlands
M-WP-2	34° 05' 07"	81° 06' 15"	0.16	0.98	Slough wetlands associated with the Broad River near the outlet of Crane Creek

Table 8. Forest Assessment Points in the Crane Creek Watershed				
Station	Latitude Longitude	Average Densiometer	75th Percentile (dbh)	Dominant Tree Species
A-FP-5	34° 21’ 05” 80° 98’ 88”	24	18	Tulip Poplar, Red Maple, Water Oak
B-FP-2	34° 18’ 30” 81° 02’ 77”	10	4.4	Loblolly Pine, Sweet Gum
B-FP-3	34° 18’ 30” -81° 01’ 93”	19	11	Red Maple, Loblolly Pine, White Oak
B-FP-4	34° 17’ 41” 81° 01’ 47”	24	26	Loblolly Pine, Red Oak, White Oak
B-FP-7	34° 18’ 54” 81° 02’ 78”	22	17	Loblolly Pine, Red Oak, White Oak
D-FP-1	34° 14’ 93” 81° 03’ 94”	23	13	Loblolly Pine
D-FP-2	34° 14’ 45” 81° 03’ 22”	21	13	White Oak, Water Oak
D-FP-3	34° 13’ 62” 81° 01’ 71”	23	14	Loblolly Pine
D-FP-4	34° 14’ 01” 81° 02’ 12”	24	11	Loblolly Pine
D-FP-5	34° 13’ 02” 81° 01’ 91”	24	26	White Oak, Beech, Southern Red Oak
J-FP-1	34° 13’ 50” 81° 03’ 66”	Did not assess using CFA		White Oak, Loblolly Pine, Poplar

Attachment F. Ranking Metrics

Potential projects in the Crane Creek watershed were inventoried following the completion of the stream assessment, upland assessment, and stormwater retrofit inventory. A ranking system was developed to prioritize candidate projects within each assessment. Using best professional judgment, stormwater retrofit, hotspots, neighborhood, ESC sites, and stream impact projects were assigned points and ranked according to the following factors:

- *Cost* – The cost associated with project implementation
- *Community Education and Involvement* – Project with potential to educate and involve the community
- *Visibility* – Project with high visibility and potential to raise the public's awareness of the watershed (visible from street or located in public park)
- *Feasibility* – Project with high potential that it will be implemented. The site has access for equipment, low maintenance burden, serves as a demonstration site and is publicly owned
- *Water Quality Improvement* – Potential for treatment or prevention of pollutants. Treats water quality volume or eliminates exposure of pollutants to stormwater runoff
- *Ecological Benefit* – Project provides an ecological, habitat, or natural resource protection benefit
- *Meeting Watershed Objectives* – Potential for project to assist in achieving watershed objectives

Water quality improvement was given the highest weight of all criteria. Cost was given the second highest weight, followed by community education / involvement, visibility and ecological benefit, all three of which received equal weighting. Watershed objectives identified by Crane Creek stakeholders were factored into the project ranking as well. Each of the seven objectives was given a weight of two points; the more objectives a project met, the higher the end score.

The ranking system was based on 100 points. Each project screening factor and ranking criteria is outlined in Table F-1.

Table F-1. Scoring criteria for identified projects in the Crane Creek watershed.

Project Screening Factor	Total Weight	Scoring Criteria	
Cost	16	Low cost	16
		Medium cost	10
		High cost	5
Community Education and Involvement	10	High educational benefit or potential to involve community in project implementation	10
		Medium educational benefit or potential to involve community in project implementation	5
		Low educational benefit or potential to involve community in project implementation	2
Visibility	10	High visibility and potential to raise the public's awareness of the project	10
		Medium visibility and potential to raise the public's awareness of the project	5
		Low visibility and potential to raise the public's awareness of the project	2
Feasibility	15	High potential that this project will be implemented	15
		Medium potential that this project will be implemented	10
		Low potential that this project will be implemented	5
Water Quality Improvement	25	High potential for treatment or prevention of pollutants	25
		Medium potential for treatment or prevention of pollutants	15
		Low potential for treatment or prevention of pollutants	5
Ecological Benefit	10	High ecological, natural resource protection, or habitat benefit provided	10
		Medium ecological, natural resource protection, or habitat benefit provided	5
		Low ecological, natural resource protection, or habitat benefit provided	2
Meeting Watershed Objectives	14	Ability to meet the watershed objectives outlined in Section 4. Each objective met resulted in 2 points.	2 (each)
Total Points	100		

Attachment G. Green Infrastructure Analysis Methodology

Existing GIS datasets from the State, County and CWP created files were reviewed for their potential use in the Green Infrastructure (GI) analysis. Once appropriate layers were selected, geographic criteria were established. For example, natural areas farther from major roads have less habitat disturbance and barriers to movement. Therefore, a general criterion would state that areas with increased distance from roads have a higher ecological value than areas closer to roads. Once all of the criteria were established, analytical tools in the GIS were used to represent each criterion geographically. For a variable such as distance from roads, distance was defined as 0-100 ft, 100-200 ft, 200-300 ft, and 300 ft or greater (Table F.1). The resulting GIS layer is a series of concentric buffers drawn around major roads quantifying distances from roads. Next, rank values were determined for features in each layer. In the roads example, each concentric buffer is assigned a numerical value based on its distance from a road. Areas adjacent to roads are given lower values than those at increased distance. These steps were performed for each GIS data layer. Once completed, each layer was converted to a grid of 30 ft^2 (~10 m^2) pixel cells (raster layer). Finally, all layers are combined by essentially stacking them on top of each other and summing the overlapping values (Figure F.1). Nine GIS layers were selected to generate the model (Table F.1). All nine final layers were overlain and the individual ranks from each layer summed to get a final rank value for each individual grid cell in the study area. The range of possible values extended from 0-475 based on this process, with increasing numbers indicating greater suitability for protection or inclusion in a green infrastructure network. The values were manually classified into 6 classes based on natural breaks within the dataset.

Dark green represents areas that are highest in terms of suitability for green infrastructure. Dark green areas have the highest priority with summed scores equal to or greater than 350. Areas in lighter green represent priority areas, typically adjacent to streams, and have scores ranging from 275-350. Areas in lighter orange represent suitable areas and have scores ranging from 220-275. Areas in darker orange represent potentially suitable areas and have scores ranging from 150-220. Areas in red are generally not suitable for green infrastructure and have scores from 50-150. Areas in light pink are highly developed areas and are not suitable for green infrastructure; these areas have scores less than 50. The green infrastructure network of hubs and corridors were selected based on high rank values, aerial photography and field observations; they generally have values of 150 or higher. In general, potential hubs represent areas where ecological integrity is greatest. The suggested greenway trail was placed just to the outside of the stream corridor and traverses the primary Crane Creek GI network.

Table F.1. Green Infrastructure GIS Layers

Criteria		Total Points	Rationale	Data Source
Protected lands	Protected	100	Lands protected in their natural state can better support native plant and animal species.	SC GAP Analysis: http://www.dnr.sc.gov/GIS/gap/mapping.html
	Not protected	0		
Wetlands	In wetland	75	Wetlands provide habitat for great numbers of species and provide important ecosystem	National Wetland Inventory: http://www.google.com/search?q=national+wetland+inventory&ie=utf-8&oe=utf-
	Within 25’ buffer	50		

Table F.1. Green Infrastructure GIS Layers				
Criteria		**Total Points**	**Rationale**	**Data Source**
	Within 50’ buffer	25	services.	8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a
	Not in a wetland or within the wetland buffer	0		
Floodplain (500 year)	In	100	Floodplains provide dynamic habitat for wildlife, and are generally considered higher risk areas for human habitation and agricultural production. Land conservation value is higher within floodway zones.	FEMA
	Out	0		
Stream Buffer	0-100’	100	At a smaller scale than rivers, streams and associated riparian areas provide for quality aquatic habitat and maintain freshwater resources.	Richland County
	100-200’	50		
	200-300	25		
	>300’	0		
Road Buffer	>300	100	Roads serve as barriers to movement and flows of all types in functioning ecosystems. Higher conservation values are associated with areas where road proximity and density decrease.	Richland County
	200-300’	50		
	100-200’	25		
	0-100’	0		
Vegetation	All other land cover	100	The closer a land cover types is to its natural undisturbed state, the greater its value for wildlife habitat and ecosystem service provision.	SC GAP Analysis: http://www.dnr.sc.gov/GIS/gap/mapping.html
	Open canopy/recently cleared forest and cultivated land	50		

Table F.1. Green Infrastructure GIS Layers

Criteria		Total Points	Rationale	Data Source
	Urban development & urban residential	0		
Hydrologic connection of wetlands and streams	Overlap of buffers	25	Wetlands that are hydrologicially connected to streams provide opportunities for groundwater recharge and filtering of pollutants before they get to the stream. Areas where streams and wetland buffers begin to intersect were assumed to have an intrinsically higher value.	CWP-created based on NWI wetland layer and Richland County streams
	No overlap of buffers	0		
CWP Stream Reach Assessment	Excellent	50	Streams field verified as in good or excellent condition are more favorable for the movement of species and processing of nutrients.	CWP-created, based on field assessment
	Good	25		
	Fair, Poor or Very Poor	0		
CWP Wetland Assessment – total functional score[1]	1.6-2.0	75	Wetlands field verified with a high functional value provide more benefits to the watershed.	CWP-created, based on field assessment
	1.1-1.5	50		
	0-1.0	25		
	Other	0		

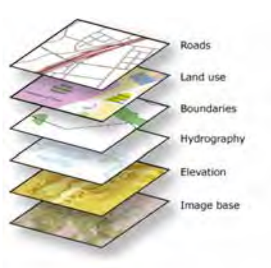


Figure F.1. Depiction of GI analysis: Individual cells are laid on top of each other and then summed. The higher the resulting value, the more suitable is that cell for inclusion in the GI network. (Source of Figure: ESRI)

[1] Points were converted to polygons with a 50’ buffer

Attachment H – High Priority Retrofit Concepts

Site: A-RRI-21A

Location: Ashley Oaks Neighborhood Stormwater Ponds

Site Description: 3 stormwater ponds are designed in series to capture and treat runoff from the subdivision. The first two ponds are wet ponds that contain turbid water from on-going development (Figure H.1). The third pond is a dry pond located down a steep hill and is undersized and eroding (Figure H.2). Runoff from the third pond discharges directly into Beasley Creek.

Proposed Practice: Maintenance should be performed on the top two ponds to remove pond sediment and increase pond storage. Also, a no-mow zone should be encouraged around the perimeter of the ponds to filter runoff from residential lawns, to deter geese, and to act as a barrier to prevent residents and children from falling in the pond. In the lower pond, repair is needed to stabilize the pond banks and prevent the blow-out of the pond walls into Beasley Creek. An energy dissipater should be installed at the pond inlet pipe to slow influent stormwater. This project should be coupled with a stream stabilization project along the adjacent banks of Beasley Creek, which are also eroding.

Figure H.1. Wet pond in need of maintenance. Also, a no-mow zone should be established around the pond perimeter.

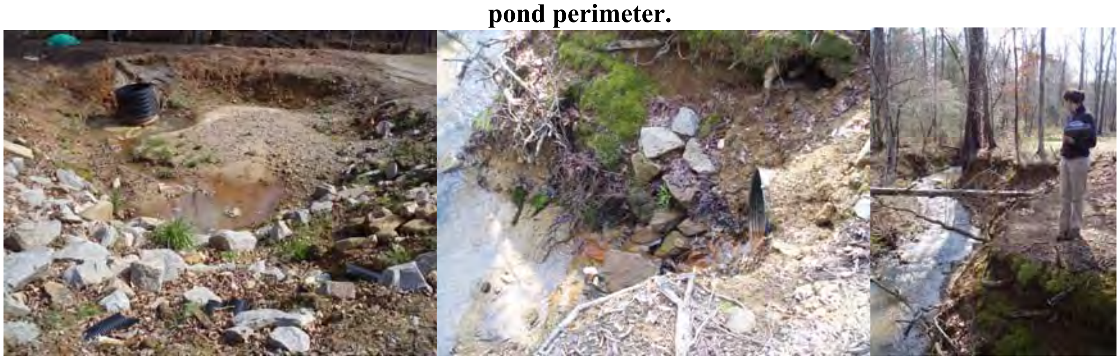


Figure H.2. Third pond in series which is undersized, badly eroded, and on the verge of failure. Stabilization and repair are needed to prevent blow-out of this pond into Beasley Creek.

Next Steps: Some active development is still occurring in the subdivision, and no homeowner's association has been established. Since this property is located in the Town, the County should work with them to contact the developer to implement the necessary repairs at the third pond and ensure sediment removal and proper maintenance of the top two ponds is performed. Some engineering will be required to properly design the energy dissipater in the third pond.

Site: E-RRI-31A/B

Longleaf Middle School Pond Repair and Site Stabilization

Site Description: Runoff from the school site drains to a stormwater wet pond that is filled in with sediment and lacking adequate vegetation. Sediment in the pond has likely accumulated because of runoff from unstable site areas of the school property. The school site is poorly vegetated and it appears that establishment of grass in the sandy soils has been a challenge. External roof downspouts on the school roof are directly connected to an underdrain stormwater system that conveys roof runoff into the wet pond.

Proposed Practice: The school site and stormwater pond should be stabilized with vegetation. Plant trees and reforest portions of the site that are not being used for athletic fields. Native shrub and tree plantings should be planted on the wet pond cut embankments (avoid embankments constructed of fill material). Also, vegetation should be planted around the pond bottom to create an aquatic vegetated shelf. Once the site is properly stabilized, pond maintenance should be performed to remove sediment from the bottom of the pond and increase the pond storage volume. Also, a trash grate should be installed on the pond outlet.

An additional opportunity exists to disconnect the rooftop downspouts and create rain gardens to capture and treat the rooftop runoff. This project could serve as a good educational opportunity for students and can be incorporated into a school environmental program.

(a) (b)

Figure H.3. (a) Opportunities for downspout disconnection to a demonstration rain garden and (b) stormwater wet pond in need of sediment removal.

Next Steps: This would be a good outreach opportunity for the Richland County Stormwater Consortium (RCSC) to involve students and faculty in the construction of the rain garden or tree plantings. School officials should be contacted to initiate this project.

Site: E-RRI-32

Killian Park Rain Garden

Site Description: Runoff from the Killian Park parking lot flows down to a grassed area, into an eroded channel that then flows into a vegetated area. The eroded channel also receives runoff from other portions of the site.

Proposed Practice: Construct a rain garden to capture and treat runoff from the parking lot. The raingarden should have a 6-9" ponding depth and be planted with native plants. Educational signage should be installed adjacent to this project.

Stabilize the eroding channel by placing vegetative matting, rip-rap, or other material.

(a) (b)

Figure H.4. (a) Killian Park parking lot and (b) proposed bioretention location.

Next Steps: This would be a good outreach opportunity for the RCSC to involve the community and youth sport leagues in the construction of the rain garden.

Site: G-RRI-38

North Spring Park Bioretention

Site Description: Runoff from several parking lots and two tennis courts sheet flows into a grassed area, through an eroded swale (Figure H.5), and into the storm drain system. There is currently no stormwater treatment on the site. Also, no curb and gutter exists along the parking or driving areas.

Proposed Practice: Construct up to four bioretention facilities in the grassed areas adjacent to the parking lot to capture and treat runoff from the lot, roof of an outbuilding, and tennis courts. The bioretention areas should have a 6-9" ponding depth and be planted with native plants. An existing berm can be modified to provide ponding. The practice overflow should tie back into the existing drainage system.

This project would serve as an excellent demonstration site and would also capture and treat runoff from almost all of the site parking areas. The bioretention areas should be designed around large trees so as not to flood and drown them. Utilities at the site should be avoided.

(a) (b) (c)

H.5. (a) North Spring Park eroded swale carries untreated stormwater runoff from a parking lot into the storm drain system and (b & c) Proposed locations of bioretention facilities.

Next Steps: This would be a good outreach opportunity for the RCSC to involve community and youth sport leagues in the construction of the bioretention; involving the community in the planting aspect of the project would be ideal. Utility lines should be mapped before further planning efforts are undertaken. Safety of park patrons should be taken into account with the final project design.

Site: G-RRI-39

North Springs Elementary Stormwater Pond Improvement

Site Description: The North Springs Elementary school rooftop, parking lot and other runoff drains to an existing retention pond. The pond appears to have no outlet and water infiltrates through a sandy bottom (Figure H.6).

Proposed Practice: Plant native vegetation along the pond bottom and around the perimeter of pond. The project would serve as a good demonstration and education site for students at the school who could be involved in propagating and/or planting the native plant materials. Some recommended species include: northern spicebush (*Lindera benzoin*), Coralberry (*Symphoricarpos orbiculatus*), common persimmon (*Diospyros virginiana*), Myrtle dahoon (*Ilex myrtifolia*), common buttonbush (*Cephalanthus occidentalis*), Virginia springbeauty (*Claytonia virginica*), Lesser creeping rush (*Juncus repens*), savannah iris (*Iris tridentate*), medowbeauty (*Rhexia mariana*), lanceleaf rose gentian (*Sabatia difformis*), among others.

(a) (b)

Figure H. 6. (a) Infiltration pond at North Springs Elementary school and (b) Drainage from the school's rooftop (background) and parking lot (foreground).

Next Steps: Contact school officials and involved teachers and parents to explain the benefits of the project. Determine a source of locally adapted native plants or encourage the school and students to propagate the plants themselves. Develop a maintenance plan for the plantings.

Site: I-RRI-17A & C

W. J. Keenan High School Detention Basin & Bioretention

Site Description: The roof downspouts of W. J. Keenan High School are directly connected to the storm drain system. One large parking lot in the southwest corner of the site drains into a riprap basin before it discharges into a forest. The basin is currently full of sediment and does not attenuate flow (Figure H.7). The school roof downspouts are external to the building.

Proposed Practice: In the riprap basin (site I-RRI-17C), block the spillway and create a detention basin to attenuate flow. This will allow stormwater to be slowly released into the forested area, which will reduce peak flows and allow for settling of some stormwater pollutants. Where possible, disconnect roof downspouts and direct runoff into created bioretention areas with 1' of ponding depth (site I-RRI-17A).

(a) (b) (c)

Figure H.7. (a) Downspouts directly connected to the storm drain system at W.J. Keenan High School; (b) Stormwater outlet; and (c) Proposed bioretention area at the high school.

Next steps: This downspout disconnection and bioretention concept (I-RRI-17A) would be a good outreach opportunity for the RCSC to involve students and faculty in the project construction. School officials should be contacted to initiate this project.

Site: K-RRI-6

Forest Heights Elementary School Demonstration Site

Site Description: Runoff from the rooftops of the school and some of the parking area is directed to an underground storage facility. Runoff from the remaining parking areas appears to be conveyed directly to wetlands on the east side of the site without treatment. When the field crew was at the site, school officials were excited about opportunities for a demonstration project on school grounds.

Proposed Practice: Two locations were identified for creating bioretention areas on the south side of the school (Figure H.8). Ponding depth would be excavated to approximately 1 foot at the deepest point. Due to the sandy nature of the underlying soils, no underdrain will be necessary for the practice design. Existing catch basins can be used to capture overflow. Additional opportunities for tree plantings exist at this site.

(a)

(b)

Figure H.8. (a) Proposed bioretention area at Forest Heights Elementary School; (b) outlet from the storm drain system facility that flows to a wetland area. This portion of the site did not appear to receive any stormwater treatment.

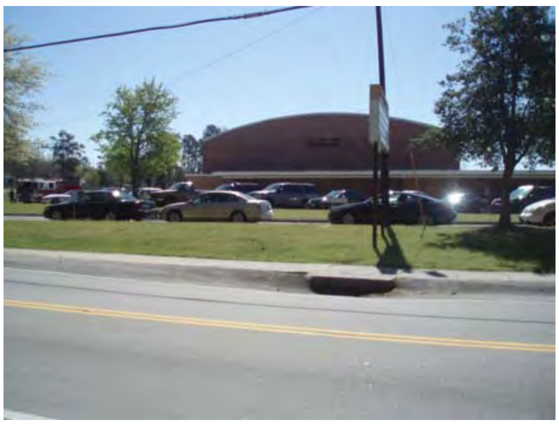
Next steps: This would be a good outreach opportunity for the RCSC to involve students and faculty in the construction of the bioretention. School officials should be contacted to initiate this project.

Site: L-RRI-9A & B

W. G. Sanders Middle School Downspout Disconnection and Bioretention

Site Description: A 72" pipe from a nearby subdivision runs under the athletic fields at this site. Runoff from the school enters the pipe via catch basins and yard drains (Figure H.9). Many of the catch basins observed by field crews were partially clogged. The top of pipe was determined to be approximately 1' below grade at the south catch basin.

Proposed Practice: Numerous opportunities for downspout disconnection and bioretention are proposed, especially on the south side of the school. The entire site could be treated with these practices. A potential opportunity exists to daylight the 72" storm drain pipe in the open field. Because the school was due to close in the summer, 2009, opportunity exists to implement these proposed practices when the lot is converted or sold.



(a)

(b)

Figure H.9. (a) W.G. Sanders Middle School was due to close in summer, 2009, so an opportunity may be available to implement stormwater retrofits and (b) Outlet of 72"pipe that may have the potential to be daylighted.

Next Steps: The upstream subdivision should be assessed before pipe daylighting as well as for potential implementation of retrofit practices in the neighborhood. Site plans should be evaluated to further investigate the pipe daylighting option. Work with the new property owner as the site is redeveloped to implement stormwater retrofit practices.

Site: L-RRI-10

Greenview Elementary School Rain Gardens

Site Description: The Greenview Elementary School has a mixture of downspouts that are directly connected to the storm drain system or disconnected entirely. Disconnected downspouts drain via overland flow to catch basins located in the grass. At least 3' of head is available in all of the catch basins that were inspected.

Proposed Practice: Numerous opportunities exist for the implementation of bioretention at the site. It is recommended that all downspouts that are not adjacent to sidewalks or pavement be disconnected. Near the school, 6" deep rain gardens can be constructed in several locations. No underdrains or soil replacement would be necessary. Overflow can drain via sheetflow into the catch basins.

Next Steps: No photos were taken at this site. This would be a good outreach opportunity for the RCSC to involve students and faculty in the construction of the rain gardens. School officials should be contacted to initiate this project.

Site: L-RRI-12

Medowlakes Recreation Center Demonstration Project

Site Description: Much of the runoff from the Meadowlakes Recreation Center site drains via sheetflow to a nearby forested buffer area (Figure H.10). Grass channels from the parking area convey the stormwater off-site. The building on-site is essentially disconnected from the stormdrain system.

Proposed Practice: Since the site is largely disconnected already, improvements would be primarily for demonstration purposes. The existing swale near the parking area could be enhanced with a planting of native vegetation. Educational signage can be installed so that patrons of the site are aware of Richland County efforts to improve water quality.

(a) (b)

Figure H.10. (a) Much of the runoff at the Medowlakes Recreation Center drains via sheetflow to a nearby buffer and (b) An existing swale at he site could be enhanced with plantings.

Next Steps: This would be a good outreach opportunity for the RCSC to involve the community and youth sport's leagues in planting of the existing swale.

Site: L-RRI-100

Northminster Presbyterian Church Bioretention

Site Description: No existing stormwater treatment exists at the Northminster Presbyterian Church. Stormwater runoff is conveyed via sheetflow to a grassed area and then to Gavilan Ave. The site is near L-RRI-11 at Greenview Park, a medium priority project site.

Proposed Practice: Catch the existing sheetflow from the parking lot and some roof area with a 9" bioretention in the grass before it reaches Gavilan Ave. No underdrain is necessary for the practice. This project was identified as a potential early action project.

Next Steps: No photos were taken at this site. The drainage area, drainage area impervious cover and volume computations need to be confirmed. Contact the church to assess interest in the project and potential involvement of the congregation.

Site: E-RRI-33

Westmoreland and Robin's Egg Stormwater Pond Repair

Site Description: Stormwater runoff from an unfinished development near Westmoreland Ave and Robin's Egg Rd. drains to a wet pond. Sediment is accumulating at the stormwater pond inlet. Algae is prolific in the pond (Figure H.11). Further, the pond contained lots of trash, which appeared to be a result of littering by site contractors. A short flow path conveys water through the pond itself. Active erosion was observed along the pond outfall to the stream.

Proposed Practice: The pond outlet should be repaired through stabilization. The pond is in need of maintenance. Accumulated sediment and trash should be removed.

(a) (b) (c)

Figure H.11. (a) Algae in stormwater pond; (b) Sediment accumulation from development in stormwater pond; and (c) Outlet of stormwater pond into wooded area.

Next Steps: Work with the site developer or the homeowner's association to repair and maintain the pond. Encourage and educate neighbors on the use of household retrofit projects such as downspout disconnection, rain barrels, native landscaping and tree planting. Also, consider posting signs against littering and encouraging proper disposal of waste.

Site: G-RRI-201

The Commons of Winchester Right-of-Way Bioretention

Site Description: Untreated stromwater runoff from Shamley Green and Alderston Roads drains to a tributary of Upper Crane Creek (Figure H.12). Land use in the drainage area is single family homes on ½ acre lots. Runoff from residential lawns, driveways, and rooftops is conveyed into the street, which drains directly to the creek tributary. The existing roadway is very wide, approximately 40' in width.

Proposed Practice: Create a bump-out bioretention area with a 6-9" ponding depth in the roadway. The bump-pout would be approximately one car-width wide. Construct storm drain berms up-slope, along roadway inlets, to divert runoff from low flows and small storms to the bioretention area. Stabilize the inlet and modify the outlet to provide appropriate ponding. The project has the potential to capture a large area of roadway, residential lawn, driveway and rooftop runoff. The drainage area to the proposed retrofit assumes diverting low flows of four upstream inlets; this volume can be reduced if necessary. This design would serve to calm and slow traffic.

(a) (b) (c)

Figure H.12. (a) Alderston Rd. conveys untreated stormwater runoff to (b) a tributary of Upper Crane Creek. (c) Proposed retrofit location.

Next Steps: Map existing gas and utility lines for potential conflicts. Conduct education and outreach to neighbors and the local homeowner association to garner support for the project. Couple education and outreach efforts with a neighborhood nutrient and bacteria reduction program. Work with the homeowner's association for project implementation.

Attachment I. Crane Creek Retrofit Profile Sheets

RR-1	Rooftop Retrofit Design Sheets	
	STORMWATER PLANTERS	

Stormwater or foundation planters are an on-site retrofit practice that can treat rooftop runoff. They consist of confined planters that store and/or infiltrate runoff through a soil bed to reduce runoff volumes and pollutant loads (Figure 1). Two major design variations exist based on the condition of the underlying soil. The *infiltration planter* is designed to allow runoff to first filter through the planter soil and then infiltrate down through native soils. The *filter* or *flow-through planter box* has compacted bottom soils or an impervious liner that prevents infiltration. When it overflows, water surcharges from the bottom of the planter after it filters through the soil through a perforated underdrain and discharges to the storm drain system. Both planter designs are sized to temporarily store runoff in a reservoir above the planter soil.

Stormwater planters combine an aesthetic landscaping feature with a functional form of stormwater treatment. Stormwater planters generally receive runoff from adjacent rooftop downspouts. As runoff passes through the planter, pollutants are captured on soils. Stormwater planters are landscaped with plants that are tolerant to both periods of drought and inundation.

Stormwater planters are useful in treating rooftop runoff in highly urban areas, such as a central business district. They can also be used to establish a pervious area within the hardscape of a plaza, courtyard, riverfront, or streetscape. While they treat a very small drainage area, they can be incorporated into municipal or corporate demonstration projects. Since each planter treats runoff from a few hundred to a few thousand square feet of contributing rooftop (plus the additional area of the planter bed itself), it takes quite a few planters to provide meaningful stormwater treatment in a subwatershed. On the other hand, planters are one of the few on-site or storage retrofit options available to treat ultra-urban sites.

The two primary factors to assess when considering stormwater planter retrofits are the contributing roof area to each roof leader, and how and where the excess runoff will be discharged from the planter. A planter designed to encourage infiltration should have adequate waterproofing and dewatering components to prevent foundation seepage.

Design

Two basic design variations for stormwater planters are the infiltration planter and the filter planter.

An **infiltration planter** filters rooftop runoff through planter soils followed by infiltration

Figure 1: Portland Stormwater Planter

into soils below the planter (Figure 2). The recommended minimum width is 30 inches; length and shape can be decided by architectural considerations. The planter should be sized to temporarily store at least one-half inch of runoff from the contributing rooftop area in a reservoir above the planter bed. Infiltration planters should be placed at least ten feet away from a building to prevent possible flooding or basement seepage damage.

A **filter planter** has an impervious liner on the bottom of the planter. The minimum planter width is 18 inches with the shape and length governed by architectural considerations. Runoff is temporarily stored in a reservoir located above the planter bed. Overflow pipes are installed to discharge runoff when maximum ponding depths are exceeded to avoid water spilling over the side of the planter (Figure 3). Since a filter planter is self-contained and does not infiltrate into the ground, it can be installed right next to a building.

All planters should be placed at grade level or above ground, and sized to allow captured runoff to drain out within four hours after a storm event. Plant materials should be capable of withstanding moist and seasonally dry conditions. Planting media should have an infiltration rate of at least two inches per hour. The sand and gravel on the bottom of the planter should have a minimum infiltration rate of five inches per hour. The planter can be constructed of stone, concrete, brick, wood or other durable material. If treated wood is used, care should be taken so that trace metals and creosote do not leach out of the planter. Supplemental irrigation may be necessary in some regions to ensure plant survival during dry weather.

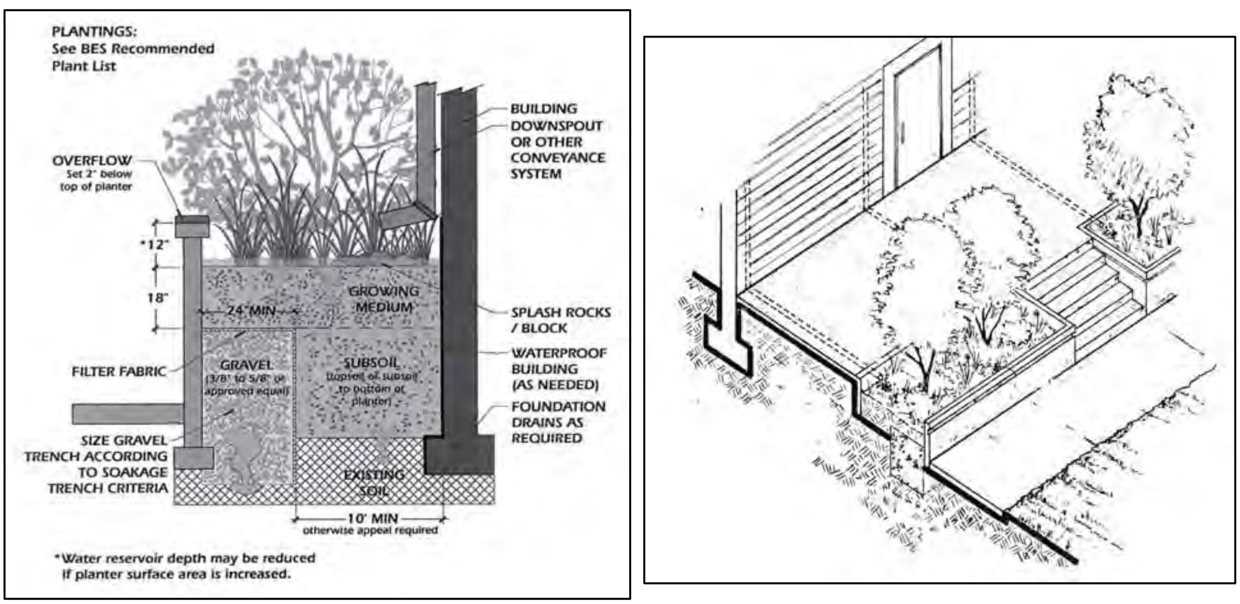


Figure 2: Infiltration Planter Schematic (left) and Infiltration Planter Box (right)
Source: Portland Stormwater Manual, 2002

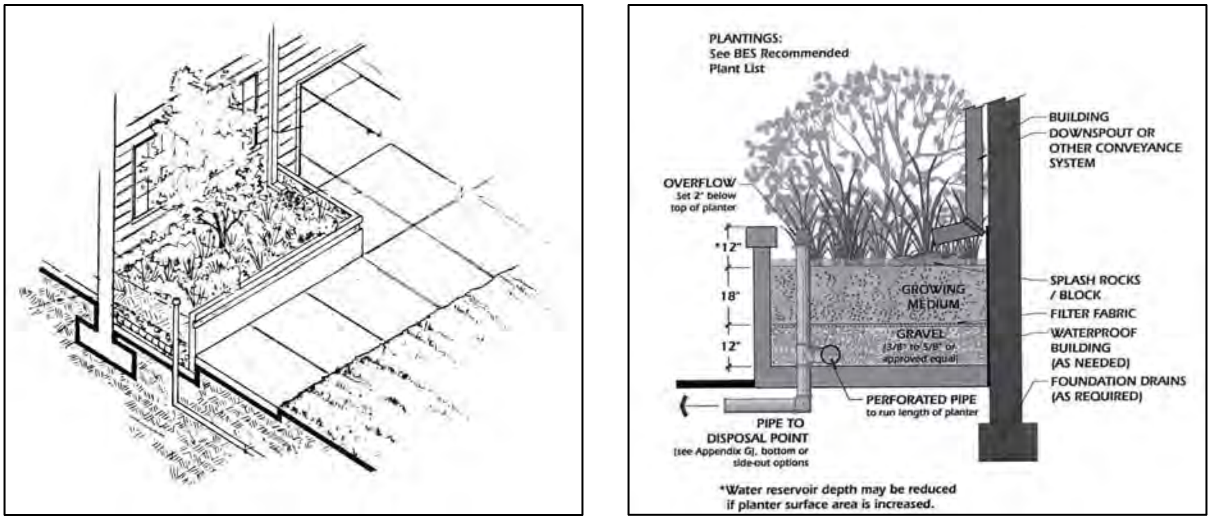


Figure 3: Finished Flow-Through Stormwater Planter (left) and Schematic (right)

Construction - It is advisable to use a single contractor throughout the construction and landscaping maintenance. Contractors should understand the purpose of stormwater planters including appropriate sizing, filtering media, setbacks from current utilities and buildings and care and maintenance of planted material.

Maintenance - Maintenance for stormwater planters involves routine landscaping, checking the integrity of the planter structure, and removal of organic matter. Planter container and overflow pipes should be inspected annually to ensure continued efficiency. Particular care should be taken to ensure that desired infiltration rates are being maintained through the planter soil and subsoils.

Cost – The median cost to construct stormwater planters is estimated to be $27.00 per cubic foot of runoff treated (ranging from $18.00 to $36.00)

Further Resources

City of Portland. 2004. *Stormwater Management Manual – Revised*. http://www.portlandonline.com/bes/index.cfm?c=35122&

Low Impact Development (LID) Center www.lowimpactdevelopment.org/

New York State. *New York State Stormwater Management Design Manual: Stormwater Planters.* *http://www.rpi.edu/~kilduff/Stormwater/planters1.pdf*

RR-2	Rooftop Retrofit Design Sheets	
	RAIN BARRELS	

Description

Rain barrels are used to capture, store and reuse residential rooftop runoff. They consist of a simple stormwater collection device that stores rainwater from individual rooftop downspouts. Stored water can be used as a source of outdoor water for car washing or lawn or garden watering. The rooftop runoff stored in a rain barrel would normally flow onto a paved surface and eventually into a storm drain. Rain barrels typically have a capacity of 50 to 100 gallons of water (Figure 1).

Rain barrels can be applied to new and existing residential developments. They are most applicable for single family residential and townhouse uses. Rain barrels can have benefits on both a site level and subwatershed wide basis. Rain barrels promote water conservation, reduce water demand, and lower irrigation costs and demand (a rain barrel can save homeowners about 1,300 gallons of water during the peak summer months). Rain barrels are inexpensive and easy to build and install and create stronger watershed awareness.

Feasibility

Rain barrels are a common on-site retrofit practice to treat rooftop runoff from individual homes. Because each rain barrel retrofit treats such a small area, dozens or hundreds are needed to make a measurable difference at the subwatershed level. Consequently, widespread homeowner implementation of rain barrels requires targeted education, technical assistance and financial subsidies.

The potential to retrofit with rain barrels is normally evaluated as part of the neighborhood source assessment of the USSR. The most important factor is the proportion of existing homes that are directly connected to the storm drain system. In general, neighborhoods with residential lot sizes as small as 4000 square feet can be effectively retrofit with rain barrels (Figure 2). Negative neighborhood factors include the presence of basements, limited space for barrel de-watering, and lack of active homeowner association.

Regional and Climatic Considerations - Several issues pertaining to water quality, climate, and algae and mosquito control

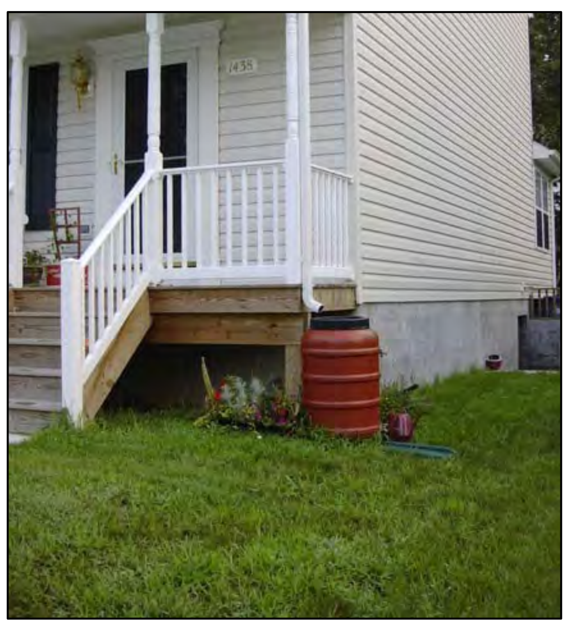


Figure 1: Installed Rain Barrel

should be taken into account in design. Water quality is usually not a major issue unless the stored water will be used for drinking water, which is not recommended without additional filtering and treatment. Rooftop runoff contains trace metals, such as zinc, copper and lead. The presence of these metals, however, should not adversely affect the use of rooftop runoff for supplemental lawn and garden irrigation.

Rain barrels require modification in regions with cold winters. Rain barrels do not function if temperatures regularly reach the freezing mark during winter months. Consequently, rain barrels should be drained and disconnected during winter months to ensure that frozen water does not damage the rain barrel, to back up into downspouts or overflow into a building foundation. Alternatively, rain barrels can be installed inside a building or garage.

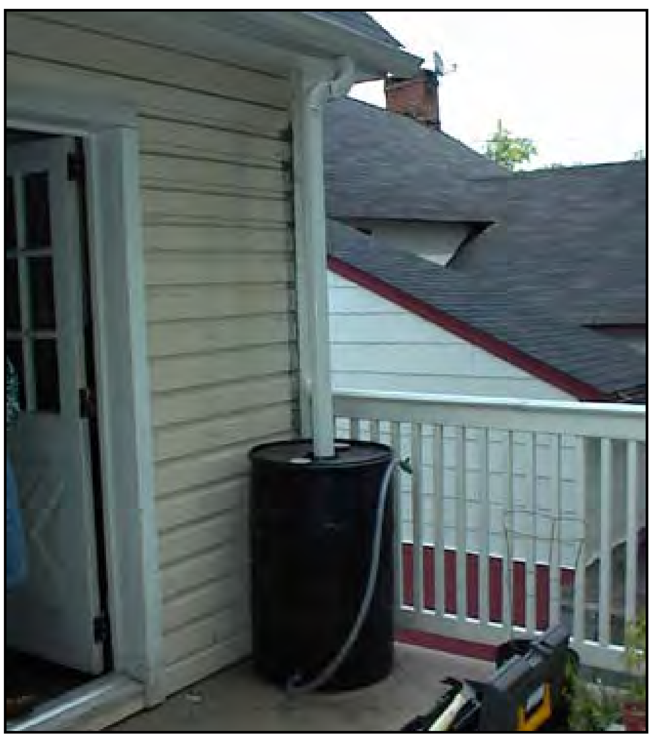


Figure 2: Rain barrel installed on a balcony due to space constraints on a small lot.

It is important to reduce the amount of organic matter entering the barrel to prevent algae from growing in a rain barrel. This can be a problem for rain barrels serving a downspout whose gutters fill with leaves and other debris.

Since rain barrels have standing water, there is some risk that they may become mosquito-breeding sites. Simple solutions to reduce mosquito breeding include routine emptying of the barrel on a five day cycle to interfere with breeding time required by mosquitoes or screening the rainwater inlet so mosquitoes cannot enter the rain barrel (USWG, 2003).

Site Constraints and Permits - Rain barrels may not be appropriate in high-density urban settings where there is little or no green space to irrigate using the collected water. Similarly, neighborhoods where homes are close together may not have adequate surface area to safely discharge rain barrel overflow. Lastly, installation of rain barrels in neighborhoods where downspouts are already disconnected provides little or no retrofit benefit.

Implementation

Design - Rain barrels are much easier to design compared to other on-site retrofit practices. Still, the rain barrel should always incorporate the same basic design elements of any good stormwater practice, such as pretreatment (clean gutters), adequate storage capacity, and safe conveyance of flooding with rain barrel overflows).

Construction - Rain barrels can be purchased or custom made from large plastic drums (typically 55-gallon drums). They are relatively easy to construct using a few basic components available from hardware stores. Installation of a typical rain barrel involves disconnecting individual downspouts and redirecting it into the top of the rain barrel.

Rain barrels have an overflow pipe that redirects the rainwater back into the downspout or onto the lawn or other pervious surface when the rain barrel is full. Other rain barrel components may include spigots, connector barrels, mosquito proofing, and even water filters (CWP, 2003).

Maintenance – The maintenance required for rain barrels involves regular dewatering of the barrel to preserve capacity for the next storm event. Roof gutters should be inspected to ensure that leaves and organic matter are not entering the downspout to the rain barrel. In addition, the rain barrel, gutters, and downspouts need to be checked for leaks or obstructions. Lastly, the overflow pipe should be checked to ensure that overflow is draining in a non-erosive manner

Cost - Although costs vary across manufacturers, the average cost of a single rain barrel ranges from about $50 to $300, with an average of about $150 The cost per cubic foot treated is about $25 per cubic foot treated (ranging from $7 to $40) Costs can be reduced if volunteers or watershed groups perform the instillation. Consult Profile Sheet 0S-10 for some helpful resources on rain barrel delivery.

Further Resources

The following internet resources are recommended for a detailed description on how to build and install a rain barrel.

How to Build and Install a Rain Barrel
http://www.cwp.org/Community_Watersheds/brochure.pdf

Rain Barrels for Dummies: Unofficial Guidance for Backyard Retrofitters.
http://www.cwp.org/Community_Watersheds/Rain_Barrel.htm

King County, WA. Rain Barrel Information and Sources for the Pacific Northwest.
http://dnr.metrokc.gov/wlr/PI/rainbarrels.htm

Low Impact Development Center (LID). Rain Barrels and Cisterns.
http://www.lid-stormwater.net/raincist/raincist_maintain.htm

Maryland Green Building Program: Building a Simple Rain Barrel.
http://www.dnr.state.md.us/ed/rainbarrel.html

City of Bremerton. Rain Barrel Program: A Modern Spin On An Old Idea.
http://www.cityofbremerton.com/content/sw_makeyourownrainbarrel.html

Portland, OR Downspout Disconnection Program
http://www.portlandonline.com/bes/index.cfm?c=43081

RR-3

Rooftop Retrofit Design Sheets

RAIN GARDENS

Rain gardens capture, filter and infiltrate residential rooftop runoff, and consist of small, landscaped depressions that are usually 6 to 18 inches deep. A sand/soil mixture below the depression is planted with native shrubs, grasses or flowering plants (Figure 1). Rooftop runoff is detained in the depression for no more than a day until it either infiltrates or evapotranspires. Rain gardens can replenish groundwater, reduce stormwater volumes, and remove pollutants. A rain garden allows at least 30% more water to infiltrate into the ground compared to a conventional lawn (UWEO, 2002).

Rain gardens can be applied to existing single-family homes within targeted neighborhoods. Rain gardens have many benefits including increased watershed awareness and personal stewardship, improved neighborhood appearance, and creation of habitat for birds and butterflies. Rain gardens must be properly maintained; otherwise they may create basement flooding and standing water, and become an eyesore. For this reason, implementation of rain gardens requires a dedicated homeowner and community buy-in.

Feasibility

Rain gardens are essentially a non-engineered form of bioretention that treats rooftop runoff from individual roof leader. (see Profile Sheet ST-4). Because each rain garden treats a rather small area, dozens or hundreds are needed to make a measurable difference at the subwatershed level. Consequently, widespread homeowner implementation of rain gardens requires targeted education, technical assistance and financial subsidies.

The potential to retrofit rain gardens is normally evaluated as part of the neighborhood source assessment of the USSR. The most

Figure 1: Rain Garden

important factor is the proportion of existing homes that are directly connected to storm drain system. In general, neighborhoods with large residential lot sizes are most suitable (1/4 acre lots and larger). Negative neighborhood factors include the presence of basements, compacted soils, and poor neighborhood awareness. Positive factors are large rooftop areas that are directly connected to the storm drain system, lots with extensive tree canopy and good neighborhood housekeeping.

Regional and Climatic Considerations - One common misperception associated with rain gardens is that they provide a breeding ground for mosquitoes. Mosquitoes need three to seven days to breed, and standing water in the rain garden should last for only a few hours after most storms USWG, 2003).

Plant selection is also an important element of a successful rain garden. Considerations should include drought-tolerant plants that will not require much watering, but can withstand wet soils for up to 24 hours. Plant selection also depends on the amount of sun the garden receives. Xeriscaping (the practice of landscaping to conserve water) is recommended in arid climates (Figure 2). For a listing of the native plants in your region, visit: http://plants.usda.gov/ (USDA NRCS). This database allows the user to search for plants by name (common or scientific) or by state or county.

Site Constraints and Permits - The site constraints for rain gardens include soils and proximity to the house. The garden should be located a minimum of 10 feet away from the house to prevent basement seepage. Rain gardens work best in areas with well-drained soils. However, performance can be enhanced in poorly draining soils by providing an underdrain system or soil amendments.

Implementation

Design - The surface area of a rain garden should be between 20% and 30% of the roof area it drains to it to ensure it can temporarily hold water from a 1-inch rainstorm. Further guidance on sizing a rain garden is provided in Table 1.

To ensure that the water flows from the impervious surface to the garden, maintain at least a 1% slope from the lawn down to the rain garden (a shallow swale can be used). A downspout extension can be used to direct rooftop flow into the garden.

Construction - Construction of rain gardens is simple but requires physical labor to dig the garden, prepare the soil, and plant desired species. Select plants that have a well-established root system and plant them approximately one foot apart (UWEO, 2002). More information on how to install rain gardens can be found online in the Further Resources section.

Figure 2: Xeriscaped Garden

Table 1: Rain Garden Sizing Example
30' x 30' house footprint
¼ of this area drains to one downspout
15' x 15' = 225 sf
20% of 225sf = 45sf
30% of 225sf = 67.5 sf
The rain garden area should be between 45 and 67.5 square feet, depending on the soil type (use 20% for sandier soils in Soil Group A)

Maintenance - Maintenance of rain gardens is essential to ensure public acceptance and proper performance, and reduce nuisance problems. Typical maintenance includes periodic watering and weeding. The use of native plants can significantly reduce overall yard maintenance needs since they require less mowing, watering and fertilizer than conventional lawns.

Cost - The cost to construct a rain garden includes labor for construction and design, plants, and soil mixture. Design and construction costs can vary widely depending on the complexity of the project. Rain gardens typically cost about $4.00 per cubic foot of runoff treated (ranging from $3 to $5). Do-it-yourselfers can create beautiful rain gardens for a fraction of this cost.

Further Resources

Center for Watershed Protection *How to Install a Rain Garden*. http://www.cwp.org/Community_Watersheds/brochure.pdf

UWEO (University of Wisconsin Extension Office). Rain Gardens: http://clean-water.uwex.edu/pubs/pdf/home.gardens.pdf

Bannerman, R. and E. Considine. 2003. Rain Gardens: A how-to manual for homeowners http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/documents/rgmanual.pdf

Center for Watershed Protection . *Rain Garden Applications and Simple Calculations*. http://www.cwp.org/Community_Watersheds/Rain_Garden.htm

Friends of Bassett Creek. 2000. *Rain Gardens: Gardening with Water Quality in Mind*. http://www.mninter.net/~stack/bassett/gardens.html.

Minneapolis, MN Neighborhood Rain Gardens http://www.fultonneighborhood.org/lfrwm.htm

Portland, OR Downspout Disconnection Program http://www.portlandonline.com/bes/index.cfm?c=43081

Rain Gardens for Stormwater Bioretention and Ecological Restoration.. http://www.nwf.org/campusecology/files/reillyprop.pdf

"Plotting to Infiltrate? Try Rain Gardens." *Yard and Garden Line News* 3(6). http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-May0101.html

West Michigan Environmental Action Council and the City of Grand Rapids RainGardens.org. http://www.raingardens.org

RR-4	Rooftop Retrofit Design Sheets	
	FRENCH DRAINS and DRY WELLS	

French drains and dry wells are an on-site retrofit practice that can capture and infiltrate residential rooftop runoff. Runoff from rooftop leaders is directed to the trench via a downspout or swale, is temporarily stored in the voids of the stone-filled trench, and ultimately percolates into the ground. The terms *french drain* and *dry well* are often used interchangeably since they perform the same function, however, their design and application differ slightly. A french drain is a shallow underground trench with a perforated pipes running along the bottom (Figure 1). A typical dry well is a deeper and shorter excavated trench with perforated pipes that run both vertically and horizontally through the stone (Figure 2).

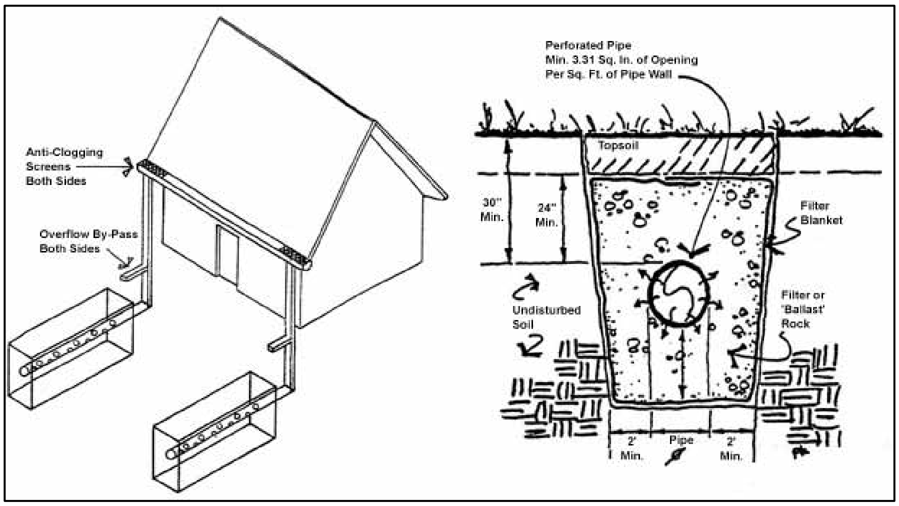


Figure 1: Schematic of French Drain

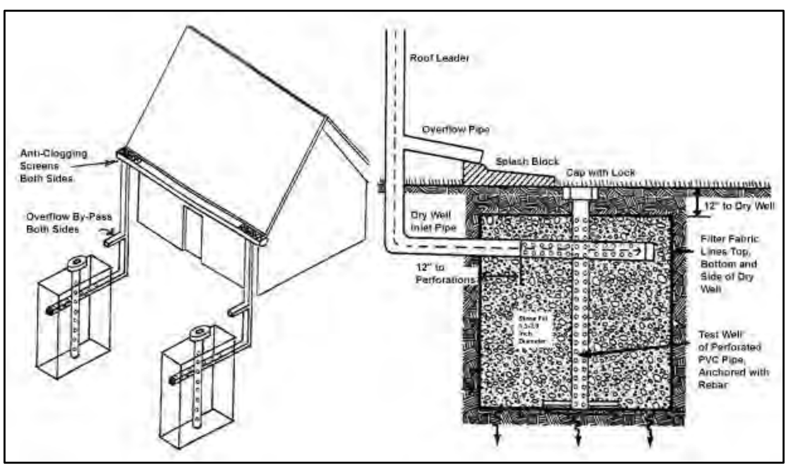


Figure 2: Schematic of Dry Well

French drains are almost exclusively used for residential sites, whereas dry wells can be used at both residential and commercial sites. Each practice serves a small drainage area, such as a single rooftop or roof leader. While not much space is needed to install these practices, very high-density neighborhoods will have limited opportunities.

Feasibility

Because each french drain/dry well treats a rather small area, dozens or hundreds are needed to make a measurable difference at the subwatershed level. Consequently, widespread homeowner implementation of these practices requires targeted technical assistance and financial subsidies.

The potential to retrofit with french drains/drywells is normally evaluated as part of the Neighborhood Source Assessment of the USSR The most important factor is the proportion of existing homes that are directly connected to the storm drain system. In general, neighborhoods with large residential lot sizes are most suitable (1/4 acre lots and larger). Negative neighborhood factors include the presence of basements, compacted soils, and poor neighborhood awareness or involvement. Positive factors are large rooftop areas that are directly connected to the storm drain system, lots with extensive tree canopy, and neighborhoods known for good housekeeping and active involvement.

Regional and Climatic Considerations - Dry wells and french drains do not function during winter months in colder climates unless the trench extends below the frost line. Also, dry wells are not feasible in regions with high water tables.

Site Constraints and Permits - The three main site constraints pertaining to french drains and dry wells are soils, hydrology and slope (LGPC, 2003). The soils must be permeable enough to ensure adequate infiltration within 48 hours. An infiltration rate of at least 0.5 inches per hour is recommended for underlying soils. To limit the risk of groundwater contamination, the bottom of these devices should be located at least three feet above the seasonally high water table or bedrock layer. Steep slopes and fill soils should also be avoided. These practices should be located on the down slope side of buildings and extend at least ten feet from building foundations to prevent potential seepage into basements (ARC, 2001).

Implementation

Design - Several design features can make french drains and dry wells more effective. First, it is important to provide pretreatment to reduce the high rate of clogging typically associated with these practices. While pretreatment options are limited, a screen placed on top of rooftop gutters can help to filter out materials such as leaves and other debris (LGPC, 2003). Guidance for sizing a french drain is provided in Table 1.

The design should provide some type of runoff bypass to direct large storm flows away from the house. The bypass is often an aboveground opening of the downspout as shown in Figures 1 and 2.

Table 1: French Drain Sizing Example
French Drain Surface Area = $\frac{(DA)(P)}{12(D)(V)}$
30' x 30' house footprint ¼ of this area drains to downspout Rainfall Depth (P) = 1" Drainage Area (DA) = 15'x 15' = 225ft^2 Depth of Proposed Trench (D) = 2ft Voids Ratio for Gravel (V) = 0.35 $\frac{(225)(1)}{12(2)(0.35)} = 26.8\ ft^2$ Trench dimensions: 13' length; 2' wide; 2' deep
Notes: Depth (D) can vary depending on site constraints Rainfall Depth (P) can vary; should reflect retrofit water quality target volume or local water quality criteria

Construction - Dry wells generally require more construction effort than other on-site practices due to the deeper excavation required. These practices require relatively simple materials, such as perforated pipe, stone (two to four inches in diameter) and filter fabric. Basic construction involves digging a slightly sloped trench (to carry the water away from the house), lining the sides of the trench with the filter fabric, laying the perforated pipe, and then backfilling the trench with gravel or stone.

Maintenance - Because these practices are out of sight, maintenance tends to be neglected. Regular maintenance consists of a cleaning out leaves and debris caught in the gutter screen and periodic replacement of the reservoir with clean rock. Inspection of the observation well should be done annually to ensure that the stone fill is level to the ground surface and that the filter fabric has not become clogged with material (ADEQ, 2000).

Cost – The unit cost to install these practices is about $12.00 per cubic foot treated (ranging from $10.50 to $13.50).

Further Resources

Guidance for Design, Installation, and Operation and Maintenance of Dry Wells. Phoenix, AZ. http://www.azdeq.gov/environ/water/permits/download/dwguid.pdf

Stormwater Management Guide for Minor Projects. http://www.lgpc.state.ny.us/pdf/strmguid.htm

Development Planning for Stormwater Management: A Manual for the Standard Urban Stormwater Mitigation Plan. http://www.ladpw.org/wmd/NPDES/table_contents.cfm

New York State Stormwater Management Design Manual. http://www.dec.ny.gov/chemical/29072.html

New Jersey Stormwater Best Management Practices Manual. *Standard for Dry Wells*. http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.3%20print.pdf

Houston Landscape Images: Drainage System Components. http://www.houstonlandscape.com/Drain_Systems.htm

Grounds Magazine. *How to Install a French Drain* http://www.grounds-mag.com/mag/grounds_maintenance_install_french_drain/

RR-5	Rooftop Retrofit Design Sheets	
	PERMEABLE PAVERS	

Permeable pavers treat or reduce parking lot runoff using a porous or semi-porous material on driveways, access roads, parking lots and walkways. Permeable pavers can also allow for surface storage or infiltration of runoff, which can reduce stormwater flows compared to traditional surfaces like concrete or asphalt pavement.

The basic design presented here is for permeable pavers, which consist of a permeable asphalt or concrete surface that allows stormwater to quickly infiltrate into soils or a shallow underground stone reservoir (Figure 1). Runoff then percolates into the soil, where it recharges groundwater and traps stormwater pollutants. Other materials include grass paving blocks, interlocking concrete modules and brick pavers to provide some infiltration and detention of runoff.

Feasibility

Permeable pavers can be used as a retrofit to treat runoff from parking lots or adjacent rooftops. Good opportunities can be found in spillover parking areas, schools, municipal facilities and urban hardscapes (see Profile Sheet OS-12). Other opportunities include redevelopment of commercial sites, especially when parking lots are renovated or expanded.

It is extremely important to confirm that local soils can support adequate infiltration, since past grading, filling, disturbance and compaction can greatly alter their original infiltration qualities. The greatest opportunity to retrofit infiltration exists for sensitive or impacted subwatersheds, where some of the original soil structure may still exist. By contrast, most of the soils in subwatersheds are not likely to be suitable for infiltration. Some regions of the country still have highly permeable soils, which do allow for widespread use of permeable pavers (e.g., glacial tills, sand).

When evaluating a proposed permeable paver retrofit, designers should assess the same constraints for infiltration practices (see Profile Sheet ST-6d in Appendix I). Additional factors to consider include traffic volume and the intended use and ownership of the surface. Permeable pavers are much more versatile, because they do rely less on soil infiltration as compared to surface storage to provide runoff treatment.

Regional and Climate Concerns - Permeable pavers can be applied in most regions of the country, but needs to be adapted to meet the unique challenges of cold climates. Permeable pavers should not be used when sand or other

Figure 1: Permeable Pavement

materials are applied for winter traction since they quickly clog the pavers. Similarly, care should be taken when applying salt to permeable pavers, since chlorides can migrate into the groundwater. Permeable pavers have been successfully used in cold climate in Norway where design features were incorporated to reduce frost heave. Further, some experience suggests that snow melts faster on a porous surface because of rapid drainage below the snow surfaces.

Site Constraints and Permits – Permeable pavers has the same site constraints of any infiltration practice and should meet the following criteria:

- Soils need to have an infiltration rate between one-half and three inches per hour
- The bottom of the stone reservoir should be completely flat so that infiltrated runoff will be able to infiltrate through the entire surface
- Permeable pavers should be located at least three feet above the seasonally high groundwater table, and at least 100 feet away from drinking water wells
- Permeable pavers should not be used to treat stormwater hotspot areas due to the potential for groundwater contamination

Implementation

Design - Pretreatment, treatment, conveyance, and maintenance reduction should be considered in all permeable pavers retrofits.

In most permeable pavers designs, the pavers itself acts as pretreatment to the stone reservoir below. Because the surface serves this purpose, frequent maintenance of the pavers surface is critical to prevent clogging. Another pretreatment element is a fine gravel layer above the coarse gravel treatment reservoir. The effectiveness of both of these pretreatment measures can be inconsistent, which is one reason frequent vacuum sweeping is needed to keep the surface clean.

One design option intended as a backup water removal mechanism within a permeable pavers system is an "overflow edge." An "overflow-edge" is a trench surrounding the edge of a permeable pavers area. The trench connects to the stone reservoir below the surface of the pavers. Although this feature does not in itself reduce maintenance requirements, it acts as a backup in case the surface clogs. If the surface clogs, stormwater will flow over the surface and into the trench, where some infiltration and treatment will occur. The stone reservoir below the pavers should be composed of layers of small stone and be sized for the WQv storm event.

Variations to the reservoir design include the use of perforated corrugated metal piping, plastic arch pipe, and plastic lattice blocks. Water is conveyed through the stone reservoir from the surface of the pavers, then infiltrates into the underlying soil at the bottom of this stone reservoir. A layer of sand or choker stone should be placed below the stone reservoir to prevent preferential flow paths and to maintain a flat bottom.

Designs should include methods to convey larger storms to the storm drain system. One option is to set storm drain inlets slightly above the surface elevation of the pavers. This allows for temporary ponding above the surface if the surface clogs, but bypasses larger flows that are too large to be treated by the system.

Variations in the design of permeable pavers can address treatment of offsite sources. In one design variation, the stone reservoir below the filter can also treat runoff from other sources such as rooftop runoff. In this design, pipes are connected to the stone reservoir to direct flow throughout the bottom of the storage reservoir.

Construction - Installation of permeable pavers is a specialized project and should involve experienced contractors. It is also important to ensure that the drainage area is fully stabilized prior to construction to slightly prevent sediment from clogging the pavers.

Maintenance - Permeable pavers requires slightly more maintenance than traditional pavement in order to ensure continued porosity of the surface. Owners should understand that using a sealer or repaving permeable pavers is not a viable option. Areas contributing to the permeable pavers site need to be mowed and bare areas should be seeded. The surface should be vacuumed three to four times each year to remove sediment and debris.

A carefully worded maintenance agreement is essential to provide specific guidance for the parking lot. The agreement should clearly specify how to conduct routine maintenance tasks, and repave the surface when the pavers reaches the end of their design life. Ideally, signs should be posted on the site identifying permeable paver areas to increase public awareness.

Inspections of permeable pavers should include inspection of surface for spalling or deterioration and testing to ensure that water is draining between storms. Adequate drawdown should occur within 24 to 48 hours.

Cost - Permeable pavers are more expensive than traditional asphalt or concrete pavement. While traditional pavement is approximately $.50 to $1.00 per square foot, permeable pavers can range from $2 to $3 per square foot, depending on the design. The cost per cubic foot of runoff treated is about $120.00 (ranging from $96.00 to $144.00). However, if the cost estimates were to include the savings due to a reduced need for storm drains and land consumption for stormwater treatment, the cost differential for permeable pavers drops sharply.

Further Resources

BioPaver. http://www.biopaver.com/problems.html

Concrete Network. *Permeable/Porous Pavers.* http://www.concretenetwork.com/concrete/porous_concrete_pavers/

Green Builder. A Source Book for Green and Sustainable Building: Pervious Paving Materials. http://www.greenbuilder.com/sourcebook/PerviousMaterials.html

Pavers Search. *Paver Products and Resources for Homeowners and Professionals.* http://www.paversearch.com/permeable-pavers-menu.htm

Puget Sound Online. *Natural Approaches to Stormwater Management: Permeable Pavement.* http://www.psat.wa.gov/Publications/LID_studies/permeable_pavement.htm

RR-6	Retrofit Design Sheets	
	EXTENDED DETENTION	

Typical Constraints

Some common constraints for retrofitting extended detention ponds include:

Space Required: A typical ED pond requires a footprint of 1 to 3% of its contributing drainage area, depending on depth of the pond (the deeper the pond, the smaller footprint needed).

Available Head: Bottom elevations for ED retrofits are typically determined by the existing elevation of the downstream conveyance system (e.g., a stream, channel or pipe). Backwater in the upstream conveyance system can also constrain the head available at the retrofit site. Typically, a minimum of about six to 10 feet of head is needed to construct an ED retrofit.

Contributing Drainage Area: A minimum contributing drainage area is recommended for each ED design variant. For micropool ED ponds, a minimum of 10 acres is suggested in humid regions to sustain a permanent micropool to prevent clogging. A minimum of 25 acres is recommended in humid regions to maintain constant water elevations in wet ED ponds and ED wetlands. The minimum drainage area may increase in arid or semi-arid climates. A water balance should be conducted if the designer needs to maintain a constant pool elevation. ED may still work on drainage areas less than 10 acres, but designers should be aware that these “pocket” ponds will have very small orifices that will be prone to clogging, experience fluctuating water levels, and generate future maintenance problems.

Minimum Setbacks: Local ordinances and design criteria should be consulted to determine minimum setbacks to property lines, structures, and wells. Generally, ED retrofits should be setback at least 10 feet from property lines, 25 feet from building foundations, 50 feet from septic system fields, and 100 feet from private wells.

Utilities: Site designers should check to see if any utilities cross the proposed retrofit site. ED retrofits should not submerge existing sewer manholes as this can lead to infiltration/inflow problems and make maintenance access more difficult. Dry utilities such as underground electric or cable should never be inundated.

Depth to Water Table: The depth to the groundwater table is typically not a major concern for ED retrofits. In fact, intercepting a high water table can sustain a shallow pool or pocket wetland within the retrofit. Designers should keep in mind that groundwater inputs may reduce retrofit pollutant removal capability and could sharply increase excavation costs.

Depth to Bedrock: If bedrock layers are discovered near the surface of the proposed retrofit, it may be too difficult or expensive to excavate the storage needed for ED retrofits.

Special Community and Environmental Considerations about ED Retrofits

ED retrofits can create several community and environmental concerns to anticipate during design:

Aesthetics: ED retrofits tend to accumulate sediment and trash, especially if they are undersized. Many residents perceive dry ED ponds as being unsightly and creating nuisance conditions. Fluctuating water levels in ED retrofits also create a tough landscaping environment. In general, designers should avoid retrofit designs that rely solely on dry ED.

Existing Wetlands: ED retrofits should not be constructed within existing natural wetlands nor should they inundate or otherwise change the hydroperiod of existing wetlands.

Existing Forests: Clearing of mature trees should be avoided during retrofit layout. Designers should be aware that even modest changes in inundation frequency can kill upstream trees (Wright *et al.*, 2007).

Stream Warming Risk: ED ponds have less risk of stream warming than other pond options, but can warm streams if their low flow channel is not shaded. If the retrofit discharges to temperature-sensitive waters, the pond should be forested and have a maximum detention time of 12 hours or less to minimize potential stream warming.

Safety Risk: Dry ED ponds are generally considered to be safer than other pond options since they have few deep pools. Steep side-slopes and unfenced headwalls, however, can still create some safety risks.

Mosquito Risk: The fluctuating water levels within dry ED ponds have potential to create conditions that lead to mosquito breeding. Mosquitoes tend to be more prevalent in irregularly flooded ponds than in ponds with a permanent pool (Santana *et al*., 1994). Designers can minimize the risk by combining ED with a wet pond or wetland.

ED Retrofit Design Issues

ED retrofits are normally squeezed into very tight sites, so designers are always tempted to eliminate standard design features to maximize storage. However, designers should think twice before dropping the following critical design features:

Low Flow Orifice: Unless the drainage area to an ED retrofit is unusually large, the diameter of the ED orifice will be less than six inches in diameter. Small diameter pipes are prone to chronic clogging by organic debris and sediment. Retrofit designers should always look at upstream conditions to assess the potential for higher sediment and woody debris loads. The risk of clogging in such small openings can be reduced by:

- Sticking to a minimum orifice diameter of three inches or greater, even if this means walking away from the proposed retrofit site.
- Protecting the ED low flow orifice by installing a reverse-sloped pipe that extends to mid-depth of the permanent pool or micropool.
- Providing an over-sized forebay to trap sediment, trash and debris before it reaches the ED low flow orifice.
- Installing a trash rack to screen the low flow orifice.

Maximum Vertical Depth of ED: Designers often seek to maximize the depth of ED retrofits to treat a greater volume of runoff within a smaller footprint. Increasing the vertical fluctuation or "bounce" within an ED retrofit, however, can reduce pollutant removal, promote invasive species and create a difficult landscaping environment. In the context of retrofitting, the vertical elevation of ED storage should not extend more than 5 feet above the normal water surface elevation. The bounce effect is not as critical for channel protection or flood control storm events. These storms can exceed the 5 foot vertical limit if they are managed by a multi-stage outlet structure.

ED Retrofit Pond Maintenance Issues

Several maintenance issues can be addressed during retrofit design and future maintenance operations:

Clogging: Retrofits are prone to higher clogging risk at the ED low flow orifice and any upstream flow splitters. These aspects of retrofit plumbing should be inspected at least twice a year after initial construction. Designers should provide easy access to both the micropool and the pond drain to allow maintenance crews to dewater the retrofit.

Sediment Removal: Good maintenance access is also needed to allow crews to remove accumulated sediments. Designers should check to see whether sediments can be spoiled on-site or must be hauled away. The frequency of sediment removal should be increased if:

- A micropool is used within the ED retrofit
- The retrofit is undersized relative to the target WQv
- Significant development activity or winter road sanding is projected to occur in the retrofit's contributing drainage area

Vegetation Management: The constantly changing hydrologic regime of ED retrofits makes it hard to mow or manage vegetative growth. The bottom of dry ED retrofits often become soggy, and water-loving trees such as willows may take over. Retrofit designers should carefully evaluate how vegetation will be cost-effectively managed in the future. Landscape architects can prepare a planting plan that allows the retrofit to mature into a native forest in the right places yet keeps mowable turf along the embankment and all access areas. The wooded wetland concept proposed by Cappiella *et al*., (2005) may be a good option for many ED retrofits.

Trash Removal: Trash, debris and litter tend to accumulate in the forebay, micropool and on the bottom of ED ponds. The maintenance plan should schedule cleanups at least once a year.

A retrofit maintenance plan should be created to address each of the items listed above. The maintenance plan should identify the responsible party and contain a legally enforceable agreement that specifies maintenance duties and schedules.

Adaptation ED for Special Climates and Terrain

Cold Climates: Winter conditions can cause freezing problems within inlets, flow splitters, and ED outlet pipes due to ice formation. Designers can minimize these problems by:

- Not submerging inlet pipes

- Increasing the slope of inlet pipes by a minimum of 1% to discourage standing water and potential ice formation in upstream pipes
- Placing all pipes below the frost line to prevent frost heave and pipe freezing
- Designing low flow orifices to withdraw at least six inches below the typical ice layer
- Placing trash racks at a shallow angle to prevent ice formation

Sand loadings to ED retrofits may increase due to winter road maintenance. Consequently, designers may want to over-size forebays and/or micropools to account for the higher sedimentation rate. ED retrofits can also be designed to operate in a seasonal mode that provides additional WQv storage to treat snowmelt runoff (MSSC, 2005; Caraco *et al*., 1997).

Arid regions: Water rights can be significant issue when it comes to capturing and detaining stormwater runoff in Western states. Also, ED retrofits in arid regions are subject to high sediment loads and may lack vigorous vegetative cover unless they receive supplemental irrigation (Caraco, 2000). The higher evaporation rates and limited inflows of arid regions always make it hard to sustain a permanent pool in the micropool and/or forebay. Designers may want to compute a water balance to determine if pools can be sustained, or if supplemental irrigation will be needed to maintain vegetative cover.

Karst Terrain: Geotechnical investigations are recommended when ED retrofit ponds are situated in active karst areas to minimize the risk of groundwater contamination and avoid sinkhole formation. An impermeable liner and a minimum three foot vertical separation distance from the underlying rock layer is recommended.

Costs to Install ED Retrofits

Extended detention ranks among the least expensive stormwater options, particularly when free storage can be obtained at pond and crossing retrofit sites (SR-1 and SR-2). The cost to install dry ED ponds at new development sites can be determined from the cost equations of Brown and Schueler (1997). The equations (updated to 2006 dollars) predict the base construction cost of new ED construction based on the storage volume of the pond, including excavation, control structures, and appurtenances:

$$BCC = (10.97)(V_s^{0.780})$$

Vs = Total storage volume (ft^3)
BCC = Base construction cost (2006 dollars)

The median cost to construct a new ED pond is about $3,800 per impervious acre treated (range: $2,200 to $7,500). Please note that ED retrofit construction costs are generally at least three times greater (see Chapter 2 and Appendix E).

Design Resources

Several state stormwater manuals provide extensive guidance on ED pond design:

Georgia Stormwater Management Manual
http://www.georgiastormwater.com

Minnesota Stormwater Management Manual
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

Vermont Stormwater Management Manual
http://www.anr.state.vt.us/dec/waterq/cfm/ref/Ref_Stormwater.cfm

RR-7	Retrofit Design Sheets	
	WET PONDS	

Typical Constraints

Some common constraints hinder the use of wet pond retrofits in developed watersheds:

Space Required: The proposed surface area for a wet pond retrofit should be at least 1 to 3 % of its contributing drainage area, depending on the pond's depth.

Contributing Drainage Area: A minimum contributing drainage area of 10 to 25 acres is recommended for wet pond retrofits to maintain constant water elevations, although these can vary by design type and climatic region. Smaller drainage areas may be treated if the retrofit will intercept the groundwater table (but this may reduce pollutant removal and increase excavation costs). Wet ponds can still work on drainage areas less than 10 acres, but designers should be aware that these "pocket" ponds will be prone to clogging, experience fluctuating water levels, and generate more nuisance conditions. A water balance should be conducted if the designer needs to maintain constant pool elevations.

Utilities: Most utilities do not permit existing underground pipes or dry utilities to be submerged as a result of retrofit construction. It may be possible to submerge water or sewer lines if manholes are raised above the maximum water surface elevation of the pond and if the pipes were originally constructed in a watertight manner.

Excavation: Wet ponds normally entail several feet of excavation. Retrofit designers need to understand the quality of subsoils in terms of their suitability for embankment fill, potential excavation problems and whether they need to be hauled off-site.

Available Head: The depth of a wet pond retrofit is usually determined by the head available on the site. The bottom elevation is normally set by the existing downstream conveyance system to which the retrofit discharges (e.g., a stream, channel or pipe). While it is possible to excavate a pool below the outlet invert, this resulting dead storage may not mix well with the rest of the pond, thereby reducing performance and creating nuisance problems. Typically, a minimum of six to eight feet of head are needed to construct a wet pond retrofit.

Minimum Setbacks: Local ordinances and design criteria should be consulted to determine minimum setbacks to property lines, structures, and wells. As a general rule, wet pond retrofits should be setback at least 10 feet from property lines, 25 feet from building foundations, 50 feet from septic system fields, and 100 feet from private wells.

Depth to Water Table: The depth to the water table can be a design concern for wet pond retrofits. If the water table is close to the surface, it may make excavation difficult and expensive. Groundwater inputs can also reduce the pollutant removal rates. On the other hand, a high groundwater table can help provide a constant pool elevation to maintain a pocket pond when the contributing drainage area is small.

Depth to Bedrock: If bedrock layers occur near the surface of a proposed retrofit, it may be too expensive to blast the site to get enough storage volume.

Community and Environmental Considerations for Wet Pond Retrofits

Wet ponds are readily accepted by communities if they are properly designed and maintained. Pond retrofits, however, can generate several community and environmental concerns:

Aesthetic Issues: Many residents feel that wet ponds are an attractive landscape feature, promote a greater sense of community and are an attractive habitat for fish and wildlife. Designers should note that these benefits are often diminished if retrofits are under-sized or have small contributing drainage areas.

Existing Wetlands: A wet pond retrofit should not be constructed within an existing natural wetland. Any discharges from the retrofit into an existing natural wetland should be minimized to prevent changes to its hydroperiod.

Existing Forests: Construction of wet pond retrofits may involve major clearing of existing forest cover. Designers can expect a great deal of neighborhood opposition if they do not make a concerted effort to save mature trees during retrofit design and layout.

Stream Warming Risk: Wet ponds can warm streams by two to 10 degrees Fahrenheit, although this may not be a major problem for degraded urban streams (Galli, 1990). To minimize stream warming, wet pond retrofits should be shaded and provide shorter ED detention times (e.g., 12 hours vs. 24).

Safety Risk: Pond safety is an important community concern, as young children have perished by drowning in wet ponds after falling through the ice. Gentle side slopes and safety benches should be provided to avoid potentially dangerous drop-offs, especially when retrofits are located near residential areas. Residents may request fences around the pond or its outfalls in some retrofit situations.

Mosquito Risk: Mosquitoes are not a major problem for larger wet ponds (Santana *et al*., 1994; Ladd and Frankenburg, 2003). However, fluctuating water levels in smaller or under-sized wet ponds could pose some risk for mosquito breeding. Mosquito problems can be minimized through simple design features and maintenance operations described in Chapter 4 and MSSC (2005).

Geese and Waterfowl: Wet ponds with extensive turf and shallow shorelines can attract nuisance populations of resident geese and other waterfowl whose droppings can reduce pond nutrient and bacteria removal. Several design and landscaping features can make a pond retrofit much less attractive to geese (see Schueler, 1992).

Wet Pond Retrofit Design Issues

Wet pond retrofits are often squeezed into very tight sites, so designers can be tempted to eliminate standard design features in order to obtain maximum pool storage. It is generally advisable to sacrifice some storage volume in order to incorporate design features critical to retrofit performance, function and longevity. The following design features should be included in wet pond retrofits:

Pretreatment: Sediment forebays located at major inlets help extend the longevity of wet pond retrofits. Each forebay should be sized to have about 10% of the total retrofit storage volume and have easy access for sediment cleanouts.

Long Flow Path: Retrofits should have an irregular shape and a long flow path from inlet to outlet to increase residence time and pond performance (ideally 2:1). Internal berms can be used to extend flow paths and create multiple pond cells.

Safety/Access Bench: Retrofits should include a flat bench just outside of the perimeter of the permanent pool to allow for maintenance access and reduce safety risks. The bench can be variable in width (10 to 15 feet).

Aquatic Bench: Aquatic benches are shallow areas just inside the perimeter of the normal pool that promote growth of aquatic and wetland plants. The bench also serves as a safety feature, reduces shoreline erosion and conceals floatable trash. In retrofit situations, the aquatic bench can vary in width from three to 10 feet.

Avoid Deep Pools: Designers often seek to maximize the depth of a wet pond retrofit to store a greater runoff volume within a smaller footprint. Pool depths greater than eight feet, however, should be avoided in most retrofit situations. Deep ponds can cause seasonal pond stratification that release pollutants stored in bottom sediments back into the water column (and have a much greater safety risk).

Wet Pond Retrofit Maintenance Issues

Wet ponds normally have less routine maintenance requirements than other stormwater treatment options. The frequency of maintenance operations may need to be scaled up if retrofits are undersized or have a small contributing drainage area. Designers should consult CWP (2004b) for more information on wet pond maintenance problems and solutions. Several maintenance issues can be addressed during retrofit design and future maintenance operations:

Maintenance Access: Good maintenance access should always be provided to the sediment forebay, access bench, riser and outlet structure so crews can more easily perform maintenance tasks. The riser structure should be placed within the embankment.

Sediment Removal: Sediments excavated from wet ponds are not normally classified as toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be needed prior to sediment disposal if the retrofit serves a hotspot land use.

Clogging: There is always some risk that the low flow orifice or upstream flow splitter may clog. These aspects of retrofit hydraulics should be inspected frequently after construction. The retrofit should have a pond drain so crews can de-water the pond to relieve clogging and remove sediments.

Vegetation Management: The maintenance plan should clearly outline how vegetation in the pond and its buffer will be managed or harvested in the future. Methods to establish desired aquatic plants and control invasive plant species should be outlined. Annual mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or as forest.

Trash Removal: The maintenance plan should schedule a shoreline cleanup at least once a year to remove trash and floatables.

Adapting Wet Ponds for Special Climates and Terrain

Cold climates: The performance of wet pond retrofits in cold climates can be enhanced when designers:

- Treat larger runoff volumes in the spring by adopting seasonal operation of the permanent pool (see MSSC, 2005)
- Plant salt-tolerant vegetation in pond benches
- Do not submerge inlet pipes and provide a minimum 1% pipe slope to discourage ice formation
- Locate low flow orifices so they withdraw at least 6 inches below the typical ice layer
- Angle trash racks to prevent ice formation
- Oversize riser and weir structures to avoid ice formation and freezing pipe
- Increase forebay size if road sanding is prevalent in the contributing drainage area

Arid Climates: Wet pond retrofits require special design in regions with low annual rainfall or high evapotranspiration. Ponds are generally not a preferred option if the permanent pool cannot be maintained without supplemental irrigation. Some tips for designing wet ponds in arid climates include the following:

- Pond vegetation flourishes when temperatures are warm and the growing season is long or year-round, which can result in prolific growth of algae, wetland plants, shrubs and trees (Figure 1). Regular mowing or even plant harvesting should be considered to keep vegetative growth in check.
- Designers should always check to make sure there is an adequate water balance to support a permanent pool throughout the year- otherwise the potential of algal blooms, odors and other nuisances can increase sharply. When in doubt, install a clay or synthetic liner to prevent water loss via infiltration.
- Arid regions generate higher sediment loads, so designers should consider adding extra sediment trapping capability in retrofit forebays (Caraco, 2000).

Karst Terrain: Deep pools increase the risk of sinkhole formation and groundwater contamination in regions with active karst. Designers should always conduct geotechnical investigations to assess this risk. Pond retrofits in karst areas should include impermeable liners and maintain at least three feet of vertical separation from the underlying rock layer.

Wet Pond Installation Costs

Wet ponds are more expensive on a unit area basis than constructed wetlands and ED ponds, primarily due to the need for deeper excavation and safety features such as side-slope control and benches (Wossink and Hunt, 2003). Several cost equations (updated to 2006 dollars) can predict the

Figure 1: Warm temperatures have led to algal blooms in this wet pond.

base construction cost of new wet ponds, given their proposed storage volume or drainage area treated.

Wet Extended Detention Ponds (Brown and Schueler, 1997)
$BCC = (10.97)(V_s^{0.750})$

Wet Ponds (Brown and Schueler, 1997)
$BCC = (263.99)(V_s^{0.553})$

Wet Ponds (Wossink and Hunt, 2003)
$BCC = (17{,}333)(A^{0.672})$

Vs = Total storage volume (ft^3)
A = area treated (acres)
BCC = Base construction cost (2006 dollars)

Solving these equations for a range of common pond sizes yields a median construction cost for a new wet pond of $ 8,350 per impervious acre treated (range: $ 3,100 to $28,750). Please note that the wet pond retrofit construction costs are typically 1.5 to 2 times higher than new pond construction (see Chapter 2 and Appendix E).

Wet Pond Design Resources

Many existing state and local stormwater manuals provide extensive guidance on wet pond design:

Vermont Stormwater Management Manual
http://www.anr.state.vt.us/dec/waterq/cfm/ref/Ref_Stormwater.cfm

Minnesota Stormwater Management Manual
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

Austin, TX Drainage Criteria Manual
http://www.cityofaustin.org/watershed/publications.htm

New York State Stormwater Management Design Manual
http://www.dec.state.ny.us/website/dow/toolbox/swmanual/index.html

Maryland Stormwater Design Manual
http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

RR-8	Retrofit Design Sheets	
	CONSTRUCTED WETLANDS	

Typical Constraints

Constructed wetlands are subject to several constraints when it comes to retrofitting:

Contributing Drainage Area: The contributing drainage area must be large enough to sustain a permanent water level within a stormwater wetland. A minimum of 25 acres of drainage area is typically needed to maintain constant water elevations in humid regions, although the precise area varies based on local hydrology. The minimum drainage area can be relaxed if the bottom of the retrofit intercepts the groundwater table or if designers are willing to accept periodic wetland drawdown. Designers should note that these "pocket" wetlands will have lower pollutant removal, higher excavation costs, and a greater risk of invasive plant colonization.

Space Requirements: Wetland retrofits require a footprint ranging between 3 and 5% of the contributing drainage area, depending on the average depth of the wetland and the extent of its deep pool features.

Available Head: The depth of a wetland retrofit is usually constrained by the head available on the site. The bottom elevation is fixed by the elevation of the existing downstream conveyance system to which the retrofit will ultimately discharge. Head requirements for constructed wetlands are typically less than wet ponds because of their shallow nature - a minimum of two to four feet of head is usually needed.

Minimum Setbacks: Local ordinances and design criteria should be consulted to determine minimum setbacks to property lines, structures, utilities, and wells. As a general rule, wetland retrofits should be setback at least 10 feet from property lines, 25 feet from building foundations, 50 feet from septic system fields and 100 feet from private wells.

Depth to Water Table: The depth to the groundwater table is not a major constraint for constructed wetlands as a high water table can maintain wetland conditions within the retrofit. Designers should keep in mind that high groundwater inputs may reduce pollutant removal rates and increase excavation costs.

Community and Environmental Considerations for Constructed Wetlands

Constructed wetlands can generate several community and environmental concerns:

Aesthetics: Wetland retrofits can create wildlife habitat and become an attractive community feature. Designers should carefully think through how the wetland community will evolve over time, as the future plant community seldom resembles the one initially planted. Constructed wetlands require continual vegetative management to maintain desired wetland species, control woody growth and prevent invasive plants from taking over.

Existing Wetlands: It can be tempting to construct a stormwater wetland within an existing natural wetland, but this should never be done unless it is part of a broader effort to restore a degraded urban wetland approved by the local or state wetland review authority. Designers should investigate the wetland status of adjacent areas to determine if the discharge from the constructed wetland will change the hydroperiod of a downstream natural wetland (see Cappiella et al., 2006b, for guidance on minimizing stormwater discharges to existing wetlands).

Regulatory Status: Constructed wetlands built for the express purpose of stormwater treatment are not considered jurisdictional wetlands in most regions of the country, but designers should check with their wetland permit authority to ensure this is the case.

Existing Forests: Given the large footprint of constructed wetlands, there is a strong chance that construction may cause extensive tree clearing. Designers should preserve mature trees during retrofit layout, and may want to use a wooded wetland concept to create a forested wetland community (see Cappiella *et al*., 2006b).

Stream Warming Risk: Constructed wetlands have a moderate risk of stream warming. If the retrofit discharges to temperature-sensitive waters, designers should consider the wooded wetland design, and any ED storage should be released in less than 12 hours.

Safety Risk: Constructed wetlands are safer than other pond options, although forebays and micropools should be designed with benches to reduce safety risks.

Mosquito Risk: Mosquito control can be a concern for stormwater wetlands if they are under-sized or have a small contributing drainage area. Few mosquito problems are reported for well designed, properly-sized and frequently maintained constructed wetlands (Santana *et al*., 1994) but no design can eliminate them completely. Simple precautions can be taken to minimize mosquito breeding habitat within a wetland retrofit, such as constant inflows, benches that create habitat for natural predators, and constant pool elevations (see Walton 2003 and MSSC, 2005).

Design Issues for Constructed Wetland Retrofits

Several elements should be considered when designing constructed wetland retrofits:

Sediment Forebays: Forebays should be located at all major inlets to trap sediment and preserve the capacity of the main wetland treatment cell. A major inlet is defined as serving at least 10% of the retrofit is contributing drainage area. The forebay should be at least four feet deep, contain about 15% of the total retrofit WQv, and have a variable width aquatic bench.

Constructed Wetland Layout: The layout of the stormwater wetland affects its pollutant removal capability and plant diversity. Performance is enhanced when the wetland has multiple cells, longer flowpaths, and a high surface area to volume ratio. Whenever possible, constructed wetlands should be irregularly shaped with a long, sinuous flow path.

Microtopography: Retrofits should have variable microtopography - a mix of shallow, intermediate, and deep areas that promote dense and diverse vegetative cover.

Planting Strategy: Wetland retrofits should outline a realistic, long-term planting strategy to establish and maintain desired wetland vegetation. The plan should indicate how wetland plants will be established within each pondscaping zone (e.g., wetland plants, seed-mixes, volunteer colonization, and tree and shrub stock) and whether soil amendments are needed to get plants started. The future species trajectory of wetland retrofits is hard to predict, so several different strategies should be considered. Several excellent resources on wetland planting strategies are available (Schueler, 1992; and Shaw and Schmidt, 2003).

Wooded Wetland vs. Emergent Wetland Model: The traditional model for constructed wetlands has been a shallow emergent marsh. In many parts of the country, however, forested wetlands are the most common natural wetland community. In these regions, it may be desirable to design the wetland as a wooded wetland to more closely match local wetland types and reduce future wetland management problems (Cappiella et al., 2006a).

Maintenance Access: Good maintenance access should always be provided to the forebay so that crews can remove sediments and preserve wetland treatment capacity. More frequent sediment removal will be needed if the retrofit is undersized or has a small contributing drainage area.

Maintenance Issues for Constructed Wetland Retrofits

Several maintenance issues can be addressed during the design of constructed wetland retrofits:

Sediment Removal: Frequent sediment removal from the forebay is essential to maintain the function and performance of a constructed wetland. Maintenance plans should schedule cleanouts every five years or so, or when inspections indicate that 50% of the forebay capacity has been lost. Designers should also check to see whether removed sediments can be spoiled on-site or must be hauled away. Sediments excavated from constructed wetlands are not usually considered toxic or hazardous, and can be safely disposed by either land application or land filling.

Clogging: There is always some risk that the low flow orifice and any upstream flow splitters may clog. Clogging can quickly change design water elevations for the wetland and possibly kill wetland vegetation. The inlet and outlet structures to the wetland should be inspected frequently to discover any clogging problems.

Vegetation Management: Managing wetland vegetation is an important ongoing maintenance task. Designers should expect significant changes in wetland species composition over time. Invasive plants should be dealt with as soon as they colonize the wetland. Vegetation may need to be periodically harvested if the retrofit becomes overgrown. Construction contracts should include a care and replacement warranty extending at least two growing seasons after initial planting to selectively replant portions of the wetland that fail to take.

Trash Removal: Cleanups should be scheduled at least once a year to remove trash and debris from the retrofit.

Adapting Constructed Wetlands for Special Climates and Terrain

Cold Climates: Wetland performance decreases when snowmelt runoff delivers high pollutant loads. Shallow constructed wetlands can freeze in the winter, which allows runoff to flow over the ice layer and exit without treatment. Inlet and outlet structures close to the surface may also freeze, further diminishing wetland performance. Several design tips can improve wintertime performance for wetland retrofits (see Profile Sheets ST-1d and ST-2d).

Salt loadings are higher in cold climates due to winter road maintenance. High chloride inputs have a detrimental effect on native wetland vegetation, and can shift the wetland to more salt-tolerant species such as cattails (Wright *et al*., 2007). Designers should choose salt-tolerant species when crafting their planting plan and consider reducing salt application in the contributing drainage area to the retrofit.

Arid Climates: Constructed wetlands are hard to establish in regions with low annual rainfall and high evapotranspiration rates. These climates make it difficult to maintain a constant pool water elevation throughout the growing season. Designers should always check to make sure there is an adequate water balance to support a wetland throughout the year - otherwise the potential of algal blooms, odors and other nuisances will increase sharply. When in doubt, install clay or synthetic liners to prevent water loss via infiltration. Wetland vegetation flourishes when temperatures are warm and the growing season is long or year-round. Regular mowing or even harvesting should be considered to keep vegetative growth in check.

Karst Terrain: Even shallow pools in active karst terrain can increase the risk of sinkhole formation and groundwater contamination. Designers should always conduct geotechnical investigations in karst terrain to assess this risk. If in doubt, designers should employ an impermeable liner and maintain at least three feet of vertical separation from the underlying karst layer.

Constructed Wetland Installation Costs

Constructed wetlands are less expensive on a unit area basis than wet ponds and extended detention ponds since they require less excavation and need fewer safety features (Wossink & Hunt, 2003). On the other hand, some constructed wetlands have a larger surface footprint. These construction cost savings may disappear if land must be acquired to install the retrofit.

Wossink and Hunt (2003) developed an equation to predict the cost of new wetland construction based on the acreage of the contributing drainage area treated (updated to 2006 dollars):

$$BCC = (4{,}465)(A^{0.484})$$

Where:
A = Size of contributing drainage area (acres)
BCC = Base construction cost (2006 dollars)

Brown and Schueler (1997) devised a similar equation for new wetland and pond construction based on storage volume needed that yields slightly higher costs:

$$BCC = (27.95)(V_s^{0.701})$$

Where:
V_s = Total storage volume (ft^3)
BCC = Base construction cost (2006 dollars)

Based on typical wetland sizes, the equations yield a median construction cost of $2,900 per impervious acre treated (range: $2,000 to $9,600). Few retrofit sites will meet the criteria for use of these equations. Under most retrofit conditions, wetland retrofit construction costs will be 3 to 4 times greater than new wetland construction (see Chapter 2 and Appendix E).

Constructed Wetland Design Resources

Vermont Stormwater Management Manual
http://www.anr.state.vt.us/dec/waterq/cfm/ref/Ref_Stormwater.cfm

Connecticut 2004 Stormwater Management Manual
http://dep.state.ct.us/wtr/stormwater/strmwtrman.htm#download

Stormwater Management Manual for Western Washington
http://www.ecy.wa.gov/programs/wq/stormwater/manual.html

Minnesota Stormwater Manual
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

RR-9	Retrofit Design Sheets	
	BIORETENTION	

Typical Constraints

Bioretention can be applied in most soils or topography since runoff percolates through an engineered soil bed and is returned to the stormwater system. Key constraints when retrofitting with bioretention include:

Available Space: Not every open area will be a good candidate for bioretention. To start with, designers should look for open areas that are at least five to 10% of the contributing drainage area and are free of underground utilities.

Site Topography: Bioretention is best applied when contributing slopes are more than 1% and less than 5%. Ideally, the proposed treatment area will be located in depression to minimize excavation costs.

Available Head: Bioretention retrofits are fundamentally constrained by the invert elevation of the existing conveyance system they discharge to. These elevations generally establish the bottom elevation needed to tie the underdrain from the bioretention area into the storm drain system. In general, four to five feet of elevation above this invert is needed to drive stormwater through a proposed bioretention area. Less head is needed if underlying soils are permeable enough to dispense with the underdrain.

Water Table: Bioretention should always be separated from the water table to ensure groundwater does not intersect with the filter bed. Mixing can lead to possible groundwater contamination or practice failure. A separation distance of 3 feet is recommended between the bottom of the filter bed and the seasonally high water table.

Overhead Wires: Designers should also check whether future tree growth in the bioretention area will interfere with existing overhead utility lines.

Soils: Soil conditions do not constrain the use of bioretention although they determine whether an underdrain is needed. Impermeable soils in Hydrologic Soil Group C or D usually require an underdrain, whereas A or B soils often do not. Designers should verify soil permeability when designing a bioretention retrofit, using the on-site soil investigation methods presented in Appendix H.

Community and Environmental Considerations for Bioretention Retrofits

Bioretention is a popular practice, since it can meet local landscaping requirements and improve site appearance. The only major drawbacks relate to who will handle future landscape maintenance and whether landowners will modify or replace the bioretention area in the future. If bioretention areas will be installed on private lots, homeowners need to be educated on their routine maintenance tasks and fully understand their intended stormwater function.

Design Issues for Bioretention

Several issues should be considered when designing bioretention retrofits:

Pretreatment: Pretreatment can prevent premature clogging and prolong the effective function of bioretention retrofits. Several pretreatment measures can be used, including directing runoff over a grass filter strip, adding a three to six inch drop or installing a pea gravel diaphragm that spreads flow evenly and drops out larger sediment particles. A two-cell design is recommended when bioretention is used as a storage retrofit or for larger on-site applications. The first cell is a sediment forebay that pretreats runoff and traps sediment before discharge into the main bioretention cell.

Landscaping is critical to the function and appearance of bioretention areas. Where possible, a combination of native trees, shrubs, and herbaceous plant species are preferred. Plants should be able to tolerate both wet and dry conditions. Most upland vegetation does not do well in the deepest center areas that are more frequently inundated. “Wet footed” plants, such as wetland forbs, should be planted near the center, whereas upland species are better for the edges of the bioretention area. Regional lists of plant species suitable for bioretention areas can be found at the end of this profile sheet.

Type of media: The choice of filter media is important to provide adequate drainage, support plant growth and optimize pollutant removal within the filter bed. Early design guidance recommended a mix of 50-60% sand, 20-30% topsoil and 20-30% organic leaf compost. The topsoil component should consist of loamy sand, sandy loam, or loam with a clay content no greater than 5%.

Hunt and Lord (2006a) has recently advocated a bioretention soil mix with a greater proportion of sand (85-88% sand; 8-12% fines; and 3-5% organic matter) as a more effective choice for pollutant removal. They also strongly recommend that topsoil be tested to ensure that it has a low phosphorus index value to prevent phosphorus leaching. If nitrogen removal is the goal, it may be advisable to increase the percentage of soil fines.

Designers should also ensure that the media is well mixed and homogeneous. The media should have an infiltration rate of 1.0 to 2.0 inches per hour as recent research indicates that pollutant removal is optimized in this range.

Depth of Media: Early bioretention design guidance recommended a minimum filter bed depth of 4 feet. However, the filter bed may be reduced in depth to 1.5 to 2.5 feet in certain retrofit applications, particularly when available head is limited. Research has shown that good pollutant removal can still be achieved in filter beds as shallow as 1.5 feet, with the possible exception of nitrogen (Davis, 2005, and Hunt *et al.*, 2006). It is doubtful that filter beds less than 1.5 feet deep can provide reliable pollutant removal efficiency over the long run. Designers should also remember that filter beds need to be at least 4 feet deep to provide enough soil volume for the root structure of mature trees (i.e., use turf, perennials or shrubs instead of trees for shallower filter beds).

Underdrain: In many bioretention retrofits, filtered runoff will be collected by a perforated underdrain and conveyed to the storm drain system. If the site has permeable soils, however, the underdrain can be reduced or eliminated altogether. The need for an underdrain depends on the permeability of the underlying soils, which have often been previously altered or compacted in many retrofit situations. Soil permeability rates should always be verified when designing a bioretention retrofit (see Appendix H). If an underdrain is required at a bioretention retrofit, it should have a minimum diameter of 6 inches and be placed in a foot deep gravel bed.

Overflow: Designers should always incorporate an overflow structure to safely bypass larger storms around the bioretention retrofit. The invert of the overflow should be placed at the maximum water surface elevation of the bioretention area, which is typically 6 to 12 inches above the surface of the filter bed.

Surface Cover: A three-inch layer of hardwood mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, and pretreats runoff before it reaches the filter bed. Shredded hardwood bark mulch makes a very good surface cover, as it retains a significant amount of nitrogen and typically will not float away. On the other hand, hardwood mulch needs to be replaced every few years, may not be durable or attractive enough for certain retrofit situations, and may not be available in some regions of the country. In these situations, designers may wish to consider alternative covers such as turf, river stone, gravel or pumice stone.

Contributing Drainage Area: Designers should always verify that the actual contributing area and inlet elevations are accurately determined at the retrofit site. Designers should walk the site during a rainstorm to look at actual flowpaths to the proposed treatment area, and confirm these boundaries using fine resolution topographic surveys.

Bioretention Maintenance Issues

Bioretention requires seasonal landscaping maintenance to establish and maintain vigorous plant cover:

Vegetation Management: Vegetation management is an important to sustain the pollutant removal and landscaping benefits of the bioretention area. The construction contract should include a care and replacement warranty to ensure vegetation gets properly established and survives during the first growing season after construction.

Surface Cover/Filter Bed: The surface of the filter bed can become clogged with fine sediments over time. Core aeration or deep tilling may relieve the problem. The surface cover layer will need to be removed and replaced every two or three years. The inlets and pretreatment measures for the bioretention retrofit also need frequent inspections to ensure they are working properly and to remove deposited sediments.

Training Landscape Contractors: Maintenance can be performed by landscaping contractors who are already providing similar landscaping services on the property, but they will need training on bioretention maintenance tasks.

Adapting Bioretention for Special Climates and Terrain

Bioretention areas can be applied almost everywhere, with the proper design modifications:

Arid Climates: Bioretention areas should be landscaped with drought-tolerant plant species. A xeriscaping approach is preferred since supplemental irrigation makes little sense in arid and semi-arid climates. It may also be advisable to switch from mulch to a more durable surface cover such as riverstone or pumice. The planting plan may also have fewer trees and plants to minimize the need for supplemental irrigation. Designers should recognize that longer growing seasons increase both the frequency and cost of landscape maintenance.

Cold Climates: Bioretention areas can be used for snow storage as long as an overflow is provided and they are planted with salt-tolerant, non-woody plant species (for a species list, consult MSSC, 2005). While several studies have shown that bioretention operates effectively in winter conditions, it is a good idea to extend the filter bed and underdrain pipe below the frost line and/or oversize the underdrain by one pipe size to reduce the freezing potential.

Karst Terrain: Bioretention should utilize impermeable liners and underdrains when located in an active karst area. A geotechnical investigation may be needed to confirm that three feet of vertical separation exists from the underlying rock layer.

Bioretention Installation Costs

The cost to construct bioretention areas are extremely variable, and are strongly influenced by the area treated, the depth of filter bed, the presence or absence of an underdrain and whether it is professionally designed, installed or landscaped. Wossink and Hunt (2003) report that bioretention has the lowest construction costs of all new stormwater treatment options serving smaller drainage areas from 1 to 5 acres. On the other hand, the unit costs to retrofit bioretention in highly urban settings may be 10 to 20 times higher (See Appendix E). The long-term maintenance costs for bioretention areas are not expected to be very different from normal landscaping maintenance costs.

Brown and Schueler (1997) developed equations to predict the base construction cost of bioretention as a function of the water quality volume provided. When these equations are adjusted to 2006 dollars, they yield:

$$BCC = (7.62)(WQ_v^{0.990})$$

Where:
WQ_v = Water quality volume (ft^3)
BCC = Base construction cost (2006 dollars)

More recently, Wossink and Hunt (2003) developed equations to predict the cost of new bioretention construction as a function of their contributing drainage area. This equation yields lower cost estimates compared to the Brown equation:

$$BCC = (11{,}781)(A^{1.088})$$

Where:
A = Size of contributing drainage area (acres)
BCC = Base construction cost (2006 dollars)

Using these equations, it is possible to establish median bioretention costs of $25,400 per impervious acre treated (range: $19,900 to $41,750). Construction cost drops sharply when site soils are permeable enough to dispense with an underdrain (although this is not a common retrofit situation).

Bioretention Design Resources

Several state and local stormwater manuals provide useful bioretention design guidance:

Prince George's Co., MD Bioretention Manual
http://www.goprincegeorgescounty.com/Government/AgencyIndex/DER/ESD/Bioretention/bioretention.asp?nivel=foldmenu(7)

Lake Co., OH Bioretention Guidance Manual
http://www2.lakecountyohio.org/smd/Forms.htm

Low Impact Development Technical Guidance Manual for Puget Sound, WA
http://www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.htm

Wisconsin Stormwater Management Technical Standards
http://www.dnr.state.wi.us/org/water/wm/nps/stormwater/techstds.htm#Post

Maryland Stormwater Design Manual
http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

RR-10	Retrofit Design Sheets	
	SWALES	

Typical Constraints

Constraints to consider when evaluating a potential swale retrofit include:

Contributing Drainage Area: The maximum contributing drainage area to a swale retrofit should be five acres and preferably less.

Space Required: Swale retrofits usually consume about five to 15% of their contributing drainage area.

Site Topography: Site topography constrains swale retrofits; some gradient is needed to provide water quality treatment but not so much that treatment is impeded. Swales generally work best on sites with relatively flat slopes (e.g., less than 5% slope for grass channels and 2% for wet and dry swales). Steeper slopes create rapid runoff velocities that can cause erosion and do not allow enough contact time for infiltration or filtering. Swales perform poorly in extremely flat terrain because they lack enough grade to create storage cells, and lack head to drive the system.

Available Head: A minimum amount of head is needed to implement each swale retrofit. Dry swales typically require three to five feet of head since they require a filter bed and underdrain. Wet swales require about two feet of head, whereas grass swales need only a foot. Designers should measure gradient in the field to ensure enough head exists to drive the swale retrofit.

Hydraulic Capacity of Existing Open Channel: Most open channels were originally sized with enough capacity to convey runoff from the ten-year storm, and be non-erosive during the two-year design storm event. In many cases, the open channel may be under-capacity due to upstream development or past sedimentation. The capacity of the existing open channel should be verified during the retrofit project investigation. Field observations that may indicate an existing channel is undersized channel include excessive erosion of the channel side slopes, poor vegetative stabilization and overbank debris.

Width of Existing Right of Way or Easement: Designers should investigate whether the existing right of way or stormwater easement is wide enough to accommodate retrofit construction and maintenance access. In most cases, the existing channel will need to be widened or flows split into adjacent off-channel treatment cells.

Depth to Water Table: Designers should separate the bottom of the swale from the groundwater by at least two feet for dry swales and grass channels. It is permissible to intersect the water table for wet swales, since the pool enhances water quality treatment.

*Soils: S*oil permeability influences which swale design variant will work best in the existing channel. Designers should note that past construction and compaction may have severely reduced the permeability of the original swale soils. Several on-site tests should be conducted at the proposed retrofit to measure actual soil infiltration retrofit rates (see Appendix H). In general, grass swales are restricted to soils in Hydrologic Soil Groups A or B. Dry swales also work well on these soils, but can be applied to more impermeable C or D soils if an underdrain is used. Wet swales work best on more impermeable C or D soils.

Utilities: Many utilities run along or underneath open channels, so designers should always check for utility lines or crossings at each swale retrofit site. The presence of dry or wet utilities usually renders a swale retrofit infeasible.

Community and Environmental Considerations for Swale Retrofits

Swale retrofits are normally accepted by communities if they are properly designed and maintained, but require approval by multiple landowners to secure additional right of way. The main concerns of adjacent residents are perceptions that swale retrofits will create nuisance conditions or will be hard to maintain. Common concerns include the continued ability to mow grass, landscape preferences, weeds, standing water, and mosquitoes. For these reasons, wet swales are not recommended in residential settings - the shallow, standing water in the swale is often viewed as a potential nuisance by homeowners. Dry swales are a much better alternative.

Key Design Issues for Swale Retrofits

Several design elements can ensure the swale retrofit performs effectively over the long run:

Pretreatment: Adequate pretreatment is needed to trap sediments before they reach the main treatment cell of the swale retrofit. A small sediment forebay located at the upstream end of the swale often works best. A pea gravel flow spreader along the top of each bank can pretreat lateral runoff from the road shoulder to the swale.

Swale Dimensions: Swales should have a bottom width ranging from two to eight feet to ensure an adequate surface area exists along the bottom of the swale for filtering. If a swale will be wider than eight feet, designers should incorporate berms, check dams, level spreaders or multi-level cross sections to prevent braiding and erosion within the swale bottom. Swale retrofits should be designed with a parabolic or trapezoidal cross section and have side slopes no steeper than 3:1 (h:v). Designers should seek side slopes much less than 3:1 to promote more treatment of lateral sheet flow, if space is available.

Ponding Depth: Drop structures or check dams can be used to create ponding cells along the length of the swale. The maximum ponding depth in a swale should not exceed 18 inches at the most downstream point. The average ponding depth throughout the swale should be 12 inches.

Drawdown: Dry swale retrofits should be designed so that the desired WQv is completely filtered within six hours or less. This drawdown time can be achieved by using a sandy soil mix or an underdrain along the bottom of the swale. No minimum drawdown time is required for wet swale retrofits.

Swale Media: Dry swales require replacement of native soils with a prepared soil media. The soil media provides adequate drainage, supports plant growth and facilitates pollutant removal within the dry swale. The soil media should have an infiltration rate of at least one foot per day and be comprised of a mix of native soil, sand and organic compost similar to bioretention design recommendations presented in ST-4. At least 18 inches of soil media should be mixed into the swale bottom.

Underdrain: Underdrains are provided in dry swale retrofits to ensure they drain properly after storms. The underdrain should have a minimum diameter of 6 inches and be encased in a foot deep gravel bed. Underdrains are not needed in wet swales or grass channels.

Swale Maintenance Requirements

Swale maintenance often fits within normal turf management operations that are already being performed. Swale retrofits are often located near landowners that have real or perceived concerns on how the swale may affect their front yards and property value. Therefore, designers should consider how to:

- Minimize standing water
- Minimize interference of check dams with regular mowing
- Manage vegetative growth in the future
- Educate residents on how to properly maintain the swale over time

Regular inspections should be conducted on the swale retrofit to schedule maintenance operations such as sediment removal, spot revegetation and inlet stabilization. Maintenance crews may need to be educated on the purpose and maintenance needs of swale retrofits installed along streets or highway right-of-way.

Adapting Swales for Special Climates and Terrain

Swale retrofits can be applied in most climates and terrain with some design modifications:

Cold Climates: Swales can store snow and treat snowmelt runoff. If roadway salt is applied, swales should be planted with salt-tolerant and non-woody plant species. Consult the Minnesota Stormwater Manual for a list of salt-tolerant grass species (MSSC, 2005). The dry swale underdrain pipe should extend below the frost line and be oversized by one pipe size to reduce the chances of freeze-up.

Arid Climates: It is extremely hard to maintain a wet swale retrofit in arid and semi-arid climates. Swales should be planted with drought-tolerant vegetation and the planting plan should specify fewer broad-leaved plants to minimize the need for supplemental irrigation. A xeriscaping approach is preferred for any swale in arid or semi-arid regions since irrigation makes little sense and is expensive in these regions.

Karst Terrain: Swale retrofits should utilize impermeable liners and underdrains to prevent sinkhole formation in active karst areas.

Swale Installation Costs

Only limited cost data has been published on swale construction costs. Equations to estimate swale costs for new construction are outlined in Appendix E. The projected cost for swales at new development sites is estimated to be $18,150 per impervious acre treated (range: $10,900 to $36,300). Few retrofit sites will meet the construction conditions for new development sites; most swale retrofits will cost about twice as much, particularly if they involve off-channel treatment.

Swale Design Tools

New York State Stormwater Management Design Manual
http://www.dec.state.ny.us/website/dow/toolbox/swmanual/index.html

Vermont Stormwater Management Manual
http://www.anr.state.vt.us/dec/waterq/cfm/ref/Ref_Stormwater.cfm

Stormwater Management Manual for Western Washington
http://www.ecy.wa.gov/programs/wq/stormwater/manual.html#How_to_Find_the_Stormwater_Manual_on_the

CNMI and Guam Stormwater Management Manual
http://www.guamepa.govguam.net/programs/water/index.html

Attachment J. Crane Creek Hotspot / Pollution Prevention Profile Sheets

N-1

Neighborhood Source Area: Yard

REDUCED FERTILIZER USE

Description

The ideal behavior is to not apply fertilizer to lawns. The next best thing for homeowners who feel they must fertilize is to practice natural lawn care: using low inputs of organic or slow release fertilizers that are based on actual needs as determined by a soil test. The obvious negative watershed behavior is improper fertilization, whether in terms of the timing, frequency or rate of fertilizer applications, or a combination of all three. The other important variable to define is who is applying fertilizer in the neighborhood. Nationally, about 75% of lawn fertilization is done by homeowners, with the remaining 25% applied by lawn care companies (Figure 1). This split, however, tends to be highly variable within individual neighborhoods, depending on its income and demographics.

How Fertilizer Influences Water Quality

Recent research has demonstrated that lawn over-fertilization produces nutrient runoff with the potential to cause downstream eutrophication in streams, lakes, and estuaries (Barth, 1995a and 1995b). Scientists have also discovered that nitrogen and phosphorus levels in lawn runoff are about two to 10 times higher than any other part of the urban landscape such as streets, rooftops, driveways or parking lots (Bannerman *et al.*, 1993; Steuer *et al.*, 1997; Waschbusch *et al.*, 2000; Garn, 2002).

Figure 1: Lawn Care Company Truck

Percentage of People Engaging in Fertilizer Use

Lawn fertilization is among the most widespread watershed behaviors in which residents engage. A survey of lawn care practices in the Chesapeake Bay indicated that 89% of citizens owned a yard, and of these, 50% applied fertilizer every year (Swann, 1999). The average rate of fertilization in 10 other regional lawn care surveys was even higher (78%), although this may reflect the fact that these surveys were biased towards predominantly suburban neighborhoods and excluded non-lawn owners. Several studies have measured the frequency of lawn fertilization, and have found that lawns are fertilized about twice a year, with spring and fall being the most common season for applications (Swann, 1999).

A significant fraction of homeowners can be classified as “over-fertilizers” who apply fertilizers above recommended rates. Surveys indicate the number of over-fertilizers at 50% to 70% of all fertilizers (Morris and Traxler, 1996; Swann, 1999; Knox *et al.*, 1995). Clearly, many homeowners, in a quest for quick results or a bright green lawn, are applying more nutrients to their lawns than they actually need.

Variation in Fertilization Behavior

Many regional and neighborhood factors influence local fertilization behavior. From a regional standpoint, climate is a very important factor, as it determines the length of the growing season, type of grass, and the irrigation needed to maintain a lawn. A detailed discussion of the role these factors play in fertilization can be found in Barth (1995a). A host of factors also comes into play at the individual neighborhood scale. Some of the more important variables include average income, market value of houses, soil quality, and the age of the development (Law *et al.*, 2004). Higher rates of fertilization appear to be very common in new suburban neighborhoods where residents seek to establish lawns and landscaping. Also, lawn irrigation systems and fertilization are strongly associated.

Difficulty in Changing Behavior

Changing fertilization behaviors can be hard since the desire for green lawns is deeply rooted in our culture (Jenkins, 1994; Teyssott, 1999). For example, the primary fertilizer is a man in the 45 to 54 year age group (BHI, 1997) who feels that "a green attractive lawn is an important asset in a neighborhood" (De Young, 1997). According to surveys, less than 10% of lawn owners take the trouble to take soil tests to determine whether fertilization is even needed (Swann, 1999; Law *et al.*, 2004). Most lawn owners are ignorant of the phosphorus or nitrogen content of the fertilizer they apply (Morris and Traxler, 1996), and are unaware that grass-cycling can sharply reduce fertilizer needs.

Most residents rely on commercial sources of information when making their fertilization decisions. The average consumer relies on product labels, store attendants, and lawn care companies as their primary, and often exclusive, sources of lawn care information. Consumers are also influenced by direct mail and word of mouth when they choose a lawn care company (Swann, 1999 and AMR, 1997).

Two approaches have shown promise in changing fertilization behaviors within a neighborhood, and both involve direct contact with individual homeowners. The first relies on using neighbors to spread the message to other residents, through master gardening programs. Individuals tend to be very receptive to advice from their peers, particularly if it relates to a common interest in healthy lawns. The second approach is similar in that it involves direct assistance to individuals at their homes (e.g., soil tests and lawn advice) or at the point of sale.

Techniques to Change Behavior

Most communities have primarily relied on carrots to change fertilization behaviors, although sticks are occasionally used in phosphorus-sensitive areas. The following are some of the most common techniques for changing fertilization behaviors:

- Seasonal media awareness campaigns
- Distribution of lawn care outreach materials (brochures, newsletters, posters, etc.; Figure 2)
- Direct homeowner assistance and training
- Master gardener program
- Exhibits and demonstration at point-of-sale retail outlets
- Free or reduced cost for soil testing
- Training and/or certification of lawn care professionals
- Lawn and garden shows on radio
- Local restrictions on phosphorus content in fertilizer

Good Examples

King County, Washington- Northwest Natural Yard Days. This month-long program offers discounts on natural yard care products and educational information about natural yard care in local stores throughout King County and Tacoma. Education specialists came to Saturday and Sunday events at some stores and spent time with buyers to help them make good choices and learn about natural yard care, including the use of organic fertilizers that don't wash off into streams and lakes as easily as "quick release" chemical fertilizers. For more details, consult: http://dnr.metrokc.gov/swd/ResRecy/events/naturalyard.shtml

North Carolina Department of Agriculture Free Residential Lawn Soil Testing. Residents can get a free soil test to determine the exact fertilizer and lime needs for their lawn, as well as for the garden, landscape plants and fruit trees. Information sheets and soil boxes are available from various government agencies, or local garden shops and other businesses. For more information, consult: http://www.ncagr.com/agronomi/stfaqs.htm

Minnesota Department of Agriculture Phosphorus Lawn Fertilizer Use Restrictions. Starting in 2004, these restrictions limit the concentration of phosphorus in lawn care products and restrict its application at higher rates to specific situations based on need. http://www.mda.state.mn.us/appd/ace/lawncwaterq.htm

Top Resources

Cornell Cooperative Extension. The Homeowner's Lawn Care Water Quality Almanac.
http://www.gardening.cornell.edu/lawn/almanac/index.html

University of Rhode Island Cooperative Extension Home*A*Syst Healthy Landscapes Program
http://www.healthylandscapes.org/

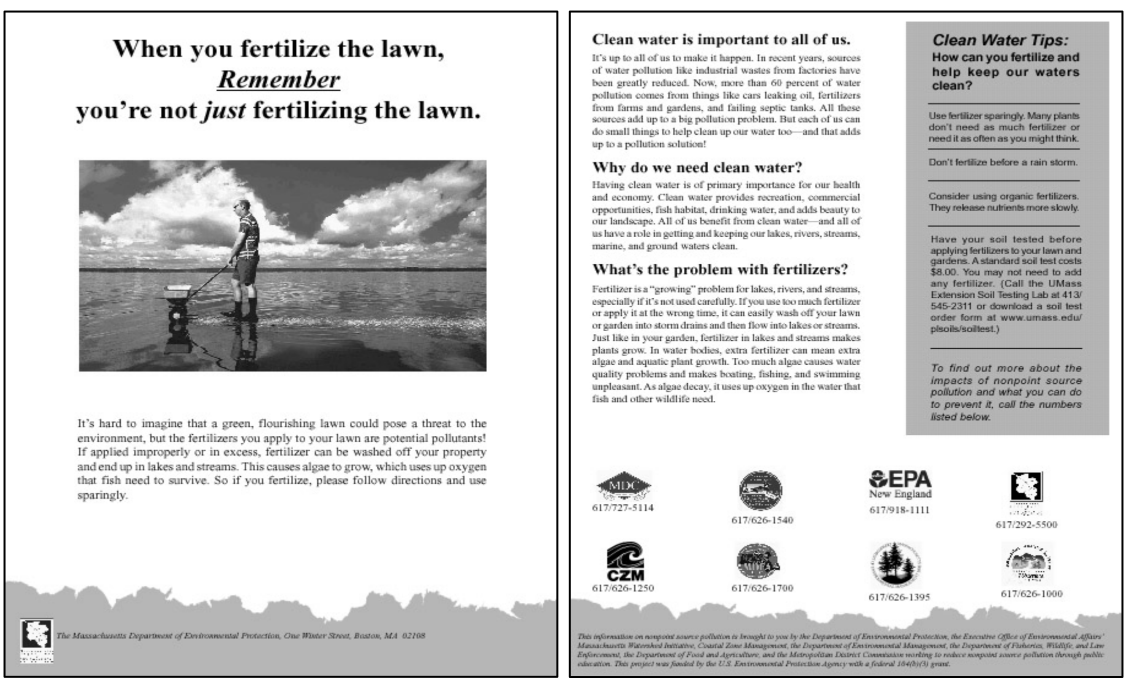
University of Maryland Cooperative Extension - Home and Garden Information Center.
http://www.agnr.umd.edu/users/hgic/

Turf and Landscape Best Management Practices. South Florida Water Management District and the Broward County Extension Education Division
http://www.sfwmd.gov/org/exo/broward/c11bmp/fertmgt.html

Florida Yards and Neighborhoods Handbook: A Guide to Environmentally Friendly Landscaping
http://hort.ufl.edu/fyn/hand.htm

University of Minnesota Extension Service Low-Input Lawn Care (LILaC)
http://www.extension.umn.edu/distribution/horticulture/DG7552.html

Austin TX, Stillhouse Spring Cleaning
http://www.ci.austin.tx.us/growgreen/stillhouse.htm



When you fertilize the lawn,
Remember
you're not *just* fertilizing the lawn.

It's hard to imagine that a green, flourishing lawn could pose a threat to the environment, but the fertilizers you apply to your lawn are potential pollutants! If applied improperly or in excess, fertilizer can be washed off your property and end up in lakes and streams. This causes algae to grow, which uses up oxygen that fish need to survive. So if you fertilize, please follow directions and use sparingly.

The Massachusetts Department of Environmental Protection, One Winter Street, Boston, MA 02108

Clean water is important to all of us.

It's up to all of us to make it happen. In recent years, sources of water pollution like industrial wastes from factories have been greatly reduced. Now, more than 60 percent of water pollution comes from things like cars leaking oil, fertilizers from farms and gardens, and failing septic tanks. All these sources add up to a big pollution problem. But each of us can do small things to help clean up our water too—and that adds up to a pollution solution!

Why do we need clean water?

Having clean water is of primary importance for our health and economy. Clean water provides recreation, commercial opportunities, fish habitat, drinking water, and adds beauty to our landscape. All of us benefit from clean water—and all of us have a role in getting and keeping our lakes, rivers, streams, marine, and ground waters clean.

What's the problem with fertilizers?

Fertilizer is a "growing" problem for lakes, rivers, and streams, especially if it's not used carefully. If you use too much fertilizer or apply it at the wrong time, it can easily wash off your lawn or garden into storm drains and then flow into lakes or streams. Just like in your garden, fertilizer in lakes and streams makes plants grow. In water bodies, extra fertilizer can mean extra algae and aquatic plant growth. Too much algae causes water quality problems and makes boating, fishing, and swimming unpleasant. As algae decay, it uses up oxygen in the water that fish and other wildlife need.

Clean Water Tips:
How can you fertilize and help keep our waters clean?

Use fertilizer sparingly. Many plants don't need as much fertilizer or need it as often as you might think.

Don't fertilize before a rain storm.

Consider using organic fertilizers. They release nutrients more slowly.

Have your soil tested before applying fertilizers to your lawn and gardens. A standard soil test costs $8.00. You may not need to add any fertilizer. (Call the UMass Extension Soil Testing Lab at 413/545-2311 or download a soil test order form at www.umass.edu/plsoils/soiltest.)

To find out more about the impacts of nonpoint source pollution and what you can do to prevent it, call the numbers listed below.

MDC 617/727-5114
617/626-1540
EPA New England 617/918-1111
617/292-5500
CZM 617/626-1250
617/626-1700
617/626-1395
617/626-1000

This information on nonpoint source pollution is brought to you by the Department of Environmental Protection, the Executive Office of Environmental Affairs' Massachusetts Watershed Initiative, Coastal Zone Management, the Department of Environmental Management, the Department of Fisheries, Wildlife, and Law Enforcement, the Department of Food and Agriculture, and the Metropolitan District Commission working to reduce nonpoint source pollution through public education. This project was funded by the U.S. Environmental Protection Agency with a federal 104(b)(3) grant.

Figure 2: Educational Brochure on Fertilizer
Source: http://www.state.ma.us/dep/brp/wm/files/fertiliz.pdf

N-2	Neighborhood Source Area: Yard REDUCED PESTICIDE USE	

Description

The ideal watershed behavior is to not apply any insecticides or herbicides to the lawn or garden. Many residents, however, still want to control pests and weeds, so the next best behavior is a natural approach that emphasizes limited use of safer chemicals, proper timing and targeted application methods. The negative residential behavior is over-use or improper application of insecticides and herbicides that are known to have an adverse impact on aquatic life.

How Pesticide Use Influences Subwatershed Quality

The leading source of pesticides to urban streams is homeowner applications in the lawn and garden to kill insects and weeds. The pesticides of greatest concern are insecticides, such as diazinon and chloropyrifos, and a large group of herbicides (CWP, 2003; USGS, 2001; Schueler, 1995; Figure 1). Very low levels of these pesticides can be harmful to aquatic life. According to a national monitoring study, one or more pesticides were detected in 99% of urban streams sampled (USGS, 2001). Pesticide levels in urban streams exceeded national water quality standards to protect aquatic life in one out of every five samples. Even more troubling was the finding that 100% of fish in urban streams had detectable levels of pesticide in their tissues, with 20% exceeding recommended guidelines for fish-eating wildlife (such as racoons, kingfishers, ospreys and eagles).

Figure 1: Bag of Pesticide Granules

Percentage of People Engaging in Pesticide Use

About half of Chesapeake Bay residents reported that they had applied pesticides to their lawn or garden (Swann, 1999). Surveys on residential pesticide use for other regions of the country indicate that home pesticide use varies greatly, ranging from a low of 17% to a high of 87% of households (Swann, 1999). According to EPA, the average acre of maintained suburban lawn receives five to seven pounds of pesticides each year.

Variation in Pesticide Use

Many regional and neighborhood factors influence the degree of local pesticide use. From a regional standpoint, climate is an extremely important factor. For example, insecticides are applied more widely in warmer climates where insect control is a year round problem (e.g., 50 to 90% of warm-weather residents report using them). This can be compared to 20 to 50% of insecticide use reported for colder regions where hard winters help keep insects in check (Schueler, 2000b). By contrast, herbicide application rates tend to be higher in colder climates in order to kill weeds that arrive with the onset of spring (e.g., 60 to 75% of cold weather residents report use).

Many neighborhood factors can play a strong role in the degree of pesticide use. These include lot or lawn size, presence of gardens, condition of turf, presence or absence of irrigation and neighborhood age. The average income and demographics within a neighborhood are also thought to play a strong role, particularly if residents rely on lawn care and landscaping companies to maintain their lawns.

Difficulty in Changing the Behavior

Pesticide use is a difficult behavior to change for several reasons. First, many residents want a quick and effective solution to their pest problems. Second, many residents lack awareness about the link between their pesticide use and stream quality. Lastly, many residents rely on commercial sources of information when choosing pesticides, and lack understanding of safer alternatives and practices. As with fertilizers, product labels are the primary source of information about pesticides. Nearly 90% of homeowners rely on them to guide their pesticide use (Swann, 1999). In addition, many residents are unaware of the pesticide application practices that their lawn care company applies to their yard and prefer to rely on professional know-how (Knox *et al*., 1995).

Confusion also stems from the recent growth of "weed and feed" lawn care products that combine weed control and fertilizer in a single bag. In one Minnesota study, 63% of residents reported that they used weed and feed lawn products, but only 24% understood that they were applying herbicides to their lawn (Morris and Traxler, 1996).

Techniques to Change the Behavior

Most communities rely on the same basic combination of carrots to change pesticide use as they do for fertilizer use, since they are so interrelated. The following are some of the most common techniques to change pesticide use:

- Seasonal media awareness campaigns
- Distribution of lawn care outreach materials (brochures, newsletters, posters, etc.)
- Direct homeowner assistance and training
- Master gardener program
- Exhibits and demonstration at point of sale at retail outlets
- Pest advice hotlines
- Training, certification and/or licensing of lawn care professionals and pesticide applicators
- Radio lawn and garden advice shows

Figure 2: Educational Pesticide Brochure
Source: http://www.lacity.org/SAN/wpd/index.htm

Good Examples

Perdue Pesticide Program - Web-based program to help comply with the State of Indiana regulations that help homeowners use pesticides effectively and safely. According to Indiana law and recently enacted regulations, all retail establishments in the state that sell gardening and pest control products and offer recommendations on their use must be licensed as consultants, while their sales associates must be trained to knowledgeably disseminate product information.
http://www.btny.purdue.edu/PPP/

Green Communities Association's Pesticide Free Naturally: A Campaign to Reduce the Cosmetic Use of Pesticides - The campaign includes an Action Kit that includes pesticide-free lawn signs, fact sheets on health impacts, tips on how to engage neighbors in discussions about pesticide use, a children's activity pack, and information on effective alternatives to pesticides, including home recipes.
http://www.gca.ca/indexcms/index.php?pfn

Top Resources

Tips for Homeowners on Hiring a Pesticide Applicator
http://www.epa.gov/oppfead1/Publications/Cit_Guide/citguide.pdf

Try Pesticide Alternatives
http://www.mda.state.md.us/pdf/Tip1.pdf

Washington State University - Pesticide Safety Programs
http://pep.wsu.edu/psp/

National Pesticide Information Center Site - Provides objective, science-based information about a variety of pesticide-related subjects, including pesticide products, toxicology, and environmental chemistry.
http://npic.orst.edu/

IPM Practitioners Association IPM ACCESS Webpage
http://www.efn.org/~ipmpa/

Our Water, Our World
http://sfwater.org/detail.cfm/MC_ID/4/MSC_ID/78/MTO_ID/NULL/C_ID/1402

Grow Green: Landscaping for Clean Water
http://www.ci.austin.tx.us/growgreen/default.htm

N-3	Neighborhood Source Area: Yard	
	NATURAL LANDSCAPING	

Description

The ideal watershed behavior is to replace existing turf cover with native species of annuals, perennials, shrub and forest cover in mulched beds that produce less runoff and create backyard habitat. The negative watershed behavior is exclusive reliance on turf cover in the yard and/or use of non-native invasive species that can spread from the yard into adjacent stream corridors or natural area remnants.

How Natural Landscaping Influences Subwatershed Quality

The cumulative effect of natural landscaping practices on subwatershed quality are hard to quantify, but can provide some clear benefits. First, reduced turf area produces more natural hydrologic conditions in the yard, since mulched beds intercept and adsorb rainfall and can produce less runoff (Figure 1). Natural landscaping also creates native habitats, increases forest cover, and creates a natural seed bank of native plant species in subwatersheds. Natural landscaping can also prevent the spread of invasive non-native plant species into the stream corridor, which is an increasing problem in many urban subwatersheds. English ivy, bamboo, and other fast-spreading non-native species can quickly dominate the plant community of the urban stream corridor.

Percentage of Homeowners Engaging in Natural Landscaping

The proportion of homeowners that engage in natural landscaping is poorly understood at both the national and neighborhood level. About half of Americans report that home gardening and landscaping is one of their major hobbies (Figure 1), but the proportion using native plants or landscape for wildlife or watershed appears to constitute a much smaller niche market.

Variation in Landscaping Behavior

Native plant species are adapted to local differences in soil, rainfall and temperature conditions. Neighborhood factors such as neighborhood age, lot size, income level and watershed awareness appear to influence the promotion of natural landscaping.

Figure 1: Before (a) and After (b) Natural Landscaping

Difficulty in Changing Landscaping Behavior

While natural landscaping practices have been growing in recent years, there are a number of barriers to more widespread implementation. The first barrier is that many homeowners are not aware of which plant species are native or non-native, and they do not know the benefits of natural landscaping. Second, native plant materials are not always widely available at garden centers and nurseries. Third, some communities still have weed and vegetation control ordinances that discourage natural landscaping.

Techniques to Promote Natural Landscaping

A range of carrots and sticks can help promote more widespread use of natural landscaping in a subwatershed, including:

- Conventional outreach on natural landscaping (brochures, newsletters, plant guides)
- Backyard habitat programs
- Free or reduced mulch
- Distribution of free or discounted native plant material
- Repeal of local weed ordinances with natural landscaping criteria
- Support of garden clubs and native plant societies
- Demonstration gardens (e.g. Bayscapes)
- Invasive species alerts
- Promotion of native plant nurseries
- Homeowner award/recognition programs
- Xeriscaping rebates

Good Examples

City of Austin, TX - WaterWise Program. Owners of new and existing homes may qualify for rebates up to $500 for Water Wise plantings of trees and shrubs. The goal of this program is to install a quality, low water use, low maintenance native landscape. http://www.ci.austin.tx.us/watercon/wwlandscape.htm

Village of Long Grove, IL - Village Code. Natural landscaping is encouraged in the city code, which states "impervious surfaces, shall not exceed forty percent (40%) of the total lot area. The remaining minimum sixty percent (60%) of the lot area shall be maintained as a 'green area' and shall consist of native wild areas, grass, trees, ponds or other natural vegetation." The code also does not limit residential vegetation height, which in other communities can limit use of natural plant species. http://www.longgrove.net/

Top Resources

National Wildlife Federation - Natural Back Yard Habitat Program. The Backyard Wildlife Habitat program educates people about the benefits and techniques of creating and restoring natural landscapes. Through a backyard wildlife "certification" process, guided efforts of homeowners and other community members to improve wildlife habitat where they live and work are formally acknowledged. http://www.nwf.org/backyardwildlifehabitat/

Alliance for the Chesapeake Bay - Bayscapes. This website provides practical guidance on how to design a "Bayscape," which is a watershed friendly form of natural landscaping. http://alliancechesbay.org/bayscapes.cfm

Wild-Ones- Native Plants, Natural Landscaping Publications and Model Ordinances. Website contains a wealth of information on natural landscaping, including the *Wild Ones Handbook* - a compendium of useful information for the native plant landscaper and wildflower gardener, appropriate for all bioregions. The site also provides vegetation and weed control model municipal ordinances that encourage the use of native plant communities as an alternative in urban landscape design. http://www.for-wild.org/

N-4

Neighborhood Source Area: Yard

TREE PLANTING

Description

The ideal watershed behavior is to ultimately achieve a mature tree canopy that covers more than 50% of residential lots within a neighborhood through tree planting and care (Figure 1a). The negative watershed behavior is tree clearing that reduces existing tree canopy on a residential lot and in neighborhoods (Figure 1b).

How Tree Planting Influences Subwatershed Quality

Forested neighborhoods have a distinctly different hydrological profile than non-forested neighborhoods. For operational purposes, American Forests defines forested neighborhoods as having at least 50% forest canopy covering the residential lot. The branches and leaves of the forest canopy help intercept and slowdown rainfall. For example, a large oak tree can intercept and retain more than 500 to 1,000 gallons of rainfall in a given year, which is roughly equivalent to a rain barrel in terms of runoff reduction (Cappiella, 2004). According to American Forests (1999), a healthy forest canopy can reduce storm water runoff by as much as 7% in a neighborhood.

Figure 1: Lots with Extensive Tree Cover (a) and Less Tree Cover (b)

A healthy residential forest canopy provides many additional environmental and economic benefits within a neighborhood. These include savings on home heating and cooling costs, higher property values, shading, removal of air pollutants, and noise reduction (Cappiella, 2004).

Percentage of Homeowners Engaging in Tree Planting

Regional GIS analyses of urban areas conducted by American Forests (2001) reveal that about 60% of neighborhoods have less than 50% forest canopy cover. The actual rate of tree planting is a poorly understood residential behavior. The actual rate of tree planting is a poorly understood residential behavior. A survey in the Chesapeake Bay watershed indicated that 71% of residents had planted a tree within the last five years (CBP, 2002). Tree planting rates by homeowners of around 50% were reported in urban metropolitan areas such as Baltimore, MD and Washington, D.C.; however, more research is needed to determine the frequency and impact of tree planting in urban subwatersheds.

Variation in Tree Planting Behavior

Trees may not be part of the native plant community in some regions of the country, and specific tree or prairie species will be determined by local climate and soils. Also, concerns about fire safety may make the 50% forest canopy goal impractical in regions that experience wildfires. At the neighborhood level, several factors influence the extent of forest canopy that can be attained. Probably the most important factor is the neighborhood age, as recently constructed neighborhoods generally lack established forest cover (Figure 2). Other factors include the existing forest canopy, lot subsidies or rebates for energy conservation plantings, size and soil depth.

Difficulty in Increasing Tree Planting Behavior

Generally, tree planting is a relatively easy behavior to encourage, although it may take decades to grow a mature canopy on a residential lot. Perhaps the biggest barrier to overcome is to find the best locations in the yard to plant trees that can grow to maturity (e.g., away from overhead powerlines, underground utilities, septic systems, etc.). The second concern is proper planting and care techniques to ensure that trees can survive and flourish in the critical first few years after they are planted. Third, some localities may discourage tree planting in the right-of-way due to maintenance concerns and pavement cracking.

Techniques for Increasing Residential Forest Canopy Cover

A series of techniques can promote tree planting and discourage tree clearing:

- Distribution of outreach materials on tree planting (brochures, newsletters, plant guides)
- Tree clearing ordinances and permits
- Direct forestry assistance
- Free seedlings or other native tree stocks
- Native tree planting guidebooks

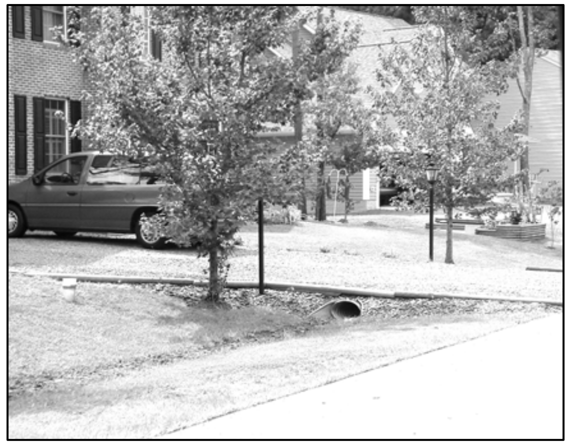


Figure 2: Newly Planted Trees in a New Neighborhood

Good Examples

Slinger, WI -Residential Tree Power Incentive Program. The electric utility in this community offers cash incentives for planting deciduous trees that conserve energy by providing significant shading of an air conditioning unit or the south or west exposure of a home upon tree maturity.
http://www.slinger-wi-usa.org/utilityprograms.htm

Tucson Electric Power (TEP) Tree Planting Incentives for Residents. TEP, working with the Trees for Tucson program, offers residents up to two five-gallon size trees at $3.00 per tree for planting on the west, east or south side of their homes. The program has distributed more than 22,000 trees since its inception, and also provides information to homeowners, neighborhood groups, and schools on low-water species appropriate to the local environment, and optimum placement of trees for energy and water conservation.
http://swenergy.org/programs/arizona/utility.htm

Banks and Buffers: A Guide to Selecting Native Plants for Streambanks and Shorelines. Produced by the Tennessee Valley Authority, this guide includes a software application to assist in plant selection. It also contains selected characteristics and environmental tolerances of 117 native plants and over 400 color photographs illustrating habitat and growth form.
http://www.tva.gov/river/landandshore/stabilization/index.htm

National Arbor Day Foundation Awards
This award recognition program honors the achievements of citizens, communities, the media, and schools whose work in the cause of tree planting, care, and conservation have set an example of excellence. Applications are submitted through the Department of Natural Resources to the National Arbor Day Foundation. Contact: DNR - Forest Service regional office or The National Arbor Day Foundation, 100 Arbor Avenue, Nebraska City, NE 68410. http://www.arborday.org/

Top Resources

American Forests - CityGreen GIS software
http://www.americanforests.org./

Center for Urban Forest Research
http://wcufre.ucdavis.edu/

Guidelines for Developing and Evaluating Tree Ordinances
http://www.isa-arbor.com/publications/ordinance.aspx

Treelink
http://www.treelink.org/

National Tree Trust
http://www.nationaltreetrust.org/

Treepeople
http://www.treepeople.org/

Society of Municipal Arborists
http://www.urban-forestry.com/

Urban Forest Ecosystems Institute
http://www.ufei.calpoly.edu/

USDA Forest Service, Northeastern Research Station
http://www.fs.fed.us/ne/

USDA Forest Service, Southern Region
http://www.urbanforestrysouth.org/

USDA Forest Service, Pacific Northwest Research Station
http://www.fs.fed.us/pnw/

USDA Forest Service, Pacific Southwest Research Station
http://www.fs.fed.us/psw/

N-5	Neighborhood Source Area: Yard	
	EROSION REPAIR	

Description

While most yards have extensive vegetative cover, soil erosion can occur on steep slopes, in bare patches, and around driveways. The ideal watershed behavior is to survey the yard for any patches of exposed soils and establish a fast-growing grass or ground cover (Figure 1). The negative watershed behavior is to allow erosion to continue unchecked. In most cases, existing residential yards are exempt from local erosion and sediment control laws, which means that a voluntary approach to erosion control is needed.

Figure 1: Reseeded Areas on a Lawn

How Lawn Erosion Influences Subwatershed Quality

Source area monitoring has revealed that some of the highest sediment concentrations in residential neighborhoods are generated from the yard (CWP, 2003). In many cases, erosion occurs in areas of the yard that are close to driveways, sidewalks and roads, or are directly in the flow path of storm water runoff. Bare patches of exposed soils can be caused by vehicles, snowplows, plant dieback, foot traffic and many other disturbances.

Percentage of Homeowners Engaging Erosion Repair

Reliable percentages could not be developed to profile the proportion of homeowners that repair soil erosion.

Factors that Contribute to Variation in Lawn Erosion

Climate appears to play a major role in residential soil erosion problems. For example, it is extremely difficult to maintain a vigorous ground cover on yards in arid and semi-arid climates without supplemental irrigation. Consequently, yards in these regions tend to have higher sediment erosion rates. Also, yards in regions with heavy snowfall or hard winters often require spot re-seeding in the spring. Neighborhood factors also play a strong role. For example, exposed soils are considered a social anathema in neighborhoods where turf care is widely practiced. Other factors that contribute to the potential for yard erosion are small lot size, heavy foot or vehicular traffic, inadequate parking capacity, older neighborhoods, and the absence of a strong neighborhood or civic association.

Techniques to Address Soil Erosion

- Conventional outreach methods (bill inserts, brochures, newsletters, neighborhood meetings)
- Distribution of free or discounted mulch
- Distribution of free or discounted grass patch repair kits
- Technical assistance on solving severe erosion problems on steep slopes
- Non-regulatory erosion and sediment control (ESC) consultations
- Enforcement actions under existing ESC, water quality, or nuisance ordinances

Good Examples

Riparian Homeowner's Stewardship Project (Ingham County, MI). County staff developed and distributed the *Red Cedar River Riparian Homeowner's Handbook* to more than 300 individual homeowners, local government officials, and other interested groups, and conducted individual, on-site consultations with interested homeowners on buffer strip design and erosion control.
http://www.glc.org/basin/project?id=74

Top Resources

Erosion in Your Own Backyard (Virginia Cooperative Extension). This fact sheet emphasizes how a properly planted landscape is the best protection against erosion.
http://www.ext.vt.edu/departments/envirohort/articles/lawns_and_landscaping/erosion.html

*University of Rhode Island Cooperative Extension Home*A*Syst*
http://www.uri.edu/ce/wq/has/html/has.html

Reducing Erosion and Runoff Information Webpage (Master Gardeners). This website covers signs of erosion and runoff, reasons to control runoff and erosion, using plants to reduce erosion, handling steep slopes, ground cover selection, and building and protecting soil.
http://www.mastergardenproducts.com/sustainablelandscape/erosion.htm

N-6	Neighborhood Source Area: Driveway	
	SAFE CAR WASHING	

Description

The ideal watershed behavior is to wash cars less often, wash them on grassy areas, and use phosphorus-free detergents and non-toxic cleaning products. Alternatively, residents can use commercial car washes that treat or recycle wash water. The negative behavior is to wash cars in a manner where dirty wash water frequently flows into the street, storm drain system, or the stream. This behavior applies not only to individuals, but to community groups that organize outdoor car washes for charitable purposes (Figure 1).

How Car Washing Influences Subwatershed Quality

Outdoor car washing has the potential to generate high nutrient, sediment, metal, and hydrocarbon loads in many subwatersheds. Detergent-rich water used to wash the grime off cars can flow down the driveway and into the storm drain, where it can be an episodic pollution source during dry weather. Not much is currently known about the quality of car wash water, but local water quality sampling can easily characterize it. Car wash water can also be a significant flow source to streams during dry weather. As an example, a typical hose flowing at normal pressure produces between 630 and 1,020 gallons of water per hour, depending on its diameter. These flows can be sharply reduced if the hose is equipped with a shut-off nozzle.

Figure 1: Poor Practices at a Charity Car Wash Event at a Local Gas Station

Percentage of Residents Engaging in Car Washing

Car washing is one of the most common watershed behaviors in which residents engage. According to surveys, about 55 to 70% of homeowners wash their own cars, with the remainder utilizing commercial car washes (Schueler, 2000b). Of these, 60% of homeowners can be classified as "chronic car-washers," in that they wash their car at least once a month (Smith, 1996; PRG, 1998; and Hardwick, 1997). Between 70 and 90% of residents reported that their car wash-water drained directly to the street, and presumably, to the nearest stream.

Variation in Car Washing

Regional and climatic factors play a strong role in determining the frequency of residential car washing. In colder climates, many residents utilize commercial car washes during the winter months, and then wash their cars themselves during the summer. In warmer climates, residential car washing is often a year-round phenomenon. Neighborhood factors that influence car washing include the number of vehicles per household, lot size, driveway surfaces, income and demographics. Another key factor is the nature of the storm water conveyance system. If a neighborhood has open section roads with grass swales, the impact of car wash water will be less.

Difficulty in Changing Car Washing Behaviors

Residential car washing is a hard watershed behavior to change, since the alternative of using commercial car washes costs more money. In addition, many residents are not aware of the water quality consequences of car washing, nor do they understand the chemical content of the soaps and detergents they use. Lastly, many residents do not understand that their driveway is often directly connected to the storm drain system and the urban stream. Consequently, many communities will need to educate homeowners about the water quality implications of car washing.

Techniques to Change Car Washing Behavior

Several communities have developed effective techniques to promote safer car washing, including:

- Media campaigns to increase awareness about water quality impacts of car washing (billboards, posters, etc.)
- Conventional outreach materials (brochures, posters, water bill inserts)
- Promote use of nozzles with shut-off valves
- Provide information on environmentally safe car washing products at point of sale
- Provide storm drain plugs and wet vacs for charity carwash events
- Provide discounted tickets for use at commercial car washes
- Modify sewer bylaws or plumbing codes to prevent storm drain discharges
- Storm drain marking (see N-21)

Good Examples

Puget Sound Car Wash Association - This charity car wash program allows qualifying nonprofit organizations to raise money for their group by selling tickets that can be redeemed at participating commercial car wash facilities. http://www.charitycarwash.com/

Drain Plugs and Bubble Busters (Kitsap County) – This program provides drain plugs to contain car wash water from charitable car wash events, as well as “bubble busters” to pump out and safely dispose of wash water. http://www.kitsapgov.com/sswm/carwash.htm

Top Resources

RiverSafe Carwash Campaign
http://www.riversides.org/riversafe/

The Dirty Secret of Washing Your Car at Home
http://www.forester.net/sw_0106_trenches.html

Best Management Practices for Controlling Runoff from Commercial Outdoor Car Washing
http://environment.alachua-county.org/Natural_Resources/Water_Quality/Documents/Commercial Outdoor Car Wash.pdf

How to Run a Successful Carwash fundraiser
http://www.carwashguys.com/fundraisers/LASchools.html

Make Your Next Car Wash “Environmentally Smart”
http://www.ci.eugene.or.us/PW/storm/Publications/Carwash fundraiser.pdf

N-7	Neighborhood Source Area: Rooftop DOWNSPOUT DISCONNECTION	

Description

Downspout disconnection spreads rooftop runoff from individual downspouts across the lawn or yard where it filters or infiltrates into the ground. While some disconnections are simple, most require the installation of an on-site storm water retrofit practice. These simple practices capture, store and infiltrate storm water runoff from residential lots, and include rain barrels, rain gardens, French drains or dry wells. *Rain barrels* capture runoff from rooftops and are typically installed on individual roof leaders. Runoff captured in the barrel is stored for later use as supplemental irrigation. *Rain gardens* are shallow, landscaped depressions in the yard used to store and infiltrate runoff from rooftops and other impervious surfaces on the lot. *French drains and dry wells* are shallow small stone trenches used to infiltrate rooftop runoff into the ground, where soils are permeable. More details about on-site retrofit practices can be found in Profile Sheets 0S-15 through 0S-17 in Manual 3.

The ideal watershed behavior is to disconnect all downspouts so individual rooftops deliver no runoff to the storm drain system or stream. The negative watershed behavior is to pipe downspouts across the yard and into the curb or street in order to promote positive drainage (Figure 1).

How Downspout Disconnection Influences Subwatershed Quality

Downspout disconnection reduces the amount of impervious cover on a developed lot that can generate stormwater runoff. In addition to reducing the volume of runoff, downspout disconnection promotes groundwater recharge, reduces storm water runoff volumes, and filters out pollutants through the lawn soil. Since each individual retrofit for downspout disconnection treats only a few hundred or thousand square feet of impervious cover, dozens or hundreds are needed to make a measurable difference at the subwatershed level. Consequently, an intensive campaign to target education, technical assistance, and financial resources within a neighborhood or subwatershed to encourage widespread adoption of disconnection is needed.

Percentage of Residents Engaging in Downspout Disconnection

Data is not currently available to estimate the rate at which homeowners voluntarily disconnect downspouts. The frequency of this behavior is thought to be extremely low in most neighborhoods unless a community aggressively promotes and subsidizes disconnections. If this occurs, homeowner participation rates of 20 to 30% have been reported in pilot projects (Environment Canada, 2001).

Figure 1: Downspout Intentionally Bypassing Landscaped Area and Draining onto Driveway

Variation in Downspout Disconnection

The potential to disconnect downspouts is normally evaluated as part of the Neighborhood Source Assessment component of the USSR survey (see Manual 11). The most important neighborhood factor is the proportion of existing homes directly connected to the storm drain system. Negative neighborhood factors include the presence of basements, compacted soils, and poor neighborhood awareness or involvement. Positive factors are large rooftop areas that are directly connected to the storm drain system, lots with extensive tree canopy, and good neighborhood housekeeping. In general, large residential lots are most suitable for most disconnection retrofits (1/4 acre lots and larger), although rain barrels can be used on lots as small as 4,000 square feet (Figure 2).

To date, the impetus for most disconnection retrofit programs has been to separate residential storm water from sewer flows in older neighborhoods in order to minimize basement sewer backups or combined sewer overflows.

Figure 2: Rain Barrel Used on a Back, Second Floor Balcony

Techniques to Promote Downspout Disconnection

Communities are experimenting with many different carrots to promote disconnection retrofits, including:

- Conventional outreach materials (flyers, brochures, posters)
- Free or discounted rain barrel distribution
- Municipal or schoolyard demonstration projects
- Credits or subsidies for disconnection retrofits
- Direct technical assistance
- Provision of discounted mulch, piping or plant materials
- Modification of sewer and storm water ordinances to promote disconnection
- Mandatory disconnection for targeted subwatersheds

Good Examples

Downspout Disconnection Program (Portland, OR). The City offers residents a credit of $53 per disconnection in the form of a check or a one-time lump sum credit toward their sewer bill after inspection and approval of the work. In addition, neighborhood associations and other civic groups (churches, schools, etc.) can earn $13 for every downspout they disconnect. http://www.portlandonline.com/bes/index.cfm?c=32144

Rain Blocker Program (*City of Chicago)*. The Rain Blocker pilot program is specifically designed to eliminate or greatly reduce the amount of basement flooding caused by sewer surcharge. The program works by restricting the rate of storm water flow into the city sewer system, via installing vortex restrictors within the catch basins of city streets and through downspout disconnection from buildings. http://www.cityofchicago.org/WaterManagement/blocker.html

Neighborhood Rain Gardens (Minneapolis, MN). This program works with neighborhood associations to encourage landscaping for rainwater management. The Fulton Neighborhood Association has worked with eight homeowners to install rain gardens, rain barrels, gutter downspout redirection, and infiltration systems that reduce runoff delivered from individual properties to streets, alleys and sidewalks.
http://www.fultonneighborhood.org/lfrwm.htm

Top Resources

How to Disconnect Your Downspouts (Portland Oregon)
http://www.portlandonline.com/bes/index.cfm?c=32144

Milwaukee Downspout Disconnection Program
http://www.mmsd.com/projects/downspout.cfm

Boston Water and Sewer Commission's Downspout Disconnection Program
http://www.bwsc.org/Customer_Service/Programs/downspout.htm

RainGardens.org
http://www.raingardens.org/

Rain Gardens: A how-to manual for homeowners
http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/documents/rgmanual.pdf

Rain Garden Applications and Simple Calculations
http://www.cwp.org/Community_Watersheds/Rain_Garden.htm

How to Build and Install a Rain Barrel
http://www.cwp.org/Community_Watersheds/brochure.pdf

Skills for Protecting Your Stream: Retrofitting Your Own Backyard
http://www.cwp.org/Community_Watersheds/Retrofitting_Backyard.pdf

N-8	Neighborhood Source Area: Common Areas
	PET WASTE PICKUP

Description

The ideal watershed behavior is to pick up and properly dispose of pet waste (Figure 1). The negative watershed behavior is to leave pet waste in common areas and the yard, where it can be washed off in storm water runoff.

How Pet Waste Influences Subwatershed Quality

Pet waste has been found to be a major source of fecal coliform bacteria and pathogens in many urban subwatersheds (Schueler, 1999). A typical dog poop contains more than three billion fecal coliform bacteria and as many as 10% of dogs are also infected with either *giardia* or salmonella, which is not surprising considering they drink urban creek water. Fecal coliform bacteria are frequently detected in urban streams and rivers after storms, with levels as high 5,000 fecal coliform per tablespoon. Thus, it is not uncommon for urban and suburban creeks to frequently violate bacteria standards for swimming and water contact recreation after larger rainstorms.

Percentage of Residents that Pick Up After Pets

Surveys indicate that about 40% of all households own one or more dogs (Swann, 1999). Not all dog owners, however, are dog walkers. Only about half of dogs are walked regularly. About 60% of dog walkers claim to pick up after their dog some or all of the time (Swann, 1999; HGIC, 1998; and Hardwick, 1997). The primary disposal method reported by residents for pet waste is the trash can, with toilets coming in distant second. Dog walkers that do not pick up after their dogs are highly resistant to change; nearly half would not pick up even if confronted with fines or complaints from neighbors (Swann, 1999). Men are also prone to pick up after their dogs less often than women (Swann, 1999).

Figure 1: Pet Waste Pickup Station

Techniques to Promote Pet Waste Pickup

The key technique is to educate residents on sanitary and convenient options for retrieving and disposing of pet waste. Several communities have used both carrots and sticks to get more owners to pick up after their pets, including:

- Mass media campaigns of the water quality impacts of pet waste
- Conventional outreach materials (brochures, flyers, posters)
- Pooper bag stations in parks, greenways and common areas
- Educational signs in same areas
- “Pooper scooper” ordinances and enforcement
- Banning dogs from beaches and waterfront areas
- Providing designated “dog parks”

Good Examples

Water Quality Consortium Nonpoint Source Education Materials
The Water Quality Consortium implemented an ad campaign focused on four themes: a man pushing a fertilizer spreader, a car driving on water leaking oil, a man washing his car, and man walking his dog. Each ad explains how the behavior leads to water pollution and provides specific tips outlining what residents can do to protect water quality.
http://www.psat.wa.gov/Programs/Pie_Ed/Water_Ed_Materials.htm

Pick It Up - It's Your Doodie Campaign (Gwinnett County Parks & Recreation Department) - The county park agency provides plastic grocery bags for pet owners to use to clean up after their pets as part of a pilot program. The baggies are attached to a wooden post at a local park. Underneath a sign explains their purpose. Pet owners are also encouraged to bring replacement bags when they visit the park.
http://www.gwinnettcitizen.com/0203/doodie.html

Top Resources

Public Open Space and Dogs: A Design and Management Guide for Open Space Professionals and Government
http://www.petnet.com.au/openspace/frontis.html

Considerations for the Selection and Use of Pet Waste Collection Systems in Public Areas
http://www.ecy.wa.gov/programs/wq/nonpoint/pet_waste/petwaste_station.pdf

Properly Disposing of Pet Waste
http://www.cleanwatercampaign.com/what_can_i_do/pet_waste_home.html

Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water
U.S. EPA Source Water Protection Practices Bulletin.
http://www.epa.gov/safewater/protect/pdfs/petwaste.pdf

N-9	Neighborhood Source Area: Common Areas	
	STORM WATER PRACTICE MAINTENANCE	

Description

The ideal watershed behavior is to regularly maintain storm water treatment practices, which are normally located in common space managed by a homeowner's association. The negative behavior is to ignore routine and non-routine maintenance tasks to the extent that the ability of the practice to remove pollutants and protect streams is impaired. Storm water maintenance consists of routine and non-routine tasks. Routine tasks include on-going inspections, mowing, vegetation management, trash and debris pickup, and removal of any obstructions within pipes and riser structures. Non-routine tasks include sediment clean-outs, structural repairs, tree removal, fence repair, and other major tasks performed every five to 10 years.

How Storm Water Maintenance Influences Subwatershed Quality

Storm water detention or treatment practices have been constructed in many subwatersheds over the last few decades. The vast majority of these practices have been dry or wet storm water ponds. These ponds were designed to detain flood waters and, in some cases, remove pollutants as well. Ongoing pond maintenance is needed to maintain pollutant removal rates, keep the pond safe, and to enhance its habitat, wetland or landscaping value (Figure 1).

Percentage of People Engaging in Storm Water Practice Maintenance

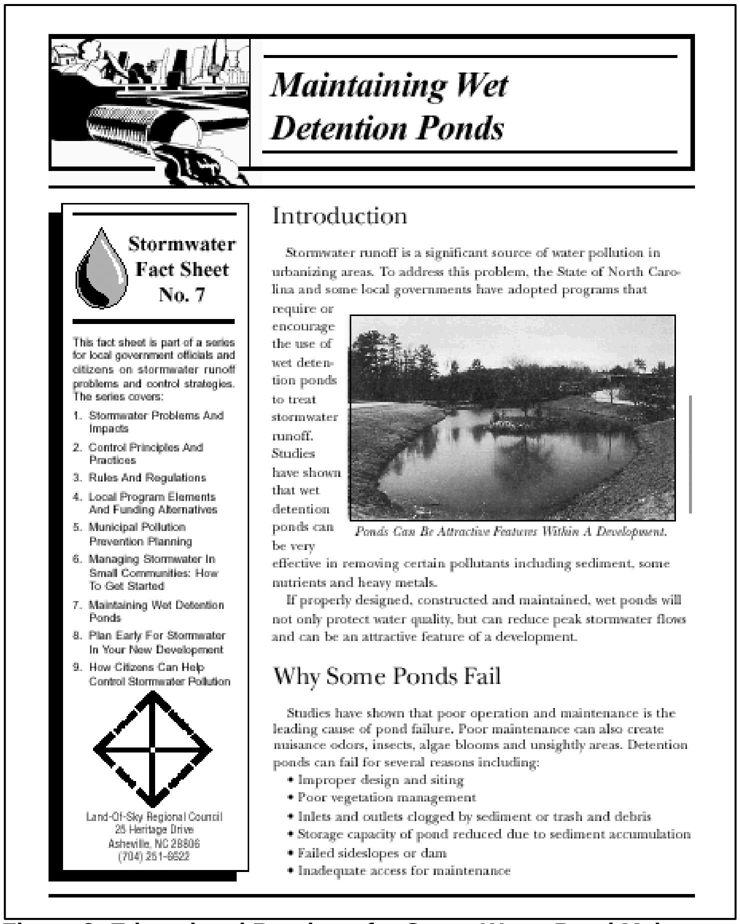
Little data is available to characterize this watershed behavior, although anecdotal evidence indicates that maintenance is the exception rather than the rule at many ponds.

Figure 1: Wet Storm Water Pond

Variation in Storm Water Practice Maintenance

Each state or locality has its own storm water history, which begins when storm water detention or treatment practices were first required on new development projects. Thus, some communities may have hundreds or even thousands of storm water practices built over decades, while others may have few practices and no real history of managing storm water.

If a community has a history of managing storm water, several neighborhood factors play a role in defining maintenance behaviors. The most critical factor is the age of the neighborhood, since most storm water practices have only been built in the last 10 to 15 years. The second key neighborhood factor is the design objective of the past storm water management practices (e.g., provide flood control, peak shaving, water quality or recharge). The last important factor is the size, sophistication and financial health of the homeowners association that has maintenance responsibility for the pond.



Maintaining Wet Detention Ponds

Stormwater Fact Sheet No. 7

This fact sheet is part of a series for local government officials and citizens on stormwater runoff problems and control strategies. The series covers:

1. Stormwater Problems And Impacts
2. Control Principles And Practices
3. Rules And Regulations
4. Local Program Elements And Funding Alternatives
5. Municipal Pollution Prevention Planning
6. Managing Stormwater In Small Communities: How To Get Started
7. Maintaining Wet Detention Ponds
8. Plan Early For Stormwater In Your New Development
9. How Citizens Can Help Control Stormwater Pollution

Land-Of-Sky Regional Council
25 Heritage Drive
Asheville, NC 28806
(704) 251-6622

Introduction

Stormwater runoff is a significant source of water pollution in urbanizing areas. To address this problem, the State of North Carolina and some local governments have adopted programs that require or encourage the use of wet detention ponds to treat stormwater runoff. Studies have shown that wet detention ponds can be very effective in removing certain pollutants including sediment, some nutrients and heavy metals.

Ponds Can Be Attractive Features Within A Development.

If properly designed, constructed and maintained, wet ponds will not only protect water quality, but can reduce peak stormwater flows and can be an attractive feature of a development.

Why Some Ponds Fail

Studies have shown that poor operation and maintenance is the leading cause of pond failure. Poor maintenance can also create nuisance odors, insects, algae blooms and unsightly areas. Detention ponds can fail for several reasons including:

- Improper design and siting
- Poor vegetation management
- Inlets and outlets clogged by sediment or trash and debris
- Storage capacity of pond reduced due to sediment accumulation
- Failed sideslopes or dam
- Inadequate access for maintenance

Figure 2: Educational Brochure for Storm Water Pond Maintenance
Source: http://h2o.enr.state.nc.us/su/PDF_Files/Land_of_Sky_factsheets/FactSheet_7.pdf

Difficulty in Improving Maintenance of Storm Water Practices

Improving routine and non-routine maintenance can be difficult, since many homeowner or civic associations lack adequate maintenance budgets. They may also be ignorant of the purpose and functions of storm water practices, and not understand basic maintenance operations. Consequently, targeted education and direct technical assistance to homeowner associations is important to improve maintenance behaviors.

Techniques to Improve Maintenance Behavior

Some communities have adopted innovative techniques to improve the frequency of maintenance of storm water practices, including the following:

- Conventional outreach materials (maintenance guidebooks)
- Liaison w/homeowner and civic associations
- Free inspections and contractor referral
- Pondscaping assistance (e.g., technical assistance, free plant material)
- Adopt-a-pond programs
- Storm water maintenance classes and work parties
- Pond beautification awards
- Annual maintenance reminder letters

Good Examples

Adopt- a-Pond Program (Baltimore County, MD). The County developed a pilot pond adoption program that features four different levels of participation. The basic level includes inspections and trash pickup, while the most advanced involves pondscaping, wildlife enhancements, and simple retrofits. Another interesting feature of this pond adoption program is the fact that the training and administration of the program are subcontracted to a local watershed organization. Contact the Center for Watershed protection for information on how to access.

Adopt-a-Pond Program (Hillsborough County, FL). This Florida county has the largest and longest running "adopt a pond" program in the nation. Nearly 200 ponds have been adopted by neighborhood groups and service clubs. The program features signs, volunteer recognition, newsletters and work parties to actively engage, train and retain volunteers. For more details: http://www.swfwmd.state.fl.us/documents/publications/files/adopt.htm

Pond Maintenance Training and Work Parties (Lacey, WA). This version of an adopt-a-pond program uses a series of night-time training classes on the basics of storm water maintenance, followed by weekend work parties to spruce up and landscape storm water ponds.

Top Resources

Thurston County, Washington, "How to Care for Your Stormwater Pond." This web document is an excerpt from the publication *Maintaining Your Stormwater Pond: A Step-by-Step Guide to Keeping Your Stormwater Pond Happy and Healthy.* Geared toward private landowners and homeowner associations, this document answers basic questions on storm water pond maintenance. http://www.co.thurston.wa.us/wwm/stormwaterpages/maintainpond.pdf

Northern Virginia Planning District Commission, Maintaining Your BMP - A Guidebook for Private Owners and Operators in Northern Virginia. This document is designed for individual property owners, homeowner association leaders, and residential/commercial property managers. The guidebook outlines the basic maintenance and planning tasks to help keep practices functioning properly, and includes information on general maintenance needs, who should carry out maintenance, inspections, and basic planning. The document also includes a simple inspection checklist and a maintenance cost planning sheet. http://www.novaregion.org/pdf/Maintaining_BMPs.pdf

Montgomery County, MD "Maintaining Urban Storm water Facilities: A Guidebook for Common Ownership Communities." This guidebook describes the four primary types of storm water practices found in the County and outline some basic maintenance tasks to keep them functioning properly. http://www.montgomerycountymd.gov/mcgtmpl.asp?url=/content/dep/stormwater/maintain.asp

City of Eugene, Oregon - *Storm Water Drain Maintenance on Private Property.* This short guide discusses the maintenance of storm water drains, street gutters, underground pipes, roadside ditches, and open drainage channels. Proper storm water drain maintenance is crucial for flood control and water quality protection. This guide explains the private property owner's responsibility to maintain storm water drains on his or her property and some simple maintenance procedures to meet this responsibility. http://www.stormwatercenter.net/

South Carolina Department of Health and Environmental Control, Ocean and Coastal Resource Management's A Citizen's Guide to Storm Water Pond Maintenance. This booklet is a guide for individuals and homeowner associations on the proper function and maintenance of storm water ponds. Instructions are provided on inspections, dredging, weed control, herbicides, pollutants and pesticides. Photos and descriptions of nuisance aquatic plant species are provided to aid in the identification and removal of these species from storm water ponds.
http://www.scdhec.net/ocrm/pubs/ponds.pdf

Howard County, MD – Maintaining Your Stormwater Management Structure. This manual is directed at commercial property managers who own storm water management structures. The purpose of this manual is to describe the four types of stormwater management structures and their maintenance requirements.
http://www.co.ho.md.us/DPW/DOCS/stormwatermanual.pdf

Stormwater Manager's Resource Center.
This website offers information on maintenance arrangements, agreements, costs, frequencies, and educational materials.
http://www.stormwatercenter.net
(Click on "Program Resources" then "STP Maintenance")

N-10	Neighborhood Source Area: Common Areas	
	BUFFERSCAPING	

Description

Many neighborhoods built in the last few decades still have a decent stream corridor protected by buffers, flood plain setbacks or wetland protection requirements. The stream corridor that remains is often in common or private ownership. The ideal watershed behavior is to respect the boundaries of the stream corridor and expand it where possible through "bufferscaping" and backyard planting of native plants and trees. The negative watershed behavior is stream corridor encroachment, through clearing, dumping, allowing invasive plant species to spread from private yards, and erecting structures (Figure 1).

How Bufferscaping Influences Subwatershed Quality

A forested stream corridor is an essential ingredient of a healthy stream, except in certain arid and semi-arid regions. Bufferscaping can add to the total area of the stream corridor, provide wildlife habitat and enhance the structure and function of the buffer. By contrast, encroachment activities diminish the quality, function and attractiveness of the stream buffer.

Percentage of People Encroaching on/Expanding the Stream Corridor

Data is not currently available to estimate the rate at which homeowners add to the stream corridor, but several troubling studies have examined the degree of residential buffer encroachment. Many residents perceive buffers as an extension of their backyard, and think little of removing trees, dumping yard wastes or erecting structures on their land. A major reason is that nearly 60% of residents are ignorant of the boundaries and intended purpose of stream buffers (Heraty, 1993). Studies of wetland buffer encroachment in Washington residential areas found that 95% of buffers were visibly altered, 40% to such a degree that their functional value was eliminated (Cooke, 1991). Other studies of Maryland buffers indicate encroachment rates of as much as 1% of area buffer per year. Clearly, residential awareness and behaviors in regard to the stream corridor need to be improved in many subwatersheds.

Neighborhood Factors that Contribute to Buffer Stewardship

Several factors play a role in how buffers are managed within a neighborhood: the age of the development, lot size, activism of homeowner association, boundary signs, and the prior existence of stream buffer or flood plain regulations.

Figure 1: A New Subdivision Encroaching on the Stream Buffer

Techniques to Encourage Buffer Stewardship

Protecting or expanding stream buffers requires direct education and interaction with individual property owners that back up to the buffer. Some useful techniques include:

- Bufferscaping assistance and guides
- Community buffer walks
- Buffer boundary inspections
- Boundary signs (Figure 2)
- Defining unallowed uses in local stream buffer ordinances
- Presentations to community associations
- Adopt-a-stream program
- Financial incentives for bufferscaping

Figure 2: Sign Identifying a Buffer Boundary

Good Examples

Burnett County, WI Natural Shoreline Incentives. The county pays homeowners to enroll in a program to maintain shorelines in their natural state. The program asks for a voluntary commitment by placing a covenant on a homeowner's property stating that the shoreline will remain natural. Program members receive a payment of $250 after an initial inspection that certifies the property meets program standards, and the shoreline covenant is recorded. Participants also receive an annual deduction from their tax statement as a thank you.
http://www.burnettcounty.com/burnett/lwcd/preserve.html

Tennessee Valley Authority Banks and Buffers Software: A Guide to Selecting Native Plants for Streambanks and Shorelines includes software application to help homeowners select plants for bufferscaping. It also contains selected characteristics and environmental tolerances of 117 plants and more than 400 color photographs illustrating habitat and growth form.
http://www.tva.gov/river/landandshore/stabilization/websites.htm

Top Resources

The Architecture of Urban Stream Buffers
http://www.stormwatercenter.net/Library/Practice/39.pdf

Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers
http://www.chesapeakebay.net/pubs/subcommittee/nsc/forest/riphbk.pdf

Riparian Forest Buffer Design, Establishment, and Maintenance
http://www.agnr.umd.edu/MCE/Publications/Publication.cfm?ID=13

Riparian Area Management: A Citizen's Guide
http://www.co.lake.il.us/elibrary/publications/smc/riparian.pdf

Backyard Buffers for the South Carolina Lowcountry
http://www.scdhec.net/ocrm/pubs/backyard.pdf

Alliance for the Chesapeake Bay – Backyard Buffers
http://www.acb-online.org/pubs/projects/deliverables-158-1-2003.pdf

Cayuga County, NY – Green Thumbs for Blue Water Workshops
http://www.co.cayuga.ny.us/wqma/greenthumbs

Tree-mendous Maryland
http://www.dnr.state.md.us/forests/treemendous/

N-11	Neighborhood Source Area: Common Areas	
	STORM DRAIN MARKING	

Description

The ideal watershed behavior is to get residents to fully understand the connection between storm drains and downstream waters and avoid any activity that discharges pollutants. This awareness is most often created by marking or stenciling storm drain inlets with a "Don't dump, drains to..." message (Figure 1). The negative watershed behavior is to use storm drains as a means of disposal for trash, yard waste and household products.

How Storm Drain Marking Influences Water Quality

Storm drain marking sends a clear message to keep trash and debris, leaf litter and organic matter out of the storm drain system. Stencils may also reduce residential spills and illicit discharges. Marking is also a direct and local way to increase watershed awareness and practice neighborhood stewardship. The actual water quality benefits of storm drain marking have yet to be demonstrated through field research or monitoring. Still, marking is always a sign of good neighborhood housekeeping. Santa Monica, CA also marks the hotline phone number on storm drains to report water quality problems and illegal dumping.

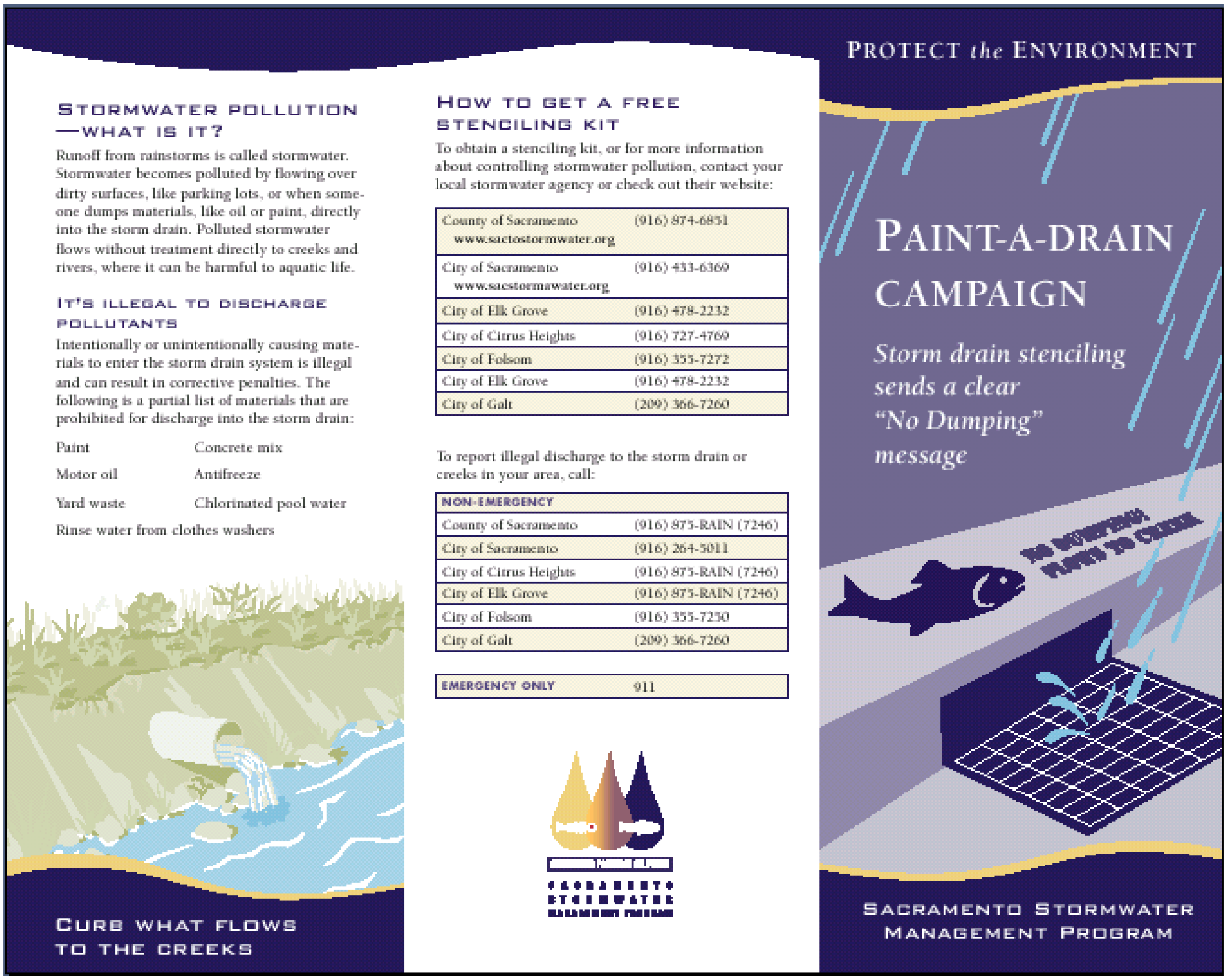
Percentage of Residents Engaging in Storm Drain Marking

This behavior does not require extensive resident participation; only a few trained volunteers are needed to thoroughly mark storm drains within a neighborhood. Volunteers can include scouts, service groups, high school students, neighborhood associations, and other volunteers. Normally, marking is "sanctioned" by the local public works authority or environmental agency, so it is important to coordinate closely with them (Figure 2). Table 1 provides guidance for marking storm drains.

Factors to Consider in Storm Drain Marking

The only significant impediment to storm drain marking is when a neighborhood is primarily served by open channels or grassed channels, rather than enclosed storm drains.

Figure 1: Storm Drain Marking



PROTECT *the* ENVIRONMENT

PAINT-A-DRAIN CAMPAIGN

Storm drain stenciling sends a clear "No Dumping" message

SACRAMENTO STORMWATER MANAGEMENT PROGRAM

STORMWATER POLLUTION —WHAT IS IT?

Runoff from rainstorms is called stormwater. Stormwater becomes polluted by flowing over dirty surfaces, like parking lots, or when someone dumps materials, like oil or paint, directly into the storm drain. Polluted stormwater flows without treatment directly to creeks and rivers, where it can be harmful to aquatic life.

IT'S ILLEGAL TO DISCHARGE POLLUTANTS

Intentionally or unintentionally causing materials to enter the storm drain system is illegal and can result in corrective penalties. The following is a partial list of materials that are prohibited for discharge into the storm drain:

Paint	Concrete mix
Motor oil	Antifreeze
Yard waste	Chlorinated pool water
Rinse water from clothes washers	

CURB WHAT FLOWS TO THE CREEKS

HOW TO GET A FREE STENCILING KIT

To obtain a stenciling kit, or for more information about controlling stormwater pollution, contact your local stormwater agency or check out their website:

County of Sacramento www.sactostormwater.org	(916) 874-6851
City of Sacramento www.sacstormwater.org	(916) 433-6369
City of Elk Grove	(916) 478-2232
City of Citrus Heights	(916) 727-4769
City of Folsom	(916) 355-7272
City of Elk Grove	(916) 478-2232
City of Galt	(209) 366-7260

To report illegal discharge to the storm drain or creeks in your area, call:

NON-EMERGENCY	
County of Sacramento	(916) 875-RAIN (7246)
City of Sacramento	(916) 264-5011
City of Citrus Heights	(916) 875-RAIN (7246)
City of Elk Grove	(916) 875-RAIN (7246)
City of Folsom	(916) 355-7250
City of Galt	(209) 366-7260

EMERGENCY ONLY	911

Figure 2: Educational Brochure on Storm Drain Marking/Stenciling
Source: http://www.sactostormwater.org/documents/stencil_brochure_03.pdf

Table 1: Storm Drain Marking Guidance
• Enlist one person to serve as the team leader, and make sure he/she knows all marking rules and safety procedures. • Review all safety procedures before marking. • Marking should be performed by at least two people, so one can be on the lookout for oncoming vehicles. Safety vests and traffic cones can be used to alert vehicles. • Remember to wear old cloths and shoes. • Bring paper towels or a rag to wipe up and two trash bags – one for the wet stencil (when necessary), which is not garbage, and one to pick-up garbage along the way. • Keep track of all storm drain stencils and turn this information over to the team leader or the appropriate local government agency. • Do not mark any storm drains with vehicles parked nearby. • Record the locations of any storm drains that have leaves, grass clippings, oil, or other pollutants. • Properly dispose of all trash at the end of the day, and return all empty paint cans and supplies to the team leader.
Information adapted from the following sources: *http://www.deq.state.la.us/assistance/litter/stormdrain.htm* Storm Drain Stenciling: A Manual for Communities (GI-212) *developed by the Texas Natural Resource Conservation Commission*

Top Resources

Texas Natural Resource Conservation Commission's Storm Drain Stenciling: A Guide for Communities. This extensive guide includes information on how to get volunteers involved, guidelines and materials for marking, reviews of five marking programs, and sample recognition certificates, press releases, door hangers, and public service announcements.
http://www.tnrcc.state.tx.us/exec/sbea/education.html

The Urban Dweller's Guide To Watersheds
http://www.museumca.org/creeks/umbrella.html

University of Wisconsin-Extension Water Resources Program Storm Drain Stenciling Web Page
http://clean-water.uwex.edu/wav/stormdrain/index.htm

Earthwater Stencils Home Page
http://www.earthwater-stencils.com/

Storm Drain Stenciling Project Guidelines
http://www.epa.gov/adopt/patch/html/guidelines.html
The Ocean Conservancy's Storm Drain Sentries
http://www.oceanconservancy.org/site/PageServer?pagename=op_sentries

South Carolina Department of Health and Environmental Control's Water Watch Campaign: Conducting a Storm Drain Tagging Project
http://www.scdhec.net/water/pubs/wwtag2.pdf

Multilingual Storm Drain Stenciling GreenSpace Partners worked with local watershed groups and volunteers to stencil storm drains with messages in English, Somali and Spanish.
http://www.greeninstitute.org/GSP/programs/stormwater/stencils/stencils.html

North Carolina's Storm Drain Stenciling Project This project was piloted in 1994 along coastal NC watersheds and has received support from many state and national organizations and has received the "Take Pride in North Carolina" Award.
http://www.bae.ncsu.edu/bae/programs/extension/wqg/smp-18/stormdrain/

Attachment K. Post Construction Audit

Memorandum

CENTER FOR WATERSHED PROTECTION
8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.net

Date: November 3, 2009

To: Srinivas Valavala
Richland County, SC Stormwater Manager

From: Laurel Woodworth and David Hirschman
Center for Watershed Protection, Inc.

Re: Richland County Stormwater Division:
Implementation Plan matrix and Implementation Budget worksheet

---

The Center for Watershed Protection (CWP) has prepared the attached Implementation Plan materials for Richland County, SC (the County) Stormwater Management Division as the final deliverable in the assessment of the County's post-construction stormwater management program. These materials satisfy the third and final task of the following scope of work:

Task 1. Self-assessment and interview with Richland County staff **(March 2009)**

- CWP would provide Richland County with the post-construction self-assessment to fill out. It should be filled out by input from various Richland County staff including stormwater manager, planning staff, plan review staff, etc.
- Once the self-assessment is completed, Richland County will provide the Center with a copy.
- CWP will travel to Richland County for a face-to-face interview with Richland County staff to review and discuss the self-assessment.

Task 2. Technical Memo **(April 2009)**

- CWP will write a technical memo that identifies program gaps and provides recommendations for improvement based on the self-assessment.

Task 3. Implementation Plan

- CWP will create an implementation plan to achieve recommendations and fill program gaps. The plan will include a timeline, budget, checklists and procedures.

Three items are included on the enclosed CD: (1) Implementation Plan matrix, (2) Implementation Budget worksheet, and (3) some helpful stormwater program resources. Each of these items is described below.

Implementation Plan matrix

This matrix lists tasks that CWP, in its April 2009 memo, recommended to the Department of Public Works (primarily the Stormwater Division) to improve the County's stormwater management program. This matrix is divided into 12 program elements with one or more tasks listed for implementing each element. The program elements include:

- Post-construction inspections
- Erosion and sediment control
- BMP maintenance
- Program planning
- Inter-departmental coordination
- Funding & staffing
- Staff training
- Ordinance
- Stormwater criteria
- Manuals
- Stormwater monitoring
- Public information

In order to provide County staff with ideas for how to implement these tasks, this matrix shows (1) a potential timeframe for conducting each task, (2) County staff that would likely conduct each task, (3) potential revenue sources, and (4) resources that may provide guidance for implementing the tasks.

This matrix looks at a 10-year timeframe for implementing the tasks, from approximately 2010 through 2020. For the sake of tackling this 10-year plan in gradual steps and for budgeting purposes, County staff may want to consider splitting it into several phases. We have suggested three phases for this plan, yet this is certainly open to revision:

- "Phase 1": remainder of 2009 – 2010
- "Phase 2": 2011 – 2014
- "Phase 3": 2015 – 2020

Tasks that require immediate attention and implementation are shown in bold type.

The matrix differentiates between two types of tasks. Tasks which are labeled as "Program Development" (in green) are one-time projects that would occur during specific years, generally toward the beginning of the 10-year period. These are generally not routine, annual activities, but rather specific efforts that will help build a stronger foundation for the long-term stormwater program. The tasks which are labeled as "Operations" (in orange) are routine, annual functions of the stormwater management program. **It is important to note that the list of tasks in this matrix does not include ALL activities of the County's stormwater program. Rather, these are activities that would build upon the current stormwater program and improve its effectiveness by filling in some gaps (referred to in the matrix as "incremental" activities).**

County staff should refer to CWP's April 2009 memo for more details about the programmatic gap that each recommended task would fill.

Implementation Budget worksheet

This Excel worksheet is based on Tool #2 from CWP's Post-Construction Manual (included on the CD). In this worksheet, we have made estimates of the staff hours that would be required to implement each task listed in the matrix and the cost of implementing each task. Stormwater *Program Development* tasks are listed on the first tab of the worksheet, *Operations* tasks are listed on the second tab of the worksheet, and estimated values (salaries & benefits) of each type of staff position are listed on the third tab. **Because we have used national average estimates, you will likely need to change the staff position values in order to reflect actual salaries and benefits of Richland County stormwater staff.**

Because *Program Development* tasks do not occur on an annual basis, the total projected expenses shown in column G of the first tab do not reflect annual costs. For example, the costs for finishing up the inventory of all existing BMPs in the County (shown in row 5), would only be incurred in 2010 and 2011. Therefore, at the bottom of the first tab, we have shown incremental costs (above and beyond current program costs) by phase of implementation.

In contrast, the *Operations* tasks shown on the second tab would occur annually throughout the 10-year period. Therefore, the "total incremental stormwater operations" costs shown at the bottom of the second tab should be considered annual costs.

This budget spreadsheet is not meant to be a detailed budgeting tool but rather an overview of general costs to achieve various milestones in the implementation plan. We encourage Richland County stormwater staff to modify this spreadsheet to better reflect actual staff costs, program costs, and program priorities.

Stormwater Resources

The Implementation Plan matrix shows several resources that may be useful guides for implementing the various tasks listed. The following resources are included on the enclosed CD:

- CWP's Post-Construction manual *(Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program*) and its 8 Tools
- CWP's guidance document, *Monitoring to Demonstrate Environmental Results*
- Lexington, SC BMP maintenance agreement
- Virginia Beach maintenance agreement

Other resources listed but not on this CD are available through the internet.

Memorandum

Date: April 22, 2009

To: Srinivas Valavala (Richland County, SC Stormwater Manager)

From: Laurel Woodworth and David Hirschman (CWP)

Re: Richland County post-construction stormwater program assessment and recommendations for improvement

Center for Watershed Protection
8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.net

I. Background

Purpose

In 2008, Richland County's Department of Public Works requested a third-party assessment of its post-construction stormwater management program along with a set of recommendations for improving the program. In early 2009, the Center for Watershed Protection (CWP), as part of an existing scope of work to review the county's development codes, conducted this assessment in early 2009 using the post-construction manual, *A Guide for Building an Effective Post-Construction Program* (Hirschman et al, 2008), as a framework. Much of the information garnered for this program review is based on a self-assessment survey (Tool 1 of manual) completed by several Richland County Stormwater Management Division staff members and a follow-up interview with those same individuals, conducted in March 2009. This technical memorandum describes the existing state of Richland County's stormwater management program and provides specific recommendations for filling gaps and making improvements for the program's future.

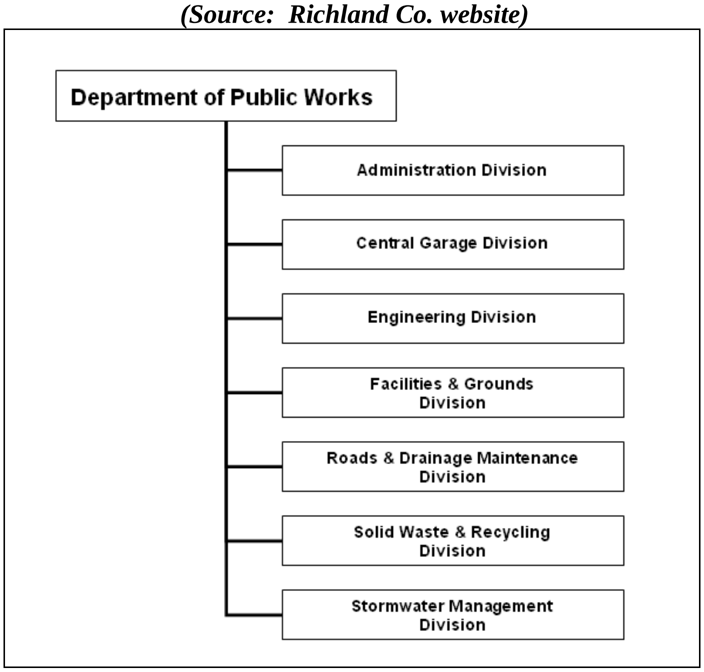
NPDES Permit History

Richland County, as a "medium MS4" community (population of 100,000 to 250,000), is required to hold a stormwater discharge permit under Phase I of the National Pollutant Discharge Elimination System (NPDES) regulations. Richland County received its first NPDES permit on April 16, 2000. In December of 2003, the Environmental Protection Agency conducted an audit of the permit that resulted in the identification of deficiencies in the program. Based on the audit, a revised application was submitted in 2004 that was considered incomplete due to the lack of required monitoring data. In June 2005, Richland County received a Notice of Alleged Violation/Notice of Enforcement Conference that cited violations of the Pollution Control Act and Water Pollution Control Permits. In 2005, a meeting was held to develop a Corrective Action Plan to address the deficiencies and develop a wet weather monitoring program. These changes were approved by SC Department of Health and Environmental Control (SCDHEC) and a new permit became effective in September 2006 (Valavala, 2008).

This current permit has two co-permittees, the Town of Arcadia Lakes and the City of Forest Acres, established through Intergovernmental Agreements. Through these agreements Richland County is responsible for roads, drainage, plan review, inspections and compliance with the NPDES permit. Arcadia Lakes and Forest Acres are responsible for pollution prevention and good housekeeping within their town/city boundaries, while Richland County is responsible for public education and involvement in these jurisdictions (Valavala, 2008).

The Department of Public Works manages and implements the various components of Richland County's stormwater management program. The Stormwater Management Division is the main point of contact and manager of the NPDES permit, but other divisions within Public Works also have roles in the stormwater management program (see Figure 1). The Engineering Division conducts reviews of development site plans, including erosion and sediment control and stormwater management plans. The Engineering Division is also responsible for inspections of erosion and sediment control practices for sites under construction. The Roads and Drainage Division responds to road drainage complaints and inspects and grades un-paved roads to reduce potential sediment runoff.

Figure 1: Divisions of Richland Co. Public Works
(Source: Richland Co. website)



<u>Context of Program Assessment</u>

As part of the Corrective Action Plan created in response to EPA's Notice of Violation of NPDES regulations, Richland County has already moved forward with many improvements to its stormwater management program. The Stormwater Management Division has increased its water monitoring efforts, improved its geographic inventory of stormwater infrastructure, and developed a road runoff management program, among other initiatives. Richland County staff also proposed changes to the County Code's stormwater ordinance in order for County regulations to be in better compliance with federal NPDES requirements. The proposed amendments are currently moving through the public and County Council review process. In addition, the County's primary stormwater management design manual, the *Storm Drainage Design Standards* manual from 2001, is being updated. As these multiple efforts indicate, the following assessment and recommendations are only one part of a larger, on-going effort to improve Richland County's stormwater management program. As such, this memorandum should be considered a road map for achieving both short-term and long-term improvements in the effectiveness of the stormwater program.

II. Current Program Features

<u>Program Development and Management</u>

Personnel

The point of contact for Richland County's NPDES permit is the Stormwater Manager, Srinivas Valavala, who is head of the Stormwater Management Division in the Department of Public Works. This division's employees perform stormwater management infrastructure inspections and maintenance tasks, monitor water quality, conduct illicit discharge detection and elimination (IDDE) reconnaissance, and occasionally participate in public education events related to stormwater management. The Stormwater Management Division also has a GIS specialist on staff. The Stormwater Manager oversees all of these employees.

Stormwater Program Plan

The *Stormwater Management Plan and 2007 NPDES Report* submitted by Richland County to SCDHEC currently serves as a phased implementation plan for the post-construction stormwater program in Richland County. This plan outlines specific stormwater program components that need to be developed and implemented (e.g., inspection program for privately-owned BMPs; pesticide/herbicide control program). The plan also outlines *overarching* goals that might serve to guide program development, such as: assessing sources of water quality problems in the County before initiating large capital projects, focusing efforts on problem areas first, focusing efforts on problems that can be fixed with reasonable effort, etc. There are a number of other features of a master comprehensive program plan that are not covered in the *Stormwater Management Plan*, such as:

- Relationship of stormwater management to current and future land use
- Plan review process for permanent stormwater BMPs
- Training needs and schedule for stormwater personnel
- Forecast of staffing needs

Assessments of Watersheds and Community

The Stormwater Management Division has compiled basic information about the geographic, demographic, and water quality characteristics of Richland County. The

County has conducted one full watershed assessment and plan in the Gills Creek watershed and a stream study in the tributaries leading into Lake Elizabeth. The County is also in the process of developing a watershed assessment and plan for the Crane Creek watershed, with assistance from CWP. Water quality monitoring of streams and stormwater outfalls is ongoing as part of NPDES requirements. GIS maps are available to stormwater staff depicting aerial photos, streams and other water bodies, stormwater infrastructure, and developed areas.

Funding

Funding for the Stormwater Management Division comes from a percentage of County property taxes, or "millage." No stormwater utility has been established, although the Division hopes to establish such a funding mechanism in the next 5 to 10 years. In recent years, the Division has had a budget of approximately $3.5 million per year. The Engineering Division's budget, on the other hand, is only $415,000 per year. This discrepancy could be a source of problems in the plan review stage and erosion and sediment control enforcement stages of development if Engineering plan reviewers and inspectors are understaffed and overburdened.

Inter-Departmental Coordination

Since the Engineering Division is responsible for reviewing site plans for new development, Stormwater Management Division personnel are not involved in the review process nor are provided an opportunity to visit stormwater BMPs before construction of a site is complete. Only once final site stabilization is completed, does the Stormwater Management Division become involved in a site's stormwater management issues. In general, the stormwater personnel do not seem to have the opportunity to provide input on the design, design features, or types of BMPs that are installed in new developments.

This system indicates a lack of coordination between these two divisions and has likely led to several lost opportunities to prevent foreseeable future stormwater BMP maintenance problems. Including post-construction stormwater inspectors and/or maintenance personnel in the plan review process can be beneficial for all parties involved. This kind of co-ordination can also allow plan reviewers and stormwater staff to consider ways of encouraging developers to use low-impact development and Better Site Design techniques on their sites, early in the plan review process. Recommendations on how to establish better collaboration and consistency between these divisions are provided in the Table 1.

Public Access and Involvement

Richland County formed the Richland Countywide Stormwater Consortium to combine all stormwater and water quality education efforts in the County. Clemson University through the Carolina Clear program oversees this effort and develops education materials, including TV ads and brochures. Every year, the Stormwater Management Division provides training events for County staff, developers, and contractors. These events cover topics such as spill prevention, SWPPP compliance, and BMP maintenance. These two forms of public involvement comprise the majority of public engagement efforts by the Stormwater Management Division. In addition, any changes to the stormwater ordinance or other NPDES-related portions of the County Code undergo the standard public comment process and review by County Council.

The public can make maintenance requests to the County (e.g., drainage complaints) by calling the county-wide customer service hotline. Requests related to stormwater management are funneled to the Stormwater Management Division and addressed by the appropriate staff person. As the internet has become a primary resource for communicating with the public, the following information related to Richland County's stormwater management program is found on the Department of Public Works' website (www.richlandonline.com/departments/publicworks)

- For Construction:
    - SCDHEC Construction General Permit
    - SCDHEC Notice of Intent forms
    - Plan Review Checklist for Design Professionals
    - Contractor's Inspection Form for construction sites
    - Storm Water Construction Monthly Report
    - Plan Review Status list (updated frequently)
    - Designer's and Applicant's Certification
    - NPDES Construction Permitting Flow Chart
    - Engineering Designs and Standards:
        - Storm Drainage Design Standards
        - Road Design Standards
        - Subdivision Regulations
        - Stormwater Ordinance
        - SCDOT Standard Specifications summary
- For Industrial NPDES:
    - SWPPP forms
    - SWPPP training materials and Industrial training materials
    - Industrial inspections forms
    - Other education materials
- Maps of wet weather and ambient monitoring stations
- Monitoring data
- Additional Links to outside organizations related to stormwater management
- Information request directed to "Stormwater Guru"
- Recent news and upcoming events
- Updates on proposed changes to stormwater ordinance

Recommended additions and improvements to the website are discussed in Table 1.

Staffing Needs

The Department of Public Works has experienced a lot of staff turnover in the past five years or so, that has reduced the amount of institutional memory amongst the personnel. The Stormwater Management Division is no exception. In filling out the self-assessment survey for this program assessment, all three staff members responding were not able to answer a good majority of the questions. This may be due to simple lack of experience or knowledge, and likely, lack of time working in the Division. In order to ensure that significant amounts of information about the stormwater programs and infrastructure are not lost as staff leave the Division, staff should be diligent about making sure that policies are formalized in writing, that data is securely kept, and that information about the program is routinely shared among various staff members.

A training plan is made each year, outlining the training events conducted by the Stormwater Management Division (described in Public Access section above). In order to ensure that personnel *within* the Division have a diverse set of skills and knowledge, they should also be provided the opportunity to receive training in such topics as:

- Hydrology
- Water quality and biology
- Construction, inspections, facilities maintenance
- Land use planning
- Capital project management
- Budget planning and management

Land Use Planning

According to the self-assessment survey completed by Stormwater Management Division staff, stormwater personnel are involved in the County's comprehensive planning process. This has allowed stormwater management and NPDES requirements to be considered during the comprehensive planning process.

Land use characteristics in Richland County are somewhat incorporated into the stormwater management program's system of prioritizing projects. If the proposed amendments to the stormwater ordinance are approved, stormwater capital improvement projects will be targeted for "Environmental Protection Overlay Districts." These overlay districts are areas (e.g., rare species protection areas) that the County feels are in need of more stringent stormwater management standards. In addition, the proposed amendments designate that special stormwater management criteria will apply to water bodies labeled as impaired by the County or SDHEC or that have Total Maximum Daily Load limits. These criteria are not yet officially in place.

Stormwater Ordinance

Since stormwater ordinance amendments are currently on the table for review and adoption by County Council, it is more useful to look at the content of those revisions than at the current ordinance. The proposed ordinance changes contain the following elements:

- Requires a SWPPP for all construction sites
- Requires ESC on all sites greater and less than 1 acre
- Gives County staff the authority to conduct inspections on private property
- Dictates specific penalties for not maintaining private BMPs
- Defines water quantity control requirements
- Defines water quality control requirements

The Richland County Better Site Design Roundtable, specifically the stormwater subcommittee, is currently reviewing the proposed ordinance changes and addressing the content of the ordinances in more detail.

Stormwater Guidance Manuals

The *Storm Drainage Design Standards* manual is the main source of guidance for the design of stormwater BMPs in Richland County and includes details on required quantity and water quality design volumes for each BMP. The County's stormwater ordinance makes direct reference to this manual as the source of design requirements for stormwater management in Richland County. The manual is comprised of a great deal of detail on culvert and drain design, but less information on the design of stormwater BMPs. The menu of BMPs from which to choose is fairly limited. It consists of design guidelines for: retention ponds, modified extended detention ponds, extended detention ponds, constructed wetlands, infiltration trenches, and dry wells. The manual does not provide very much information about:

- Site requirements / feasibility for each BMP type
- Pre-treatment options
- Proper vegetation choices for each BMP type
- Maintenance requirements
- Maintenance reduction guidance
- Options for dispersed, on-site BMPs (LID-style)
- Integration of Better Site Design into stormwater management
- Guidance on acceptable hydrologic / hydraulic models

The Stormwater Management Division has also developed a *BMP Manual*, in response to NPDES requirements, but it has not yet been approved by County Council, nor does it appear to be available to the public on the County's website. The intended purpose of this manual is to provide guidance to stormwater inspectors and maintenance personnel, whereas the *Storm Drainage Design Standards* manual is geared more towards outlining design specifications for design engineers. There appears to be a good deal of overlap between the two documents and some confusion as to their intended purpose. Anecdotal evidence suggests that many designers and developers in Richland County are not aware of the existence of the *BMP Manual.* The *Storm Drainage* manual is currently undergoing revision by a contractor to the County, which provides the opportunity for making some improvements, filling in gaps, and eliminating redundancies between the manuals.

Plan Review Process

As mentioned, the Engineering Division currently carries out all reviews of site plans for new development in the County. This Division tracks the status of plans in a spreadsheet, which is posted on the Department of Public Works website for public viewing. According to our interview with stormwater staff, the Engineering Division currently only has two plan reviewers on staff who collectively review approximately 350 plans a year. Each reviewer, therefore, is reviewing about 175 plans each year, which suggests that development plans may not be reviewed as thoroughly as is necessary to ensure a site's compliance with erosion and sediment control and stormwater management standards, among other issues. According to our interview, the current plan review fee paid by applicants is $350, no matter how many reviews are involved. On the other hand, the Plan Review Checklist available on the Department of Public Works website indicates a plan review fee of $100 per disturbed acre. In either case, there may exist an opportunity to raise the fees in order to better support the plan reviewing workload of the Engineering Division.

Erosion and Sediment Control

Richland County recently gained legal authority from SCDHEC to administer an erosion and sediment control (ESC) program by becoming a Qualifying Local Program (QLP). This provides the County the authority to inspect sites and enforce water quality requirements. To become a QLP, the County adopted more stringent erosion and sediment control requirements than the state (CWP, 2009).

Richland County requires a performance bond to be posted before land disturbance commences in order to ensure that construction work is performed according to the County's codes and ordinances. This bond is then released back to the developer when the site is stabilized, all BMPs properly installed, and the site has satisfied regulations. In addition, the County requires as-built plans to be produced once construction is complete that show any discrepancies between the original County-approved plan and the actual final site layout.

The Engineering Division is charged with conducting the inspections of development sites during construction to enforce the use of proper erosion and sediment control methods. The Division has several inspectors on staff that are Certified Professionals in Erosion and Sediment Control (CPESC) and conduct erosion and sediment control inspections in the field. Unfortunately, based on the state of some construction sites in certain parts of the County and from anecdotal evidence, in many cases ESC practices in Richland County are not well implemented and/or maintained. According to our interview, this is partly due to the fact that the group of ESC inspectors is under-staffed in comparison to the amount of new development that has occurred in the County in recent years.

Inspection and Maintenance of Permanent BMPs

The Stormwater Management Division is charged with inspecting stormwater facilities in Richland County to identify potential maintenance problems. Richland County Code gives authority to County staff to enter private property in order to inspect BMPs and details specific monetary penalties for landowners who do not comply with BMP maintenance requests by the County. Currently, stormwater staff do not regularly conduct inspections of BMPs on private property, but do respond to citizen complaints regarding drainage problems and other maintenance issues, often entering private property in the process. Although the County Code provides the backbone of authority for enforcing the maintenance of private BMPs, the Stormwater Management Division has not established specific internal measures for dealing with landowners or Homeowner's Associations who are not properly maintaining their BMPs. Since private landowners are responsible for maintenance of BMPs on their property, as is the case in Richland County, some communities require stormwater BMP maintenance agreements to be signed by developers and/or landowners before their site plans are approved. This establishes a written reminder of the landowner's maintenance responsibility. According to our interview, this is not yet the case in Richland County, but will likely change soon.

Currently, the Stormwater Management Division regularly inspects and maintains approximately 29 stormwater ponds in the County, whose locations are mapped in GIS. These BMPs fall under the purview of the County for various reasons – some are on County property and others have been "conveyed" to the County for maintenance purposes. The latter are typically located in large subdivisions. According to our interview, the Engineering Division makes the determination, during the plan review process, of which privately-owned BMPs are assigned to the County for maintenance. The post-construction stormwater staff believe that *developers* are given the option to choose whether or not their BMPs' maintenance falls under County responsibility or landowner/HOA responsibility. There appears to be no commonly understood criteria or policy used to make this determination.

Tracking, Monitoring, and Evaluation

When Stormwater Management Division staff conduct inspections of BMPs, they use paper maps in the field to mark the location of the BMPs and then log this information into a GIS map. Observations from the inspections, as well as maintenance requests and complaints, are documented in a database. The Division uses 3 to 4 different databases at the moment, each with a slightly different data composition. Some of these databases are internal to the Stormwater Management Division, some are internal to Public Works, and one is County-wide ("One Stop"). An effort is underway to combine these databases into an *Assist* software program.

As per NPDES regulations, amongst other motivators, the Stormwater Management Division conducts a water quality monitoring program in all three main watersheds of the County. This program consists of several monitoring components (Valavala, 2008):

- Wet weather monitoring of BMPs
- Sampling in impaired streams and lakes: 25 – 30 different elements tested
- Sediment & benthic community monitoring in streams
- Stormwater sampling for water quality assessments

The Stormwater Management Division also conducts illicit discharge detection and elimination.

III. Strengths & Recommendations

Richland County's stormwater management program consists of a number of different components that should be considered clear strengths. Among others, these strengths include:

- Annual stormwater training events for County staff and private sector
- Required performance bonds and as-built plans
- Digital tracking of inspection data & GIS stormwater infrastructure mapping
- Effective system in place to respond to stormwater maintenance requests
- Significant numbers of staff available to respond to maintenance requests
- Strong, forward-thinking leadership

The following table of recommendations addresses areas of possible improvement for Richland County's stormwater management program. This list is not exhaustive, but concentrates on program gaps that were most evident from conversations with staff in the Stormwater Division.

Table 1: Recommendations		
Program Element	**Issue or Gap**	**Recommendations**
Program Planning	Stormwater program goals and procedures not yet aligned with County's desire to incorporate Better Site Design practices.	1. *Expand upon 2007 Stormwater Management Plan by developing a phased implementation plan for the next 5-10 years, based on funding sources and priorities for the stormwater program. Elaborate on these subjects:* • *Relationship of stormwater management to current and future land use* • *Plan review process for permanent stormwater BMPs* • *Training needs and schedule for stormwater personnel* • *Forecast of staffing needs* • *Integration of stormwater management with Better Site Design practices / policies (e.g., from Roundtable recommendations)*
Inter-Departmental Coordination	Stormwater Management Division not involved in design or type of BMPs approved for new development.	1. *Include stormwater staff in the protocol of plan review/approval.* 2. *Include stormwater staff in construction inspections and/or final E&S inspection prior to releasing performance bond.* 3. *Consider including stormwater staff member in a weekly meeting with Engineering Division to discuss site plans undergoing review.* 4. *Influence stormwater strategy early in review process.* 5. *Consider relocating one plan reviewer from Engineering to the Stormwater Division (or create new position).* 6. *Develop checklists, forms, Standard Operating Procedures to ensure all departments proceed in a consistent manner.* 7. *Considering Richland County's new leadership structure in Dept. of Public Works, set overall priorities amongst the leadership of each Division so that all managers have an understanding of the needs and protocols of other divisions.*

Table 1: Recommendations		
Program Element	**Issue or Gap**	**Recommendations**
Staff Training	Need for more training of internal staff and more sharing of information within Stormwater Management Division	1. *Consider a policy allowing stormwater staff to attend a certain number of training events per year.* 2. *Keep staff informed of upcoming opportunities to gain skills in areas such as: Hydrology; Water quality and biology; Construction, inspections, facilities maintenance; Land use planning; Capital project management; Budget planning and management.* 3. *If not currently doing so, conduct regular staff meetings (e.g., every 2-4 weeks) to share information about current projects, upcoming events, and NPDES compliance needs.* 4. *Conduct training events in conjunction with Engineering Division and others to promote better communication between divisions.*
Funding and Staffing	Engineering Division not well funded and plan reviewers overtaxed – E&S inspections not thoroughly/frequently completed.	1. *Increase funding for Engineering Division through County's budget and/or Stormwater Division should take on some E&S inspection responsibilities.* 2. *Hire more plan reviewers such that each is not reviewing more than 100 plans per year, ideally 70.* 3. *Increase plan review fee or consider charging per review rather than fixed fee.*
	Stormwater Management Division complying with increasing NPDES requirements	4. *Stormwater Division may consider getting assistance from grant professional to apply for outside grants, especially for special projects such as watershed assessments/plans.*

Table 1: Recommendations		
Program Element	**Issue or Gap**	**Recommendations**
Public Information (Website)	DPW / Stormwater Management website lacks certain basic components.	1. *DPW home page should have easy-to-understand listings of the roles of each division and clear ways to navigate to each division's page.* 2. *Stormwater Division webpage should have:* • *Stormwater facts for citizens* • *Basic information about NPDES, watershed, non-point pollution* • *Permanent information about benefits of riparian buffers.* • *FAQs about maintaining BMPs* • *County's BMP maintenance policy* • *Easy link to* Storm Drainage Design Standards *manual (and BMP manual?)* • *Easy link to the stormwater ordinance* • *Information on Gills Creek and Crane Creek watersheds*
Ordinance	Proposed stormwater ordinance amendments will be a great improvement, but may consider other additions…	1. *Consider developing an off-site mitigation system for situations in which water quality management standards are too difficult to comply with on site (e.g., high-density developments, redevelopment). This could provide funds for watershed plan project implementation while providing developers with some flexibility.* 2. *Develop criteria for which sites could get waiver to pay mitigation fees (e.g., see Henrico County, VA system).* 3. *For riparian buffer portion of ordinance amendments, be specific about allowable uses/activities within the buffer.*
Manuals	Confusion about the role of *Storm Drainage Design Standards* manual and *BMP manual*.	1. *Combine the two manuals and discard overlapping sections.* 2. *Provide clear language in design manual(s) about the*

Table 1: Recommendations		
Program Element	**Issue or Gap**	**Recommendations**
		regulatory nature of the specifications included therein. 3. *Make role and purpose of the stormwater guidance manual(s) very clear to County staff in other Divisions/Departments and developers.* 4. *Design manual(s) should include:* • *Site requirements / feasibility for each BMP type* • *Pre-treatment options* • *Proper vegetation choices for each BMP type* • *Maintenance requirements* • *Maintenance reduction guidance* • *Options for dispersed, on-site BMPs (LID-style)* • *Guidance on acceptable hydrologic / hydraulic models*
Stormwater Criteria	Most stormwater BMPs built in the County consist of wet and dry ponds.	1. *Organize workshop with County stormwater staff, plan reviewers, and engineers to provide design standards and credit to LID-type stormwater practices.* 2. *In this workshop, explore why only ponds are used, how other practices can be encouraged, and how to move forward with integrating LID-type practices into the plan review process.*
Plan Review Process	Stormwater Management Division personnel not involved in plan reviews; Engineering Division overtaxed with plans	1. *See Inter-Departmental Coordination recommendations above.* 2. *See Funding and Staffing recommendations above.*
E & S Control	E&S standards not thoroughly enforced on new development sites.	1. *Provide better enforcement of E&S measures during construction through more frequent County inspections – hire more inspectors or contract with third-party inspectors (e.g., Delaware program).*

Table 1: Recommendations		
Program Element	**Issue or Gap**	**Recommendations**
		2. Provide more frequent E&S training to inspectors. *3. Consider involving post-construction stormwater inspectors in final E&S site visit prior to release of performance bond.* *4. When a performance bond is released, the following should be provided to stormwater maintenance staff:* • *Approved as-built* • *Design computations and as-built modifications* • *Recorded maintenance agreement and plan* • *Contact information for responsible maintenance party* • *Construction plans* • *Photographs of BMPs (if available)*
Post-Construction Inspections	BMPs on private property not currently inspected	*1. Continue cataloguing location of private and public BMPs.* *2. Request that Engineering Division provide location and basic data on all new permanent BMPs once plan is approved.* *3. Create staff position in Stormwater Division focused on enforcement of BMP maintenance.* *4. Set goal to inspect all BMPs in the County every 2-3 years.*
BMP Maintenance	Maintenance agreements not required from developers/landowners.	*1. New stormwater ordinance should require that all owners/developers of new development sign a BMP maintenance agreement that will convey with the deed of the property, from one owner to the next.* *2. Revised stormwater/BMP manual should contain maintenance agreement form and explanation of maintenance policy.*

Table 1: Recommendations		
Program Element	**Issue or Gap**	**Recommendations**
	No formal process for conveying BMPs to County for maintenance responsibility.	1. *Conduct meetings with Engineering Division to clarify what their policy is on conveying certain BMPs to County for maintenance.* 2. *In collaboration with Engineering Division, develop specific criteria for which BMPs fall under County maintenance and write policy.* 3. *Disperse new policy to all stormwater staff and staff involved in plan review process.*
	No internal procedure formalized on how to deal with enforcement of maintenance.	1. *Create internal policy on escalating enforcement measures for situations where private BMPs are not maintained.* 2. *Share with all stormwater staff* 3. *Target outreach on BMP maintenance to HOAs, using workshops, mailings, personal contact, etc.*
Water Monitoring	Monitoring system established. Possible improvements include…	1. *If feasible, add herbicide/pesticide chemicals to list of constituents that are tested in wet weather monitoring.* 2. *Integrate County's monitoring data with SCDHEC monitoring data.* 3. *Review IDDE program for needed improvements and provide staff with necessary training.*
Data Management	Three to four databases currently used to track stormwater-related information.	1. *Consider consolidating all databases containing stormwater data and inspections reports into one database that is easy to use, without losing control of the data.* 2. *Consider linking post-construction inspections database to E&S inspections database (if one exists), so that post-construction inspectors have access to site history information.*

References

Center for Watershed Protection (CWP). 2009. *Crane Creek Watershed Characterization Report.* Ellicott City, MD.

Hirschman, D. and Kosco, J. 2008. *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program.* Center for Watershed Protection, Ellicott City, MD.

Richland County Department of Public Works. 2007. *Richland County Storm Water Management Plan and 2007 Annual Report.* NPDES SCS400001. Richland County, SC.

Valavala, S., Stormwater Manager. 2008. "Richland County NPDES Program Implementation." PowerPoint Presentation. Richland County, SC.

10-Year Stormwater Program Implementation Matrix - Richland County, SC
Period: 2010 - 2020

Program Dev. = Program development tasks which would be completed during specific years, and which are not routine
Operations = Operations of the routine stormwater management program, and which happen on an annual basis

Program Element	Task	Timeframe	Staff involved	Revenue sources	References / Resources (some included on CD)
Post-construction inspections	Continue inventory of all existing stormwater BMPs	2010 – 2011 *Program Dev.*	SW manager; SW inspectors; Data management staff; interns	General fund	
	Catalogue location of all new private & County permanent stormwater BMPs	*Operations*	Data management staff; interns		
	Create staff position in SW Division dedicated to enforcing BMP maintenance	2012 *Program Dev.*	New SW inspector	General fund; stormwater utility	
	Inspect each BMP in County every 2-3 years	*Operations*	SW inspectors; interns	General fund; stormwater utility	Tool 6: Maintenance checklist
E&S control	Involve post-construction SW inspectors in construction E&S inspections	*Operations*	SW manager ; Engineering manager; SW Division inspectors		Tool 6: Construction checklist
	Hire more E&S inspectors	2011-2012 *Program Dev.*	SW manager ; Engineering manager; new hired staff	General fund; plan review fees	
	Establish enhanced training program for E&S inspectors	2011 *Program Dev.*	SW manager; Engineering manager; E&S inspectors		E&S Trainings: www.envirocertintl.org SWPPP guide: www.epa.gov/npdes/swpppguide
	More E&S and SWPPP training for inspectors	*Operations*	Engineering manager; all E&S and SW inspectors	General fund; plan review fees	

	Provide essential site info to SW Division after release of performance bond; record in SW database: • Location • Contact info for responsible maintenance party • Recorded maintenance agreement & plan • Approved as-built • Design computations & as-built modifications • BMP construction plans • Photos of BMPs (if available)	2010 - 2020 *Program Dev.* *Operations*	Engineering Division staff; SW Division data management staff		
BMP maintenance	**Include maintenance agreement form & description of maintenance responsibilities in BMP manual.**	**2009** *Program Dev.*	**SW manager ; legal staff**		**Lexington County, SC**: http://www.lex-co.com/Departments/publicworks/stormwater.html (App. E of Land Development manual) Virginia Beach, VA maintenance agreement
	Develop policy for dedicating private stormwater BMPs to County for maintenance.	2011 *Program Dev.*	SW manager ; Engineering manager ; legal staff		Tool 3: SW Model Ordinance (pg. 25)
	Develop outreach & education materials for BMP maintenance	2011 - 2012 *Program Dev.*	SW Division staff		Northern Virginia BMP Handbook, Ch. 6: http://www.novaregion.org/DocumentView.aspx?DID=1679
	Target outreach about BMP maintenance to HOAs, with workshops, mailings, etc.	*Operations*	SW Division staff; Carolina Clear contract	General fund; stormwater utility; grants	Adopt-a-Pond program: www.hillsborough.wateratlas.usf.edu/AAP/
Program planning	Update stormwater management program plan regularly	Every 2-4 years *Program Dev.*	SW manager		Post-Construction manual (CWP), Ch. 2 &10
Inter-departmental coordination	SW Division staff to participate in plan review/approval	*Operations*	New SW Division hire		Tool 6: Plan review checklist
	Include SW Division staff in regular Engineering Division meetings to discuss SW plans under review.	*Operations*	SW Division staff; Engineering manager		

	DPW Division managers to set overall priorities and protocols to conduct NPDES program	2010 *Program Dev.*	All DPW managers		
Funding & staffing	Increase funding for Engineering Division	2012-2020 *Program Dev.*	DPW director; Administrative Division	General fund; stormwater utility; plan review fees	
	Increase plan review fees in order to generate more funds	2012-2020 *Program Dev.*	Engineering manager; Administrative Division	Plan review fees	
	Hire more plan reviewers in Engineering Division, so each is reviewing 70-100 plans per year	2012-2020 *Program Dev.*	Engineering manager; new hire(s)	General fund; stormwater utility; plan review fees	
Staff training	Develop training materials for Stormwater Division and Engineering Division staff	2015-2020 *Program Dev.*	SW Manager		
	Conduct trainings in conjunction with Engineering Division and others to promote better communication	*Operations*	SW, Engineering, and Roads & Drainage Divisions		
Ordinance	Require signed BMP maintenance agreement prior to approval of SWPPP. **Clarify Section 26-64(g)(3)(j) of proposed stormwater ordinance.**	**2009** *Program Dev.*	**SW manager ; legal staff**; Engineering Division staff		**Tool 3: SW Model Ordinance (pg. 22)**
	Implement SW ordinance changes as recommended by the Site Planning Roundtable in 2009	**2009 - 2011** *Program Dev.*	**SW manager ; legal staff**		Roundtable Consensus document
	Consider developing an off-site/fee-in-lieu program when stormwater requirements are too difficult to comply with (e.g., redevelopment, high-density sites)	2015-2020 *Program Dev.*	SW manager ; legal staff	Mitigation fees	Tool 3: SW Model Ordinance (pg. 38) Lexington, KY Stormwater Manual http://www.lexingtonky.gov/index.aspx?page=780

Stormwater criteria	Conduct workshop to discuss ways to incorporate LID features into County projects and encourage use of LID on private sites	2011 *Program Dev.*	SW Division; Engineering Division; Facilities & Grounds Division		
Manuals	Discard sections of the *Storm Drainage Design* manual and the *BMP manual* that overlap each other	2010 *Program Dev.*	SW Division		Tool 5: Manual Builder
	Provide clear language in *Storm Drainage Design* manual about regulatory nature of specifications	2010 *Program Dev.*	SW Division		
	Conduct workshop for DPW staff (SW, plan reviewers) to review changes to *Storm Drainage Design* manual & *BMP Manual*	2010 *Program Dev.*	SW Division; Engineering Division		
Stormwater monitoring	Provide training opportunities and resources for staff to learn about current stormwater monitoring techniques.	*Operations*	SW Division monitoring staff	General fund; stormwater utility	*Urban Stormwater BMP Performance Monitoring*, *www.epa.gov/guide/stormwater/monitor.htm* *Monitoring to Demonstrate Environmental Results* by CWP, 2008
Public information (website)	Update Public Works website with new department structure & show how NPDES program is conducted by different Divisions.	2010 *Program Dev.*	IT staff; DPW manager		
	Improve Stormwater Division web pages (see suggestions listed in April memo)	2010 *Program Dev.*	SW Division; IT staff		One example is Charlottesville, VA's stormwater page: http://www.charlottesville.org/Index.aspx?page=562
	Keep Stormwater Division web pages updated regularly	*Operations*	SW Division; IT staff		

Overall timeframe = 2010 - 2020

- "Phase 1" = 2009 – 2010
- "Phase 2" = 2011 – 2014
- "Phase 3" = 2015 – 2020

Richland County, SC (developed by the Center for Watershed Protection, Inc.)
INCREMENTAL* Stormwater Program Development Costs -- Planning Level**

	Timeframe	**FTEs (# on annual basis)***	**Annual Cost/FTE****	**Total Personnel**	**Other Program Expenses*******	**Total Projected Expenses**
Post-Construction Inspections						
1. Continue inventory all existing BMPs	2010 - 2011					
SW Manager		0.10	$100,000	$10,000		$10,000
SW Inspector		0.50	$60,000	$30,000	$2,000	$32,000
GIS/Database Technician		0.10	$70,000	$7,000	$5,000	$12,000
2. Create position to enforce BMP maintenance	2012					
SW Manager		0.05	$100,000	$5,000	$5,000	$10,000
SW Eng Technician / Watershed Planner		0.25	$70,000	$17,500		$17,500
Task Subtotal				**$69,500**	**$12,000**	**$81,500**
E&S Control						
1. Hire more E&S inspectors	2011 - 2012					
SW Engineer		0.05	$85,000	$4,250	$500	$4,750
2. Establish enhanced training program for inspectors	2011					
SW Engineer		0.10	$85,000	$8,500	$5,000	$13,500
SW Eng Technician / Watershed Planner		0.05	$70,000	$3,500		$3,500
E&S Inspector		0.05	$60,000	$3,000		$3,000
Task Subtotal				**$19,250**	**$5,500**	**$24,750**
BMP Maintenance						
1. Include maintenance agreement form in BMP Manual	**2009**					
SW Manager		0.03	$100,000	$3,000		$3,000
2. Set policy about transfer of BMPs to County	2011					
SW Manager		0.05	$100,000	$5,000		$5,000
3. Develop outreach materials for BMP maintenance	2011 - 2012					
SW Eng Technician / Watershed Planner		0.15	$70,000	$10,500	$1,000	$11,500
Task Subtotal				**$18,500**	**$1,000**	**$19,500**
Program Planning						
1. Update stormwater plan regularly	Every 2 - 4 years					
SW Manager		0.10	$100,000	$10,000	$10,000	$20,000
Task Subtotal				**$10,000**	**$10,000**	**$20,000**
Inter-Departmental Coordination						
1. DPW managers to set priorities for NPDES program	2010					
SW Manager		0.15	$100,000	$15,000	$2,000	$17,000
Task Subtotal				**$15,000**	**$2,000**	**$17,000**

	Timeframe	FTEs (# on annual basis)*	Annual Cost/FTE**	Total Personnel	Other Program Expenses****	Total Projected Expenses
Funding & Staffing						
1. Increase funding for Engineering Division	2012 - 2020					
2. Increase plan review fees	2012 - 2020					
3. Hire more plan reviewers in Engineering Division	2012 - 2020					
SW Manager		0.05	$100,000	$5,000		$5,000
Task Subtotal				**$5,000**	**$0**	**$5,000**
Staff Training						
1. Develop trainings materials	2010					
SW Manager		0.15	$100,000	$15,000	$5,000	$20,000
Task Subtotal				**$15,000**	**$5,000**	**$20,000**
Ordinance						
1. Require signed maintenance agreement	**2009**					
SW Manager		0.05	$100,000	$5,000		$5,000
SW Eng Technician / Watershed Planner		0.05	$70,000	$3,500		$3,500
2. Implement SW recommendations from Roundtable	**2009 - 2011**					
SW Manager		0.20	$100,000	$20,000	$5,000	$25,000
SW Engineer		0.05	$85,000	$4,250	$5,000	$9,250
3. Consider off-site / fee-in-lieu program	2015 -2020					
SW Manager		0.10	$100,000	$10,000		$10,000
Task Subtotal				**$42,750**	**$10,000**	**$52,750**
Stormwater Criteria						
1. Conduct LID workshop / work session	2011					
SW Eng Technician / Watershed Planner		0.15	$70,000	$10,500	$10,000	$10,500
Task Subtotal				**$10,500**	**$10,000**	**$10,500**
Manuals						
1. Discard redundant parts stormwater manuals	2010					
SW Eng Technician / Watershed Planner		0.10	$70,000	$7,000		$7,000
2. Describe regulatory status of *Design Standards* manual	2010					
SW Manager		0.05	$100,000	$5,000		$5,000
3. Conduct DPW workshop about SW manual changes	2010					
SW Manager		0.10	$100,000	$10,000	$1,000	$11,000
Task Subtotal				**$22,000**	**$1,000**	**$23,000**
Stormwater Monitoring						
Task Subtotal				**$0**	**$0**	**$0**

	Timeframe	FTEs (# on annual basis)*	Annual Cost/FTE**	Total Personnel	Other Program Expenses****	Total Projected Expenses
Public Information						
1. Update DPW website with new department structure	**2009**					
GIS/Database Technician		0.02	$70,000	$1,400		$1,400
2. Improve Stormwater Division webpages	2010					
GIS/Database Technician		0.15	$70,000	$10,500	$4,000	$14,500
Task Subtotal				**$11,900**	**$4,000**	**$15,900**
TOTAL INCREMENTAL PROGRAM DEVELOPMENT				**$239,400**	**$60,500**	**$289,900**

"Phase 1" = 2009 – 2010	$121,650
"Phase 2" = 2011 – 2014	$158,250
"Phase 3" = 2015 – 2020	$10,000

* FTEs = Full Time Equivalents

** Annual Cost/FTE was approximated using the following assumptions about program staff: Program Administrator @ $100,000; Stormwater/Watershed Engineer @ $85,000; Stormwater Engineering Technician/Watershed Planner @ $70,000; GIS/Database Technician @ $70,000; Stormwater Inspector @ $60,000; Erosion and Sediment Inspector @ $60,000; Clerical @ $55,000. Annual Cost is assumed to include salary and benefits. See last tab in worksheet.

*** INCREMENTAL costs are those above and beyond existing program development costs. As such, the incremental costs represent a laundry list of recommended practices, although the County may pick and choose based on priorities. Also, costs are approximated based on the percent of an FTE's time to accomplish the task; however, the cost may also represent a planning-level estimate if the County chose to engage the services of a contractor. A specific scope of work would be needed to refine this cost estimate.

**** Other program expenses are highly variable and dependent on overall program expenses and budgets. Expenses in this category can include vehicles, equipment, contractual and other services, and other "direct" costs. The numbers in this spreadsheet are largely place-holders for the local program to fill in and modify as appropriate.

INCREMENTAL* Stormwater Operations Costs -- Planning Level**

	FTEs (# on annual basis)*	Annual Cost/FTE**	Total Personnel	Other Program Expenses****	Total Projected Expenses
Post-Construction Inspections					
1. Catalogue all new BMPs as they are installed					
SW Inspector	0.10	$60,000	$6,000		$6,000
GIS/Database Technician	0.10	$70,000	$7,000		$7,000
2. Inspect each BMP every 2-3 years					
SW Inspector	2.00	$60,000	$120,000	$40,000	$160,000
Task Subtotal			**$133,000**	**$40,000**	**$173,000**
E&S Control					
1. Involve SW inspectors in construction inspections					
SW Inspector	0.25	$60,000	$15,000		$15,000
2. Hire new E&S inspectors					
E&S Inspector	2.00	$60,000	$120,000	$20,000	$140,000
3. Ongoing E&S and SWPPP training for staff					
SW Manager	0.05	$100,000	$5,000	$4,000	$9,000
SW Engineer	0.05	$85,000	$4,250		$4,250
SW Eng Technician / Watershed Planner	0.05	$70,000	$3,500		$3,500
E&S Inspector	0.20	$60,000	$12,000		$12,000
4. Provide site data to SW Division to record in database					
GIS/Database Technician	0.10	$70,000	$7,000	$500	$7,500
Task Subtotal			**$166,750**	**$24,500**	**$191,250**
BMP Maintenance					
1. Target education/outreach about BMP maintenance to HOAs & owners					
SW Eng Technician / Watershed Planner	0.20	$70,000	$14,000	$10,000	$24,000
Task Subtotal			**$14,000**	**$10,000**	**$24,000**
Program Planning					
Task Subtotal			**$0**	**$0**	**$0**

	FTEs (# on annual basis)*	Annual Cost/FTE**	Total Personnel	Other Program Expenses****	Total Projected Expenses
Inter-Departmental Coordination					
1. SW Division staff participate in plan review					
SW Engineer	0.20	$85,000	$17,000	$1,000	$18,000
2. SW Division staff meet w/ Engineering Division regularly to discuss plans under review					
SW Engineer	0.10	$85,000	$8,500		$8,500
Task Subtotal			**$25,500**	**$1,000**	**$26,500**
Funding & Staffing					
1. Hire more plan reviewers in Engineering Division					
SW Engineer	1.00	$85,000	$85,000	$20,000	$105,000
SW Eng Technician / Watershed Planner	1.00	$70,000	$70,000	$20,000	$90,000
Task Subtotal			**$155,000**	**$40,000**	**$195,000**
Staff Training					
1. Conduct ongoing trainings with Engineering Division					
SW Manager	0.10	$100,000	$10,000	$500	$10,500
SW Engineer	0.20	$85,000	$17,000	$500	$17,500
SW Eng Technician / Watershed Planner	0.20	$70,000	$14,000	$500	$14,500
Task Subtotal			**$41,000**	**$1,500**	**$42,500**
Ordinance					
Task Subtotal			**$0**	**$0**	**$0**
Stormwater Criteria					
Task Subtotal			**$0**	**$0**	**$0**
Manuals					
Task Subtotal			**$0**	**$0**	**$0**

	FTEs (# on annual basis)*	Annual Cost/FTE**	Total Personnel	Other Program Expenses****	Total Projected Expenses
Stormwater Monitoring					
1. Provide training about current monitoring techniques					
SW Eng Technician / Watershed Planner	0.10	$70,000	$7,000	$5,000	$12,000
SW Inspector	0.10	$60,000	$6,000	$5,000	$11,000
Task Subtotal			**$13,000**	**$10,000**	**$23,000**
Public Information					
1. Keep SW website updated on ongoing basis					
GIS/Database Technician	0.10	$70,000	$7,000	$4,000	$11,000
Task Subtotal			**$7,000**	**$4,000**	**$11,000**
TOTAL INCREMENTAL STORMWATER OPERATIONS			**$555,250**	**$131,000**	**$686,250**

The above total reflects ***annual operational costs.*** *Not all functions of the Stormwater Division may be represented in this budget*

* FTEs = Full Time Equivalents

** Annual Cost/FTE was approximated using the following assumptions about program staff: Program Administrator @ $100,000; Stormwater/Watershed Engineer @ $85,000; Stormwater Engineering Technician/Watershed Planner @ $70,000; GIS/Database Technician @ $70,000; Stormwater Inspector @ $60,000; Erosion and Sediment Inspector @ $60,000; Clerical @ $55,000. Annual Cost is assumed to include salary and benefits. See last tab in worksheet.

	FTEs (# on annual basis)*	Annual Cost/FTE**	Total Personnel	Other Program Expenses****	Total Projected Expenses

*** INCREMENTAL costs are those above and beyond existing operational costs. As such, the incremental costs represent a laundry list of recommended practices, although the County may pick and choose based on priorities. Also, costs are approximated based on the percent of an FTE's time to accomplish the task; however, the cost may also represent a planning-level estimate if the County chose to engage the services of a contractor. A specific scope of work would be needed to refine this cost estimate.

**** Other program expenses are highly variable and dependent on overall program expenses and budgets. Expenses in this category can include vehicles, equipment, contractual and other services, and other "direct" costs. The numbers in this spreadsheet are largely place-holders for the local program to fill in and modify as appropriate.

Stormwater Manager	100,000
Stormwater/Watershed Engineer	85,000
SW Engineering Technician or Watershed Planner	70,000
Stormwater Inspector	60,000
E&S Inspector	60,000
GIS/Database Technician	70,000
Clerical	55,000