Smith Creek Watershed Restoration Plan

Wake and Franklin Counties
North Carolina




Prepared for the Town of Wake Forest
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1 Introduction

1.1 Executive Summary

The Town of Wake Forest has contracted WK Dickson and Co., Inc. (WKD) to develop a watershed management plan (WMP) for the Smith Creek Watershed, which comprises the headwaters and tributaries of Smith Creek, which drains into the Neuse River. This WMP was developed in accordance with the nine watershed plan elements recognized by the US Environmental Protection Agency (EPA). Pursuant to these elements, the WMP provides a watershed characterization and prioritized solutions to identified watershed functional deficits. The characterization reviews and summarizes existing conditions in the watershed based on: available digital data (e.g. land use and impervious surface conditions and trends, aquatic and terrestrial habitats, soils, geology, hydrology, and water quality), and select field evaluation. It also identifies non-point source pollutant categories and identifies, recommends, and prioritizes management and implementation strategies. This plan will be formally updated periodically (approximately every five years). As conditions merit, it will be informally updated more frequently.

The Smith Creek Watershed is located in Wake and Franklin counties, in the northeast central region of North Carolina, east of the City of Raleigh and within the towns of Wake Forest and Rolesville (Figure 1). The watershed is in the Piedmont Physiographic Province and is characterized by rolling hills. The area included in the assessment contains 14, 920 acres and 451,262 stream-feet. Elevation in the study area ranges from 184 feet above mean sea level (AMSL) near the confluence of Smith Creek and the Neuse River to 488 AMSL on a hill top at the northernmost edge of the watershed in Franklin County. For purposes of this study, 13 subwatersheds within the Smith Creek watershed were delineated.

Until recently the Smith Creek watershed has been primarily an agricultural area. For approximately the last two decades it has transitioned into primarily residential land use. Because of the increase in residential development, the population has increased many new roads, parking lots, and other impervious areas have been created. As population and development density have increased, riparian habitat has been negatively impacted.

In 2008, Smith Creek was added to the 303(d) impaired waters list because of its 2006 benthic macroinvertebrate “Fair Bioclassification” sampling results. The sample site that caused the listing is located at the Burlington Mills Road Bridge, approximately 0.75 mile upstream of the Neuse River confluence. If the stream is not removed from the impaired waters list, Total Maximum Daily Loads are likely to be implemented. This study identifies and prioritizes the likely causes and sources of the impairment, as well as recommendations to improve both water quality and aquatic habitat.

1.2 Purpose and Objectives

The WMP’s purpose is to provide a foundation for addressing non-point source pollution sources in the Smith Creek Watershed, to provide the community and Town staff with recommendations of how to monitor the progress of impairments over time and to provide information for implementing the restoration and monitoring efforts outlined herein. This WMP also summaries available sources, including stream conditions and load reduction estimates, which will enable Town staff to make informed land use management decisions and identify data gaps throughout the watershed. Existing conditions were evaluated using available state, town, and federal data, as well as select on-site evaluation.

To conform to the Town's management objectives, several public meetings have been held since the project's January 2013 inception. These meetings helped demonstrate the Town's commitment to the wellbeing of its residents through their ongoing involvement and participation in the planning process. In addition to supporting and educating the public in appropriate regulatory interpretation and compliance, it is also important for the Town to tailor this Plan to address the nine elements necessary for USEPA Clean Water Act , Section 319 grant funding. These elements include:

- Identify causes and sources of pollution that need to be controlled;
- Determine load reductions needed;
- Identify management measures to achieve goals;
- Develop implementation schedules;
- Develop interim milestones to track implementation of management measures;
- Develop criteria to measure progress toward meeting watershed goals;
- Develop monitoring component;
- Develop information /education component; and
- Identify technical and financial assistance needed to implement plan.

The overarching goals of the watershed plan are to promote and facilitate responsible resource management decisions and actions to:

1. Restore, enhance, and protect watershed functions, including water quality, aquatic habitat, and hydrology;
2. Support waters' designated use classifications;
3. Protect human health; and
4. Support interdisciplinary resource management goals for the Smith Creek Watershed and other natural resources.

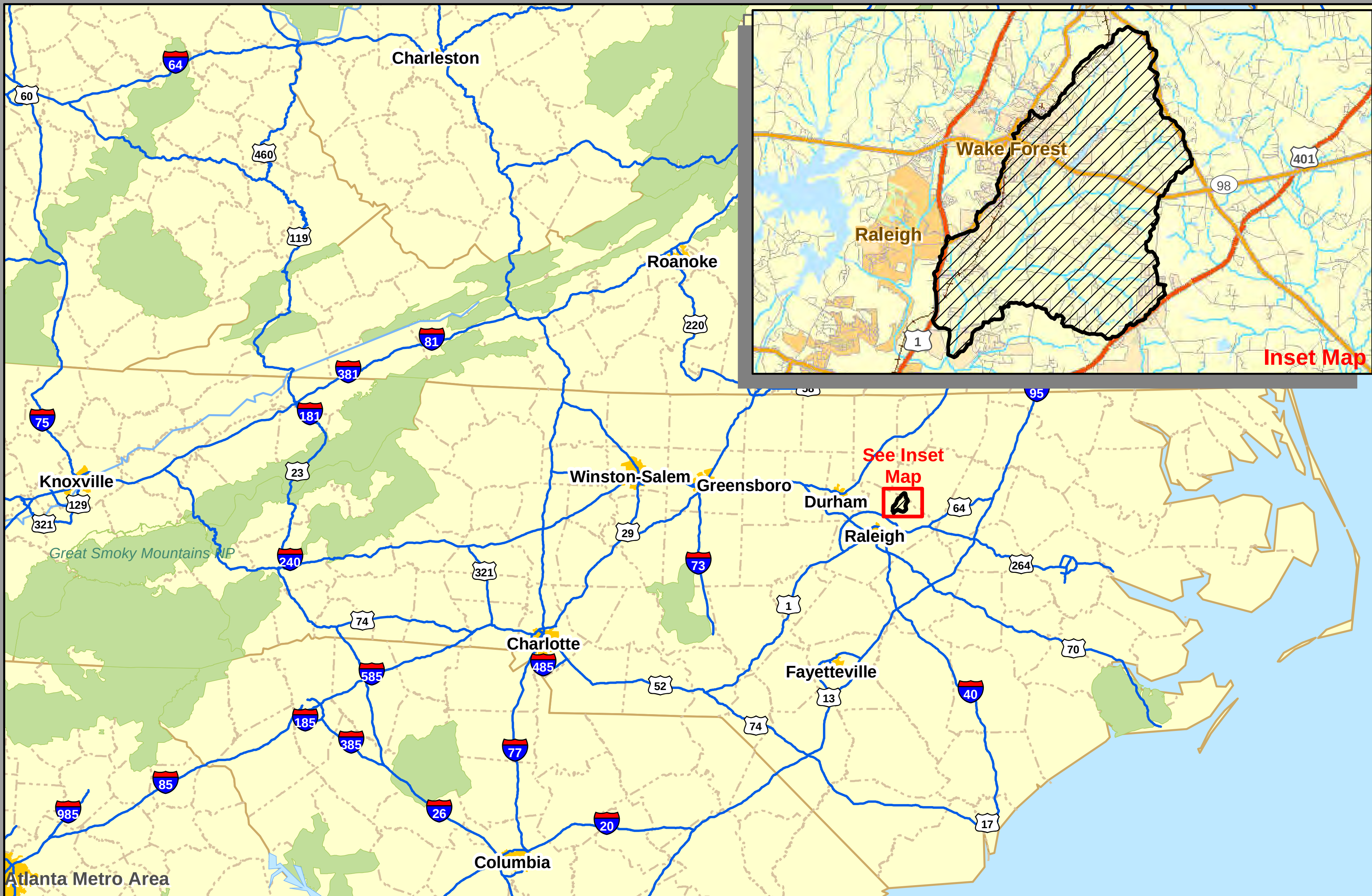
2 Watershed Characterization

2.1 Project Location

The Smith Creek Watershed (United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 030202010702) occupies 14,919.37 acres (23.31 square miles) in north-central North Carolina. A majority (91 percent; 13,513.82 acres; 21.12 square miles) is along Wake County's north-central border. The balance (9 percent; 4,405.55 acres; 2.19 square miles) is in Franklin County, along its southwestern border. The watershed extends from the headwaters of Smith Creek and its tributaries, downstream to the confluence of Smith Creek with the Neuse River (Figure 1). Subwatersheds delineated for this study include: Austin Creek (1,469 acres; 47,475 stream feet), Austin Creek 2 (675 acres; 26,004 stream feet), Dunn Creek (1,428 acres; 38,576 stream feet), Sanford Creek (971 acres; 36,205 stream feet), Sanford Creek 2 (1,014 acres; 28,885 stream feet), Sanford Creek 3 (903 acres; 33,937 stream feet), Sanford Creek 4 (882 acres; 25,888 stream feet), Smith Creek (1,895 acres; 53,055 stream feet), Smith Creek 2 (1,520 acres; 47,346 stream feet), Smith Creek 3 (1,282 acres; 32,728 stream feet), Smith Creek 4 (1,638 acres; 43,878 stream feet), Spring Branch (774 acres; 17,604 stream feet), and Wake Forest Reservoir (469 acres; 19,681 stream feet) (Figure 2).

The watershed studied is bordered to north and east by the Little River Headwaters (HUC 030202011501); to the west by Richland Creek (HUC 030202010701); to the south and southwest by Perry Creek (HUC 030202010704); and to the southeast by Harris Creek (HUC 030202010703).

Historical aerial photographs indicate that agriculture and forestry have been the Smith Creek Watershed's dominant land uses for more than a century. It has been transitioning into primarily residential and commercial land use within the past twenty years, particularly the Smith Creek and Smith Creek 2 watersheds. As the population has increased, many agricultural areas have been converted to residential use and many new roads have been created.



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Watershed Boundary Outline

N
W E
S

Figure 1.

Smith Creek Watershed Restoration Plan and Implementation Project Location Map

0 25 50 Miles

1 inch = 50 miles

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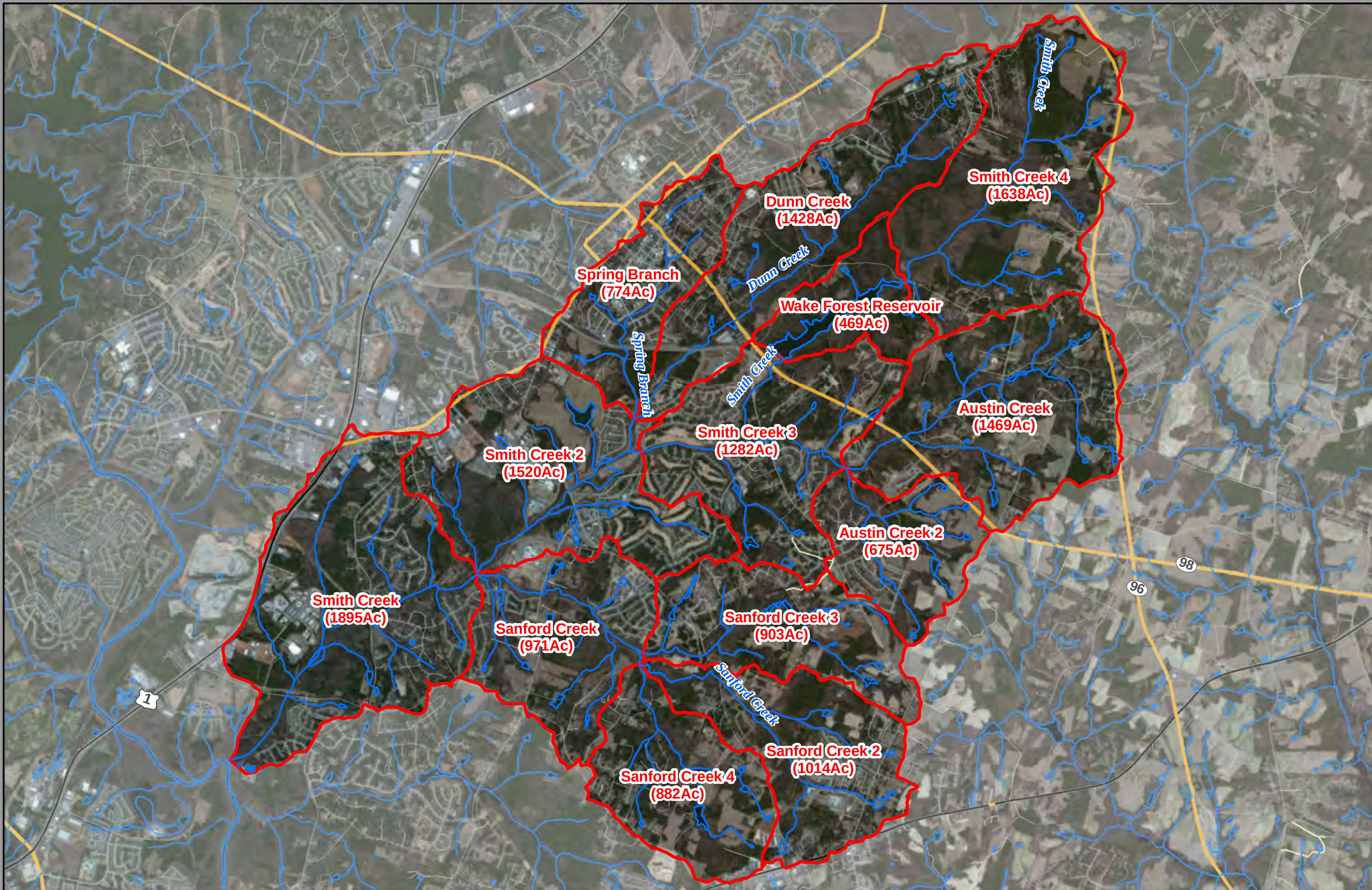

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Streams

Sub-Watershed Boundary

N W E S

Figure 2

Smith Creek Watershed Restoration Plan and Implementation Project Subwatersheds Map

0 0.225 0.45 0.9 Miles

1 in = 1 miles

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2.2 Existing Conditions

WK Dickson used existing Geographic Information Systems (GIS) data and other available information to describe and quantify existing natural resources throughout the study area. GIS and other available information were obtained from the Town of Wake Forest, US Geological Survey (USGS), NC Department of Transportation (DOT), Wake and Franklin counties, NC Division of Water Quality (DWQ), and NC One Map. All data presented herein are projected on the North American Datum of 1983, North Carolina State Plane Feet (NAD83SPF). The entire study area is within the Neuse River Basin and is comprised of the USGS Hydrologic Unit 03020201070070. Data used in this evaluation include:

- USGS Hydrologic Units
- USGS Topographic Quadrangles
- Stream centerlines and use classifications
- Topographic data (two foot contour intervals)
- North Carolina Geological Survey data
- State and Federally protected species element occurrence records (North Carolina Natural Heritage Program)
- Municipal and county boundaries
- Wake County parcel boundaries
- Land cover from National Land Cover Database (NLCD)

2.2.1 Physiography, Topography, and Relief

The Smith Creek Watershed is in the Piedmont Physiographic Province and is characterized by rolling hills. Elevations in the watershed range from 184 feet above mean sea level near Smith Creek's confluence with the Neuse River, to 488 feet above mean sea level on a hill top at the northernmost edge of the watershed. Slopes range from 0 to 55 degrees with a mean slope of 20 degrees (Std dev 9.92). Spring Branch, Dunn Creek, Austin Creek, and Sanford Creek are Smith Creek's main tributaries inside the watershed.

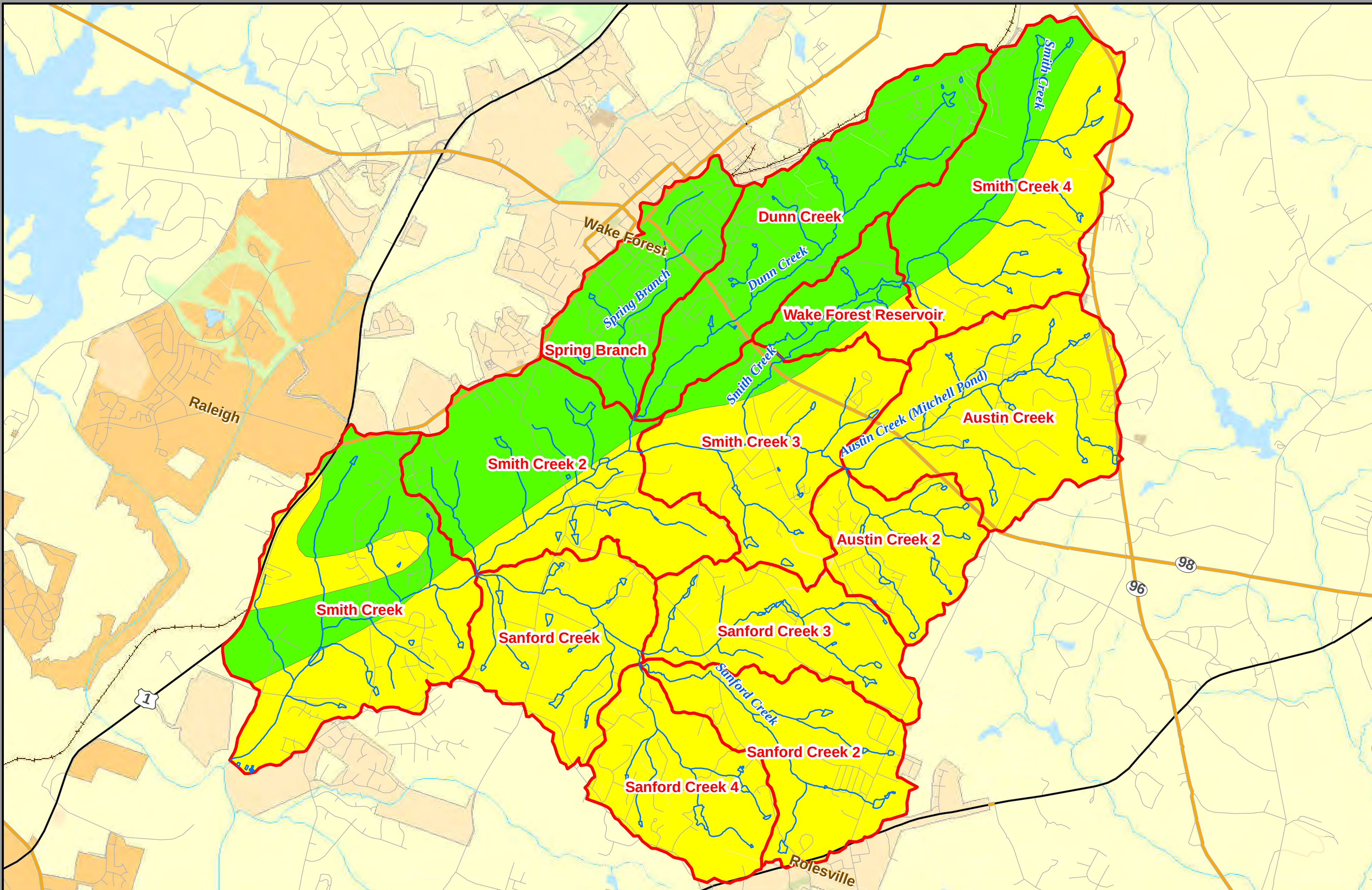
2.2.2 Regional Geology

The formations within the Smith Creek Watershed include two geologic units (Figure 3):

a) Foliated to Massive Granitic Rock
b) Injected Gneiss

Foliated to Massive Granitic Rock-- Foliated to Massive Granitic Rock is situated in the eastern portion of the Smith Creek watershed with a small inclusion in the southwestern portion and is the most common geologic unit within the watershed. This formation has been classified as Permian/Pennsylvanian granite and is found at the surface. It is interlayered and gradational with mica schist and amphibolite and includes small masses of granite rock. Approximately 9,750 acres of this formation have been mapped within the Smith Creek watershed and is primarily located east of Smith Creek with the exception of a small pocket west of Smith Creek in the watershed's southwest corner. This geologic unit is found in all of the subwatersheds with the exception of Dunn Creek and Spring Branch.

Injected Gneiss—The Injected Gneiss formation is found in the western portion of the site. This formation has been classified as a Cambrian to Late Proterozoic age rock. This formation consists of biotite gneiss and schist with numerous sills and dikes of granite, pegmatite, and aplite, as well as minor hornblende gneiss. Within the watershed, there have been 5,167 acres of the Injected Gneiss formation mapped. This geologic unit is found west of Smith Creek in the Dunn Creek, Smith Creek, Smith Creek 2, Smith Creek 3, Smith Creek 4, Spring Branch, and Wake Forest Reservoir watersheds.



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Sub-Watershed Boundary

CZig - Injected Gneiss

PPmg - Foliated to Massive Granite Rock

N W E S

Figure 3

Smith Creek Watersh estoration
Plan and Implementation Project
Geologic Map

0 0.25 0.5 1 Miles

1 in = 1 miles

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2.2.3 Hydrology

The Smith Creek Watershed drains a total area 14,916.73 acres (23.31 sq. mi.). Within the watershed there are 255,411 linear feet (48.37 mi) of first order streams, 66,576 linear feet (12.61 mi) of second order streams, 66,880 linear feet (12.67 mi) of third order streams, 24,575 linear feet (4.65 mi) and 15,547 linear feet (2.94 mi) of fifth order streams. Drainage density inside the watershed is 3.66 mi/mi2. The watershed has bifurcation ratios of 1:2, 4.53; 2:3, 3.17; 3:4, 3.00; and 4:5, 0.50 with a watershed-wide bifurcation ratio of 2.80 (Figure 5).

2.2.4 Precipitation

Precipitation data was obtained from the State Climate Office of North Carolina. Weather data was extrapolated for the Smith Creek watershed from the Weather.com website (Figure 4, Table 1).

Figure 4. Thirty-year monthly average precipitation chart.

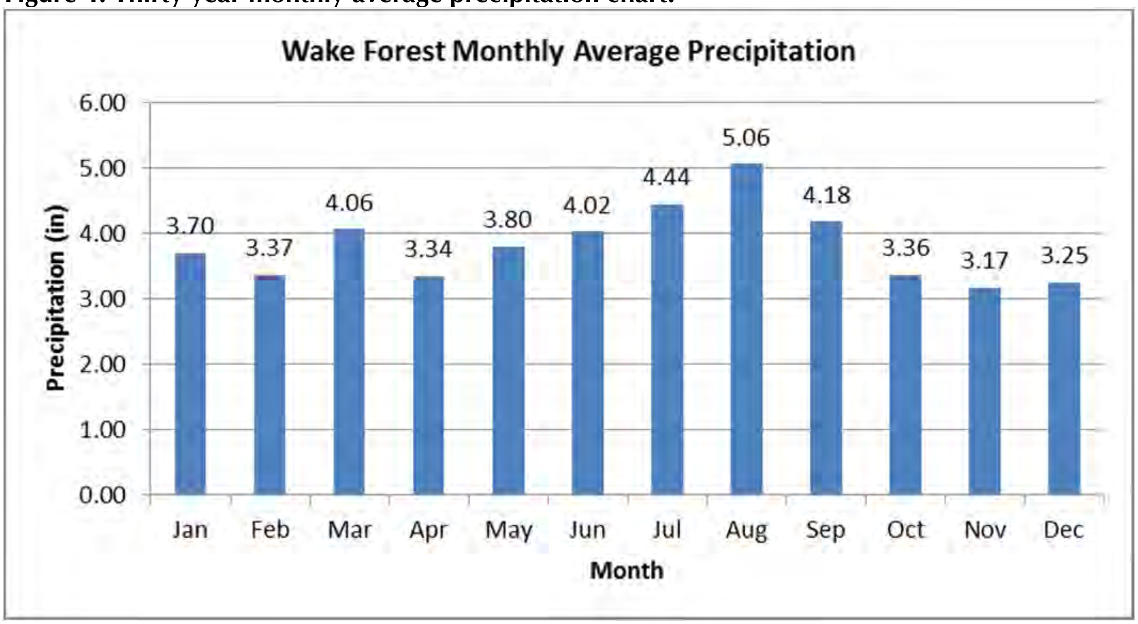


Table 1. Weather Station Information

Station: Wake Forest 4.6 SW (NC-WK-21)
City, State: Wake Forest, NC **County:** Wake County
Latitude: 35.917° **Longitude:** -78.568°
Climate division: NC04 – Central Piedmont
River basin: Upper Neuse

2.2.5 Surface Water Classifications/Designated Uses

Surface Water Classifications define the designated use of surface waters thought North Carolina. They define the best uses to be protected within these waters and carry with them an associated set of water quality standards to protect those uses. Each classification has associated standards that are used to determine if the designated uses are being protected.

The Smith Creek watershed's waters have three classifications. From the headwaters to a point approximately 1.6 miles upstream from the Wake Forest Reservoir Dam the classification is Water Supply-II; High Quality Waters; Nutrient Sensitive Waters (WS-II; HQW; NSW). From the Wake Forest Reservoir Dam to a point approximately 1.6 miles upstream, the classification is Water Supply-II; High Quality Waters; Nutrient Sensitive Waters; Critical area (WS-II; HQW; NSW; CA). From the Wake Forest Reservoir Dam to its confluence with the Neuse River, Smith Creek is assigned a Class C designation.

As stated in *SURFACE WATER AND WETLAND STANDARDS (*15A NCAC 02B .0100, .0200, and .0300; aka "The Red Book"):

.0101 GENERAL PROCEDURES

c) Freshwater shall be assigned to one of the following classification:

1) Class C: freshwaters protected for secondary recreation, fishing, aquatic live including propagation and survival, and wildlife. All freshwaters shall be classified to protect these uses at a minimum.

4) Class WS-II: waters protected as water supplies which are generally in predominantly undeveloped watersheds. Point source discharges of treated wastewater are permitted pursuant to Rules .0104 and .0211 of this subchapter. Local programs to control nonpoint sources and stormwater discharges of pollution shall be required. Suitable for all Class C uses.

.0211 FRESH SURFACE WATER QUALITY STANDARDS FOR CALSS C WATERS

1) Best Usage of Waters: aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation, agriculture and any other usage except for primary recreation or as a source of water supply for drinking, culinary or food processing purposes;

2) Conditions Related to Best Usage: the waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture. Sources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard;

.0214 FRESH SURFACE WATER QUALITY STANDARDS FOR CALSS WS-II WATERS

1) The best usage of WS-II waters are as follows: a source of water supply for drinking, culinary, or food-processing purposes for those users desiring maximum protection for their water supplies where a WS-I classification is not feasible and any best usage specified for Class C waters;

2) The conditions related to the best usage are as follows: waters of this class are protected as water supplies which are in predominantly undeveloped watersheds and meet average watershed development density levels as specified in Sub-Items (3)(b)(i)(A), (3)(b)(i)(B), (3)(b)(ii)(A) and (3)(b)(ii)(B) of this Rule; discharges which qualify for a General Permit pursuant to 15A NCAC 2H .0127, trout farm discharges, recycle (closed loop) systems that only discharge in response to 10-year storm events and other stormwater discharges are allowed in the entire watershed; new domestic and industrial discharges of treated wastewater are not allowed in the entire watershed; the waters, following treatment required by the Division of Environmental Health, shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, and food-processing purposes *which are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500. Sources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard. The Class WS-II classification may be used to protect portions of Class WS-III and WS-IV water supplies. For reclassifications of these portions of Class WS-III and WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, the more protective classification requested by local governments shall be considered by the Commission when all local governments having jurisdiction in the affected area(s) have adopted a resolution and the appropriate ordinances to protect the watershed or the Commission acts to protect a watershed when one or more local governments has failed to adopt necessary protection measures;*

.0223 NUTRIENT SENSITIVE WATERS

a) *In addition to existing classifications, the Commission may classify any surface waters of the state as nutrient sensitive waters (NSW) upon a finding that such waters are experiencing or are subject to excessive growths of microscopic or macroscopic vegetation. Excessive growths are growths which the Commission determines impair the use of the water for its best usage as determined by the classification applied to such waters.*
b) *NSW may include any or all waters within a particular river basin as the Commission deems necessary to effectively control excessive growths of microscopic or macroscopic vegetation.*
c) *For the purpose of this Rule, the term "nutrients" shall mean phosphorous or nitrogen or any other chemical parameter or combination of parameters which the commission determines to be contributing to excessive growths of microscopic or macroscopic vegetation.*
d) *Those waters additionally classified as nutrient sensitive shall be identified in the appropriate schedule of classifications as referenced in Section .0300 of this Subchapter.*
e) *Nutrient strategies applicable to NSW shall be developed by the Commission to control the magnitude, duration, or frequencies of excessive growths of microscopic or macroscopic vegetation so that the existing and designated uses of the waterbody are protected or restored.*

.0224 HIGH QUALITY WATERS

High Quality Waters (HQW) are a subset of waters with quality higher than the standards and are as described by 15A NCAC 2B .0101(e)(5). The following procedures shall be implemented in order to implement the requirements of Rule .0201(d) of this Section.

2) *Development activities which require an Erosion and Sedimentation Control Plan in accordance with rules established by the NC Sedimentation Control Commission or local erosion and sedimentation control program approved in accordance with 15A NCAC 4B .0218 (correct reference is 4B .0118), and which drain to and are within one mile of High Quality Waters (HQW) shall be required to follow the stormwater management rules as specified in 15A NCAC 2H .1000. Stormwater management requirements specific to HQW are described in 15A NCAC 2H .1006.*

2.2.6 Subwatershed Delineation

Data for the study area were compiled in ArcGIS and used for the subwatershed characterization. Spatial analysis was performed by intersecting (clipping) various GIS layers within subwatershed boundaries to develop datasets for each subwatershed. Characteristics measured included:

- Total area
- Impervious surface
- Forested and herbaceous land cover
- Total linear feet of streams and linear feet of each stream order

The total area of each subwatershed was calculated in acres (Table 2).

Table 2. Smith Creek Subwatershed Areas

Hydrography Summary

Subwatershed Name	Area (acre)
Austin Creek	1,468.51
Austin Creek 2	675.40
Dunn Creek	1,427.85
Sanford Creek	970.52
Sanford Creek 2	1,014.42
Sanford Creek 3	902.51
Sanford Creek 4	882.35
Smith Creek	1,894.66
Smith Creek 2	1,519.99
Smith Creek 3	1,281.68
Smith Creek 4	1,638.38
Spring Branch	773.87
Wake Forest Reservoir	469.24

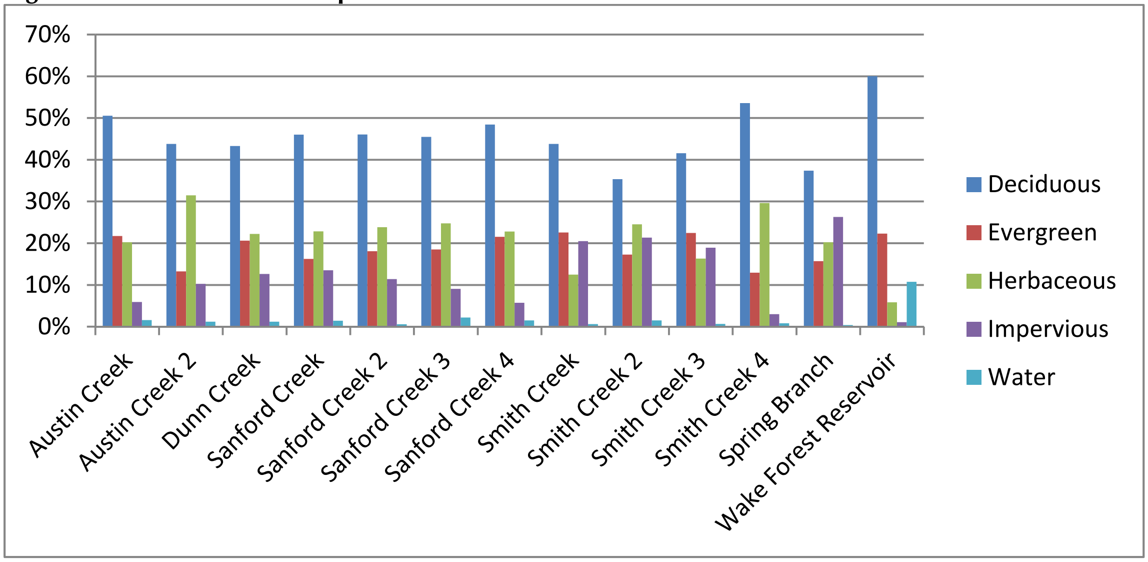
2.2.7 Land Use

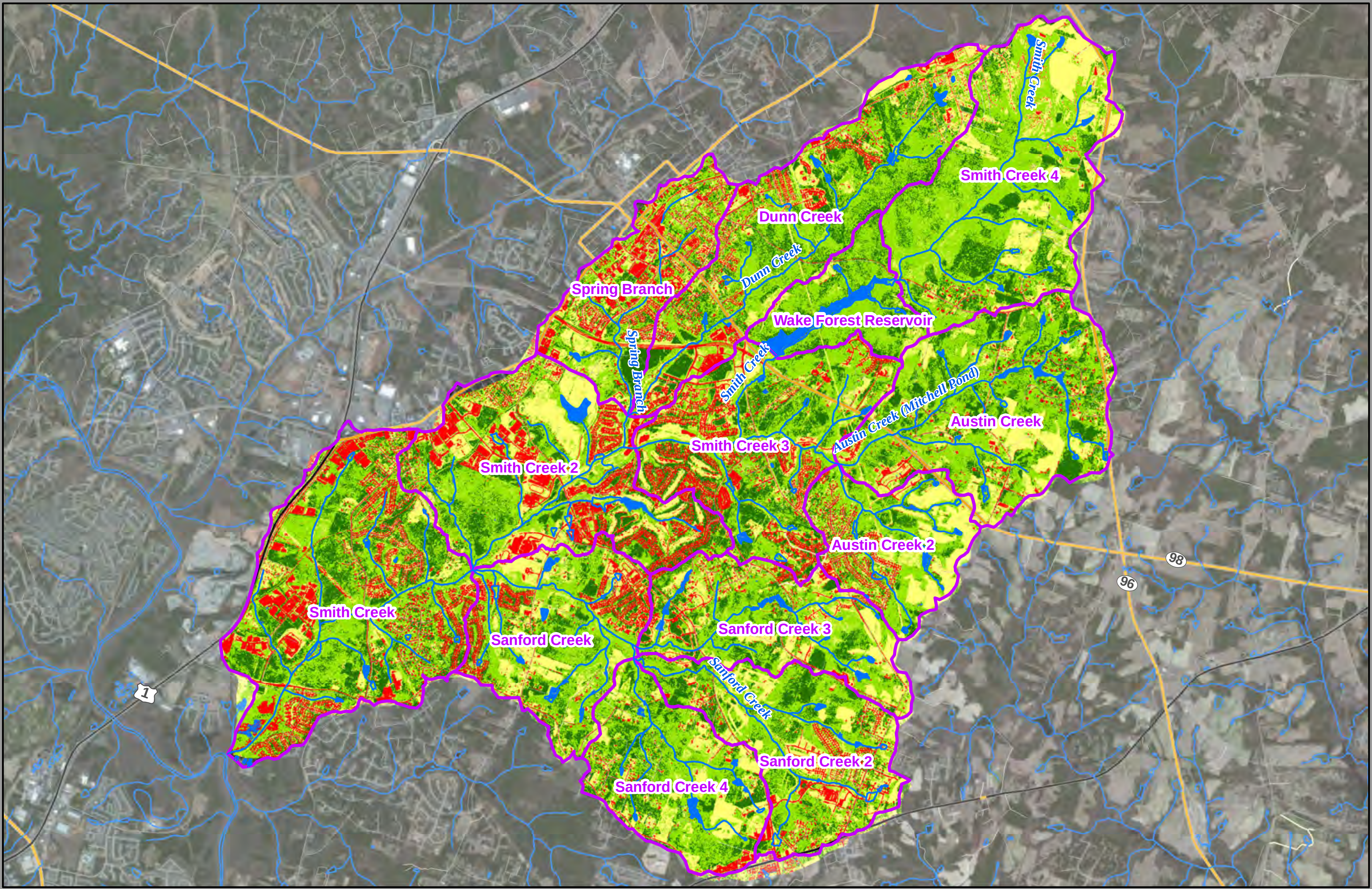
Geographic information system (GIS) data were obtained from the Town of Wake Forest, Wake County, and Franklin County, and all relevant data were clipped to the project boundary. New GIS data, such as impervious surface cover and subwatershed boundaries were created for the Smith Creek WMP. Subwatershed boundaries were delineated using two-foot contour data derived from the most-recently available NCDOT LIDAR datasets. Impervious surface data were created by running a supervised classification on false-color infrared imagery. Change detection data was created by comparing aerial photography from 1959, 2005, 2006, and 2010. Field study locations were recorded using Trimble GPS devices with sub-meter accuracy.

A land use dataset for the Smith Creek Watershed was created using a supervised classification in GIS. The supervised classification utilized false-color infrared aerial photography. No single false-color infrared dataset spanning both Wake and Franklin Counties was available. The analysis utilized the most recent false-color infrared imagery available; 2012 imagery was used for Wake County, and 1998 imagery was used for Franklin County. Both datasets were clipped to the Smith Creek watershed boundary. A signature file was created by hand-digitizing areas of each imagery dataset that were representative of five land use categories: evergreen forest, deciduous forest, herbaceous cover, impervious surface, and water. A supervised classification was then run using the signature file. This is an automated GIS process in which the signature file is used to assign a value (one of the five land use categories) to each cell in the imagery dataset. This method is used to save time compared to hand-digitizing, and provides an estimate of current land use in the watershed. The result of the supervised classifications was two raster datasets (one for the portion of the watershed in Wake County, and one for the portion in Franklin County) in which each cell is coded as one of the five land use categories listed above. These datasets provide a somewhat better representation of impervious surfaces in the watershed than does the 2006 NLCD dataset. Figures 5 and 6 show the results of the supervised land use classification. The amount of forested and agricultural land cover in each subwatershed was determined using the 2006 National Land Cover Database (NLCD) obtained from the USGS (**Error! Reference source not found.**3).

As shown below, the Spring Branch Watershed had the highest relative amount of impervious cover (26%) and the Wake Forest Reservoir Watershed had the lowest (1%). Conversely, Wake Forest had the most deciduous cover (60%), and Smith Creek had the lowest (35%): Spring Branch came in a close second to last (35%). Smith Creek 1, 3, Austin Creek, Wake Forest Reservoir had the highest evergreen cover (23%, 22%, 22%, 22%, and 22%, respectively).

Figure 5. Land Use Chart: Supervised Classification





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Landuse/Cover

- Evergreen
- Herbaceous
- Deciduous
- Water
- Impervious
- Streams
- Sub-Watershed Boundary

N W E S

0 0.225 0.45 0.9 Miles

1 in = 1 miles

Figure 6

Smith Creek Watershed Restoration Plan and Implementation Project Land Use/Land Cover Map

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Table 3. Land Use for Smith Creek Subwatersheds
Source: NLCD 2006

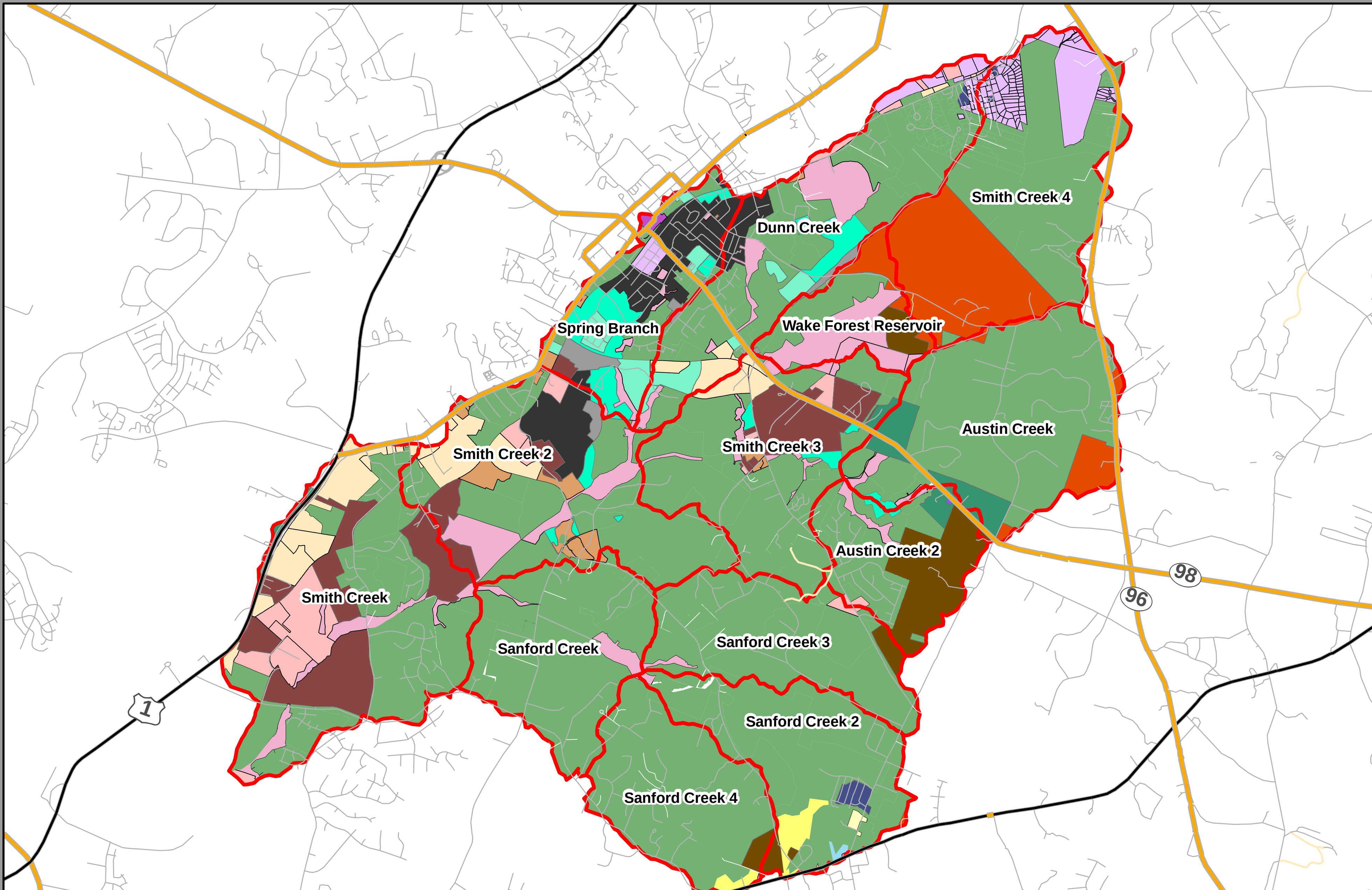
Subwatershed	Developed, High Intensity		Developed, Medium Intensity		Developed, Low Intensity		Developed, Open Space		Barren Land (Rock/Sand/Clay)	
	Acres	Percent (%)	Acres	Percent (%)	Acres	Percent (%)	Acres	Percent (%)	Acres	Percent (%)
Austin Creek	0.00	0.00%	0.00	0.00%	23.65	1.46%	117.11	5.90%	38.25	13.64%
Austin Creek 2	1.10	1.11%	8.96	1.99%	64.62	3.99%	98.06	4.94%	0.11	0.04%
Dunn Creek	23.25	23.45%	27.99	6.23%	141.08	8.71%	318.09	16.04%	22.60	8.06%
Sanford Creek	0.00	0.00%	28.16	6.27%	115.70	7.14%	138.02	6.96%	80.51	28.70%
Sanford Creek 2	8.08	8.15%	28.41	6.33%	119.14	7.36%	102.32	5.16%	24.87	8.86%
Sanford Creek 3	0.01	0.01%	1.50	0.33%	35.21	2.17%	43.20	2.18%	15.08	5.37%
Sanford Creek 4	0.42	0.42%	7.47	1.66%	10.53	0.65%	52.15	2.63%	24.54	8.75%
Smith Creek	19.62	19.80%	108.16	24.08%	430.90	26.61%	281.31	14.18%	4.08	1.45%
Smith Creek 2	24.04	24.25%	108.25	24.10%	247.17	15.26%	283.02	14.27%	7.96	2.84%
Smith Creek 3	3.74	3.77%	61.36	13.66%	193.12	11.93%	268.86	13.56%	60.69	21.64%
Smith Creek 4	0.00	0.00%	0.00	0.00%	24.12	1.49%	69.34	3.50%	0.00	0.00%
Spring Branch	18.87	19.04%	68.93	15.35%	214.21	13.23%	203.93	10.28%	1.03	0.37%
Wake Forest Reservoir	0.00	0.00%	0.00	0.00%	0.00	0.00%	7.97	0.40%	0.81	0.29%
Total Acres/% of Study Area	**99.12**	**0.66%**	**449.18**	**3.01%**	**1619.44**	**10.85%**	**1983.36**	**13.29%**	**280.51**	**1.88%**

Subwatershed	Cultivated Crops		Pasture/Hay		Forest, Deciduous		Forest, Evergreen		Mixed Forest	
	Acres	Percent (%)	Acres	Percent (%)	Acres	Percent (%)	Acres	Percent (%)	Acres	Percent (%)
Austin Creek	4.26	6.51%	373.28	16.84%	370.69	10.76%	333.67	13.29%	92.35	9.94%
Austin Creek 2	8.11	12.40%	258.14	11.65%	119.19	3.46%	27.14	1.08%	32.94	3.55%
Dunn Creek	5.41	8.27%	66.39	3.00%	352.87	10.25%	310.39	12.36%	104.89	11.29%
Sanford Creek	10.86	16.60%	157.30	7.10%	153.19	4.45%	137.96	5.50%	13.82	1.49%
Sanford Creek 2	10.57	16.16%	108.02	4.87%	282.68	8.21%	166.91	6.65%	74.10	7.98%
Sanford Creek 3	25.65	39.21%	277.27	12.51%	221.24	6.42%	178.05	7.09%	27.49	2.96%
Sanford Creek 4	0.23	0.35%	256.81	11.59%	233.02	6.77%	146.50	5.84%	38.29	4.12%
Smith Creek	0.00	0.00%	77.47	3.50%	254.33	7.38%	310.52	12.37%	206.66	22.25%
Smith Creek 2	0.00	0.00%	210.37	9.49%	205.03	5.95%	218.44	8.70%	60.55	6.52%
Smith Creek 3	0.33	0.50%	61.63	2.78%	253.33	7.36%	240.71	9.59%	40.24	4.33%
Smith Creek 4	0.00	0.00%	295.85	13.35%	709.31	20.59%	275.81	10.99%	131.71	14.18%
Spring Branch	0.00	0.00%	39.85	1.80%	63.42	1.84%	79.44	3.16%	60.52	6.51%
Wake Forest Reservoir	0.00	0.00%	33.77	1.52%	225.96	6.56%	84.93	3.38%	45.45	4.89%
Total Acres/% of Study Area	**65.42**	**0.44%**	**2216.14**	**14.85%**	**3444.25**	**23.07%**	**2510.46**	**16.82%**	**929.02**	**6.22%**

Subwatershed	Grassland/Herbaceous Acres	Grassland/Herbaceous Percent (%)	Open Water Acres	Open Water Percent (%)	Shrub/Scrub Acres	Shrub/Scrub Percent (%)	Woody Wetlands Acres	Woody Wetlands Percent (%)
Austin Creek	66.32	8.93%	13.32	9.00%	6.33	4.83%	29.22	9.62%
Austin Creek 2	38.21	5.14%	3.11	2.11%	10.67	8.14%	5.01	1.65%
Dunn Creek	44.33	5.97%	6.88	4.65%	5.54	4.23%	0.00	0.00%
Sanford Creek	87.80	11.82%	8.28	5.60%	1.14	0.87%	37.80	12.44%
Sanford Creek 2	70.79	9.53%	4.88	3.30%	11.74	8.96%	1.87	0.62%
Sanford Creek 3	52.63	7.08%	5.38	3.64%	12.61	9.62%	7.15	2.35%
Sanford Creek 4	88.12	11.86%	9.67	6.54%	11.17	8.52%	3.39	1.12%
Smith Creek	46.42	6.25%	6.20	4.19%	8.02	6.12%	143.22	47.15%
Smith Creek 2	53.84	7.25%	22.47	15.19%	17.93	13.68%	58.64	19.31%
Smith Creek 3	59.88	8.06%	10.17	6.88%	13.17	10.05%	14.95	4.92%
Smith Creek 4	97.31	13.10%	3.47	2.35%	29.25	22.32%	2.49	0.82%
Spring Branch	18.73	2.52%	2.41	1.63%	2.54	1.94%	0.00	0.00%
Wake Forest Reservoir	18.54	2.49%	51.66	34.93%	0.96	0.73%	0.00	0.00%
Total Acres/% of Study Area	**742.91**	**4.98%**	**147.91**	**0.99%**	**131.05**	**0.88%**	**303.73**	**2.03%**

2.2.8 Zoning

Because the study area occupies four areas of planning and zoning jurisdiction (i.e. towns of Wake Forest and Rolesville and Wake and Franklin counties), zoning districts and GIS data from all was integrated into common categories, as shown in the tables and charts below. Overall, the Residential zoning district occupied 65.43 percent of the study area. Sanford Creek 4 had the highest percent (92.3) of any subwatershed. The Rural Holding District and Open Space were distant second and third, occupying 5.11 and 4.97 percent of the study area, respectively. Zoning in Smith Creek 1 includes 23.55 percent Rural Holding District, the most of any subwatershed. Open Space occupies 41.82 percent of the Wake Forest Reservoir subwatershed, much more than any other (Figure 7).



Neighborhood Residential
Office and Professional
Open Space
Residential
Residential - Agriculture
Residential Mixed Use
Residential Watershed
Residential and Planned Unit Development
Rural Manufactured Home District
Urban Residential
Rurual Holding District

Subwatersheds
Commercial
Commercial - Outlying
General Business
Highway Business
Highway District
Industrial
Institutional Campus Development
Neighborhood Business

Figure 7

Smith Creek Watershed Restoration Plan and Implementation Project Zoning Map

0 0.25 0.5 1 Miles

1 in = 1 miles

N E S W

WK DICKSON
community infrastructure consultants

Table 4. Zoning

Original Zoning Code	Zoning Group	Austin Creek	Austin Creek 2	Dunn Creek	Sanford Creek	Sanford Creek 2	Sanford Creek 3	Sanford Creek 4	Smith Creek	Smith Creek 2	Smith Creek 3	Smith Creek 4	Spring Branch	Wake Forest Res.	Total Area
CU GR3 CU GR10 GR10 CD CU GR5 R R-30 R-15 GR3 GR5 CD CU-R-15 R 40 GR5 GR10 R40 R-I R S R2-SUD R2-CZ GR3 CD R-40	Residential	82.26%	45.91%	61.39%	95.11%	87.17%	92.30%	94.65%	47.87%	52.40%	66.37%	61.32%	19.76%	30.26%	65.43%

Table 4. Zoning

Original Zoning Code	Zoning Group	Austin Creek	Austin Creek 2	Dunn Creek	Sanford Creek	Sanford Creek 2	Sanford Creek 3	Sanford Creek 4	Smith Creek	Smith Creek 2	Smith Creek 3	Smith Creek 4	Spring Branch	Wake Forest Res.	Total Area
OS CU OS OS CD	Open Space	1.47%	4.19%	CU OS (TND)											
R-40W R-80W R40W	Residential Watershed	7.29%				0.39%						26.20%		16.04%	4.73%
RMX CD CU RMX RMX CU RMX (TND)	Residential Mixed Use	0.60%	1.46%	9.96%						1.96%	21.19%		32.56%	0.29%	3.03%
RPUD R&PUD GR3 (PUD) GR5 (PUD)	Residential and Planned Unit Development	0.30%	41.56%			2.29%	2.72%	2.84%						10.73%	2.64%
HD	Highway District	8.10%	5.72%						1.06%		1.18%				1.29%
GB	General Business		0.10%												0.00%
I-I	Industrial		1.07%	1.93%		0.20%	0.99%	0.08%	10.90%	2.62%	1.87%				2.03%

Table 4. Zoning

Original Zoning Code	Zoning Group	Austin Creek	Austin Creek 2	Dunn Creek	Sanford Creek	Sanford Creek 2	Sanford Creek 3	Sanford Creek 4	Smith Creek	Smith Creek 2	Smith Creek 3	Smith Creek 4	Spring Branch	Wake Forest Res.	Total Area
L I H I MU LI LI I-1 CU LI HI I															
A R R A RMH/RA R MH/RA R40 RA RA HC	Residential - Agriculture			4.84%								12.31%	3.54%		2.26%
RMH R MH R-MH	Rural Manufactured Home District			0.69%		2.64%						0.15%			0.23%
HB H B CU HB HB CD	Highway Business			4.34%					12.07%	9.59%	4.72%		0.18%		3.19%
CU RD	Rural Holding			0.17%					23.55%	6.24%			1.77%		5.11%

Table 4. Zoning

Original Zoning Code	Zoning Group	Austin Creek	Austin Creek 2	Dunn Creek	Sanford Creek	Sanford Creek 2	Sanford Creek 3	Sanford Creek 4	Smith Creek	Smith Creek 2	Smith Creek 3	Smith Creek 4	Spring Branch	Wake Forest Res.	Total Area
RD	District														
NB CU NB NB CD	Neighborhood Business				0.90%					6.90%	0.96%		1.74%		0.92%
CO-SUD CO	Commercial - Outlying					5.33%		2.32%							0.52%
C C-CZ	Commercial					0.70%									0.05%
UR UMX CU UMX CU UR CU UR (TND) UR CD	Urban Residential			4.44%			3.01%			9.33%			29.74%		2.99%
NMX CU NMX (TND) CU NMX	Neighborhood Residential			1.33%						1.06%			5.31%	0.86%	0.52%

Table 4. Zoning

Original Zoning Code	Zoning Group	Austin Creek	Austin Creek 2	Dunn Creek	Sanford Creek	Sanford Creek 2	Sanford Creek 3	Sanford Creek 4	Smith Creek	Smith Creek 2	Smith Creek 3	Smith Creek 4	Spring Branch	Wake Forest Res.	Total Area
OP-SUD	Office and Professional					0.88%									0.06%
ICD	Institutional Campus Development												1.59%		0.08%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

2.2.9 Stream Order

The National Hydrologic Dataset (NHD) layer, obtained from USGS, was used as a baseline from which to delineate streams within the Smith Creek watershed. The NHD data is based off of the blue line streams on USGS 1:24,000-scale topographic maps. Stream alignments and locations were adjusted to match georeferenced aerial photography and NCDOT four foot vector contours. Stream order was determined using Strahler's stream order method (Strahler, 1952) and correlated with sub-watershed extents to determine length of stream order by subwatershed (Figure 8; Table 5).

Table 5: Stream Order in Smith Creek Sub-watersheds

Sub-Watershed	Stream Order (Linear Feet)					Total
	1st	2nd	3rd	4th	5th	
Austin Creek	29,074	12,554	5,847	-	-	47,475
Austin Creek 2	21,037	4,967	-	-	-	26,004
Dunn Creek	22,294	9,012	7,269	-	-	38,576
Sanford Creek	26,841	1,126	235	8,294	-	36,497
Sanford Creek 2	17,432	5,511	5,942	-	-	28,885
Sanford Creek 3	19,098	4,136	10,468	-	-	33,702
Sanford Creek 4	20,342	2,681	2,865	-	-	25,888
Smith Creek	36,076	1,432	-	-	15,547	53,054
Smith Creek 2	29,497	4,042	1,321	12,072	-	46,932
Smith Creek 3	15,524	4,380	8,974	4,403	-	33,280
Smith Creek 4	27,400	8,478	8,001	-	-	43,878
Spring Branch	10,177	7,427	-	-	-	17,604
Wake Forest Reservoir	3,729	-	15,955*	-	-	19,681
Total:	**278,521**	**65,746**	**18,296**	**16,475**	**15,547**	**451,456**

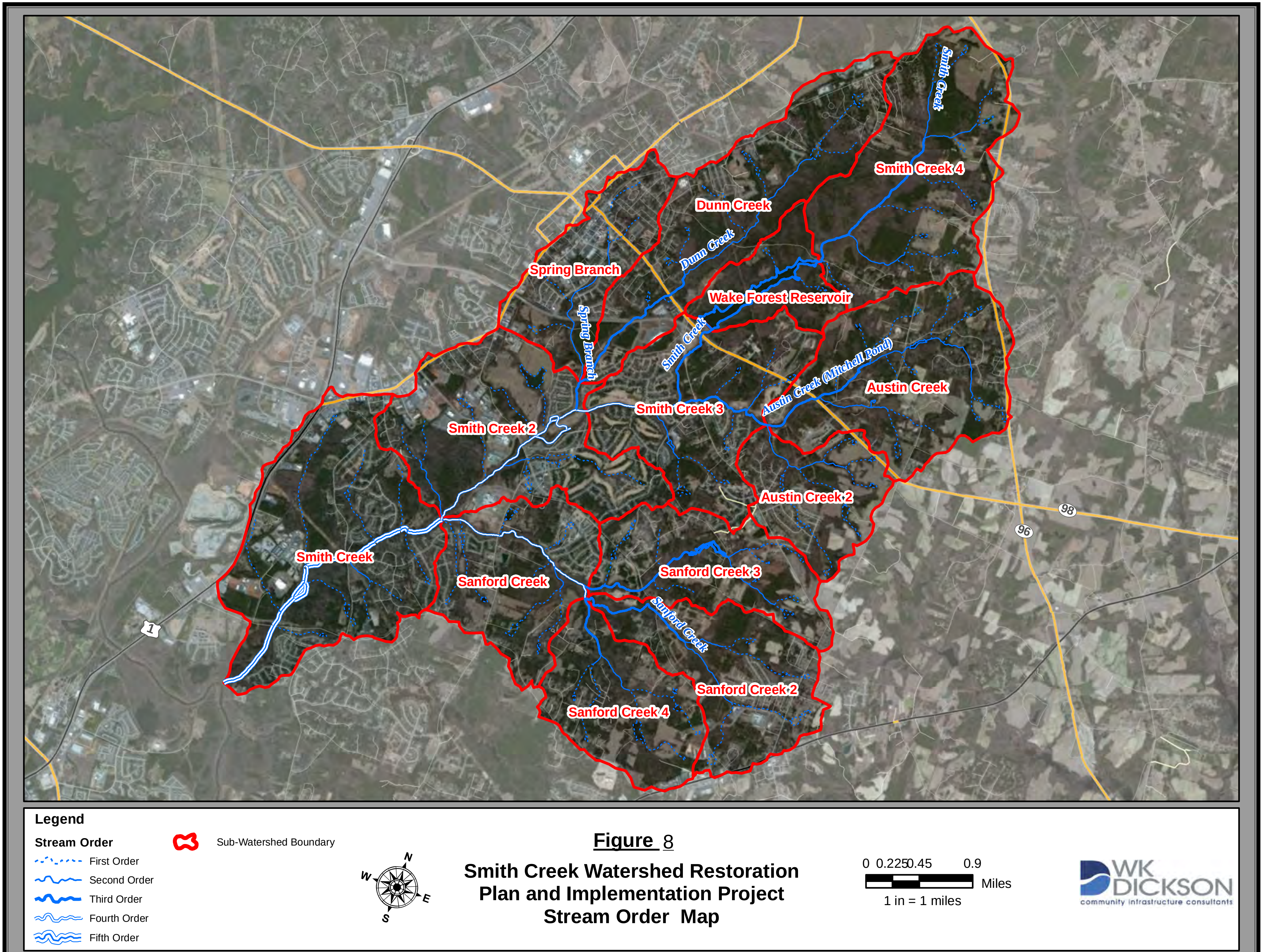


Figure 8

Smith Creek Watershed Restoration Plan and Implementation Project Stream Order Map

2.2.10 Stream Buffer Assessment

A stream buffer assessment was completed using GIS analysis within the Smith Creek watershed. Using the stream alignments within each sub-watershed, buffer layers were created for 30-, 50-, 100-, 150-, and 200-foot buffer widths. Each buffer layer was then intersected with the land cover data. Next each buffer area was clipped to the thirteen sub-watershed boundaries giving a result of the land cover type located in the various buffer widths. The subsequent data was analyzed and sorted for each sub-watershed (Table 6).

The results show that, like total cover, Spring Branch has the highest percentage of impervious surfaces within the stream buffers (nine percent in 30 foot buffer to 17 percent in 200-foot buffer). The vast majority of the sub-watersheds have a much smaller percentage of impervious surfaces within the buffer areas (five percent or less). The buffer areas in all of the sub-watersheds were more than 60 percent forested, with the majority being more than 80 percent forested.

Table 6: Land Use/Land Cover for Smith Creek Sub-watersheds Buffers

Watershed	Buffer Width (feet)	Land Cover										Total (acres)
		Evergreen Forest		Herbaceous		Deciduous Forest		Open Water		Impervious		
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	
Austin Creek	30	8.72	14%	2.70	4%	41.72	65%	9.67	15%	1.02	2%	63.83
	50	14.75	14%	5.07	5%	68.08	65%	14.40	14%	1.93	2%	104.23
	100	31.88	16%	15.07	8%	126.76	64%	20.06	10%	4.51	2%	198.28
	150	53.13	18%	27.89	10%	177.78	62%	21.27	7%	7.97	3%	288.04
	200	75.91	20%	42.29	11%	223.08	59%	21.69	6%	13.12	3%	376.09
Austin Creek 2	30	4.59	13%	2.19	6%	24.14	69%	3.42	10%	0.73	2%	35.07
	50	7.66	13%	4.20	7%	39.28	68%	5.15	9%	1.26	2%	57.55
	100	15.17	14%	12.34	11%	71.55	65%	7.27	7%	3.80	3%	110.13
	150	21.68	14%	25.80	16%	96.88	61%	7.67	5%	7.59	5%	159.62
	200	28.42	14%	43.97	21%	116.83	56%	7.68	4%	12.14	6%	209.05
Dunn Creek	30	6.25	13%	3.19	7%	33.46	69%	4.22	9%	1.26	3%	48.37
	50	10.88	13%	5.92	7%	57.35	70%	5.69	7%	1.98	2%	81.82
	100	24.85	16%	13.28	8%	107.12	68%	8.50	5%	4.56	3%	158.31
	150	40.87	18%	20.11	9%	152.35	66%	8.95	4%	8.58	4%	230.86
	200	58.70	19%	26.57	9%	193.39	64%	9.04	3%	13.89	5%	301.59
Sanford Creek	30	0.29	2%	1.62	12%	10.97	84%	0.05	0%	0.19	1%	13.12
	50	0.52	2%	2.73	13%	18.14	83%	0.07	0%	0.27	1%	21.73
	100	1.16	3%	5.67	13%	35.30	83%	0.10	0%	0.56	1%	42.79
	150	2.32	4%	8.79	14%	50.24	80%	0.11	0%	1.56	2%	63.02
	200	3.66	4%	12.12	15%	62.51	77%	0.13	0%	3.13	4%	81.56
Sanford Creek 2	30	2.24	7%	2.25	7%	22.91	75%	2.35	8%	0.88	3%	30.64
	50	4.04	8%	3.76	7%	37.97	75%	3.34	7%	1.53	3%	50.64

Table 6: Land Use/Land Cover for Smith Creek Sub-watersheds Buffers

Watershed	Buffer Width (feet)	Land Cover										Total (acres)
		Evergreen Forest		Herbaceous		Deciduous Forest		Open Water		Impervious		
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	
	100	9.79	10%	9.75	10%	71.13	72%	4.16	4%	3.89	4%	98.73
	150	16.48	11%	16.35	11%	100.16	69%	4.38	3%	7.33	5%	144.70
	200	24.70	13%	23.68	13%	125.59	66%	4.44	2%	10.99	6%	189.41
Sanford Creek 3	30	3.15	8%	2.92	7%	25.16	60%	9.63	23%	1.07	3%	41.93
	50	5.24	8%	5.12	8%	41.26	61%	14.19	21%	1.93	3%	67.73
	100	12.17	10%	12.47	10%	78.81	63%	18.24	14%	4.37	3%	126.07
	150	21.68	12%	21.86	12%	111.34	61%	19.11	11%	7.89	4%	181.88
	200	30.91	13%	33.37	14%	141.20	60%	19.23	8%	11.45	5%	236.17
Sanford Creek 4	30	2.34	9%	2.60	10%	15.65	63%	3.99	16%	0.27	1%	24.83
	50	4.06	10%	4.59	11%	25.68	63%	5.98	15%	0.40	1%	40.70
	100	8.94	11%	9.87	13%	49.38	63%	9.05	12%	0.92	1%	78.15
	150	14.30	13%	16.29	14%	71.23	63%	10.06	9%	1.50	1%	113.39
	200	20.55	14%	23.66	16%	90.46	61%	10.28	7%	2.41	2%	147.37
Smith Creek	30	3.54	10%	2.77	8%	24.69	70%	1.419	4%	2.71	8%	35.13
	50	6.28	11%	4.57	8%	41.41	71%	1.869	3%	4.31	7%	58.44
	100	13.64	12%	9.29	8%	81.21	70%	2.465	2%	9.73	8%	116.33
	150	22.76	13%	13.80	8%	117.39	68%	2.954	2%	16.88	10%	173.78
	200	32.90	14%	17.93	8%	150.35	65%	3.542	2%	26.18	11%	230.89
Smith Creek 2	30	4.87	8%	7.46	13%	36.65	62%	5.33	9%	4.73	8%	59.04
	50	8.09	8%	13.34	14%	59.16	61%	8.68	9%	8.06	8%	97.32
	100	18.44	10%	27.82	15%	110.29	58%	15.20	8%	17.39	9%	189.14
	150	30.86	11%	45.67	17%	149.06	54%	18.76	7%	29.76	11%	274.11
	200	43.94	12%	66.96	19%	179.90	51%	20.73	6%	44.38	12%	355.91

Table 6: Land Use/Land Cover for Smith Creek Sub-watersheds Buffers

Watershed	Buffer Width (feet)	Land Cover										Total (acres)
		Evergreen Forest		Herbaceous		Deciduous Forest		Open Water		Impervious		
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	
Smith Creek 3	30	4.94	11%	2.47	6%	33.55	75%	2.46	6%	1.27	3%	44.70
	50	8.71	12%	4.54	6%	54.74	74%	3.72	5%	1.88	3%	73.59
	100	19.14	13%	11.90	8%	101.15	71%	5.47	4%	4.61	3%	142.27
	150	31.98	15%	22.30	11%	136.93	66%	6.24	3%	10.80	5%	208.24
	200	45.91	17%	34.25	13%	166.14	61%	6.72	2%	19.52	7%	272.55
Smith Creek 4	30	3.77	6%	3.07	5%	47.61	80%	4.38	7%	0.48	1%	59.31
	50	6.17	6%	5.83	6%	78.27	80%	6.36	7%	0.75	1%	97.37
	100	13.92	7%	15.42	8%	148.64	79%	8.03	4%	1.96	1%	187.96
	150	23.43	8%	27.66	10%	212.58	77%	8.44	3%	3.80	1%	275.92
	200	34.26	9%	42.49	12%	271.15	75%	8.48	2%	6.13	2%	362.52
Spring Branch	30	3.09	15%	2.39	11%	12.46	59%	1.42	7%	1.81	9%	21.17
	50	5.01	14%	4.12	12%	20.88	60%	1.93	6%	3.00	9%	34.93
	100	10.00	15%	9.08	13%	39.24	58%	2.41	4%	7.50	11%	68.23
	150	15.94	16%	14.42	14%	53.40	53%	2.43	2%	14.24	14%	100.42
	200	21.69	16%	20.25	15%	65.40	50%	2.44	2%	22.34	17%	132.12
Wake Forest Reservoir	30	4.58	17%	0.33	1%	12.03	46%	9.01	34%	0.33	1%	26.29
	50	7.57	18%	0.57	1%	19.33	45%	15.12	35%	0.49	1%	43.08
	100	13.97	17%	1.23	2%	36.20	45%	29.36	36%	0.59	1%	81.35
	150	19.53	17%	2.21	2%	52.62	45%	40.78	35%	0.79	1%	115.93
	200	24.59	17%	3.45	2%	68.79	47%	48.17	33%	0.99	1%	145.98

2.2.11 Federally Protected Species

Plants and animals with a federal designation of Endangered (E), Threatened (T), Proposed endangered (PE), and Proposed Threatened (PT) are protected under the provisions of Section 7 and Section 9 of the Endangered Species Act of 1973. A list of threatened and endangered species in Wake and Franklin Counties was obtained from the North Carolina Natural Heritage Program (NCNHP) database. Twenty federally listed Threatened or Endangered species were identified in Wake or Franklin counties (Table 7).

While the management plan will primarily be concerned with federally protected species within the watershed, it is also useful to be aware of other species in the area that are still of concern to the USFWS and the National Park Service, as well as North Carolina protected species. Because NCNHP's mission is to protect rare species, element occurrence locations are not mapped. Specific locations of know populations/individuals can be provided on a case by case basis by contacting NCNHP and USFWS directly.

Table 7. Federally Protected Species in Smith Creek Watershed (Wake and Franklin Counties)

Family	Scientific Name	Common Name	Federal Status	State Status
		Vertebrates		
Centrarchidae	*Ambloplites cavifrons*	Roanoke Bass	FSC	SR
Colubridae	*Heterodon simus*	Southern Hognose Snake	FSC	SC
Vespertilionidae	*Myotis austroriparius*	Southeastern Myotis	FSC	SC
Ictaluridae	*Noturus furiosus*	Carolina Madtom	FSC	T
Emberizidae	*Peucaea aestivalis*	Bachman's Sparrow	FSC	SC
Picidae	*Picoides borealis*	*Red-cockaded Woodpecker*	*E*	*E*
Vespertilionidae	*Myotis septentrionalis*	*Northern Long-eared Bat*	*T-4(d)*	*SC*
Cyprinidae	*Lythrurus matutinus*	*Pinewoods Shiner*	*FSC*	*S3*
Proteidae	*Necturus lewisi*	*Neuse River Waterdog*	*FSC*	*S2*
		Invertebrates		
Unionidae,	*Alasmidonta heterodon*	Dwarf Wedgemussel	E	E
Unionidae	*Elliptio lanceolata*	Yellow Lance	FSC	E
Unionidae	*Fusconaia masoni*	Atlantic Pigtoe	FSC	E
Gomphidae	*Gomphus septima*	Septima's Clubtail	FSC	SR
Unionidae	*Lasmigona subviridis*	Green Floater	FSC	E
Unionidae	*Elliptio steinstansana*	Tar River Spinymussel	*E*	*E*
Nymphalidae	*Speyeria diana*	Diana Fritillary	*FSC*	*S3S4*
Unionidae	*Lampsilis cariosa*	Yellow Lampmussel	*FSC*	*S3*
Corduliidae	*Macromia margarita*	Mountain River Cruiser	*FSC*	*S2*
		Plants		
Fabaceae	*Acmispon helleri*	Carolina Birdfoot-trefoil	FSC	SC-V
Lauraceae	*Lindera subcoriacea*	Bog Spicebush	FSC	SR-T
Ericaceae	*Monotropsis odorata*	Sweet Pinesap	FSC	SC-V
Anacardiaceae	*Rhus michauxii*	Michaux's Sumac	E	E
Alismataceae	*Sagittaria weatherbiana*	Grassleaf Arrowhead	FSC	E
Liliaceae	*Trillium pusillum var. virginianum*	Virginia Least Trillium	FSC	E

Table 7. Federally Protected Species in Smith Creek Watershed (Wake and Franklin Counties)

Family	Scientific Name	Common Name	Federal Status	State Status
Pinaceae	*Tsuga canadensis*	Eastern Hemlock	FSC	S4S5
Boraginaceae	*Phacelia covillei*	Buttercup Phacelia	FSC	S3
Lichen				
Parmeliaceae	*Canoparmelia amabilis*	Worthy Shield Lichen	FSC	SC-V

Notes:

E: An Endangered species is one whose continued existence as a viable component of the state's flora or fauna is determinded to be in jeopardy.
SC: A Special Concern species is one that requires monitoring but may be taken or collected and sold under regulations adopted under the provisions of Article 25 of Chapter 113 of the General Statutes (animals) and the Plant Protection and Conservation Act (plants).
T: Threatened. A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
T(S/A): Threatened due to similarity of appearance. A species that is threatened due to similarity of appearance with other rare species and is listed for its protection. These species are not biologically endangered or threatened and are not subject to Section 7 consultation.
SR: Reported from North Carolina, but without persuasive documentation for either accepting or rejecting the report.
SC-V: Any species or higher taxon of plant which is likely to become a threatened species within the foreseeable future (NCAC 02 NCAC 48F .0401).
S2: Imperiled in North Carolina due to rarity or some factor(s) making it very vulnerable to extirpation from the State. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)
S3: Vulnerable to extinction in North Carolina either because rare or uncommon, or found only in a restricted range (even if abundant at some locations), or due to other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
S4: Apparently secure and widespread in North Carolina, usually with more than 100 occurrences and more than 10,000 individuals.
S5: Common, widespread, and abundant in North Carolina. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.
S#S#: A numeric range rank (e.g., S2S3) is used to indicate uncertainty about the exact status of the element.

Federally Protected Vertebrates

Ambloplites cavifrons (Roanoke bass)
Roanoke bass are described as having dark, olivegreen to olivebrown backs that fade to grayish sides and a white belly. This species reaches a maximum of 14 inches and is a member of the sunfish family. These fish prefer clear rocky creeks and pools. Little is known about their spawning habitats, but it is known that they nest in fairly fast currents, where they construct circular nests in gravel or clay during the month of June. Their diet consists mostly of crayfish and small fish, although juveniles prefer crustaceans. It has a very narrow range, only being found in the Eno River in North Carolina and the Roanoke River in Virginia and North Carolina.

Heterodon simus (Southern hognose snake)
The southern hognose snake is a non-venomous snake species. Adults are commonly found to be between 14 to 24 inches long. They have a snout that is upturned and a wide neck.

The dorsal side of the snake consists of light brown, reddish, yellowish, or grayish base with distinct dark blotches that alternate with smaller blotches on their sides. Juveniles have a darker underside which becomes pale white as the snake ages. These snakes prefer dry and open sandy areas, sandy woods, dry river floodplains, fields, and wire grass flatwoods. Little is known about their reproduction, but eggs are commonly sound in clutches of 6 to 14 eggs and are laid in late spring or early summer. They primarily consume toads, although they also eat frogs and lizards on occasion. They are known for a distinctive anti-predatory behavior. They will flatten their heads and necks, hiss, and inflate their bodies with air to appear more intimidating, and if this does not work, the snake will roll on their back, open their mouths, and lie still as though dead. If flipped back onto their stomach, the snake will roll over again onto its back.

Myotis austroriparius (Southeastern myotis)
The Southeastern myotis is a small bat, weighing only 5 to 8 grams and have a wingspan of 9 to 11 inches. The bat varies from gray to bright orange-brown, although females are often more brightly colored than males. These bats primarily eat insects, foraging at night for their prey. They are often found hunting over water. These bats are unique among the Myotis genus in that they are capable of producing twins while others in the genus usually only produce one baby. The Southeastern Myotis roosts in a variety of shelters including caves, mines, bridges, buildings, culverts, and tree hollows. They prefer to hibernate during the winter in tightly packed clusters, but males roost individually or in small groups during the summer.

Noturus furiosus (Carolina madtom)
The Carolina Madtom is a small fish that reaches a total length of 4.75 inches. The body is yellow to dark brown with dark mottling on the top and yellow to white below. They have four distinct dark saddles and have blotched fins, with two crescent shaped fins on the caudal fin. These fish are found in the Piedmont and Coastal Plain in the Neuse and Tar River drainages in North Carolina and is generally disappearing from the upstream areas. The Carolina madtom prefers sandy and gravelly riffles and runs of small to medium rivers and is commonly found near woody debris. Their diet consists of benthic invertebrates, and they spawn in May.

Peucaea aestivalis (Bachman's sparrow)
The Bachman's sparrow is a large sparrow that can reach 15 cm long and has a large bill with a long, dark, rounded tail. Their upper parts are streaked with chestnut or dark brown, gray sides of their heads, a grayish-buff stripe, a thin dark line extending back from their eye, buff or gray sides and breast, and a white belly. Juveniles have a distinct eye ring and have a streaked throat, breast, and sides. Eggs are laid mostly between May and June. They have a clutch size of 3 to 5 and often brood two to three times per year. These birds prefer mature to old growth pine woodlands with frequent growing season fires and a well-developed herbaceous and grass layer. Their diet consists mostly of seeds and insects.

Picoides borealis (Red-cockaded woodpecker)
The Red-cockaded woodpecker is a small to mid-sized woodpecker measuring 7 to 9 inches long and has a 13 to 16 inch wingspan. The woodpecker's back is barred with black and white horizontal stripes. Its head has a black cap and nape that encircle white cheek patches. The male has a small red streak on each side of the black cap that is usually only visible during breeding season and while the bird is defending his territory. Their diet consists mainly of insects and other invertebrates and occasionally fruits and berries. These

birds are non-migratory and territorial. The nesting season runs from April to June, with the birds maintaining the same mate for several years. The clutch size ranges from 3 to 4 eggs. The young often remain with the parents, forming groups. There is a single pair of breeding birds within the group, with the birds that are not a part of this breeding pair helping to incubate the eggs and feed the young. These birds require mature pine forests for habitat, excavating cavities in living pine trees for their nests. They prefer longleaf pine, but other species of pine can be acceptable. Their territories usually range from about 125 to 200 acres.

Myotis septentrionalis (Northern Long-eared Bat)
The Northern Long-eared Bat is a medium-sized bath with a wingspan of 9 to 10 inches. The bat varies from medium brown to dark brown on the back and pale brown on the underside. As its name suggests, the bat has long ears compared to other bats in the *Myotis* genus. They often hunt between dusk and dawn through the understory of forested areas feeding on insects. The Northern Long-eared Bat roosts singly or in colonies underneath bark, in cavities, or in crevices of trees (dead or alive). While the bats are flexible in selecting summer roosting spots, they are rarely found in structures and cooler places like mine and caves. During the winter time they prefer to hibernate in caves and mines which provide constant temperatures, high humidity, and no air currents.

Federally Protected Invertebrates

Alasmidonta heterodon (Dwarf wedgemussel)
The dwarf wedgemussel is a small freshwater mussel rarely growing more than 45 mm in length and 25 mm tall. They have trapezoid shaped shells which are brown or yellowish-olive in color. Younger individuals may have reddish brown or greenish rays. Their inner shell is bluish or silvery white. This species prefers small creeks to deep rivers with substrates ranging from mixed sand, pebble, and gravel to clay and silty sand. In its southern ranges, it is often found buried under logs or root mats in shallow water while in its northern ranges, it is more likely to be found in substrates of mixed sand, gravel, or cobble and embedded in clay banks with water of varying depths. These mussels require a host fish on which its larvae will parasitize and metamorphose into juvenile mussels. There are several fish species that have been identified as hosts for the dwarf wedgemussel.

Elliptio lanceolata (Yellow lance)
The yellow lance is a freshwater mussel which grows approximately 86mm long and 40mm tall. Their outer shell is commonly waxy yellow when young. Older individuals of this species may have a brown discoloration on the shell. Their inner shell color ranges from salmon to a white to bluish. They are found in sandy substrates, rocks, and in mud, in slack water areas. They are most commonly found in drainages as small as 3 feet across. While they do require host fish for reproduction, the species of their hosts are unknown.

Fusconaia masoni (Atlantic pigtoe)
The Atlantic pigtoe is subrhomboidal in shape and the outer surface is yellow to dark brown while the inside of the shell is bluish to salmon, white, or orange. The species is small, with a shell commonly being less than 50 mm in length. These mussels prefer course sand and gravel as a substrate and are commonly found in the downstream edge of riffles. They require fast flowing water which is well oxygenated. Due to a high sensitivity to pollutants and low oxygen conditions, these mussels are only found in relatively pristine

habitats. While they do require host fish for reproduction, the species of their hosts are unknown.

Gomphus septima (Septima's clubtail)
Septima's clubtail is a species of dragonfly. The adult male has a greenish thorax with wide U-shaped yellow stripes. The dragonfly has a series of yellow stripes down the abdomen, but the moderately sized club is usually black. The face is dark with no markings and the legs are dark brown to black. They grow to be approximately 6 cm long. Juvenile larvae are found in small to medium rivers which a rapid current. They prefer clean, rocky rivers with muddy or silty reaches. They are only found in high quality water that is highly oxygenated and require water that is not too cold. Adults forage from the ground or trees.

Lasmigona subviridis (Green floater)
This mussel has a thin shell that is subrhomboidal to subovate in shape and can grow from 60-65mm in length. The outer shell is yellow, tan, dark green, or brown with dark green rays. The inner shell is bluish to white with small pink spots near the beak. The green floater prefers streams, small rivers, and canals with low to medium gradients, fine gravel and sand substrates, and mid-range calcium concentrations. In general, species in this family group require host fish for larval dispersion and metamorphosis to the juvenile stage, but evidence suggests that this species either has an variety of host fish depending on its physical location, or that the species does not require a host fish, which would be rare.

Elliptio steinstansana (Tar River spinymussel)
The Tar River spinymussel is one of three freshwater mussels with spines. Their outer shell is brownish and can be up to 6 cm long with 0 to 6 spines on each valve. Younger individuals are orange- brown with greenish rays emanating from the hinge area of the shell. Adults are darker with less distinctive rays. The inner shell is salmon colored on the upper end and bluish on the lower end. Juveniles can have up to 12 spines, losing them as they mature. These mussels prefer silt-free waters with a loose gravel substrate and/ or coarse sand. The streams must be fast-flowing and well oxygenated. This species reproduced between April and August and has several different species of known and suggested host fish.

Federally Protected Plants

Acmispon helleri (Carolina birdfoot-trefoil)
The Carolina birdfoot-trefoil is a native annual herb that is up to 25 cm in height. The flowers grow to approximately 6 mm and are pale pink to cream in color. The leaves are trifoliate. This herb preferns dry woodlands and openings, such as a fire maintained site. They are now found on roadsides or powerline rights of way where mowing maintains the open and sunny habitat required.

Lindera subcoriacea (Bog spicebush)
The bog spicebush is a shrub that grows to between 6 and 13 feet depending on the level of sunlight. Leaves are aromatic when young and grow to between 1 to 3 inches long. They are elliptical to oblanceolate in shape and are somewhat leathery. The fruiting bodies consist of red drupes. This plant prefers evergreen-shrub bogs, acidic swamps of blackwater swamp forests, and acidic seepage bogs. It is usually found near the heads of streams and along the banks of small braided streams. It requires acidic sites with permanent saturation and high organic material content in the soil.

Monotropsis odorata (Sweet pinesap)
The sweet pinesap is an herbaceous perennial wildflower that reaches 2 to 4 inches in height. The leaves are scale like. The flower stem is purplish brown and the flowers are a cluster of flowers at the top of the stalk. They are pink or yellowish and are hairy inside. The plant has a capsule fruit, releasing seeds from slits forming in the capsule once they are ripe. The sweet pinesap is known to flower in mid to late spring and is commonly found in mature, moist, shaded hardwood forests. This plant has a strong odor that can sometimes be smelled before the plant is sighted and is often said to smell like violets. This plant does not produce chlorophyll, instead obtaining its food through the parasitism of fungi.

Rhus michauxii (Michaux's Sumac)
Michaux's sumac is a perennial shrub growing between 12 and 24 inches tall. It is very hairy in texture, and can be distinguished from other sumac species by the size and hairy texture. The leaves are compound and made up of 9 to 13 leaflets which have coarse teeth that are evenly spaced along the leaflet edge. The plant has conical- shaped, terminal cluster flowers and flowers in the month of June. Each small flower has 4 to 5 small greenish-yellow petals. The plants are dioecious, meaning that the male and female parts of the plant are located on different plants. Fruit consists of a clump of red drupes. These plants are found in open upland woods, along forest edges, and within maintained rights-of-way, preferring full sunlight.

Sagittaria weatherbiana (Grassleaf arrowhead)
The grassleaf arrowhead is an aquatic perennial herb that typically grows to between 8 and 24 inches. Leaves grow above the water surface and are 4 to 10 inches long and 0.3 to 1.5 inches wide. The flowers are white with three petals and three sepals, flowering between April and September. These plants require high levels of soil moisture and are often found in waterways, marshes, swamps, drainage ditches, or irrigation channels.

Trillium pusillum var. virginianum (Virginia least trillium)
The Virginia least trillium is a spring emphemeral perennial herb that reaches less than 1 foot in height. Above ground, the plant has three large leaf-like bracts. The true leaves are limited to small paper like coverings around the rhizomes. Their flowers are white or pink, are sessile, and bloom between March and early May. The plant prefers shady, low, alluvial woodlands. The plans prefer wet sites and are often found on hummocks.

2.2.12 DWQ Water Quality Results

Physiochemical data were collected by the North Carolina Division of Water Quality (NC DWQ) Ambient Monitoring System approximately 0.7 miles upstream of the confluence of Smith Creek and the Neuse River between 2006 and 2010. Based on these results, dissolved oxygen, pH, specific conductivity, water temperature, total suspended solids, turbidity, and fecal coliform concentrations are typically within standards set forth within the North Carolina Department of Environment and Natural Resources- Division of Water Quality "Redbook" Surface Waters and Wetlands Standards (NCDWQ, 2007). Turbidity values exceeded the evaluation levels in 3.5 percent of samples, but were not found to be a statistically significant exceedance of the criterion, as discussed in the NCDWQ Redbook. Fecal coliform values exceeded the acceptable geometric mean of coliform colonies in 14 percent of samples, but was considered to be within normal parameters. Higher fecal coliform counts can indicate failing septic systems, leaking or overloaded sewer systems or an abundance of animal waste from pets, waterfowl, or livestock.

2.2.13 Turbidity Sampling

Turbidity is one of the primary contributions to water quality degradation and, specifically, the reductions of benthic macroinvertebrate diversity in Smith Creek. Following initial evaluations of the Smith Creek Watershed, 15 sampling locations were selected to conduct an analysis of both ambient (typical) and 'first flush' turbidity throughout the watershed (Figure 9, Table 8).

On 3 April 2013 a storm event was forecast for the following day with anticipated 24-hour precipitation totals of 0.5-1.0 inch. To evaluate 'first flush' events' impacts to turbidity, ambient 'grab' samples were taken within, or immediately downstream of each subwatershed on 4 April, prior to the precipitation event. The weather station at RDU recorded 0.87 inch of rain between 1:51 PM on 4 April and 5:51 AM on 5 April. Following the precipitation event, sampling was repeated on 5 April 2013, beginning at the downstream-most location.

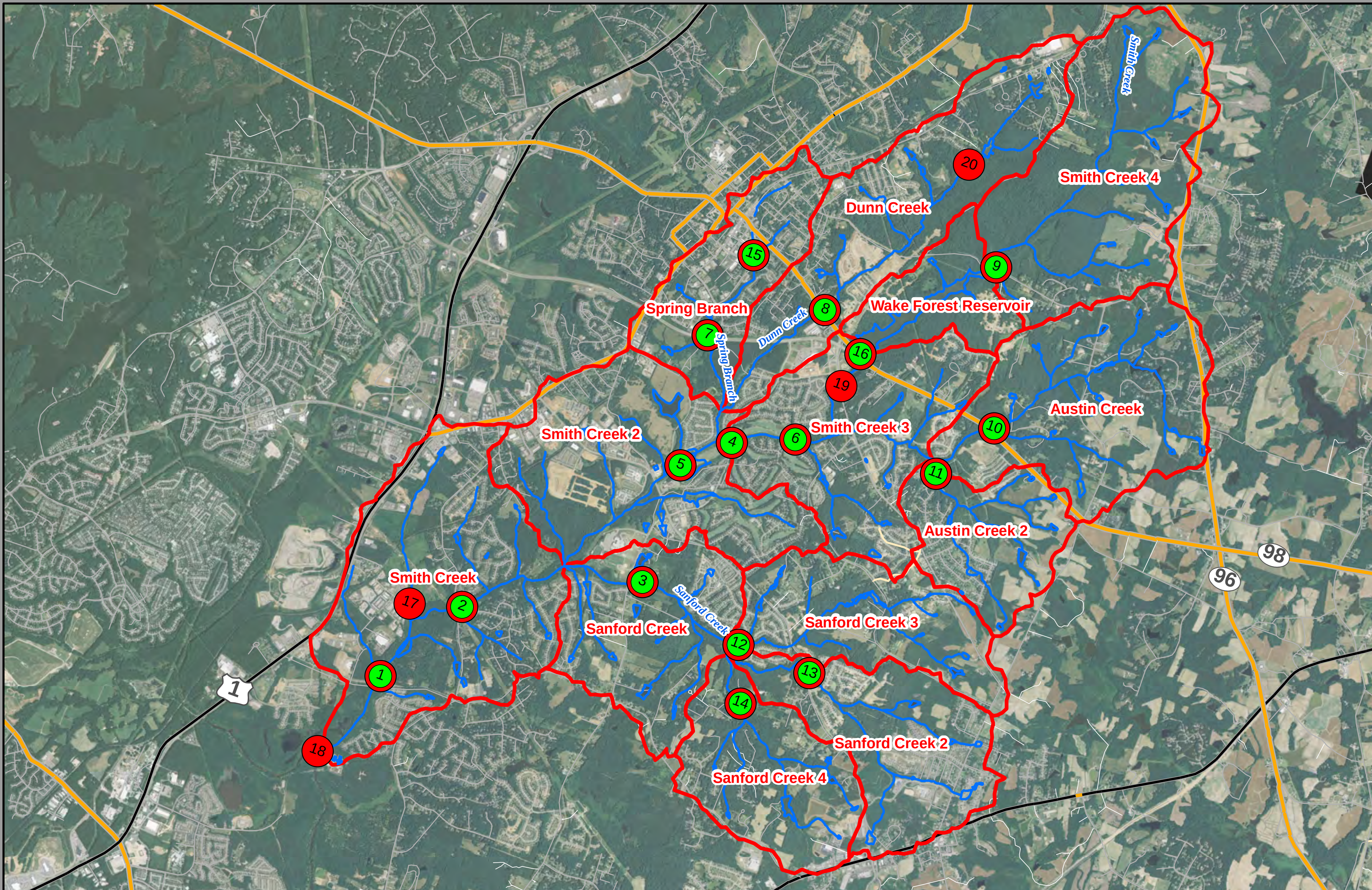
As shown in Table 8, the results indicate that Smith Creek 1 and Spring Branch had the highest percent increases following the rain event, while Smith Creek 1 and Sanford Creek 1 had the highest total increases. The Wake Forest Reservoir and Sanford Creek 4 subwatersheds had both the lowest absolute and percent increases.

Table 8. Smith Creek Watershed Turbidity Analysis

		----NTUs* ----		
Subwatershed	**Sample Site**	**4-4-13 (Before Rain)**	**4-5-13 (After Rain)****	**% Increase**
Austin 1	T10	3.83	20.8	443
Austin 2	T11	3.11	16.82	441
Dunn	T8	1.15	18.13	1477
Sanford 1	T3	4.92	44.3	800
Sanford 2	T13	2.18	30.7	1308
Sanford 3	T12	4.27	19.86	365
Sanford 4	T14	4.45	12.36	178
Smith 1	T1	3.19	79.8	2402
Smith 1	T2	4.54	69.3	1426
Smith 2	T4	3.91	43	1000
Smith 2	T5	3.05	40.6	1231
Smith 3	T6	4.1	36.8	798
Smith 4	T9	3.67	24.2	559
Spring	T7	0.65	11.95	1738
Spring	T15	0.5	12.47	2394
WF Reservoir	T16	3.21	10.26	220

*Nephelometric Turbidity Units

**Rain overnight 0.76" at RDU



Legend

- 2014 Turbidity Sample Locations
- Adopt a Stream Sample Locations
- Streams
- Sub-Watershed Boundary

N W E S

0 0.25 0.5 1 Miles

1 in = 1 miles

Figure 9

Smith Creek Watershed Restoration Plan and Implementation Project Turbidity and Adopt a Stream Monitoring Locations Map

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2.2.14 Benthic Macroinvertebrate Sampling

Smith Creek was added to the state's 2008 303(d) impaired waters list as a result of its 2006 benthic macroinvertebrate "Fair Bioclassification." The sample site that caused the listing (JB51) is located at Burlington Mills Road (SR 2045). This site is near the bottom of the watershed, approximately 0.75 mile upstream from Smith Creek's confluence with the Neuse River. In order to expand the data set, and in hopes of determining that more upstream portions of the watershed were not impaired, benthic macroinvertebrate "benthos" samples were collected from this site, and two others using the NCDEQ (formerly DENR) "Standard Qualitative Method." As part of the Watershed Plan, data were collected at these three sites (Figure 10) for three consecutive years; 2013, 2014, and 2015. The sampling method is detailed in the project's Quality Assurance Project Plan, which was approved by DEQ on 12 August 2013 (Appendix A).

After the initial 2013 results indicated Good-Fair ratings at the Smith Creek 2 site (approximately 0.5 mile upstream of Heritage Lake Rd.), and Fair ratings at the Smith Creek 1 (Burlington Mills Road; aka: DEQ Site JB 51) and the Sanford Creek sites (approximately 0.5 mile upstream of Forestville Rd.) (Table 9), it was determined that six additional sites would be sampled in the spring of 2014 to further document benthic conditions throughout the study area (Figure 11). As shown in Table 10 with the exception of Sample 3D1 (Dunn Creek Greenway), all samples scored Good Fair or better. Most notably, Sample 1S1's (Smith Creek at Oak Grove Church Rd.) score was the best recorded: nearly excellent. This site was used in the 2014/2015 Sanford Creek benthic habitat enhancement.

The Sanford Creek habitat enhancement, described in more detail in the Public Involvement Section below, was initiated following the 2014 July sampling at the three permanent sites. It included construction of structures using coir fabric, leaf packs, and twig/branch bundles at the Sanford Creek (SA) site. Structures were initially installed in August, 2014. In November 2014 diverse benthic populations were collected from the Smith Creek 1 (1S1) site, identified in April 2014, and transplanted into the new structures at the SA site. In April 2014 additional habitat enhancement structures were installed and another relocation was completed. While the SA site's 2015 July sampling results did not indicate an improved rating (i.e. it remained Good-Fair), several species known from the 1S1 site were identified for the first time at the SA site (Appendix B). Several of these species are assigned low tolerance values in the *Standard Operating Procedures for Benthic Macroinvertibrates* (NCDENR, 2012), which assigns values (0-10) to taxa collected 50 times or more, with higher values indicating more tolerance for poor conditions (e.g. *Neophylax oligius: 2.4; Eccoptura xanthenes: 4.7; Anchytarsus bicolor: 2.4).*

While the results following one year did not result in changes to the site's overall rating, the presence of intolerant species not previously found support the hypothesis that habitat conditions, and not water quality, may be the primary limiting factor for the site's benthic diversity.

Based on the results below, Smith Creek should be removed from the 303(d) impaired waters list.

Table 9. Benthic Macroinvertebrate Sampling Results – Permanent Locations – July Sampling

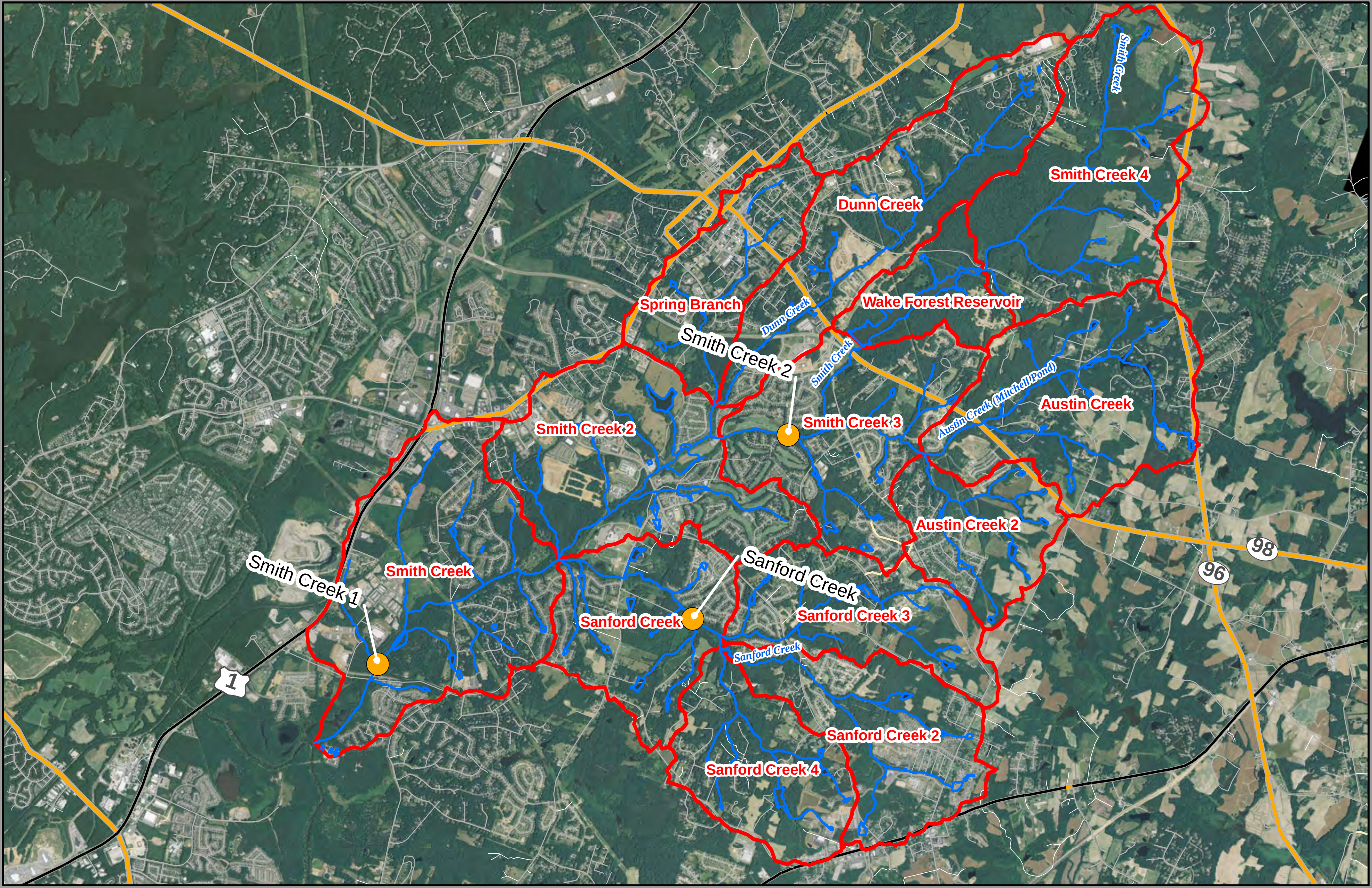
	2013			2014			2015		
Site:	SA	S1	S2	SA	S1	S2	SA	S1	S2
Total Taxa Richness	39	30	45	42	37	49	42	51	38
EPT Taxa Richness	12	8	13	15	14	15	12	16	13
EPT Abundance	59	46	90	62	60	61	65	64	69
NC Biotic Index	6.0	5.8	5.5	5.7	5.9	6.0	5.8	6.1	5.7
EPT score	2	1.6	2	2.4	2.4	2.4	2	2.6	2
BI Score	3	3.4	4	4	3	3	3.4	3	4
Site Score	2.5	2.5	3	3.2	2.7	2.7	2.7	2.8	3
Rating	**Fair/G-F***		**G-F**	**G-F**	**G-F**	**G-F**	**G-F**	**G-F**	**G-F**

*Rating rounds down to Fair, based on EPT Abundance critera (<71). Under estimation of EPT taxa richness in 2013, however, suggests that these would more likely be Good-Fair. Compare to the 2014 collections.

Table 10. Benthic Macroinvertebrate Sampling Results – 2014 Locations – April Sampling

Site:	1S1	2A1	3D1	4D2	5S2	6S3
Total Taxa Richness	37	34	25	31	25	30
EPT Taxa Richness	19	19	11	14	10	15
NC Biotic Index	4.4	5.0	6.4	5.3	5.8	5.6
Rating (Small Stream Criteria)	**G***	**G**	**F**	**GF**	**GF**	**GF**

*Almost Excellent



Legend

- Permanent Benthic Locations
- Streams
- Sub-Watershed Boundary

Figure 10

Smith Creek Watershed Restoration Plan and Implementation Project Permanent Benthic Monitoring Locations Map

0 0.25 0.5 1 Miles

1 in = 1 miles

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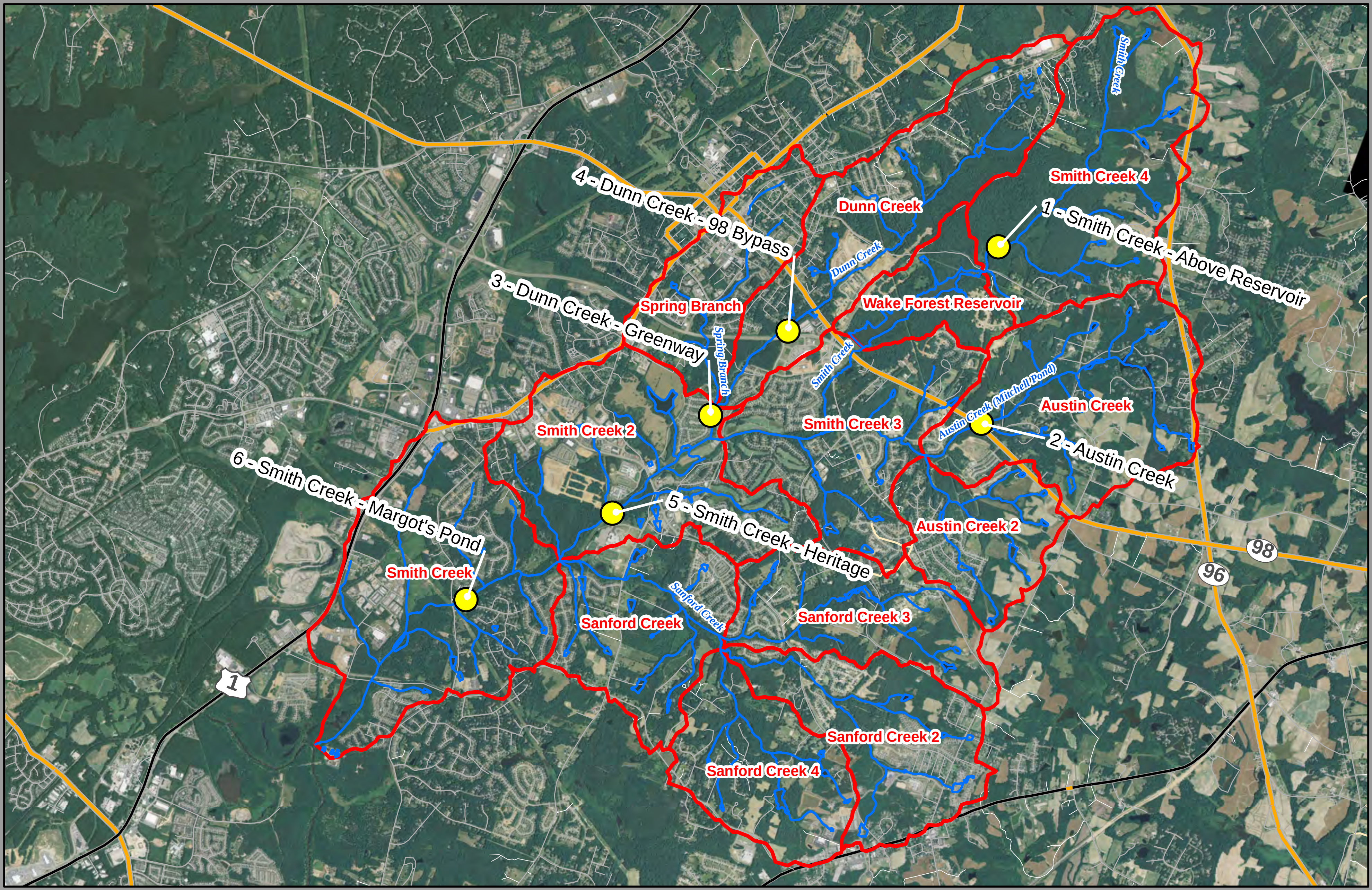

Legend

Spring 2014 Benthic Locations

Streams

Sub-Watershed Boundary

Figure 11

Smith Creek Watershed Restoration
Plan and Implementation Project
Spring 2014 Benthic Monitoring Locations Map

0 0.25 0.5 1 Miles

1 in = 1 miles

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2.2.15 Subwatershed Summaries

2.2.16 Smith Creek 1 Subwatershed

The Smith Creek 1 subwatershed is located in Wake County, North Carolina and is in both the southern- and downstream-most sections of the Smith Creek watershed (Figure 2). With a drainage area of 1,895 acres this subwatershed is the largest in size of the thirteen subwatersheds in the study area. It also has the greatest length of stream. It is composed of 53,054 linear feet of stream, which is primarily Smith Creek and eight of its unnamed tributaries. The main reach consists of the downstream portion of Smith Creek, including its confluence with the Neuse River. This portion of Smith Creek is a fifth order stream with a length of 15,547 linear feet. The unnamed tributaries to Smith Creek are first and second order streams, the majority of which are first order with a combined total length of 36,076 linear feet. The remaining second order stream has a length of 1,432 linear feet.

Land use in the Smith Creek subwatershed is primarily forested; 44 percent is deciduous forest and 23 percent is evergreen forest. Impervious surfaces make up approximately 20 percent of this subwatershed. The remaining area is 12 percent herbaceous cover and one percent water. The western portion of the subwatershed is dominated by commercial and industrial development along Capitol Boulevard, whereas residential development dominates much of the eastern and southern portions of the subwatershed. The central portion of the watershed is forested.

Figure 12. Smith Creek 1 Subwatershed Land Use Chart

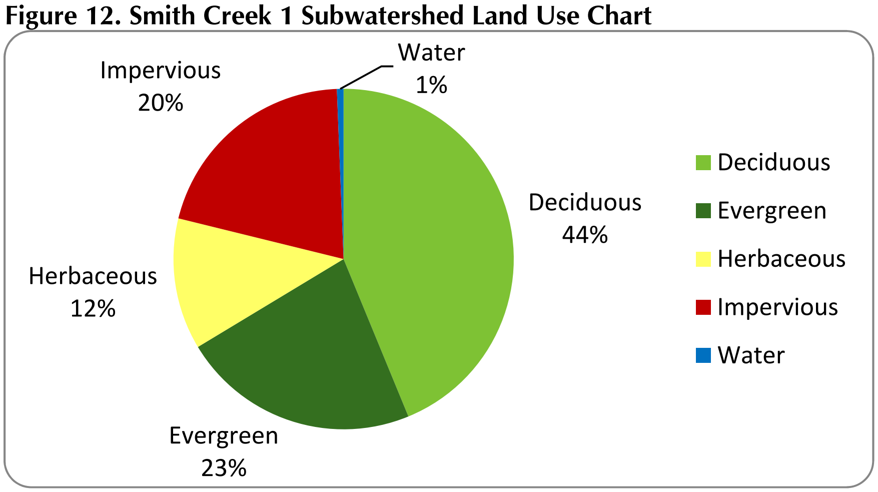
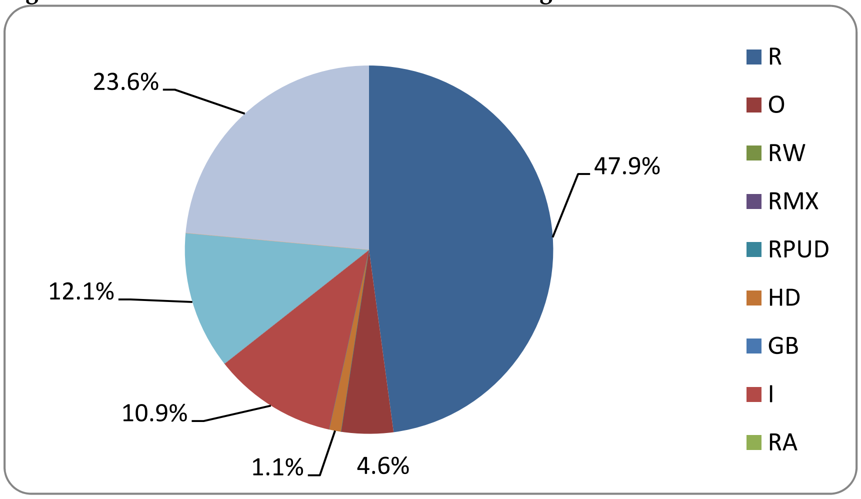
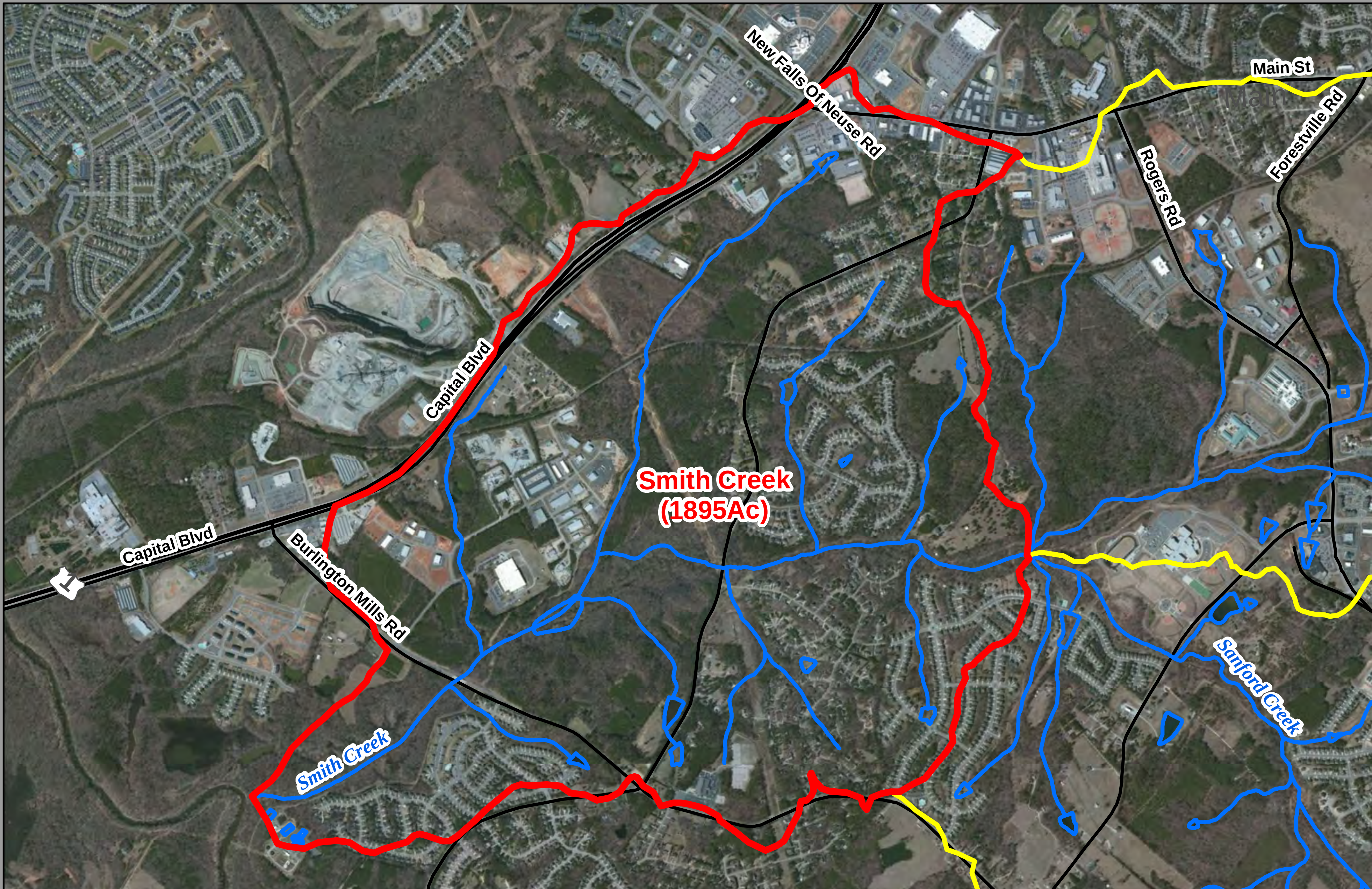


Figure 13. Smith Creek 1 Subwatershed Zoning Chart





Legend

- Smith Creek Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

Figure 14

Smith Creek Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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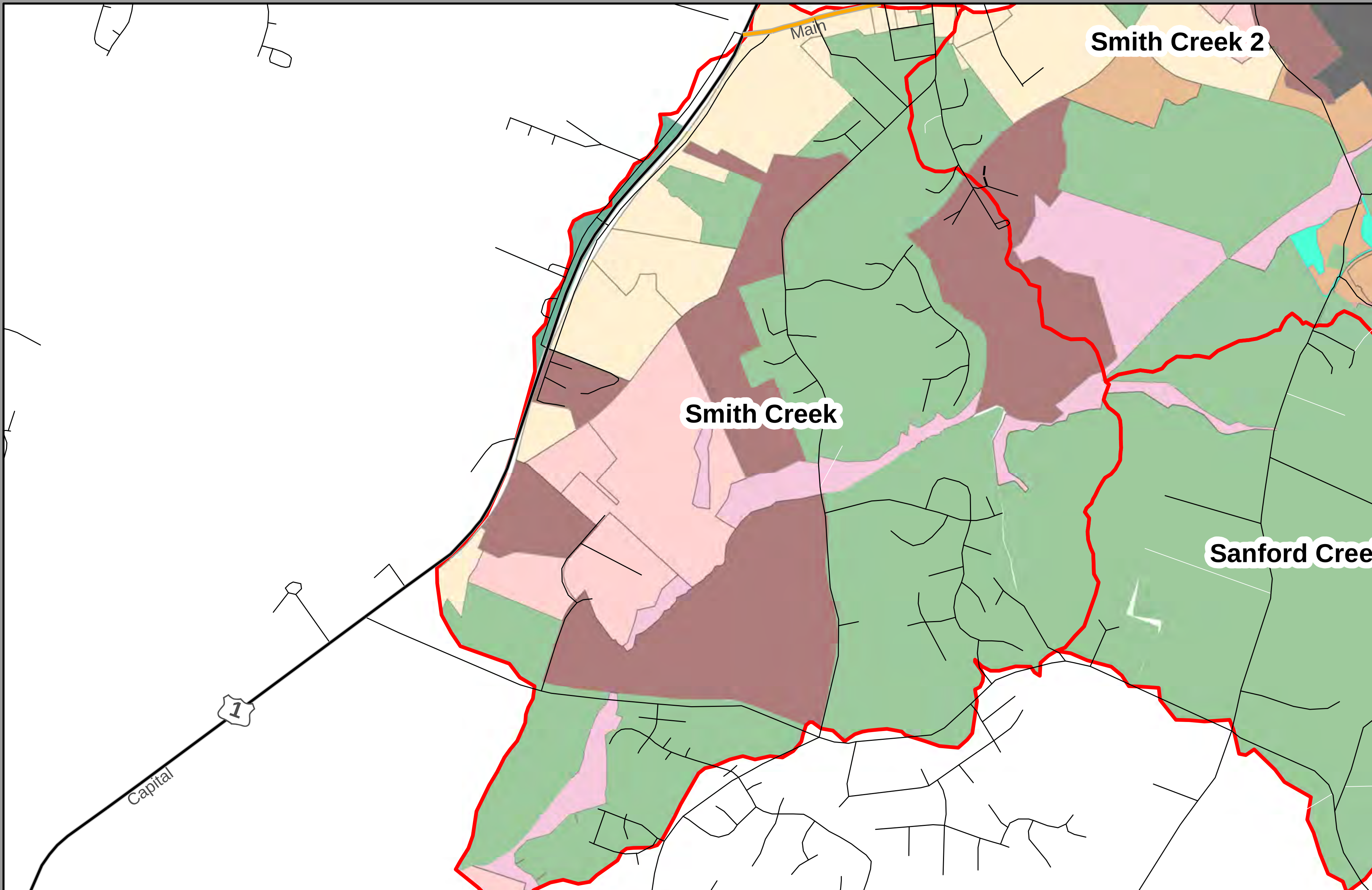

Neighborhood Residential	Subwatersheds
Office and Professional	Commercial
Open Space	Commercial - Outlying
Residential	General Business
Residential - Agriculture	Highway Business
Residential Mixed Use	Highway District
Residential Watershed	Industrial
Residential and Planned Unit Development	Institutional Campus Development
Rural Manufactured Home District	Neighborhood Business
Urban Residential	
Rurual Holding District	

Figure 15

Smith Creek Watershed Restoration Plan and Implementation Project Smith Creek Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

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2.2.17 Smith Creek 2 Subwatershed

The Smith Creek 2 subwatershed is located in Wake County in the southwestern portion of the study area (Figure 2). This subwatershed has a drainage area of 1,520 acres and is the third largest in the watershed. It contains 46,932 linear feet of stream, which is mainly Smith Creek, several of its unnamed tributaries and a portion of Dunn Creek (a tributary of Smith Creek). Smith Creek is a fourth order stream within this subwatershed, with a length of 9,018 linear feet. The tributaries to Smith Creek are first, second, and third order streams. The majority of the tributaries are first order, with a combined total length of 32,965 linear feet. The second order streams have a total length of 4,042 linear feet, and the third order stream (Dunn Creek) has a total length 1,321 linear feet within the Smith Creek 2 subwatershed.

About half of the land use in the Smith Creek 2 subwatershed is forested; 35 percent is deciduous forest and 17 percent is evergreen forest. Impervious surfaces make up approximately 21 percent of this subwatershed. The remaining area is 25 percent herbaceous cover and two percent water. The area surrounding Rogers Road, running east-west through the middle of the subwatershed, is dominated by commercial development. Residential developments are primarily scattered around the perimeter of this subwatershed, with a golf course and surrounding homes dominating the eastern-most portion of the subwatershed. Agricultural fields are present in the northern portion of the subwatershed.

Figure 16. Smith Creek 2 Subwatershed Land Use Chart

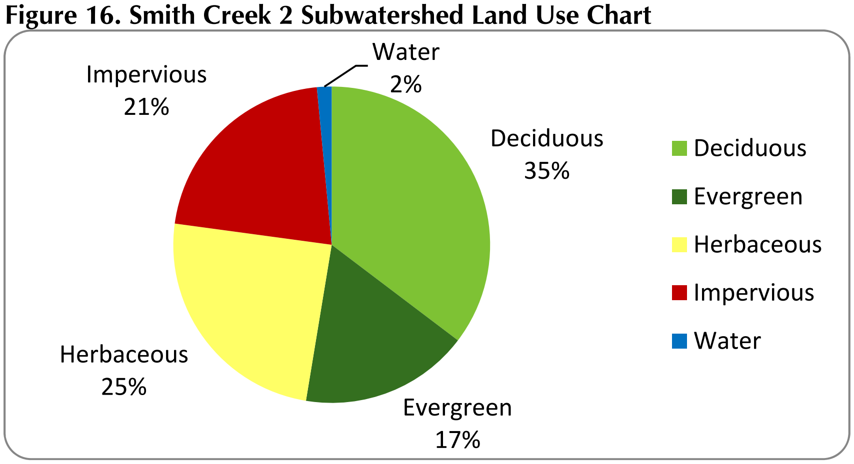
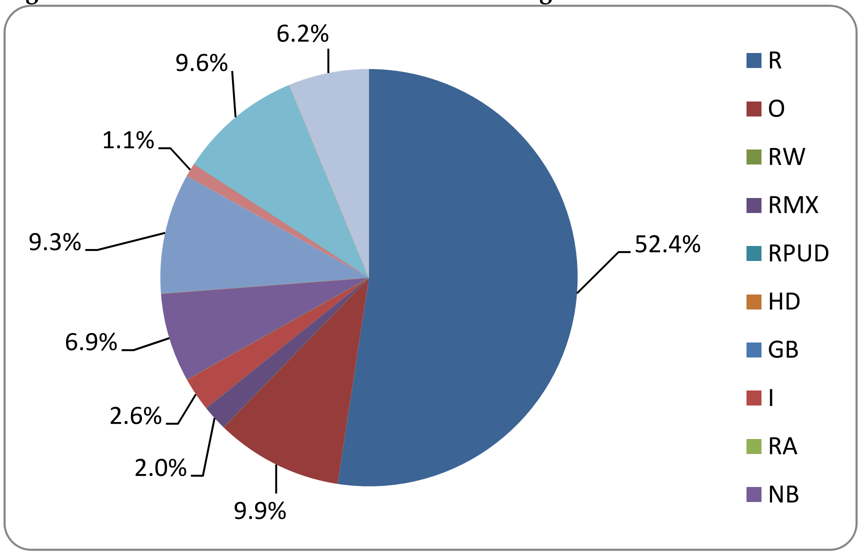
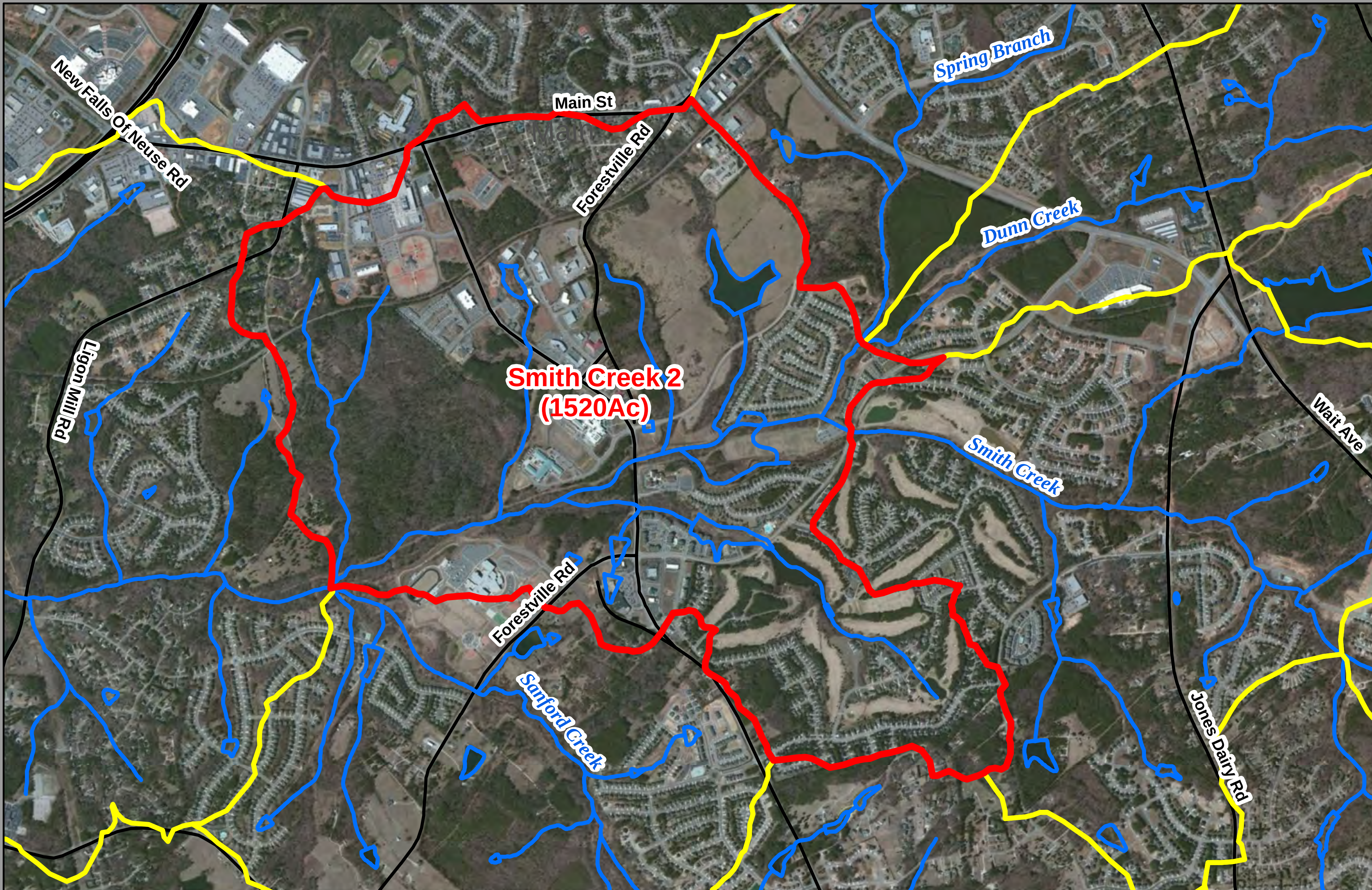


Figure 17. Smith Creek 2 Subwaterhsed Zoning Chart





Legend

- Smith Creek 2 Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

Figure 18

Smith Creek 2 Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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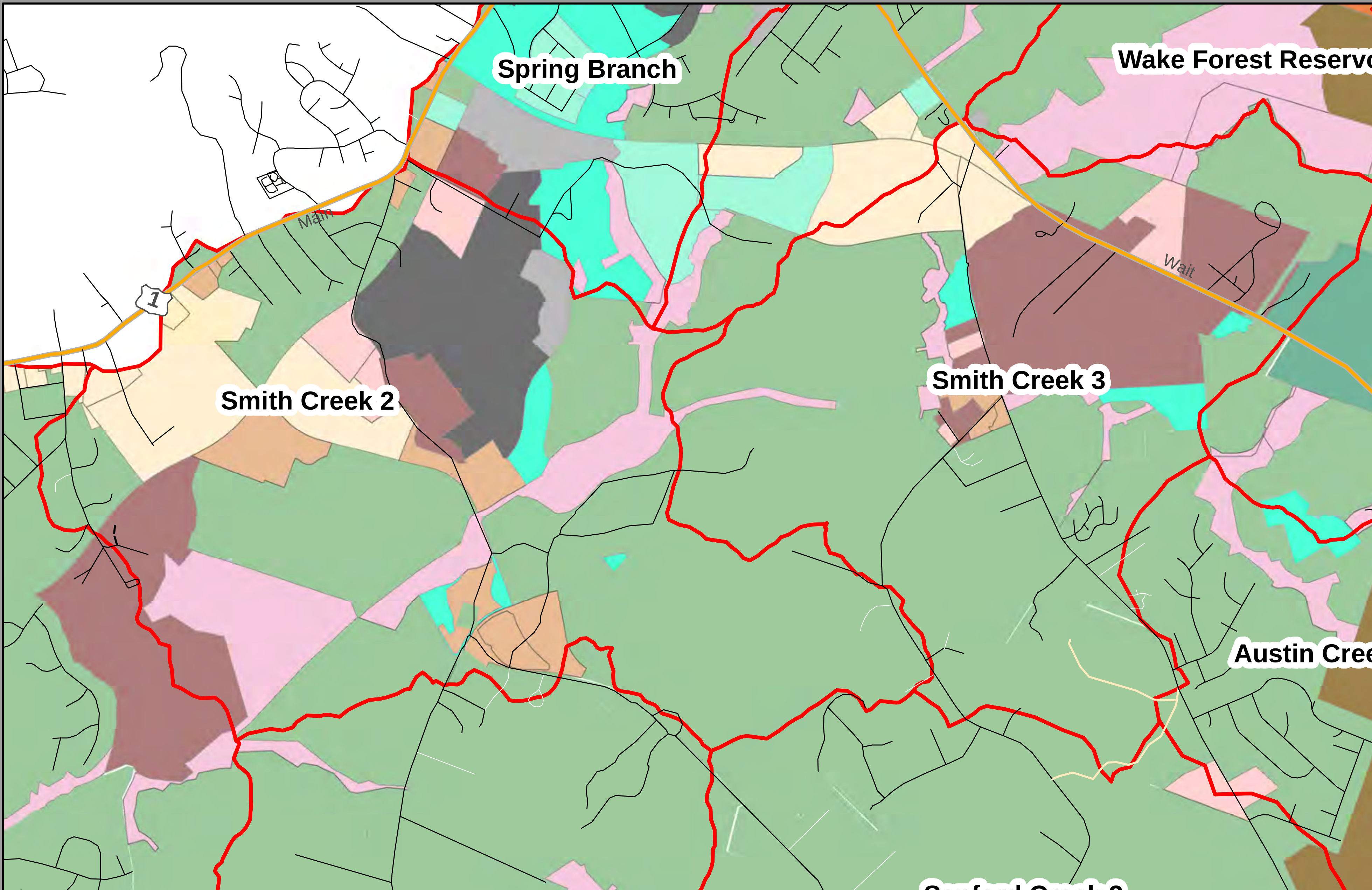

- Neighborhood Residential
- Office and Professional
- Open Space
- Residential
- Residential - Agriculture
- Residential Mixed Use
- Residential Watershed
- Residential and Planned Unit Development
- Rural Manufactured Home District
- Urban Residential
- Rurual Holding District
- Subwatersheds
- Commercial
- Commercial - Outlying
- General Business
- Highway Business
- Highway District
- Industrial
- Institutional Campus Development
- Neighborhood Business

Figure 19

Smith Creek Watershed Restoration Plan and Implementation Project Smith Creek 2 and Smith Creek 3 Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

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2.2.18 Smith Creek 3 Subwatershed

The Smith Creek 3 subwatershed is located in the central region of the study area in Wake County (Figure 2). This subwatershed has a drainage area of 1,282 acres and is the sixth largest subwatershed. The subwatershed contains the confluence of Smith Creek and Austin Creek. The Smith Creek 3 subwatershed contains 33,931 linear feet of stream, which is comprised of Smith Creek, a section of Austin Creek (a tributary of Smith Creek), and several unnamed tributaries. Smith Creek is a third and fourth order stream within this subwatershed; 4,296 linear feet are third order and 4,403 linear feet are fourth order. The unnamed tributaries to Smith Creek are first and second order streams, the majority of which are first order with a total length of 6,386 linear feet. The remaining second order streams have a total length of 3,226 linear feet. The portion of Austin Creek located in this sub-watershed is a third order stream (4,678 linear feet). The unnamed tributaries to Austin Creek are first (9,139 linear feet) and second order streams (1,153 linear feet).

Land use in the Smith Creek 3 subwatershed is primarily forested; 42 percent is deciduous forest and 22 percent is evergreen forest. Impervious surfaces make up approximately 19 percent of this subwatershed. The remaining area is 16 percent herbaceous cover and one percent water. Development in this subwatershed is almost entirely residential, and occurs primarily south of Jones Dairy Road.

Figure 20. Smith Creek 3 Subwatershed Land Use Chart

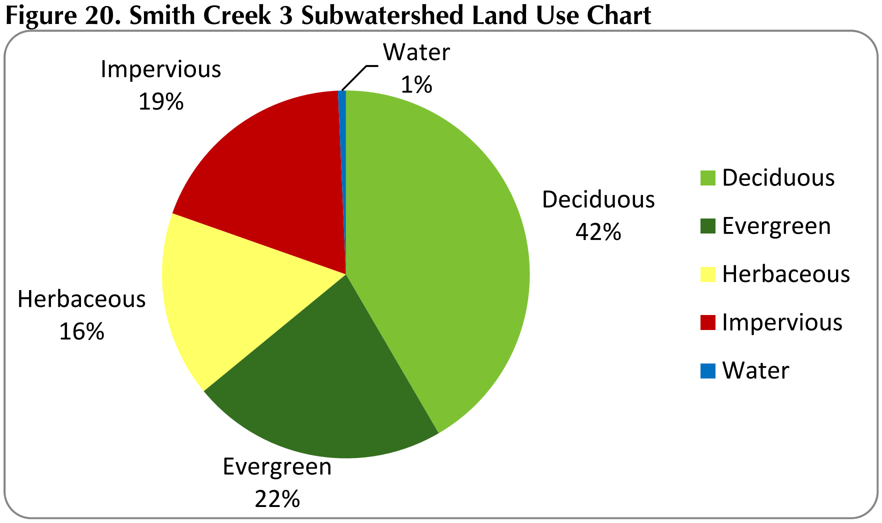
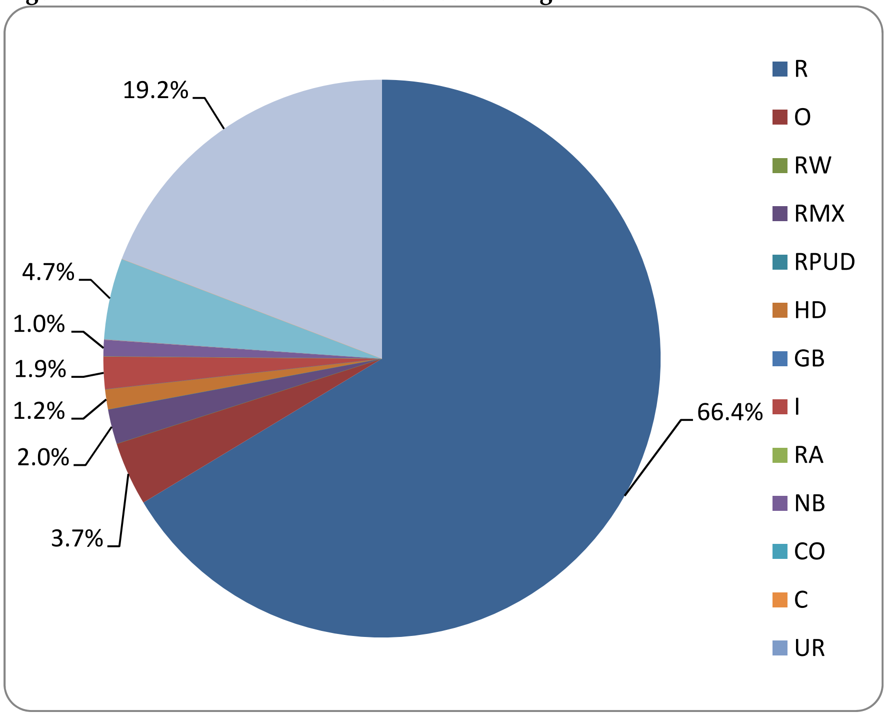


Figure 21. Smith Creek 3 Subwatershed Zoning Chart



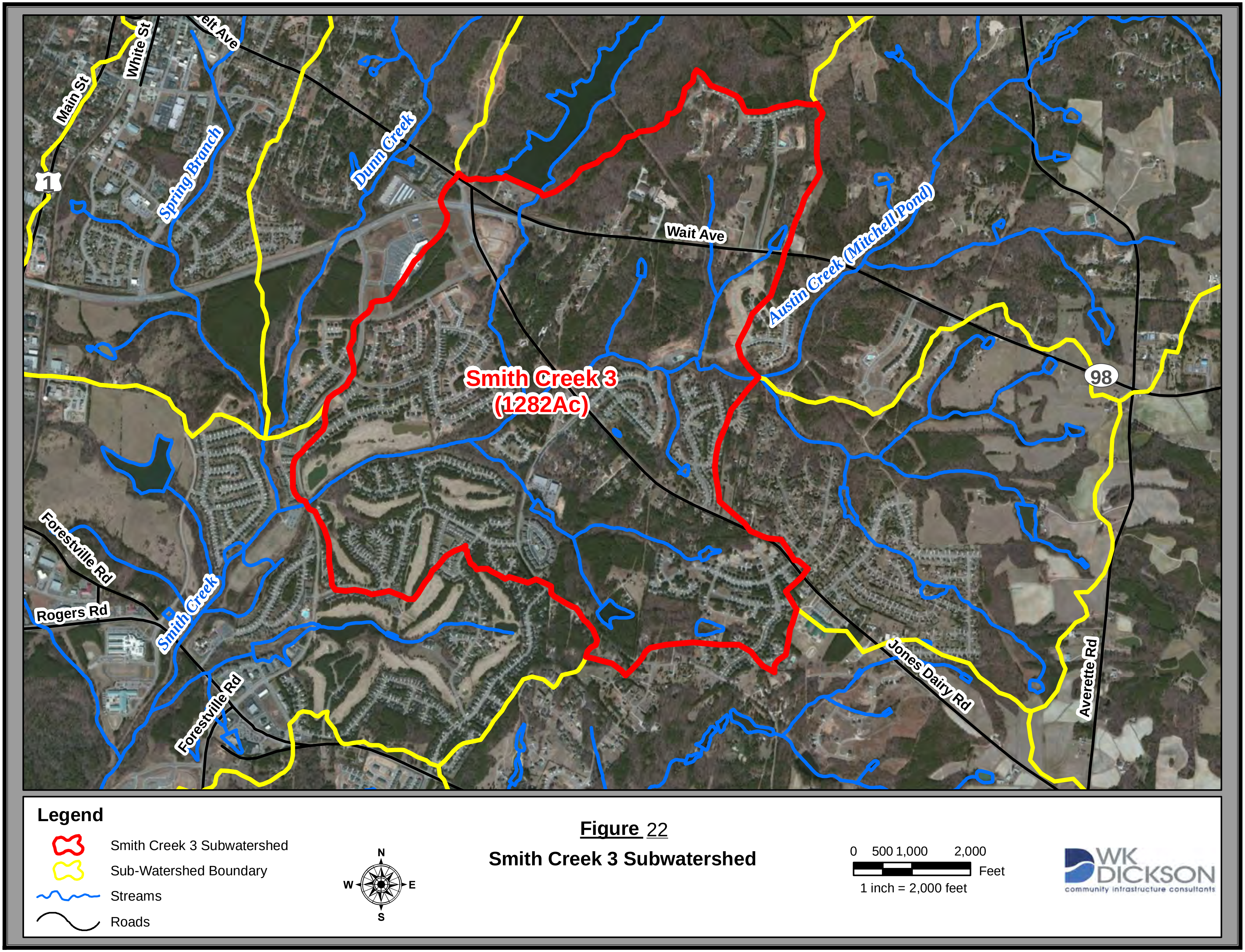
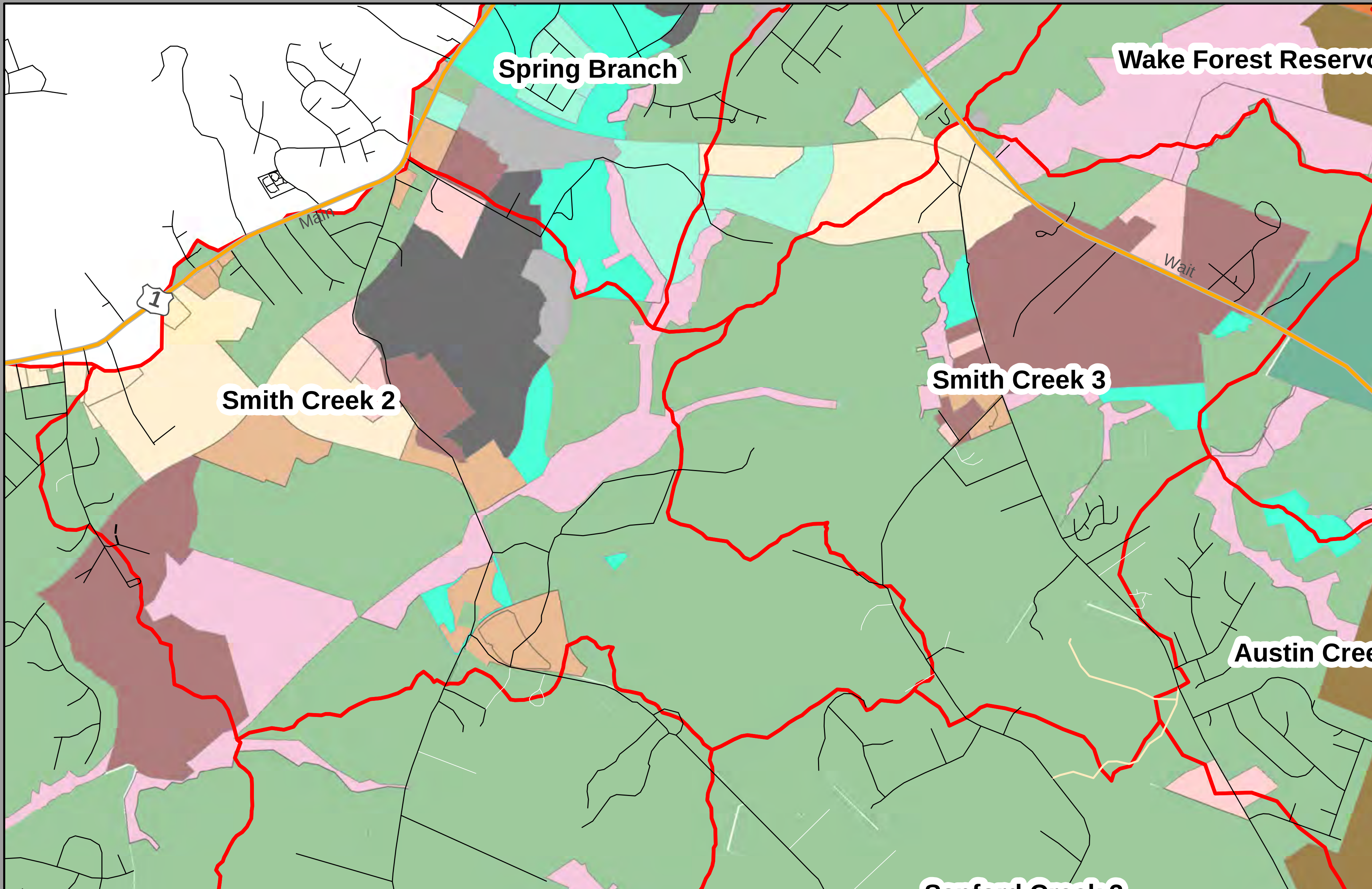


Figure 22

Smith Creek 3 Subwatershed



- Neighborhood Residential
- Office and Professional
- Open Space
- Residential
- Residential - Agriculture
- Residential Mixed Use
- Residential Watershed
- Residential and Planned Unit Development
- Rural Manufactured Home District
- Urban Residential
- Rurual Holding District
- Subwatersheds
- Commercial
- Commercial - Outlying
- General Business
- Highway Business
- Highway District
- Industrial
- Institutional Campus Development
- Neighborhood Business

Figure 23
Smith Creek Watershed Restoration Plan and Implementation Project Smith Creek 2 and Smith Creek 3 Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

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2.2.19 Smith Creek 4 Subwatershed

The Smith Creek 4 subwatershed is located in the northern region of the Smith Creek watershed (Figure 2) in Wake and Franklin Counties. This subwatershed has a drainage area of 1,638 acres and is the second largest in the watershed. Of these 1,638 acres, 1,376 acres (84.0%) are within Franklin County and 262 acres (16.0%) are within Wake County. The Smith Creek 4 subwatershed is the second largest in size of the thirteen sub-watersheds. It is composed of 43,878 linear feet of stream which is mainly Smith Creek along with several of its unnamed tributaries. Smith Creek is a first, second, and third order stream within this sub-watershed; 2,726 linear feet are first order, 2,513 linear feet are second order, and 7,822 linear feet are third order. The unnamed tributaries are first and second order streams, the majority of which are first order with a combined total length of 24,674 linear feet. The second order streams have a total length of 5,965 linear feet.

Nearly 85 percent of the land use in the Smith Creek 4 subwatershed is forested; 30 percent is deciduous forest and 54 percent is evergreen forest. Herbaceous cover makes up 13 percent of the subwatershed. Water makes up three percent of the subwatershed, and with just one impervious surface, this is the least developed of the subwatersheds in the Smith Creek basin. The sparse development in this subwatershed is primarily residential and occurs in the upper reaches of the subwatershed and in the southern portion along Oak Grove Church Road. Agricultural fields are present in the northern and eastern portions of the subwatershed.

Figure 24. Smith Creek 4 Subwatershed Land Use Chart

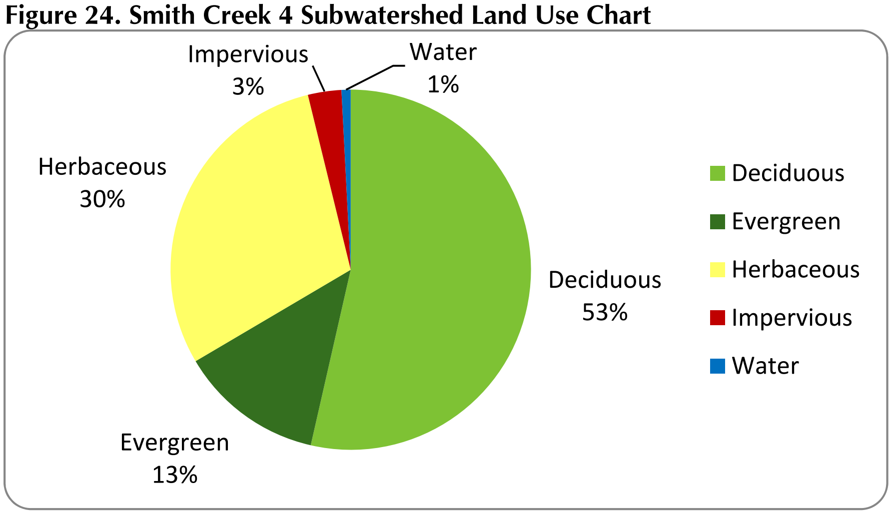
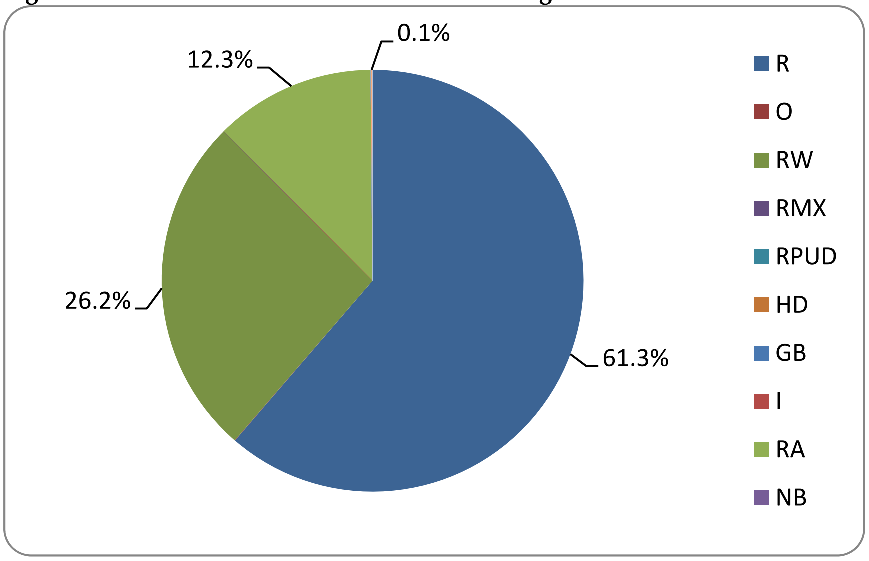
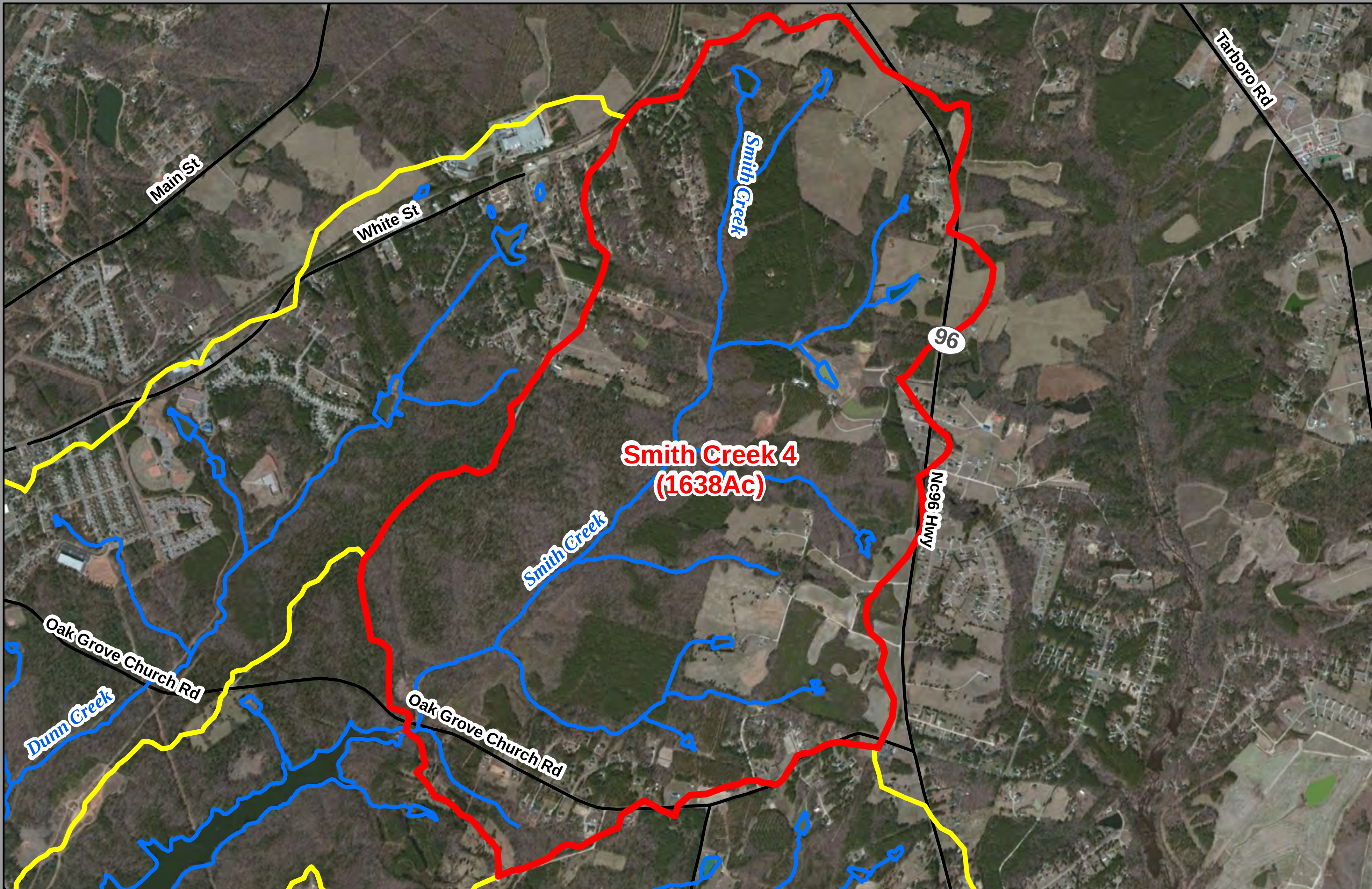


Figure 25. Smith Creek 4 Subwatershed Zoning Chart





Legend

- Smith Creek 4 Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

N W E S

Figure 26

Smith Creek 4 Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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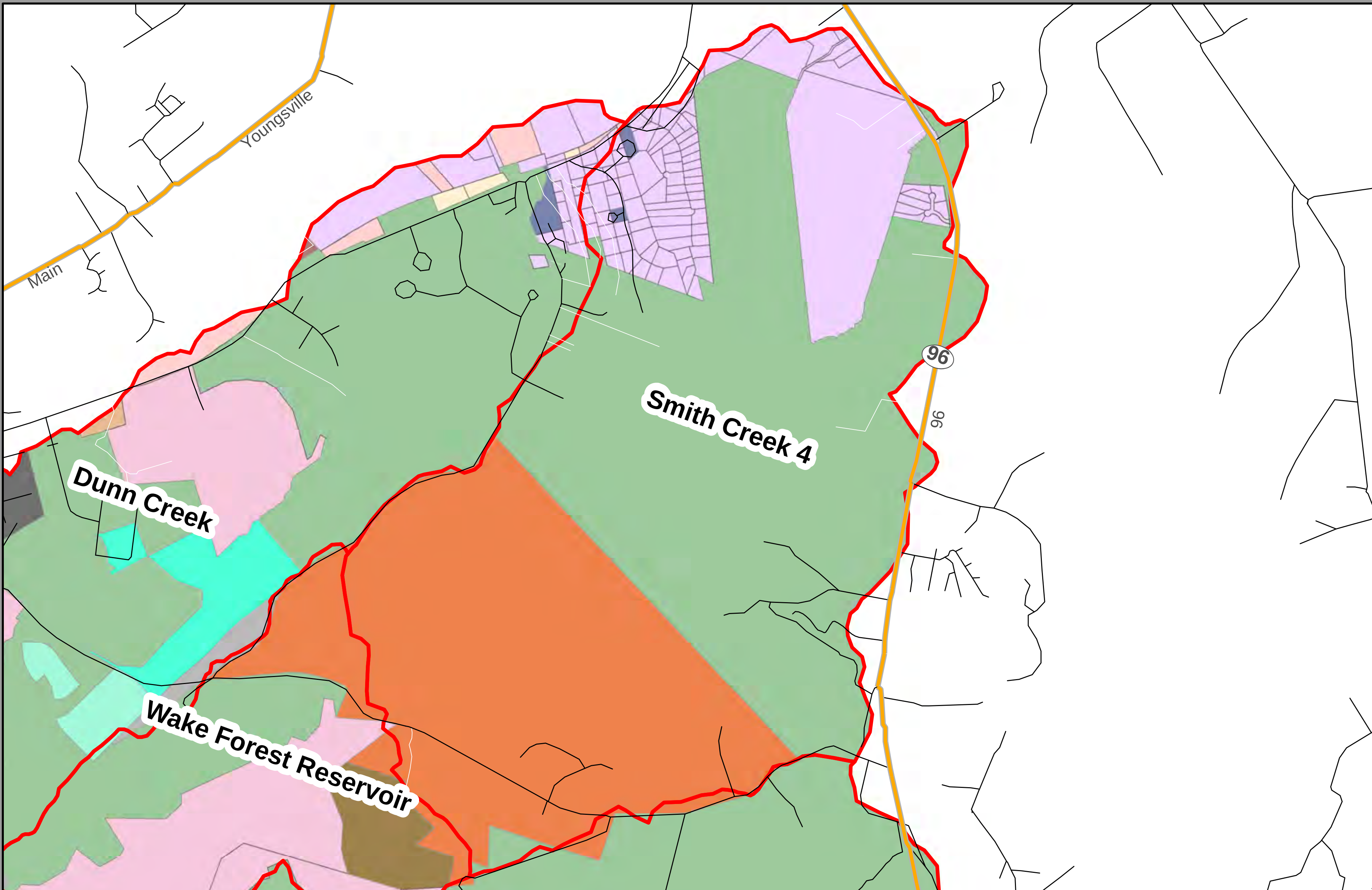

- Neighborhood Residential
- Office and Professional
- Open Space
- Residential
- Residential - Agriculture
- Residential Mixed Use
- Residential Watershed
- Residential and Planned Unit Development
- Rural Manufactured Home District
- Urban Residential
- Rurual Holding District
- Subwatersheds
- Commercial
- Commercial - Outlying
- General Business
- Highway Business
- Highway District
- Industrial
- Institutional Campus Development
- Neighborhood Business

Figure 27

Smith Creek Watershed Restoration Plan and Implementation Project
Smith Creek 4
Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

N W E S

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2.2.20 Sanford Creek 1 Subwatershed

The Sanford Creek subwatershed is located in Wake County and is in the southeast portion of the Smith Creek watershed (Figure 2). This subwatershed has a drainage area of 971 acres and is the sixth smallest subwatershed. The Sanford Creek subwatershed is composed of 36,497 linear feet of stream. It consists primarily of Sanford Creek and six of its unnamed tributaries. Sanford Creek is a third and fourth order stream within this subwatershed; 235 linear feet are third order, and 8,294 linear feet are fourth order. The unnamed tributaries to Sanford Creek are first and second order streams, the majority of which are first order streams, with a combined total length of 22,556 linear feet. The remaining second order streams have a total length of 1,126 linear feet.

Land use in the Sanford Creek subwatershed is primarily forested; 46 percent is deciduous forest and 16 percent is evergreen forest. Impervious surfaces make up approximately 14 percent of this subwatershed. The remaining area is 23 percent herbaceous cover and one percent water. There are residential developments in the northeast and western portions of the subwatershed. The remaining area is primarily forested areas and agricultural fields.

Figure 28. Sanford Creek 1 Subwatershed Land Use Chart

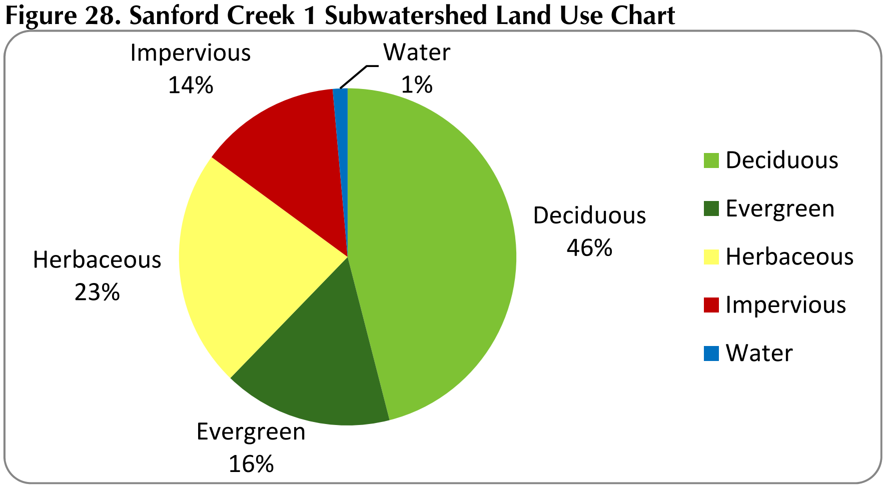
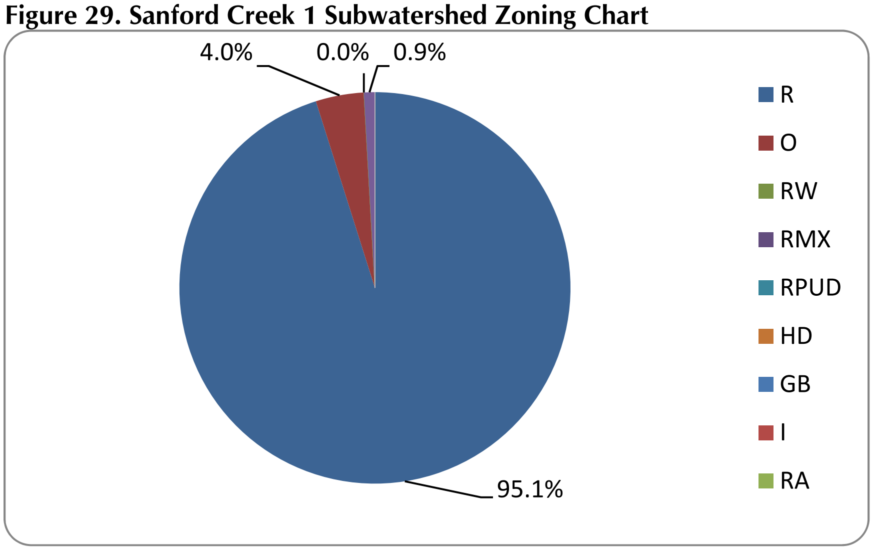


Figure 29. Sanford Creek 1 Subwatershed Zoning Chart



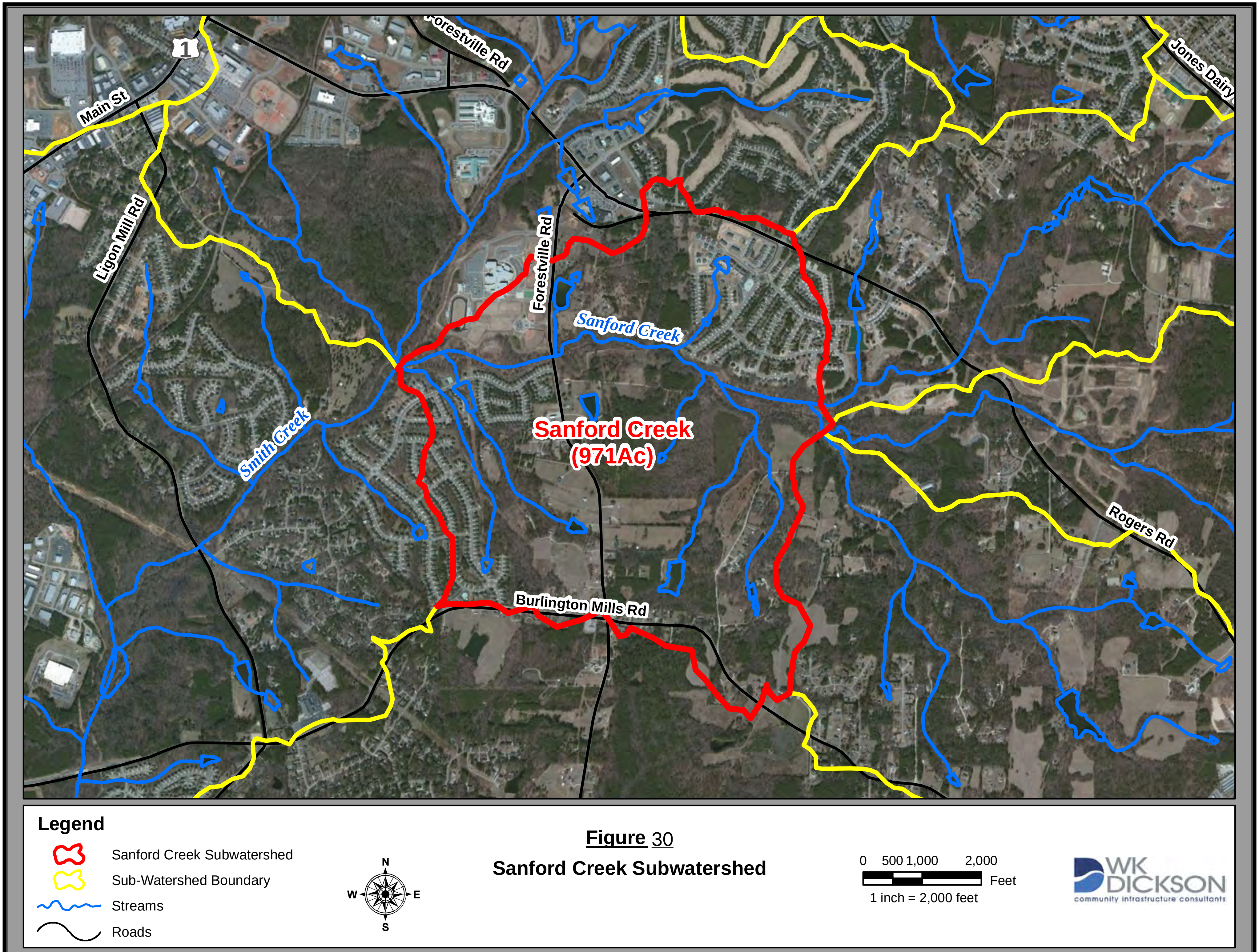
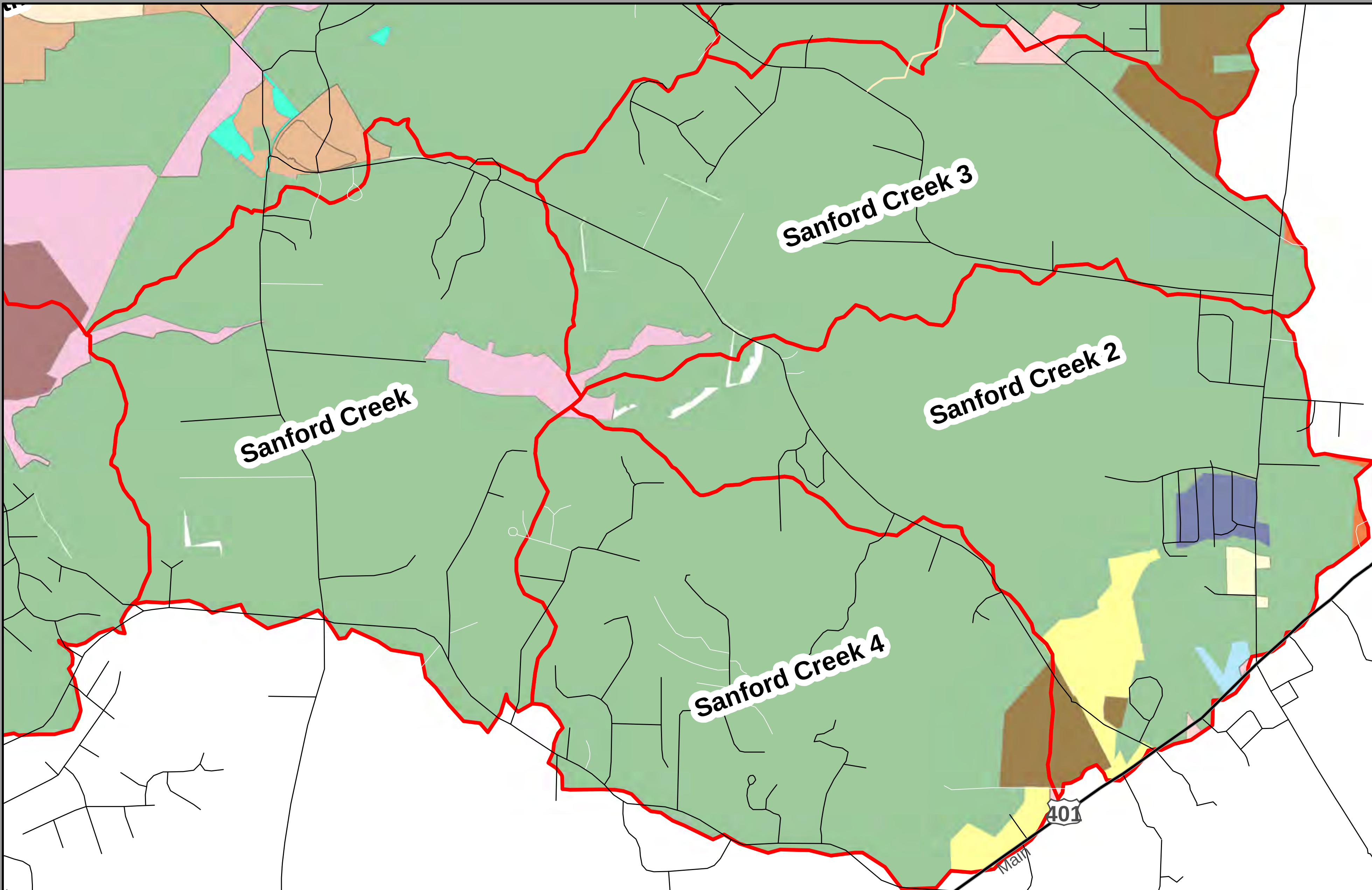


Figure 30

Sanford Creek Subwatershed



Neighborhood Residential
Office and Professional
Open Space
Residential
Residential - Agriculture
Residential Mixed Use
Residential Watershed
Residential and Planned Unit Development
Rural Manufactured Home District
Urban Residential
Rurual Holding District

Subwatersheds
Commercial
Commercial - Outlying
General Business
Highway Business
Highway District
Industrial
Institutional Campus Development
Neighborhood Business

Figure 31
Smith Creek Watershed Restoration Plan and Implementation Project Sanford Creek, Sanford Creek 3, Sanford Creek 2, and Sanford Creek 4 Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

N W E S

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2.2.21 Sanford Creek 2 Subwatershed

The Sanford Creek 2 subwatershed is located in Wake County and is in the southeastern portion of the Smith Creek watershed (Figure 2). This subwatershed has a drainage area of 1,014 acres and is the seventh largest subwatershed in the Smith Creek watershed. The Sanford Creek 2 subwatershed contains 28,885 linear feet of stream, including the headwaters of Sanford Creek. It consists primarily of Sanford Creek and three of its unnamed tributaries. Sanford Creek is a first, second, and third order stream within this subwatershed; 4,168 linear feet are first order, 3,655 linear feet are second order, and 5,942 linear feet are third order. The remaining three streams are unnamed second and first order streams totaling approximately 15,120 linear feet.

Land use in the Sanford Creek 2 subwatershed is primarily forested; 46 percent is deciduous forest and 18 percent is evergreen forest. Impervious surfaces make up approximately 11 percent of this subwatershed. The remaining area is 24 percent herbaceous cover and one percent water. Residential and commercial/industrial development is concentrated primarily in the eastern portion of the subwatershed. One residential development includes a number of undeveloped lots along paved streets, suggesting that this subwatershed may experience increased development in the near future. The eastern portion of the watershed is primarily forested and herbaceous with some residential development.

Figure 32. Sanford Creek 2 Subwatershed Land Use Chart

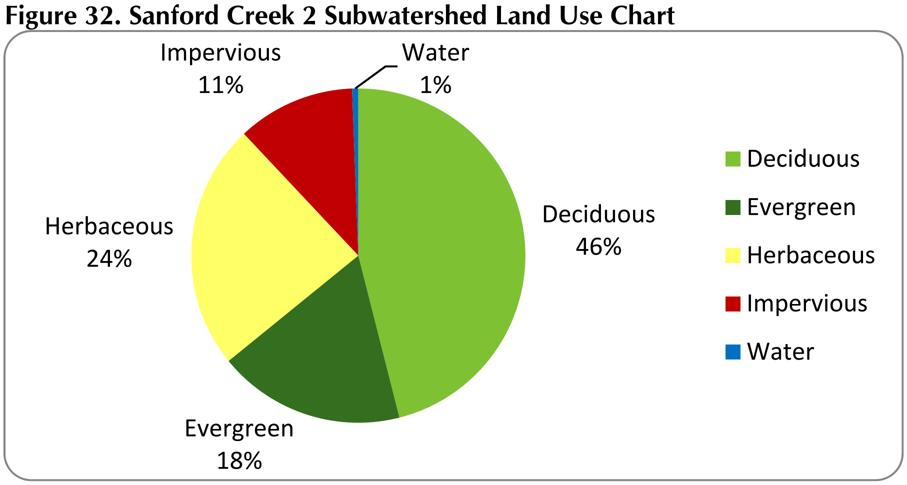
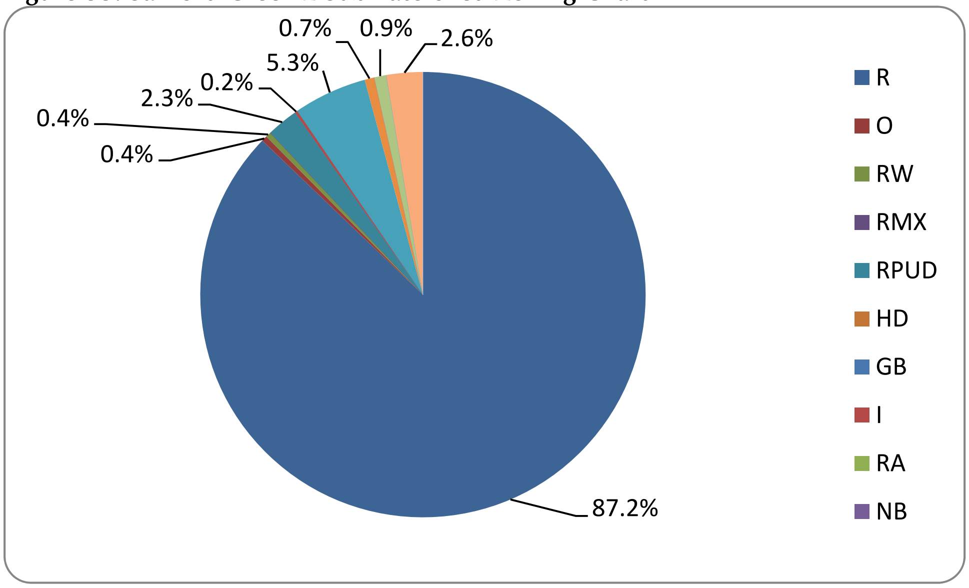


Figure 33. Sanford Creek 2 Subwatershed Zoning Chart



Legend

Sanford Creek 2 Subwatershed

Sub-Watershed Boundary

Streams

Roads

N W E S

Figure 34

Sanford Creek 2 Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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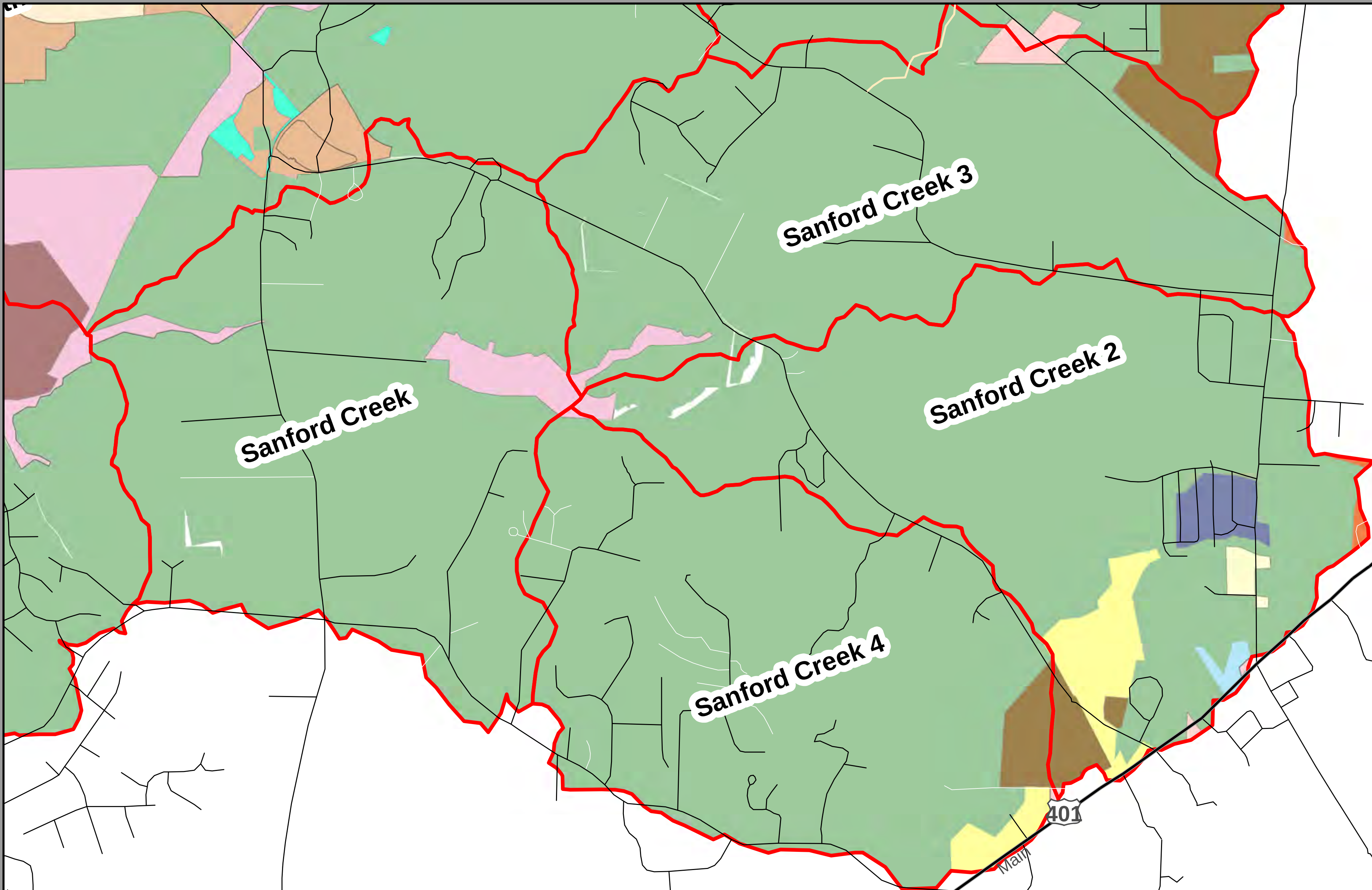

- Neighborhood Residential
- Office and Professional
- Open Space
- Residential
- Residential - Agriculture
- Residential Mixed Use
- Residential Watershed
- Residential and Planned Unit Development
- Rural Manufactured Home District
- Urban Residential
- Rurual Holding District
- Subwatersheds
- Commercial
- Commercial - Outlying
- General Business
- Highway Business
- Highway District
- Industrial
- Institutional Campus Development
- Neighborhood Business

Figure 35

Smith Creek Watershed Restoration Plan and Implementation Project Sanford Creek, Sanford Creek 3, Sanford Creek 2, and Sanford Creek 4 Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

N W E S

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2.2.22 Sanford Creek 3 Subwatershed

The Sanford Creek 3 subwatershed is located in the southeastern region of the Smith Creek watershed in Wake County (Figure 2). The drainage area for this subwatershed is 903 acres and is the fifth smallest subwatershed in the Smith Creek watershed. This subwatershed contains eight streams, all of which are unnamed tributaries to Sanford Creek. The main stem of these unnamed tributaries flows east to west before reaching the confluence with Sanford Creek. This tributary is first, second, and third order within this subwatershed; 2,057 linear feet are first order, 3,129 linear feet are second order, and 10,468 linear feet are third order. The rest of the streams are mostly first order, with one second order stream; the remaining first order streams have a combined total length of 17,041 linear feet, and the second order stream has a length of 1,007 linear feet. These streams mainly flow east to west, with three of the eight streams flowing north to south.

Nearly two thirds of the Sanford Creek 3 subwatershed is forested; 45 percent is deciduous forest and 19 percent is evergreen forest. Impervious surfaces make up approximately nine percent of this subwatershed. The remaining area is 25 percent herbaceous cover and two percent water. Development is primarily residential, and is focused around the northern and western portions of the subwatershed. Several large agricultural fields lie along the eastern edge.

Figure 36. Sanford Creek 3 Subwatershed Land Use Chart

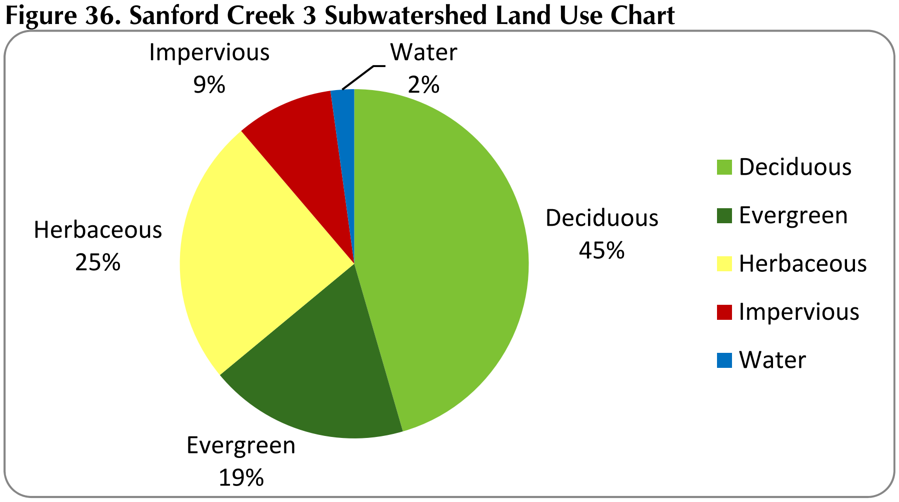
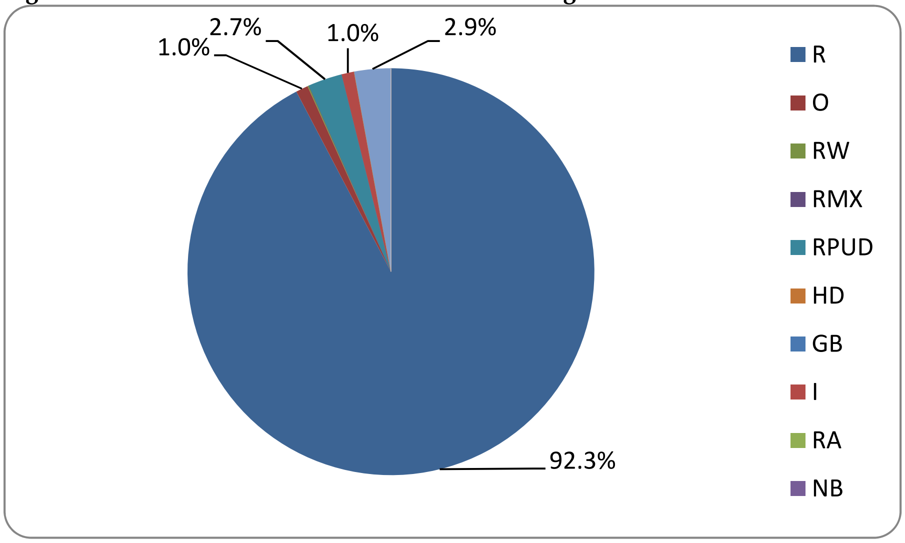
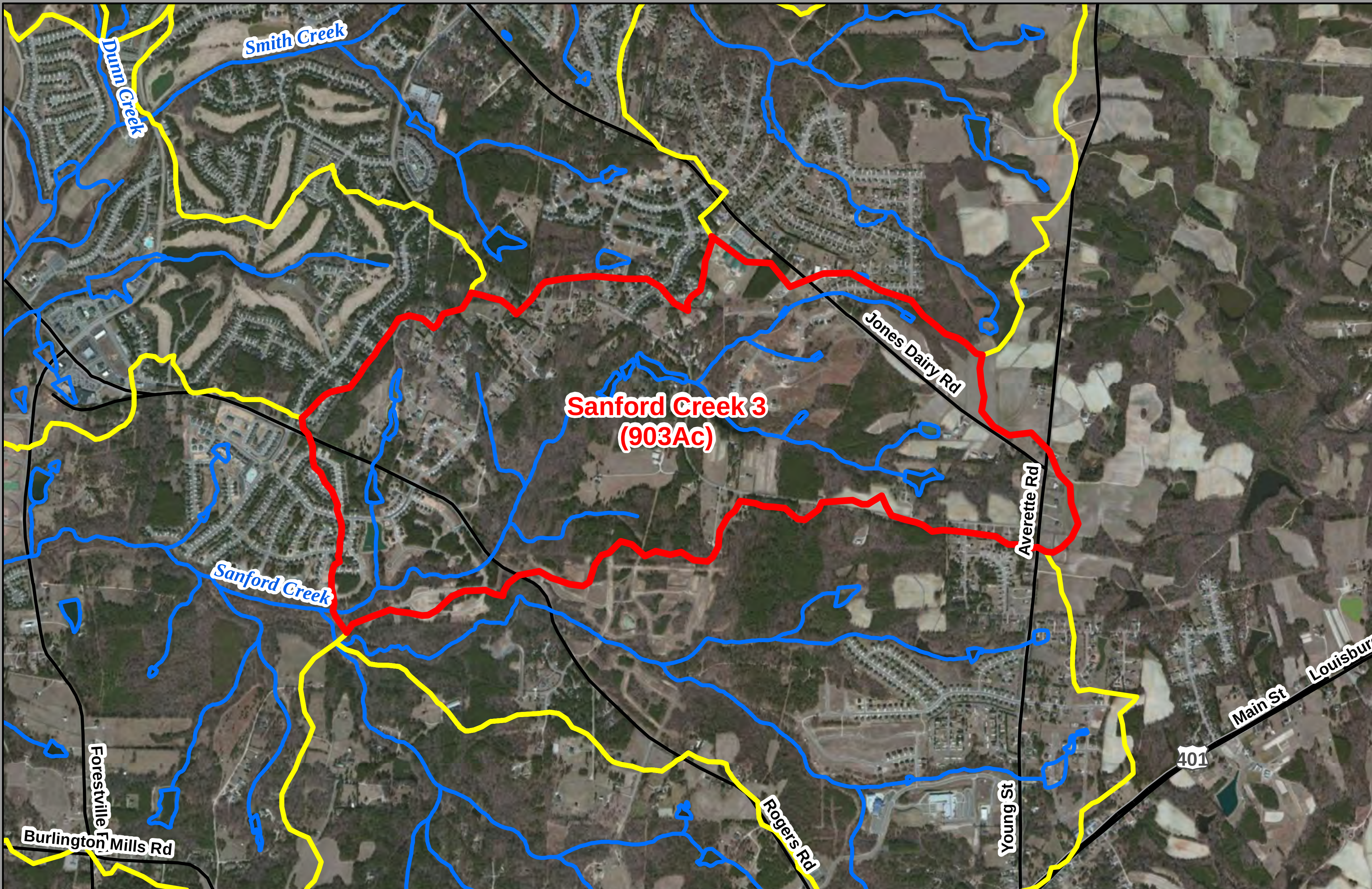


Figure 37. Sanford Creek 3 Subwatershed Zoning Chart





Legend

- Sanford Creek 3 Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

N
W E
S

Figure 38

Sanford Creek 3 Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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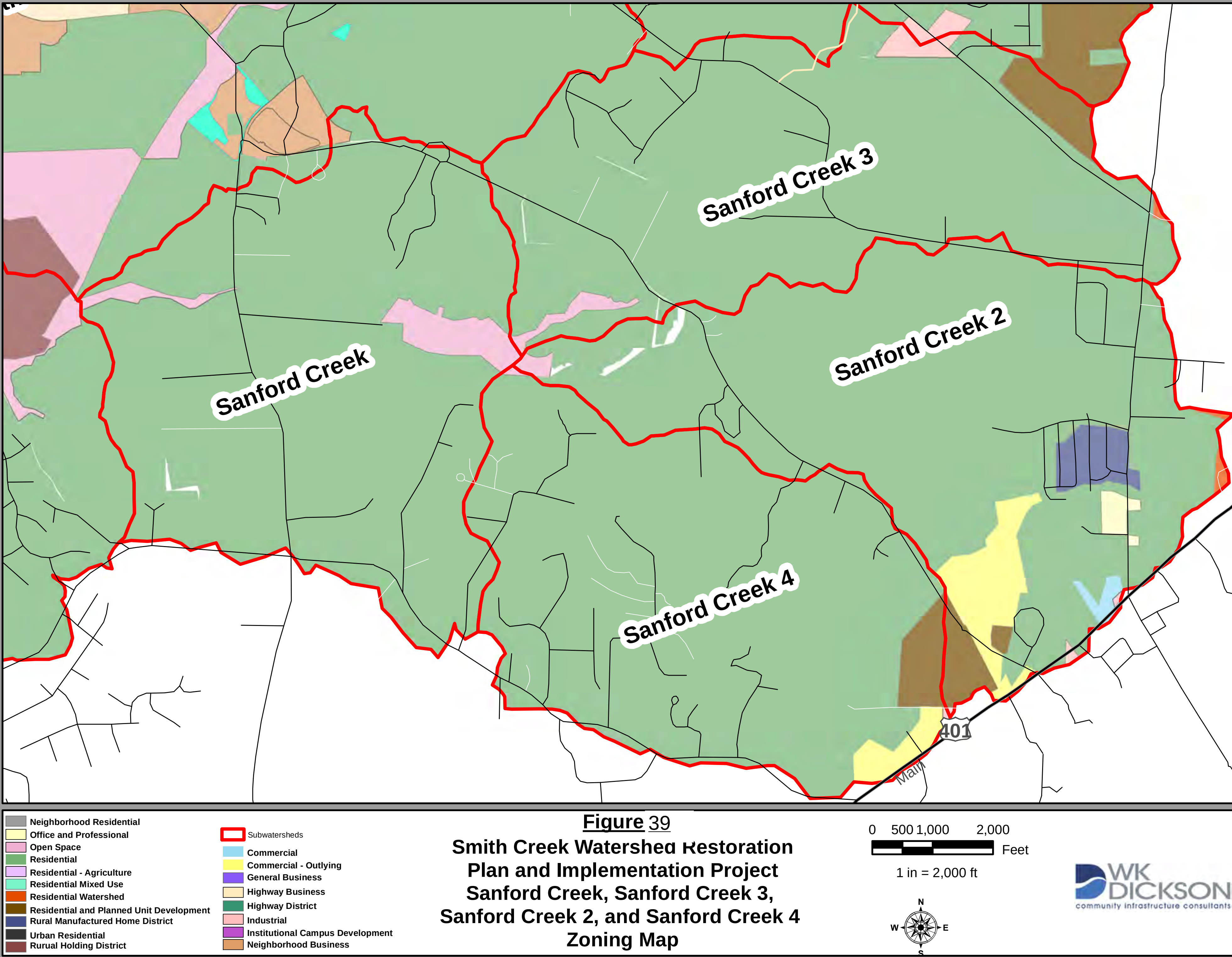


Figure 39

Smith Creek Watershed Restoration Plan and Implementation Project Sanford Creek, Sanford Creek 3, Sanford Creek 2, and Sanford Creek 4 Zoning Map

2.2.23 Sanford Creek 4 Subwatershed

The Sanford Creek 4 subwatershed is located in the southeastern portion of the Smith Creek watershed in Wake County (Figure 2. The subwatershed has a drainage area of 882 acres and is the fourth smallest subwatershed in the Smith Creek watershed. The Sanford Creek 4 subwatershed is composed of 25,888 linear feet of stream. This subwatershed contains five streams which are unnamed tributaries of Sanford Creek. The main stem in this subwatershed is a first, second, and third order stream within this subwatershed that flows southeast to northwest and flows directly into Sanford Creek; 7,048 linear feet of this tributary are first order, 2,161 linear feet are second order, and 2,865 linear feet are third order. The remaining streams are first and second order tributaries that total 13,294 linear feet and 520 linear feet of stream, respectively. These streams flow southeast to northwest and flow directly into the third order stem before reaching Sanford Creek.

Land use in the Sanford Creek 4 subwatershed is 70 percent forested; 48 percent is deciduous forest and 22 percent is evergreen forest. Impervious surfaces make up approximately six percent of this subwatershed. The remaining area is 23 percent herbaceous cover and two percent water. Commercial/industrial development is concentrated along S. Main Street and Rogers Road in the southeast and eastern portions of the subwatershed. Residential development is scattered throughout the subwatershed, with several developments stemming north from Burlington Mills Road. There are a number of agricultural fields throughout the eastern portion of the subwatershed.

Figure 40. Sanford Creek 4 Subwatershed Land Use Chart

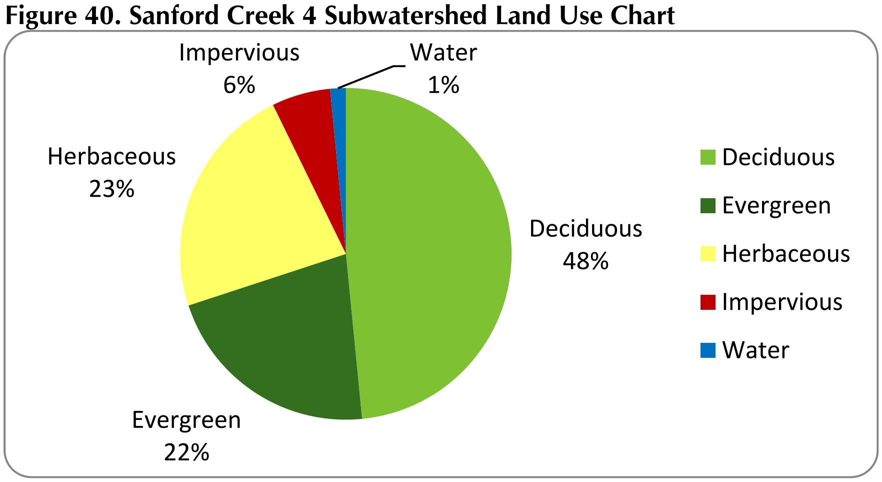
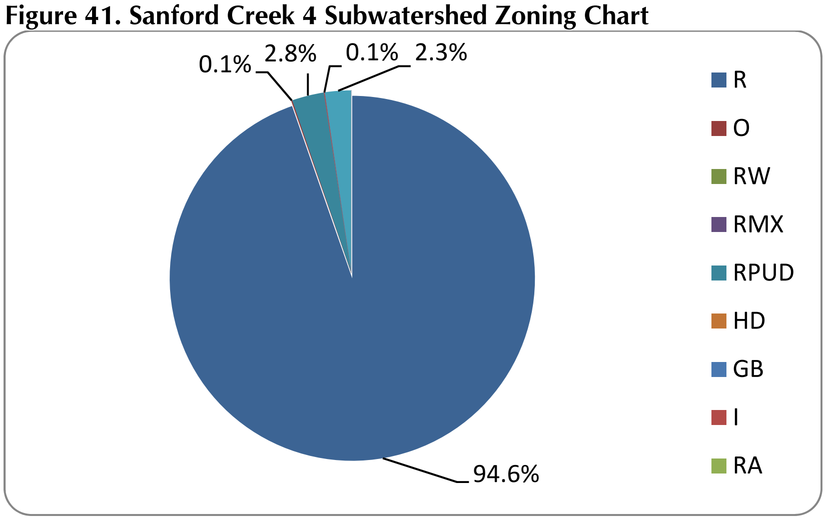
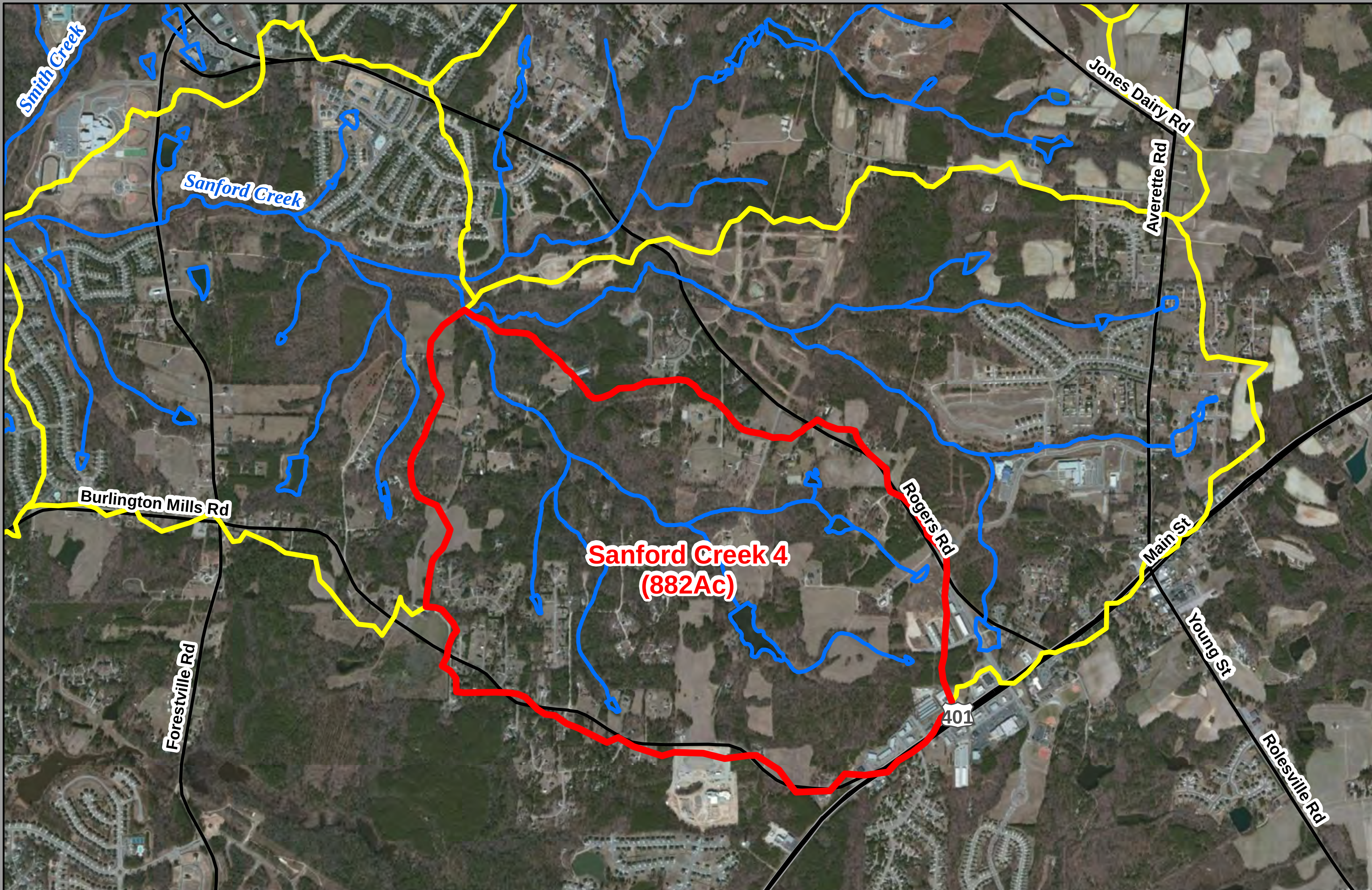


Figure 41. Sanford Creek 4 Subwatershed Zoning Chart





Legend

- Sanford Creek 4 Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

N S W E

Figure 42

Sanford Creek 4 Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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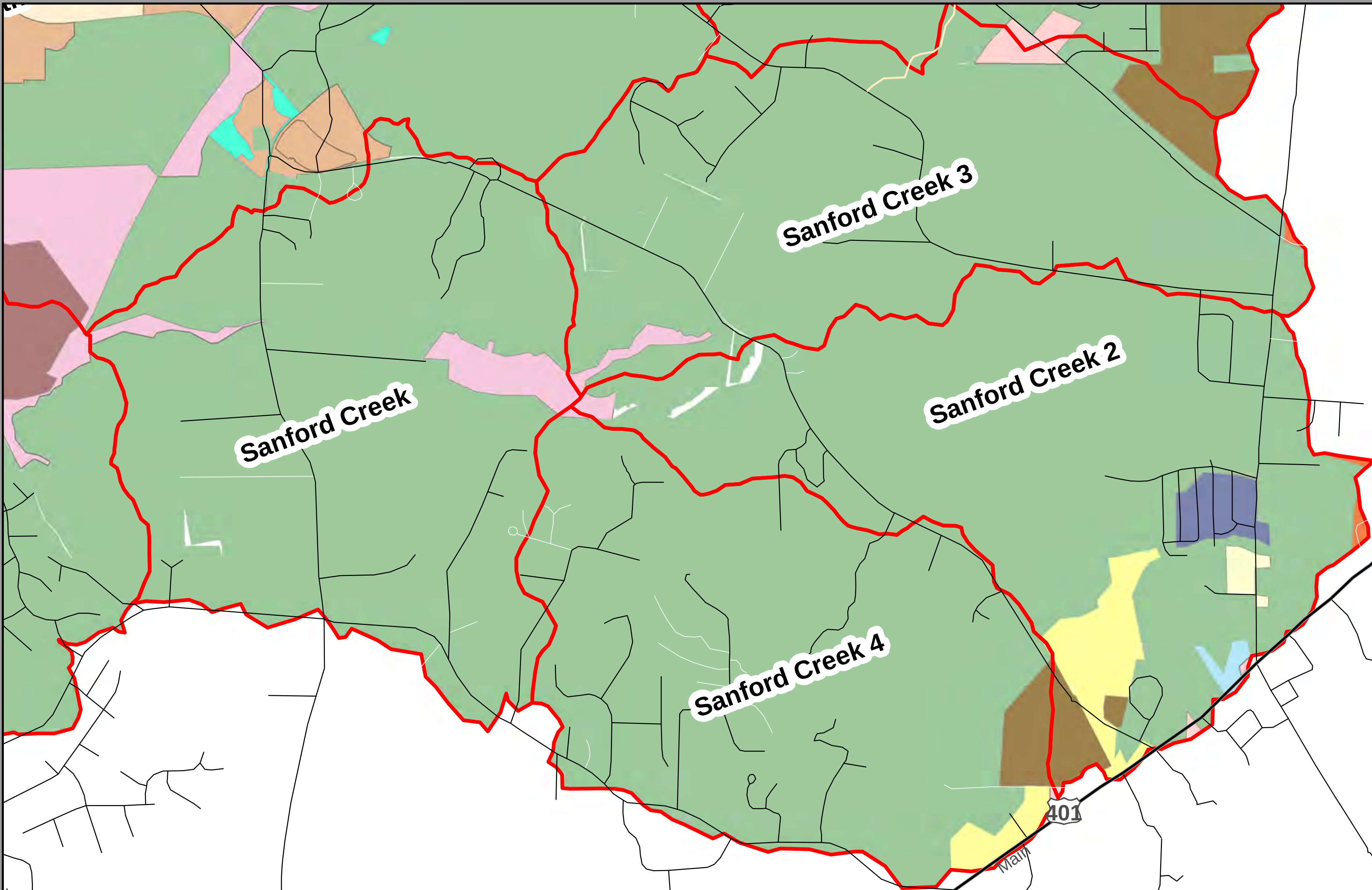

- Neighborhood Residential
- Office and Professional
- Open Space
- Residential
- Residential - Agriculture
- Residential Mixed Use
- Residential Watershed
- Residential and Planned Unit Development
- Rural Manufactured Home District
- Urban Residential
- Rurual Holding District
- Subwatersheds
- Commercial
- Commercial - Outlying
- General Business
- Highway Business
- Highway District
- Industrial
- Institutional Campus Development
- Neighborhood Business

Figure 43
Smith Creek Watershed Restoration Plan and Implementation Project Sanford Creek, Sanford Creek 3, Sanford Creek 2, and Sanford Creek 4 Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

N W E S

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2.2.24 Austin Creek Subwatershed

The Austin Creek subwatershed is located in the northeastern region of the Smith Creek watershed (Figure 2). This subwatershed has a drainage area of 1,469 acres. Of these 1,469 acres, 30 acres (two percent) are located in Franklin County, NC and 1,439 (98 percent) are located in Wake County, NC. The headwaters of Austin Creek are located within this subwatershed, along with several unnamed first and second order tributaries. The Austin Creek subwatershed is composed of 47,475 linear feet of stream. It consists primarily of Austin Creek and eight of its unnamed tributaries. Austin Creek is first, second, and third order within this sub-watershed; 3,529 linear feet are first order, 8,082 linear feet are second order, and 5,847 linear feet are third order. This stream flows in an east to southwest direction before reaching the Smith Creek 3 subwatershed. The eight unnamed tributaries are first and second order, the majority of which are first order streams with a combined total length of 16,350 linear feet. The remaining second order streams have a combined length of 4,472 linear feet.

Nearly three quarters of the land use in the Austin Creek subwatershed is forested; 51 percent is deciduous forest and 22 percent is evergreen forest. Impervious surfaces make up approximately six percent of this subwatershed. The remaining area is 20 percent herbaceous cover and two percent water. NC-96 runs through the eastern edge of the subwatershed, and NC-98 runs through the southern edge. Residential development is primarily in the northern portion between NC-96 (Zebulon Road) and Averette Road. There are several large agricultural fields east of Averette Road in the eastern portion of the subwatershed.

Figure 44. Austin Creek Subwatershed Land Use Chart

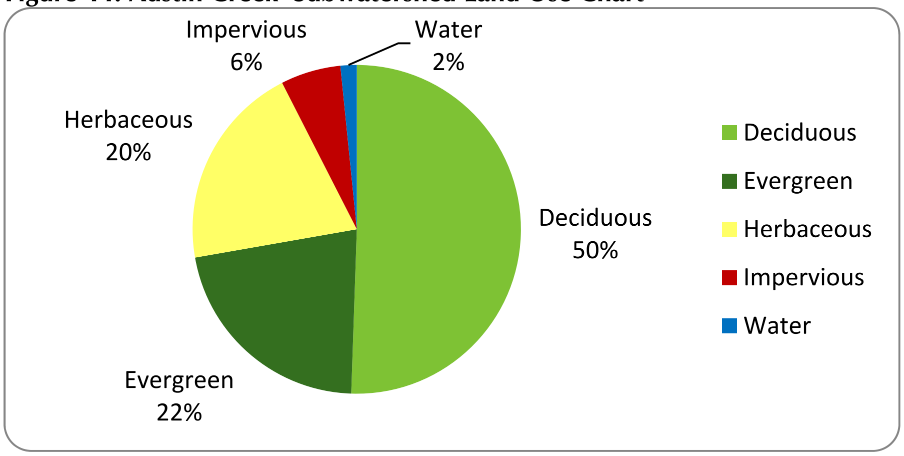
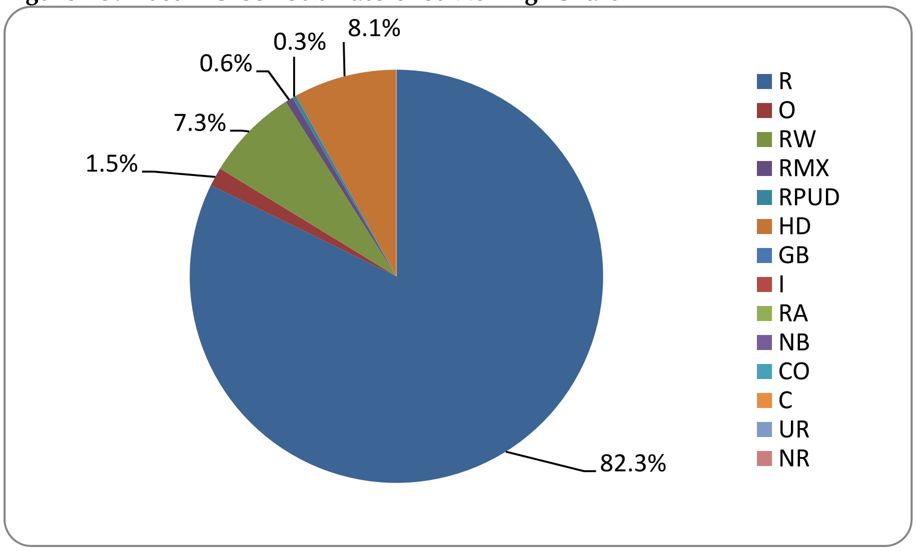
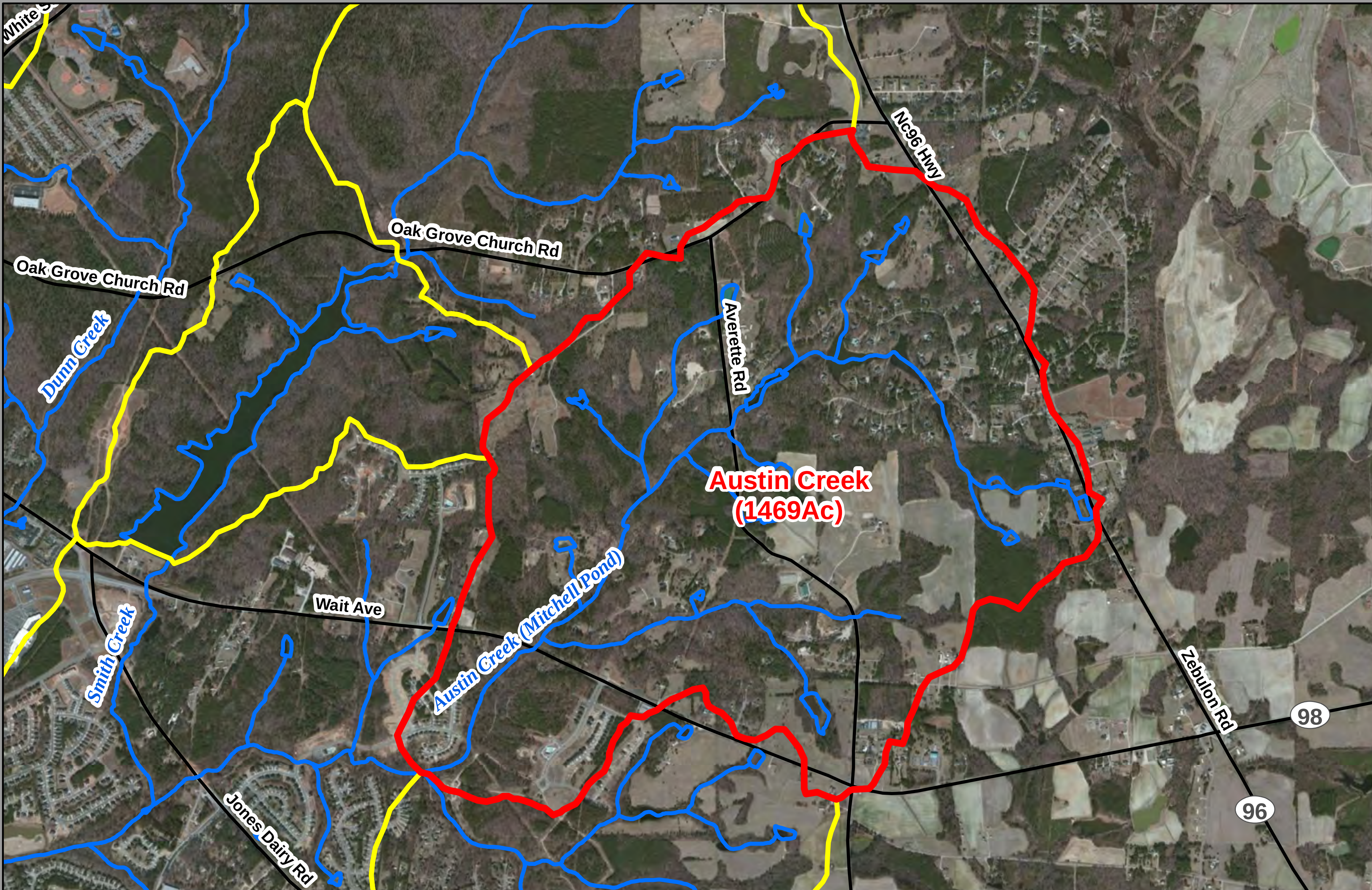


Figure 45. Austin Creek Subwatershed Zoning Chart





Legend

- Austin Creek Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

Figure 46

Austin Creek Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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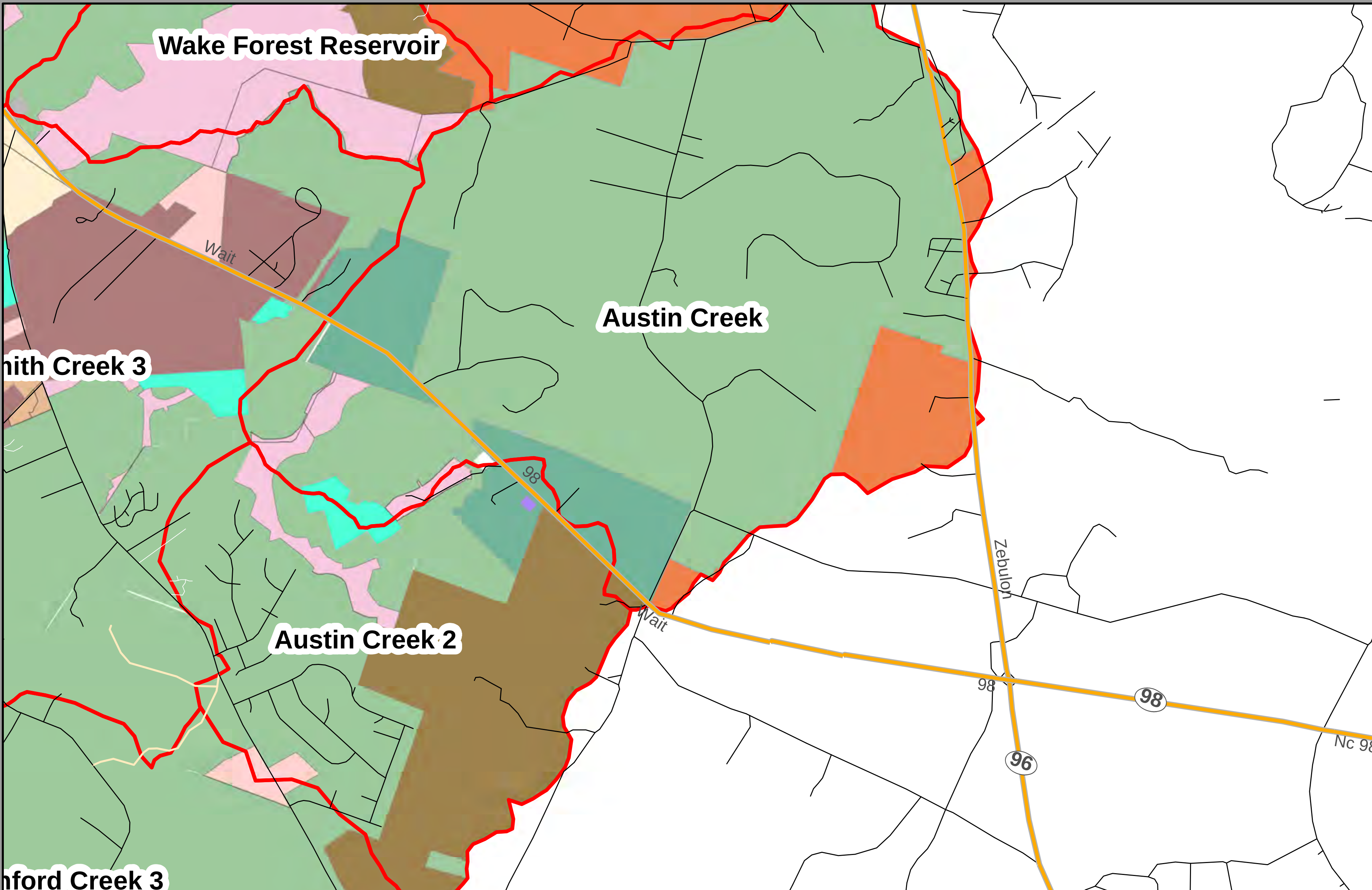

Neighborhood Residential
Office and Professional
Open Space
Residential
Residential - Agriculture
Residential Mixed Use
Residential Watershed
Residential and Planned Unit Development
Rural Manufactured Home District
Urban Residential
Rurual Holding District

Subwatersheds
Commercial
Commercial - Outlying
General Business
Highway Business
Highway District
Industrial
Institutional Campus Development
Neighborhood Business

Figure 47

Smith Creek Watershed Restoration Plan and Implementation Project Austin Creek 2 and Austin Creek Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

N E S W

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2.2.25 Austin Creek 2 Subwatershed

The Austin Creek 2 subwatershed is located in the eastern portion of the Smith Creek watershed and is located within Wake County (Figure 2). This subwatershed has a drainage area of 675 acres and is the second smallest subwatershed in the Smith Creek watershed. The Austin Creek 2 subwatershed includes 26,004 linear feet of stream. It is comprised of an unnamed tributary to Austin Creek along with four additional unnamed tributaries. The unnamed tributary to Austin Creek is a first and second order stream within this subwatershed; 2,490 linear feet are first order and 4,967 linear feet are second order. The four additional unnamed tributaries are first order streams with a combined length of 18,547 linear feet. These streams primarily flow east to west to their eventual confluence with Austin Creek.

Over half of the land use in the Austin Creek 2 subwatershed is forested; 44 percent is deciduous forest and 13 percent is evergreen forest. Impervious surfaces make up approximately 10 percent of this subwatershed. The remaining area is 32 percent herbaceous cover and one percent water. The southwest portion of this subwatershed is dominated by dense single-family residential development and a school south of Jones Dairy Road. The eastern portion of the subwatershed is dominated by agricultural land use.

Figure 48. Austin Creek 2 Subwatershed Land Use Chart

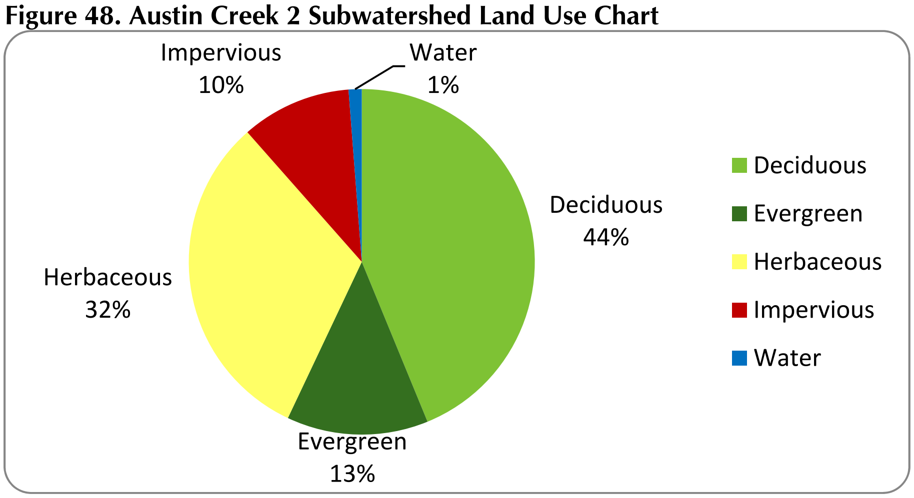
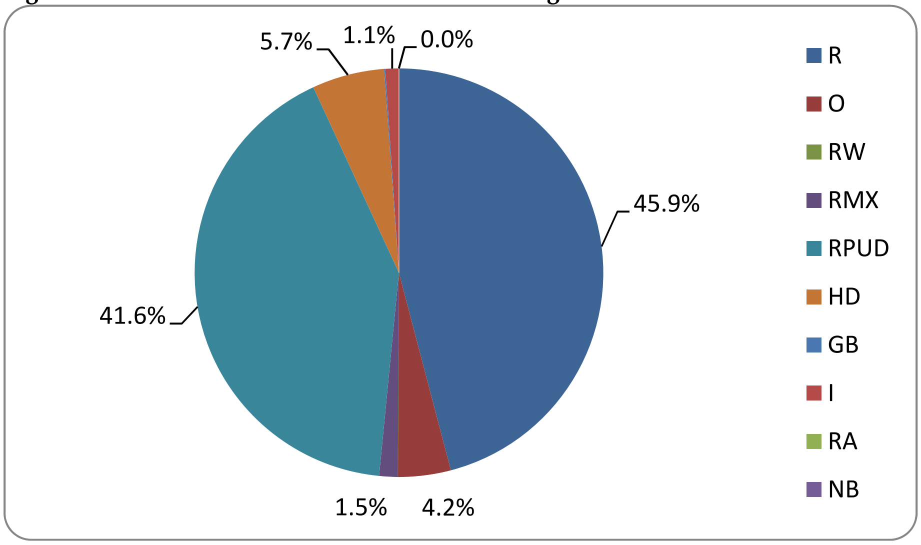
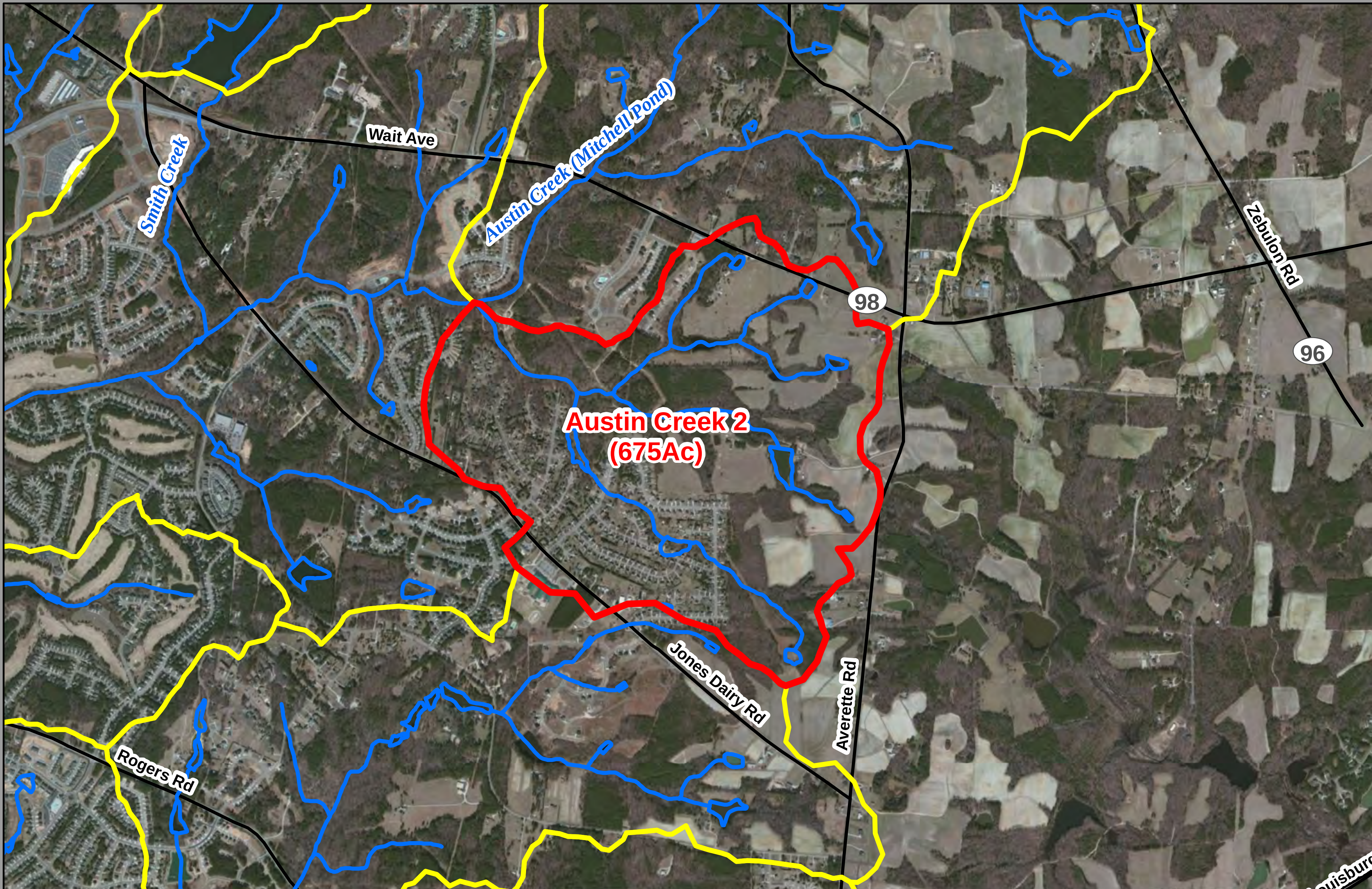


Figure 49. Austin Creek 2 Subwatershed Zoning Chart





Legend

Austin Creek 2 Subwatershed
Sub-Watershed Boundary
Streams
Roads

N W E S

Figure 50

Austin Creek 2 Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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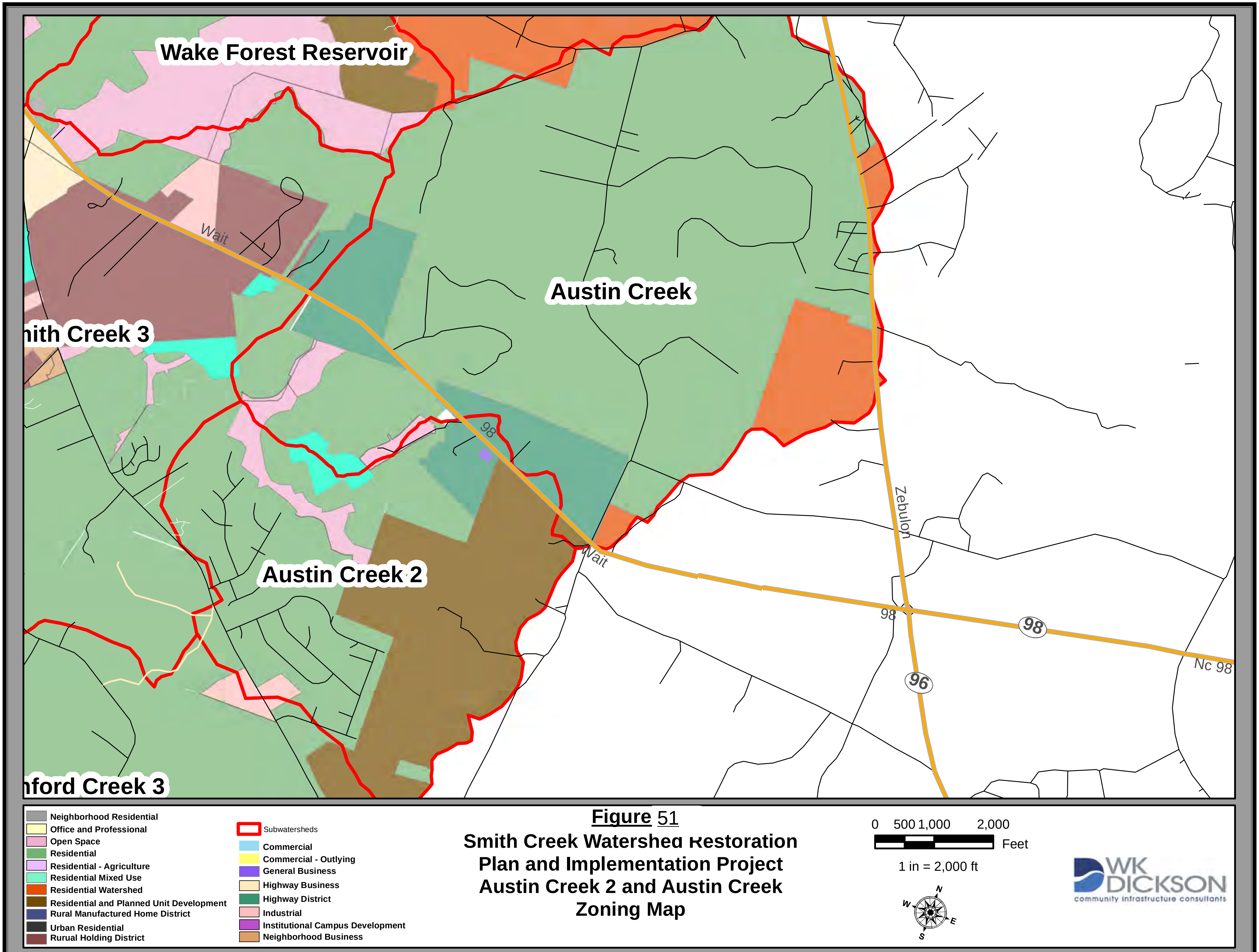


Figure 51

Smith Creek Watershed Restoration Plan and Implementation Project Austin Creek 2 and Austin Creek Zoning Map

2.2.26 Spring Branch Subwatershed

The Spring Branch subwatershed is located in the northwestern region of the Smith Creek watershed (Figure 2) in Wake County. This subwatershed has a drainage area of 774 acres, which is the third smallest in the Smith Creek watershed. The Spring Branch subwatershed includes 17,604 linear feet of stream, which is comprised of Spring Branch (a tributary of Dunn Creek) along with three of its unnamed tributaries. Spring Branch is a first and second order stream; 1,928 linear feet are first order and 7,427 linear feet are second order. The unnamed tributaries to Spring Branch are all first order streams with a combined total length of 8,248 linear feet. Spring Branch flows directly into Dunn Creek, which has a confluence with Smith Creek approximately 1,320 feet downstream of the Spring Branch and Dunn Creek confluence.

Over one quarter of the land use in this subwatershed is impervious (26 percent), making this the most developed subwatershed in the project area. The Spring Branch subwatershed includes most of downtown Wake Forest. NC-98 runs through the southern portion of the subwatershed and South Main Street runs along the eastern edge; the area north of NC-98 is relatively densely developed with a mix of commercial and residential structures. Just over half of the land use in the Spring Branch subwatershed is forested; 37 percent is deciduous forest and 16 percent is evergreen forest. The remaining area is 20 percent herbaceous cover and one percent water.

Figure 52. Spring Branch Subwatershed Land Use Chart

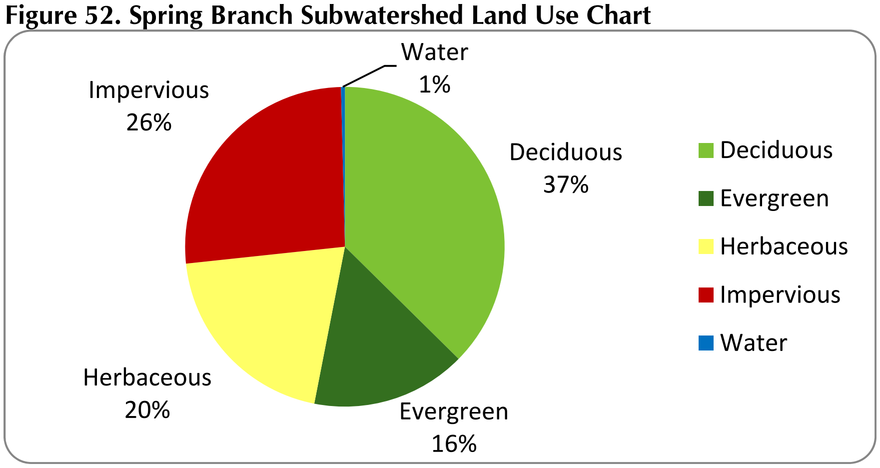
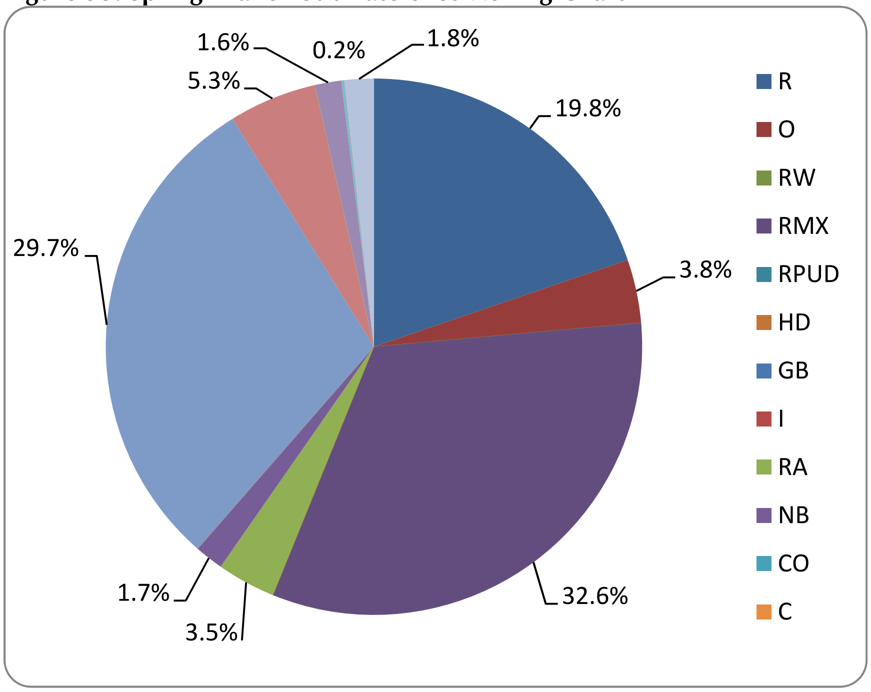
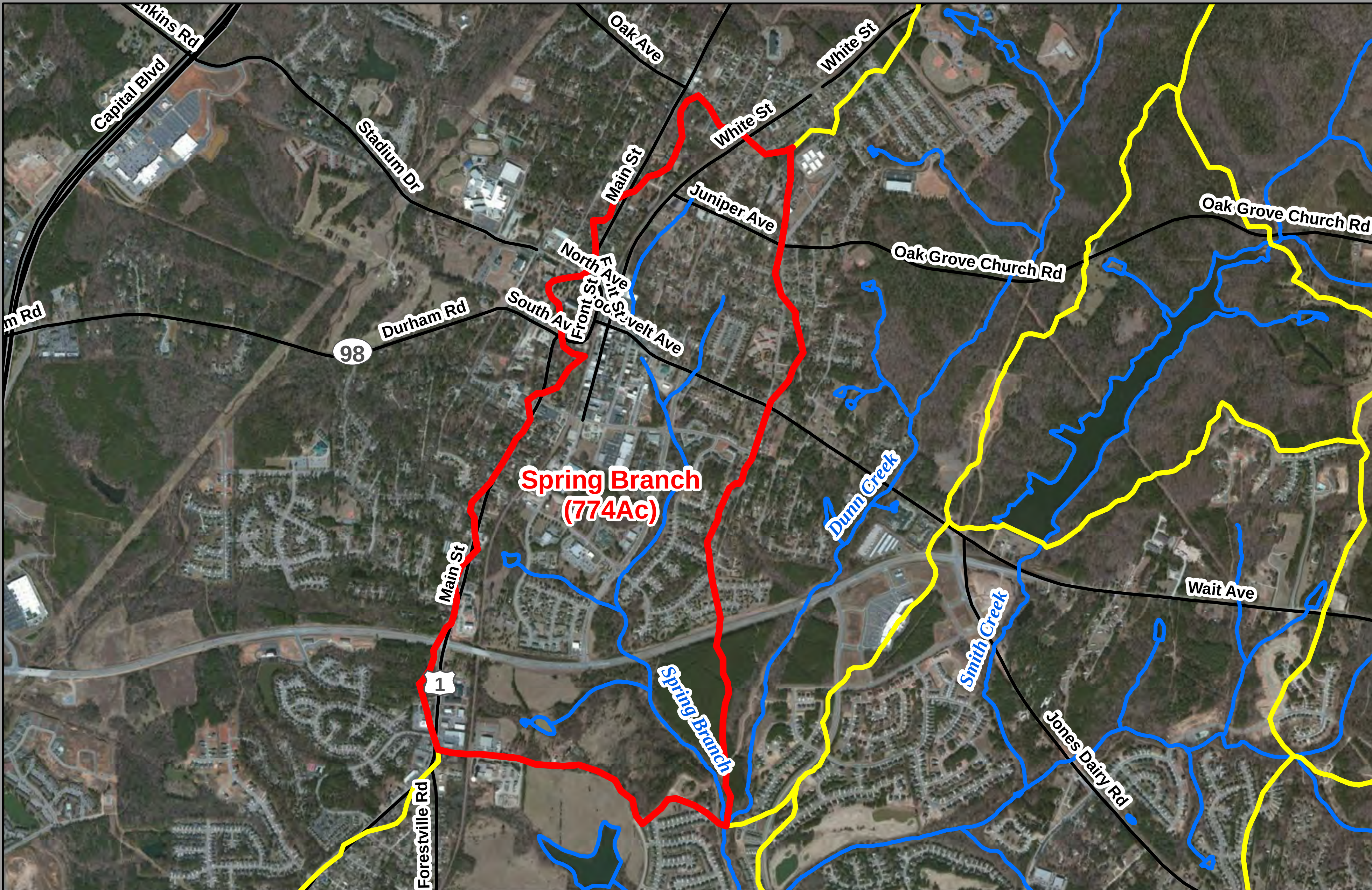


Figure 53. Spring Branch Subwatershed Zoning Chart





Legend

Spring Branch Subwatershed

Sub-Watershed Boundary

Streams

Roads

N W E S

Figure 54

Spring Branch Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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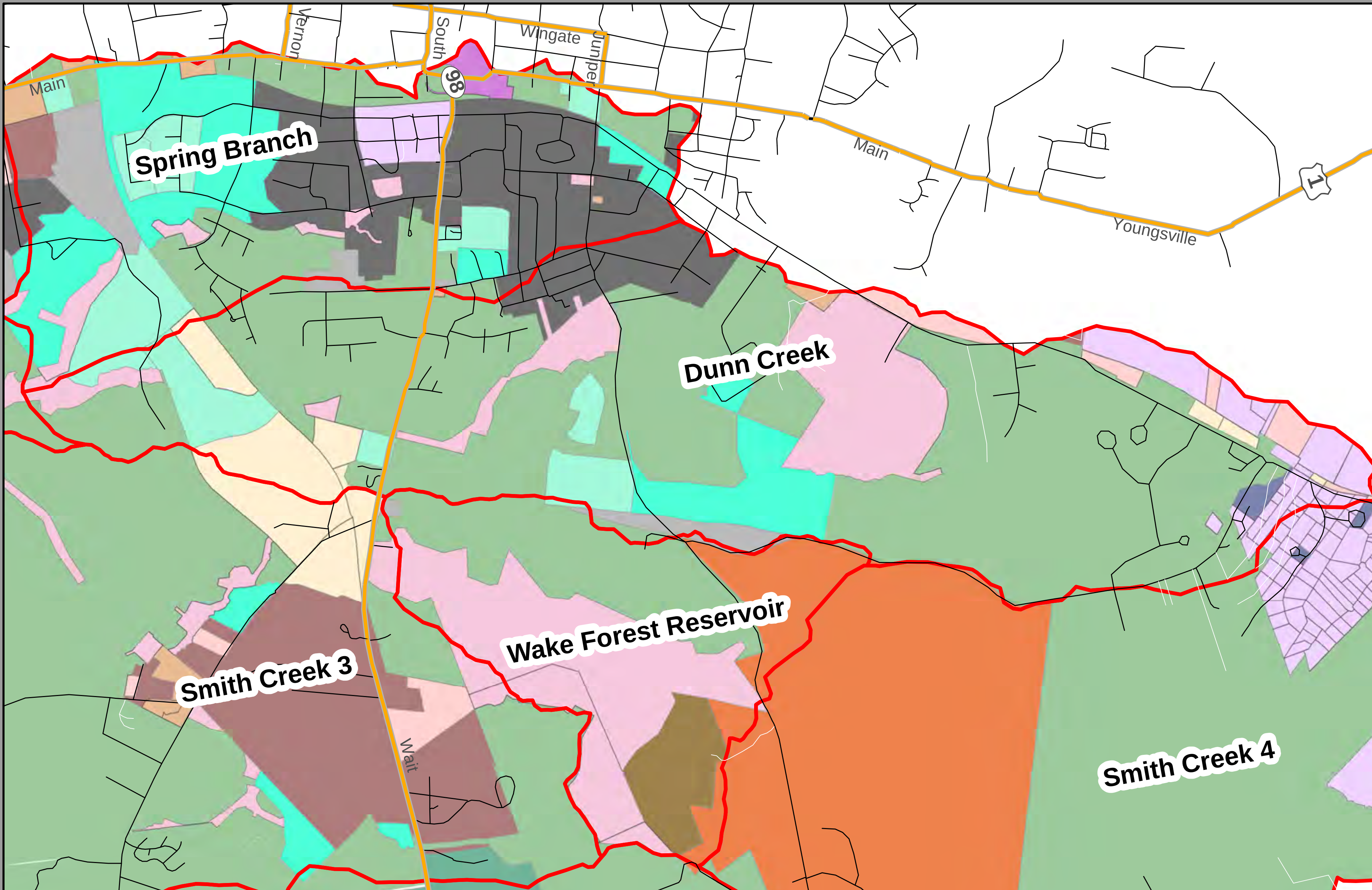

Neighborhood Residential
Office and Professional
Open Space
Residential
Residential - Agriculture
Residential Mixed Use
Residential Watershed
Residential and Planned Unit Development
Rural Manufactured Home District
Urban Residential
Rurual Holding District

Subwatersheds

Commercial
Commercial - Outlying
General Business
Highway Business
Highway District
Industrial
Institutional Campus Development
Neighborhood Business

Figure 55

Smith Creek Watershed Restoration Plan and Implementation Project
Spring Branch, Dunn Creek, and Wake Forest Reservoir Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

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2.2.27 Dunn Creek Subwatershed

The Dunn Creek subwatershed is located in the northwestern region of the Smith Creek watershed (Figure 2) in Wake and Franklin Counties. Of the 1,428 total acres of the drainage area, approximately 282 acres (19.7 percent) are within Franklin County and 1,146 acres (80.3 percent) are within Wake County. The Dunn Creek subwatershed is the fifth largest subwatershed. The Dunn Creek subwatershed contains 38,576 linear feet of stream. It consists primarily of Dunn Creek and six of its unnamed tributaries. Dunn Creek is a first, second, and third order stream within this subwatershed; 6,637 linear feet are first order, 8,387 linear feet are second order, and 7,269 linear feet are third order. The unnamed tributaries to Dunn Creek are first and second order streams, the majority of which are first order with a combined total length of 15,657 linear feet. The remaining second order streams have a total length of 625 linear feet.

Land use in the Dunn Creek subwatershed is primarily forested; 43 percent is deciduous forest and 21 percent is evergreen forest. Impervious surfaces make up approximately 13 percent of this subwatershed. The remaining area is 22 percent herbaceous cover and one percent water. Development in this subwatershed is primarily residential, with some areas of commercial and industrial development.

Figure 56. Dunn Creek Subwatershed Land Use Chart

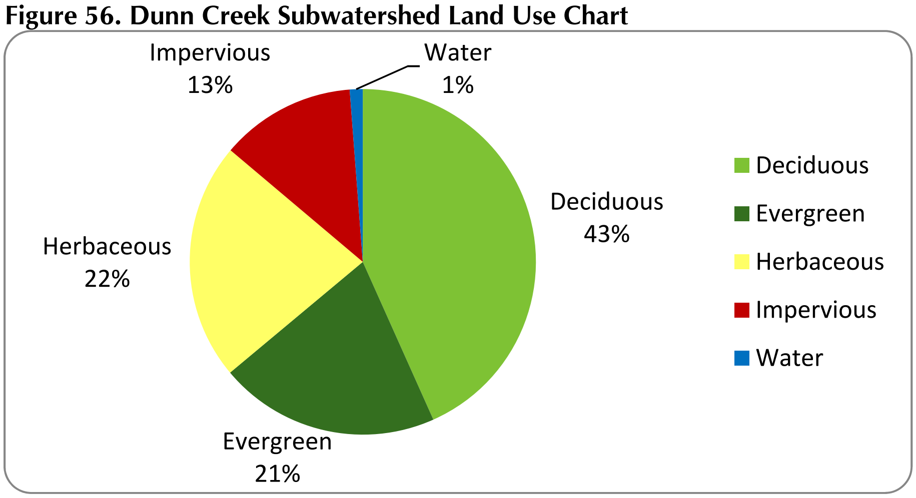
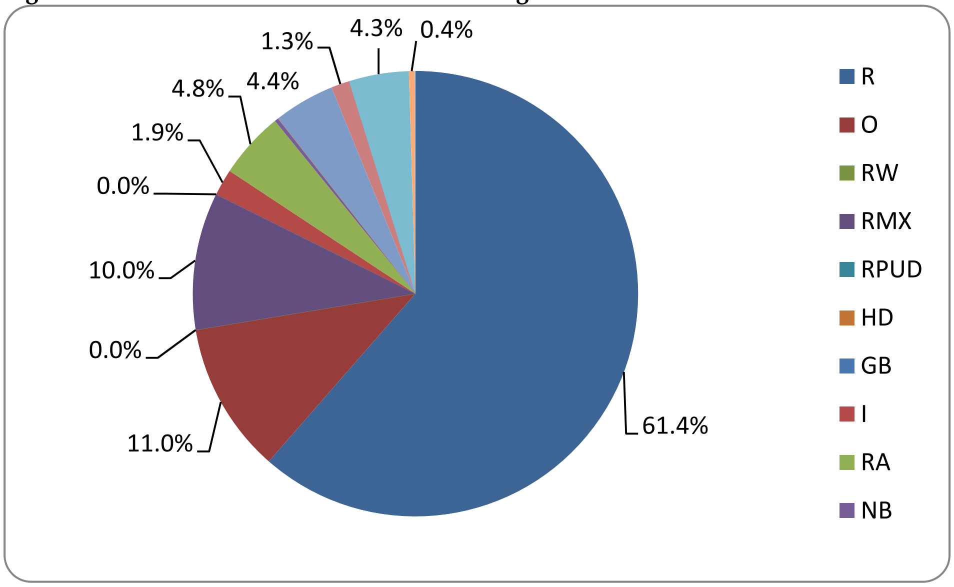
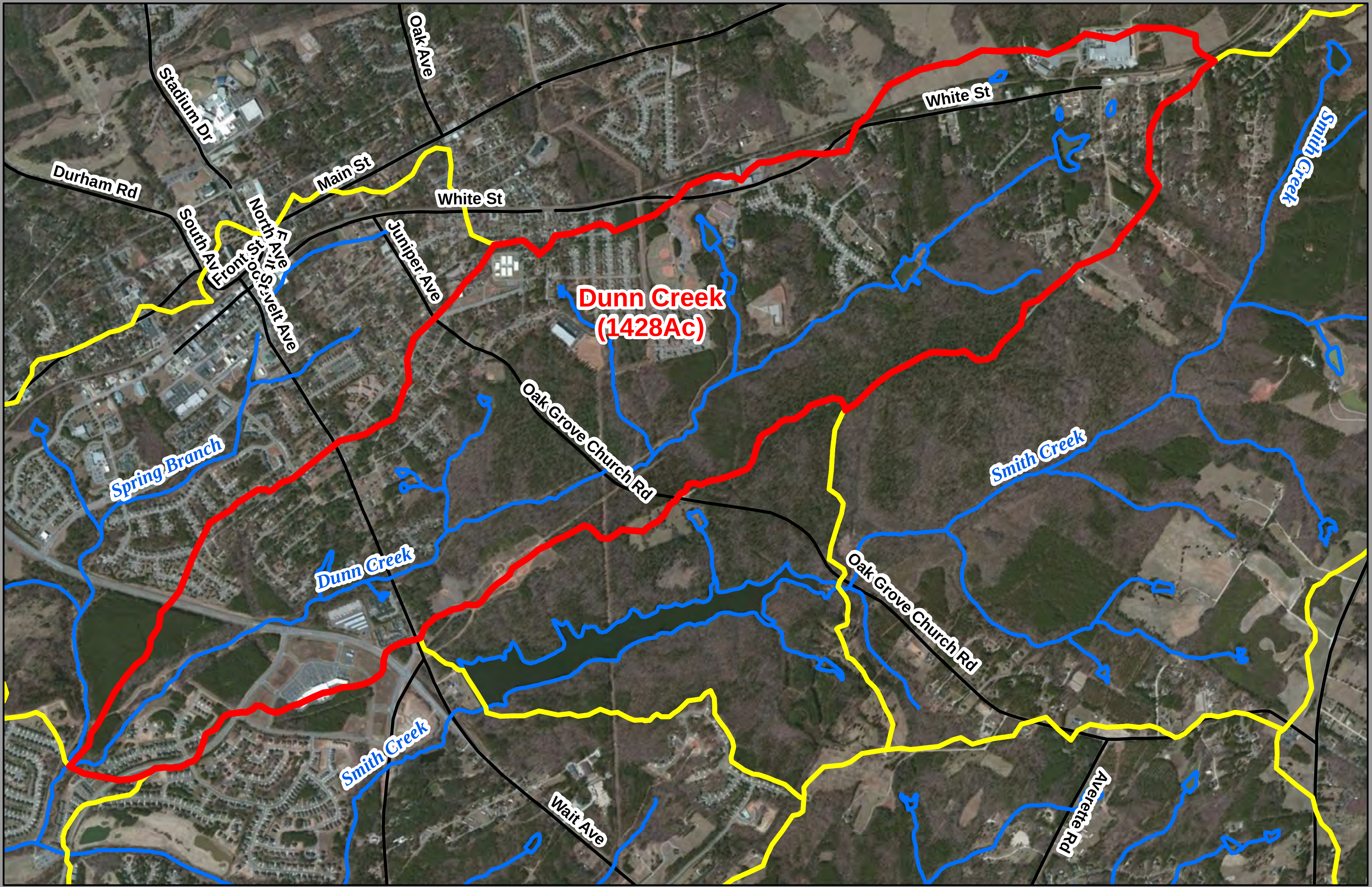


Figure 57. Dunn Creek Subwatershed Zoning Chart





Legend

Dunn Creek Subwatershed

Sub-Watershed Boundary

Streams

Roads

<u>**Figure**</u> <u>58</u>

Dunn Creek Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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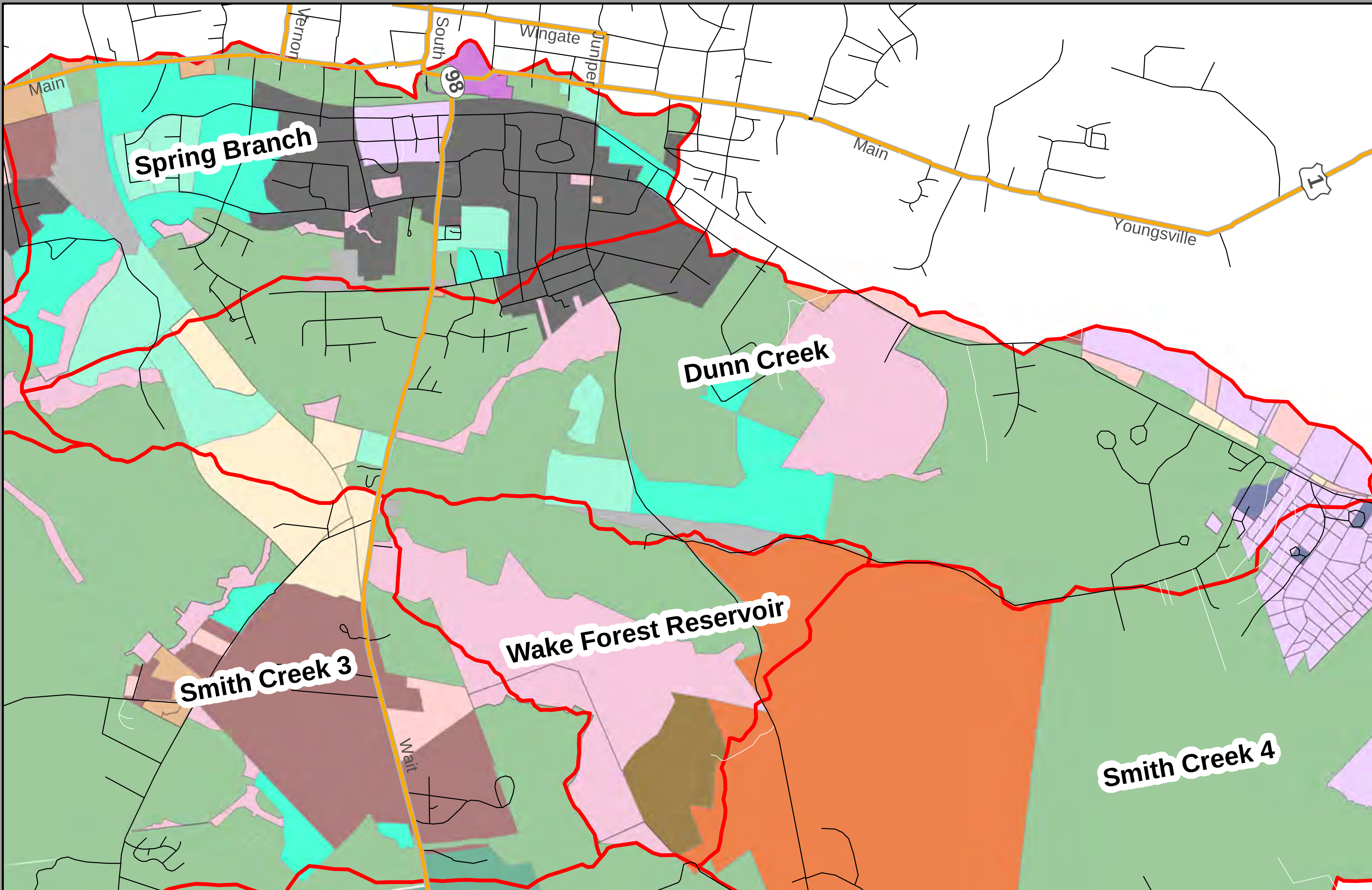

- Neighborhood Residential
- Office and Professional
- Open Space
- Residential
- Residential - Agriculture
- Residential Mixed Use
- Residential Watershed
- Residential and Planned Unit Development
- Rural Manufactured Home District
- Urban Residential
- Rurual Holding District
- Subwatersheds
- Commercial
- Commercial - Outlying
- General Business
- Highway Business
- Highway District
- Industrial
- Institutional Campus Development
- Neighborhood Business

Figure 59

Smith Creek Watershed Restoration Plan and Implementation Project Spring Branch, Dunn Creek, and Wake Forest Reservoir Zoning Map

0 500 1,000 2,000 Feet

1 in = 2,000 ft

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2.2.28 Wake Forest Reservoir Subwatershed

The Wake Forest Reservoir subwatershed is located in the central region of the Smith Creek watershed (Figure 2) in Wake County. This subwatershed has a drainage area of 469 acres, and is the smallest in size of the thirteen subwatersheds. It is composed primarily of the Wake Forest Reservoir along with two of its unnamed tributaries. The reservoir is approximately 50 acres in area with a perimeter of 15,955 linear feet. The unnamed tributaries to the Wake Forest Reservoir are first order streams with a combined total length of 3,729 linear feet.

Over 80 percent of the land use in the Wake Forest Reservoir subwatershed is forested; 60 percent is deciduous forest and 22 percent is evergreen forest. Impervious surfaces make up just one percent of this subwatershed. The reservoir, along with several smaller water bodies, make up 11 percent of the subwatershed. Just six percent of the subwatershed is herbaceous.

Figure 60. Wake Forest Reservoir Subwatershed Land Use Chart

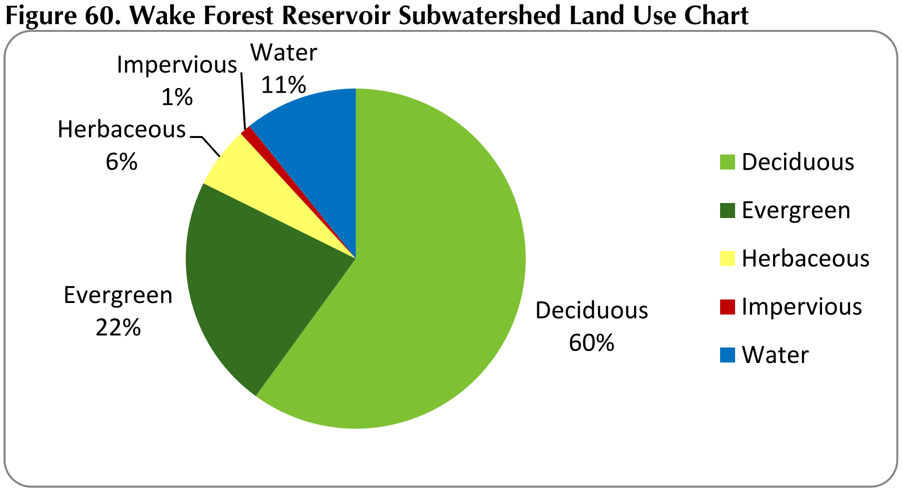
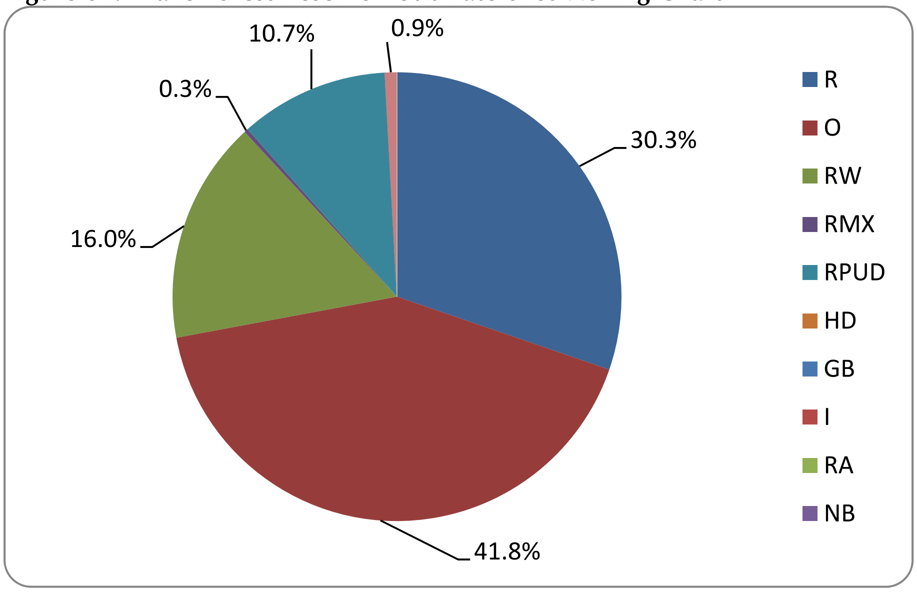
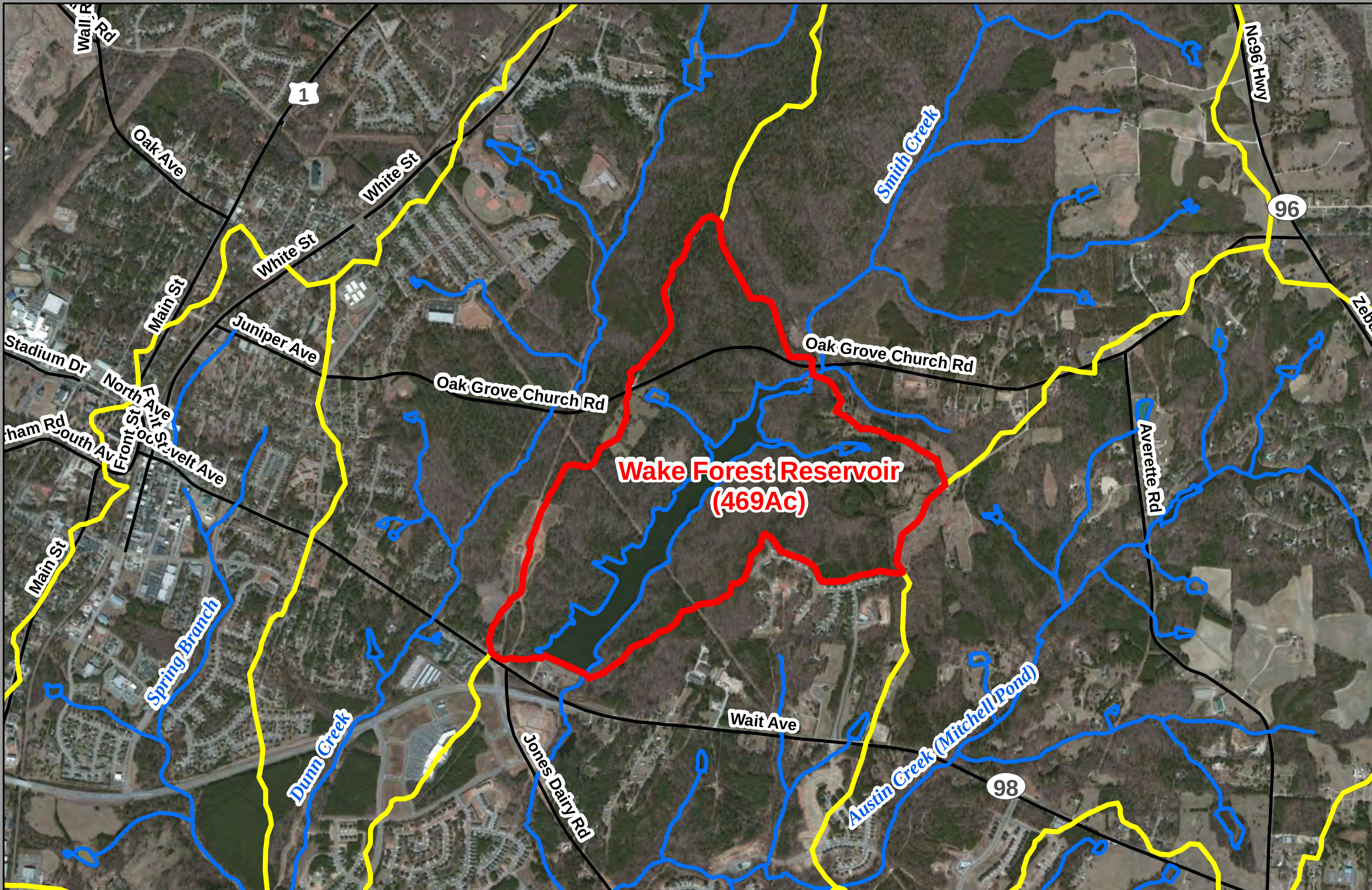


Figure 61. Wake Forest Reservoir Subwatershed Zoning Chart





Legend

- Wake Forest Reservoir Subwatershed
- Sub-Watershed Boundary
- Streams
- Roads

N W E S

Figure 62

Wake Forest Reservoir Subwatershed

0 500 1,000 2,000 Feet

1 inch = 2,000 feet

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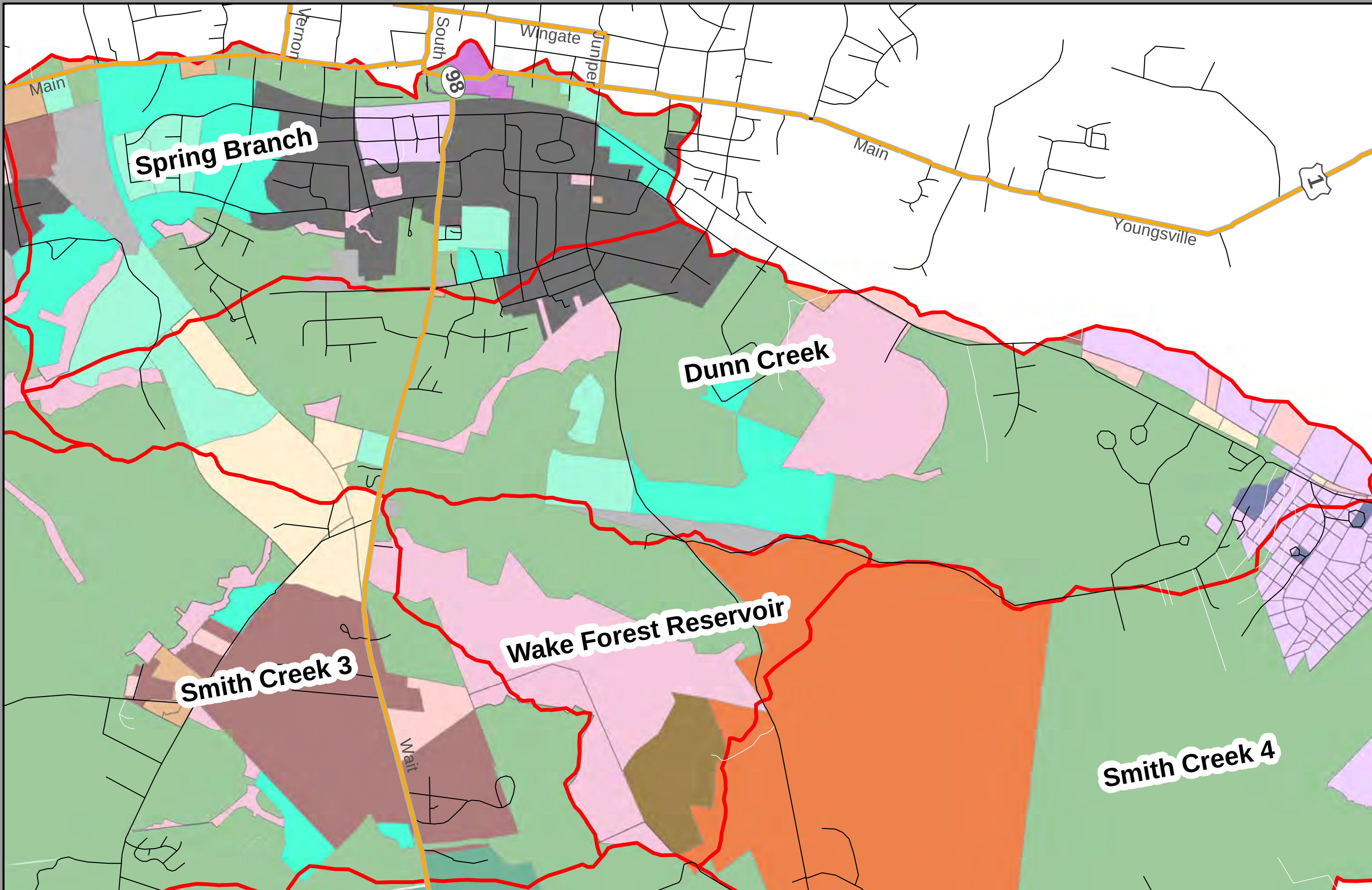

Neighborhood Residential
Office and Professional
Open Space
Residential
Residential - Agriculture
Residential Mixed Use
Residential Watershed
Residential and Planned Unit Development
Rural Manufactured Home District
Urban Residential
Rurual Holding District

Subwatersheds
Commercial
Commercial - Outlying
General Business
Highway Business
Highway District
Industrial
Institutional Campus Development
Neighborhood Business

Figure 63
Smith Creek Watershed Restoration Plan and Implementation Project
Spring Branch, Dunn Creek, and Wake Forest Reservoir
Zoning Map

0 500 1,000 2,000 Feet
1 in = 2,000 ft

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2.3 Restoration and Preservation Prioritization

Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) is a US Environmental Protection Agency (EPA) model that employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that could result from implementation of various stream restoration and best management practices (BMPs). It computes surface runoff; nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD_5); and sediment delivery based on various land uses and management practices.

STEPL was used to estimate reductions in sediment and nutrient loading resulting from the implementation of stream restoration and BMP projects identified during field evaluation efforts, including both formal stream walks using DWQ Habitat Assessment Field Data Sheets (Appendix C) and 'spot' evaluations at sites identified using aerial photography and land use data. In addition to load reductions, parcel ownership, project cost, and constructability were used to rank and prioritize projects.

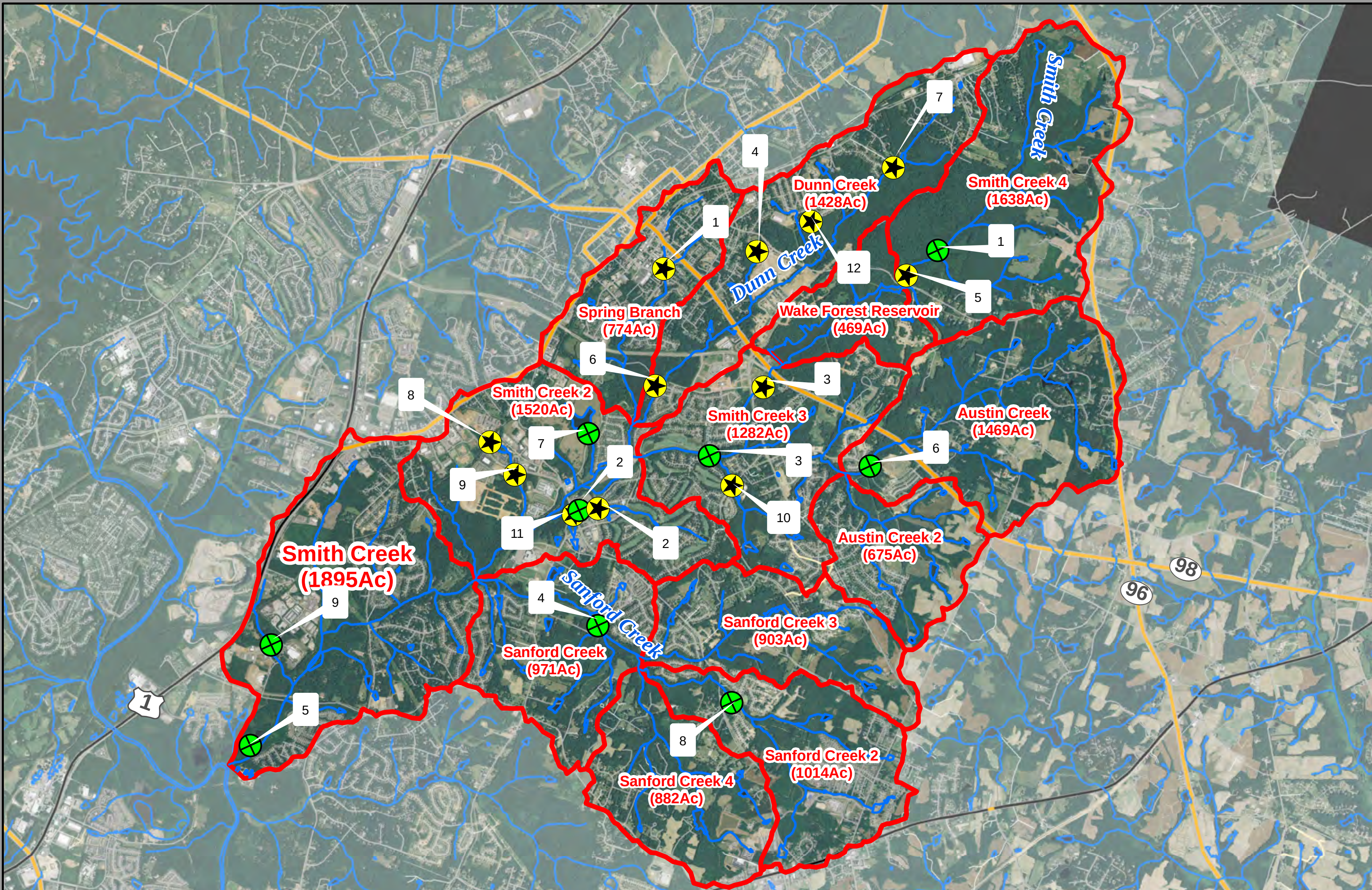
Identified and ranked restoration and preservation projects included:

Table 11. Prioritized Stream/Channel Restoration Sites

				----------Reductions (Total)----------				---Reductions (% catchment)---				
Rank	Site Name	Wake PIN	WF Owned	TN (lb/y)	TP (lb/y)	BOD (lb/y)	Sediment (t/y)	TN	TP	BOD	Sedi ment	Estimated Cost
1	Miller Park	1841509382	YES	176.20	67.84	352.40	95.76	8.69	19.10	4.71	66.91	$ 360,000
2	Hope Lutheran	1840608418	NO	141.05	54.30	282.10	76.66	6.27	14.24	3.36	59.40	$ 580,000
3	Joyner Lateral Dam	1850175500	NO	91.77	35.33	183.54	49.88	1.80	3.62	0.98	25.94	$ 100,000
4	Dam Failure at Alley Young	1841829179	NO	79.23	30.50	158.46	43.06	15.0 4	30.22	8.44	77.30	$ 140,000
5	Traditions	1851356014	YES	71.58	27.56	143.16	38.90	4.01	6.33	2.35	37.60	$ 720,000
6	Dunn Creek	1840752863	NO	28.63	11.02	57.26	15.56	0.30	0.73	0.15	6.45	$ 180,000
7	Sedgefield Park Dam	1851371218	YES	11.93	4.59	23.86	6.48	1.23	1.23	0.27	10.39	$ 30,000
8	Thales Academy RR	1840211551	NO	9.54	3.67	19.09	5.19	1.54	3.75	0.80	26.62	$ 80,000
9	Heritage Middle	1840301692	NO	8.14	3.13	16.27	4.42	0.44	1.09	0.23	9.38	$ 140,000
10	Franklin Academy	1850137022	NO	2.39	0.92	4.77	1.30	0.13	0.32	0.07	2.95	$ 12,000
11	Rogers Rd. Culvert	1749690660	NO	2.39	0.92	4.77	1.30	0.66	1.63	0.34	13.40	$ 20,000
12	Royal Mill Ave Gully	1851044195	NO	1.32	0.60	18.06	0.20	0.92	2.70	3.23	5.89	$ 20,000

Table 12. Prioritized Preservation Sites

Rank	Site Name	Wake PIN	Acres	$/acre
1	Traditions	1850044265	410.67	$ 55,619
2	Hope Lutheran	1840608418	22.73	$ 100,308
3	Heritage Lake	1850044265	12.07	$ 15,596
4	Sanford Creek	1749769436	14.03	$ 36,328
5	Smith/Neuse Floodplain	1738678968	91.68	$ 13,604
6	Austin Creek	1850663228	10.16	$ 10,000
7	Holding Village	1840458166	134.54	$ 199,716
8	Heritage Gates Dr.	1759542974	21.83	$ -
9	Unicon Beaver Impoundment	1739519535	32.13	$ 45,334



Legend

- Preservation
- Restoration
- Streams
- Sub-Watershed Boundary

Prioritization Rank

#

N W E S

<u>Figure</u> 64

Smith Creek Watershed Restoration Plan and Implementation Project Implementation Priority Map

0 0.25 0.5 1 Miles

1 in = 1 miles

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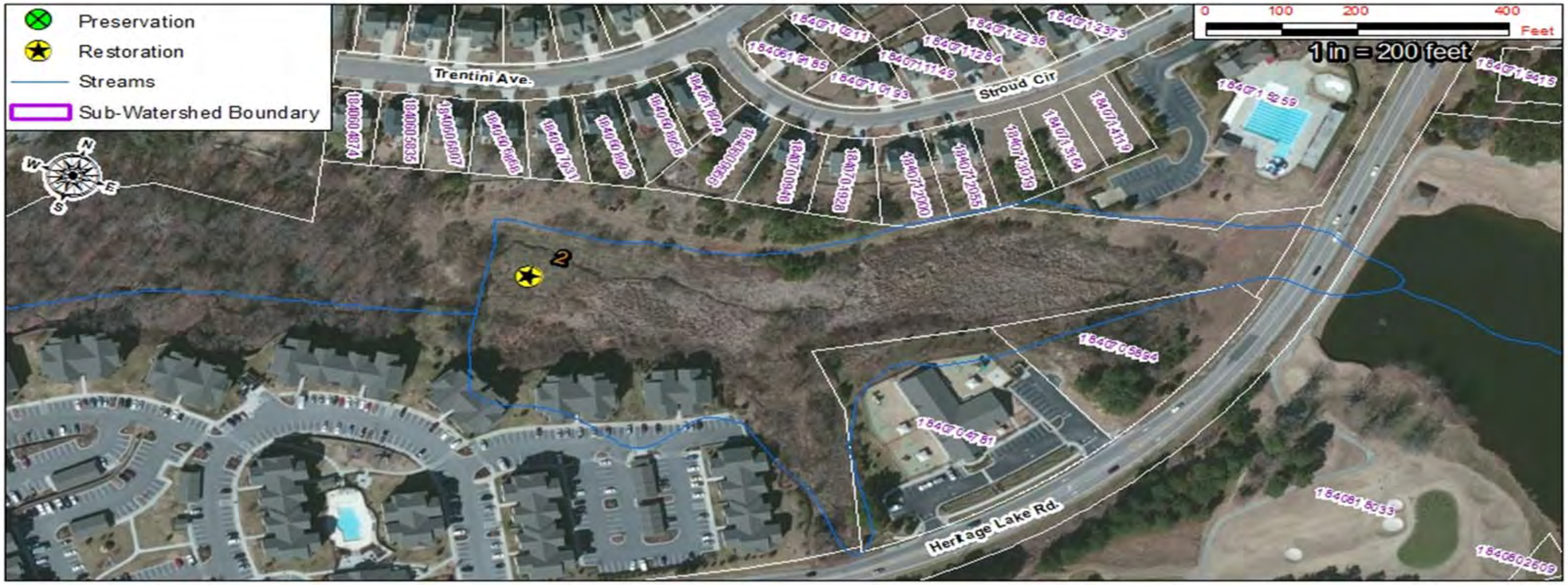
Restoration Priority 1: Miller Park Stream Restoration

Watershed Size (ac)	229
Watershed % Urban	99
Restoration Length (ft)	900
Estimated Cost	$360,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	176.20
Total Phosphorous (lb/yr)	67.84
Biological Oxygen Demand (lb/yr)	352.40
Sediment (ton/yr)	95.76


Restoration Priority 2: Hope Lutheran Stream Restoration

Watershed Size (ac)	265
Watershed % Urban	98%
Restoration Length (ft)	1450
Estimated Cost	$580,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	141.05
Total Phosphorous (lb/yr)	54.30
Biological Oxygen Demand (lb/yr)	282.10
Sediment (ton/yr)	76.66

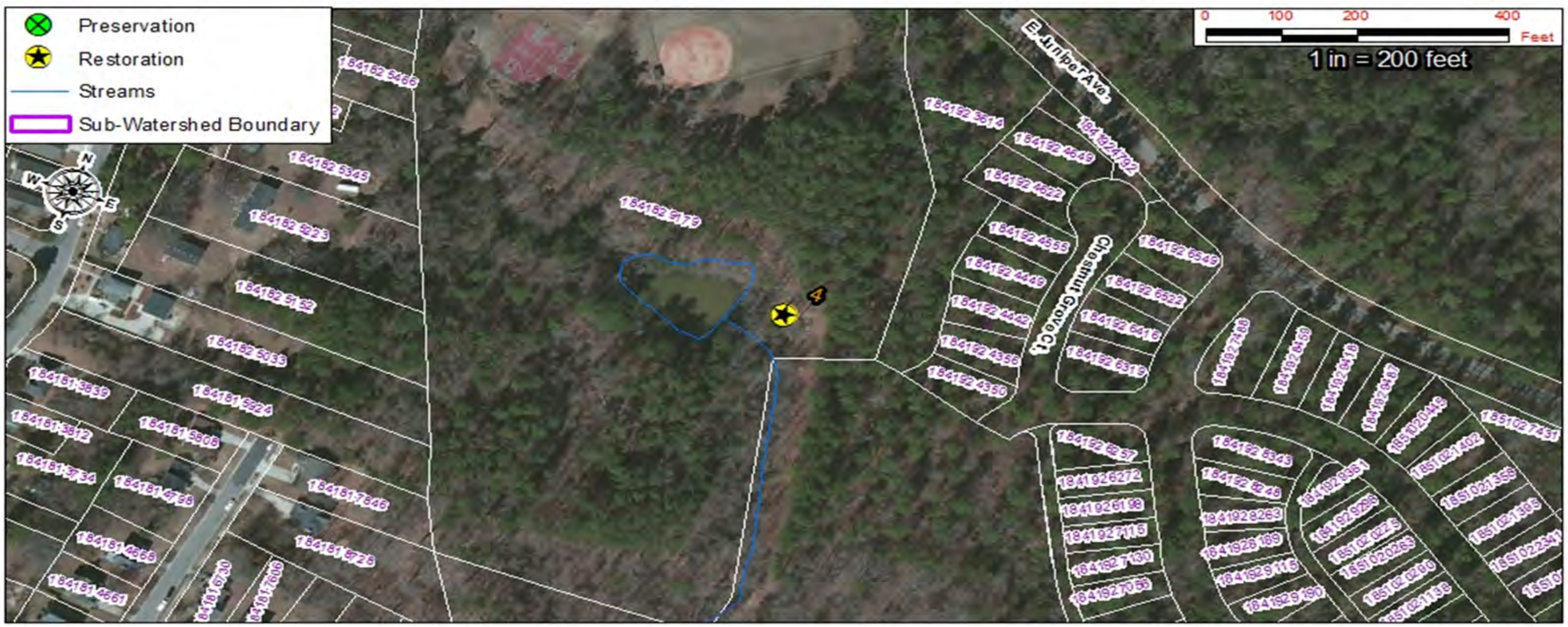


Restoration Priority 3: Joyner Lateral Dam Cut Stream Restoration

Watershed Size (ac)	2207
Watershed % Urban	25%
Restoration Length (ft)	250
Estimated Cost	$100,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	91.77
Total Phosphorous (lb/yr)	35.33
Biological Oxygen Demand (lb/yr)	183.54
Sediment (ton/yr)	49.88

Restoration Priority 4: Dam Failure at Alley Young Park

Watershed Size (ac)	59
Watershed % Urban	92%
Restoration Length (ft)	350
Estimated Cost	$140,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	79.23
Total Phosphorous (lb/yr)	30.50
Biological Oxygen Demand (lb/yr)	158.46
Sediment (ton/yr)	43.06



Restoration Priority 5: Traditions Stream Restoration

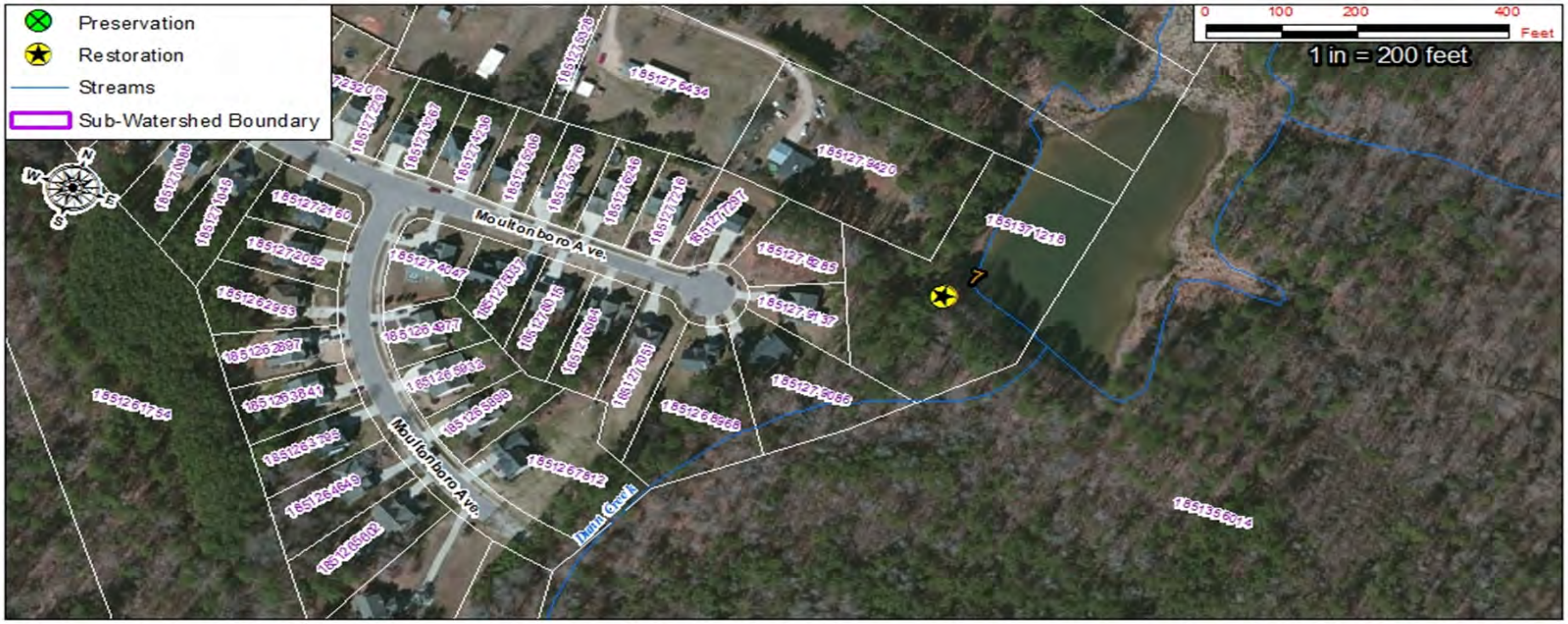
Watershed Size (ac)	1552
Watershed % Urban	10%
Restoration Length (ft)	1800
Estimated Cost	$720,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	71.58
Total Phosphorous (lb/yr)	27.56
Biological Oxygen Demand (lb/yr)	143.16
Sediment (ton/yr)	38.90

Restoration Priority 6: Dunn Creek Stream Restoration

Watershed Size (ac)	1388
Watershed % Urban	85%
Restoration Length (ft)	450
Estimated Cost	$180,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	28.63
Total Phosphorous (lb/yr)	11.02
Biological Oxygen Demand (lb/yr)	57.26
Sediment (ton/yr)	15.56

Restoration Priority 7: Sedgefield Park Dam Stream Restoration

Watershed Size (ac)	383
Watershed % Urban	73%
Restoration Length (ft)	75
Estimated Cost	$30,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	11.93
Total Phosphorous (lb/yr)	4.59
Biological Oxygen Demand (lb/yr)	23.86
Sediment (ton/yr)	6.48



Restoration Priority 8: Thales Academy RR Stream Restoration

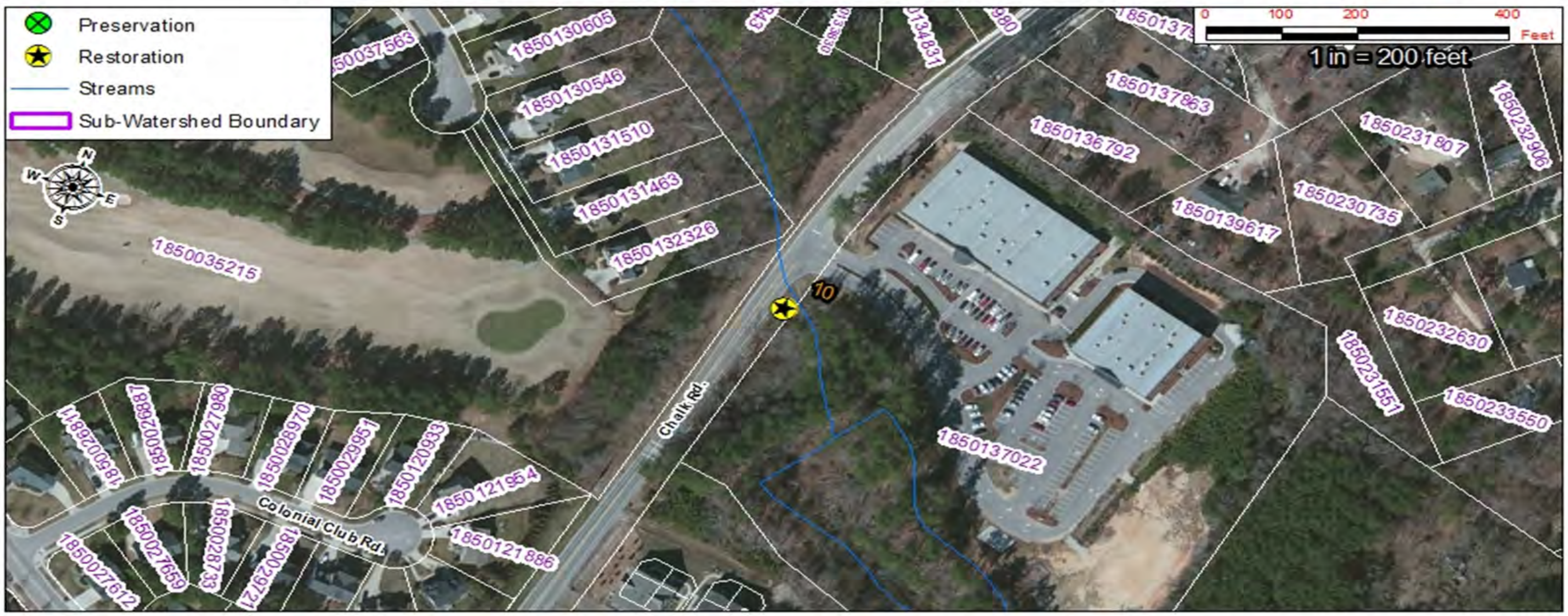
Watershed Size (ac)	75
Watershed % Urban	100%
Restoration Length (ft)	200
Estimated Cost	$80,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	9.54
Total Phosphorous (lb/yr)	3.67
Biological Oxygen Demand (lb/yr)	19.09
Sediment (ton/yr)	5.19

Restoration Priority 9: Heritage Middle School Stream Restoration

Watershed Size (ac)	228
Watershed % Urban	100%
Restoration Length (ft)	350
Estimated Cost	$140,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	8.14
Total Phosphorous (lb/yr)	3.13
Biological Oxygen Demand (lb/yr)	16.27
Sediment (ton/yr)	4.42

Restoration Priority 10: Franklin Academy Perched Culvert

Watershed Size (ac)	288
Watershed % Urban	75%
Restoration Length (ft)	30
Estimated Cost	$12,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	2.39
Total Phosphorous (lb/yr)	0.92
Biological Oxygen Demand (lb/yr)	4.77
Sediment (ton/yr)	1.30



Restoration Priority 11: Rogers Rd. Culvert Stream Restoration

Watershed Size (ac)	46
Watershed % Urban	95%
Restoration Length (ft)	50
Estimated Cost	$20,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	2.39
Total Phosphorous (lb/yr)	0.92
Biological Oxygen Demand (lb/yr)	4.77
Sediment (ton/yr)	1.30

Restoration Priority 12: Erosion at Royal Mill Ave Gully Restoration

Watershed Size (ac)	18
Watershed % Urban	100%
Restoration Length (ft)	100
Estimated Cost	$20,000
Estimated Load Reductions	
Total Nitrogen (lb/yr)	1.32
Total Phosphorous (lb/yr)	0.60
Biological Oxygen Demand (lb/yr)	18.06
Sediment (ton/yr)	0.20

Preservation Priority 1: Traditions

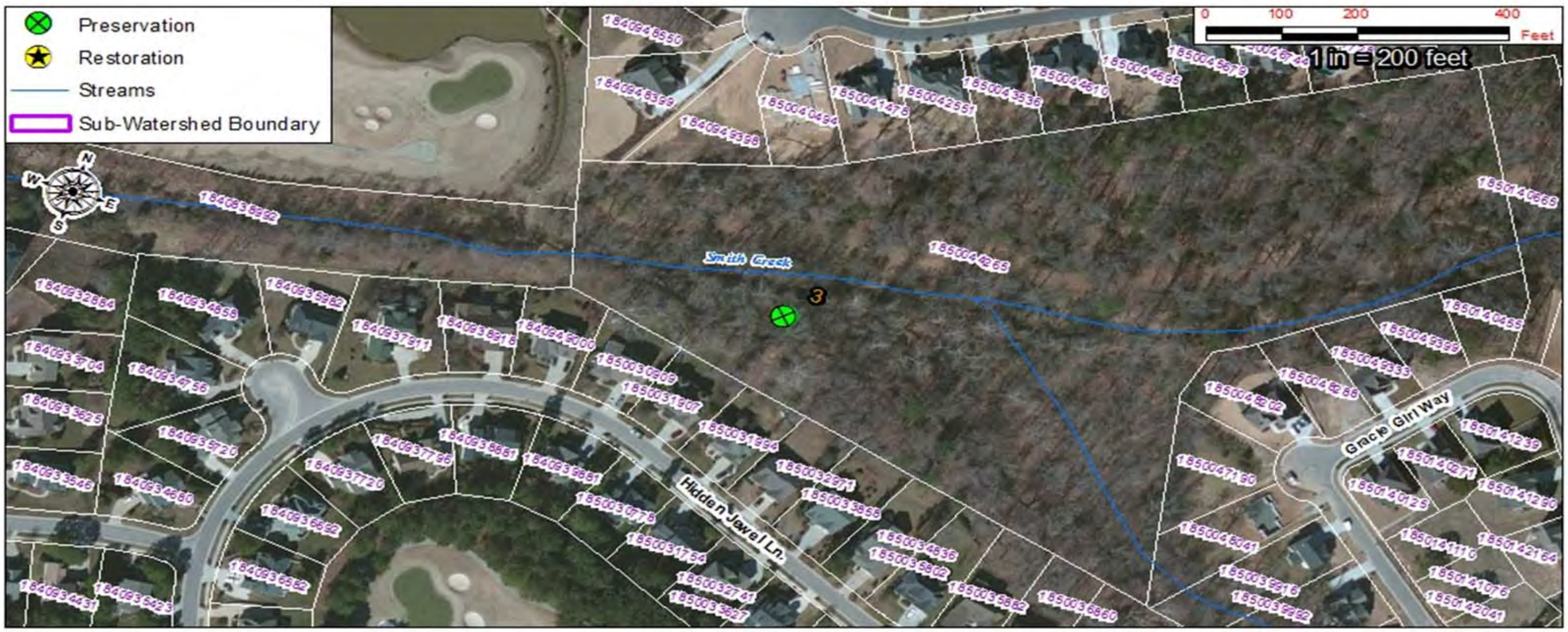
Watershed Size (ac)	1117
Watershed % Urban	20%
Acres	410.67
Wake Parcel ID	1851452306
Assessed Value/Acre	$55,619

Preservation Priority 2: Hope Lutheran

Watershed Size (ac)	293
Watershed % Urban	98%
Acres	4.75
Wake Parcel ID	1840608418
Assessed Value/Acre	$100,308

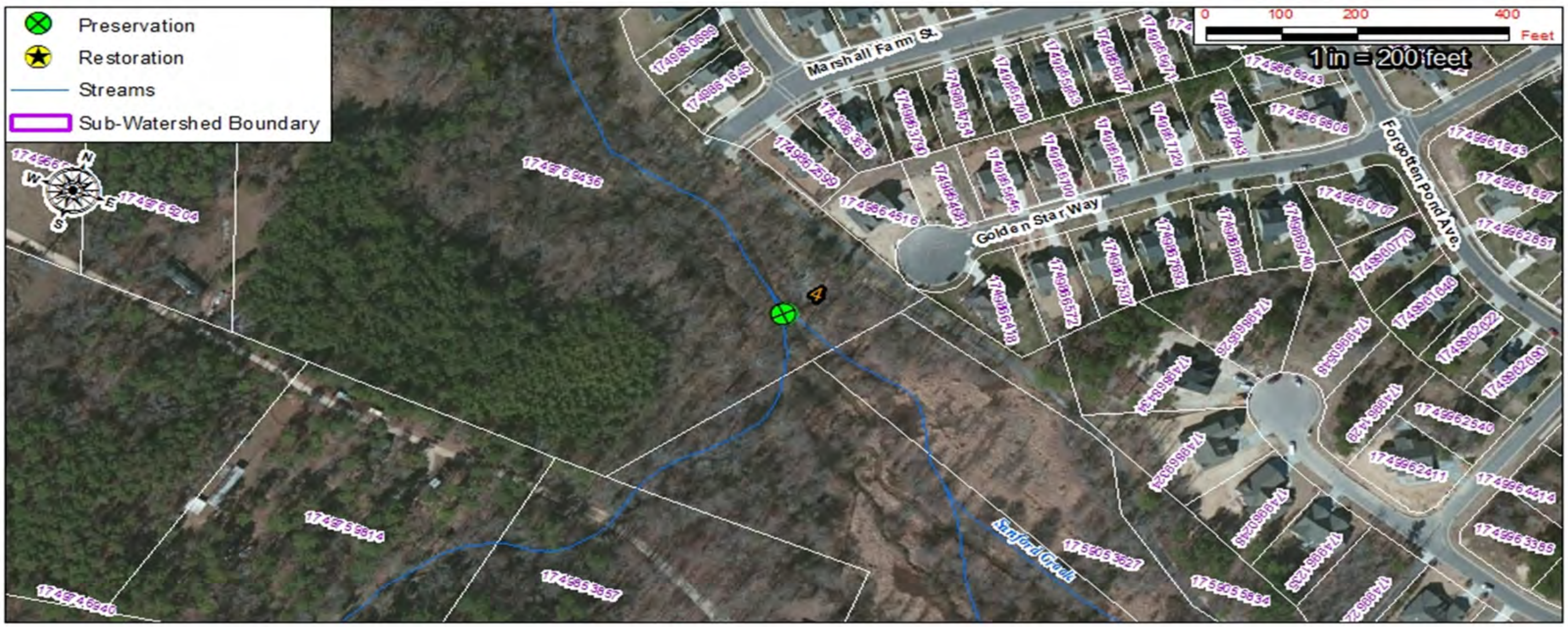
Preservation Priority 3: Heritage Lake

Watershed Size (ac)	5336
Watershed % Urban	50%
Acres	12.07
Wake Parcel ID	1850044265
Assessed Value/Acre	$15,595



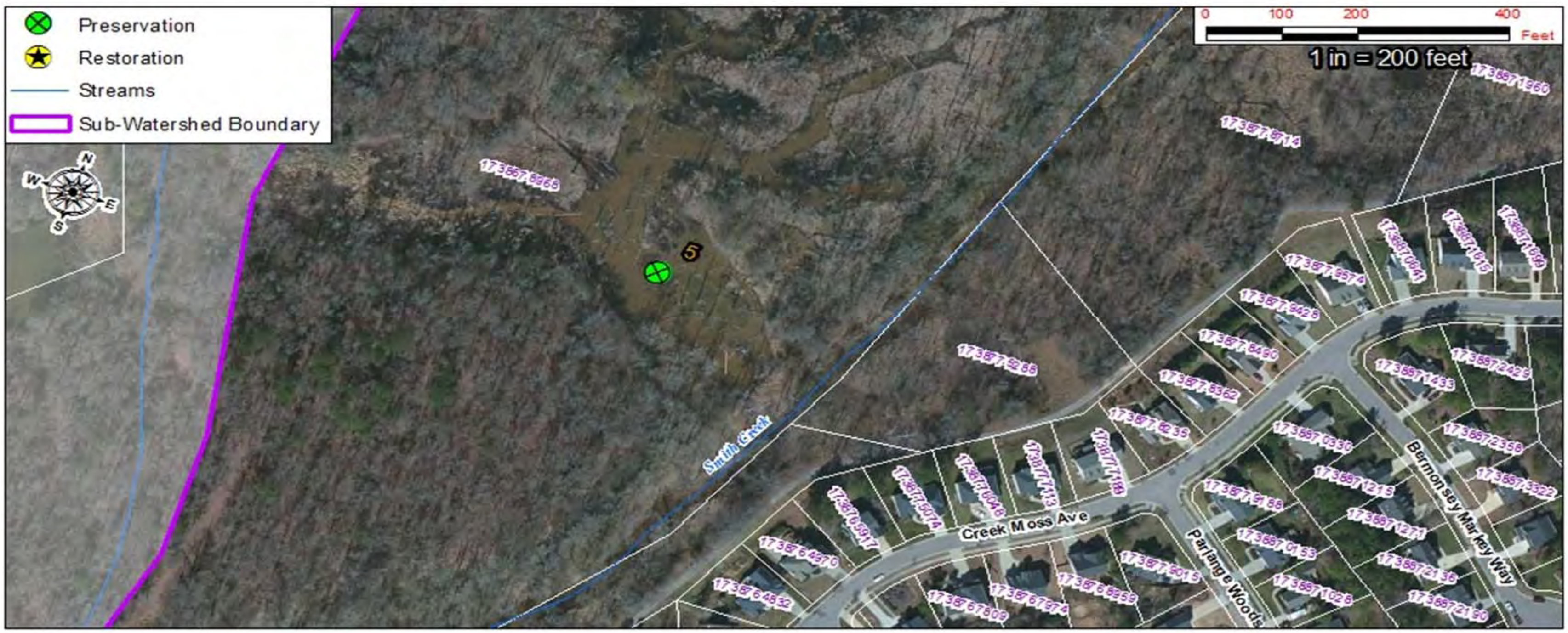
Preservation Priority 4: Sanford Creek

Watershed Size (ac)	3308
Watershed % Urban	90%
Acres	14.03
Wake Parcel ID	1749769436
Assessed Value/Acre	$36,328



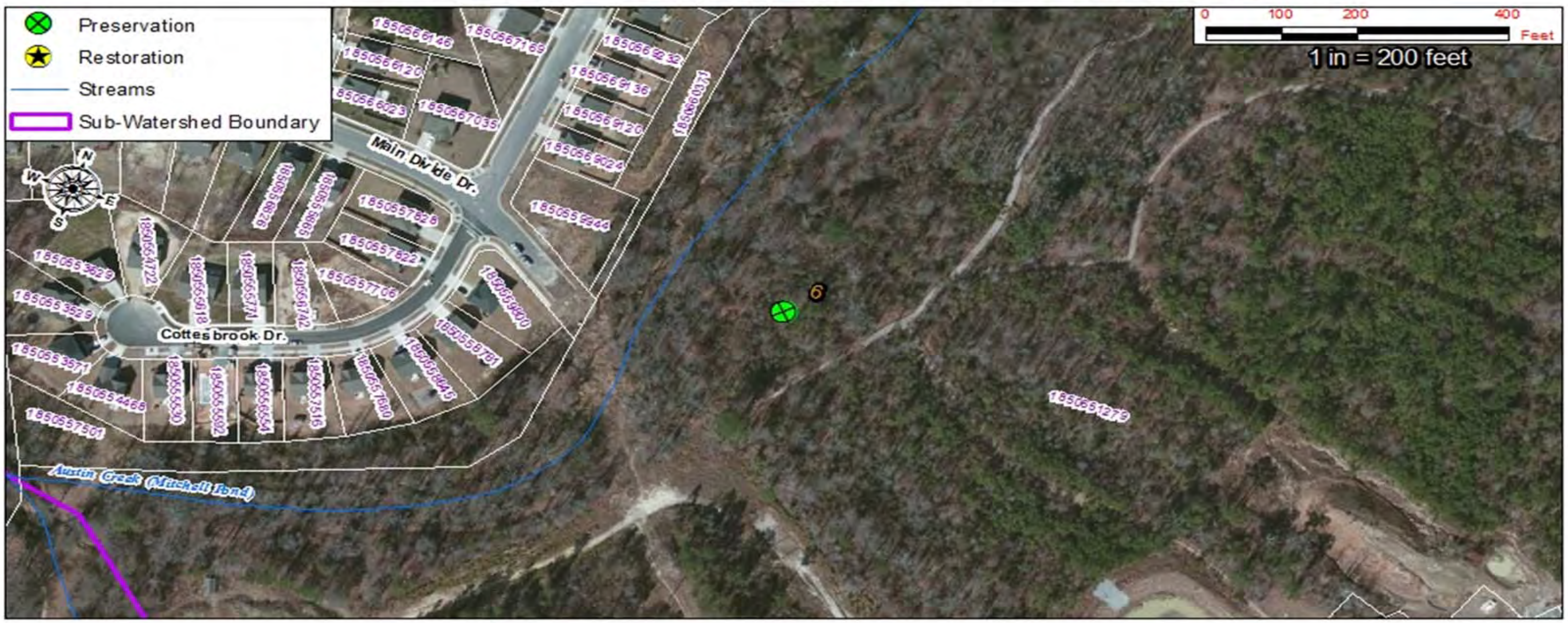
Preservation Priority 5: Smith/Neuse Floodplain

Watershed Size (ac)	14594
Watershed % Urban	90%
Acres	91.68
Wake Parcel ID	1738678968
Assessed Value/Acre	$13,604



Preservation Priority 6: Austin Creek

Watershed Size (ac)	1434
Watershed % Urban	67%
Acres	10.16
Wake Parcel ID	1850663228
Assessed Value/Acre	$10,000

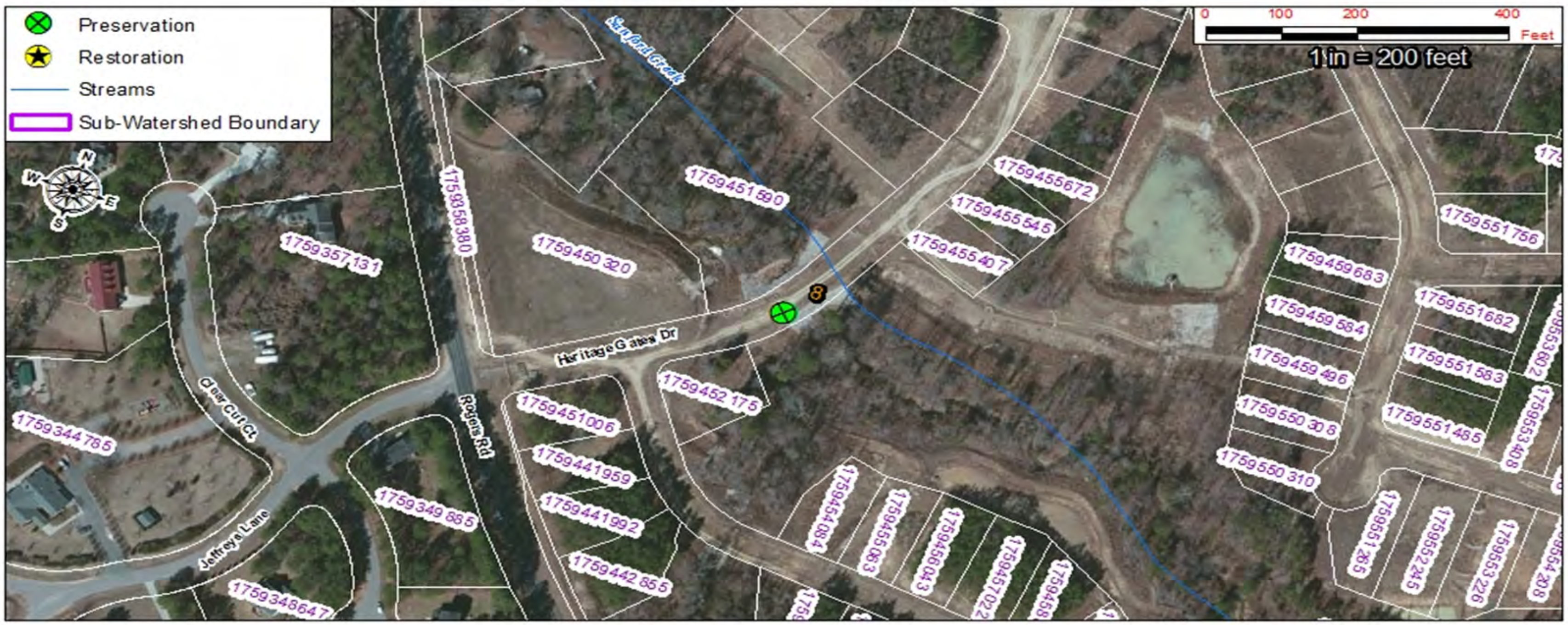


Preservation Priority 7: Holding Village

Watershed Size (ac)	122
Watershed % Urban	100%
Acres	3.25
Wake Parcel ID	1840458166
Assessed Value/Acre	$199,716

Preservation Priority 8: Heritage Gates Dr.

Watershed Size (ac)	936
Watershed % Urban	80%
Acres	21.83
Wake Parcel ID	1759542974
Assessed Value/Acre	$0.00

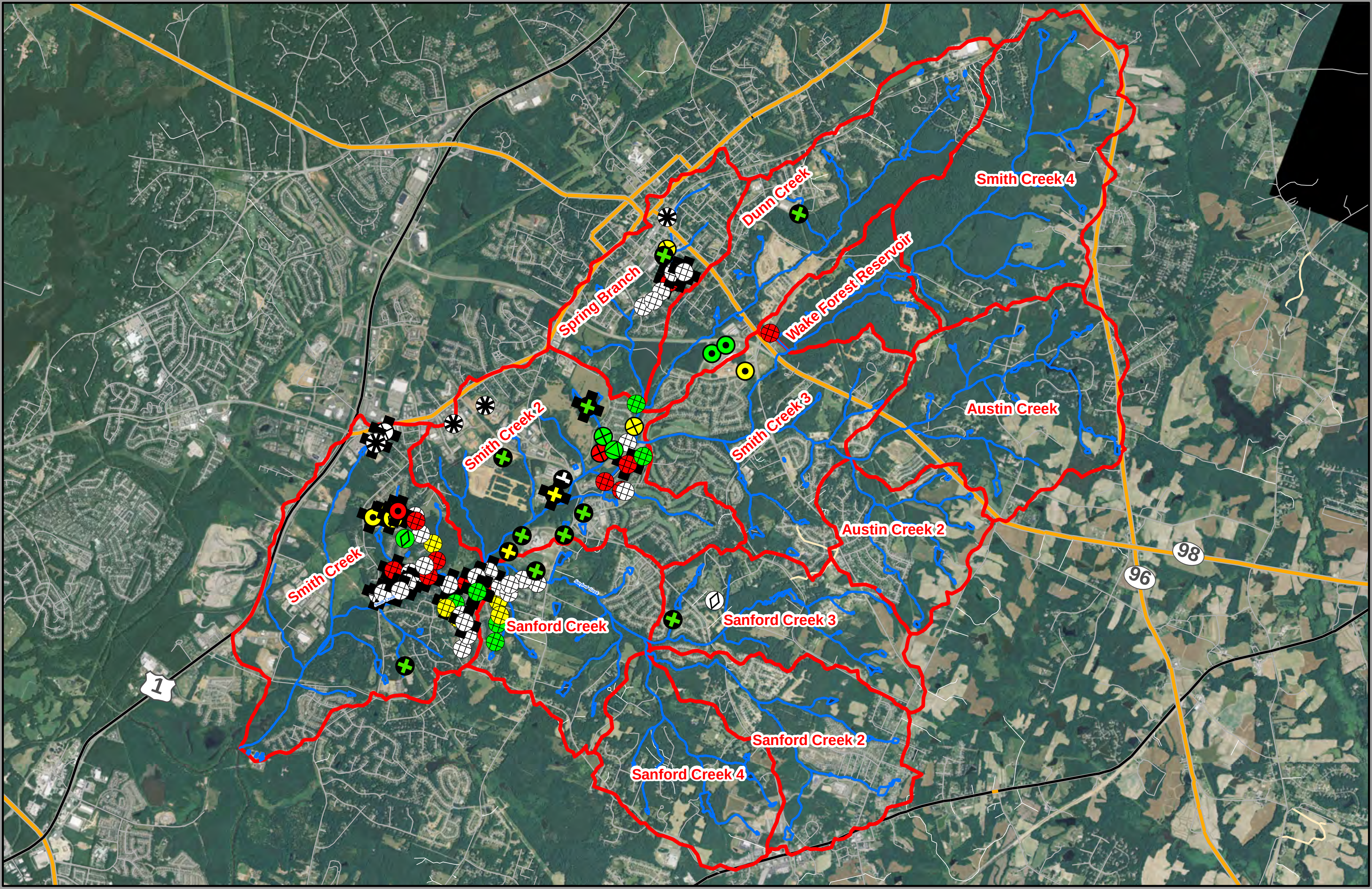


Preservation Priority 9: Unicon Beaver Impoundment

Watershed Size (ac)	90
Watershed % Urban	99%
Acres	18.0
Wake Parcel ID	1739519535
Assessed Value/Acre	$45,334

2.4 Stormwater BMPs

Using a GIS dataset provided by the Town, 87 stormwater best management practices (BMP) sites were evaluated in the field. Each site visit included analysis of BMP presence, condition, and functionality (Table 13). Photos were taken at all sites. Sketches were completed at 25 (Appendix D). BMP location, type and condition are shown in Figure 65.



Level Spreader
Scour Hole
Underground Detention
Wet Detention
Bio-Swale
Bioretention
Dry Pond
Condition: Good
Condition: Fair
Condition: Poor
Condition: N/A
Retrofit Necessary
Streams
Sub-Watershed Boundary

N
W
E
S

Figure 65

Smith Creek Watershed Restoration Plan and Implementation Project BMP Evaluation Map

0 0.25 0.5 1
Miles
1 in = 1 miles

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Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
22	level spreader	Poor	Yes	9408 WHITE CARRIAGE DR	No	Inspected	No	No level spreader present; Scour at 18-in outlet, replace rip rap'; Outfalls to low slope, 50 ft from stream
35	dry pond	Poor	Yes	9804 LIGON MILL RD	Yes	Inspected	Yes	dry pond with 7.5-ft 6-in dia riser; Pond severly damaged by heavy machinery; Needs regrading/replanting on at least half the banks, both inlet pipes are damaged
58	level spreader	Poor	Yes	1157 TRENTINI AVE	Yes	Inspected	Yes	One end broken down, leading to eroded channel; Needs repair
66	level spreader	Poor	Yes	400 DEACON RIDGE ST	Yes	Inspected	Yes	Rebuild/armor berm/spillway; Basically a small detention area
17	level spreader	Poor	Yes	9516 DUMAS CT	Yes	Inspected	Yes	6-in pvc may bypass pool, rip rap needs replaced; main 24-inch goes straight thru, 6-in pvc overflows into small riprap pool
5	level spreader	N/A	Yes	9205 DANSFORESHIRE WAY	No	Inspected	No	No level spreader present; 24" outlets to level ground
14	level spreader	N/A	Yes	1504 LAGERFELD WAY	No	Inspected	No	No level spreader present; outlets to flat area; Has rip rap pad
68	level spreader	N/A	Yes	546 ELM AVE	No	Inspected	No	No level spreader present; 15" RCP with rip rap pad 70' from stream, in grass, could retrofit as bioretention
19	level spreader	N/A	Yes	9401 PHILBECK LN	No	Inspected	No	No level spreader present; 15-inch Outlet onto floodplain; some rip rap; 100+ from stream
20	level spreader	N/A	Yes	9320 DOSS CT	No	Inspected	No	No level spreader present; 70-foot filter strip; small rip rap pool at 18-in outlet
21	level spreader	N/A	Yes	9400 BUGGY RUN CIR	No	Inspected	No	No level spreader present; Replace rip rap, clean out sediment; Energy dissipator with 50' filter strip

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
69	level spreader	N/A	Yes	518 ELM AVE	No	Inspected	No	No level spreader present; 18" RCP with rip rap in fenced corner, could retrofit as bioretention
18	level spreader	N/A	Yes	9425 PHILBECK LN	No	Inspected	No	No level spreader present; Outlet discharges onto flood plain; flat ground 40 feet from stream
77	level spreader	N/A	Yes	9312 GLAMIS CIR	No	Inspected	No	No level spreader present; Energy dissipator; rip rap channel on flat ground; good distance from stream
25	level spreader	N/A	Yes	9433 PHILBECK LN	No	Inspected	No	No level spreader present; 24-in RCP outfalls to floodplain 100 ft from stream
11	level spreader	N/A	Yes	9332 DANSFORESHIRE WAY	No	Inspected	No	No level spreader present; Energy dissipator; 6x30; rip rap channel on flat ground; 50 from stream
38	underground detention	N/A	Yes	1655 WAKE DR	Yes	Inspected	No	No underground detention found, but prime site for retrofit
39	bioretention	N/A	Yes	2121 S MAIN ST	No	Inspected	No	No bioretention present; Inlet only; Very small island, possible small bio retrofit, but not cost effective
12	level spreader	N/A	Yes	9321 BRAMDEN CT	No	Inspected	No	Behind fence; No level spreader present; Outlet over 50% obstructed'; Flat slope; good distance from stream
67	level spreader	N/A	Yes	209 DEACON RIDGE ST	No	Inspected	No	No level spreader present; 18" RCP with rip rap pad 40' from stream, in grassy area, could retrofit bioretention
15	level spreader	Good	Yes	9248 LINSLADE WAY	No	Inspected	Yes	No level spreader present; Energy dissipator; basically a rip rap channel
16	level spreader	Good	Yes	9252 LINSLADE WAY	No	Inspected	No	No level spreader present; Energy dissipator; basically a rip rap channel. not level spreader

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
48	wet detention	Good	Yes	234 FRIENDSHIP CHAPEL RD	No	Inspected	No	Farm pond, not BMP, no development, could be used as BMP if property developed in future
46	wet detention	Fair	Yes	3500 ROGERS RD	Yes	Inspected	Yes	No safety fence, some erosion; Add control structure and re-grade bottom to retrofit
34	scour hole	Fair	Yes	9616 STABLE POINT CIR	No	Inspected	No	No scour hole present; Downstream erosion15-in RCP outfalls to 30-ft filter strip, after which erosion begins
36	dry pond	Fair	Yes	2804 POMPEII PL	Yes	Inspected	Yes	dry pond with 7.5-ft 6-in dia riser; inlet scour, bank erosion, no safety fence; Need to expose outlet pipe, easy retrofit to wet detention with different outlet
37	dry pond	Fair	Yes	9804 PORTO FINO AVE	No	Inspected	Yes	Dry pond with 7 foot PVC riser; Expose outfall; remove spillway debris; Could be easily retrofitted as wet detention with different outlet structure, needs safety fence
9	level spreader	Fair	Yes	3533 SONG SPARROW DR	Yes	Inspected	Yes	Trees in berm; steep grade behind north end
26	level spreader	Fair	Yes	9301 PERINI CT	No	Inspected	Yes	Has overflow to small level spreader; Sediment; 18" main into jb with 12" weir, 6" overflow to level spreader/bioretention
60	level spreader	Poor	No	100 SPRINGTIME FIELDS LN	Yes	Inspected	Yes	Major scour underneath splitter box
31	level spreader	Poor	No	9628 WHITE CARRIAGE DR	No	Inspected	No	No level spreader present; Overgrown, replace rip rap, FES damaged; Energy dissipator 6x30, low slope, 15" RCP outfall, 30 ft to stream

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
28	level spreader	Poor	No	9500 WHITE CARRIAGE DR	No	Inspected	No	No level spreader present; Replace rip rap, channel erosion, pipe collapse; 18-in outlet to short rip rap channel that falls steeply to stream with heavy erosion
13	level spreader	Poor	No	9316 BRAMDEN CT	No	Inspected	No	No level spreader present; steep slope, close to stream; Slope below outlet has collapsed'; Slope needs maintenance, major erosion risk
55	level spreader	Poor	No	1085 TRENTINI AVE	No	Inspected	No	No level spreader present; Major erosion from outfall to stream; Energy dissipator, steep grade to stream
53	bioretention	Poor	No	1716 HERITAGE GARDEN ST	Yes	Inspected	Yes	Pipe damage, overgrown, full of lawn clippings
56	level spreader	Poor	No	853 STROUD CIR	No	Inspected	No	No level spreader present; 15" RCP 75% clogged; In woods, med slope, 75' to stream, very difficult access from street
27	level spreader	Poor	No	9300 DOSS CT	Yes	Inspected	Yes	Replace riprap, clean out sediment; Splitter box with weir diverts low flow to level spreader
41	underground detention	N/A	No	1839 S MAIN ST	No	Not Found	No	
64	level spreader	N/A	No	600 DEACON RIDGE ST	No	Inspected	No	No level spreader present; 24" RCP with rip rap 15 feet from stream
23	level spreader	N/A	No	2948 CARRIAGE MEADOWS DR	No	Inspected	No	No level spreader present; Replace rip rap, remove sediment; Energy dissipator not close to stream;18-in outlets to low slope channel
6	level spreader	N/A	No	9217 DANSFORESHIRE WAY	No	Inspected	No	No level spreader present; outlet too close to creek for level spreader

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
4	level spreader	N/A	No	9101 DANSFORESHIRE WAY	No	Inspected	No	No level spreader present; pipe outlets on ground
79	level spreader	N/A	No	1537 LINDENBERG SQ	No	Not Found	No	
65	level spreader	N/A	No	500 DEACON RIDGE ST	No	Inspected	No	No level spreader present; 15" RCP with rip rap 70' from stream
1	scour hole	N/A	No	5644 CLEARSPRINGS DR	No	Inspected	No	No scour hole present; 15" outfall far from stream in heavy vegetation
85	wet detention	N/A	No	3500 ROGERS RD	No	Difficult Access	Yes	Gated, need access from school/city; Large stormwater pond, not in original inventory file
78	level spreader	N/A	No	1517 LINDENBERG SQ	No	Not Found	No	
32	level spreader	N/A	No	2908 STEEPLE RUN DR	No	Difficult Access	No	No level spreader present; Inside fence
76	level spreader	N/A	No	1312 THORNY VINE CT	Yes	Not Found	No	
24	level spreader	N/A	No	2808 MARGOTS AVE	No	Not Found	No	
80	level spreader	N/A	No	3909 SONG SPARROW DR	No	Not Found	No	
81	level spreader	N/A	No	4021 SONG SPARROW DR	No	Not Found	No	
57	level spreader	N/A	No	910 SUGAR GAP RD	No	Inspected	No	No level spreader present; Scour at outfall, downstream erosion; Steep slope from 18" RCP outfall, 100-ft from stream
42	underground detention	N/A	No	1742 HERITAGE CENTER DR	No	Not Found	No	Area under construction, possible vault, but need more info

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
72	underground detention	N/A	No	102 N WHITE ST	No	Not Found	No	No underground detention found, need more info.
30	level spreader	N/A	No	9600 WHITE CARRIAGE DR	No	Inspected	No	No level spreader present; 25-ft rip rap channel with large drop to stream
3	level spreader	N/A	No	9029 DANSFORESHIRE WAY	No	Inspected	No	No level spreader present; pipe outlets on ground;
63	level spreader	N/A	No	628 DEACON RIDGE ST	No	Inspected	No	No level spreader present; 15" RCP with rip rap pad 20 ft from stream
51	level spreader	N/A	No	1121 HERITAGE GREENS DR	No	Difficult Access	Unknown	Behind fences, heavy vegetation
59	level spreader	Good	No	1185 TRENTINI AVE	Yes	Inspected	Yes	
73	level spreader	Good	No	9100 LINSLADE WAY	No	Inspected	Yes	
82	wet detention	Good	No	1941 HERITAGE BRANCH RD	Yes	Inspected	Yes	Veg in bottom may need replenishing
43	wet detention	Good	No	1150 FORESTVILLE RD	No	Inspected	Yes	Heavily vegetated
45	wet detention	Good	No	1150 FORESTVILLE RD	No	Inspected	Yes	Clean out trash rack; rip rap spillway at south end
86	wet detention	Good	No	1150 FORESTVILLE RD	No	Inspected	Yes	
47	wet detention	Good	No	900 FORESTVILLE RD	No	Difficult Access	Yes	Fenced restricted access; CMP riser, could not inspect inlets or riser due to restricted access
52	bio-swale	Good	No	1205 HERITAGE GREENS DR	Yes	Inspected	Yes	
54	bioretention	Good	No	1608 HERITAGE GARDEN ST	Yes	Inspected	Yes	Minor pipe damage

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
74	level spreader	Good	No	9132 LINSLADE WAY	Yes	Inspected	Yes	No inlet pipe, just sheet flow
61	dry pond	Good	No	914 GATEWAY COMMONS CIR	No	Inspected	Yes	24" Inlet beside Calvin Jones Highway
62	dry pond	Good	No	914 GATEWAY COMMONS CIR	No	Inspected	Yes	12" CHDPE inlet, 24" RCP outlet
10	level spreader	Good	No	9301 DANSFORESHIRE WAY	Yes	Inspected	Yes	
2	wet detention	Good	No	3229 BURLINGTON MILLS RD	Yes	Inspected	Yes	
33	scour hole	Good	No	2808 STIRRUP CT	No	Inspected	Yes	18-in outfall
70	wet detention	Good	No	225 S TAYLOR ST	Yes	Inspected	Yes	
49	level spreader	Good	No	948 CORAL BELL DR	Yes	Inspected	Yes	Minor erosion from yard to splitter box
0	wet detention	Good	No	4110 HERITAGE VIEW TRL	No	Inspected	Yes	Community pond, very nicely kept
40	wet detention	Good	No	648 FLAHERTY AVE	No	Inspected	Yes	
83	level spreader	Fair	No	3708 TANSLEY ST	No	Inspected	Yes	Very overgrow'; No inlet pipe; only sheet flow
44	wet detention	Fair	No	1150 FORESTVILLE RD	No	Inspected	Yes	Low water level; possible bad control
7	level spreader	Fair	No	3513 TRAWDEN DR	Yes	Inspected	Yes	Heavy vegetation
50	bioretention	Fair	No	1025 HERITAGE GREENS DR	Yes	Inspected	Yes	Replace mulch/veg, remove sediment

Table 13. BMP Evaluation Results

ID	BMP	Condition	Retrofit	Address	Sketch*	Status	BMP	Comments
8	level spreader	Fair	No	3525 SONG SPARROW DR	Yes	Inspected	Yes	Heavy veg; inlet pipe over 50% full;
87	dry pond	Fair	No	951 GATEWAY COMMONS CIR	No	Inspected	Yes	Control structure overgrown on 3 sides; Not in original inventory file
75	level spreader	Fair	No	3716 ANDOVERSFORD CT	No	Inspected	Yes	Inlet 50% obstructed, heavy vegetation
71	bioretention	Fair	No	225 S TAYLOR ST	Yes	Inspected	Yes	Scour at outlet, some cleanouts need replaced
29	level spreader	Fair	No	9528 WHITE CARRIAGE DR	No	Inspected	No	No level spreader present; FES has minor damage, replace rip rap; 18-in outfall to 15-ft flat rip rap channel that then falls steeply to stream
84	level spreader	Fair	No	9140 LINSLADE WAY	No	Inspected	Yes	Very overgrown; No inlet pipe, only sheet flow

*Appendix D

2.5 Stakeholder Involvement

The Town of Wake Forest has dedicated 1,000 hours and $84,000 in kind to provide over 62,000 contact hours for watershed environmental education during the Smith Creek Watershed Project. The Town obtained a small grant from SEEA in the amount of $4,425 to kick off a new Adopt a Stream Program. The goals of the program were to establish a monitoring program to track project progress; educate citizens about watershed ecology, stream buffers, floodplains, wetland benefits, point and non-point source pollution; and develop an adopt a stream program where citizens care for stream reaches by conducting quarterly clean ups, physical, biological, and chemical monitoring, bank stabilization, and stream enhancement via live stake plantings.

In addition to the Adopt a Stream Program, the Town held regular public meetings and educational events to solicit public input into the Watershed Plan's goals, as well as keep stakeholders abreast of the project's findings.

2.5.1 Public Meetings

On 7 March 2013 Town Assistant Engineer Holly Miller, PE and WK Dickson Senior Project Manager Ward Marotti held a public introductory meeting at Town Hall to summarize the results of the preliminary watershed evaluation and request input on the creation of water quality goals. The meeting began with a slide presentation describing existing conditions in the watershed, the 303(d) impairment listing, benthic macroinvertebrates, recent and planned development, EEP stream restoration projects, erosion and sediment control permits, the Town's existing and planned greenway system, and the Watershed Plan's tasks and implementation schedule.

Attendees included representatives from; the Town's business/greenway and environmental education advisory boards, the City of Raleigh, NC Division of Mitigation Services (formerly the Ecosystem Enhancement Program), the NC Department of Environmental Quality Division of Water Resources (formerly the Department of Environment and Natural Resources Division of Water Quality), the Neuse Riverkeeper, the Town's Mayor, Franklin County Soil and Water Conservation Service, home owners, environmental/engineering consultants (3E, Entrix, and Baker), Some of the primary watershed concerns discussed during the meeting included:

1. Development pressure;
2. Erosion and sedimentation;
3. Riparian buffers;
4. Greenways;
5. Stakeholder involvement;
6. Invasive species; and

7. Wake Forest Reservoir.

Subsequent public informational meetings and educational events included:

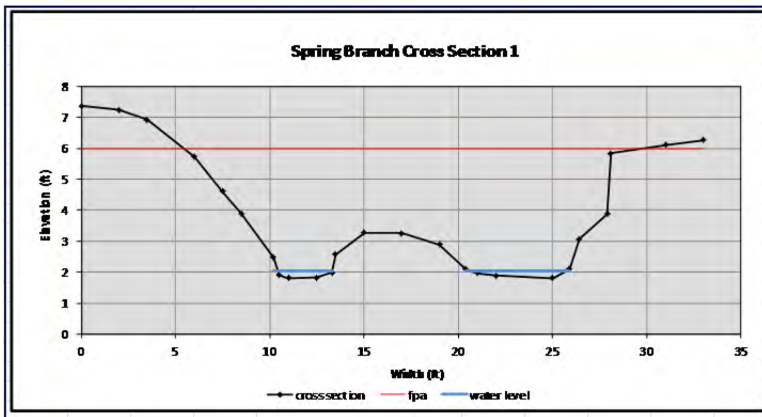
4 May 2013 (Saturday)
Meet in the Street: public educational booth with interactive watershed model and benthic macroinvertebrate sampling stations.

Meet in the Street: Watershed Model

Meet in the Street: Benthic Macroinvertebrates

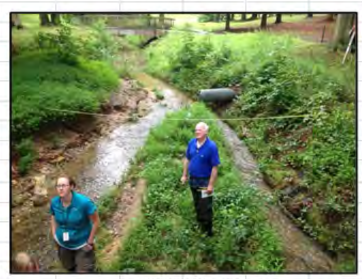
13 July 2013

Streams, Buffers, and Floodplains 101: public educational event with classroom and field lessons.



Summary Data	
Parameters	2013
Bankfull Cross Section Area (ft^2)	26.3
Bankfull Width (ft)	19.4
Bankfull Mean Depth (ft)	1.4
Bankfull Max Depth (ft)	2.1
Width/Depth Ratio	14.3
Entrenchment Ratio	1.2

Looking upstream.



Looking downstream.

Geomorphologic data collection

17 July 2013
Public Meeting/Project Update

26 July 2013
Meeting with Town of Rolesville Staff: discussion of the Watershed Plan process and goals.

30 October 2013
Public Meeting/Project Update

16 August 2014
Benthic Macroinvertebrate Habitat Enhancement Workshop

The education-focused event discussed land use and its impacts to water quality, aquatic habitat and biological diversity. Following the 'lecture' component, habitat enhancement was completed in Sanford Creek at permanent benthic sampling station SA (Figure 10), using various methods, including the securing of woody debris and leaf packs. In November, and again in March, after the initial habitat enhancements were complete, diverse benthic populations were collected from the 1S1 Site (Figure 11), and relocated into the enhanced habitats. The ultimate goal is to re-establish a diverse benthic population, which will help document improved water quality and support the removal of Smith Creek from the 303(d) impaired waters list.

One of these events piqued the interest of a high school student preparing to formulate his Eagle Scout project. The young man approached the Town after the event, requesting the opportunity to continue the project. The Town approved the project and in July 2015, he and several scouts from his troop and friends assisted with continuing the habitat enhancement project.

In July 2015, WK Dickson again collected data from the three monitoring sites. The results were encouraging at the Sanford Creek enhancement site. As detailed above, while not significant enough to change the 2014 Good-Fair rating results, increases to diversity through the presence of species less tolerant of poor water quality were obvious. The hope is that ongoing monitoring of the site will continue to document increased diversity and assist in the removal of Smith Creek from the 303(d) list.

Benthic identification

Benthic field collection

Benthic habitat enhancement

25 July 2015

Benthic Macroinvertebrate Habitat Enhancement Workshop: Eagle Scout Project

As noted above, following the 16 August 2014 benthic workshop, an attendee requested to participate in further efforts as part of his Boy Scouts of America Eagle Scout Service Project. The Scout provided his application and request for support documentation to WK Dickson and the Town. Upon completion, he submitted his application, and was approved to proceed by the Occoneechee Council. After the project was completed, he submitted the necessary documentation and anticipates being awarded his Eagle Scout Badge in Spring 2016.

As a result of the project's innovative integration of science, engineering and public involvement/education, it was awarded an American Council of Engineering Companies of North Carolina Engineering Excellence Award on 5 November 2015. WK Dickson, the Town of Wake Forest and the Scout accepted the award together.

Benthic Field Collection/ID

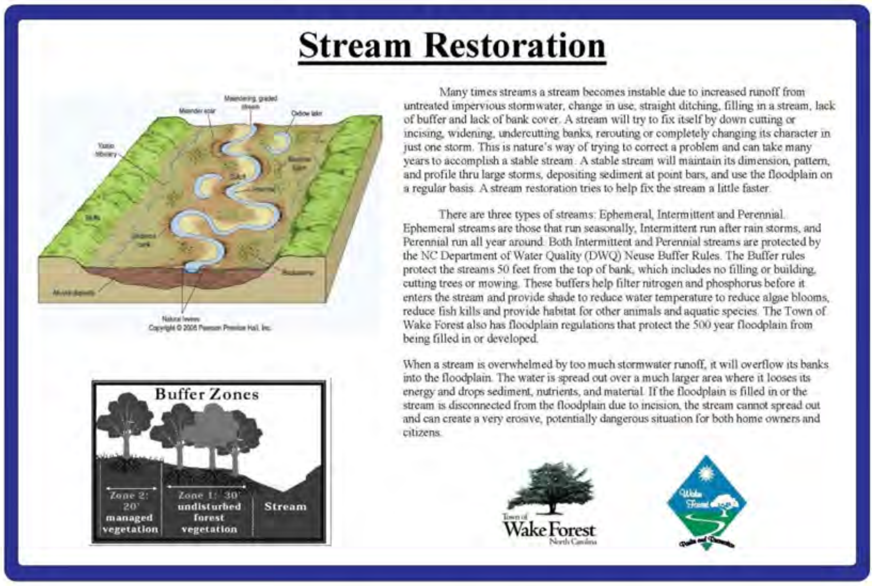
Benthic habitat enhancement

Engineering Excellence Awards Ceremony
(WK Dickson, Town of Wake Forest, Eagle Scout)

27 January 2016
Final Public Meeting

Additional information re: public involvement is available in Appendix E (319 Quarterly Reports).

In addition to the public meetings and direct community involvement, the Town has invested heavily in educational signage throughout its parks and open spaces. The plan to continue and expand this effort as additional water quality projects are completed on publically accessible lands.



Stream Restoration
Many times streams a stream becomes instable due to increased runoff from untreated impervious stormwater, change in use, straight ditching, filling in a stream, lack of buffer and lack of bank cover. A stream will try to fix itself by down cutting or incising, widening, undercutting banks, rerouting or completely changing its character in just one storm. This is nature's way of trying to correct a problem and can take many years to accomplish a stable stream. A stable stream will maintain its dimension, pattern, and profile thru large storms, depositing sediment at point bars, and use the floodplain on a regular basis. A stream restoration tries to help fix the stream a little faster.
There are three types of streams: Ephemeral, Intermittent and Perennial. Ephemeral streams are those that run seasonally, Intermittent run after rain storms, and Perennial run all year around. Both Intermittent and Perennial streams are protected by the NC Department of Water Quality (DWQ) Neuse Buffer Rules. The Buffer rules protect the streams 50 feet from the top of bank, which includes no filling or building, cutting trees or mowing. These buffers help filter nitrogen and phosphorus before it enters the stream and provide shade to reduce water temperature to reduce algae blooms, reduce fish kills and provide habitat for other animals and aquatic species. The Town of Wake Forest also has floodplain regulations that protect the 500 year floodplain from being filled in or developed.
When a stream is overwhelmed by too much stormwater runoff, it will overflow its banks into the floodplain. The water is spread out over a much larger area where it looses its energy and drops sediment, nutrients, and material. If the floodplain is filled in or the stream is disconnected from the floodplain due to incision, the stream cannot spread out and can create a very erosive, potentially dangerous situation for both home owners and citizens.
Buffer Zones
Zone 2: 20' managed vegetation
Zone 1: 30' undisturbed forest vegetation
Stream
Town of Wake Forest North Carolina

Stream Restoration Design:
Stream restorations are engineered and built to mimic the natural system with series of step pools, grade control riffles, runs, pools, cross vanes, and J hooks to stabilize the stream bed and keep it from eroding. The banks are seeded and then covered with a biodegradable coconut matting, live stakes are hammered in the bank slope and bare root trees (sticks) are planted at the top of bank. The species include river birch and black willow trees which will grow fast in this wet environment. They also will help stabilize the bank, provide shade and habitat.
Black Willow
Southern Red Oak
high flow
intermediate flow
low flow
water surface
A
riffle
pool
B
thalweg
Pool run riffle sequence (above)
Wake Forest

Stormwater Wetland

Picture: NCDENR BMP Manual page 9.5 figure 9-3, 9.19

A stormwater wetland is a water quality device that is used to treat developed areas for increased amounts of Total Nitrogen, Total Phosphorus, and Total Suspended Solids by utilizing plants and microbes. A typical wetland can reduce amounts of TN by 40%, TP by 35% and TSS by 85%.

The wetland consists of deep pools, shallow water, shallow land, and upland areas. The water moves thru the system in a sinusoidal pattern to achieve the longest contact time possible with the plants and microbes. Water depths vary but can be as shallow as 3 inches and as deep as 36 inches. Constructed stormwater wetlands have several different types of non-invasive plants that help treat the Nitrogen and Phosphorus. These plants act as pollution filters. A constructed wetland is one of the most efficient Best Management Practice's (BMP). These plants can make the wetland a very attractive landscape feature. Cattails are not permitted and can cause habitat for mosquito breeding. Water should drain in all areas except the deep pools in 2-5 days. The deep pools contain gambusia known as "mosquito fish" which feed on the mosquito larvae.

Common Problems:

1. Mosquitoes
2. Worries about drowning
3. Standing Water for more than 2-5 days

Solutions:

1. Remove cattails, add gambusia fish, add dragonfly attracting plants
2. Education and/or fence
3. Check orifice inlet, maintenance

Town of Wake Forest North Carolina

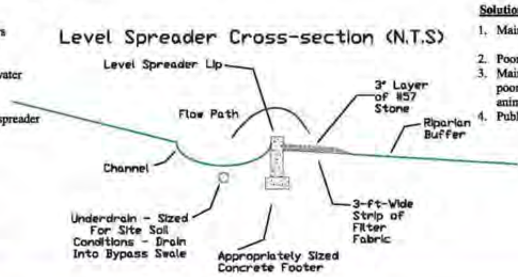
Level Spreader

Picture: NCDENR BMP Manual page 8.2 and 8.6

Level spreaders are linear water quality measures that receive water from storm pipes. Water enters the level spreader and is dispersed along a grassed swale. As the water rises in the level spreader ditch it is forced over a level concrete lip creating a uniform flow that is non-erosive and mimics a natural system. There is an underdrain installed below the ditch to allow water to infiltrate from the level spreader into the soil, into the pipe and out of the system so water does not stand in the ditch and create a standing water problem.

Common Problems:

1. Filling in level spreaders (human and natural)
2. Not being level
3. Not draining/standing water (after 48 hours)
4. Direct ditching of level spreader



Solutions:

1. Maintenance and education
2. Poor construction, settling, piping
3. Maintenance, clogged underdrain, poor soils, high water table, animals
4. Public education

Town of Wake Forest North Carolina

2.5.2 Adopt a Stream Program

The Town of Wake Forest's Adopt-a-Stream Program was created in 2013 to improve and foster environmental stewardship among all its citizens by giving them ownership in the wellbeing of the Town's watersheds. The program has utilized the Community Projects model and has focused on matching groups with their local watershed area. The Town provided volunteers with information, workshops, training, and resources to create a plan to improve the area's health. Once a group developed a plan, they were given the necessary tools, personal protective equipment, and professional help to accomplish it. Adopt-a-Stream groups will continue evaluating the health and wellbeing of the streams and generate usable information on the success of their efforts well after the grant is completed. The Town's hopes that the Adopt-a-Stream Program will further the EPA's Protect America's Waters Environmental Priority by removing one or more of Wake Forest's streams from the North Carolina 303(d) list of impaired waterways and thereby improving the habitat of aquatic life as well as ensuring the citizens of Wake County and the entire Neuse River Basin have safe and clean water. In addition, Wake Forest intends for the program to foster a trend of citizen ownership. Through education and empowerment, the Adopt-a-Stream Program has the potential to catalyze other citizen lead initiatives, not only with streams, but also in community pollution control, air quality, and safe chemical disposal practices.

The Town of Wake Forest has developed an Adopt-a-Stream Program though announcements on the Town's website, Facebook, Twitter, e-alerts, a Town of Wake Forest new smart phone app, information sessions, handouts/fliers, and ads on The Town's local television channel 10. Through these efforts, the Town has built interest in the Program while simultaneously educating the public on ways to reduce pollution and runoff into local streams. This advertising campaign has presented citizens with the awareness level education needed to begin the process of reducing the amount of nitrates and phosphorus in the Town's waterways.

Once volunteer groups signed up, the Town provided starter workshops covering the basics of developing a plan for stream health as well as safety concerns and any limits relating to private property access. The groups were then be given freedom to personalize and schedule implementation dates for their plan as well as choose parts of the plans focus. Each plan requires one stream cleanup day a year as well as a choice of one or more additional activates. Each group can adopt a segment of stream for a minimum of one year. These activates allowed citizens of various skills and interests to participate. Senior citizens and those with certain physical disabilities may chose to use the Town's YSI Professional Plus meter to periodically monitor streams. Young children may choose to analyze stream health by catching and counting the number of macro invertebrates in the Town's waterways. High school students and those who enjoy hands on work may chose to install brush mattresses and live staking to reinforce stream banks and reestablish riparian buffers. All groups were given the information to choose where they can personally make the largest impact through the various projects on local waterways.

Once a group had the chance to understand and design their own plan for revitalizing their stream, they were given the chance to implement their plan. Through the efforts of volunteer monitoring groups, long term information on stream health will be provided back to the volunteers with the intention of allowing them to see the results of their work or adjust their plans to ensure results are seen in the near future. The efforts of these groups will create habitats for water insects and other aquatic life to thrive.

Multiple training sessions were held to introduce volunteers to water quality monitoring techniques and need for testing. Groups included families, businesses, Girl Scout and Boy Scout Troops, neighboring municipality of Rolesville, school groups, and church groups. Maps with testing locations were shown and informative handouts were given to each participant for further investigation. Water Quality data was collected with LaMotte Low Cost Water Quality kits. Each training session included review and sample testing of desired parameters: dissolved oxygen, nitrogen, phosphorus, pH, temperature in degrees Celsius, and turbidity. Each parameter was discussed, acceptable range, units of measure (mL, jtu/ntu, percentage, degrees C/F conversion, and ppm). The data was then put into an excel spreadsheet for analysis and also uploaded to the Town web page. Any parameters that were out of an acceptable range was red flagged and additional samples were taken with a YSI Professional Plus meter. Several sites had low Dissolved Oxygen during the winter months and one site had a very low pH of 4. The field investigation conducted on 12/5/2013 revealed that a local business was washing their carpet cleaning water into the storm drain system just above Burlington Mills Road located at 5100 Unicon Drive, STE 102, Wake Forest, NC 27587. The was water caused a soapy foam that originally was thought to be a sewer leak. NC DEQ was contacted to conduct further investigation.

In addition to the water quality sampling quarterly educational workshops were held with NC Museum of Science, and various project partners; NC Cooperative Extension, Wake County Soil and Water, and Franklin County Soil and Water Conservation Districts, materials from Clean Water Education Partnership and NC Watershed Stewardship Network were provided to participants on various topics along the watershed reach.

The Town also hosted/conducted three Backyard Stream Repair Workshops and one BMP Maintenance and Inspection Training in coordination with NC Cooperative Extension. Both classes gave participants the opportunity to see projects in action, understand the impacts and benefits of water quality in the Smith Creek Watershed.

The Town partnered with local schools to conduct training and education. Heritage High School and Envision Charter were both strong partners, requesting quarterly training and volunteering for clean ups, stream repair and tree planting. Local Boy Scout and Girl Scout groups also got involved by conducting clean ups, providing Eagle Scout stream repair projects, trail rebuilding, planting, volunteering and education.

Surveys were conducted both before and after each activity and a larger online survey was conducted to respond to general public knowledge base pre and post grant period. The online survey showed how little citizens know about our local streams. The Town did see significant improvement in knowledge base during the post survey.

The Town of Wake Forest is currently involved in SWANC, Clean Water Education Partnership and the new statewide NC Water Stewardship Network. All of these groups meet regularly where we share our experiences with each other.

The Town has also devoted several web pages and videos to the project to host the monitoring data and educational information;

WebPages:
http://wakeforestnc.gov/environmental-education.aspx
http://www.wakeforestnc.gov/watershed-education.aspx
http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
http://www.wakeforestnc.gov/water-quality-data.aspx

http://www.wakeforestnc.gov/backyard-stream-repair.aspx
http://www.wakeforestnc.gov/soil-erosion-101-.aspx
http://www.wakeforestnc.gov/residents-engineering_stormwatereducation101.aspx

Videos:

Wake Forest 411 - Erosion Control - https://vimeo.com/139983620
In Focus - Richland Creek Greenway Update - https://vimeo.com/139983620
Focus on Wake Forest - Smith Creek - https://vimeo.com/73417181

Table 14. EE Contact Hours for CY 2013-2015

Environmental Education Event	People	Hours	Total
Meet in the Street Festival- 2013	1,000	6	6,000
Good Neighbor Day- 2013	500	4	2,000
Children's EE Workshops- 2013	250	10	2,500
Adopt a Stream Program Training- 2013, 2014	45	50	2,250
Water Quality Sampling- 2013-2015	45	12	540
Arbor Day Tree Planting- 2013	25	4	100
Arbor Day Festival- 2013	1,000	4	4,000
Arbor Day Festival- 2014	1,000	4	4,000
Stream Repair Workshop-2014	25	14	350
Girl/Boy Scout Education/Clean Ups- 2013, 2014	45	2	90
Local Schools- 2013-2015	500	2	1,000
Town Employee Education- 2013	40	2	80
WRRI Annual Conference Presentaion	500	2	1,000
Eagle Scouts- 2013-2015	5	10	50
Indirectly via webpage, Facebook, emails	10,000	1	5,000
National Trails Day- 2014	2,000	6	12,000
National Trails Day- 2015	3,500	6	21,000

Table 14. EE Contact Hours for CY 2013-2015

Environmental Education Event	People	Hours	Total
Summer Stream Project- 2014	10	6	60
WSN Presentation	20	1	20
Total	20,510	146	62,040

Examples of materials used in the Adopt a Stream Program are in Appendix F.

2.6 Existing and Potential Water Quality Threats

For purposes of watershed planning, a threat can be anything that degrades habitat or impedes achievement of water quality standards. As stated in Section 2.2.5,

A combination of factors threatens the water quality in Smith Creek, in relation to its designated uses. Based on the field and desktop evaluations described above, by far the largest threat to aquatic life and water quality is sediment loads. Due to the volume of primarily residential development over the past twenty years, and, until recently, the lack of significant stormwater treatment design requirements, storm flow volumes and velocities have caused a large influx of sediment into Smith Creek at various points throughout the watershed. Sediments fill habitats used for rearing and refugia of fish and benthic macroinvertebrates. Dark sediments entering the stream combined with increased light inputs from riparian degradation can increase water temperatures since these sediments tend to absorb more heat. Many problem areas have been identified where sediment is continuing to enter the watershed. Identification of susceptible and sensitive areas can be utilized to prevent and minimize further degradation. The worst and most prevalent threats can generally be grouped together under the following headings:

2.6.1 Development

As historic photos indicate, prior to approximately 1995, with the exception of the Spring Branch Subwatershed, land use in nearly all of the Smith Creek Watershed was dominated by mature forests and low intensity/density rural residential and agricultural areas. During the past two decades significant land clearing and suburban residential development have replaced these uses in significant portions of the watershed. While all of the subwatersheds maintain more than half of their land uses as forested, development pressures continue.

The increase in impervious surfaces typically associated with residential and commercial development, including rooftops, roads, sidewalks and parking lots, often act as conduits for pollutants and sediments to enter surface waters. Increases in stream temperature can occur when large volumes of water drain off sun heated black top surfaces. Temperature increases and sediment and pollution loading can significantly impair water quality. In addition, increases in impervious surface can increase discharge rates during flood events. An increase in flood discharge combined with increases in sediment loads often further accelerate existing erosion problems and lead to long-term degradation of aquatic habitat. Well planned best management practices and stormwater control ordinances, and enforcement of compliance issues related to erosion and sediment control ordinances are critical to decreasing the impact of current and future development. Integrating a WMP with land and development planning goals will facilitate actions that help meet the WMP goals and objectives.

Stormwater control requirements that have been implemented throughout the watershed on new development over the past ten years have done much to offset many of their negative water quality impacts. The significant amounts of untreated storm flow inputs from areas developed prior to implementation of development restrictions are, therefore, the watershed's primary stressors.

2.6.2 Riparian Buffer Degradation

Riparian buffer zones have been compromised throughout the watershed where residential development and roads have been established. Riparian buffer zones act to filter water of pollution and sediments before entering surface waters. Riparian canopy cover provides critical shade for regulating temperatures for aquatic life and preventing the growth of unwanted algae and aquatic plants. Low growing riparian plants provide fish cover habitat and aquatic insect reproductive substrate critical to ecosystem functions. Leaf fall from riparian zone trees provides the majority of energy source to mountain streams and is critical to the upkeep of healthy fish populations. Management plans that enforce buffer rules along with riparian zone improvements where needed, will help ensure that designated use water quality standards are met.

3 Conclusions and Recommendations

The analysis of water quality, use of GIS analyses, and results of field surveys have resulted in the identification of the primary conditions of concern throughout the Smith Creek Watershed. WK Dickson used these analyses' results to identify watershed restoration practices that would contribute to an effective strategy for addressing functional deficits. The general feasibility, cost, and long-term chance of success for potential strategies were considered for prioritizing solutions. The preliminary cost estimates associated with each solution were determined based on general, existing market conditions and are for planning only. Project specific cost estimates are necessary for actual budget allocation purposes.

While much of Smith Creek and its tributaries are relatively stable and provide adequate aquatic habitat throughout the study area, some reaches, especially in the Dunn Creek, Spring Branch, and Smith Creek 1,2, and 3 watersheds, are degraded and are contributing significant sediment and nutrient loads into the Smith Creek and the Neuse River. These watersheds are among the oldest and most densely developed in the study area. Because much of their development occurred before the establishment of stormwater development requirements, many of their stream reaches are experiencing significant aggradation, degradation, and lateral instability.

To prevent further degradation of Smith Creek and restore water quality and aquatic habitat in its tributaries, a number of structural, non-structural, direct, and procedural measures have been identified and prioritized. In order of direct benefit to aquatic resources, they include:

3.1 Stream Restoration/Stabilization

The Smith Creek Watershed has rapidly transitioned from a largely rural agricultural area to a suburban residential and commercial one. The resulting impervious surface area increases and vegetated stream buffer elimination have resulted in significant horizontal and lateral stream instability. The resultant sediment and nutrient loading have caused elimination of aquatic habitats, which have resulted in negative impacts to aquatic diversity, particularly benthic macroinvertebrates. Restoration of stream stability will alleviate worsening conditions as well as provide additional aquatic function. Projects detailed in Section 2.3are listed in order of functional uplift potential, constructability and unit cost. Of those, the 'top ten' include:

1. Miller Park Stream Restoration: $360,000
2. Hope Lutheran Stream Restoration: $580,000
3. Joyner Lateral Dam Stabilization: $100,000
4. Alley Young Park Dam Removal/Stream Restoration: $140,000
5. Traditions Stream Restoration: $720,000
6. Dunn Creek Restoration: 180,000
7. Sedgefield Park Dam Removal: $30,000
8. Thales Academy Stormwater Culvert and Stream Restoration: $80,000
9. Heritage Middle School Stream Restoration: 140,000
10. Franklin Academy Stream Restoration: $12,000

3.2 Smith Creek Watershed Conservation Assets

Many watersheds throughout the country have been severely impaired by the actions of people. Fortunately, numerous locations within the Smith Creek Watershed have been spared many of these negative impacts. This is true of much of the watershed's upper- most, and lower-most areas. Based on observation during stream walks and ambient and benthic macroinvertebrate sampling, good habitat for healthy aquatic populations exists in the Smith Creek and many of its tributaries. This good habitat is a function of the surrounding land use. Because of the development restrictions associated with WS-II waters, and the proximity of downstream areas to existing development and infrastructure, numerous locations retain mature hardwood forests, stable stream banks and diverse aquatic and terrestrial ecological communities. In order to ensure that future impairment does not occur, resource managers and planners should balance development with conservation practices that preserve large tracts of undeveloped land. Based on field and existing data evaluations, undeveloped locations that represent the best value for conservation include:

1. Traditions: $55,619/acre
2. Hope Lutheran: $100,308/acre
3. Heritage Lake: $15,596/acre
4. Sanford Creek: $36, 328/acre
5. Smith/Neuse Floodplain: $13,604/acre
6. Austin Creek: $10,000/acre
7. Holding Village: $199,716/acre
8. Heritage Gates Dr.: N/A
9. Unicon Beaver Impoundment: $45,334/acre

The costs/acre presented above and in Table 12 are based on the Wake County Assessed Land Value. Negotiations with landowners may allow acquisition of donations of easements on these parcels, or purchase for considerably less investment.

3.3 Structural Stormwater BMPs

While project budget and scope did not include a detailed and complete stormwater BMP inventory and master plan, scores of existing BMP sites were evaluated and the results are detailed in Table 13. Of the 87 sites evaluated, the several of the locations likely to provide significant uplift include:

1. Site # 22: 9408 White Carriage Dr.
2. Site # 35: 9804 Ligon Mill Rd.
3. Site # 58: 1157 Trentini Ave.
4. Site # 66: 400 Deacon ridge St.
5. Site # 17: 9516 Dumas Ct.
6. Site # 5: 9205 Dansforeshire Way
7. Site # 14: 1504 Lagerfeld Way
8. Site # 68: 546 Elm Ave.
9. Site # 19: Philbeck Ln.
10. Site # 20: 9320 Doss Ct.

3.4 Nonstructural Stormwater BMPs

1. Enforce riparian buffer rules
2. Enforce erosion and sediment control ordinances
3. Prohibit site development on steep slopes
4. Cluster new development to reduce impervious surfaces
5. Reduce large-scale "clearing and grubbing"
6. Minimize construction access locations at construction sites
7. Minimize stockpiling and storage areas at construction sites

4 Implementing the Smith Creek Watershed Plan

Table 15. Project Schedule for Watershed Plan Implementation

Primary Tasks	**Frequency/Schedule**
A. Draft QAPP for Town review and submittal to NCDEQ -Make revisions as necessary and get QAPP approval	-Once: complete -Minor revisions annually; major updates every 3-5 years
B. Data review and analysis of resource conditions -Analyze water quality data (physical chemical and biological) -Characterize and assess geomorphic and general biological (terrestrial) conditions (field reconnaissance) -Data and literature research -GIS Mapping updates	-Annually
C. Scoping/Brainstorming sessions for watershed plan updates -Coordinate interdisciplinary stakeholder team -Non-point source identification and opportunities discussion	-6-8 months -4-5 years
D. Update goals and objectives	-4-5 years
E. Attendance at community meetings for:	-3-6 month; year 4

-Kick-off of iniatiative; gathering of input for goals and objectives -Providing periodic updated while drafting watershed plan -Consucting educational events in support of watershed plan -Gathering input for plan updates	-Quarterly; years 4-5 -Bi-monthly; ongoing -ongoing
F. Refine goals and objectives; draft management strategies	-6-8 months; years 4-5
G. Continue analysis of available data; conduct field surveys in support of prioritized projects	- years 1-3
H. Develop schedule for implementing management measures; identify major interim milestones *Any contingency measures, schedule and milestones should be developed at this time also	-1-2months; year 5; revise as needed
I. Develop monitoring strategies for tracking progress of watershed plan implimentatino and watershed conditions (via use of paramaters highlited in QAPP)) as well as (interim) adaptive management measures	-2-3 months; yesr 5 (revisit in year 3 as needed)
J. Draft list of potential educational tools and activities to conduct with community members and implement -Make revisions as necessary and get QAPP approval	-ongoing
K. Commence with monitoring and on the ground restoration and protection activities	-Monitoring ongoing; on-the-ground projects should commence years 1-3
L. Complete draft watershed management plan. Present to community members	-18-24 months; year 5
M. Finalize changes to watershed plan	-6-9 months; year 5
N. Adoption by the Town	-2-3 months; year 5
O. Submit applications for funding based on the watershed plan	-as approved by Town after Plan approved
P. Review watershed plan and make necessary updates	-annually
Q. Revision to watershed plan	-every 5 years

4.1 Plan implementation Recommendations

In order to have the Smith Creek Watershed Plan succeed, funding sources will have to be identified and secured, and after management strategies are implemented, results will have to be monitored and success measured. To insure success the Town should:

4.1.1 Assess Sediment Load Reductions

Because Smith Creek is not on EPA's 303d impaired waters list for TSS, and the improvement of benthic macroinvertebrate sampling results, no TMDL formal pollutant load reductions are anticipated. Sediment, however, is still the primary pollutant of concern in the watershed and without active efforts to reduce loadings, water quality throughout the watershed will decline. Restoration of riparian buffers, bank stabilization measures, and active maintenance of erosion and sedimentation control measures will go a long way to significantly reducing these problems.

To assess the sediment loading from selected unstable stream banks within the Smith Creek Watershed, Bank Erosion Hazard Index (BEHI) and Bear Bank Stress (NBS) assessments should be performed. These quantitative estimates can be used to compare different projects' sediment load reduction capability. They are based on a combination of qualitative field and quantitative desktop evaluation of the existing conditions in the subject reaches, including: bank slope, bank height, surface protection, root density, and qualitative sheer stress estimates.

In addition to decreasing sediment loads, stream stabilization projects will improve water quality by reducing nutrient loading (Nitrogen and Phosphorus); improve aquatic habitat by providing shade, refugia, and diversity; and improve terrestrial habitat by providing breeding and feeding cover.

4.1.2 Implementation Schedule with Interim Milestones and Management Measures

Implementation of this watershed management plan will involve selecting management strategies, identifying funding sources, assigning responsible parties, selecting success indicators, implementation strategies, and monitoring success. Short, medium, and long term goals must be set for each strategy to measure success. The GIS database should be periodically updated to track process.

Management strategies have been recommended and prioritized. The Town must select which strategies to implement based on feasibility and each specific project's cost/benefit analysis (including but not limited to: pollutant removal, biological habitat improvement, public education, public safety, property protection; capital and maintenance costs). The most critical issues facing the Town of Wake Forest and the Smith Creek Watershed are impaired streams and riparian buffers resulting from residential and commercial development.

Parties responsible for implementing and monitoring each strategy should be assigned. A Community watershed committee, subcontractors and Town staff may all be involved in these responsibilities. Analysis should be linked to management solutions by choosing solution indicators and targets. These indicators may be quantitative or qualitative. A short-, medium-, and long-term goals will guide implementation and aid in assessing success.

Implemented strategies should be monitored to gauge success and provide lessons learned. Some implementation strategies, like stream restoration and buffer enhancement will be easy to track. Periodic geomorphological and vegetation surveys will quantify progress. Education and outreach are important but often overlooked strategies. Education may be monitored by continuing to count the activities accomplished and stakeholders contacted.

Implemented management solutions should be recorded in a GIS database (e.g., areas where exotic invasives are removed, stream bank stabilization sites, buffer enhancement sites, and stormwater BMP sites).

A matrix fore each management practice should be developed and updated to monitor the plan's implementation. A partially completed sample worksheet is provided below in Table 17. The matrix should be filled out as tasks are implemented and during quarterly reviews.

Table 16. Management Matrix

Task	Responsible Party	Cost	Possible Funding Source	Indicators	Milestones (Term)		
					Short	Med.	Long
Streambank Stabilization	Town	$100 - $500/	USEPA; USFWS;	Lateral and vertical			

Table 16. Management Matrix

Task	Responsible	Cost	Possible	Indicators	Milestones (Term)		
		foot	NCDEQ; NCDOJ	stability; sedimentation reduction			
Buffer Enhancement	Town	$55 - $75/ foot	USEPA; USFWS; NCDEQ; NCDOJ	Vegetation success; sedimentation reduction			
Trail Enhancement & Maintenance	Town, Wake County,	$200 - $250/ foot	USEPA; FHWA; NCDEQ; NCPARTF	Trail erosion; sedimentation downstream			
Rain Barrels	Town; Property Owners	$60 - $150/ barrel	USEPA; Town;	Number installed; storm volume abated			
Structural BMPs	Town	$5,000 - $100,000	Develpers; USEPA; NCDEQ; NCDOJ	Sediment and nutrient reduction; downstream bank stability			
Education	Town, Wake County	Varies	USEPA; NCDEQ; NCDOJ	Number of residents educated			

4.1.3 Progress Measurement Criteria

4.1.4 Partnering with the Community

Resource management at the watershed scale requires the unification of social, economic and environmental considerations and the integration of agricultural, forestry, wetland, fisheries, and residential uses and concerns. Broad-based community support is essential to successful implementation of watershed management plans. Public education is the primary tool to acquire and sustain broad-based support. Individual landowner education, stakeholder meetings, and encouraging open discussions help minimize impacts to the watershed, as well as promoting successful remedial actions. Many resources can be drawn upon to promote watershed management education, including: Adopt-a-stream, Adopt-a Highway, and primary and secondary school program creation. The target audience for this education/outreach should not be limited to Town residents. All those living in the Smith Creek Watershed are stakeholders and should be included in education and outreach activities. The success of the Town's Adopt-a-stream program should be continued.

Some examples of community service and volunteer organizations that may be of assistance in increasing community participation with implementation of this watershed plan include:

- North Carolina Commission on Volunteerism and Community Service
- AmeriCorps
- US Freedom Corps
- Citizen Corps
- Boys and Girls Club of America

- Kiwanis Club
- Local and regional watershed groups and conservation organizations

4.1.5 Resources for Technical and Financial Assistance

Numerous resources are available to the Town for securing technical and financial assistance. The resources identified in this section do not represent a comprehensive list. The USEPA has recently updated the *Guidebook of Financial Tools: Paying for Environmental Systems* http://www.epa.gov/efinpage/publications/GFT2008.pdf. This document serves as an aid for identifying funding sources for watershed management practices. As with any grant, matching funds increase the chances of procuring monies. The following entities and/or programs represent sources that can help the Tribe ensure its watershed management goals are addressed:

- *Handbook for Developing Waterhsed Plans to Restore and Protect Our Waters*. EPA 841-B-05-005. October 2008: http://www.epa.gov/nps/watershed_handbook/
- Recreation Trails Program (RTP): http://www.fhwa.dot.gov/environment/rectrails/
- National Off-Highway Vehicle Conservation Council: http://www.nohvcc.org/
- Cooperative Conservation: http://cooperativeconservation.gov/funding-opportunities/index.html
- Philanthropy News Digest: http://foundationcenter.org/pnd/rfp/index.jhtml
- Laura Jane Musser Fund: http://www.musserfund.org/
- National Fish and Wildlife Foundation: http://www.nfwf.org/Content/NavigationMenu/GrantPrograms/ProgramsOverview/Keystones/default.htm
- Grants.gov: http://www.grants.gov/search/advanced.do
- USDA: http://www.nrcs.usda.gov/programs
- National Oceanic and Atmospheric Administration: http://www.ago.noaa.gov/grants/funding.shtml
- US Army Corps of Engineers: http://www.usace.army.mil/missions/environment.html
- US Fish and Wildlife Service: http://www.fws.gov/grants/
- US Environmental Protection Agency: http://www.epa.gov/epahome/grants.htm
- NC Nonpoint Source 319 Grant Program: http://portal.ncdenr.org/web/wq/ps/nps/319program
- Smithfield Foods Agreement: http://www.ncdoj.gov/getdoc/c7588fb1-c970-4415-9d80-2dd0d62139eb/2-0-4-2-Environmental-Grants.aspx
- Duke Energy Water Resources Fund: https://www.duke-energy.com/community/foundation/water-resources-fund.asp

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Appendix A.
EPA/DEQ Quality Assurance Project Plan

North Carolina Department of Environment and Natural Resources
Division of Water Resources
Water Quality Programs

Pat McCrory
Governor

Thomas A. Reeder
Director

John E. Skvarla, III
Secretary

August 12, 2013

Ms. Holly Miller
Town of Wake Forest
301 South Brooks Street
Wake Forest, NC 27587

Dear Ms. Miller:

The "Smith Creek Watershed Restoration and Implementation Plan" project Quality Assurance Project Plan (QAPP) prepared for 319 Grant contract #5038 has been reviewed and is approved. Therefore, you may proceed with the project and all data collection/monitoring activities as outlined in the QAPP.

If you have questions about any additional reporting requirements to the 319 Grant Program associated with this project, please contact me at 919-807-6438.

Sincerely,

Kimberly Nimmer

Kim Nimmer
319 Grant Program Administrator

Quality Assurance Project Plan

Required for certain US EPA funded grants and contracts that are awarded by the Division of Water Quality, NCDENR

NCDENR- DWQ QUALITY ASSURANCE PROJECT PLAN CHECKLIST

To first assess whether a Quality Assurance Project Plan is necessary, please answer the following four questions:

1. Is Federal money from the US EPA being spent on this activity? *(If the answer is "No" then a QAPP is not necessary; proceed to answer section A1 only. If "Yes" then proceed to # 2).* ❑ **Yes** ❑ **No**
2. Will work require acquisition of environmental data generated from direct measurements activities (i.e., water quality sampling), collected from other sources, or compiled from computerized databases? *(If the answer is "No", then a QAPP is not necessary; proceed to answer section A1 only. If "Yes" then proceed to # 3).* ❑ **Yes** ❑ **No**
3. *Will all instream water quality samples be analyzed by a Laboratory certified by the State of North Carolina? Proceed to # 4.* ❑ **Yes** ❑ **No**
4. Has a QAPP already been approved for your activity? *(If the answer is "No" then please complete Sections A-D on the following pages. If "Yes", then please answer section A1 and attach a copy of the approved QAPP, or provide a reference (including Agency, Telephone number, and Web Address, if available) for the complete approved QAPP, and return this form with attachments to your DWQ EPA Funds Manager).* ❑ **Yes** ❑ **No**
5. Do you intend for your data to be considered for Use Support decisions, e.g., 303(d) ❑ **Yes** ❑ **No**

Quality Assurance Project Plan Form

Adopted from the US EPA by the Division of Water Quality, NCDENR

A1. Project Title and Approval Sheet

Smith Creek Watershed Restoration and Implementation Plan

Town of Wake Forest

7 August 2013

5038

(NC DENR Contract #)

Project Manager Signature ______

(Holly Miller)

Project QA Officer Signature ______

(Ward Marotti 6 August 2013)

DWQ EPA Funds Manager: Kim Nimmer

Signature of Receipt ______

A.2 Table of Contents

Appendices

A3. Distribution List

Names and telephone numbers of those receiving copies of this QAPP. Attach additional page, if necessary. (Name, Organization, Telephone)

i. Kim Nimmer, NCDENR, 919-807-6438

ii. Holly Miller, Town of Wake Forest, 919-435-9443

iii. Ward Marotti, WK Dickson, 919-368-8043

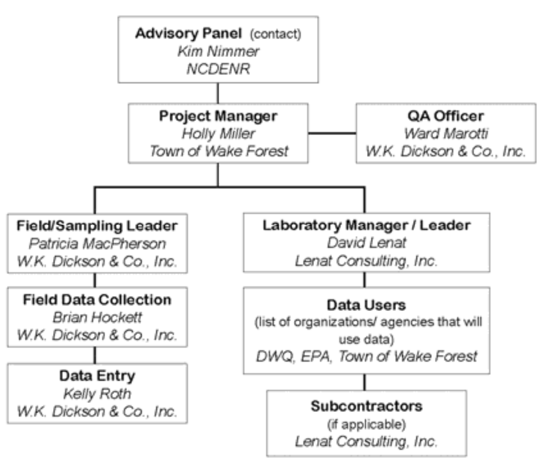
iv. Trish MacPherson, WK Dickson, 919-363-4601

v. David Lenat, Lenat Consulting, 919-787-8087

A4. Project/Task Organization

Key project personnel and their corresponding responsibilities are listed below. Organization chart is Figure 1.

Name, Position	Project Title/Responsibility
Kim Nimmer	Advisory Panel (contact)
Holly Miller, Assistant Town Engineer, Town of Wake Forest	Project Manager
Ward Marotti, Senior Scientist, WK Dickson	QA Officer
Patricia MacPherson, Aquatic Scientist, WK Dickson	Field/Sampling Leader
David Lenat, President, Lenat Consulting	Laboratory Manager/Leader
Lenat Consulting, Inc.	Subcontractors (if applicable)
DWQ, EPA, Town of Wake Forest	Data users (list organizations/agencies that will use data)



Organization Chart

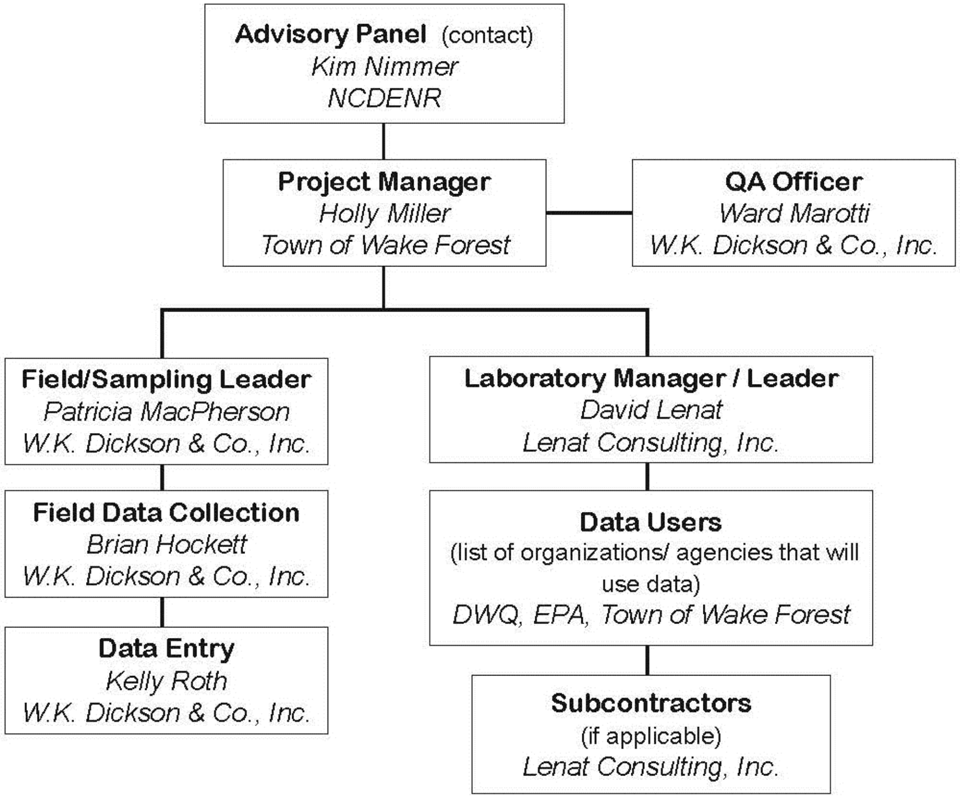


Figure 1. Organization Chart.

A5. Problem Definition/Background

Problem Statement - Explain the background of the project and the reasons for initiating the project Also include uses and/or designated uses and impairment of the water resource, if applicable.)

The *Neuse River Basinwide Water Quality Plan* (2009) indicates that Smith Creek "...is Impaired for aquatic life based on a Fair fish community bioclassification at site JF 31." The *2012 Draft North Carolina 303(d) List-Category 5* rates Smith Creek as Impaired because of its "Fair Bioclassification." The "Reason for Rating" listed is "Fair Bioclassification" and the "Parameter" listed is "Ecological/biological Integrity Benthos." Based on this, Smith Creek (from the Wake Forest Reservoir dam at the GG Hill Water Treatment Plant, to its confluence with the Neuse River) was added to the 2008 303(d) list of impaired waters, and remains on the 2010 and 2012 303(d) lists. This reach is classified as C; NSW.

From the dam to its headwaters in Franklin County, Smith Creek is fully supporting. This reach is classified as WS IV.

The watershed plan is intended to identify causes and sources of impairment and determine appropriate actions to have Smith Creek removed from the impaired waters list.

Intended Usage of Data - State the usage and outcomes expected from the information to be collected (e.g., remove from impaired list, show that the BMP is effective, watershed characterization or background data, environmental education, etc.). Describe type of data to be collected (e.g., screening, definitive, characterization, baseline/background). If applicable, cite technical or regulatory standards or criteria to which data will be compared.

Benthic macroinvertebrate data will be collected at DWQ's existing Burlington Mills site, as well ass two additional locations further up the watershed. The results will be provided to DWQ (third party) for use support evaluation.

A6. Project/Task Description

General Overview of Project - Summarize the work to be performed. Define geographic, spatial, and/or temporal boundaries. Briefly describe the monitoring/experimental design and how monitoring data will assist in achieving project monitoring objectives. Note, details on sample locations and monitoring design should be provided in Section B1 below. Discuss resource and time constraints, as appropriate.

Monitoring will include benthic macroinvertebrate data collection at three sites: Burlington Mills Rd, Heritage, and Sanford Creek. Sampling methodology will follow established, published DWQ SOQ protocols.

Project Timetable - Work schedule indicating critical project points

Activity	Start Date	Known or Anticipated Date of Completion
2013 Benthos sample	July 2013	July 2013
2014 Benthos sample	July 2014	July 2014
2015 Benthos sample	July 2015	July 2015
2016 Benthos sample	July 2016	July 2016

A7. Quality Objectives and Criteria Identify performance/measurement criteria for all information to be collected; and acceptance criteria, including project action limits and laboratory detection limits, and range of anticipated concentrations of each parameter of interest (includes field and lab, if applicable)

Data Precision, Accuracy, Measurement Range

Express the degree to which sample results are repeatable. State decision error limits, if applicable
Note: Projects which are based on authoritative rather than statistical sampling designs will not have quantitative decision error limits

Matrix	Parameter	Measurement Range	Accuracy	Precision
N/A				

Data Representativeness

Express the degree to which the data accurately represents the population or the environmental condition at the sampling location (i.e. explain how well the monitoring characterizes the physical conditions)

The Benthic Macroinvertebrate Community Assessment Program (BMCAP) is based on judgmental sampling design. As a result, bias will exist due to site locations (i.e., sites that can be safely waded or accessed by the sampling crew). However, this is acceptable given that monitoring sites are generally established for targeted long-term monitoring of known or suspected areas of concern; identification of temporal patterns at these static locations are a major objective of the program.
Other sources of bias:

- Sampling is performed under existing flow and water clarity conditions. Ideally, monitoring is conducted under low to normal flow conditions with clear or slightly turbid water clarity. Sampling is not conducted if the water is so turbid that instream habitat, which lies below the surface of the water, cannot be seen. In addition, if the water level is so high or swift that sampling would jeopardize the safety of the staff, collection operations are suspended.

- Almost all sites are located at bridge crossings for ease of access and to avoid trespassing on private property. Field staff is instructed to sample on the upstream side of the bridge, if possible, and beyond the artificially created bridge pool and bridge substrate habitats.

Using consistent sampling techniques, laboratory methods, and data analyses as described in the Benthic Macroinvertebrates Standard Operating Procedures minimizes bias from other sources.

Fixed station locations, generally consistent seasonal sampling, and adherence to the BMCAP's SOP for sampling ensure that comparable samples are taken at each site visit.

Data Comparability

Express the degree of confidence that one data set can be compared to another at the sample location or to a sample taken at another location

Fixed station locations, generally consistent seasonal sampling, and adherence to the BMCAP's SOP for sampling ensure that comparable samples are taken at each site visit. Deviations from the SOP or from the written study plan due to unusual sampling situations are documented.

Data Completeness

Measure of the amount of valid data needed to develop conclusions (i.e., estimate how many measurements are needed to meet each monitoring objective(s))

Parameter	No. Valid Samples Anticipated	Minimum No. Valid Samples needed	Monitoring Objective
Benthic macroinvertebrate	3	1	Water quality

A8. Special Training/Certification - General description of training requirements and needs. Describes special personnel or equipment requirements, if applicable.

Training Logistical Arrangements

Training Topic(s)	Personnel Trained	Training/Certification Frequency
Benthic macroinvertebrate collection	Brian Hockett, Ward Marotti, Trish MacPherson	N/A

Description of Training and Trainer Qualifications

Training Topic(s)	Training Description	Trainer Qualifications
N/A		

A9. Documents and Records - Identify all data reporting information and list all project documents, reports, and electronic files that will be produced. Include QA records and reports, List information and records to be included in data reports (e.g., lab/field raw data, field logs, lab records, results of QC checks, problems encountered). Note retention time and location of records and reports.

Information/Data Type	Recording Medium & Retention Duration	Responsible Party
Benthic results	Digital, perpetual	WK Dickson

B1. Monitoring Experimental Design - Describe and justify the experimental monitoring design strategy, indicating size of the area, volume, or time period to be represented by the monitoring (detail the type and total number of sample types/matrix or test runs/trials expected and needed). Also include monitoring of covariates such as rainfall and discharge.

Rationale or Criteria for Selection of Sampling Sites- Describe and justify the experimental monitoring design strategy, indicating size of the watershed area, discharge volume, or time period to be represented by the monitoring. Describe appropriate validation study information for nonstandard sampling situations (if applicable).

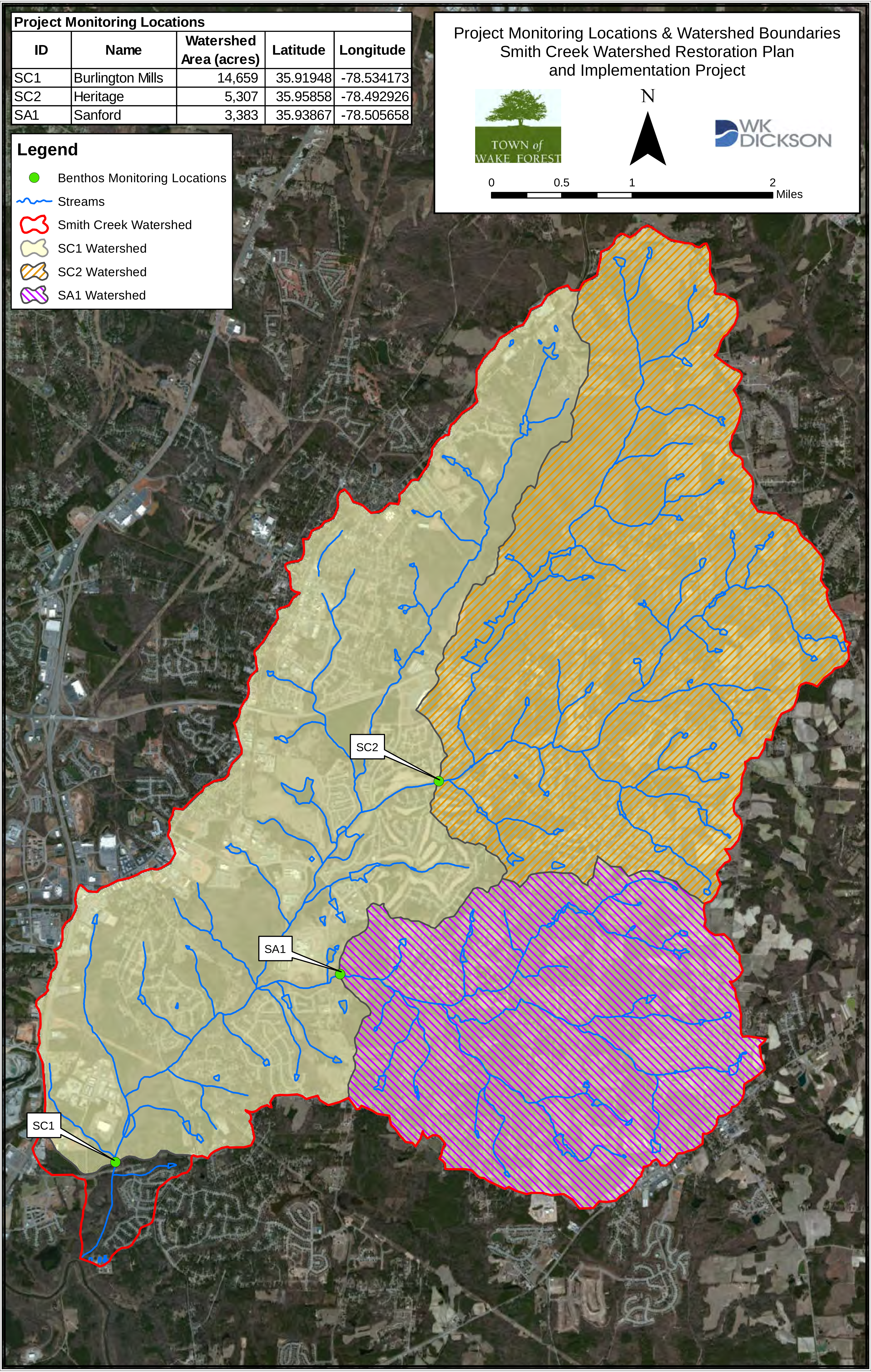
Three sites were selected to be representative of watershed conditions throughout the study area. The Burlington Mills site is in the same location that resulted in Smith Creek's impaired waters listing. It drains 14,659 acres. The Heritage site is located downstream of the confluence of Smith and Austin creeks and represents conditions in the upper Smith Creek watershed (including the Wake Forest Reservoir). It drains 5,307 acres. The Sanford site is located approximately 0.5 mile upstream of Sanford Creek's confluence with Smith Creek. It drains 3,383 acres.

Project Monitoring Locations and Watershed Boundaries -

See attached.

Project Monitoring Locations				
ID	Name	Watershed Area (acres)	Latitude	Longitude
SC1	Burlington Mills	14,659	35.91948	-78.534173
SC2	Heritage	5,307	35.95858	-78.492926
SA1	Sanford	3,383	35.93867	-78.505658

Project Monitoring Locations & Watershed Boundaries
Smith Creek Watershed Restoration Plan
and Implementation Project



Sample Design Logistics - Sample numbers and frequency. Also include monitoring of covariates such as rainfall and discharge. State if parameter is for informational purposes only and not critical.

Type of Sample/ Parameter (i.e. storm/grab, water/sediment, etc.)	Number of Samples	Sampling Frequency and Period
Kick net sample	2	Once/year/site (July)
Sweep-net sample	3	Once/year/site (July)
Leaf-pack sample	1	Once/year/site (July)
Fine-mesh rock and/or log wash sample	2	Once/year/site (July)
Sand sample	1	Once/year/site (July)
Visual collection	1	Once/year/site (July)

B2. Sampling Methods

Identify Sampling Equipment, Collection Methods and SOPs

Parameter	Sampling Equipment	Sampling Method
Benthic macroinvertebrates	Kick net, sieve bucket with us standard no. 30 mesh (0.600 mm opening) bottom	Kick-net
Benthic macroinvertebrates	Long-handled triangular sweep net	Sweep-net
Benthic macroinvertebrates	Sieve bucket with us standard no. 30 mesh (0.600 mm opening) bottom	Leaf-pack
Benthic macroinvertebrates	Chironomid-getter (fine-mesh sampler), large plastic tub	Fine-mesh rock and/or log wash
Benthic macroinvertebrates	Large fine-mesh (300 microns) nitex netting bag	Sand sample
Benthic macroinvertebrates	N/A	Visual collection

Field Sampling Methods. Describe procedures for collection of monitoring samples. Describes sample preservation methods. Describe process for preparation and decontamination of sampling equipment. Describe or reference selection and preparation of sample containers and sample volumes. (Please do not simply reference another document, but summarize the procedures to be used here and include reference for details! Identify individuals responsible for corrective action

Kick Net: A kick net is an easily constructed and versatile sampling device. It consists of a double layer of flexible nylon door or window screening held in place between two halves of a wooden pole using wood screws. The screening is reinforced with denim along all edges and has lead weights sewn into the bottom edge. The screening can be sewn onto the denim using a heavy duty sewing machine. The net is positioned upright on the stream bed, while the area upstream is physically disrupted using feet and/or hands. The debris and organisms in the kick net are then washed down into a sieve bucket with a US Standard No. 30 mesh (0.600 mm opening) bottom, and larger leaves and debris are removed. Two kicks are taken from riffle areas. The two samples should be collected from areas of differing current speed. In very small streams, or in sandy areas lacking riffles, kicks should be taken from root masses, snags, or bank areas. All types of benthic macroinvertebrates are collected by this sampling device, but emphasis is placed on Ephemeroptera, Plecoptera and Trichoptera.

Sweep Net: A long-handled triangular sweep net is another versatile sampling device. Three samples are taken by physically disrupting an area and then vigorously sweeping through the disturbed area. Sweeps are usually taken from bank areas, including mud banks and root masses, and macrophyte beds. Bank samples are particularly important for the collection of "edge" species which prefer low current environments. Look for Chironomini (red chironomids), Oligochaeta, Odonata, mobile cased Trichoptera, *Sialis*, Crustacea, and certain Ephemeroptera. A sweep net also can be used to sample gravel riffle areas where stone-cased Trichoptera may be abundant.

Fine-Mesh Sampler: Since the kick and sweep nets utilize a relatively coarse mesh size, an alternate sampling technique was devised to sample the smaller invertebrates (especially the Chironomidae). The resulting sampler is known as a "chironomid-getter". Fine nitex mesh (300 microns) is placed between four-inch PVC pipe fittings that are designed to screw together. The exact dimensions are not critical, but the cylinder should be able to fit inside another container, usually a slightly larger, round plastic container. This device can be used in a variety of ways. The simplest technique is to wash down rocks or logs in a large plastic tub partially filled with water. Rocks are selected which have visible growths of periphyton, *Podostemum*, or moss. Any large particulate material (leaves, etc.) is washed down and discarded. A single composite sample can be made from several (usually 10-15) rocks and/or logs. The material remaining in the tub is poured through the fine mesh sampler and the water allowed to drain out completely. The sample is allowed to sit for several minutes, pulled out of the alcohol, and then backwashed into a picking tray. This method of field preservation requires only a small amount of alcohol, and it may be reused several times. Usually 2-3 of the fine mesh samplers are used, so that one may be soaking while another is being picked. Take care to rinse samplers between sites. Field preservation makes small chironomids and oligochaetes more visible, and easier to pick up with forceps. This technique is also good for fast moving organisms such as baetid mayflies or amphipods, or small grazing taxa such as hydroptilid caddisflies. The "pour-and-preserve" technique also can be used in conjunction with other sampling methods. For example, the elutriate from a kick or sweep sample can be processed in this manner. It is also used in conjunction with sand samples (see below).

Sand Sample: Sandy habitats often contain a distinct fauna, but extraction of this fauna by means of dredge-type sampling can be tedious. Sandy substrates (in areas with definite flow, if possible) are sampled with a large bag constructed of fine mesh (300 microns) nitex netting. It can be quickly constructed from a one-meter square piece of netting, folded in half and sewn together on the opposite side and the bottom. This bag is employed like a Surber sampler, but the lack of a rigid frame allows for easy storage when folded. The bag is held (open) near the substrate with the left foot holding the bag on the sand, and the sand is vigorously disturbed by the collector's other hand or foot. The material collected (a lot of sand and a few organisms) is emptied into a large plastic container half-filled with water. A "stir and pour" elutriation technique is used in conjunction with the fine mesh sampler. After field preservation, the elutriate is picked, looking especially for small Chironomidae (*Cryptochironomus*, *Robackia*, *Rheosmittia*, *Harnischia* group, *Polypedilum*), oligochaetes, and Baetidae. The remaining sand can be picked quickly for large or heavy organisms such as Gomphidae or *Corbicula*.

Leaf-Pack Sample: Leaf-packs, sticks and small logs are washed down in a sieve bucket with a U.S. Standard No. 30 sieve (0.600 mm openings) bottom, and then discarded. Generally, three to four leaf packs are collected from rocks or snags in fast current areas. The best leaf packs consist of older leaves (not freshly fallen) that have begun to decay. Piles of leaves in pool areas should not be collected. Leaf-pack and small log samples are particularly useful in large sandy rivers. In such habitats, many of the species are confined to "snags" (Benke et al. 1984, Neuswanger et al. 1982). Look for "shredders", especially Tipulidae, Plecoptera, and Trichoptera.

Visual Search: Visual inspection of large rocks and logs (the larger, the better) often adds to the species list. Large rocks and logs are a preferred microhabitat because of their stability during floods. Always look in a number of different areas (not just riffles). Rocks and logs in pools often yield additional species, as this habitat is not well sampled by either kicks or sweeps. The tops of rocks is a specialized microhabitat with a number of characteristic taxa. Both the caddisflies, *Psychomyia* and *Leucotrichia*, and the lepidoptera family Pyralidae, build retreats on the top of rocks. These are often made more visible by lightly washing off any silt which has accumulated on the top of the rock. Stone cased caddisflies, such as *Glossosoma*, *Agapetus*, *Ceraclea*, and *Goera* can also be found on the tops or sides of rocks. Decaying logs should be picked apart to look for chironomids, and many taxa can be found under loose bark. Rocks near the shore (in negligible current) will harbor taxa such as *Stenacron* and *Pycnopsyche*, and leaves near the shore may be the primary habitat for some Gastropoda. Certain caddisflies (*Nyctiophylax* and related genera) select crevices in rocks or logs, often along the edge, and cover them over with silk strands. The silk becomes covered with silt and periphyton and is hard to see. There is usually a faint opening on each end of this retreat. If the tip of forceps is inserted into one opening, the larvae usually will come out the other opening. Microcaddisflies make small (2-4 millimeters) cases found attached to rocks and logs, usually on the top or along an edge. The sides of rocks are the best place to look for the caddisflies *Neophylax*, *Psilotreta* and *Agarodes*.

Polycentropodid caddisflies build funnel-shaped silken retreats (up to six inches in length) in areas of relatively slow current. Out of water, the case collapses and resembles a gelatinous brown glob. The larvae will often crawl out if left out of the water for several minutes. It's a good idea to recheck some logs during visuals for these caddisflies. In sandy coastal plain rivers, look for a log that is in an area of faster current, with some portion raised above the substrate. This is a good place to look for hydropsychids and other filter-feeders. The net may be the only visible evidence of these organisms, and they must be dug out of their retreats with forceps. Aquatic macrophytes and sponges are other habitats to be closely examined. Mussel species can be obtained by careful visual inspection of the bottom. A mussel search should be conducted if dead shells are evident along the shore; look for midden heaps resulting from the feeding of muskrats and other vertebrates. However, only live specimens should be added to the species list. During periods of receding water levels, many species will move to deeper water, leaving a visible "track". The bases of aquatic weeds (especially water willow) may contain many mussel species and must be searched by hand. If possible, mussels should be identified in the field and returned (alive) to the stream. If sampling in an area with known populations of endangered or threatened mussels, any live mussels should be photographed or sketched and returned to the stream. Approximately 10 minutes is allocated for these visual searches. In general, look for attached cases of Trichoptera, for Turbellaria (flatworms), Coleoptera (beetles), Odonata (dragonflies, especially on large logs), Gastropoda (snails), Hirudinea (leeches) and Megaloptera.

Trish MacPherson is responsible for corrective action.

Sources and References used as Guidance for Typical Data Collection (e.g., USGS field collection methods, data needs for watershed models, monitoring design guidance documents)

Lenat, D.R. 1988. Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. Journal of the North American Benthological Society 7: 222-233.

NCDWQ Biological Assessment Unit. 2012. Standard Operating Procedures for Benthic Macroinvertebrates.
NCDWQ Biological Assessment Unit. 2012. Benthic Macroinvertebrate Community Assessment Program Quality Assurance Project Plan, Version 1.1. Approved by EPA February 2012

NCDWQ, 2009. Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009.

B3. Sample Handling and Custody - Identify how the samples will be physically handled, transported, and received; and describe the documentation of sample information handling and chain-of-custody. Include maximum allowed holding times from collection to analysis and lab preservation procedures.

All samples are field picked using DWQ's Standard Qualitative Method. The number of samples collected is dependent on the type of methodology used. Sampling equipment is simple to use, durable and portable. Samples are labeled before leaving the site with waterbody name, station location, collection card number, initials of collectors, and date of collection. A gage reading is taken if a gage is present or gage height (stream stage) taken from the USGS web site immediately upon return to the office. Stream stage and stream flow (cfs) should be added to the collection card and entered in the comments section of the database, along with notes about range of gage heights that should be targeted for adequate sample collection. Photographs of the site must be taken.

A Mountain/Piedmont habitat assessment form is filled out for all collections.

The benthos **collection card** must be filled out. Field observations should include:

Immediate watershed - type of land use, extent of disturbed land, any floodplain deposition of sediment, any evidence of stream widening and/or filling in, presence of upstream tributaries or dams (including beaver dams), evidence of recent water level changes such as leaf packs out of water, submerged terrestrial vegetation, and sediment on vegetation above water level, any livestock with access to stream, any point sources, any unique habitats.

Substrate - **Two** collectors must make independent estimates of substrate percentages and the independent and average values recorded on the collection card. Also note embedded substrate (interstitial spaces filled in with sand), any atypical habitats such as bridge rubble, large bedrock or other rock outcrops or unusual geological formations, abrupt changes in slope, presence of normal riffle-pool sequence (riffles spaced at intervals equal to 5-7 times stream width), any large areas of unstable coarse sand or movement of bedload material, and amount of substrate covered with *Aufwuchs* or silt.

Width - Since DWQ studies have suggested that stream width is a primary factor in determining expected taxa richness, especially in unimpacted headwater streams, the measurement of wetted stream width should be done as accurately as possible..

Water - Look for color, odor (especially sewage and/or chlorine), foaming, algal mats, and oil sheen.

Benthic Community - Note presence of organisms not usually collected such as bryozoa, sponges, mussel shells. Note dominant organisms and any that are very abundant. Note if diversity is limited to banks and snags above the effects of sediment scour. Give overall impression of site.

All samples are transported to the WK Dickson Watershed Sciences Lab in Raleigh by field personnel. Vehicles used to transport samples are locked when unsupervised, and sample custody is maintained at all times by field collectors.

A fixed number of benthic samples are processed at each location. The sampling techniques outlined here usually take 4-6 person hours, i.e. 1 1/2 - 2 hours per site with three collectors for the standard qualitative method. Without unforeseen weather conditions (heavy rain), all three sites will be collected during a single day.

B4. Analytical Methods

Identify laboratory(ies) to conduct testing and indicated if they are State certified. Identify all analytical SOPs including field and laboratory procedures (include method for every parameter being monitored). Specify needed laboratory turnaround time. Identify individuals responsible for corrective action.

Field Procedures – Standard Qualitative Method

This collection technique consists of two kick net samples (kicks), three sweep-net samples (sweeps), one leaf-pack sample, two finemesh rock and/or log wash samples, one sand sample, and visual collections. Invertebrates are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol. Organisms are picked roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field (an example would be *Isonychia*), then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples. These include colonial species (Bryozoa, Porifera), Nematoda, Collembola, semiaquatic Coleoptera such as Chrysomelidae, and all Hemiptera except Naucoridae, Belostomatidae, Corixidae and Nepidae. These are not picked either because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic. The hemipteran families that are included can spend long periods below the water surface.

Laboratory Procedures & Data Interpretation

When a sample is returned to the laboratory for analysis, the person identifying the sample will combine all vials collected from a site into one petri dish for identification. All organisms in the sample are then identified to the lowest possible taxonomic level, recorded on a Benthic Macroinvertebrate Lab Sheet, and tabulated as Rare=1 (1-2 specimens), Common=3 (3-9 specimens) or Abundant=10 (>10 specimens). Most organisms may be identified using only a dissecting microscope, but Oligochaeta, Chironomidae and some mayfly structures must be mounted on glass slides and identified with a compound microscope. Following identification, samples are labeled and stored for an indefinite time period.

After the sample is identified and the lab sheet is complete, all taxonomic data, along with data from the benthos collection card, is entered by biologists into a benthos database utilizing a Microsoft Access database. After the data is entered, it is checked for coding or relative abundance errors. It is imperative that consistent coding be used when entering data in the fields for waterbody, sample type, ecoregion and bioclassification. Please use the most current coding memo for the correct codes. When the data is saved, total taxa richness, EPT taxa richness, Biotic Index value for the sample, EPT Biotic Index value and EPT abundance are automatically calculated. A species list for one or many samples can be retrieved using this system.

The ultimate result of a benthos sample is a bioclassification for the sample. Bioclassifications used by BAU are Excellent, Good, Good/Fair, Fair or Poor for standard qualitative and EPT samples. This bioclassification is automatically calculated in Microsoft Access, unless the sample is outside the summer period, from a small stream, or from a swamp stream. Any seasonal corrections are made manually (outside the database) after all taxa in a sample are entered into the database. The bioclassification is entered manually based on the corrected values and notes about corrections are made in the comments section for each sample.

A complete list of all benthic macroinvertebrates collected (BINDEX) is maintained in the Microsoft Access database, or in an Access database. The BINDEX list contains the taxa code, the species name, order, family, tolerance value (an index based on the pollution tolerance of each taxa), and feeding type of each taxa. This list is given in Appendix 1 of the DWQ SOP for Benthic Macroinvertebrates for all taxa that have been assigned a tolerance value.

EPT Criteria: The simplest method of data analysis is the tabulation of species richness. Species richness is the simplest measure of biological diversity (Larsen and Herlihy 1998). The association of good water quality with high species (or taxa) richness has been thoroughly documented. Increasing levels of pollution gradually eliminate the more sensitive species, leading to lower and lower species richness. Total taxa richness (S or ST) and taxa richness for Ephemeroptera + Plecoptera + Trichoptera (EPT S or SEPT) are calculated and EPT S is one metric used to assign a biological classification. The bioclassification or rating primarily reflects the influence of chemical pollutants. The effects of sediment are not assessed as well by taxa richness analysis, because the multi-habitat sampling technique allows finding suitable habitats which remain above the level where scour or sediment deposition are having the most impact. Bioclassification criteria for EPT taxa richness values for three major ecoregions have been developed. For EPT samples, the criteria below are the only metric used.

EPT TAXA RICHNESS CRITERIA FOR EPT SAMPLES

	Mountain	Piedmont	Coastal Plain (CA)
Excellent	>35	>27	>23
Good	28-35	21-27	18-23
Good-Fair	19-27	14-20	12-17
Fair	11-18	7-13	6-11
Poor	0-10	0-6	0-5

For standard qualitative samples, the EPT criteria shown here were historically used to directly assign bioclassifications, but now are not used directly because new criteria using borderline values were developed in 1995. (See Derivation of Final Bioclassification for Standard Qualitative Samples.)

Seasonality Corrections: Bioclassifications are assigned from the EPT taxa richness values, based on the expected values for summer (June-September) collections. However, expected EPT taxa richness values will vary seasonally, and adjustments should be made to all non-summer collections. Because all collections will be conducted in July, not corrections will be necessary.

Biotic Index Criteria: The Biological Assessment Unit had historically (1983-1990) assigned water quality ratings (= bioclassifications) based on EPT taxa richness alone or in combination with total taxa richness. The sole use of these taxa richness values to produce bioclassifications, however, made interpretation of some data very difficult. EPT taxa richness values must often be adjusted to account for collection method, stream size, seasonal changes, and ecoregion. For this reason, a North Carolina Biotic Index (NCBI) was derived as another (independent) method of bioclassification to support water quality assessments (Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987) with tolerance values derived from the NC database. Biotic indices may be calculated for both standard qualitative samples (NCBI or BI) or EPT samples (BIEPT), based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst. Only the BI values are used to produce a final site classification; the BIEPT values are only intended to aid in the interpretation of data.

The Biotic Index for a sample is a summary measure of the tolerance values of organisms found in the sample, relative to their abundance.

$$\text{Biotic Index (BI)} = \frac{\text{Sum}(TV_i)(n_i)}{N}$$

TV_i = ith taxa's tolerance value
n_i = ith taxa's abundance value (1, 3 or 10)
N = sum of all abundance values

Classification criteria for biotic index values were derived using the existing data base in 1991 by examining average biotic index values for each combination of bioclassification (based on EPT taxa richness), ecoregion and season. At that time a 0-5 scale was used for NCBI values. In 1992, the scale and associated criteria were expanded to 0-10 and tolerance values were recalculated using the database of samples collected to that time. A re-evaluation of tolerance values was done in early 1994. New Biotic Index values for all samples in the database were calculated. This revision led to the conclusion that separate criteria are needed for the mountain, piedmont and coastal plain (Coastal A) ecoregions. It also indicated that different seasonal corrections for fall, winter and spring are needed for these regions. These are the original criteria before borderline values were derived.

	Biotic Index*		
	Mt	P	CA
Excellent	<4.05	<5.19	<5.47
Good	4.06-4.88	5.19-5.78	5.47-6.05
Good-Fair	4.89-5.74	5.79-6.48	6.06-6.72
Fair	5.75-7.00	6.49-7.48	6.73-7.73
Poor	>7.00	>7.48	>7.73

* Historical use only

Occasional problems have been observed with Biotic Index value use:
1. BI and BIEPT may not measure impacts that are largely due to sediment, especially if measurements are conducted after a period of scour when sediment-tolerant species ("stable-sand" community) have not yet been established, or chironomids are sparse. In this instance, there may be a change in habitat quality, but no change in water quality. Similar communities will be found both above and below the source of sediment, but abundances will be sharply reduced in the sediment-impacted area. Both taxa richness and abundance values will be lower at impacted sites. For sites where such habitat changes are the primary cause of stress, the biotic index rating should be used with caution and discussion of results should clearly note the influence of sediment and flow.
2. In some intermediate piedmont/mountain regions, there is the problem of trying to decide which set of criteria should be used. The biotic index should be reviewed carefully at such sites to reduce the possibility of inappropriate criteria being used.
3. The BIEPT, and to some extent the BI, produce very low numbers in some high altitude mountain streams. This problem is immediately evident when control site values are so low that substantial increases do not result in a change in bioclassification. The BIEPT can be used to support other data, give site rankings and an assessment of damage if there are large between-site differences.
4. BIEPT values have little meaning when EPT N is very low (<30). In these cases, the EPT taxa could be mainly drift organisms from upstream, with no development of tolerant taxa at the stressed site. BI values also may not reflect additional impact if the control site is highly stressed, especially if it is rated as Poor. A typical example of this is when urban runoff impacts an upstream site.

Derivation of Final Bioclassification for Standard Qualitative Samples: For most mountain, piedmont and coastal plain (Coastal A) streams, equal weight should be given to both the NC Biotic Index value and EPT taxa richness value in assigning bioclassifications. Exceptions are detailed in the preceding paragraphs. For these metrics, bioclassifications are assigned from the following scores:

Excellent: 5 Good: 4 Good-Fair: 3 Fair: 2 Poor: 1

"Borderline" values are assigned near half-step values (1.4. 2.6, etc.) and are defined as boundary EPT values +1 (except coastal plain), and boundary biotic index values +0.05. The two ratings are then averaged together, and rounded up or down to produce the final classification. The exception to this is discussed below and occurs when the EPT and BI score differ by exactly one.

The following table should be used to determine the scores for EPT taxa richness values and Biotic Index values for all standard qualitative (Full Scale) samples after seasonal corrections are made:

Score	BI Values			EPT Values		
	Mt	P	CA	MT	P	CA
5	<4.00	<5.14	<5.42	>43	>33	>28
4.6	4.00-4.04	5.14-5.18	5.42-5.46	42-43	32-33	28
4.4	4.05-4.09	5.19-5.23	5.47-5.51	40-41	30-31	27
4	4.10-4.83	5.24-5.73	5.52-6.00	34-39	26-29	22-26
3.6	4.84-4.88	5.74-5.78	6.01-6.05	32-33	24-25	21
3.4	4.89-4.93	5.79-5.83	6.06-6.10	30-31	22-23	20
3	4.94-5.69	5.84-6.43	6.11-6.67	24-29	18-21	15-19
2.6	5.70-5.74	6.44-6.48	6.68-6.72	22-23	16-17	14
2.4	5.75-5.79	6.49-6.53	6.73-6.77	20-21	14-15	13
2	5.80-6.95	6.54-7.43	6.78-7.68	14-19	10-13	8-12
1.6	6.96-7.00	7.44-7.48	7.69-7.73	12-13	8-9	7
1.4	7.01-7.05	7.49-7.53	7.74-7.79	10-11	6-7	6
1	>7.05	>7.53	>7.79	0-9	0-5	0-5

Biotic Index corrections for non-summer data:
Summer = Jun-Sep, Fall = Oct-Nov, Winter = Dec-Feb, Spring = Mar-May

	Fall	Winter	Spring
Mountain Correction	+0.4	+0.5	+0.5
Piedmont Correction	+0.1	+0.1	+0.2
Coastal A Correction	+0.2	+0.2	+0.3

EPT N Criteria for Rounding Decisions

The Biological Assessment Unit has in prior years (1983-1996) used EPT abundance (EPT N) values in evaluating water quality impacts without formal quantification of criteria. EPT abundance is the sum of the abundance values for all EPT taxa in a sample, where Rare = 1, Common = 3, and Abundant = 10. EPT N allows differentiation of situations where intolerant groups are simply present from situations where healthier (more abundant) populations exist in a stream. One example is a stressed site that is a short distance downstream of a much cleaner site. There could be continual drift colonization of the downstream site, but most EPT taxa should remain rare. EPT N will illustrate changes between these two sites more clearly than a simple count of EPT taxa.

EPT N, however, also might be expected to vary depending on flow, season, and normal sampling variability. For this reason, a slightly different approach relative to prior DWQ criteria development is used here to determine rounding criteria using EPT abundance. Normally, the suggested criteria would be derived by calculating the mean EPT N for each bioclassification, and then establishing the criteria values as half-way between these means. Instead, the means and standard deviations were calculated for each bioclassification in three ecoregions. The criteria, therefore, include most potential sources of variation. Seasonal variation was relatively low, and effect of stream width determined to be minor. EPT abundance is highest in the mountains and least in the coastal plain. Expected ranges for each bioclassification (+/- one standard deviation (SD)) show little overlap for areas of poorer water quality, especially the Fair and Poor bioclassifications. There is greatest overlap for the Good and Excellent categories in the piedmont and coastal plain.

The rounding approach is applied only when the BI and the EPT scoring differ by exactly one bioclassification, producing a final score midway between two ratings: 1.5, 2.5, 3.5, or 4.5. When trying to decide between two bioclassifications, use the EPT abundance value criteria below (derived from mean for the higher bioclassification minus one SD), and round down if the EPT N is less than the value and round up if it is equal to or above the value. Example: When comparing data from a Piedmont stream, and the BI score = 5, but the EPT score = 4. Round down (to Good) if EPT N < 135.

Rounding Criteria: Round down if EPT N < criterion, otherwise round up.

Bioclassification (Score)	MT	P	CA
Excellent (5) vs. Good (4)	191	135	108
Good(4) vs. Good-Fair (3)	125	103	91
Good-Fair (3) vs. Fair (2)	85	71	46
Fair (2) vs. Poor (1)	45	38	18

B5. Quality Control - Identify QC activities which will be used for each type of sampling, analysis, or measurement technique; for example, blanks, spikes, duplicates, etc., and at what frequency (also include what criteria will be used to determine if a corrective action is needed and what that corrective action will be).

Field QC Checks

The following table outlines QC procedures

Activity	QC Procedure	Purpose
Check field equipment	Look for holes in nets, rinse all nets and tubs carefully between sites.	Ensure that samples are high quality and representative of conditions

Laboratory QC Checks - Describe Laboratory QC procedures

Taxonomic quality control in the laboratory is maintained in several ways. Organisms are first identified using current, regional identification manuals and other appropriate taxonomic literature. If questions occur, identifications are verified by other taxonomists. In order to maintain consistency in the taxonomic identifications, a Benthos Taxonomy Document has been compiled for the EPT and Coleoptera orders. This document specifies the level of identification to be used (genus or species), the references to be used for the IDs, and any pertinent ecological or distribution data available. This document will be updated regularly and other orders added as resources allow. Copies of all taxonomic papers used have been placed in a readily accessible location in the laboratory for the use of all benthic biologists. Taxonomic assistance is obtained from specialists when appropriate.

Reference specimens (most verified by taxonomic experts) are maintained in a reference cabinet, and samples are stored for future reference. A reference specimen list is maintained, and updated periodically. Also, random samples are re-identified for taxonomic consistency. Identification of the QA sample should begin as soon as it is received, and must be completed within one week, if in the office. After QA discussions (which may involve more than one biologist) the lead benthic biologist logs the information into a QA log book. If a QA accuracy of 90% or greater is not found, then the prior 10 samples will be re-identified by the lead biologist and the original identifier.

Data Analysis QC Checks- Describe data analysis QC procedures. Include what criteria will be used to determine if a corrective action is needed and what that corrective action will be. Provide or reference QC statistics used to determine precision and bias, if applicable.

Following raw data entry into the Access database, an independent check of 100% of the entered data is conducted by an individual not involved with data entry or collection. Following the original data entry QC, another check, by a different individual will be conducted on 10% of the entered data.

B6. Instrument/Equipment Testing, Inspection, and Maintenance - Identify field and laboratory equipment needing periodic maintenance, and the required inspection schedule. Describe preventative and corrective maintenance activities.

Equipment Type	Inspection Frequency	Type of Inspection/Preventative/ Corrective Action
Kick-net	one day prior to sampling	Visual inspection of seams and netting continuity
Sweep-net	one day prior to sampling	Visual inspection of seams and netting continuity
Sieve bucket	one day prior to sampling	Visual inspection for holes or other seal breaches
Chironomid-getter	one day prior to sampling	Visual inspection of seams, netting, and pipe continuity
Large plastic tub	one day prior to sampling	Visual inspection for holes or other seal breaches
Fine mesh (300 microns) netting bag	one day prior to sampling	Visual inspection of seams and netting continuity
Collection vials	one day prior to sampling	Ensure enough clean vials are packed
Forceps	one day prior to sampling	Visual inspection of tip alignment and body
Stereo microscope	Immediately prior to identification	Visual inspection of lighting, focus, and lens clarity

B7. Instrument/Equipment Calibration and Frequency - Identify equipment, tools, and instruments that should be calibrated, and the frequency and method for this calibration (include summary of method for calibrating laboratory equipment unless a state certified lab is used; also include calibration of field equipment such as stage recorders and flow meters). Note how calibration records will be kept and traceable to equipment.

Equipment Type	Calibration Frequency	Standard or Calibration Instrument Used
N/A – Certified benthos lab (Lenat Consulting) used for IDs		

B8. Inspection/Acceptance of Supplies and Consumables

Identify critical supplies and consumables for field and laboratory, and acceptance criteria. Note responsible individual(s).

Equipment/Supply	Inspection/Maintenance Activity	Acceptance Criteria
Field Collection equipment (above)	Brian Hockett	All holes, bends, and other indications of unsatisfactory conditions fixed, or equipment not used in field effort.
Water		
Bug spray		

B9. Non-Direct Measurements - Identify data sources, for example, computer databases or literature files, or models that will be accessed and used, data recording methods, and references for this information.

Non-direct Measurements.

Identify data sources, for example, computer databases or literature files, or models that will be accessed and used. Describe limitations of the secondary data. Document rationale for original collection of data and its relevance to this project.

All data are directly generated through the field activities and subsequent laboratory analysis, with two exceptions:

- Geo-referenced data (latitude and longitude) are obtained from either Trimble GeoXT sub-meter GPS collection, or Google Earth aerial image interpretation.
- Watershed drainage areas are calculated using Wake County topographic data (one foot contour intervals).

Data Recording Methods for Non-Direct Measurements

Data Element/Measurement	Minimum Data Recording Method
N/A	

B10. Data Management

Describe data management scheme from field to final use and storage, and describe the process for data archival and retrieval. Include a summary of data analysis procedures, data transformations, and statistical analyses, if applicable.

Data Type and Data Management/Storage

Data Type	Management and Storage
Benthic field samples	Collected individuals are saved in alcohol in vials. Upon completion, the vials are hand-delivered to the certified lab for identification.
Sample ID	Once ID'd, physical samples are maintained for one year. ID results are entered into Acess database and permanently saved on WK Dickson and DENR Environmental Sciences Section servers, both of which have daily off-site backup.

Data Management and Analysis. Describe data management scheme from field to final use, data compiling and data storage. Describe the process for data archival and retrieval. Include summary of data analysis procedures, data transformations, and statistical analyses, if applicable. Include project-specific calculations or algorithms, if applicable.

Benthic macroinvertebrate samples are “picked” in the field and stored in plastic vials containing 95% ethanol. Following collection, samples are transported in WK Dickson vehicles to the Watershed Sciences Lab (Raleigh). Samples are hand-delivered to Lenat Consulting (State Certified Lab, Raleigh). Identification results are provided digitally to WK Dickson (MS Word format). Data results are entered into DENR BAU’s Access database, which is delivered to Cam McNutt (NCDWQ Planning) for use support evaluation.

C1. Assessments and Response Actions - List the number, frequency, and type of assessment activities that should be conducted. Specific response actions for the situations listed below will generally apply. Also list who is responsible for each action.

Situation	Response Action	Responsible Person/Organization
Sample sites too turbid to accurately identify collection sites	Re-schedule	Existing Conditions Evaluation: Trish MacPherson/WK Dickson
		Scheduling: Ward Marotti/WK Dickson
Sample lost, dropped, or otherwise compromised	Schedule re-collection	Ward Marotti/WK Dickson
Significant errors in data entry observed	Re-enter and 100% QC	Ward Marotti/WK Dickson

C2. Reports to Management - Identify what project QA status reports are needed and how frequently they will be prepared

Report	Frequency	Who Prepares Report	Who Receives Report
Project Status	Quarterly	Holly Miller	Kim Nimmer
Results of performance evaluation and audits (if applicable)	N/A		
Results of periodic data quality assessments (if applicable)	N/A		
Any significant QA problems	Quarterly	Holly Miller	Kim Nimmer

D1. Data Review, Verification and Validation - Describe the criteria that will be used for accepting, rejecting, or qualifying project data. (include criteria for determining anomalies or outliers, what portion of data will be reviewed, who will do it, and what happens if data deemed ‘bad’)

Criteria for Accepting, Rejecting, or Qualifying Project Data.

Include criteria for determining anomalies or outliers, what portion of data will be reviewed, who will do it, and what happens if data deemed 'bad'

Data verification and validation occurs at every step of data generation and handling. Ward Marotti is responsible for verifying that all records and results produced or handled are completely and correctly recorded, transcribed, and transmitted. Mr. Marotti is responsible for ensuring that all activities performed (sampling, analyses, data entry, etc.) comply with all requirements outlined in the Smith Creek QAPP. These responsibilities include, but are not limited to: taxonomic QA/QC, annual overlap field sampling, and annual database audits.

Data that are entered into the BMCAP's database are constantly being checked for errors, and a random subset (10%) of all data entered that year is audited for accuracy. Some of the data entry checks include:
•County - Only North Carolina counties allowed; confirmation that the county in the database matches the site location;

•Ecoregion - Only four physiographic regions can be entered for non-swamps (Mountains, Piedmont, Sand Hills, or Coastal Plain); For swamps, there are five physiographic regions (Region A, B, C, P, and S);

•Latitude and Longitude - Only coordinates located in North Carolina can be entered;

•Road Crossing - Confirmation that the crossing in the database matches the site on the map;

•Water Quality Variables (temperature, specificconductance, dissolved oxygen, and pH) – "Flag" values outside ranges normally encountered and do not allow the data to be saved;

•Validate seasonal taxa corrections;

•Validate the river basin and subbasin; does it match the site location, etc. In terms of data acceptance.

Decision Rule or "if/then" Statement. Provide if applicable.
Note: Some projects, especially research or preliminary investigations, may not require a specific "if/then" statement. This is also applicable for decisions regarding data "outliers."

N/A

D2. Verification and Validation Methods - Describe the process for data verification and validation, providing SOPs and indicate what data validation software will be used. State the percentage of the data to be reviewed. List the responsible individual/organization.

Data Element	Typical Validation and Verification Methods
ID data entry	100% QC, WK Dickson

D3. Reconciliation with User Requirements and Data Quality Objectives

Also include how the data will be summarized to be able to report results to decision makers. Describe process for reconciling project results with data quality objectives (DQOs) and reporting limitations on use of data. Identify issue resolution procedure(s) and responsible individuals

Access-entered data, as well as a summary PDF will be provided to Cam McNutt (DWQ Planning) for use support evaluation. Results will also be summarized in the Smith Creek Watershed Restoration Plan.

Appendix 1:

Benthic Macroinvertebrate Community Assessment Program (BMAP) EPA Quality Assurance Project Plan

BENTHIC MACROINVERTEBRATE COMMUNITY ASSESSMENT PROGRAM (BMCAP)

QUALITY ASSURANCE PROJECT PLAN

Program Administered and Plan Prepared by:
North Carolina Department of
Environment & Natural Resources
Division of Water Quality
Environmental Sciences Section
Biological Assessment Unit

Approved by EPA
February 2012
Version 1.1

NCDENR

Abbreviations

BAU	Biological Assessment Unit
BI	Biotic Index
BMCAP	Benthic Macroinvertebrate Community Assessment Program
CWA	Clean Water Act
DO	Dissolved Oxygen
DWQ	Division of Water Quality
EBIII	Lead Environmental Biologist
EEP	Ecosystem Enhancement Program
EPA	Environmental Protection Agency
EPT	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies)
EPTBI	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies) Biotic Index
EPT N	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies) Abundance
EPTs	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies) Taxa Richness
ESS	Environmental Sciences Section
HQW/ORW	High Quality Waters/Outstanding Resource Waters
ISU	Intensive Survey Unit
NCBI	North Carolina Biotic Index
NCDENR	North Carolina Department of the Environment and Natural Resources
NCDOT	North Carolina Department of Transportation
NFQA	National Field Quality Assurance
NGO	Nongovernmental Organizations
NPDES	National Pollutant Discharge Elimination System
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
S	Total Taxa Richness
SOP	Standard Operating Procedures
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WAT	Watershed Assessment Team
WWTP	Wastewater Treatment Plant

REVISION LOG

BENTHIC MACROINVERTEBRATE COMMUNITY ASSESSMENT PROGRAM QUALITY ASSURANCE PROJECT PLAN

Note: Actions older than 5 years may be removed from this record

Date Edited	Editor	Version Edited	Section Edited	Changes/updates
11/30/2011	Eric Fleek	07/03/2007	Cover Page	Updated submittal date and added version identification (version 1.1)
11/30/2011	Eric Fleek	07/03/2007		Added a revision log to QAPP
11/30/2011	Eric Fleek	07/03/2007	Analytical Methods	Referenced the completion of the small streams biocriteria and changes in sampling methodologies. Also, added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009.
12/01/2011	Eric Fleek	07/03/2007	References	Added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009.
12/20/2011	Joanna Gmyr	07/03/2007	A1, A2, A3	Updated signature list, distribution list, & project organization.
12/20/2011	Joanna Gmyr	07/03/2007	Acronyms	Updated list of acronyms
12/20/2011	Joanna Gmyr	07/03/2007	A5	Updated Figures A5.1 and A5.2
12/20/2011	Joanna Gmyr	07/03/2007	Appendix 1	Inserted newly revised Benthic SOP (Revised Dec. 2011)
12/20/2011	Joanna Gmyr	07/03/2007	Appendix 2	Inserted current Field Meter Calibration Sheet (Revised 04/18/2010)
12/20/2011	Joanna Gmyr	07/03/2007	A3	Updated Figure A3.1

Table of Contents

SECTION A:

PROJECT MANAGEMENT

A1. Signature and Approval Sheet

Approved by:

(for Michael Walters)

Michael Walters
Benthic MacroInvertebrate Program Coordinator
Environmental Sciences Section, NC DWQ

12/21/2011
Date

Eric D. Fleek
Biological Assessment Unit Supervisor
Environmental Sciences Section, NC DWQ

12/21/2011
Date

Joanna Gmyr
Joanna Gmyr
Quality Assurance Coordinator
Environmental Sciences Section, NC DWQ

12/21/11
Date

Jay H. Sauber
Jay Sauber
Section Chief
Environmental Sciences Section, NC DWQ

12/21/2011
Date

Marion D. Hopkins
Designated Approving Official
Environmental Protection Agency Region IV

2/1/2012
Date

A2. Distribution List

Primary Distribution:

EPA, Region IV, Water Protection Division, Water Quality Planning Branch

Marion Hopkins, NC Monitoring, Grant Technical Officer
Andrea Zimmer, Monitoring and Information Analysis Section Chief
Joanne Benante, Water Quality Planning Branch Chief

NC Department of Environment and Natural Resources, Division of Water Quality

Environmental Sciences Section

Jay Sauber, Environmental Sciences Section Chief

Eric Fleek, Biological Assessment Unit Supervisor
Steven Kroeger, Ecosystems Unit Supervisor
Jason Green, Intensive Survey Unit Supervisor
Cindy Moore, Aquatic Toxicology Unit Supervisor
Jill Paxson, Estuarine Monitoring Team Leader

Jeff DeBerardinis, Fish Tissue Monitoring Program Coordinator
Joanna Gmyr, Quality Assurance Coordinator
Debra Owen, Lakes Monitoring Program Coordinator
Andrea Thomas, Ambient Monitoring System Coordinator
Bryn Tracy, Stream Fish Community Assessment Program Coordinator
Michael Walters, Benthic Macroinvertebrate Community Assessment Program Coordinator

Biological Assessment Unit Staff:
Steven Beaty, Benthic Biologist
Dee Dee Black, Benthic Biologist
Victor Holland, Benthic Biologist
Tracy Morman, Benthic Biologist
Michael Shepherd, Fisheries Biologist

Regional Office Surface Water Protection Supervisors:
Corey Basinger, Winston-Salem (WSRO)
Chuck Cranford, Asheville (ARO)
Jim Gregson, Wilmington (WiRO)
Belinda Henson, Fayetteville (FRO)
Al Hodge, Washington (WaRO)
Rob Krebs, Mooresville (MRO)
Danny Smith, Raleigh (RRO)

Planning Section

Alan Clark, Planning Section Chief

Courtesy Distribution:

Coleen Sullins, NC Division of Water Quality Director
Chuck Wakild, NC Division of Water Quality Deputy Director
Matt Matthews, Surface Water Protection Chief
Jeff Manning, Basinwide Planning Unit Supervisor
Jeff Poupart, Point Source Branch Head
Dana Satterwhite, Laboratory QA/QC Officer
Kathy Stecker, Modeling & TMDL Unit Supervisor
Kent Wiggins, Laboratory Section Chief

A3. Project Organization

The Benthic Macroinvertebrate Community Assessment Program (BMCAP) is housed within the Environmental Sciences Section of the Division of Water Quality (DWQ), within the North Carolina Department of Environment and Natural Resources (NCDENR). Activities associated with the BMCAP (fieldwork, project management, QA, data management, analysis, and reporting) are performed by Biological Assessment Unit (BAU) staff members, with additional assistance provided by other staff in the Environmental Sciences Section (ESS).

An abbreviated organizational chart for the Division of Water Quality is provided in Figure A3.1. Information on specific individuals' roles and responsibilities follows. Phone numbers and addresses for the offices listed can be found at http://portal.ncdenr.org/web/wq

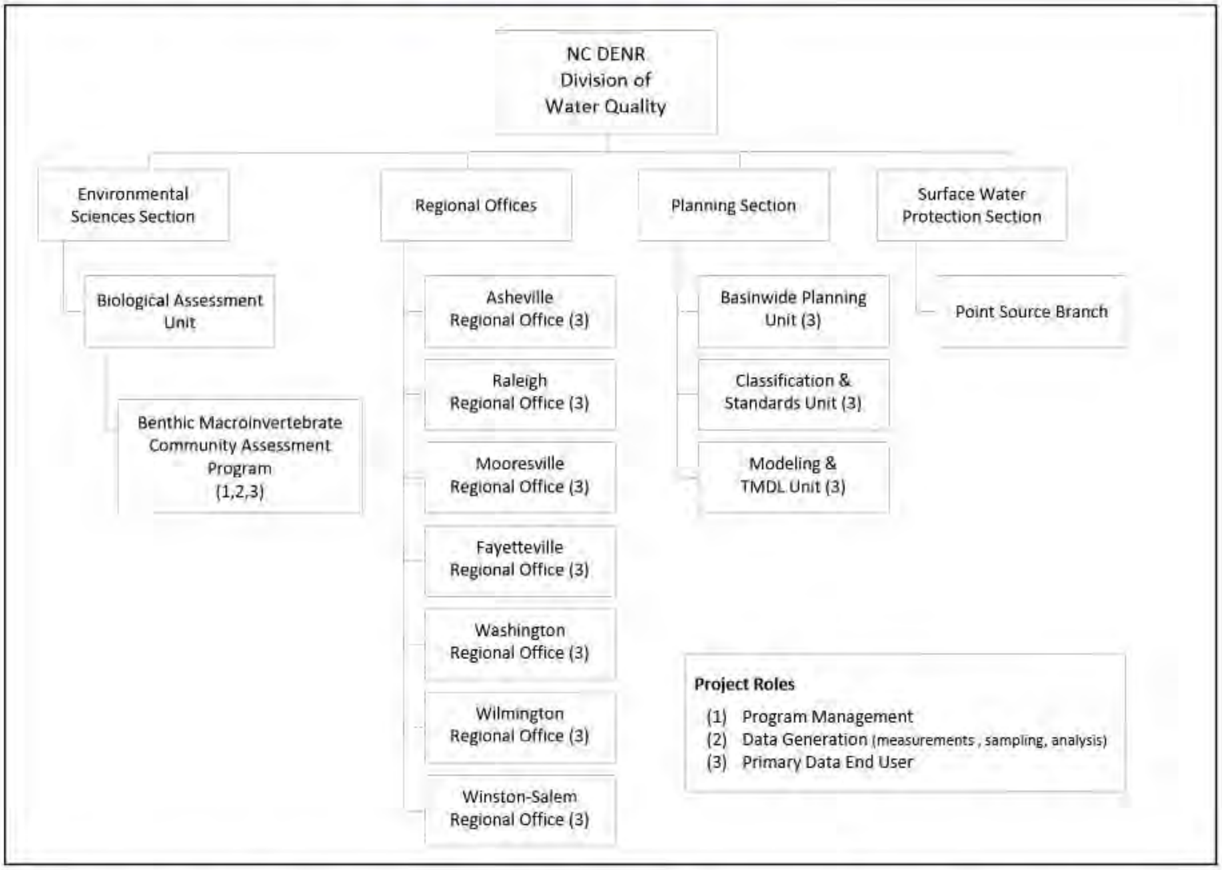


Figure A3.1 Benthic Macroinvertebrate Community Assesment Program Organizational Chart.

Project Management and Oversight

Biological Assessment Unit (BAU) Supervisor
Eric D. Fleek

Supervises benthic macroinvertebrate and fisheries programs. Serves as liaison between BAU and other internal NC DWQ consumers of BAU data. Acts as a liaison with other divisions within NCDENR, NCDOT, EPA, USGS, and various NGO's as well as with individual citizens. Approves all final reports and policy/method revisions. Responsible for QA/QC of macroinvertebrate database and participates in QA/QC of some macroinvertebrate samples. Assists the Lead Environmental Biologist with acquiring new regional taxonomic keys and the identification of difficult or problematic taxonomic invertebrate groups. Primary curator of the physical macroinvertebrate reference collection. Maintains BAU's Macroinvertebrate bench sheet, collection card, and habitat records collection. Participates in field sampling, laboratory identification, data entry, and report generation. Maintains and updates the BAU macroinvertebrate SOP and the Taxonomy Document. Maintains sampling equipment. Ensures the BMCAP is conducted in accordance with all pertinent QAPP's and SOP's. Recommends new employee hires and approves changes to the BMCAP.

Lead Environmental Biologist BAU
Michael Walters
Program Coordinator

Conducts annual taxonomic reviews and updates. Provides primary assistance to other staff with problematic invertebrate taxonomy and acquires new and/or revised regional invertebrate taxonomic keys. Acts as the primary macroinvertebrate QA/QC for BAU staff. Maintains the macroinvertebrate QA/QC database and conducts QA/QC of macroinvertebrate samples. Curates the virtual macroinvertebrate collection. Responsible for macroinvertebrate programmatic development, study designs, field sampling, stream reclassifications (e.g., ORW/HQW), laboratory identification, data entry, and report generation. Also maintains contact with regional macroinvertebrate taxonomic experts. Leads field and laboratory training of BMCAP staff.

Field Staff
Consists primarily of staff from the Biological Assessment Unit. Additional assistance and support from other units in the Environmental Sciences Section.

Field staff members assist the Lead Biologist with sample collection and processing.

Program QA Coordinator
Joanna W. Gmyr
QA Coordinator, Ecosystems Unit, ESS

Documents QA practices of BMCAP. Maintains BMCAP QAPP. Develops and recommends QA/QC improvements. Ensures that the BMCAP is conducted in accordance with the BMCAP QAPP.

Primary Data End-Users

Planning Section
Alan Clark, Section Chief

Supervises the Basinwide Planning Unit and the Modeling and TMDL Unit.
These units include numerous staff acting as primary end-users of data produced by the BMCAP.

Staff from the Planning Section should:

- Provide input to the Lead Environmental Biologist and BAU Supervisor on changes needed to the BMCAP as part of a continuous program assessment process.
- Report any data anomalies to the Lead Environmental Biologist and BAU Supervisor.
- Report any waterbodies in need of assessment.

Regional Office Surface Water Protection

Regional Supervisors:

James Gregson, Wilmington Regional Office
Chuck Cranford, Asheville Regional Office
Robert Krebs, Mooresville Regional Office
Belinda Hinson, Fayetteville Regional Office
Al Hodge, Washington Regional Office
Danny Smith, Raleigh Regional Office
Corey Basinger, Winston-Salem Regional Office

There are seven regional offices within the NCDENR. The regional offices perform the Department's duties on a local level and are responsible for compliance and enforcement actions.

Staff from the regional offices should:

- Provide input to the Lead Environmental Biologist and BAU Supervisor on changes needed to the BMCAP as part of a continuous program assessment process.
- Report data anomalies to the Lead Environmental Biologist and BAU Supervisor.
- Report waterbodies in need of assessment.

Surface Water Protection Section

Matt Matthews, Section Chief

The Surface Water Protection Section includes the Point Source and the Wetlands and Stormwater branches. The Point Source Branch is responsible for administering the State's National Pollutant Discharge Elimination System (NPDES) program that was established to control point-source discharges of water pollution. The Branch functions to protect, maintain, and enhance the State's waters by fostering compliance with North Carolina's environmental statutes, regulations, and permits. When compliance is not met, this Section may take enforcement actions.

Staff from the Section should:

- Provide input to the Lead Environmental Biologist and BAU Supervisor on changes needed to the BMCAP as part of a continuous program assessment process.
- Report data anomalies to the Lead Environmental Biologist and BAU Supervisor.
- Report waterbodies or impacts from permitted facilities in need of assessment.

U. S. EPA

EPA Region IV

- Reviews, provides comments, and approves QAPP and subsequent revisions on behalf of EPA Region IV.
- Performs mid-year and end-of-year assessments of all DWQ monitoring program, including the BMCAP, to determine progress on tasks listed in the annual §106 grant workplan.

A4. Problem Definition and Background

Introduction

As part of funding agreements between North Carolina and the U. S. Environmental Protection Agency (EPA), DWQ agrees to monitor the waters of the State and report findings to the EPA to support the goals of the Clean Water Act (CWA). The CWA defines as its objective: " . . . *to restore and maintain the chemical, physical, and biological integrity of the Nation's waters, and, where attainable, to achieve a level of water quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water*."

Benthic Macroinvertebrate Community Assessment Objectives

The DWQ utilizes several programs and tools to assess the quality of the State's waters. One of the most tested and peer-reviewed programs is the BMCAP. The primary objective of this program is to provide benthic macroinvertebrate community ratings for wadeable and non-wadeable streams to the Basinwide Planning Unit for use support determinations and for the Planning Section's Basinwide Water Quality Management Plans. Secondary objectives of the Benthic Macroinvertebrate Community Assessment Program are to provide data suitable for supporting the following DWQ activities:

- Planning Section
  - Biennial 303(d) and 305(b) reporting to EPA, including identification of areas of impairment or degradation,
  - TMDL development,
  - Stream reclassifications (e.g., ORW, HQW),
  - Prioritization of restoration activities, and
  - Background information for Use Attainability studies.
- Surface Water Protection Section
  - Identification of background levels of constituents for determination of NPDES permit limits, and
  - Identification of dischargers causing unacceptable impacts.
- Regional Offices
  - Background information to assist with water quality management activities in each region.
  - Benthic macroinvertebrate data used as supporting evidence for use in enforcement actions initiated by DWQ for violations of the Clean Water Act.

A5. Project/Task Description and Schedule

Overview

The BMCAP is an additional water quality assessment tool that has been in existence since the late 1970's, but with a consistent sampling methodology since 1983. Its core mission is to sample a set of fixed sites located on lower Strahler order, wadeable and non-wadeable creeks, streams, swamps, and rivers on a five-year rotating basis to support the DWQ's Basinwide Management Plan Program. More than 6,000 sites (located throughout the Coastal Plain, Piedmont, and Mountains) have been assessed by the BMCAP (Figure A5.1). Most of the stations are located at bridge crossings or other public accesses and are accessible by land.

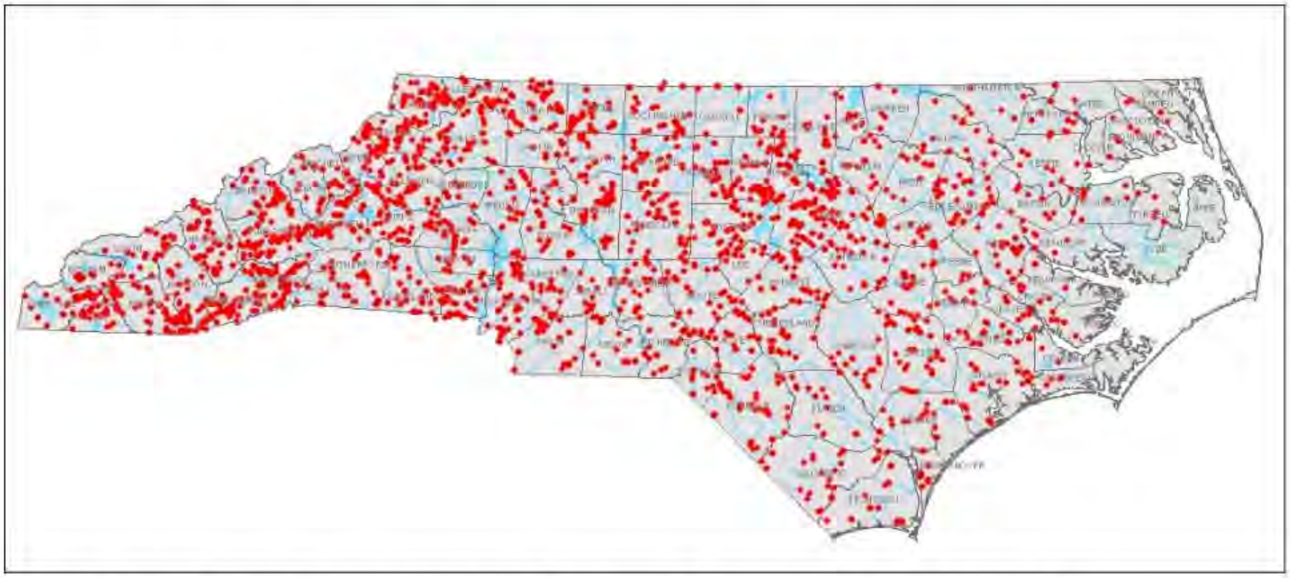


Figure A5.1 Benthic Macroinvertebrate Community Assessment Sites: 2005-2010.

Benthic Macroinvertebrate Community Indicators

The Biological Assessment Unit uses aquatic macroinvertebrates as one type of indicator of biological integrity in streams and rivers. A large number of sites are sampled each year during basinwide sampling and special studies; resulting information is used to document both spatial and temporal changes in water quality and to compliment water chemistry analyses. Although bioassessments are useful for identifying biological impairments, they do not identify the causes of impairment. Linking biological effects with their causes is particularly complex when multiple stressors impact a waterbody (USEPA, 2000).

There are several reasons for using biological surveys to monitor water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may be missed. The biota, especially benthic macroinvertebrates, reflects both long and short-term conditions. Since many species in a macroinvertebrate community have life cycles of a year or more, the effects of a short-term pollutant will generally not be overcome until the following generation appears.

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, are less mobile than many other groups of organisms, and are of a size that makes them easy to collect. Moreover, chemical and physical analyses for a complex mixture of pollutants are generally not feasible. The aquatic biota, however, show responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost-effective monitoring tool (Lenat, 1988). The sedentary nature of the benthos ensures that exposure to a pollutant or stress reliably denotes local conditions and allows for comparison of sites that are in close proximity (Engel and Voshell, 2002).

Analysis of faunal assemblages is one way to detect water quality problems (Rosenberg et al, 1986). Different kinds of stress will often produce different benthic macroinvertebrate communities. For example, the taxa associated with organic loading (and low dissolved oxygen) are well documented. Recent studies have begun to identify the biological impacts of sedimentation and toxic stress (Burton, 1991; Waters, 1995; Bode and Simpson, 1982; Clements, 1994).

The core indicators used by the BMCAP to calculate bioclassifications are EPT Taxa Richness (EPTs) and the Biotic Index (BI). In addition, some samples also use Total Taxa Richness (S), EPT Biotic Index (EPTBI), and EPT Abundance (EPT N) to calculate bioclassifications. Standard Qualitative samples, EPT samples, and Boat samples are rated *Excellent*, *Good*, *Good-Fair*, *Fair*, or *Poor*. The bioclassifications or stress categories for swamp stream samples are *Natural*, *Moderate*, and *Severe*; a habitat evaluation score is also included as a metric for swamp samples. Further discussion on these indicators can be found in Section B4 of this document and in the Benthic Macroinvertebrates SOP (Appendix 1).

Other Water Quality Indicators

Although benthic macroinvertebrate communities are the primary tools used in the BMCAP, other water quality measurements (e.g., water temperature, dissolved oxygen, pH, specific conductance, and water clarity) are also monitored at every site in accordance with the Intensive Survey Unit's SOP (http://portal.ncdenr.org/web/wq/ess/isu). In addition, a non-quantitative stream and riparian habitat assessment is also performed at each site.

Sampling Schedule

Sites that are part of the DWQ's Basinwide Monitoring Program are sampled once every five years, usually between June and September. For example, basinwide sites in the Yadkin River Basin were sampled in 1996, 2001, and will be sampled again in 2006. However, swamp streams (i.e., seasonally flowing low gradient coastal plain system, generally east of the I-95 corridor) are sampled in February and March. Special study sites that are designed to address a specific, short term question (e.g., Use Attainability, impacts from a permitted discharger, watershed modifications, *etc.*) are usually sampled only once and may be sampled at any time of the year; however, all effort is made to sample during the summer when practicable.

Additional details on sampling methodology can be found in Sections B1 and B2 of this document and in the Benthic Macroinvertebrates SOP (Appendix 1).

Data Management

All results are warehoused in the BMCAP's Fourth Dimension (4-D) database. The database is updated whenever samples are completed or when errors in previously entered data are identified during the annual audit. The annual audit randomly selects 10% of the total number of samples entered into the database that year; those samples are checked for accuracy as detailed in the Benthic Macroinvertebrates SOP (Appendix 1). Audits are conducted by either the Lead Environmental Biologist and or the BAU Supervisor.

Reporting

There are five primary forms of reporting generated by the BMCAP:

- Basinwide Assessment Reports
- HQW/ORW Stream Reclassification reports
- TMDL reports
- EEP and WAT Reports
- Other site-specific special study memoranda (e.g., regional office requests)

All documents are provided to DWQ management, Planning Section and Regional Office staff, and other interested parties. The information may be incorporated into Basinwide Water Quality Management Plans and required biennial reports to EPA for inventory and impairment (combined 303(d) and 305(b) reporting).

Basinwide Assessment Reports

All monitoring programs managed by the ESS are reported in the Basinwide Assessment Reports. These documents are made publicly available on the Internet at http://portal.ncdenr.org/web/wq/ess/reports.

This is the primary reporting method for the Benthic Macroinvertebrate Community Assessment Program. Results are reported the following year for each of the seventeen major river basins in the state on a five-year rotating schedule that is based on the DWQ Basinwide Planning Schedule (Figure A5.2). The cycle began in 1990, and as of 2005, the Year 1 basins are in their fourth monitoring and reporting cycle. All historic data are reviewed when the assessment reports are prepared. However, only data from the most recent five-year assessment period will be analyzed for Use Support determinations by the DWQ's Basinwide Planning Unit.

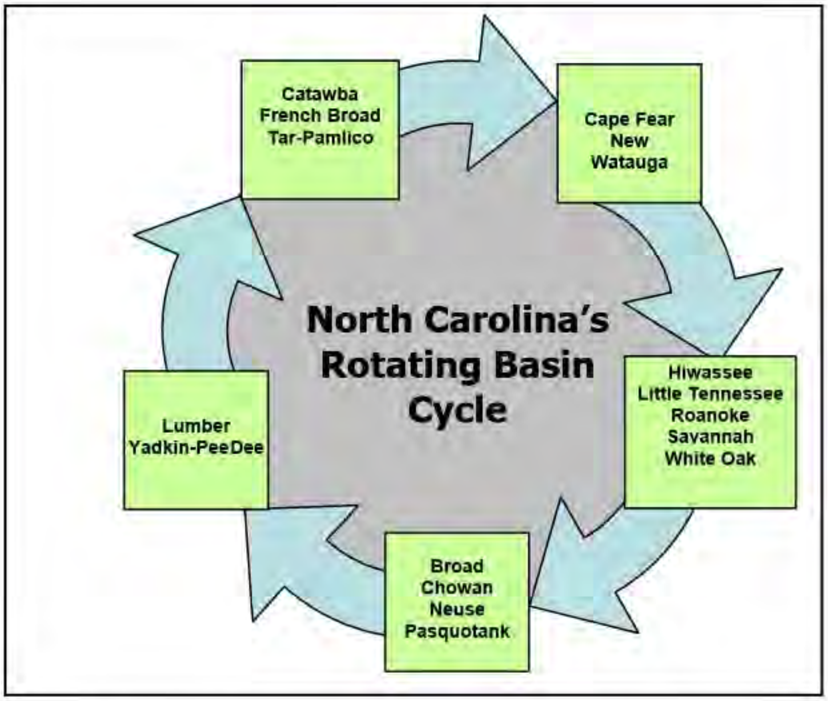


Figure A5.2: Rotating Basin Assessment Cycle

For each report, results are presented by subbasin as narrative summaries and graphical representations. Description of known issues or sources of bias (e.g., sampling conditions, significant climatic events such as droughts or hurricanes, *etc.*) should be sufficient to give the reader adequate context for appropriate interpretation of the results.

The main audience for the information reported in the Basinwide Assessment Report is staff from DWQ's Basinwide Planning Unit. For each monitoring site, if the benthic macroinvertebrate community is rated *Fair* or *Poor*, that particular stream reach may be subject to official impairment and subsequent 303(d) listing. Enough information should be provided in the Basinwide Assessment Report to allow the Basinwide Planning Unit staff to make informed decisions when determining if impairment is warranted for each monitored waterbody. Impairment can lead to further actions by other DWQ programs, such as intensive studies, development of TMDLs or other strategies, and implementation of additional pollutant controls, all of which can have costly impacts for NCDENR as well as NPDES dischargers, municipalities, industries, and animal operations. To prevent inaccurate judgments of impairment from being made, the Basinwide Planning Unit has developed basic data quality and quantity criteria, described in individual Water Quality Plans (available at http://portal.ncdenr.org/web/wqto determine data sources appropriate for the Unit's uses. Information contained in the Basinwide Assessment Report for each monitoring site allows Basinwide Planning Unit staff to easily identify whether the dataset for a particular site meets these criteria.

High Quality Waters/Outstanding Resource Waters (HQW/ORW) Reclassification Reports
HQW/ORW reports evaluate reclassification requests based on existing or new data and determine whether the waterbodies requested meet the criteria for HQW/ORW.

TMDL Reports
TMDL reports detail watershed conditions for streams on the 303(d) list and attempt to identify stressors to the biological community.

Ecosystem Enhancement Program (EEP) and Watershed Assessment Team (WAT) Reports
The BAU samples selected watersheds for EEP studies, and the biological findings are summarized in EEP reports.

Special Study Memoranda
Results of special studies are summarized in formal reports and internal memoranda. These reports are approved by the BAU supervisor and the ESS Section Chief and forwarded to the appropriate party or regional office staff.

A6. Quality Objectives and Criteria

Specific components of a quality assurance and quality control plan are described in the Benthic Macroinvertebrates SOP (Appendix 1). All investigations conducted by the BMCAP follow a written study plan that is reviewed by the BAU supervisor (and often the ESS Chief) before actual sampling is conducted.

Bias
The BMCAP is based on judgmental sampling design. As a result, bias will exist due to site locations (i.e., sites that can be safely waded or accessed by the sampling crew). However, this is acceptable given that monitoring sites are generally established for targeted long-term monitoring of known or suspected areas of concern; identification of temporal patterns at these static locations are a major objective of the program.

Other sources of bias:

- Sampling is performed under existing flow and water clarity conditions. Ideally, monitoring is conducted under low to normal flow conditions with clear or slightly turbid water clarity. Sampling is not conducted if the water is so turbid that instream habitat, which lies below the surface of the water, cannot be seen. In addition, if the water level is so high or swift that sampling would jeopardize the safety of the staff, collection operations are suspended.
- Almost all sites are located at bridge crossings for ease of access and to avoid trespassing on private property. Field staff is instructed to sample on the upstream side of the bridge, if possible, and beyond the artificially created bridge pool and bridge substrate habitats.

Using consistent sampling techniques, laboratory methods, and data analyses as described in the Benthic Macroinvertebrates SOP (Appendix 1) minimizes bias from other sources.

Comparability
Fixed station locations, generally consistent seasonal sampling, and adherence to the BMCAP's SOP for sampling ensure that comparable samples are taken at each site visit. Deviations from the SOP or from the written study plan due to unusual sampling situations are documented in the appropriate report or memorandum. To ensure that sampling effort and accuracy are comparable between disparate personnel, annual "overlap" samples of the same site are taken by different field crewmembers, and results are compared.

Random samples are re-identified for taxonomic consistency. Each benthic biologist must roll two dice after ten samples have been completed. The sample corresponding with the dice number is given to another biologist for verification. Each biologist has a number and the dice are rolled again to determine which biologist will verify the sample. If disputed identifications are encountered, the findings are discussed and debated among several biologists, and the Lead Environmental Biologist logs the findings into a QA logbook. If a QA accuracy of 90% or greater is not found, then the prior 10 samples will be re-identified by the Lead Environmental Biologist.

Completeness
It is expected that some sites will not be sampled due to problems such as inclement weather, poor water clarity, extremes in flows, equipment malfunctions, vacant positions, and staffing during the field season. As many sites as possible are sampled during the field season, given existing staffing resources. Invariably, some Basinwide Assessment Program "fixed" sites will not be sampled and may not be re-sampled until the next monitoring cycle. However, if a basinwide site is unable to be sampled during the normal basinwide schedule (June through August) it is normal practice to attempt a re-sample within that calendar year, preferably as close to June, July, or August as possible. For example, in July and August of 2005, basinwide sampling of the Broad River was hampered by high flow. However, base flows returned to normal in September 2005, and those sites that could not be sampled in July 2005 were assessed in early September 2005. Typically, this is not an issue; between 2000 and 2005, only seven out of 400 basinwide sites were not sampled during normal basinwide sampling.

Field and Laboratory Measurements

Quality control practices in place for the BMCAP are described in the Quality Assurance section of the Benthic Macroinvertebrates SOP (Appendix 1). All full-time permanent BAU staff is responsible for participating in and helping to oversee the collection of benthic macroinvertebrate community samples. Each year, the BMCAP conducts approximately six "overlap" samples and one annual habitat assessment training session. "Overlap" samples are taken with different field crewmembers, and results are compared. In addition, if new staff are hired before the annual training, these staff members are added as a fourth crew member and accompany the typical three person crew for purposes of learning BAU's field sampling procedures. Field water quality instruments are calibrated for each sampling trip prior to that day's work.

Full-time permanent BAU staff, under the general supervision of the BAU supervisor and the Environmental Biologist III, performs all laboratory identifications of samples. To ensure consistency between taxonomists, all staff members have access to the following resources:

- Regional keys and checklists,
- Internal keys,
- Internal taxonomy document,
- Internal reference collection (consisting of specimens verified by outside taxonomic experts), and
- Internal virtual reference collection available via the BAU server.

In addition, each BAU staff member is required to randomly submit one sample out of every ten for QA/QC evaluation. If less than 90% of the identified taxa are correct, the last 10 samples identified by that taxonomist are re-examined by another benthic biologist, the problem(s) identified, and the taxonomist is instructed as to what the taxonomic problems are. Additional information regarding the QA/QC procedure can be found in the Benthic Macroinvertebrates SOP (Appendix 1).

A7. Special Training/Certification

Field Staff
Components of the field sampling methods, habitat assessments, and water chemistry measurements are described in the Benthic Macroinvertebrates SOP (Appendix 1). A staff of three full-time, permanent BAU biologists conducts fieldwork for the BMCAP. An experienced benthic biologist, trained and skilled in field benthic sampling methods and organism identification, must be present for all sample collections.

One biologist of the three person field crew is the lead investigator (i.e., Trip Leader) and is primarily responsible for meter use, pre- and post-calibration, safety, required documentation, sampling methods, sample handling, safety, and other field activities. Components of the safety program are described in the Benthic Macroinvertebrates SOP (Appendix 1).

Formal documentation of training activities currently consists of annual "overlap" sampling and annual habitat assessment training, as described in the Benthic Macroinvertebrates SOP (Appendix 1). In addition, if new staff are hired before the annual "overlap" sampling, these individuals are added as a fourth crew member and accompany the typical three person crew for purposes of learning BAU's field sampling procedures.

Laboratory Staff
Each Environmental Biologist working in the benthos program is responsible for identifying varying numbers of benthos samples per year. Rigorous and redundant measures are in place to ensure that macroinvertebrate identifications are consistent between taxonomists. This is accomplished through use of the following resources:

- Current regional taxonomic keys,
- Internal taxonomy documents,
- Internal reference collection,
- Communication with external taxonomic experts,
- Annual internal taxonomic updates,
- Attendance at regional and national benthological meetings, and
- BAU's virtual reference collection, which is accessible from each biologist's desktop computer.

For additional information on the specifics of the BMCAP's QA/QC program, please refer to the Benthic Macroinvertebrates SOP (Appendix 1).

Endangered Species Permit
Each year, the BAU collects samples where Federally Listed Endangered Species are present. While these taxa are not taken during BAU sampling, an Endangered Species Permit is acquired annually for the entire BAU staff. As a result, BAU staff is able to gain entry into habitat where these organisms are known to occur.

A8. Documentation and Records

Quality Assurance Information, SOP, QAPP, and Other Support Documentation
Once all approval signatures have been obtained, the QA Coordinator will electronically distribute copies of the approved QAPP to persons on the distribution list in Section A2 of this document. Copies must be disseminated within 30 days of final approval. The original hardcopy with approval signatures will be kept on file in the QA Coordinator's office at ESS.

The QA Coordinator is to be notified of changes made to the SOP or any other documentation referenced by this QAPP. The QA Coordinator will then be responsible for distributing the information, as described above. The QA Coordinator will also be responsible for keeping current copies of all these documents on file at ESS.

Because the BMCAP is ongoing, this QAPP will be reviewed on at least an annual basis and, if appropriate, any changes or updates made at that time. However, critical revisions can be made at any time. The QA Coordinator is responsible for completing revisions, obtaining signatures of approval, and disseminating the revised document to those on the distribution list (section A2) within 30 days of final approval. The version or revision number and date shall be easily identifiable by the document control information on each page. A complete list of all revisions/updates will be provided with each annual update.

Project Records
All hard copies of benthic macroinvertebrate reports, written study plans, field meter calibration sheets (Appendix 2), macroinvertebrate taxonomic bench sheets, collection cards, and habitat forms are kept in perpetuity in file cabinets located in a common lab space in the ESS building. Data are also entered into a Microsoft Access database, which is backed up on tape daily. Electronic files are maintained indefinitely onsite at the ESS building.

Electronic Data Storage
All field and laboratory measurements and site visit comments are ultimately warehoused in the BMCAP's Microsoft Access database. Copies of this data warehouse reside on the BMCAP's shared drive on the ESS server. Tape backups are run daily on the ESS servers. The database is updated on an as needed basis whenever samples are completed or whenever errors in previously entered data are identified. In addition, corrections to data are also completed during annual database auditing. Details of electronic data management and warehousing methods are further described in Section B10 of this document.

Data Report Package: Basinwide Assessment Reports
Data are analyzed and summarized for each of the seventeen major basins in the state on a rotating five-year schedule. All available historic and current raw data, station visit comments/observations, and station information, including stream classification and index numbers, are stored electronically in the BMCAP's Fourth Dimension database. These data are used to produce the BMCAP's portion of the Basinwide Assessment Report, which summarizes all ESS monitoring activities during the appropriate assessment period. The Basinwide Assessment Reports are made publicly available *via* the ESS web site at http://portal.ncdenr.org/web/wq/ess/reports
Electronic copies of all Basinwide Assessment Reports are retained and are kept indefinitely.

The Lead Environmental Biologist and BAU Supervisor also provide raw and analyzed data to staff from other state and federal agencies, private consultants, academia, municipalities and private citizens.

SECTION B:

DATA GENERATION AND ACQUISITION

B1. Sampling Process Design

The BMCAP is an additional water quality assessment tool that has been in existence since the late 1970's, but with a consistent sampling methodology since 1983. Sites are either assessed every five years as part of the DWQ's Basinwide Monitoring Program to monitor overall basin conditions or only evaluated once if part of a watershed-specific special study. Sites are sampled by designated BAU staff and other ESS or DWQ Units if needed due to staffing constraints. Each year, approximately 140 benthic macroinvertebrate basinwide sites are sampled, with special studies increasing the number of sites up to 300.

Site Locations
Sites are established at publicly accessible, fixed locations (i.e., specific latitude and longitude), generally at bridge crossings. Locations and their geo-references were originally identified using USGS 7.5 minute topographic maps or Maptech Terrain Navigator ® software. Stations are strategically located to monitor a specific area of concern:

- Overall water quality in a larger watershed,
- Effect of point source discharges (e.g., municipal WWTP),
- Effect of non-point sources of pollution (e.g., urban areas, animal operations, agriculture),
- Effect of land use changes,
- Waters of significant ecological, recreational, political, or municipal use, or
- Waters that show impairment due to unknown causes.

Several river basins have undergone three basinwide assessments (e.g., Broad River Basin), and several large waterbodies (e.g., Cape Fear River, Tar River, Neuse River, Yadkin River, Frenchbroad River, Broad River) have data preceding the start of basinwide sampling (i.e., late 1980's). As a result, maintenance of these sites on a long-term basis is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within the benthic macroinvertebrate community. Consequently, requests from DWQ staff for station establishment and/or discontinuation are assessed on the value gained from a long-term perspective. Requests for additional sampling of sites (usually a one-time sampling event within a watershed) are handled through special studies. Adjustments to site locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff,
- Changes to location accessibility,
- Reason for sampling is no longer valid (i.e., a discontinued discharge),
- Emergence of new water quality concerns, or
- Resource constraints, particularly staff vacancies.

If any of these concerns arise, the Environmental Biologist III will meet with the BAU Supervisor to determine if it is appropriate for the site to be discontinued.

Sampling Frequency
A large number of sites are sampled each year during basinwide sampling and special studies. Resulting information is used to document both spatial and temporal changes in water quality and to compliment water chemistry analyses. The BMCAP conducts macroinvertebrate sampling in all of North Carolina's physiographic provinces (Figure B1.1) in both wadeable and non-wadeable waters. Non-swamp sites that are part of the Basinwide Monitoring Program are sampled once every five years and usually between June and September. Swamp sites that are part of basinwide sampling are sampled once every five years between February and March. Watershed-specific special study sites are usually sampled only once and may be sampled at anytime of the year.

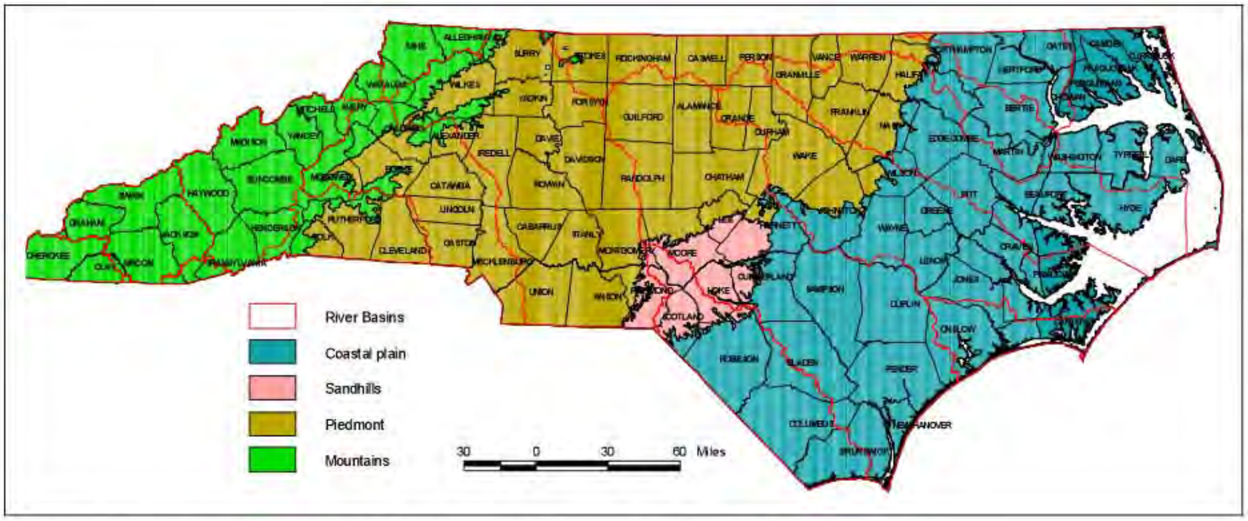


Figure B1.1 Physiographic Regions and River Basins in North Carolina

Sampling and Measurements

The Biological Assessment Unit utilizes the following five methods to collect benthic macroinvertebrates:

1. The **Standard Qualitative Method** is used to assign water quality ratings to most wadeable flowing streams and rivers in North Carolina. This methodology is applicable for most site and/or date comparisons and should be used for all evaluations of impaired streams large enough to be rated.

   Standard Qualitative collections include one leaf pack sample, three sweep net samples, two kick-net samples, one sand sample, two rock/log samples, and three visual collections with all aquatic invertebrates retained for analysis.

2. The **EPT Method**, an abbreviated version of the regular qualitative technique, is used to quickly determine differences in water quality between sites. This method is particularly useful for watershed or basin assessment studies with large numbers of sites and/or emergency sampling where it is desirable to rapidly assess the effect of spills or unusual discharges. Although the EPT method is a more rapid sampling technique, there are situations where the EPT method may provide too little information for an adequate assessment of water quality. Such situations include areas with naturally low EPT richness and areas where the abundance of more tolerant groups must be assessed. If a biotic index must be calculated, then an EPT sample is inappropriate.

   EPT collections include one kick net sample, one leaf pack sample, one sweep sample, and three visual collections with only EPT taxa retained for analysis.

3. The **Qual-4 Method** is used for small streams with drainage areas < $3.0 mi^2$ (NCDWQ 2009) that will likely have few EPT taxa but where data are needed to assess differences in the benthic community.

   Qual-4 collections include one kick net sample, one leaf pack sample, one sweep sample, and three visual collections with all aquatic invertebrates retained for analysis.

4. **Swamp Sampling** is used for swamp streams that cease to flow in the summer months but have visible flow during late winter.

   Swamp samples are comprised of three sweep net samples, three rock/log samples, and three visual collections with all aquatic invertebrates retained for analysis.

5. **Boat Sampling** is used for nonwadeable freshwater rivers.

   Boat collections include nine ponar samples, one stick/leaf pack sample, three sweeps, three visual collections with all aquatic invertebrates retained for analysis.

In order to decide which is the most appropriate sampling technique, an investigator must consider the number of sites to be sampled, what kind of existing data might be used for comparisons, how soon a report will be required, and what kind of differences must be detected between sites.

Once collected, invertebrates are separated or “picked” from the rest of the sample in the field using forceps and white plastic trays. Organisms are picked in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples. These include colonial species (Bryozoa, Porifera), Nematoda, Collembola, semiaquatic Coleoptera, and all Hemiptera (except Naucoridae, Belostomatidae, Corixidae, and Nepidae). These are not picked because either abundance is difficult to quantify, or they are not truly benthic organisms.

The picked organisms are preserved in glass or plastic vials containing 95% ethanol and transported to the BMCAP laboratory for analysis.

Field measurements and the collection of benthic macroinvertebrates are taken in accordance with the Benthic Macroinvertebrates SOP (Appendix 1). All field data (e.g., water chemistry, habitat data, etc.) are recorded on the Benthos Collection Card and Habitat Field Data Sheet. Specific collection and location data (e.g., Stream Name, County, Date, Road Crossing, Collection Type, Collection Card Number, and Collectors) are all recorded in the following three locations to ensure sample integrity: 1) Benthos Collection Card, 2) Habitat Assessment Filed Data Sheet, and 3) Label Sample, which is placed in the sample container.

B2. Sampling Methods

Benthic Macroinvertebrate Collection Techniques

Kick Net Collections
A kick net consists of a double layer of flexible nylon door or window screening held in place between two halves of a wooden pole using wood screws. The screening is reinforced with denim along all edges and has lead weights sewn into the bottom edge.

To collect samples, the kick net is positioned upright on the streambed, while the area upstream is physically disrupted using feet and/or hands. The debris and organisms in the kick net are then washed down into a sieve bucket with a US Standard No. 30 mesh (0.600 mm opening) bottom and larger leaves and debris are removed.

Two kicks are taken from riffle areas for Full-Scale samples and one riffle kick for EPT and Qual-4 samples. No kick net samples are taken for Boat and Swamp Samples. The two samples should be collected from areas of differing current speed. In very small streams or sandy areas lacking riffles, kicks should be taken from root masses, snags, or bank areas. This sampling device collects all types of benthic macroinvertebrates, but emphasis is placed on Ephemeroptera, Plecoptera, and Trichoptera.

Sweep Net Collections
A long-handled triangular sweep net is another versatile sampling device. Three samples are collected by vigorously sweeping through the appropriate habitats. Sweeps are usually taken from bank areas, including undercut banks, root mats, and macrophyte beds. A sweep net can also be used to sample small diameter gravel riffles and bedrock as a supplement to the kick net sample.

Fine-Mesh Collections
Since the kick and sweep nets utilize a relatively coarse mesh size, an alternative sampling technique was developed to sample the smaller invertebrates (especially the Chironomidae). Fine nitex mesh (300 microns) is placed between four-inch PVC pipefittings designed to screw together. This device can be used in a variety of ways; however, the simplest technique is to wash down rocks or logs into a large plastic tub partially filled with water. A single composite sample can be made from several (usually 10-15) rocks and/or logs. The material remaining in the tub is poured through the fine mesh sampler, and the water is allowed to drain completely. The fine mesh sampler and remaining residue are placed in a plastic container filled with 95% ethanol. The sample is allowed to sit for several minutes, pulled out of the alcohol, and then backwashed into a picking tray. Field preservation makes small chironomids and oligochaetes more visible and easier to pick up with forceps. This technique is also an effective method for collecting small or very firmly attached EPT taxa (e.g., *Hydroptila*, *Leucotrichia*, and *Neotrichia).*

Sand Collections
Sandy habitats often contain a distinct fauna; however, extraction of this fauna by means of dredge-type sampling can be tedious. Sandy substrates (in areas with definite flow, if possible) are sampled with a large bag constructed of fine mesh (300 microns) nitex netting. The bag is held (open) near the substrate with one foot holding the bag on the sand while the sand is vigorously disturbed by the collector's other hand or foot. The material collected is emptied into a large plastic container half-filled with water. A "stir and pour" elutriation technique is used in conjunction with the fine mesh sampler. After field preservation, the specimens are picked for collection.

Leaf-Pack Collections
Leaf-packs, sticks, and small logs are washed down into a sieve bucket with a U.S. Standard No. 30 sieve bottom (0.600 mm openings). Generally, three to four leaf packs are collected from rocks or snags in areas with fast currents.

Visual Collections
Visual inspection of large rocks and logs often yields additional specimens, as this habitat cannot be adequately sampled by either kicks or sweeps. In addition, substrate in extremely fast or slow currents is crucial in attaining a representative sample; most collection techniques used in the Standard Qualitative and EPT samples do not systematically assess these areas.

The tops of rocks are a specialized microhabitat with a number of characteristic taxa. Specimens are often more visible after lightly washing off any silt that has accumulated on the top of the rock. Decaying logs should be picked apart to look for chironomids, and many taxa can be found under loose bark.

Certain species inhabit crevices in rocks or logs and cover the openings over with silk strands. Over time, the silk becomes covered with silt and periphyton and is hard to see. There is usually a faint opening on each end of this retreat. If the tip of forceps is inserted into one opening, the larvae will usually come out the other opening.

Polycentropodid caddisflies build funnel-shaped silken retreats (up to six inches in length) in areas of relatively slow current. Out of water, the case collapses and resembles a gelatinous brown glob. The larvae will often crawl out if left out of the water for several minutes or can be more efficiently removed by probing with forceps.

In sandy coastal plain rivers, samples should be collected from a log in an area of faster current with some portion raised above the substrate. The net may be the only visible evidence of these organisms, and they must be dug out of their retreats with forceps.

If dead shells are observed along the shore, a mussel search should be conducted. If possible, mussels should be identified in the field and returned (alive) to the stream. If sampling in an area with known populations of endangered or threatened mussels, any live mussels should be photographed or sketched and returned to the stream.

Ponar Collections
Ponar grabs are collected at three locations between midstream and the bank, with three replicates at each location (a total of 9 samples). If possible, the three locations should include a variety of depths, with at least one location in the 2-3 meter range. Sandy samples should be elutriated and processed through a fine-mesh sampler. Ponars collections should not be utilized in areas normally sampled during shore work (i.e., <2 meters deep). The petite ponar should be lowered slowly to avoid disturbance of surface sediments.

Field Water Quality Measurements
Measurements made in the field include water temperature, pH, specific conductance, stream flow (low, normal, high), qualitative estimates of water clarity (clear, slightly turbid, turbid, tannin-stained, or blackwater), and dissolved oxygen. Field measurements are discrete and are made *in situ* by field staff at the time of the station visit. All field activities are to be performed in accordance with the Intensive Survey SOP (http://portal.ncdenr.org/web/wq/ess/isu).

Physical measurements are to be taken in accordance with the Intensive Survey SOP (http://portal.ncdenr.org/web/wq/ess/isu). Any irregularities or problems encountered by field staff are communicated to the Environmental Biologist III and the BAU Supervisor who will assess the situation, consult with other project personnel, and recommend a course of action for resolution. Deviations from these procedures for unusual sampling situations shall be documented in the appropriate report or memorandum.

B3. Sample Handling and Custody

All samples are handled by full-time permanent BAU staff in accordance with the Benthic Macroinvertebrates SOP (Appendix 1). While in the field, all biological samples and all data sheets are under the custody of the BAU staff and are kept locked in the field vehicle at all times. Upon arrival at the laboratory, samples and all applicable paperwork are locked in BAU staff offices and archived onsite. There are no minimum temperature requirements for invertebrate samples, and there are no maximum holding times. All applicable field data are recorded on the BMCAP's Habitat Assessment Field Data Sheets, Benthos Collection Card, and Sample Labels.

Sample Identification

While in the field, all biological samples are stored in 95% ethyl alcohol in plastic sealable containers with a pencil-written sample label placed inside. This label includes the following information:

- Name of Waterbody,
- Collection Date,
- Station Number,
- Sampler Type,
- Collection Card Number, and
- Name(s) of Collectors.

Upon arrival at the laboratory, the sample label and the contents of the plastic storage container are transferred to a glass sample jar. Once taxonomic processing commences, a Benthic Macroinvertebrate Lab Sheet is filled-out and site location information is transcribed from the Sample Label to this form.

Collection Card Number

Each sample collected as part of the BMCAP is assigned a unique identification number by the BAU Supervisor in batch form, usually once a year. This four digit Collection Card Number is recorded in the following four locations to ensure sample integrity: the Benthos Collection Card, Habitat Assessment Field Data Sheet, Sample Label, and Benthic Macroinvertebrate Lab Sheet.

B4. Analytical Methods

When a sample is returned to the laboratory for analysis, the person responsible for processing the sample will combine all vials collected from a site into one sample dish. All organisms in the sample are identified to the lowest possible taxonomic level, recorded on a Benthic Macroinvertebrate Lab Sheet, and designated as *Rare* (1-2 specimens observed), *Common* (3-9 specimens observed), or *Abundant* ($\geq$10 specimens observed).

Following identification, mollusk and crayfish samples are labeled and sent to the museum collections; all other samples are labeled and stored in the BMCAP laboratory for an indefinite period. Taxonomic data are entered into the benthos database (Microsoft Access) by the analyst who processed the sample. After the data are entered, the database is checked for coding or relative abundance errors. When the data are saved, the following values are automatically calculated by the software:

- EPT Taxa Richness,
- Biotic Index Value for the sample,
- Total Taxa Richness,
- EPT Biotic Index Value for the sample,
- EPT Abundance, and
- Bioclassification.

Typically, bioclassifications are automatically calculated by the Microsoft Access software. However, if a sample is collected outside the summer period, from a small stream, or from a swamp stream, the bioclassification must be manually calculated using the scoring tables in the Benthos Macroinvertebrate SOP (Appendix 1). After all taxa in a sample are entered into the database, any necessary seasonal corrections are performed manually. The bioclassification is entered manually based on the corrected values, and notes about corrections are made in the comment section for each sample.

Several data summaries (also referred to as indicators or metrics) can be produced from benthos samples to detect water quality problems. Research shows that unstressed streams and rivers contain many invertebrate taxa and have a relatively high proportion of intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index.

Bioclassifications

The core indicators used by the BMCAP to calculate bioclassifications are EPT Taxa Richness (EPTs) and the Biotic Index (BI). In addition, some samples also use Total Taxa Richness (S), EPT Biotic Index (EPTBI), and EPT Abundance (EPT N) to calculate bioclassifications. Standard Qualitative samples, EPT samples, and Boat samples are rated *Excellent*, *Good*, *Good-Fair*, *Fair*, or *Poor*. The bioclassifications or stress categories for swamp stream samples are *Natural*, *Moderate*, and *Severe*; a habitat evaluation score is also included as a metric for swamp samples.

EPT Taxa Richness (EPTs)

Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are the most intolerant of the aquatic insect orders. The association of good water quality with high species (or taxa) richness has been thoroughly documented. EPT Taxa Richness is a metric that indicates good water quality when EPT richness is high and degraded water quality when richness is low. Bioclassification criteria for EPT Taxa Richness values have been developed for each of the three major ecoregions (mountains, piedmont, and coastal plain) and can be used to evaluate water quality for EPT and Standard Qualitative samples.

Biotic Index (BI)

Bioclassifications are also based on the relative tolerance of the macroinvertebrate community as summarized by the North Carolina Biotic Index (NCBI). Both tolerance values for individual species and the final biotic index values have a range of 0-10, with higher numbers indicating more tolerant species or more polluted conditions. The NCBI is calculated by summing the tolerance value of individual taxa multiplied by their abundance value, to give an average tolerance value. The EPT Biotic Index (EPTBI) is a similar summary measure where only EPT taxa are used in the calculation.

Total Taxa Richness (S)
Total Taxa Richness (S) is a metric used for Swamp samples and measures how many different kinds of taxa are found in the sample. Higher values generally indicate better water quality.

EPT Abundance (EPT N)
EPT Abundance (EPT N) is a metric that is also used for swamp samples and is used in Standard Qualitative samples when EPT taxa richness and the NCBI suggest different bioclassifications. In these situations, the abundance value is used in that instance to give more weight to one metric over the other.

Stream width or drainage area of a small watershed plays a role in determining which type of sample to collect and whether the standard bioclassifications can be assigned. It was previously determined that streams less than four meters wide should not be rated using the standard criteria because fewer taxa are expected in very small watersheds. As a result, biocritiera were developed for small streams and are defined as streams with drainage areas <3.0mi2.

Small streams are sampled using the Qual-4 sample method and a set of biocritiera for the Piedmont and Mountain ecoregions are now established (NCDWQ 2009). As a result, these small streams can now be assigned one of the five bioclassifications (i.e., Excellent, Good, Good-Fair, Fair, Poor) to North Carolina's non-swamp waterbodies.

Field Measurements
In addition to the ISU SOP sections cited in Table B4.1, the instruction manual for the appropriate meter should also be consulted.

Table B4.1 Field Measurement Method References and Reporting Levels
Adopted from Intensive Survey Unit SOP (http://portal.ncdenr.org/web/wq/ess/isu).

Parameter	NC DWQ's Intensive Survey Unit's SOP & section[1]	EPA method	Reported to nearest
Dissolved oxygen	III.3	360.1	0.1 mg/L
pH	III.4	150.1	0.1 s. u.
Water temperature	III.1	170.1	0.1 ºC
Specific conductance	III.5.2	120.1	1 µmhos/cm

[1] Section numbers III.1 - III.5 refer to use of YSI combination meters and Fisher Scientific Accumet pH meters.

Laboratory Analyses
All samples are taxonomically processed in the ESS laboratory in accordance with the Benthic Macroinvertebrates SOP (Appendix 1).

B5. Quality Control

Field Activities and Training
Quality assurance and control practices in place for the BMCAP are described in the "Quality Assurance" section of the Benthic Macroinvertebrates SOP (Appendix 1). All full-time permanent BAU staff is responsible for participating in and helping to oversee the collection of benthic macroinvertebrate community samples. Each year, the BMCAP conducts "overlap" sampling and annual habitat rating training. "Overlap" samples are taken with different field crewmembers, and results are compared. In addition, if new staff are hired before the annual training, these individuals are added as a fourth crew member and accompany the typical three person crew for purposes of learning BAU's field sampling procedures.

Field water quality instruments are calibrated for each sampling trip prior to that day's work. Meter calibrations for dissolved oxygen (DO), pH, and specific conductance are checked after each sampling event to confirm that significant drift has not occurred and that the data collected is accurate and representative. If final calibration readings are beyond acceptable limits (DO = $\pm$0.5; pH = $\pm$0.2; conductance = $\pm$10%), the data are discounted and are not entered in the database.

Laboratory Activities and Training
Full-time permanent BAU staff members, under the general supervision of the BAU supervisor and the Lead Environmental Biologist, perform all laboratory identifications of samples. To ensure consistency between taxonomists, all staff have access to current regional keys, current regional checklists, in-house keys, the in-house taxonomy document, an in-house reference collection consisting of specimens verified by outside taxonomic experts, and an in-house virtual reference collection comprised of thousands of specimen photos available via the BAU server.

In addition, each BAU staff member is required to randomly submit one sample out of every ten for QA/QC evaluation. If less than 90% of the identified taxa are correct, the last 10 samples identified by that taxonomist are re-examined by another benthic biologist, the problem(s) identified, and the taxonomist is instructed as to what the taxonomic problems are. Additional information regarding the QA/QC procedure can be found in the Benthic Macroinvertebrates SOP (Appendix 1).

Reference specimens (most verified by taxonomic experts) are maintained in a reference cabinet in the ESS laboratory. A reference specimen list is also maintained and updated periodically.

Random samples are re-identified for taxonomic consistency. Each benthic biologist must roll two dice after ten samples have been completed. The sample corresponding with the dice number is given to another biologist for verification. Each biologist has a number and the dice are rolled again to determine which biologist will verify the sample. If disputed identifications are encountered, the findings are discussed and debated among several biologists, and the Environmental Biologist III logs the findings into a QA logbook. If a QA accuracy of 90% or greater is not found, then the prior 10 samples will be re-identified by the Environmental Biologist III.

In addition, each year a random subset (10%) of data entered into the database that calendar year is audited by either the BAU Supervisor or the Environmental Biologist III for accuracy.

B6. Equipment Testing, Inspection, and Maintenance

A routine preventative maintenance program minimizes the occurrence of instrument and equipment failures. Preventative maintenance is limited because most of the sampling and measuring equipment is electronic (i.e., no movable parts to repair). As a result, most repairs occur when the equipment no longer functions.

Each member of the BMCAP is responsible for regular inspection and maintenance of their assigned field sampling equipment. All sampling equipment should be visually inspected for damage at the start of each sampling day and repaired if needed before further use. Moreover, at least one extra kick and sweep net sample should be taken for each field trip. In addition to benthic macroinvertebrate equipment, the BMCAP also uses several electronic devices for measuring water chemistry *in situ* at each site; the required maintenance for this equipment is shown in Table B6.1. Refer to instruction manuals for manufacturer's recommendations for inspection, maintenance, and repair.

Table B6.1. Water Quality Field Instrumentation Maintenance.

Instrument	Task	Frequency
YSI 85 Dissolved Oxygen/Conductivity/ Temperature Meter	Check battery level	Daily
	Inspect membrane for holes, tears, bubbles, fouling or other damage	Daily
	Replace membrane and potassium chloride solution	As needed if damaged; dissolved oxygen is not calibrating or calibrations do not hold; responding slowly, showing excessive drift, or providing erratic readings
	Inspect gold cathode	As needed, when replacing membrane
	Clean cathode	As needed, if tarnished or plated
Fisher Scientific Accumet pH meter	Inspect probe for bubbles and electrolyte level	Daily
	Top off probe potassium chloride electrolyte level	As needed
	Replace probe	As needed if damaged, not calibrating or calibrations do not hold, responding slowly, showing excessive drift, or providing erratic readings

B7. Instrument Calibration and Frequency

Water Quality Field Instrumentation

All field meters are inspected and calibrated before each sampling trip and at the end of each day used. Pre- and post-sampling calibration information is recorded on a Field Meter Calibration Sheet (Appendix 2). The specific calibration procedures are documented in each meter's instruction manual. For specific conductance and pH, two-point calibrations should be performed. Dissolved oxygen meters should be calibrated using the air calibration method.

Standards should be selected so that they bracket the range of measurements expected that day. Traceable pH buffers (standards) and specific conductance standards are purchases. Specefic conductance is typically calibrated using 500 µmhos/cm and 1000 µmhos/cm standards. . The ISU also purchases traceable pH buffers (standards) and shares these with other ESS units. Current pH meters require standards of 4.0, 7.0, and 10.0 s. u.

B8. Inspection/Acceptance for Supplies and Consumables

Most of the equipment (sieve buckets, nets, picking trays, sample tubs, sample containers, forceps, fine mesh samplers, label paper, ethyl alcohol, *etc.*) used in the BMCAP is not required to meet strict technical standards for manufactured quality. Typically, the Lead Environmental Biologist and at least one other Environmental Biologist II are responsible for the selection, procurement, and maintenance of all equipment and consumables associated with the BMCAP.

B9. Acquired Data (Non-Direct Measurements)

All data are directly generated through the BMCAP field activities and subsequent laboratory analyses, with two exceptions:

- Geo-referenced data (latitude and longitude) are obtained from Maptech Terrain Navigator® software or from a Garmin GPS meter.
- Watershed drainage areas for each site are obtained from the U. S. Geological Survey or from DWQ's geographical information system software/data layers.

Both of these resources are used for planning and site characterization before site visits.

In addition to this data, regional checklists that detail the invertebrate taxa known or thought to occur in North Carolina are updated annually and added to the Taxonomy Document, which is included within the Benthic Macroinvertebrates SOP (Appendix 1).

B10. Data Management

Approximately 140 sites are sampled annually as part of the BMCAP, resulting in over 6,000 records since the program's inception. Collection cards and habitat forms are completed in the field and are locked in the field vehicle, along with the corresponding invertebrate sample, throughout the duration of the sampling trip. Upon return to the lab, the paperwork and invertebrate sample are transferred to and stored in the office of the biologist responsible for processing. After processing, the sample and all associated paperwork are stored permanently onsite. The BAU staff member who executed the taxonomic analysis enters the results into the BMCAP's Microsoft Access database. The biologist reviews the data for completeness, data entry errors, and unlikely or impossible values. Random audits of a subset (10%) of data entered into the database that year are performed by the BAU Supervisor and/or the Lead Environmental Biologist. Copies of this database reside on BAU's drive on the ESS server. Tape backups are run daily on the ESS servers. The database is updated on an as needed basis whenever new samples are completed or whenever errors in previously entered data are identified.

SECTION C:

ASSESSMENT AND OVERSIGHT

C1. Assessments and Response Actions

The Lead Environmental Biologist (in conjunction with the BAU Supervisor) is responsible for the BMCAP and serves as the coordinator and the liaison between the program, the BAU, the ESS, the Basinwide Planning Unit, and other data users. Issues with any aspect of the program noted by these entities should be reported as soon as possible to the Lead Environmental Biologist or the BAU Supervisor to determine the course of action (if any) to be taken. Any collection, data management, or taxonomic problems noted by the Lead Environmental Biologist are reported to the BAU Supervisor for corrective measures.

Annually, all field staff participate in USGS' National Field Quality Assurance (NFQA) program. The NFQA is a yearly proficiency test for pH and specific conductance. Staff who do not receive satisfactory results are provided additional field meter training and retested. The QA coordinator oversees the NFQA Program for ESS.

C2. Reports to Management

The Lead Environmental Biologist reports quarterly BMCAP sample statistics to DWQ management, which in turn reports these data to EPA Region IV. These statistics include the number of basinwide samples conducted, the number of special study samples collected, and the number of special studies conducted per quarter.

SECTION D:

DATA VALIDATION AND USABILITY

D1. Data Review, Verification, and Validation

Data verification and validation occurs at every step of data generation and handling. Each full-time permanent BAU staff member of the BMCAP is responsible for verifying that all records and results produced or handled are completely and correctly recorded, transcribed, and transmitted. The Lead Environmental Biologist and the BAU Supervisor are also responsible for ensuring that all activities performed (sampling, analyses, data entry, etc.) comply with all requirements outlined in the BMCAP QAPP and SOP. These responsibilities include, but are not limited to: taxonomic QA/QC, annual overlap field sampling, annual database audits, and meter calibration.

Data that are entered into the BMCAP's database are constantly being checked for errors, and a random subset (10%) of all data entered that year is audited for accuracy. Some of the data entry checks include:

- County - Only North Carolina counties allowed; confirmation that the county in the database matches the site location;
- Ecoregion - Only four physiographic regions can be entered for non-swamps (Mountains, Piedmont, Sand Hills, or Coastal Plain); For swamps, there are five physiographic regions (Region A, B, C, P, and S);
- Latitude and Longitude - Only coordinates located in North Carolina can be entered;
- Road Crossing - Confirmation that the crossing in the database matches the site on the map;
- Water Quality Variables (temperature, specific conductance, dissolved oxygen, and pH) – "Flag" values outside ranges normally encountered and do not allow the data to be saved;
- Validate seasonal taxa corrections;
- Validate the river basin and subbasin; does it match the site location, etc.

In terms of data acceptance, there are certain instances in which a sample collected through the BMCAP may be abandoned. Typically, these occasions are generally restricted to special studies requested by DWQ regional offices and include (but are not limited to) brackish/estuarine waters, perennially non-flowing waters, or samples taken directly below impoundments. On these occasions, the samples are collected, processed, and analyzed for inclusion in a report, but the data are not entered into the Microsoft Access database, and no bioclassification is generated.

D2. Validation and Verification Methods

Each member of the BMCAP is responsible for ensuring that each site's Habitat Assessment Field Data Sheet, Benthos Collection Card, and Sample Identification Label are filled out accurately and that the Sample Identification Label is placed in the sample container at the time of collection. These data are checked at the time of collection and at the time of data entry. Additionally, 10% of these data are re-checked during the annual database audit.

Sample data are also considered invalid if post-sampling meter calibrations for dissolved oxygen (DO), pH, and specific conductance are beyond acceptable limits (DO = ± 0.5; pH = ± 0.2; conductivity = $\pm 10\%$). If meter calibrations are not within the acceptable limits, the data are discounted and are not entered in the database.

The Lead Environmental Biologist and the BAU Supervisor also review all reports and memoranda for completeness and accuracy. Any issues will be brought to the attention of the BAU Supervisor for resolution.

Any issues observed with the data (data not plausible or not representative of the stream or watershed as a whole; conflicts with results from other DWQ monitoring programs; etc) should be communicated to the Lead Environmental Biologist and the BAU Supervisor. The recipient of the data may request that the site be re-sampled by the BMCAP the following year or may choose to not use the data in Use Support ratings, Use Attainability studies, or as background information.

D3. Reconciliation with User Requirements

After the data have been analyzed and summarized, results from the program are communicated *via* ESS Chief-approved Basinwide Assessment Reports and internal site-specific memoranda. Statistical validation methods are not used to determine possible anomalies or outliers of the data. Any issues encountered in meeting the performance criteria as stated in Section A6 of this document (or limitations in the use of data) are documented in the final report.

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Web Links

NC Division of Water Quality .... http://portal.ncdenr.org/web/wq
NC Basinwide Planning.............................. http://portal.ncdenr.org/web/wq/ps/bpu
NC 303b and 303d Reports .... http://portal.ncdenr.org/web/wq/ps/mtu NC Water Quality Standards... http://portal.ncdenr.org/web/wq/ps/csu

NC Biological Assessment Unit .... http://portal.ncdenr.org/web/wq/ess/bau

NC Intensive Survey Unit Homepage .... http://portal.ncdenr.org/web/wq/ess/isu

Intensive Survey Unit SOP .... http://portal.ncdenr.org/web/wq/ess/isu

NC Basinwide Assessment Reports .... http://portal.ncdenr.org/web/wq/ess/reports

Appendix 2:

Benthic Macroinvertebrate Community Assessment Standard Operating Procedures

STANDARD OPERATING PROCEDURES FOR COLLECTION AND ANALYSIS OF BENTHIC MACROINVERTEBRATES

DECEMBER 1, 2011 (Version 3.0)

NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT
and NATURAL RESOURCES
Division of Water Quality
Environmental Sciences Section
Bioassessment Unit

NCDENR

December 1, 2011

STANDARD OPERATING PROCEDURES
FOR COLLECTION AND ANALYSIS OF
BENTHIC MACROINVERTEBRATES

DECEMBER 2011 (Version 3.0)

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT
AND NATURAL RESOURCES
Division of Water Quality
Environmental Sciences Section
Bioassessment Unit

This report has been approved for release

Eric D. Fleek
Supervisor, Bioassessment Unit

Jay Sauber
Chief, Environmental Sciences Section

Date: 12/1/2011

REVISION LOG
NC DWQ STANDARD OPERATION PROCEDURES
(BENTHIC MACROINVERTEBRATES)

*Actions older than five years may be removed from this log.

Date Edited	Editor	Version Edited	Section Edited	Changes/updates
04/07/2010	Michael Walters	Version 3.0	Appendix 1	Updated pollution tolerance values for North Carolina benthic macroinvertebrates.
12/01/2011	Eric Fleek	Version 3.0	Laboratory Techniques & Data Interpretation	Added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009. Also, updated the SOP in this section to reflect the new methodology.
12/01/2011	Eric Fleek	Version 3.0	Laboratory Techniques & Data Interpretation (Continued)	Added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009. Also, updated the SOP in this section to reflect the new methodology.
12/01/2011	Eric Fleek	Version 3.0	References For Macroinvertebrates	Added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009.

Table of Contents

BENTHIC MACROINVERTEBRATES

INTRODUCTION

Benthic macroinvertebrates, especially aquatic insects, are associated with the substrates of streams, rivers and lakes. The Biological Assessment Unit uses aquatic macroinvertebrates as one type of indicator of biological integrity in streams and rivers. A large number of sites are sampled each year during basinwide sampling and special studies, and resulting information is used to document both spatial and temporal changes in water quality, and to complement water chemistry analyses. Although bioassessments are useful for identifying biological impairments, they do not identify the causes of impairment. Linking biological effects with their causes if particularly complex when multiple stressors impact a waterbody (USEPA 2000).

There are several reasons for using biological surveys in monitoring water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may often be missed. The biota, especially benthic macroinvertebrates, reflect both long and short term conditions. Since many species in a macroinvertebrate community have life cycles of a year or more, the effects of a short-term pollutant will generally not be overcome until the following generation appears.

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, are less mobile than many other groups of organisms, and are of a size which makes them easily collectable. Moreover, chemical and physical analysis for a complex mixture of pollutants is generally not feasible. The aquatic biota, however, show responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost-effective monitoring tool (Lenat 1988). The sedentary nature of the benthos ensures that exposure to a pollutant or stress reliably denotes local conditions, and allows for comparison of sites that are in close proximity (Engel and Voshell 2002).

Analysis of faunal assemblages is one way to detect water quality problems (Rosenberg et al 1986). Different kinds of stress will often produce different benthic macroinvertebrate communities. For example, the taxa associated with organic loading (and low dissolved oxygen) are well known. More recent studies have begun to identify the biological impacts of sedimentation and toxic stress (Burton 1991, Waters 1995, Bode and Simpson 1982, Clements 1994).

Identification at, or near, the species level is desirable for many genera (Cranston 1990, Resh and Unzicker 1975). Such genera may include *Polypedilum*, *Cricotopus*, *Hydropsyche*, *Ephemerella*, *Stenonema, Acentrella* and *Baetis*. Recent work by Lenat and Resh (2001) has shown the benefits of precise taxonomy for both pollution monitoring and conservation biology. Species-level taxonomy is more effective than family-level taxonomy in detecting both the best and worst streams within any given ecoregion. Precise taxonomy is also required to locate the rare species in potential HQW/ORW waters. Tolerant species will usually become dominant only in polluted systems. Allowances must also be made for stream size, geographic location and seasonality. Flow conditions are also related to the relative impacts due to point and nonpoint sources. High flows often increase the impact of nonpoint sources, while reducing the impacts of point sources. The reverse is often true for low flows. Drought conditions can have a more long-term impact on the benthic community than floods. The presence of rare or endangered species is often associated with good water quality.

It is the purpose of this manual to provide details on routine or standard operating procedures of the Biological Assessment Unit (BAU) of the Division of Water Quality (DWQ) for the collection and analysis of freshwater benthic macroinvertebrate data. Estuarine monitoring is no longer conducted by BAU staff. Consistency in data collection and analysis is the cornerstone for evaluating biological integrity. The procedures provided in this manual are a synthesis of widely used methodologies and methodologies developed from the experience of personnel within the unit. These have been shown to provide repeatable and useful data for water quality evaluation.

This manual will be reviewed regularly and revised as necessary. The prior approved version of this manual was dated July 2003. All current employees and new employees within the unit will be provided with this manual to serve as a guideline of the unit's activities, methods, and procedures. Revisions of this manual will be provided to each employee and it will be the responsibility of the employee to keep his or her manual current.

The standard operating procedures (SOP) and quality control procedures (QC) in this manual will be the basis for all benthic monitoring by BAU staff in the waters of North Carolina, and the subsequent data provided in memos and reports. Deviations from these procedures for unusual sampling situations shall be documented in the appropriate report or memo.

SAFETY PROGRAM

The Biological Assessment Unit is required to sample throughout North Carolina at times and places where medical facilities may not be readily available. It is imperative that all employees are instructed in and follow safety precautions when using equipment and hazardous materials. The Environmental Sciences Branch has a Safety Committee which is responsible for maintenance and development of current safety procedures. The Committee also maintains the safety standard operating procedures document, with which all personnel should be familiar.

Sampling conditions are the primary safety factor to be considered for field work. If any field conditions, such as high flows or thunderstorms, raise the question of whether a sample can be safely collected, then decisions should always be made with the safety of personnel of prime concern. This same concern for safety of staff must be of primary importance when scheduling the amount of time to be spent in the field. Long days combined with strenuous effort increase the probability of accidents occurring. Sample days longer than 12 hours will not be approved, unless an emergency requires a longer day. Safety first must always be the rule.

With the increasing prevalence of Lyme disease and West Nile virus, it is the responsibility of all employees to maximize protection against these insect borne diseases. This should include the use of insect repellants, and a thorough check for ticks after every day in the field.

All vehicles are provided with first aid kits, which should be used for minor injuries. Employees should promptly report on-the-job accidents to their supervisor. All employees must be familiar with and follow procedures and deadlines for all Workmen's Compensation claims. If an accident occurs during field operations, the first responsibility of the team leader is to get first aid or emergency treatment for the injured employee; their second responsibility is to promptly notify their supervisor. The Safety Committee maintains a written record of accidents.

STUDY PLANS

All investigations conducted by the Biological Assessment Unit will follow a written study plan including but not limited to the following:

Introduction - Will identify the nature and history of the area being investigated and the person or agency requesting the study.

Objectives - The purpose of the investigation and expected accomplishments.

Sampling Location Selection - Locating sampling points is of extreme importance in the initiation of benthic macroinvertebrate monitoring. The variables in watersheds are many and should be considered in as much detail as possible before sites are selected to monitor any body of water. Land use (i.e., urban, rural, forested, agricultural, industrial) should be considered when locating sample sites, because man-made activities significantly affect the amount of sedimentation, nutrients, and organic or inorganic compounds entering a given segment of a river, lake or stream. The location of permitted dischargers should be reviewed, using the database provided by the NPDES Unit of DWQ. Discussion of the proposed study with regional office personnel can also provide additional information useful for determining sampling locations. Pre-study planning of this nature will enhance data interpretation once collections and analysis begin. "No Trespassing" signs must be respected, and may prevent access to some sites.

Methodology - Sampling techniques should be listed with reference to those described in this manual. Any deviation from these standard methods must be noted and described.

Analytical Requirements - All parameters to be collected, and analyses that will be required, should be noted.

Logistics - Shall include estimates of manpower requirements, equipment needed, time requirements, methods of sample transport to laboratories, etc. The study plan must be submitted and approved by the employee's supervisor prior to the investigation.

A study is complete when a written memo is sent to the appropriate level of management (typically the Environmental Sciences Branch head) within DWQ and approved by that level. Each memo written for a study should contain an **Introduction or Background** section, **Sampling Sites**, **Methods**, **Results and Discussion,** and **Summary or Recommendations**, along with any figures needed to allow a reader to easily locate the sampling sites. When the report or memo is approved, a Biological Assessment Unit File Number is assigned. Finally, the report or memo is filed in a Projects File that is organized by river basin and subbasin.

SAMPLE COLLECTION

Sampling Requirements

Most of the sampling methodologies described in this manual require that freshwater streams or rivers be wadeable for efficient data collection. High water conditions severely impair sampling efficiency by making some critical habitats inaccessible. An underestimate of taxa richness due to high flows may lead to an incorrect assessment of water quality. **If high water makes sampling conditions marginal, it is better to return to the site during a more appropriate flow regime**.

Drought conditions can also play a major role in altering the composition of the benthic fauna. Every effort should be made in parts of the state that are susceptible to flow interruption during droughts to to be sure that flow has been continuous prior to sampling. Flowing water in a stream immediately following a period of rain may mask antecedent conditions. Prior flow conditions can be difficult to determine, especially in smaller streams, but USGS flow data from nearby streams should be used to make the best determination of prior flow conditions. Sampling should be delayed, if possible, when prior flow conditions have been extreme-either high or low. Streams less than 1 meter wide should not be sampled. The rule of thumb is that if you can jump across it, you shouldn't sample it.

Before any sampling trip is begun, the trip leader will have an approved study plan or list of sites for basinwide sampling. An itinerary will be planned to maximize collection efficiency. Regional Office personnel must be advised before any sampling trip as to where and when work will be done in their region. The trip leader should also use the Internet to check stream stage height from the closest USGS gage station before traveling to the site.

An experienced benthic biologist trained and skilled in field benthic sampling methods and organism identification must be present for all sample collections. New or inexperienced personnel (eg, staff from other Units of DWQ) can be used as team members, if close supervision is provided by the experienced biologist during sample collection, during sample picking (look through trays again), and during visuals.

Our Endangered Species Permit is renewed annually and requires that **permission be obtained from the Wildlife Resources Commission (WRC) before any sampling be conducted in areas with endangered species**. The back of the permit lists all such areas. If permission is granted, the WRC has also asked that a minimal amount of walking in the stream be done in reaches with endangered mussels, to reduce the possibility of inadvertently crushing the mussels.

Field Procedures

Samples are collected using the techniques described in this manual. All samples are field picked as described under Standard Qualitative Method. The number of samples collected is dependent on the type of methodology used. Sampling equipment is simple to use, durable and portable.

Samples are labeled before leaving the site with waterbody name, station location, collection card number, initials of collectors, and date of collection. A gage reading is taken if a gage is present or gage height (stream stage) taken from the USGS web site immediately upon return to the office. Stream stage and stream flow (cfs) should be added to the collection card and entered in the comments section of the database, along with notes about range of gage heights that should be targeted for adequate sample collection. Photographs of the site must be taken. Water temperature, pH, conductivity and dissolved oxygen measurements will be taken and recorded on the collection card. All meters must be calibrated in the lab and a lab calibration form filled out, before the meters are taken into the field. Data from an uncalibrated meter should not be entered into the benthos database. Calibration instructions for all meters can be found in the lab in a notebook with calibration forms.

A site sketch should be made, showing any unique habitats, for all basin assessment locations that do not have site sketches already in the Basin Site Notebooks. This sketch should include enough detail that subsequent samplers can return to the same sampling location every five years.

A habitat assessment form (Appendix 2) should be filled out for all collections. Directions are given on the form. In most areas, it is obvious whether the Mountain/Piedmont or the Coastal Plain habitat form should be used. In some transition areas, however, a field decision must be made as to which form to use. If the stream is naturally rocky with a natural riffle-pool sequence then the Mt/P habitat form should be used, even if the Level IV ecoregion map puts the site in the coastal plain. The reverse is true for a naturally sandy, low gradient stream located on the map in the Piedmont, but near a coastal plain ecoregion.

The benthos **collection card** (Appendix II) must be filled out. Field observations should include:

Immediate watershed - type of land use, extent of disturbed land, any floodplain deposition of sediment, any evidence of stream widening and/or filling in, presence of upstream tributaries or dams (including beaver dams), evidence of recent water level changes such as leaf packs out of water, submerged terrestrial vegetation, and sediment on vegetation above water level, any livestock with access to stream, any point sources, any unique habitats.

Substrate **- Two** collectors must make independent estimates of substrate percentages and the independent and average values recorded on the collection card. Also note embedded substrate (interstitial spaces filled in with sand), any atypical habitats such as bridge rubble, large bedrock or other rock outcrops or unusual geological formations, abrupt changes in slope, presence of normal riffle-pool sequence (riffles spaced at intervals equal to 5-7 times stream width), any large areas of unstable coarse sand or movement of bedload material, and amount of substrate covered with *Aufwuchs* or silt.

Width - Since DWQ studies have suggested that stream width is a primary factor in determining expected taxa richness, especially in unimpacted headwater streams, the measurement of wetted stream width should be done as accurately as possible. Pacing off a width measurement on the bridge is useful for large rivers. Reflective safety vests should be worn whenever working on bridges. A tape measure could be used to measure smaller streams at two points that are representative of the area sampled. If an actual measurement is not taken, then **two** independent estimates of stream width should be recorded and the average noted, to the nearest whole number. A width estimate of 6.5 meters (average of 6 and 7) implies a degree of accuracy not found with visual estimates. Any unusual characteristics, such as a braided channel in coastal areas, should be noted and recorded.

Water **-** Look for color, odor (especially sewage and/or chlorine), foaming, algal mats, and oil sheen.

Benthic Community **-** Note presence of organisms not usually collected such as bryozoa, sponges, mussel shells. Note dominant organisms and any that are very abundant. Note if diversity is limited to banks and snags above the effects of sediment scour. Give overall impression of site.

All samples are transported in state-owned vehicles to the Biological Assessment Unit in Raleigh. Vehicles are locked when unsupervised, and sample custody is maintained at all times by field collectors.

A fixed number of benthic samples are processed at each location. The sampling techniques outlined here usually take 4-6 person hours, i.e. 1 1/2 - 2 hours per site with three collectors for the standard qualitative method, and 45 minutes to 1 hour for the EPT method using three collectors. However, the time necessary to collect at a station may vary depending on factors such as stream size (a large river takes more time than collecting in a small stream) or flow conditions. A collection team can do a minimum of 3-4 stations per day. Seven stations in close proximity is the record for BAU.

SAMPLING METHODOLOGIES

Overview

Four different macroinvertebrate collection methods are used by the Biological Assessment Unit. The first method is a standard qualitative method which can be used to assign water quality ratings to most wadeable flowing streams and rivers in North Carolina. This methodology is applicable for most between-site and/or between-date comparisons, and should be used for all evaluations of impaired streams (those on the state 303d list), that are large enough to rate.

The second collection method is the EPT method, an abbreviated version of the regular qualitative technique. This technique is used to quickly determine between-site differences in water quality. It is particularly useful for:

Watershed or basin assessment studies with large numbers of sites, or emergency sampling where it is desirable to rapidly assess the effect of spills, unusual discharges, etc.

Although the EPT method is a more rapid sampling technique, there are situations where the EPT method may provide too little information for an adequate assessment of water quality. Such situations include areas with naturally low EPT richness and areas where the abundance of more tolerant groups must be assessed. If a biotic index must be calculated, then an EPT sample is inappropriate. In order to decide which is the most appropriate sampling technique, an investigator must consider the number of sites to be sampled, what kind of existing data might be used for comparisons, how soon a report will be required, and what kind of between-site differences must be detected.

A third sampling methodology, that was tested between this revision of the SOP Manual and the last revision, is called the Qual 5 or Qual 4 method. This uses the same collection techniques as the abbreviated EPT version, with the addition of one rock/log wash for the Qual 5, but all organisms are picked from the samples. This method should only be used for very small streams that will likely have few EPT taxa, but where data are needed to assess differences in the benthic community.

The fourth collection method is used for swamp streams that stop flowing in summer months, but have visible flow during late winter. A boat sampling technique for sampling nonwadeable freshwater rivers is an adaptation of the standard qualitative method.

Standard Qualitative Method

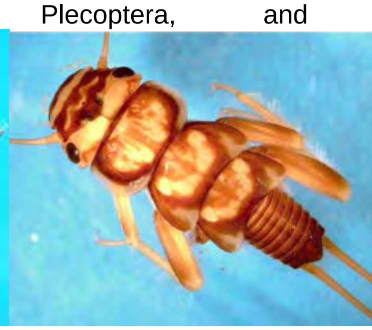
This collection technique consists of two kick net samples (kicks), three sweep-net samples (sweeps), one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections. Invertebrates are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol.

Organisms are picked roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field (an example would be *Isonychia*), then no more than 10 individuals need to be collected. A detailed discussion is given below and in Lenat (1988). Some organisms are not picked, even if found in the samples. These include colonial species (Bryozoa, Porifera), Nematoda, Collembola, semiaquatic Coleoptera such as Chrysomelidae, and all Hemiptera except Naucoridae, Belostomatidae, Corixidae and Nepidae. These are not picked either because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic. The hemipteran families that are included can spend long periods below the water surface.

EPT Method

The EPT technique is a modification of the qualitative collection. The collection and analysis time has been decreased in two ways. First, collections focus on a subset of the benthic community:

Ephemeroptera, Plecoptera, and Trichoptera = (EPT).



These orders usually include the most intolerant species of benthos. Field notes also are made concerning the abundance of other groups, especially any pollution indicator species. Secondly, the number of collections is decreased from 10 samples (in standard qualitative collections) to only 4 samples: 1 Kick, 1 Sweep, 1 Leaf-pack and "visuals". A comparison of the results between the qualitative and the EPT method is given in Eaton and Lenat (1991).

Qual 4

The Qual 4, as the name implies, is an abbreviation of the standard qualitative method, where all organisms are picked. These methods were designed to be used **only** in small streams, orginally defined as those that are less than 4 meters wide, now defined as having a DA $\leq$ 3 square miles. In these methods, 4 samples are collected: one Kick, one Sweep, one Leaf-pack, and "visuals". All organisms are picked. The Watershed and Assessment Restoration Program (WARP) began collecting many samples from small streams in impaired watersheds in 2000. This program began using the Qual 4 method. After collecting this data from small streams, especially in impaired watersheds, it was decided that an abbreviated method was needed that should enhance collection of a representative sample of the chironomid population, and a rock/log wash was added. A Qual 5 method was tested as a possible efficient way to provide enough data from small streams to eventually lead to a way to determine water quality impairments or assign bioclassifications. Data analysis indicated that the wash provided few new taxa and little change in minimum rating. The Qual 5 method was dropped in July 2003, and the Qual 4 method was retained for small streams only. In 2005 and 2006 many Qual 4 samples were collected in small reference watersheds to help develop criteria for evaluating small streams. Only limited data analysis of those sample has been done.

Swamp Method

The Biological Assessment Unit defines “swamp streams” as those streams that are within the coastal plain ecoregion and that normally have no visible flow during a part of the year. This low flow period usually occurs during summer months, but flowing water should be present in swamp streams during the winter months. Sampling during winter, high flow periods provides the best opportunity for detecting differences in communities from what is natural, and only winter (February to early March) benthos data can be used when evaluating swamp streams. The swamp stream must have visible flow in this winter period, with flow comparable to a coastal plain stream that would have acceptable flow for sampling in summer. Swamp streams with pH values of 4 or lower cannot be rated, and even those below 4.5 are difficult to evaluate.

The swamp sampling method utilizes a variety of collection techniques to inventory the macroinvertebrate fauna at a site. A total of nine sweep samples (one series of three by each field team member) are collected from each of the following habitat types: macrophytes, root mats/undercut banks, and detritus deposits. If one of these habitat types is not present, a sweep from one of the other habitats is substituted. A sweep for the swamp method is defined as the area that can be reached from a given standing location. Each sweep should be emptied into a tub before the next sweep is collected, to prevent clogging of the net, but all three sweeps can be combined in the same tub. Three log/debris washes are also collected. Visual collections are the final technique used at each site.

Samples are picked on site as described under the Standard Qualitative method above. The primary output for this sampling method is a taxa list with an indication of relative abundance (Rare, Common, Abundant) for each taxon.

FRESHWATER SAMPLING TECHNIQUES

Standard Qualitative Samples

Kick Net

A kick net is an easily constructed and versatile sampling device. It consists of a double layer of flexible nylon door or window screening held in place between two halves of a wooden pole using wood screws. The screening is reinforced with denim along all edges and has lead weights sewn into the bottom edge. The screening can be sewn onto the denim using a heavy duty sewing machine.

The net is positioned upright on the stream bed, while the area upstream is physically disrupted using feet and/or hands. The debris and organisms in the kick net are then washed down into a sieve bucket with a US Standard No. 30 mesh (0.600 mm opening) bottom, and larger leaves and debris are removed. DWQ biologists have found that this technique gives very consistent results. If too coarse a mesh is used for the kick net, many animals will not be retained. If too fine a mesh is employed, the net clogs easily and washout becomes a problem. The double layer of screening works well in this respect.

Two kicks are taken from riffle areas. The two samples should be collected from areas of differing current speed. In very small streams, or in sandy areas lacking riffles, kicks should be taken from root masses, snags, or bank areas. All types of benthic macroinvertebrates are collected by this sampling device, but emphasis is placed on Ephemeroptera, Plecoptera and Trichoptera.

Sweep Net

A long-handled triangular sweep net is another versatile sampling device. Three samples are taken by physically disrupting an area and then vigorously sweeping through the disturbed area. Sweeps are usually taken from bank areas, including mud banks and root masses, and macrophyte beds. Bank samples are particularly important for the collection of "edge" species which prefer low current environments. Look for Chironomini (red chironomids), Oligochaeta, Odonata, mobile cased Trichoptera, *Sialis*, Crustacea, and certain Ephemeroptera. A sweep net also can be used to sample gravel riffle areas where stone-cased Trichoptera may be abundant.

Fine-Mesh Sampler

Since the kick and sweep nets utilize a relatively coarse mesh size, an alternate sampling technique was devised to sample the smaller invertebrates (especially the Chironomidae). The resulting sampler is known as a "chironomid-getter". Fine nitex mesh (300 microns) is placed between four inch PVC pipe fittings that are designed to screw together. The exact dimensions are not critical, but the cylinder should be able to fit inside another container, usually a slightly larger, round plastic container. This device can be used in a variety of ways.

The simplest technique is to wash down rocks or logs in a large plastic tub partially filled with water. Rocks are selected which have visible growths of periphyton, *Podostemum*, or moss. Any large particulate material (leaves, etc.) is washed down and discarded. A single composite sample can be made from several (usually 10-15) rocks and/or logs. The material remaining in the tub is poured through the fine mesh sampler and the water allowed to drain out completely.



The residue is preserved in 95% ethanol. This is accomplished by placing the fine mesh sampler into another container (6 cup size round plastic food storage container works well) which is half filled with alcohol.

The sample is allowed to sit for several minutes, pulled out of the alcohol, and then backwashed into a picking tray. This method of field preservation requires only a small amount of alcohol, and it may be reused several times. Usually 2-3 of the fine mesh samplers are used, so that one may be soaking while another is being picked. Take care to rinse samplers between sites.

Field preservation makes small chironomids and oligochaetes more visible, and easier to pick up with forceps. This technique is also good for fast moving organisms such as baetid mayflies or amphipods, or small grazing taxa such as hydroptilid caddisflies. The "pour-and-preserve" technique also can be used in conjunction with other sampling methods. For example, the elutriate from a kick or sweep sample can be processed in this manner. It is also used in conjunction with sand samples (see below).

Sand Sample

Sandy habitats often contain a distinct fauna, but extraction of this fauna by means of dredge-type sampling can be tedious. Sandy substrates (in areas with definite flow, if possible) are sampled with a large bag constructed of fine mesh (300 microns) nitex netting. It can be quickly constructed from a one meter square piece of netting, folded in half and sewn together on the opposite side and the bottom. This bag is employed like a Surber sampler, but the lack of a rigid frame allows for easy storage when folded.

The bag is held (open) near the substrate with the left foot holding the bag on the sand, and the sand is vigorously disturbed by the collector's other hand or foot. The material collected (a lot of sand and a few organisms) is emptied into a large plastic container half-filled with water. A "stir and pour" elutriation technique is used in conjunction with the fine mesh sampler. After field preservation, the elutriate is picked, looking especially for small Chironomidae (*Cryptochironomus*, *Robackia*, *Rheosmittia*, *Harnischia* group, *Polypedilum*), oligochaetes, and Baetidae. The remaining sand can be picked quickly for large or heavy organisms such as Gomphidae or *Corbicula*.

Leaf-Pack Sample

Leaf-packs, sticks and small logs are washed down in a sieve bucket with a U.S. Standard No. 30 sieve (0.600 mm openings) bottom, and then discarded. Generally, three to four leaf packs are collected from rocks or snags in fast current areas. The best leaf packs consist of older leaves (not freshly fallen) that have begun to decay. Piles of leaves in pool areas should not be collected. Leaf-pack and small log samples are particularly useful in large sandy rivers. In such habitats, many of the species are confined to "snags" (Benke et al. 1984, Neuswanger et al. 1982). Look for "shredders", especially Tipulidae, Plecoptera, and Trichoptera.

Visual Search

Visual inspection of large rocks and logs (the larger, the better) often adds to the species list. Large rocks and logs are a preferred microhabitat because of their stability during floods. Always look in a number of different areas (not just riffles). Rocks and logs in pools often yield additional species, as this habitat is not well sampled by either kicks or sweeps.

The top of rocks is a specialized microhabitat with a number of characteristic taxa. Both the caddisflies, *Psychomyia* and *Leucotrichia,* and the lepidoptera family Pyralidae, build retreats on the top of rocks. These are often made more visible by lightly washing off any silt which has accumulated on the top of the rock. Stone cased caddisflies, such as *Glossosoma*, *Agapetus*, *Ceraclea*, and *Goera* can also be found on the top or sides of rocks. Decaying logs should be picked apart to look for chironomids, and many taxa can be found under loose bark. Rocks near the shore (in negligible current) will harbor taxa such as *Stenacron* and *Pycnopsyche*, and leaves near the shore may be the primary habitat for some Gastropoda.

Certain caddisflies (*Nyctiophylax* and related genera) select crevices in rocks or logs, often along the edge, and cover them over with silk strands. The silk becomes covered with silt and periphyton and is hard to see. There is usually a faint opening on each end of this retreat. If the tip of forceps is inserted into one opening, the larvae usually will come out the other opening. Microcaddisflies make small (2-4 millimeters) cases found attached to rocks and logs, usually on the top or along an edge. The sides of rocks are the best place to look for the caddisflies *Neophylax*, *Psilotreta* and *Agarodes*.

Polycentropodid caddisflies build funnel-shaped silken retreats (up to six inches in length) in areas of relatively slow current. Out of water, the case collapses and resembles a gelatinous brown glob. The larvae will often crawl out if left out of the water for several minutes. It's a good idea to recheck some logs during visuals for these caddisflies.

In sandy coastal plain rivers, look for a log that is in an area of faster current, with some portion raised above the substrate. This is a good place to look for hydropsychids and other filter-feeders. The net may be the only visible evidence of these organisms, and they must be dug out of their retreats with forceps. Aquatic macrophytes and sponges are other habitats to be closely examined.

Mussel species can be obtained by careful visual inspection of the bottom. A mussel search should be conducted if dead shells are evident along the shore; look for midden heaps resulting from the feeding of muskrats and other vertebrates. However, only live specimens should be added to the species list. During periods of receding water levels, many species will move to deeper water, leaving a visible "track". The bases of aquatic weeds (especially water willow) may contain many mussel species and must be searched by hand. If possible, mussels should be identified in the field and returned (alive) to the stream. If sampling in an area with known populations of endangered or threatened mussels, any live mussels should be photographed or sketched and returned to the stream.

Approximately 10 minutes is allocated for these visual searches. In general, look for attached cases of Trichoptera, for Turbellaria (flatworms), Coleoptera (beetles), Odonata (dragonflies, especially on large logs), Gastropoda (snails), Hirudinea (leeches) and Megaloptera.

Boat Sampling

Most collections are in wadable streams, but there are some locations where a boat is required. These are usually large coastal plain rivers, including the lower sections of the Alligator, Chowan, Meherrin, Neuse, Pasquotank, Perquimans, Roanoke, Tar, South, Black, Waccamaw, Wiccacon, Northeast Cape Fear and Cape Fear rivers. In such habitats, petite ponar dredge sampling replaces kick-net samples, but all other standard qualitative collection techniques are still useable. Most of these localities have little or no visible current, but it is important to record in the field notes how much current is present, especially after heavy rainfalls. Coastal B criteria are used to evaluate such sampling sites.

The standard boat method still aims at a total of 10 composite samples per site. Efficiency is maximized by leaving 1-2 people on shore to collect sweeps, epifaunal collections, visuals, part of leaf-pack/debris sample, while the boat samplers collect petite ponar samples, at least part of leaf-pack/debris sample, part of one epifaunal wash,and part of visuals (logs in the current). When the shore area is very steep, some sweeps may be collected from the boat, although this can be less effective than wading.

<u>Petite ponars</u> will be collected at 3 locations between midstream and the bank, with three replicates at each locations (a total of 9 samples). Sandy samples should be elutriated and processed through a fine-mesh sampler (chironomid getter). Samples that are mainly organic can be picked live, but some portion should be processed through the fine-mesh sampler. If possible, the 3 locations should include a variety of depths, with at least one location in the 2-3 meter range. This may not be possible in all locations; but it is preferable to utilize a variety of depths. No petite ponars should be collected from the area normally sampled during shore work, i.e., <2 meters in depth. The petite ponar should be lowered slowly, so as to avoid disturbance of surface sediments. The shallow collections are often good habitat for *Hexagenia* and *Phylocentropus*. Collection card notes should include some record of the depths sampled and the general substrate composition at each location. Large clams (*Corbicula*, *Rangia*) can be identified, recorded on the collection card, and discarded.

<u>Sweeps</u> Three sweeps will be collected from bank habitats at each site, sampling as much of the edge habitat as possible. If aquatic macrophytes are present, then these should be sampled in one of the three sweeps. Other areas to be included include roots and areas of debris. Many kinds of invertebrates are collected this way, but look for cased Trichoptera (*Triaenodes*, *Oecetis*, etc.) and Baetidae.

<u>Leaf packs/Debris</u> (1 composite sample) Leaves and other large particulate organic matter are to be rinsed in a wash bucket. It will often be necessary to use the boat to get to habitats where leaves accumulate. Where leaf packs are not present, then sticks, logs, and aquatic plants may be sampled.

<u>Epifaunal collections</u> (2 composite samples) Macrophytes and well-colonized logs (both in the current and along the shore) should be washed down and processed through the fine-mesh sampler. As usual, this is aimed at getting a good sample of the midge community, but a wide variety of other taxa also will be collected. Collections which have very few numbers of midges should be repeated, as the epifaunal community can be very patchy. If the epifaunal community is very sparse, it is important that it is known that this pattern is related to water quality/habitat quality, and is not a function of sampling technique.

<u>Visuals</u> (treated as 1 composite sample) A fairly large proportion of the EPT fauna often is collected during the visual portion of sampling. Areas to be covered during visuals include:

Macrophytes, especially those with floating leaves. Look for those with some evidence of breakage and/or decomposition. Often the plants on the outside of a macrophyte patch (away from the shore) will have more types of macroinvertebrates. Look for leaf-mining midges and beetle larvae, Hydroptilidae (several genera), snails, and limpets.

Logs along the shore. Look for evidence of long-term colonization, especially periphyton and sponge growths. If the water level has risen recently, it is necessary to search for logs in deeper waters. This often means kicking up logs with your feet, unless you want to get very wet. Look for leeches (especially under bark, Polycentropodidae (several genera), small sand-cased Trichoptera (*Ceraclea*, *Oecetis*, *Phylocentropus*), *Pycnopsyche*, Heptageniidae, wood-mining midges, and snails. It is crucial that team members can recognize polycentropodid retreats.

Logs in the current. This part of the visuals usually must be conducted from the boat, and should be continued until several well-colonized logs have been found. You should be looking for epifaunal habitat that is out in the current (or where current might be at higher flows), but is large enough not to be washed downstream. This often means dragging into the boat some very large logs; if you can lift it up easily, it is probably too small. Colonization by Hydropsychidae is a good sign, but also look for Heptageniidae, Baetidae, Plecoptera (esp. *Acroneuria* and *Neoperla*), and sand-cased Trichoptera.

LABORATORY TECHNIQUES AND DATA INTERPRETATION

When a sample is returned to the laboratory for analysis, the person identifying the sample will combine all vials collected from a site into one petri dish for identification. All organisms in the sample are then identified to the lowest possible taxonomic level, recorded on a Benthic Macroinvertebrate Lab Sheet (Appendix II), and tabulated as Rare=1 (1-2 specimens), Common=3 (3-9 specimens) or Abundant=10 (≥10 specimens). Most organisms may be identified using only a dissecting microscope, but Oligochaeta, Chironomidae and some mayfly structures must be mounted on glass slides and identified with a compound microscope. Following identification, samples are labeled and stored for an indefinite time period. All molluscs and crayfish are saved, labelled, and sent to the museum collections next door. Lab sheets and all associated information are also filed by river basins.

After the sample is identified and the lab sheet is complete, all taxonomic data, along with data from the benthos collection card, is entered by biologists into a benthos database utilizing the software application Microsoft Access. After the data is entered, it is checked for coding or relative abundance errors. It is imperative that consistent coding be used when entering data in the fields for waterbody, sample type, ecoregion and bioclassification. Please use the most current coding memo for the correct codes. When the data is saved, total taxa richness, EPT taxa richness, Biotic Index value for the sample, EPT Biotic Index value and EPT abundance are automatically calculated. A species list for one or many samples can be retrieved using this system.

The ultimate result of a benthos sample is a bioclassification for the sample. Bioclassifications used by BAU are Excellent, Good, Good/Fair, Fair or Poor for standard qualitative and EPT samples. This bioclassification is automatically calculated in Microsoft Access, unless the sample is outside the summer period, from a small stream, or from a swamp stream. Any seasonal corrections are made manually (outside the database) after all taxa in a sample are entered into the database. The bioclassification is entered manually based on the corrected values and notes about corrections are made in the comments section for each sample.

For streams in the mountain and piedmont ecoregions with drainage areas ≤ 3 square miles, the Qual 4 method is employed and biocritiera have been developed for these streams (NCDWQ 2009).

The final swamp stream criteria use a three bioclassification approach for evaluation rather than the five classes used for flowing streams because of the higher natural variability found in swamp streams. This variability makes it more difficult to evaluate minor changes in the benthic community. The final bioclassifications or stress categories for swamp streams are Natural, Moderate, and Severe, and also include habitat evaluation.

A complete list of all benthic macroinvertebrates collected (BINDEX) is maintained in the Microsoft Access database. The BINDEX list contains the taxa code, the species name, order, family, tolerance value (an index based on the pollution tolerance of each taxa), and feeding type of each taxa. This list is given in Appendix 1 for all taxa that have been assigned a tolerance value. Tolerance values (Appendix 1) were updated in April 2010 and followed procedures established in Lenat (1993).

EPT Criteria

The simplest method of data analysis is the tabulation of species richness. Species richness is the simplest measure of biological diversity (Larsen and Herlihy 1998). The association of good water quality with high species (or taxa) richness has been thoroughly documented. Increasing levels of pollution gradually eliminate the more sensitive species, leading to lower and lower species richness.

Total taxa richness (S or ST) and taxa richness for Ephemeroptera + Plecoptera + Trichoptera (EPT S or SEPT) are calculated and EPT S is one metric used to assign a biological classification. The bioclassification or rating primarily reflects the influence of chemical pollutants. The effects of sediment are not assessed as well by taxa richness analysis, because the multihabitat sampling technique allows finding suitable habitats which remain above the level where scour or sediment deposition are having the most impact. Bioclassification criteria for EPT taxa richness values for three major ecoregions have been developed. For EPT samples, the criteria below are the only metric used.

EPT TAXA RICHNESS CRITERIA FOR EPT SAMPLES

	Mountain	Piedmont	Coastal Plain (CA)
Excellent	>35	>27	>23
Good	28-35	21-27	18-23
Good-Fair	19-27	14-20	12-17
Fair	11-18	7-13	6-11
Poor	0-10	0-6	0-5

For standard qualitative samples, the EPT criteria shown here were historically used to directly assign bioclassifications, but now are not used directly because new criteria using borderline values were developed in 1995. (See Derivation of Final Bioclassification for Standard Qualitative Samples)

Historical EPT Criteria for Standard Qualitative

	Mountain	Piedmont	Coastal Plain (CA)
Excellent	>41	>31	>27
Good	32-41	24-31	21-27
Good-Fair	22-31	16-23	14-20
Fair	12-21	8-15	7-13
Poor	0-11	0-7	0-6

It should be noted that although most coastal plain samples use the above criteria, it has been found that large, deep, slow-flowing rivers have different benthic communities and need different criteria. These are discussed under Coastal B River criteria below. The Coastal Plain criteria above only apply to streams that have visible flow throughout the entire year (also called Coastal A (CA) streams). Swamp streams and coastal plain streams that stop flowing for portions of the year are now being evaluated using a different set of criteria (see below).

Seasonality Corrections

Bioclassifications are assigned from the EPT taxa richness values, based on the expected values for summer (June-September) collections. However, expected EPT taxa richness values will vary seasonally, and adjustments should be made to all non-summer collections. Seasonal studies indicate winter/spring increases in Plecoptera. Occasionally there are minima in Trichoptera during early spring and/or fall. This is one of the most station-specific patterns. DWQ sampling indicates that expected seasonal patterns for EPT taxa richness are not the same for all North Carolina streams. Until a better understanding of how these patterns vary geographically is derived, site-specific adjustments should be made:

The standard correction will be to subtract winter/spring Plecoptera, as this is found most often to be all that is needed. This correction must be noted in the 4D database in the comments section. If resources allow, it is preferred for non-summer collections to resample a nearby reference site, (as similar as possible in size and substrate type to the study site) that has prior summer data. Use this site to derive the appropriate seasonal correction, by comparing the summer data with the seasonal data to establish "normal" EPT values using comparable flow regimes and evaluations of taxa richness for each order. If non-summer values appear high, then subtract winter/spring Plecoptera, or subtract winter/spring Plecoptera + Ephemeroptera (especially for April and May samples).

All seasonal corrections should be made before using EPT values to assign bioclassifications. Review of reports within the unit will be used to maintain consistency within the unit for seasonal corrections.

Biotic Index Criteria

The Biological Assessment Unit had historically (1983-1990) assigned water quality ratings (= bioclassifications) based on EPT taxa richness alone or in combination with total taxa richness. The sole use of these taxa richness values to produce bioclassifications, however, made interpretation of some data very difficult. EPT taxa richness values must often be adjusted to account for collection method, stream size, seasonal changes, and ecoregion. For this reason, a North Carolina Biotic Index (NCBI) was derived as another (independent) method of bioclassification to support water quality assessments

(Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987) with tolerance values derived from the NC database. Biotic indices may be calculated for both standard qualitative samples (NCBI or BI) or EPT samples (BIEPT), based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst. Only the BI values are used to produce a final site classification; the BIEPT values are only intended to aid in the interpretation of data.

The Biotic Index for a sample is a summary measure of the tolerance values of organisms found in the sample, relative to their abundance.

$$\text{Biotic Index (BI)} = \frac{\text{Sum}(TV_i)(n_i)}{N}$$

TV_i = ith taxa's tolerance value
n_i = ith taxa's abundance value (1, 3 or 10)
N = sum of all abundance values

Classification criteria for biotic index values were derived using the existing data base in 1991 by examining average biotic index values for each combination of bioclassification (based on EPT taxa richness), ecoregion and season. At that time a 0-5 scale was used for NCBI values. In 1992, the scale and associated criteria were expanded to 0-10 and tolerance values were recalculated using the database of samples collected to that time. A re-evaluation of tolerance values was done in early 1994. New Biotic Index values for all samples in the database were calculated. This revision led to the conclusion that separate criteria are needed for the mountain, piedmont and coastal plain (Coastal A) ecoregions. It also indicated that different seasonal corrections for fall, winter and spring are needed for these regions. These are the original criteria before borderline values were derived.

	Biotic Index*		
	Mt	P	CA
Excellent	<4.05	<5.19	<5.47
Good	4.06-4.88	5.19-5.78	5.47-6.05
Good-Fair	4.89-5.74	5.79-6.48	6.06-6.72
Fair	5.75-7.00	6.49-7.48	6.73-7.73
Poor	>7.00	>7.48	>7.73

* Historical use only

Occasional problems have been observed with Biotic Index value use:

1. BI and BIEPT may not measure impacts that are largely due to sediment, especially if measurements are conducted after a period of scour when sediment-tolerant species ("stable-sand" community) have not yet been established, or chironomids are sparse. In this instance, there may be a change in habitat quality, but no change in water quality. Similar communities will be found both above and below the source of sediment, but abundances will be sharply reduced in the sediment-impacted area. Both taxa richness and abundance values will be lower at impacted sites. For sites where such habitat changes are the primary cause of stress, the biotic index rating should be used with caution and discussion of results should clearly note the influence of sediment and flow.

2. In some intermediate piedmont/mountain regions, there is the problem of trying to decide which set of criteria should be used. The biotic index should be reviewed carefully at such sites to reduce the possibility of inappropriate criteria being used.

3. The BIEPT, and to some extent the BI, produce very low numbers in some high altitude mountain streams. This problem is immediately evident when control site values are so low that substantial increases do not result in a change in bioclassification. The BIEPT can be used to support other data, give site rankings and an assessment of damage if there are large between-site differences.

4. BIEPT values have little meaning when EPT N is very low (<30). In these cases, the EPT taxa could be mainly drift organisms from upstream, with no development of tolerant taxa at the stressed site. BI values also may not reflect additional impact if the control site is highly stressed, especially if it is rated as Poor. A typical example of this is when urban runoff impacts an upstream site.

Derivation of Final Bioclassification for Standard Qualitative Samples

For most mountain, piedmont and coastal plain (Coastal A) streams, equal weight should be given to both the NC Biotic Index value and EPT taxa richness value in assigning bioclassifications. Exceptions are detailed in the preceding paragraphs. For these metrics, bioclassifications are assigned from the following scores:

Excellent: 5   Good: 4   Good-Fair: 3   Fair: 2   Poor: 1

"Borderline" values are assigned near half-step values (1.4. 2.6, etc.) and are defined as boundary EPT values $\pm$1 (except coastal plain), and boundary biotic index values $\pm$0.05. The two ratings are then averaged together, and rounded up or down to produce the final classification. The exception to this is discussed below and occurs when the EPT and BI score differ by exactly one.

The following table should be used to determine the scores for EPT taxa richness values and Biotic Index values for all standard qualitative (Full Scale) samples after seasonal corrections are made:

Score	BI Values			EPT Values		
	Mt	P	CA	MT	P	CA
5	<4.00	<5.14	<5.42	>43	>33	>28
4.6	4.00-4.04	5.14-5.18	5.42-5.46	42-43	32-33	28
4.4	4.05-4.09	5.19-5.23	5.47-5.51	40-41	30-31	27
4	4.10-4.83	5.24-5.73	5.52-6.00	34-39	26-29	22-26
3.6	4.84-4.88	5.74-5.78	6.01-6.05	32-33	24-25	21
3.4	4.89-4.93	5.79-5.83	6.06-6.10	30-31	22-23	20
3	4.94-5.69	5.84-6.43	6.11-6.67	24-29	18-21	15-19
2.6	5.70-5.74	6.44-6.48	6.68-6.72	22-23	16-17	14
2.4	5.75-5.79	6.49-6.53	6.73-6.77	20-21	14-15	13
2	5.80-6.95	6.54-7.43	6.78-7.68	14-19	10-13	8-12
1.6	6.96-7.00	7.44-7.48	7.69-7.73	12-13	8-9	7
1.4	7.01-7.05	7.49-7.53	7.74-7.79	10-11	6-7	6
1	>7.05	>7.53	>7.79	0-9	0-5	0-5

Biotic Index corrections for non-summer data:
Summer = Jun-Sep, Fall = Oct-Nov, Winter = Dec-Feb, Spring = Mar-May

	Fall	Winter	Spring
Mountain Correction	+0.4	+0.5	+0.5
Piedmont Correction	+0.1	+0.1	+0.2
Coastal A Correction	+0.2	+0.2	+0.3

EPT N Criteria for Rounding Decisions

The Biological Assessment Unit has in prior years (1983-1996) used EPT abundance (EPT N) values in evaluating water quality impacts without formal quantification of criteria. EPT abundance is the sum of the abundance values for all EPT taxa in a sample, where Rare = 1, Common = 3, and Abundant = 10. EPT N allows differentiation of situations where intolerant groups are simply present from situations where healthier (more abundant) populations exist in a stream. One example is a stressed site that is a short distance downstream of a much cleaner site. There could be continual drift colonization of the downstream site, but most EPT taxa should remain rare. EPT N will illustrate changes between these two sites more clearly than a simple count of EPT taxa.

EPT N, however, also might be expected to vary depending on flow, season, and normal sampling variability. For this reason, a slightly different approach relative to prior DWQ criteria development is used here to determine rounding criteria using EPT abundance. Normally, the suggested criteria would be derived by calculating the mean EPT N for each bioclassification, and then establishing the criteria values as half-way between these means. Instead, the means and standard deviations were calculated for each bioclassification in three ecoregions. The criteria, therefore, include most potential sources of variation. Seasonal variation was relatively low, and effect of stream width determined to be minor. EPT abundance is highest in the mountains and least in the coastal plain. Expected ranges for each bioclassification (+/- one standard deviation (SD)) show little overlap for areas of poorer water quality, especially the Fair and Poor bioclassifications. There is greatest overlap for the Good and Excellent categories in the piedmont and coastal plain.

The rounding approach is applied only when the BI and the EPT scoring differ by exactly one bioclassification, producing a final score midway between two ratings: 1.5, 2.5, 3.5, or 4.5. When trying to decide between two bioclassifications, use the EPT abundance value criteria below (derived from mean for the higher bioclassification minus one SD), and round down if the EPT N is less than the value and round up if it is equal to or above the value.

Example: When comparing data from a Piedmont stream, and the BI score = 5, but the EPT score = 4. Round down (to Good) if EPT N < 135.

Rounding Criteria: Round down if EPT N < criterion, otherwise round up.

Bioclassification (Score)	MT	P	CA
Excellent (5) vs. Good (4)	191	135	108
Good(4) vs. Good-Fair (3)	125	103	91
Good-Fair (3) vs. Fair (2)	85	71	46
Fair (2) vs. Poor (1)	45	38	18

High Quality Small Mountain Stream Correction Factors

Correction factors have been developed for small high quality mountain streams where data have shown that EPT taxa richness values are reduced by factors other than water quality. Low productivity in such streams are often due to their pristine nature. A series of EPT surveys of mountain streams of different widths in the same unimpacted watershed in 1991 indicated a size correction factor of x1.45 for undisturbed mountain streams 1-2 meters in width or with drainage area less than about 1 square mile. A size correction factor of x1.25 is suggested for undisturbed streams 3-4 meters in width or with drainage area less than 3.5 square miles. The size correction for EPT taxa richness is made after any seasonal corrections are made. The EPT criteria values are used to determine the bioclassification after the correction is made. Because the original study was based on EPT samples, it is valid only for EPT samples.

Example: Undisturbed stream with drainage area of 0.7 square miles has EPT value of 18. Corrected value is 18 x 1.45 = 26, which is compared to EPT sample criteria values.

Other Small Streams (Qual 4 Method)

The Biological Assessment Unit has attempted to find similar unimpacted watersheds in the piedmont where size versus EPT studies could be conducted. It was not possible to find watersheds large enough to do the same studies as had been done in the mountains. Analysis of the data indicated that streams 3 meters or less in width should not be rated, if they are in disturbed watersheds in either the mountain or the piedmont. In August 2001 the decision was made to rate these small streams as Not Impaired if they would be given at least a Good-Fair bioclassification using the criteria derived for larger streams. Sites that would be at least Fair or Poor are given the bioclassification Not Rated. Because this is a minimum rating, it would be inappropriate for such sites to be put on the impaired streams list without further data evaluation to discern if the community present is influenced more by stream size or watershed impacts.

These small streams may be sampled because of special requests, and analysis of the community differences can and should be used to determine best professional judgement about impacts. Biocriteria have been developed (NCDWQ 2009) to evaluate streams in the piedmont and mountain ecoregions with drainage areas ≤ 3 square miles. Small streams in the coastal plain are no evaluated using NCDWQ (2009) since streams in this ecoregions typically have no flow for part of the year and are either not sampled, or are sampled using swamp methods.

Coastal B Rivers Criteria

Coastal B rivers are here defined as waters in the coastal plain that are deep (nonwadeable) with little or no visible current under normal or low flow conditions and that have freshwater. Other characteristics may include open canopy, low pH, and low DO. These waters require a boat for sampling. The major rivers that are considered Coastal B were listed previously under Boat Sampling.

The Biological Assessment Unit has limited data on Coastal B rivers and has had a difficult time getting more data. Criteria have been developed based only on EPT taxa richness, though using biotic index values and total taxa richness values were also evaluated. The criteria that are presented here will continue to be evaluated, and any bioclassifications derived from them should be considered tentative and not used for use support decisions.

Bioclassification	EPT S
Excellent	>11
Good	9-11
Good-Fair	6-8
Fair	3-5
Poor	< 3

Swamp Stream Criteria

Preliminary criteria for swamp streams were developed in 1996 and tested in 1997 that used a combination of macroinvertebrate, fish and habitat data. It was difficult, however, to relate fish community information to either water quality or habitat quality and fish were difficult to sample in larger swamps with braided channels. For these reasons, only macroinvertebrate and habitat data were used to further develop swamp stream criteria. The preliminary rating system also put all swamp streams into a single category. Six years of swamp sampling suggested that both stream pH and channel type (braided or not-which must be entered into the data base) have major effects on the macroinvertebrate community, so the next investigation of swamp streams focused on examining the effect of these two variables on swamp stream benthos. Studies in both 1997 and 1998 were focused on an attempt to establish reference conditions for swamps. Learning from these initial sampling attempts, swamps streams were grouped along several physical and chemical gradients, specifically channel type, soil characteristics, and pH. Further revisions (1999-2002) indicated that criteria also must be developed for different ecoregions of North Carolina. When possible, these swamp regions coincide with the North Carolina Level IV ecoregions.

Continuing basinwide studies through 2002 sampled swamp streams through the entire North Carolina coastal plain, including the Pasquotank, Chowan, Roanoke, Tar, Neuse, Cape Fear, Lumber and White Oak basins. Criteria development was complicated by the effects of hurricanes and tropical storms, by the effects of severe drought, and by the high natural variability found in swamp streams. Despite these complications, the basinwide sampling provided enough data to finalize the swamp stream criteria. An academic panel was formed in December 2002 to review these swamp stream criteria. This panel recommended these swamp stream criteria be used to assign bioclassifications. They indicated that swamp stream criteria could be used on systems with severe hydrologic modifications (channelized streams, man-made canals), despite some concerns by BAU staff. Final criteria were approved in March 2003 for three bioclassifications or stress categories: Natural, Moderate, and Severe.

There are currently six swamp regions (Figure 1), although region D does not include sampleable streams. Ecoregion designations are taken from the Level IV ecoregions of North Carolina. Many of the swamp regions follow Level IV ecoregion boundaries, but were independently derived. The exception is the Carolina Flatwoods ecoregion, which has been subdivided into 3 swamp regions.

1. Region D. Region D is the outermost coastal area, extending northward from Carteret County in two ecoregions: the Chesapeake-Pamlico Lowlands and Tidal Marshes ecoregion (63b) and the Nonriverine Swamps and Peatlands ecoregion (63c). This area has many wetlands, but few flowing streams. No swamp streams have been located in this area.

2. Region C. Region C lies to the east of the Suffolk Scarp, within the Chesapeake-Pamlico Lowlands and Tidal Marshes ecoregion (63b). Sampleable swamp streams have been located only in the Pasquotank River basin. No undisturbed catchments exist in this area, but Deep Creek was the best stream sampled by DWQ. EPT taxa are rare or absent in these swamp streams, although they may be present in the larger rivers and low-salinity estuaries.

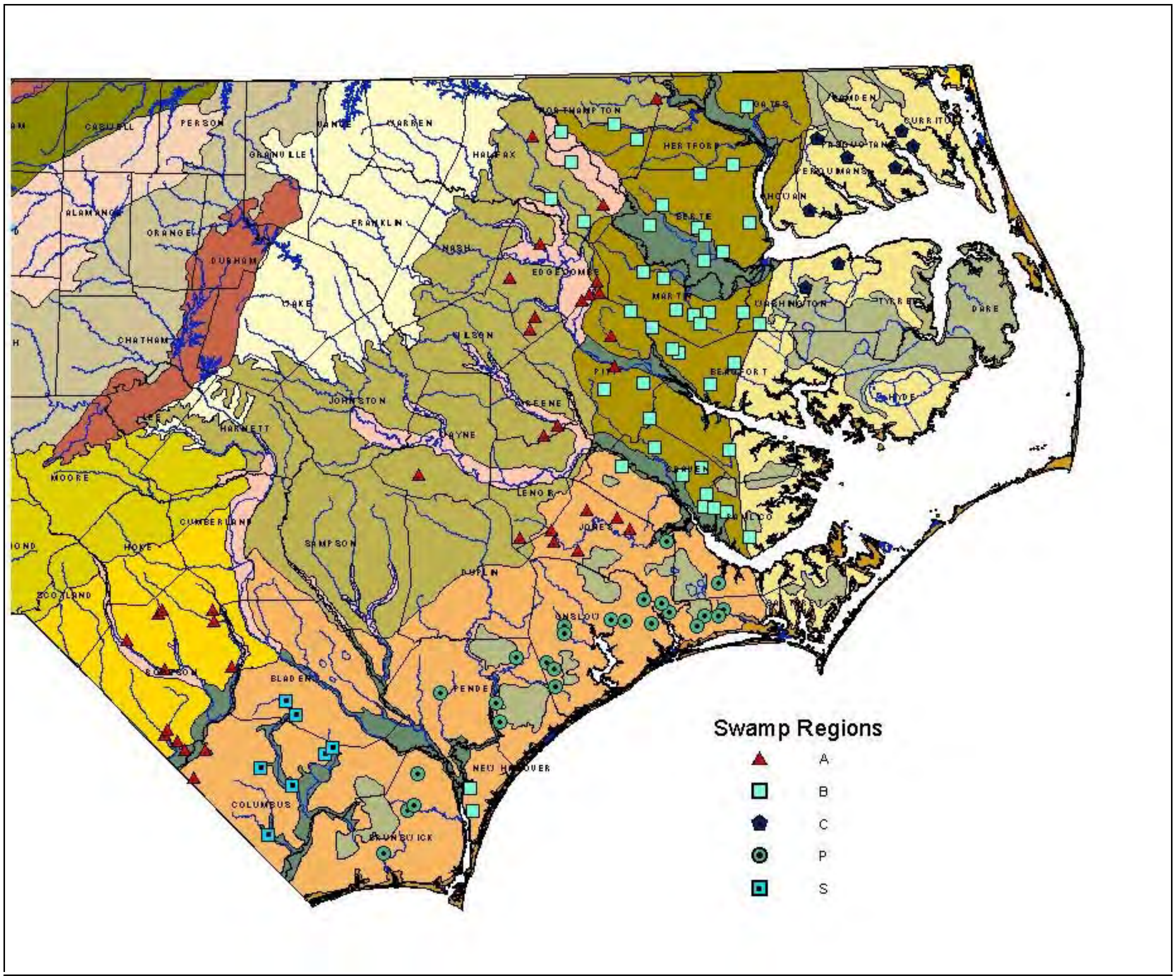


Figure 1. Swamp regions of North Carolina relative to Level IV Ecoregions (shaded areas)

3. Region B. This area generally coincides with the Mid-Atlantic Flatwoods ecoregion (63e), bounded on the south by the Neuse River and on the east by the Suffolk scarp. It also includes some of the Mid-Atlantic Floodplains and Low Terraces ecoregion (63n). A small section is also located along the southern coast. This region is generally defined by a lack of Heptageniid mayflies, especially *Stenonema*. *Stenonema modestum*, however, sometimes is found in coastal A streams within Region B.

4. Region P. This area is based on the Nonriverine Swamps and Peatlands ecoregion (63c). These streams flow through the Carolina Flatwoods (63h), but have their headwaters in the Nonriverine Swamps and Peatlands ecoregion (63c). Both the peatlands in the headwaters and the sandier soils of this region contribute to greater flow constancy relative to adjacent swamp regions. Most of the reference sites in this region have a distinct channel. Region P streams are characterized by a higher diversity of Polycentropidae (*Polycentropus*, *Lype diversa*, and *Nyctiophylax moestus*). Many of these streams also support the caddisfly *Hydropsyche decalda*.

5. Region S. Region S is also located in the Carolina Flatwoods (63h), but this is an area of very highly braided streams and extended low-flow periods. This area also has more clay soils and lower mean annual runoff (Giese and Mason, 1993). Region S has lower diversity than adjacent swamp regions.

6. Region A. Region A comprises the remainder of the swamp streams, located in the Atlantic Southern Loam Plains ecoregion (65l) and the Rolling Coastal Plain ecoregion (65m). This is a different Level III ecoregion, Southeastern Plains ecoregion (65), than the previous swamp regions which are in the Middle Atlantic Coastal Plain ecoregion (63). This area also contains many Coastal A streams.

Swamp stream criteria evaluate a stream based on three benthic macroinvertebrate metrics (Total taxa richness, EPT taxa richness, and Biotic Index) and the coastal plain form habitat value. The values for each of these metrics are used to derive a score for each metric, using the tables and graphs below.

There are only three possible scores for each metric. A **score of 5** is assigned if the metric value falls within the range **for Natural**, a **score of 3** is assigned to values in the range **for Moderate** and a **score of 1** is assigned to values in the range given **for Severe**. The final site score is derived by the formula:

Site Score = [(2xBI score + Habitat Score + EPT S score + Taxa Richness Score) – 5]/2

The biotic index is given greater weight than the other metrics (multiplied by 2), as this was shown to be the most reliable way to compare swamp streams. A value of 5 is subtracted from the sum of the scores (so that the lowest score is zero), and the sum is divided by 2 (as there were no odd numbers in the initial scores). This calculation produces a range of site scores from 0-10.

Most references sites (95%) were shown to have a **site score of 9-10** and this range was established as the Site Score criterion **for Natural** conditions. The remaining scores were separated into stress categories of **Moderate (4-8)** and **Severe (1-3**). The Severe rating was set so that at least two of the four metrics must separately indicate severe stress (a score of 1), unless the biotic index metric scores a 1.

Deriving Swamp Stream Metric Scores

Corrected Total Taxa Richness (ST) equals actual total taxa richness; or add + 8 for streams with a braided channel. Swamp regions A, P, S, and B have different criteria for pH values below 5.5. Region C uses the same criteria for all pH values.

Corrected Total Taxa Richness Values

Region:	A, P, and S			B			C		
Category:	Natural	Moderate	Severe	Natural	Moderate	Severe	Natural	Moderate	Severe
Metric Score	5	3	1	5	3	1	5	3	1
pH Value							Any pH values		
≥5.5	>51	35-51	<35	>38	25-38	<25	>34	0-34	ND
5.4	>49	32-49	<32	>36	23-36	<23			
5.3	>46	29-46	<29	>34	21-34	<21			
5.2	>43	26-43	<26	>32	19-32	<19			
5.1	>40	23-40	<23	>30	17-30	<17			
5.0	>37	20-35	<20	>28	≤28	ND			
4.9	>35	17-35	<17	>26	≤26	ND			
4.8	>33	13-33	<13	>24	≤24	ND			
4.7	>30	10-30	<10	>22	≤22	ND			
4.6	>28	0-28	ND	>20	≤20	ND			
4.5	>26	0-26	ND	>18	≤18	ND			
4.4	>23	0-23	ND						
4.3	>20	0-20	ND						
4.2	>17	0-17	ND						
4.1	>14	0-14	ND=No Data (so Category is not used)						

≤4.0 **Do Not Rate** for any region-community affected mainly by pH -probably should not be sampled

Biotic Index (BI)
Biotic Index values generally show no clear relationship between pH and channel type, and did not require any correction. Slightly elevated values are expected, however, for pH < 4.0, suggesting that these streams may be more difficult to evaluate.

Biotic Index Values

Region:		A/P/S	B	C
Category	Score			
Natural	5	<6.8	<7.0	<7.2
Moderate Stress	3	6.8-7.5	7.0-7.9	7.2-8.1
Severe Stress	1	>7.5	>7.9	>8.1

Corrected EPT taxa richness (EPT S)
First make a correction to EPT taxa richness of +2 for streams with a braided channel. Corrected EPT taxa richness is not clearly related to pH for Regions S and B, so criteria for these swamp regions are

independent of pH. Region C has few EPT taxa that this metric does not apply, but if not scored as a 1an odd rather than even number will result. A value of 2 is added to the final score of a region C site to produce a comparable score.

Corrected EPT Richness Values

Region:	A and P			S			B		
Category:	Natural	Moderate	Severe	Natural	Moderate	Severe	Natural	Moderate	Severe
Metric Score	5	3	1	5	3	1	5	3	1
pH Value				Any pH value			Any pH value		
≥5.5	>17	7-17	0-6	>10	6-10	0-5	>5	2-4	0-1
5.4	>15	6-15	0-5						
5.3	>13	5-13	0-4						
5.2	>11	4-11	0-3						
5.1	>9	3-9	0-2						
5.0	>8	0-8	ND						
4.9	>7	0-7	ND						
4.8	>6	0-6	ND						
4.7	>5	0-5	ND						
4.6	>4	0-4	ND						
4.5	>4	ND	ND						

ND=No Data (so Severe category is not used, and only a score of 3 or 5 is possible)

Habitat scores (Range is 0-100) do not require any modification for ecoregion or stream type. Based on reference site conditions, the following criteria were established:

Natural	Moderate	Severe
>79	60-79	<60

Midge Deformity Analysis

When a discharge contains both organics and toxic chemicals, the resulting community is often dominated by typical organic indicator species, especially *Chironomus* larvae. Under conditions of organic loading (low dissolved oxygen, high BOD), it would be useful to deduce the presence or absence of toxic chemicals. Researchers have shown that deformities in chironomid larvae (especially Chironomus) are associated with contaminated sediments. Using larvae from old samples and toxicity information from the DWQ Aquatic Toxicology Group, a good correlation was found between toxicity and *Chironomus* mentum deformities, leading to the use of analysis of these deformities as a screening tool for toxicity. At least 20-25 *Chironomus* heads should be slide mounted from any site to be screened.

Deformities are classified into three groups:

Class I: Slight deformities which are difficult to separate from "chipped" teeth.
Class II. Clear deformities, including extra teeth, missing teeth, large gaps, and distinct asymmetry.
Class III. Severe deformation which includes at least two Class II characters.

A "Toxic Score" is computed for each site which gives greater weight to more severe deformities:

$$\frac{[\#\text{ Class I} + 2(\#\text{ Class II}) + 3(\#\text{ Class III})] \times 100}{\text{Total }\#\text{ larvae}}$$

No significant between-group differences were found for Excellent, Good and Good-Fair nontoxic sites. The percent deformities for these unpolluted sites averaged about 5%, with a mean toxic score of about 7. Fair and Poor nontoxic sites are combined into a polluted/nontoxic group, with a deformity rate of 12% and a mean toxic score of 18. "Nontoxic" conditions for this group includes solely organic dischargers (animal wastes) and natural organic loading (swamps). A Fair/Toxic group had a 25% deformity rate and a mean toxic score of 52. A further significant increase was seen for the Poor/Toxic group: mean deformity rate = 45%, mean toxic score = 100. Both toxic groups also are characterized by a high proportion of Class II and Class III deformities.

Quality Assurance

Quality assurance begins with following the procedures found in this manual, or documenting any changes in methods. It includes taking proper care of equipment, looking for holes in nets before sampling, and rinsing all nets and tubs carefully between sites. All meters must be calibrated before and after use, if called for in the meter's operating manual, and a record maintained of calibrations. Quality assurance of field sampling is also done by conducting "overlap" samples. Two separate collections by different teams at the same site and within 2-3 weeks, with no appreciable rains in between, should be conducted annually to determine that reproducible results are being attained. In addition, field crews typically are not made up of the same three benthic biologists, so consistency in sampling is enhanced by this continuous change of staff on a field crew.

Taxonomic quality control in the laboratory is maintained in several ways. Organisms are first identified using current, regional identification manuals and other appropriate taxonomic literature. If questions occur, identifications are verified by other taxonomists in the Biological Assessment Unit. In order to maintain consistency in the taxonomic identifications, a Benthos Taxonomy Document has been compiled for the EPT and Coleoptera orders. This document specifies the level of identification to be used (genus or species), the references to be used for the IDs, and any pertinent ecological or distribution data available. This document will be updated regularly and other orders added as resources allow. Copies of all taxonomic papers used have been placed in a readily accessible location in the laboratory for the use of all benthic biologists. Taxonomic assistance is obtained from specialists when appropriate.

Reference specimens (most verified by taxonomic experts) are maintained in a reference cabinet, and samples are stored for future reference. A reference specimen list is maintained and updated periodically. Also, random samples are re-identified for taxonomic consistency. Each benthic biologist is responsible to roll two dice after ten samples have been completed. The sample corresponding with the dice number is given to another biologist for verification. Each biologist has a number and the dice are rolled again to determine which biologist gets the sample to QA. Identification of the QA sample should begin as soon as it is received, and must be completed within one week, if in the office. After QA discussions (which may involve more than one biologist) the lead benthic biologist logs the information into a QA log book. If a QA accuracy of 90% or greater is not found, then the prior 10 samples will be re-identified by the lead biologist and the original identifier.

Benthic Macroinvertebrate Basinwide Monitoring

A Benthic Macroinvertebrate Ambient Network (BMAN) was begun in 1982 at seventy five stations across the state. It grew out of a federal program designed to address long term trends in water quality through a network of fixed monitoring stations. BMAN sampling was conducted every summer (late June to early September) from 1982 through 1990 using the standard qualitative method of sampling.

Beginning in 1991, the ambient summer sampling effort was directed toward specific river basins in given years based on the NPDES permitting schedule. Biological monitoring will generally be conducted three years prior to the year of permit renewal for the basin. This will allow biological data to be incorporated in basin assessment, and subsequently into the management plan for each basin. Benthos data will be included, by subbasin, into an Environmental Sciences Branch basinwide assessment report, that will include all data from the basin that is collected by the Branch, and a review of pertinent data and information from other sources. At this time all of the 17 river basins in the state have been sampled twice for the basinwide monitoring process and basin assessment reports have been prepared for all 17. The third round of basinwide sampling has begun and second reports are completed for most basins. Beginning in 2000, all basin assessment reports are being put on the Environmental Sciences Section web page, as they are completed. An appendix in older report lists all benthos sites sampled, with results, since 1983.

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Appendix 1. **Tolerance Values** for Benthic Macroinvertebrates Used in NCBI. Many other taxa have been collected fewer than 50 times and have not been assigned a TV, and are not used in the NCBI. Taxa higher than genus also have not been assigned a TV. Tolerance values were last updated in April 2010.

Order	Family	Latin Name	Tolerance Value
Coleoptera	Dryopidae	Helichus basalis	0.5
		Helichus lithophilus	3.0
		Helichus spp	4.1
	Dytiscidae	Coptotomus spp	8.5
		Hydroporus spp	7.0
		Laccophilus spp	9.8
		Lioporeus spp	4.0
		Neoporus mellitus	3.9
		Neoporus spp	5.0
		Stictotarsus griseostriatus	4.9
	Elmidae	Ancyronyx variegatus	6.8
		Dubiraphia spp	5.5
		Dubiraphia vittata	5.0
		Macronychus glabratus	4.7
		Microcylloepus pusillus	3.3
		Optioservus ovalis	2.1
		Optioservus spp	2.1
		Oulimnius latiusculus	1.9
		Promoresia elegans	2.1
		Promoresia spp	3.1
		Promoresia tardella	0.0
		Stenelmis crenata	7.8
		Stenelmis spp	5.6
	Gyrinidae	Dineutus spp	5.0
		Gyrinus spp	5.8
	Haliplidae	Peltodytes spp	8.4
	Hydrophilidae	Berosus spp	8.8
		Enochrus spp	8.5
		Laccobius spp	6.5
		Sperchopsis tessellatus	4.4
		Tropisternus spp	9.3
	Psephenidae	Ectopria nervosa	4.3
		Psephenus herricki	2.3
	Ptilodactylidae	Anchytarsus bicolor	2.4
Crustacea	Asellidae	Caecidotea spp	8.4
		Lirceus spp	7.4
	Cambaridae	Cambarus (P.) sp C	6.3
		Cambarus spp	7.5
		Orconectes spp	2.7
		Procambarus spp	9.3
	Gammaridae	Crangonyx spp	7.2
		Gammarus fasciatus	7.0
		Gammarus spp	7.1
	Palaemonidae	Palaemonetes paludosus	6.1
		Palaemonetes spp	8.7
	Talitridae	Hyalella spp	7.2

Order	Family	Latin Name	Tolerance Value
Diptera	Chironomidae	Ablabesmyia mallochi	7.4
		Ablabesmyia rhamphe gr	6.8
		Brillia flavifrons	3.9
		Brillia spp	5.7
		Brundiniella eumorpha	2.0
		Cardiocladius spp	6.2
		Chironomus spp	9.3
		Cladotanytarsus cf daviesi	2.8
		Cladotanytarsus sp B	4.7
		Cladotanytarsus spp	4.0
		Clinotanypus spp	7.8
		Corynoneura spp	5.7
		Cricotopus annulator complex	8.4
		Cricotopus bicinctus	8.7
		Cricotopus fugax	5.6
		Cricotopus infuscatus gr	9.1
		Cricotopus vierriensis gr	5.4
		Cryptochironomus blarina gr	8.5
		Cryptochironomus fulvus	6.7
		Cryptochironomus spp	6.4
		Cryptotendipes spp	6.2
		Demicryptochironomus spp	2.2
		Diamesa spp	6.6
		Dicrotendipes fumidus	8.8
		Dicrotendipes modestus	9.4
		Dicrotendipes neomodestus	7.9
		Dicrotendipes nervosus	9.5
		Dicrotendipes simpsoni	9.8
		Dicrotendipes spp	7.2
		Diplocladius cultriger	8.0
		Eukiefferiella brehmi gr	2.5
		Eukiefferiella brevicalcar gr	2.9
		Eukiefferiella claripennis gr	6.2
		Eukiefferiella devonica gr	3.4
		Eukiefferiella gracei gr	4.4
		Eukiefferiella pseudomontana gr	1.3
		Glyptotendipes spp	8.6
		Heleniella spp	0.0
		Hydrobaenus spp	9.2
		Labrundinia pilosella	6.2
		Labrundinia spp	6.2
		Larsia spp	6.5
		Lopescladius spp	1.2
		Micropsectra spp	2.4
		Microtendipes pedellus gr	3.9
		Microtendipes rydalensis gr	1.1
		Microtendipes spp	4.6
		Nanocladius downesi	2.4
		Nanocladius spp	7.4
		Natarsia spp	9.6
		Nilotanypus fimbriatus	4.9

Order	Family	Latin Name	Tolerance Value
		Nilotanypus spp	4.1
		Nilothauma spp	5.1
		Odontomesa fulva	4.9
		Orthocladius clarkei gr	5.6
		Orthocladius dorenus	5.8
		Orthocladius dubitatus	9.0
		Orthocladius lignicola	5.4
		Orthocladius luteipes/thienemanni	6.3
		Orthocladius nigritus	3.8
		Orthocladius obumbratus gr	8.1
		Orthocladius robacki	6.4
		Orthocladius spp	4.4
		Pagastia orthogonia	1.5
		Parachaetocladius abnobaeus	0.7
		Parachironomus spp	8.0
		Paracladopelma spp	6.3
		Paracladopelma undine	4.5
		Parakiefferiella sp A	8.5
		Parakiefferiella spp	4.8
		Paralauterborniella nigrohalteralis	4.9
		Paramerina spp	4.1
		Parametriocnemus spp	3.9
		Paratanytarsus spp	8.0
		Paratendipes spp	5.6
		Pentaneura inconspicua	5.0
		Phaenopsectra obediens gr	6.6
		Phaenopsectra punctipes gr	7.1
		Polypedilum aviceps	3.6
		Polypedilum fallax/sp A	6.5
		Polypedilum flavum	5.7
		Polypedilum halterale gr	7.4
		Polypedilum illinoense gr	8.7
		Polypedilum laetum	2.2
		Polypedilum scalaenum gr	8.5
		Potthastia cf gaedii	2.4
		Potthastia longimana	8.4
		Procladius spp	8.8
		Prodiamesa olivacea	8.8
		Psectrotanypus dyari	10.0
		Pseudochironomus spp	4.9
		Rheocricotopus robacki	7.9
		Rheocricotopus spp	4.7
		Rheocricotopus tuberculatus	4.7
		Rheopelopia spp	0.3
		Rheosmittia spp	6.8
		Rheotanytarsus spp	6.5
		Robackia claviger	1.9
		Robackia demeijerei	4.3
		Saetheria tylus	7.3
		Stelechomyia perpulchra	4.0
		Stempellinella spp	5.6

Order	Family	Latin Name	Tolerance Value
		Stenochironomus spp	6.3
		Stictochironomus spp	5.4
		Sublettea coffmani	1.4
		Sympotthastia spp	4.5
		Synorthocladius spp	4.2
		Tanytarsus sp 2	6.9
		Tanytarsus sp 3	7.3
		Tanytarsus sp 4	4.7
		Tanytarsus sp 6	7.8
		Tanytarsus sp A	6.9
		Tanytarsus sp C	6.1
		Tanytarsus sp L	4.7
		Tanytarsus sp M	3.2
		Tanytarsus sp P	4.8
		Tanytarsus sp U	6.4
		Tanytarsus spp	6.6
		Thienemaniella spp	6.4
		Thienemaniella xena	8.0
		Thienemannimyia gr	8.4
		Tribelos jucundum	5.7
		Tribelos spp	6.4
		Tvetenia bavarica gr	3.6
		Tvetenia vitracies	3.5
		Xenochironomus xenolabis	6.6
		Xylotopus par	6.1
		Zavrelia spp	6.1
		Zavrelimyia spp	8.6
	Blephariceridae	Blephariceridae spp	0.0
	Ceratopogonidae	Atrichopogon spp	6.1
		Culicoides spp	8.6
		Palpomyia complex	5.7
	Culicidae	Anopheles spp	8.6
	Dixidae	Dixa spp	2.5
		Dixella indiana	4.9
	Rhagionidae	Atherix lantha	1.8
		Atherix spp	0.9
	Simuliidae	Prosimulium mixtum	3.6
		Prosimulium spp	4.5
		Simulium spp	4.9
		Simulium venustum	7.3
		Simulium vittatum	9.1
	Tabanidae	Chrysops spp	6.7
		Tabanus spp	8.5
	Tanyderidae	Protoplasa fitchii	4.0
	Tipulidae	Antocha spp	4.4
		Dicranota spp	0.0
		Hexatoma spp	3.5
		Limonia spp	9.3
		Polymeda/Ormosia spp	6.5

		Pseudolimnophila spp	6.2
		Tipula spp	7.5

Order	Family	Latin Name	Tolerance Value
Ephemeroptera	Ameletidae	Ameletus lineatus	2.4
	Baetidae	Acentrella alachua	3.0
		Acentrella nadineae	1.9
		Acentrella parvula	4.8
		Acentrella spp	2.5
		Acentrella turbida	2.0
		Acerpenna pygmaea	3.7
		Baetis flavistriga	6.8
		Baetis intercalaris	5.0
		Baetis pluto	3.4
		Baetis tricaudatus	1.5
		Callibaetis spp	9.2
		Centroptilum spp	3.8
		Cloeon spp	7.3
		Diphetor hageni	1.1
		Heterocloeon amplum	3.4
		Heterocloeon curiosum	2.1
		Heterocloeon spp	3.7
		Iswaeon anoka	4.4
		Paracloeodes spp	8.0
		Plauditus cestus	4.6
		Plauditus dubius gr	2.2
		Procloeon spp	1.9
		Pseudocloeon ephippiatum	3.5
		Pseudocloeon frondale	4.6
		Pseudocloeon propinquum	5.8
	Baetiscidae	Baetisca berneri	1.4
		Baetisca carolina	4.2
		Baetisca spp	3.2
	Caenidae	Brachycercus spp	2.1

		Caenis spp	6.8
	Ephemerellidae	Attenella attenuata	1.1
		Dannella simplex	3.4
		Drunella allegheniensis	0.3
		Drunella conestee	0.0
		Drunella cornutella	0.0
		Drunella lata	0.0
		Drunella tuberculata	0.0
		Drunella walkeri	0.6
		Drunella wayah	0.0
		Ephemerella catawba	0.0
		Ephemerella catawba/dorothea	4.0
		Ephemerella dorothea	3.3
		Ephemerella hispida	0.1
		Ephemerella invaria	2.6
		Ephemerella rossi gr	0.0
		Ephemerella rotunda	1.8
		Ephemerella spp	2.1
		Eurylophella bicolor	4.8
		Eurylophella doris	7.0
		Eurylophella funeralis	2.5

Order	Family	Latin Name	Tolerance Value
		Eurylophella spp	4.0
		Eurylophella temporalis gr	4.8
		Eurylophella verisimilis	3.9
		Penelomax septentrionalis	2.1
		Serratella carolina	0.0
		Serratella serrata	1.4
		Serratella serratoides	1.7
		Telagonopsis deficiens	2.6
	Ephemeridae	Ephemera blanda	2.4
		Ephemera guttalata	0.0
		Ephemera spp	2.0
		Hexagenia spp	4.4
	Heptageniidae	Cinygmula subaequalis	0.0
		Epeorus dispar	1.0
		Epeorus pleuralis	1.5
		Epeorus spp	1.6
		Epeorus vitreus	1.2
		Heptagenia marginalis	2.2
		Heptagenia pulla	2.2
		Heptagenia spp	1.9
		Leucrocuta aphrodite	2.9
		Leucrocuta spp	2.0
		Maccaffertium carlsoni	2.1
		Maccaffertium exiguum	3.8
		Maccaffertium ithaca	3.0
		Maccaffertium lenati	2.5
		Maccaffertium mediopunctatum	4.2
		Maccaffertium meririvulanum	0.5
		Maccaffertium mexicanum	4.7
		Maccaffertium modestum	5.7

		Maccaffertium pudicum	2.1
		Maccaffertium terminatum	4.4
		Maccaffertium vicarium	1.5
		Rhithrogena exilis	0.0
		Rhithrogena spp	0.0
		Rhithrogena uhari	0.0
		Stenacron carolina	1.3
		Stenacron interpunctatum	6.4
		Stenacron pallidum	2.8
		Stenonema femoratum	6.9
	Isonychiidae	Isonychia spp	3.6
	Leptohyphidae	Tricorythodes spp	5.0
	Leptophlebiidae	Habrophlebia vibrans	0.3
		Leptophlebia spp	6.0
		Paraleptophlebia spp	1.2
	Neoephemeridae	Neoephemera purpurea	1.5
	Polymitarcyidae	Ephoron leukon	1.5
	Potamanthidae	Anthopotamus distinctus	1.6
		Anthopotamus spp	1.5
	Siphlonuridae	Siphlonurus spp	6.0

Order	Family	Latin Name	Tolerance Value
Gastropoda	Ancylidae	Ferrissia spp	6.6
		Laevapex fuscus	6.6
	Hydrobiidae	Amnicola spp	4.1
	Lymnaeidae	Pseudosuccinea columella	7.7
		Stagnicola spp	8.1
	Physidae	Physa spp	8.7
	Planorbidae	Helisoma anceps	6.6
		Micromenetus dilatatus	7.6
	Pleuroceridae	Elimia spp	2.7
		Leptoxis spp	1.7
	Viviparidae	Campeloma decisum	5.8
Hemiptera	Belostomatidae	Belostoma spp	9.5
	Corixidae	Sigara spp	8.7
	Nepidae	Ranatra spp	6.3
Megaloptera	Corydalidae	Corydalus cornutus	5.2
		Nigronia fasciatus	6.1
		Nigronia serricornis	4.6
	Sialidae	Sialis spp	7.0
Odonata	Aeshnidae	Basiaeschna janata	7.1
		Boyeria grafiana	3.8
		Boyeria vinosa	5.8
		Nasiaeschna pentacantha	6.6
	Calopterygidae	Calopteryx spp	7.5
		Hetaerina spp	4.9
	Coenagrionidae	Argia spp	8.3
		Enallagma spp	8.5
		Ischnura spp	9.5
	Cordulegasterida e	Cordulegaster spp	5.7
	Corduliidae	Epicordulia princeps	7.3
		Helocordulia spp	5.8
		Neurocordulia obsoleta	5.3
		Neurocordulia spp	5.3
		Neurocordulia virginiensis	1.1
		Somatochlora spp	8.9
		Tetragoneuria spp	8.0
	Gomphidae	Dromogomphus spp	5.6
		Gomphus spiniceps	6.1
		Gomphus spp	5.9
		Hagenius brevistylus	4.4
		Lanthus parvulus	0.6
		Lanthus spp	1.6
		Lanthus vernalis	0.8
		Ophiogomphus spp	5.9
		Progomphus obscurus	8.2
		Stylogomphus albistylus	5.0
	Libellulidae	Libellula spp	9.4
		Pachydiplax longipennis	9.6
		Perithemis spp	9.4
		Plathemis lydia	9.8
	Macromiidae	Macromia spp	6.2

Order	Family	Latin Name	Tolerance Value
Oligochaeta	Naididae	Dero spp	9.8
		Nais spp	8.7
		Pristina spp	7.7
		Slavina appendiculata	8.4
		Stylaria lacustris	8.4
	Tubificidae	Aulodrilus pluriseta	5.6
		Branchiura sowerbyi	8.6
		Ilyodrilus templetoni	9.3
		Limnodrilus hoffmeisteri	9.4
		Limnodrilus spp	8.5
		Spirosperma nikolskyi	6.0
		Tubifex tubifex	9.9
Other	Erpobdellidae	Erpobdella/Mooreobdella spp	8.6
		Mooreobdella tetragon	9.4
	Glossiphoniidae	Desserobdella phalera	6.6
		Gloiobdella elongata	9.1
		Helobdella triserialis	9.3
		Placobdella papillifera	8.2
		Placobdella parasitica	8.9
	Planariidae	Cura foremanii	5.5
		Dugesia tigrina	7.1
	Pyralidae	Petrophila spp	3.6
	Sisyridae	Climacia areolaris	6.5
	Tetrastemmatidae	Prostoma graecens	6.6
Bivalvia	Corbiculidae	Corbicula fluminea	6.6
	Sphaeriidae	Pisidium spp	6.6
		Sphaerium spp	7.2
	Unionidae	Elliptio complanata	4.7
		Elliptio spp	4.9
Plecoptera	Capniidae	Allocapnia spp	3.3
	Chloroperlidae	Alloperla spp	1.0
		Haploperla brevis	1.4
		Suwallia marginata	2.6
		Sweltsa spp	0.2
	Leuctridae	Leuctra spp	1.5
	Nemouridae	Amphinemura spp	3.8
		Prostoia spp	5.2
	Peltoperlidae	Tallaperla spp	1.3
	Perlidae	Acroneuria abnormis	2.1
		Acroneuria arenosa	2.4
		Acroneuria carolinensis	1.2
		Acroneuria evoluta	1.7
		Acroneuria lycorias	2.1
		Agnetina spp	1.1
		Beloneuria spp	0.0
		Eccoptura xanthenes	4.7
		Neoperla spp	2.1
		Paragnetina fumosa	3.6
		Paragnetina ichusa/media	0.2
		Paragnetina immarginata	1.1
		Paragnetina kansensis	1.9

Order	Family	Latin Name	Tolerance Value
		Perlesta spp	2.9
		Perlinella drymo	1.3
	Perlodidae	Clioperla clio	5.2
		Cultus decisus complex	1.5
		Diploperla duplicata	2.8
		Helopicus subvarians	1.2
		Isoperla bilineata gr	5.2
		Isoperla holochlora	0.7
		Isoperla nr holochlora	0.0
		Isoperla nr namata	2.5
		Isoperla orata	0.0
		Isoperla similis gr	0.8
		Isoperla sp A	1.2
		Isoperla spp	3.2
		Isoperla transmarina gr	4.8
		Malirekus hastatus	1.0
		Remenus bilobatus	0.9
	Pteronarcyidae	Pteronarcys biloba	0.0
		Pteronarcys dorsata	2.4
		Pteronarcys proteus	0.4
		Pteronarcys spp	1.8
	Taeniopterygidae	Strophopteryx spp	3.3
		Taeniopteryx burksi	6.6
		Taeniopteryx spp	6.0
Trichoptera	Apataniidae	Apatania spp	0.6
	Brachycentridae	Brachycentrus appalachia	1.0
		Brachycentrus lateralis	1.9
		Brachycentrus nigrosoma	3.1
		Brachycentrus numerosus	1.7
		Brachycentrus spinae	0.0
		Brachycentrus spp	2.2
		Micrasema bennetti	0.0
		Micrasema charonis	1.0
		Micrasema rickeri	0.0
		Micrasema wataga	2.2
	Calamoceratidae	Anisocentropus pyraloides	1.3
		Heteroplectron americanum	2.0
	Dipseudopsidae	Phylocentropus spp	4.8
	Glossosomatidae	Agapetus spp	0.0
		Glossosoma spp	1.4
		Protoptila spp	2.3
	Goeridae	Goera calcarata	1.0
		Goera spp	0.7
	Helicopsychidae	Helicopsyche borealis	0.0
	Hydropsychidae	Arctopsyche irrorata	0.0
		Ceratopsyche alhedra	0.0
		Ceratopsyche bronta	2.3
		Ceratopsyche macleodi	0.7
		Ceratopsyche morosa	2.3
		Ceratopsyche slossonae	0.0
		Ceratopsyche sparna	2.5

Order	Family	Latin Name	Tolerance Value
		Cheumatopsyche spp	6.6
		Diplectrona modesta	2.3
		Hydropsyche betteni	7.9
		Hydropsyche decalda	3.2
		Hydropsyche demora	2.6
		Hydropsyche incommoda	4.6
		Hydropsyche phalerata	3.7
		Hydropsyche rossi	4.8
		Hydropsyche scalaris	2.6
		Hydropsyche venularis	5.1
		Macrostemum spp	3.4
		Parapsyche cardis	0.0
	Hydroptilidae	Hydroptila spp	6.5
		Leucotrichia pictipes	4.6
	Lepidostomatidae	Lepidostoma spp	1.0
	Leptoceridae	Ceraclea ancylus	2.8
		Ceraclea maculata	6.2
		Ceraclea spp	2.2
		Ceraclea transversa	2.8
		Mystacides sepulchralis	2.6
		Nectopsyche candida	6.5
		Nectopsyche exquisita	4.3
		Nectopsyche pavida	3.9
		Oecetis georgia	3.6
		Oecetis nocturna	5.0
		Oecetis persimilis	4.6
		Oecetis scala gr	2.7
		Oecetis spp	5.1
		Setodes spp	0.0
		Triaenodes ignitus	4.8
		Triaenodes injustus	2.7
		Triaenodes perna/helo	3.8
		Triaenodes spp	4.1
	Limnephilidae	Hydatophylax argus	2.4
		Ironoquia punctatissima	6.7
		Pycnopsyche gentilis	1.8
		Pycnopsyche guttifer	2.2
		Pycnopsyche lepida gr	3.9
		Pycnopsyche scabripennis	2.5
		Pycnopsyche spp	2.5
	Molannidae	Molanna blenda	1.6
		Molanna tryphena	2.4
	Odontoceridae	Psilotreta spp	0.5
	Philopotamidae	Chimarra spp	3.3
		Dolophilodes spp	1.0
		Wormaldia spp	2.4
	Phryganeidae	Oligostomis pardalis	6.2
		Ptilostomis spp	5.9
	Polycentropodidae	Cyrnellus fraternus	6.8
		Neureclipsis spp	4.0
		Nyctiophylax celta	0.7

Order	Family	Latin Name	Tolerance Value
		Nyctiophylax moestus	3.8
		Nyctiophylax nephophilus	0.6
		Nyctiophylax spp	0.8
		Polycentropus spp	3.1
	Psychomyiidae	Lype diversa	3.9
		Psychomyia flavida	3.0
		Psychomyia nomada	2.0
	Rhyacophilidae	Rhyacophila acutiloba	0.0
		Rhyacophila atrata	0.0
		Rhyacophila carolina	0.4
		Rhyacophila fenestra/ledra	4.6
		Rhyacophila formosa	0.1
		Rhyacophila fuscula	1.6
		Rhyacophila nigrita	0.0
		Rhyacophila torva	1.5
	Sericostomatidae	Fattigia pele	0.0
	Uenoidae	Neophylax consimilis	0.3
		Neophylax fuscus	0.0
		Neophylax mitchelli	0.0
		Neophylax oligius	2.4
		Neophylax ornatus	1.3
		Neophylax spp	1.6

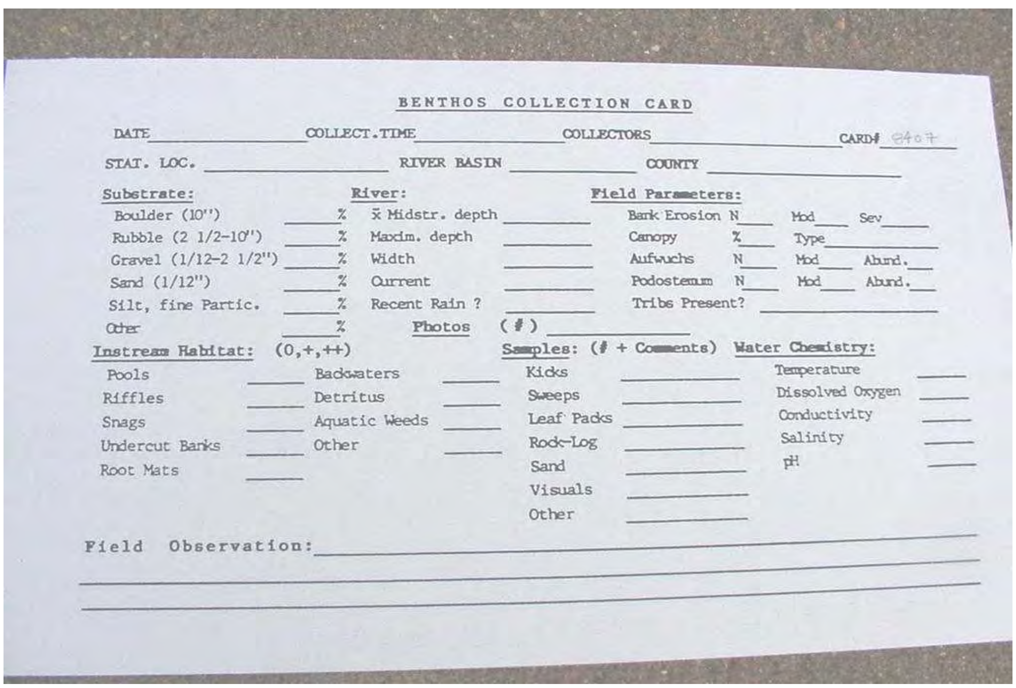
Appendix 2. Benthic Macroinvertebrate Field and Lab Equipment

A. Field Equipment

Kick nets
Sweep nets
Sand bag sampler
Fine-mesh samplers
Petite Ponar
Wash tubs
Sieve buckets
Plastic picking trays
Camera and film, or Digital camera
Forceps
Meters (YSI, pH, etc)
Waders, rain gear
Vials, and containers for vials
Alcohol
Labels and collection cards, pencils
Habitat Assessment Forms
GPS Unit
First Aid Kit
Insect Repellant

B. Laboratory Equipment and Supplies

Dissecting microscopes
Compound microscopes
Alcohol
Formalin
Polyvinyl lactophenol (CMC Mounting Media)
Rose bengal solution
Vials
Forceps
Cover slips
Microscope slides
Petri dishes
Squeeze bottles
Dissecting needles
Slide labels
Slide holders
Benthic Macroinvertebrate lab sheets


BENTHOS COLLECTION CARD

DATE ______ COLLECT.TIME ______ COLLECTORS ______ CARD# 8407

STAT. LOC. ______ RIVER BASIN ______ COUNTY ______

Substrate:
Boulder (10") ___ %
Rubble (2 1/2-10") ___ %
Gravel (1/12-2 1/2") ___ %
Sand (1/12") ___ %
Silt, fine Partic. ___ %
Other ___ %

River:
x̄ Midstr. depth ______
Maxim. depth ______
Width ______
Current ______
Recent Rain ? ______
Photos (#) ______

Field Parameters:
Bank Erosion N___ Mod___ Sev___
Canopy % ___ Type ______
Aufwuchs N___ Mod___ Abund.___
Podostemum N___ Mod___ Abund.___
Tribs Present? ______

Instream Habitat: (0,+,++)
Pools ___ Backwaters ___
Riffles ___ Detritus ___
Snags ___ Aquatic Weeds ___
Undercut Banks ___ Other ___
Root Mats ___

Samples: (# + Comments)
Kicks ______
Sweeps ______
Leaf Packs ______
Rock-Log ______
Sand ______
Visuals ______
Other ______

Water Chemistry:
Temperature ___
Dissolved Oxygen ___
Conductivity ___
Salinity ___
pH ___

Field Observation: ______

BENTHIC MACROINVERTEBRATE LAB SHEET

Water Body___________________________ Road/County______________________

Type Sample_________________________ Collection Card No._________________

Date Collected________________________ Collectors/Analyst___________________

Ephemeroptera	A,C,R		Plecoptera	A,C,R		Odonata	A,C,R	
			Misc Diptera			Oligochaeta		
			Chiros			Megaloptera		
						Crustacea		
Trichoptera								
						Mollusca		
			Coleoptera			Other		

Total Taxa______________________ Bioclassification____________________

Total EPT______________________ EPT N ___________________________

Biotic Index_____________________ EPT BI ___________________________

Notes____

3/06 Revision 7

Habitat Assessment Field Data Sheet
Coastal Plain Streams

TOTAL SCORE________

Biological Assessment Unit, DWQ

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream________________________Location/road: _____________(Road Name____________)County________________

Date__________________________**CC#**_______________Basin_______________________Subbasin_________________

Observer(s)_________ Type of Study: ☐ Fish ☐Benthos ☐ Basinwide ☐Special Study (Describe) ________________

Latitude ____________Longitude _____________Ecoregion: ☐ CA ☐ SWP ☐ Sandhills ☐ CB

Water Quality: Temperature_______^{0}C DO _______mg/l Conductivity (corr.) ______µS/cm pH _____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location. Check off what you observe driving thru the watershed in watershed land use.

Visible Land Use: ______%Forest ______%Residential ______%Active Pasture _______% Active Crops
_____%Fallow Fields ______% Commercial ______%Industrial ______%Other - Describe:_____________

Watershed land use ☐ Forest ☐ Agriculture ☐Urban ☐ Animal operations upstream

Width: (meters) Stream_________ Channel (at top of bank)_______ **Stream Depth**: (m) Avg______Max ____
☐ **Width variable** ☐**Braided channel** ☐**Large river >25m wide**
Bank Height (from deepest part of channel to top of bank): (m)________

Flow conditions : ☐High ☐Normal ☐Low
Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed....................... ☐
C. Water fills 25-75% of available channel, many logs/snags exposed... ☐
D. Root mats out of water.. ☐
E. Very little water in channel, mostly present as standing pools.. ☐

Turbidity: ☐Clear ☐ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes) ☐Green tinge
Good potential for Wetlands Restoration Project?? ☐ **YES** ☐ **NO**
Details____
____

☐Channelized ditch
☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☐Recent overbank deposits ☐Bar development ☐Sewage smell
☐Excessive periphyton growth ☐Heavy filamentous algae growth

Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Weather Conditions:________________________**Photos:** ☐N ☐Y ☐Digital ☐35mm

Remarks:____
TYPICAL STREAM CROSS SECTION DIAGRAM ON BACK

I. Channel Modification

	Score
A. Natural channel-minimal dredging..	15
B. Some channelization near bridge, or historic (>20 year old), and/or bends beginning to reappear..	10
C. Extensive channelization, straight as far as can see, channelized ditch..........................	5
D. Banks shored with hard structure, >80% of reach disrupted, instream habitat gone........	0

Remarks____ Subtotal____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >50% of the reach is snags, and 1 type is present, circle the score of 16. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as **R**are, **C**ommon, or **A**bundant.

____Sticks ____Snags/logs ____Undercut banks or root mats ____Macrophytes ____Leafpacks

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>50% Score	30-50% Score	10-30% Score	<10% Score
4 or 5 types present................	20	15	10	5
3 types present........................	18	13	8	4
2 types present........................	17	12	7	3
1 type present..........................	16	11	6	2
No substrate for benthos colonization and no fish cover..0				

☐ No woody vegetation in riparian zone Remarks____________________________________ Subtotal_____

III. Bottom Substrate (silt, clay, sand, detritus, gravel) look at entire reach for substrate scoring.

A. Substrate types mixed	Score
1. gravel dominant..	15
2. sand dominant..	13
3. detritus dominant..	7
4. silt/clay/muck dominant..	4
B. Substrate homogeneous	
1. nearly all gravel..	12
2. nearly all sand	7
3. nearly all detritus..	4
4. nearly all silt/clay/muck..	1

Remarks____Subtotal_____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow.

A. Pools present	Score
1. Pools Frequent (>30% of 100m length surveyed)	
a. variety of pool sizes..	10
b. pools about the same size (indicates pools filling in)..	8
2. Pools Infrequent (<30% of the 100m length surveyed)	
a. variety of pool sizes..	6
b. pools about the same size..	4
B. Pools absent	
1. Deep water/run habitat present..	4
2. Deep water/run habitat absent...	0
	Subtotal_____

Remarks____ Page Total_______

V. Bank Stability and Vegetation

	Score	Score
A. Banks stable or no banks, just flood plain		
1. little or no evidence of erosion or bank failure, little potential for erosion	10	10
B. Erosion areas present		
1. diverse trees, shrubs, grass; plants healthy with good root systems................................	9	9
2. few trees or small trees and shrubs; vegetation appears generally healthy......................	7	7
3. sparse vegetation; plant types and conditions suggest poorer soil binding.......................	4	4
4. mostly grasses, few if any trees and shrubs, high erosion and failure potential at high flow	2	2
5. little or no bank vegetation, mass erosion and bank failure evident.............................0	0	

Total_____

Remarks____

VI. Light Penetration (Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead).

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal....................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..	2
E. **No canopy** and no shading...	0

Subtotal____

Remarks____

VII. Riparian Vegetative Zone Width

Definition: A break in the riparian zone is any area which allows sediment to enter the stream. Breaks refer to the near-stream portion of the riparian zone (banks); places where pollutants can directly enter the stream.

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. zone width > 18 meters..	5	5
2. zone width 12-18 meters..	4	4
3. zone width 6-12 meters..	3	3
4. zone width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. zone width > 18 meters...	4	4
b. zone width 12-18 meters...	3	3
c. zone width 6-12 meters...	2	2
d. zone width < 6 meters...	1	1
2. breaks common		
a. zone width > 18 meters...	3	3
b. zone width 12-18 meters...	2	2
c. zone width 6-12 meters...	1	1
d. zone width < 6 meters...	0	0

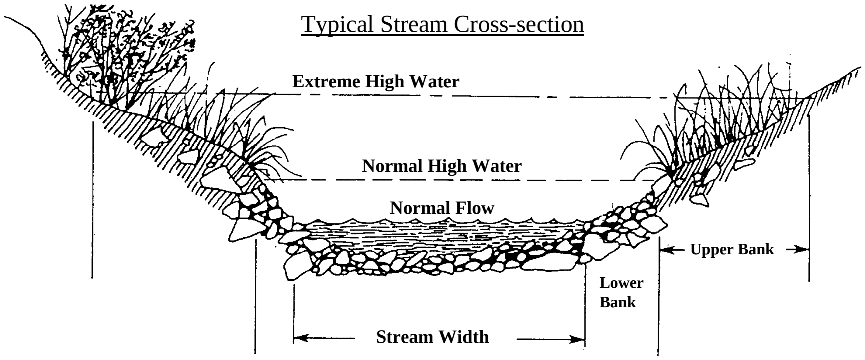
Total______

Remarks____

Page Total_______

TOTAL SCORE ___________

Typical Stream Cross-section



This side is 45º bank angle.

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE________**

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream_______________________Location/road: _____________(Road Name____________)County_______________

Date___________________**CC#**_______________Basin______________________Subbasin_______________________

Observer(s)_________ Type of Study: ☐ Fish ☐Benthos ☐ Basinwide ☐Special Study (Describe) _______________

Latitude ____________Longitude _____________Ecoregion: ☐ MT ☐ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature_______^{0}C DO _______mg/l Conductivity (corr.) ______µS/cm pH _____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: ______%Forest ______%Residential ______%Active Pasture _______% Active Crops
_____%Fallow Fields ______% Commercial ______%Industrial ______%Other - Describe:_____________

Watershed land use : ☐Forest ☐Agriculture ☐Urban ☐ Animal operations upstream

Width: (meters) Stream_________ Channel (at top of bank)_______ **Stream Depth**: (m) Avg______Max ____
☐ Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (m)________

Bank Angle: _________ º or ☐ NA (Vertical is 90º, horizontal is 0º. Angles > 90º indicate slope is towards mid-channel, < 90º indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☐Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☐Normal ☐Low
Turbidity: ☐Clear ☐ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☐NO Details____________________________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed....................... ☐
C. Water fills 25-75% of available channel, many logs/snags exposed... ☐
D. Root mats out of water.. ☐
E. Very little water in channel, mostly present as standing pools.. ☐

Weather Conditions:________________________**Photos:** ☐N ☐Y ☐ Digital ☐35mm

Remarks:____
____

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks____ Subtotal____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as **R**are, **C**ommon, or **A**bundant.

____Rocks ____Macrophytes ____Sticks and leafpacks ____Snags and logs ____Undercut banks or root mats

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks____ Subtotal_____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks____Subtotal_____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal_____

☐ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks____

Page Total_____

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent...	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream Subtotal_____

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems...................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident..	0	0

Total______

Remarks____

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal.................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..	2
E**. No canopy** and no shading..	0

Remarks____Subtotal____

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters...	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters..	3	3
c. width 6-12 meters..	2	2
d. width < 6 meters..	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters..	1	1
d. width < 6 meters..	0	0

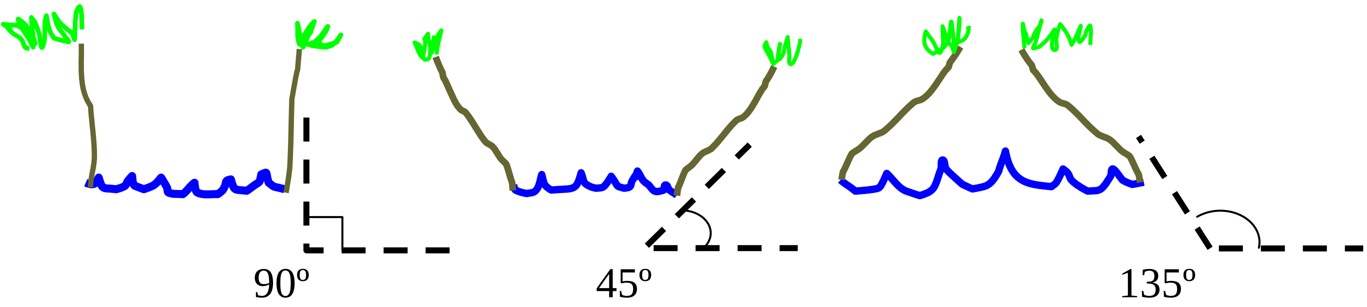
Remarks____ Total______

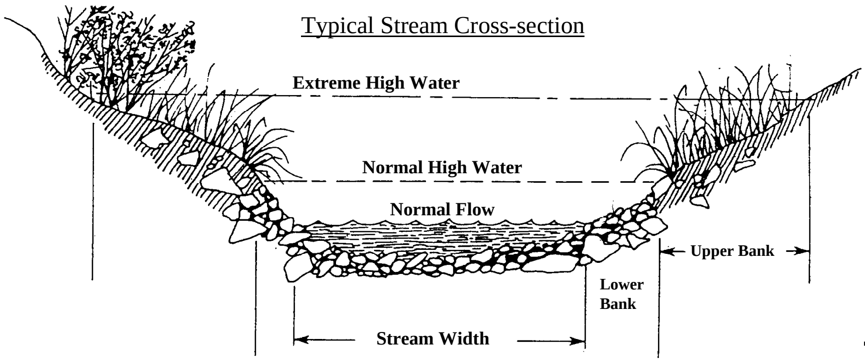
Page Total_______

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE_______**

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45º bank angle.

Site Sketch:

Other comments:____

APPENDIX B.
BENTHIC MACROINVERTEBRATE SAMPLING RESULTS

Table 1. List of macroinvertebrates collected at Sanford Branch and Smith Creek, WK Dickson, 2013-2015.

	2013			2014			2015		
Site:	SA	S1	S2	SA	S1	S2	SA	S1	S2
EPHEMEROPTERA									
Maccaffertium modestum	A	A	A	A	A	A	A	A	A
Stenacron interpunctatum	-	-	R	-	-	-	-	-	-
Acentrella parvula	-	-	-	R	-	-	-	R	-
Baetis pluto	R	-	-	-	-	C	R	-	R
B. flavistriga	-	-	R	R	R	R	R	R	R
B. intercalaris	-	-	-	-	-	-	-	C	-
Laebiobaetis propinquum	A	A	C	A	C	A	A	A	C
Procloeon sp	-	-	-	-	-	R	-	-	-
Plauditus cestus	-	-	-	-	-	-	-	C	-
Isonychia sp	-	-	R	R	R	-	-	R	-
Tricorythodes sp	-	A	A	-	A	C	-	C	R
Telagonopsis deficiens	-	-	-	-	-	-	-	-	R
PLECOPTERA									
Leuctra sp	R	-	-	-	-	-	R	-	-
Perlesta sp	-	-	-	R	-	R	-	-	-
Eccoptura xanthenes	-	-	-	R	-	-	C	-	R
Paragnetina fumosa	-	-	-	-	C	-	-	C	-
TRICHOPTERA									
Cheumatopsyche spp	A	A	A	A	A	A	A	A	A
Hydropsyche betteni	C	R	A	A	A	A	A	A	A
Hydropsyche imcommoda	-	-	-	-	R	-	-	-	-
Diplectrona modesta	C	-	R	-	-	-	-	-	-
Chimarra sp	R	-	A	A	C	C	A	-	R
Neophylax oligius	-	-	A	R	-	R	C	-	A
Pycnopsyche spp	R	-	-	R	-	R	-	-	-
Triaenodes ignitus	C	C	A	C	C	C	C	R	A
Oecetis persimilis	C	-	C	R	R	C	-	C	A
Nectopsyche equiseta	-	-	-	-	-	-	-	C	-
Lepidosoma sp	-	-	-	R	-	-	-	-	-
Lype diversa	C	R	-	-	C	R	C	R	-
Polycentropus sp	-	R	-	-	R	-	-	R	-
COLEOPTERA									
Helichus spp	C	R	R	C	-	-	C	R	C
Stenelmis crenata	-	-	R	C	R	C	R	-	-
Stenelmis sandersoni	R	-	-	-	-	-	-	-	-
Macronychus glabratus	A	A	A	A	A	A	A	A	A
Ancyronyx variegata	A	A	C	C	A	C	R	A	C
Dubiraphia sp	-	R	R	-	R	-	-	-	R
Microcylloepus pusillus	R	-	-	-	-	-	R	-	-
Anchytarsus bicolor	-	-	R	-	-	R	R	-	-
Neoporus spp	-	R	-	R	-	-	-	-	-
Dineutus sp	-	-	-	-	-	-	-	R	-

	2013			2014			2015		
Site:	SA	S1	S2	SA	S1	S2	SA	S1	S2
ODONATA									
Calopteryx sp	A	C	C	C	C	R	A	A	C
Argia spp	R	R	R	R	-	C	R	R	R
Enallagma sp	-	-	R	-	-	-	-	-	-
Ophiogomphus sp	R	-	R	R	-	C	C	R	R
Progomphus obscurus	R	-	R	-	-	R	-	-	R
Gomphus spp	C	R	R	R	-	-	R	R	R
Hagenius brevistylus	-	R	-	-	-	R	R	R	-
Boyeria vinosa	A	C	A	A	R	A	A	A	A
Boyeria grafiana	-	-	-	-	R	-	-	R	-
Baesiaeschna janata	-	-	-	-	-	-	-	R	-
Macromia sp	-	R	-	-	-	-	-	R	-
Somatochlora sp	-	-	-	R	-	-	-	-	-
MEGALOPTERA									
Sialis sp	-	-	R	-	-	R	-	R	-
Nigronia serricornis	-	-	C	C	-	C	C	R	C
DIPTERA: MISC.									
Tipula sp	C	R	C	C	-	C	C	R	C
Simulium spp	A	A	A	A	C	-	C	-	-
Antocha sp	-	-	-	-	-	R	-	-	-
DIPTERA: CHIRONOMIDAE									
Ablabesmyia mallochi	R	-	-	R	R	R	R	R	R
Conchapelopia group	C	-	R	C	C	C	C	C	C
Natarsia sp	R	R	-	-	-	-	R	R	-
Pentaneura sp	-	-	-	-	-	R	-	-	-
Procladius sp	-	-	-	-	R	-	-	-	-
Brillia sp	-	-	-	-	-	R	-	-	-
Corynoneura sp	-	-	-	-	R	-	-	-	-
Cricotopus bicinctus	R	-	-	-	-	-	-	-	-
Cricotopus annulator gr	-	-	-	-	R	-	-	-	-
Thienemaniella sp	-	-	-	-	-	R	-	-	-
Rheocricotopus robacki	-	-	-	-	-	-	R	R	-
Xylotopus par	-	C	-	-	R	-	R	R	-
Rheotanytarsus sp	C	R	R	R	-	R	-	R	R
Paratanytarsus sp	R	-	-	-	-	-	-	-	-
Tanytarsus spp	-	-	-	-	R	R	R	R	R
Chironomus sp	-	-	-	-	-	-	-	R	-
Cryptochironomus spp	-	-	R	-	-	-	-	R	-
Dicrotendipes fumidus	-	-	-	-	-	-	-	R	-
Glyptotendipes sp	-	-	-	-	-	C	-	-	-
Microtendipes sp	-	-	-	R	-	R	-	-	R
Paratendipes sp	-	-	R	-	-	-	-	-	-
Polypedilum flavum	A	A	C	A	A	C	A	A	A
Polypedilum illinoense	-	-	-	-	-	C	-	-	-
Polypedilum laetum	-	-	-	R	R	R	-	-	-
Polypedilum fallax gr	-	R	R	-	C	-	-	-	-
Polypedilum halterale gr	-	-	-	-	-	-	-	-	R
Phaenopsectra sp	-	-	R	R	-	R	-	C	-
Robackia demeijeri	-	-	-	R	R	-	R	C	-
Saetheria tylus	-	-	-	-	-	-	R	-	-
Tribelos jucundum	R	R	C	C	-	R	C	C	C
Stenochironomus sp	R	-	R	-	-	-	R	R	-

	2013			2014			2015		
Site:	SA	S1	S2	SA	S1	S2	SA	S1	S2
OLIGOCHAETA									
Ecclipidrilus sp	-	R	R	-	-	R	-	-	-
Lumbriculus variegatus	-	-	-	-	-	-	-	R	-
Enchytraeidae	-	-	R	-	-	-	-	-	-
Cambarinicolidae	-	-	-	-	-	R	-	-	-
Nais spp	-	-	-	-	-	-	-	-	R
Limnodrilus spp	-	-	-	-	-	-	C	R	-
CRUSTACEA									
Cambarus spp	R	R	R	C	-	C	R	R	R
Paleamonetes paludosus	-	-	R	-	-	R	-	-	-
Caecidotea sp	-	-	-	R	R	R	-	-	-
Hyatella azteca	-	-	-	-	R	-	-	-	-
MOLLUSCA									
Physa sp	R	-	-	-	R	-	-	R	R
Corbicula fluminea	C	R	A	R	C	-	-	R	-
Pseudosuccinea collumela	R	-	-	-	-	-	-	-	-
OTHER									
Placobdella papillifera	C	-	-	R	-	-	-	R	-
Helobdella stagnalis	-	-	-	-	-	R	-	-	-
Cura foremanii	-	-	-	-	-	-	R	-	-

	2013			2014			2015		
Site:	SA	S1	S2	SA	S1	S2	SA	S1	S2
Total Taxa Richness	39	30	45	42	37	49	42	51	38
EPT Taxa Richness	12	8	13	15	14	15	12	16	13
EPT Abundance	59	46	90	62	60	61	65	64	69
NC Biotic Index	6.0	5.8	5.5	5.7	5.9	6.0	5.8	6.1	5.7
EPT score	2	1.6	2	2.4	2.4	2.4	2	2.6	2
BI Score	3	3.4	4	4	3	3	3.4	3	4
Site Score	2.5	2.5	3	3.2	2.7	2.7	2.7	2.8	3
Rating	Fair/G-F*		G-F	G-F	G-F	G-F	G-F	G-F	G-F

*Rating rounds down to Fair, based on EPT Abundance critera (<71). Under estimation of EPT taxa richness in 2013, however, suggests that these would more likely be Good-Fair. Compare to the 2014 collections.

Notes

-A downstream site on Smith Creek (SR 1710, Granville Co.) was used as a reference site for a 1994 study of the effects of land use on water quality. This site had a mean EPT taxa richness of about 30, with a mean BI of 5.7, and received a Good rating. More recent DWQ collections at this site had EPT taxa richness of around 20 with either a Good or a Good-Fair rating.

-There is no evidence of enrichment, organic loading, or low dissolved oxygen at any sites.

-All sites support uses, based on Good-Fair rating.

Lenat, D.R. and J. K. Crawford. 1994. Effects of land use on water quality and fauna of three North Carolina streams. Hydrobiologia 294: 185-199

Table 2. Taxa list and relative abundance values, Wake Forest sites, April 17, 2014. R=Rare, C=Common, A=Abundant;

Taxon	WF1 Smith 1	WF2 Austin 1	WF3 Dunn 1	WF4 Dunn 2	WF5 Smith 2	WF6 Smith 3
EPHEMEROPTERA (mayflies)						
Stenonema modestum	A	A	C	A	C	C
Stenacron pallidum	R	-	-	-	-	-
Eurylophella doris	A	R	C	A	-	R
Ephemerella dorothea	A	A	C	C	-	R
Teloganopsis deficiens	-	-	-	-	-	R
Caenis spp	-	-	-	-	R	-
Baetis flavistriga	R	-	C	-	R	R
Acentrella alachua/parvula	C	A	R	A	R	A
Acerpenna macdunnoughi	-	R	-	-	-	-
Diphetor hageni	-	R	-	-	-	-
Baetisca carolina	C	-	R	R	-	-
PLECOPTERA (stoneflies)						
Amphinemura sp	A	C	-	-	-	-
Clioperla clio	-	R	-	-	-	-
Isoperla kircheneri	C	-	-	R	-	R
Isoperla davisi	-	R	-	-	-	R
Diploperla duplicata	C	-	-	-	-	-
Haploperla brevis	C	C	-	C	R	R
Eccoptura xanthenes	A	R	-	C	-	-
Perlesta sp	-	R	C	C	C	A
Perlinella drymo	-	R	-	-	-	-
TRICHOPTERA (caddisflies)						
Cheumatopsyche spp	A	R	C	A	C	C
Hydropsyche betteni	-	-	R	A	-	-
Diplectrona modesta	C	-	-	A	-	-
Chimarra sp	-	R	-	R	-	-
Pycnopsyche sp	A	C	-	-	-	R
Pycnopsyche gentilis	-	R	-	-	-	-
Ironoquia punctatissima	R	C	R	R	C	C
Neophylax oligius	R	-	-	-	-	-
Triaenodes ignitus	-	R	R	-	R	C
Lepidostoma sp	C	-	-	-	R	-
Lype diversa	R	-	-	-	-	-
Polycentropus sp	-	-	-	-	-	R
COLEOPTERA (beetles)						
Ancyronyx variegata	-	-	R	R	R	-
Macronychus glabratus	R	R	-	-	C	C
Helichus sp	C	R	R	C	-	-
Anchytarsus bicolor	R	C	-	-	-	-
Psephenus herricki	-	-	-	R	-	-
ODONATA (damselflies & dragonflies)						
Argia sp	-	-	-	-	R	R
Calopteryx sp	C	R	A	C	C	A
Progomphus obscurus	R	-	C	-	-	-
Gomphus sp	-	C	-	-	R	R
Ophiogomphus sp	-	-	R	R	R	R
Stylogomphus albistylus	R	-	-	-	-	-
Cordulegaster sp	R	-	-	-	-	-
Boyeria vinosa	-	R	C	C	C	C

Taxon	WF1 Smith 1	WF2 Austin 1	WF3 Dunn 1	WF4 Dunn2	WF5 Smith 2	WF6 Smith 3
MEGALOPTERA						
Nigronia serricornis	R	-	-	-	-	-
DIPTERA: MISCELLANEOUS						
Simulium sp	-	-	-	-	-	C
Prosimulium sp	-	-	-	R	-	-
Tipula spp	C	R	R	C	-	R
Dixa sp	C	R	-	R	-	-
Protoplasa fitchii	R	-	-	-	-	-
DIPTERA: CHIRONOMIDAE (midges)						
Conchapelopia group	R	C	R	C	R	R
Nilotanypus sp	R	-	-	-	-	-
Cryptochironomus sp	-	-	R	-	-	-
Paratendipes spp	-	-	-	-	-	R
Phaenopsectra sp	-	-	-	R	-	R
Tribelos sp	-	R	-	-	-	-
Polypedilum aviceps	-	-	-	-	C	-
Polypedilum flavum	-	R	C	C	-	A
Polypedilum halterale gr	-	-	R	-	-	-
Tanytarsus spp	R	-	-	-	-	-
Parametriocnemus lundbecki	-	-	-	-	R	-
Paraphaenocladius sp	-	-	-	-	-	R
Cricotopus bicinctus (C/O sp1*)*	-	-	R	R	-	-
Orthocladius robacki (C/O sp 12)	-	-	-	-	R	-
Synorthocladius sp	R	-	-	-	-	-
Brillia spp	-	-	-	-	-	R
Diamesa sp	-	-	-	R	-	-
OLIGOCHAETA (worms)						
Nais sp	-	R	C	-	-	-
Enchtraeidae	R	-	-	-	-	-
CRUSTACEA						
Cambarus sp	R	R	R	C	R	-
Caecidotea (Asellus) forbesi	-	R	-	R	R	-
Crangonyx sp	R	R	-	R	R	-
MOLLUSCA (snails and clams)						
Corbicula fluminea	-	-	-	-	R	R
Total Taxa Richness	37	34	25	31	25	30
EPT Taxa Richness	19	19	11	14	10	15
NC Biotic Index	4.4	5.0	6.4	5.3	5.8	5.6
Rating (Small Stream Criteria)	Good*	Good	Fair	Good-Fair	Good-Fair	Good-Fair

*Almost Excellent

APPENDIX C.
HABITAT ASSESSMENT FIELD DATA SHEETS

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 69

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R1 Location/road: Spring/White (Road Name White) County Wake

Date 5-21-2013 CC# ______ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKL/BS/M Type of Study: ☐ Fish ☐ Benthos ☒ Basinwide ☐ Special Study (Describe) ______

Latitude ______ Longitude ______ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 80 °F DO ______ mg/l Conductivity (corr.) ______ µS/cm pH ______

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 30 %Forest ______ %Residential ______ %Active Pasture ______ % Active Crops
______ %Fallow Fields 70 % Commercial ______ %Industrial ______ %Other - Describe: ______

Watershed land use : ☐ Forest ☐ Agriculture ☒ Urban ☐ Animal operations upstream

Width: (meters) Stream 2' Channel (at top of bank) 12 **Stream Depth:** (ft) Avg 0.2 Max 1 1/2
☐ Width variable ☐ Large river >25m wide

Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (ft) 4

Bank Angle: 65 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)

☐ Channelized Ditch
☐ Deeply incised-steep, straight banks ☐ Both banks undercut at bend ☐ Channel filled in with sediment
☐ Recent overbank deposits ☐ Bar development ☐ Buried structures ☐ Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐ Green tinge ☐ Sewage smell

Manmade Stabilization: ☐ N ☒ Y: ☒ Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐ Berm/levee

Flow conditions : ☐ High ☐ Normal ☒ Low

Turbidity: ☐ Clear ☒ Slightly Turbid ☐ Turbid ☐ Tannic ☐ Milky ☐ Colored (from dyes)

Good potential for Wetlands Restoration Project?? ☐ YES ☐ NO Details ______

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed........ ☐
C. Water fills 25-75% of available channel, many logs/snags exposed........ ☒
D. Root mats out of water........ ☐
E. Very little water in channel, mostly present as standing pools........ ☐

Weather Conditions: ______ **Photos:** ☐ N ☒ Y ☒ Digital ☐ 35mm

Remarks: Photos 12-21 (Brian's Photos)
15-16 (Olympus)

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks______________________ Subtotal 3

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as **Rare**, Common, or Abundant.

✓ **Rocks** ____ **Macrophytes** ✓ **Sticks and leafpacks** ✓ **Snags and logs** ✓ **Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks______________________ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks______________________ Subtotal 6

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 6

☐ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks______________________

Page Total 31

SB R1

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10 6	3
D. riffles absent..................	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream Subtotal 6

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems..................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding..................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident..................	0	0

Total 14

Remarks____________________

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..................	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal..................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..................	2
E. **No canopy** and no shading..................	0

Remarks____________________ Subtotal 8

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..................	5	5
2. width 12-18 meters..................	4	4
3. width 6-12 meters..................	3	3
4. width < 6 meters..................	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..................	4	4
b. width 12-18 meters..................	3	3
c. width 6-12 meters..................	2	2
d. width < 6 meters..................	1	1
2. breaks common		
a. width > 18 meters..................	3	3
b. width 12-18 meters..................	2	2
c. width 6-12 meters..................	1	1
d. width < 6 meters..................	0	0

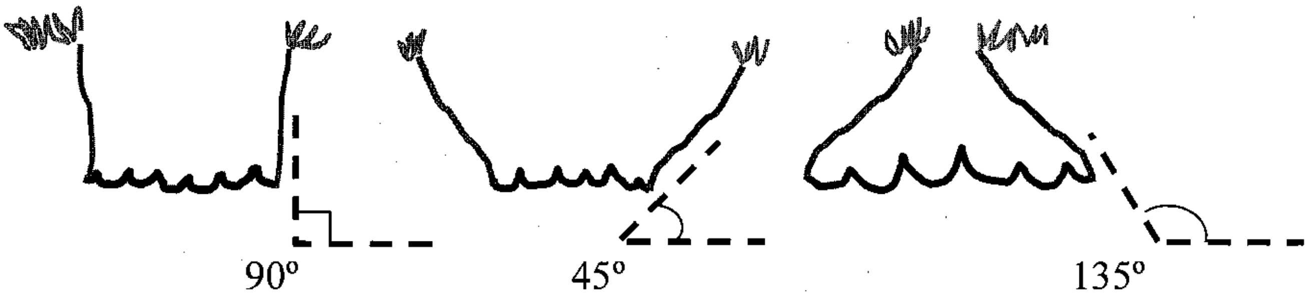
Remarks____________________ Total 10

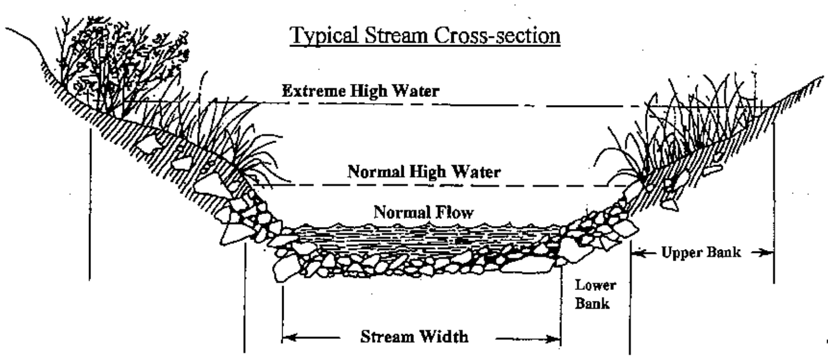
Page Total 38

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE** 69

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ — **TOTAL SCORE** 75

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R2A Location/road: ____________ (Road Name ____________) County Wake

Date 5-21-2013 CC# ____________ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKL/BSH Type of Study: ☐ Fish ☐Benthos ☐ Basinwide ☐Special Study (Describe) ____________

Latitude ____________ Longitude ____________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 80 °F DO ______ mg/l Conductivity (corr.) ______ µS/cm pH _____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 25 %Forest ______ %Residential ______ %Active Pasture ______ % Active Crops
______ %Fallow Fields 75 % Commercial ______ %Industrial ______ %Other - Describe: ____________

Watershed land use : ☐Forest ☐Agriculture ☒Urban ☐ Animal operations upstream

Width: (meters) Stream 12 Channel (at top of bank) 25 **Stream Depth:** (~~m~~ ft) Avg 0.5' Max 2'
☒ Width variable ☐ Large river >25m wide

Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (~~m~~ ft) 7'

Bank Angle: 85 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)

☐ Channelized Ditch
☒Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☒Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell

Manmade Stabilization: ☐N ☒Y: ☒Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee

Flow conditions : ☐High ☒Normal ☐Low

Turbidity: ☐Clear ☒ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)

Good potential for Wetlands Restoration Project?? ☐ **YES** ☐**NO Details** ____________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed.......... ☐
C. Water fills 25-75% of available channel, many logs/snags exposed.......... ☒
D. Root mats out of water.......... ☐
E. Very little water in channel, mostly present as standing pools.......... ☐

Weather Conditions: ____________ **Photos:** ☐N ☒Y ☒ Digital ☐35mm

Remarks: Photos 22-26 (Brian's)

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐ Evidence of desnagging=no large woody debris in stream ☐ Banks of uniform shape/height

Remarks______________________ Subtotal 5

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

X **Rocks** ____ **Macrophytes** C **Sticks and leafpacks** X **Snags and logs** X **Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks______________________ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks______________________ Subtotal 6

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 10

☐ Pool bottom boulder-cobble=hard ☒ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks______________________

Page Total 37

SB R2A

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream

Subtotal 16

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow	2	2
5. little or no bank vegetation, mass erosion and bank failure evident	0	0

Total 10

Remarks

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal	7
D. Stream with **minimal** canopy - full sun in all but a few areas	2
E. **No canopy** and no shading	0

Remarks

Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters	5	5
2. width 12-18 meters	4	4
3. width 6-12 meters	3	3
4. width < 6 meters	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters	4	4
b. width 12-18 meters	3	3
c. width 6-12 meters	2	2
d. width < 6 meters	1	1
2. breaks common		
a. width > 18 meters	3	3
b. width 12-18 meters	2	2
c. width 6-12 meters	1	1
d. width < 6 meters	0	0

Remarks

Total 2

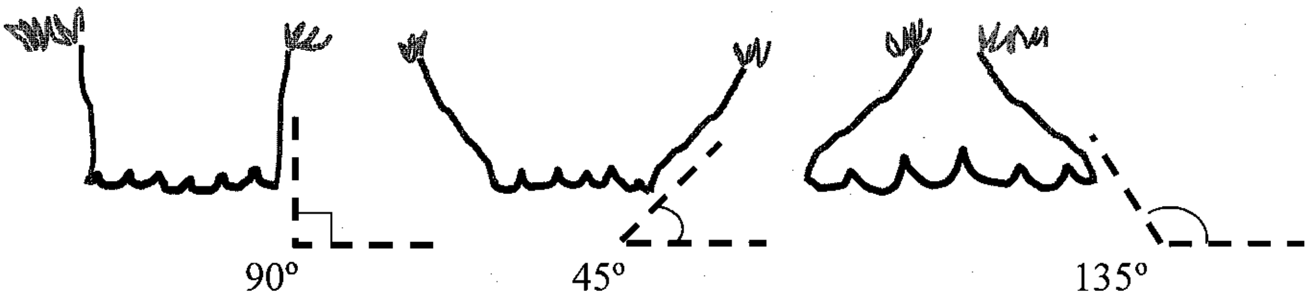
Page Total 38

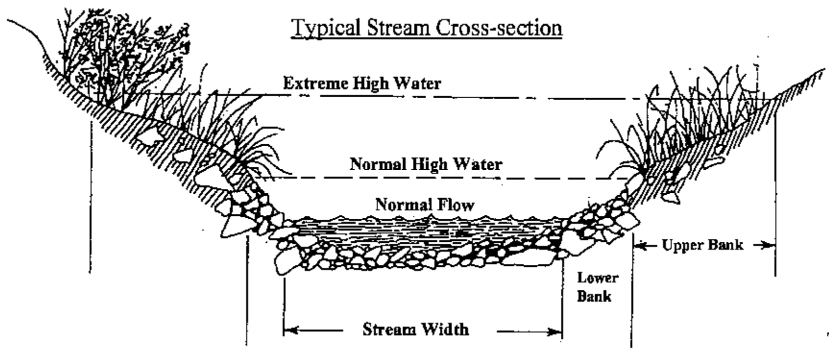
☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream.

TOTAL SCORE 75

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

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3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ | **TOTAL SCORE** 75

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch 2b Location/road: Miller Park (Road Name ________)County wake

Date 5-21-2013 CC# ________ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKL/BSH Type of Study: ☐ Fish ☐Benthos ☒Basinwide ☐Special Study (Describe) ________

Latitude ________ Longitude ________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 75 °F DO ____mg/l Conductivity (corr.) ____µS/cm pH ____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 70 %Forest Park 10 %Residential ____%Active Pasture ____% Active Crops
____%Fallow Fields 20 % Commercial ____%Industrial ____%Other - Describe: ________

Watershed land use : ☐Forest ☐Agriculture ☒Urban ☐ Animal operations upstream

Width: (meters) Stream 6-8 Channel (at top of bank) 20 **Stream Depth**: (ft) Avg 0.5' Max 1½'
☒Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (ft) 5

Bank Angle: LB 45 RB 90 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☒Bar development ☐Buried structures ☒Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☒Normal ☐Low
Turbidity: ☐Clear ☒ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☒NO Details ________

Channel Flow Status
Useful especially under abnormal or low flow conditions.
A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed........ ☒
C. Water fills 25-75% of available channel, many logs/snags exposed........ ☐
D. Root mats out of water........ ☐
E. Very little water in channel, mostly present as standing pools........ ☐

Weather Conditions: ________ **Photos:** ☐N ☒Y ☒ Digital ☐35mm

Remarks: Photos 1-5 (Olympus Camera)

I. Channel Modification — Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks__________ Subtotal 4

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

✓ Rocks ____Macrophytes ✓ Sticks and leafpacks ____Snags and logs ____Undercut banks or root mats

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks__________ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks__________ Subtotal 8

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 10

☐ Pool bottom boulder-cobble=hard ☒ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks__________

Page Total 38

SB K2B

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score		Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	15	12
B. riffle as wide as stream but riffle length is not 2X stream width	14		7
C. riffle not as wide as stream and riffle length is not 2X stream width	10		3
D. riffles absent..........	0		

Channel Slope: ☒Typical for area ☐Steep=fast flow ☐Low=like a coastal stream Subtotal 15

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems..........	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..........	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding..........	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident..........	0	0

Total 10

Remarks ______

VII. Light Penetration

Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..........	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal..........	7
D. Stream with **minimal** canopy - full sun in all but a few areas..........	2
E. **No canopy** and no shading..........	0

Remarks ______ Subtotal 7

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..........	5	5
2. width 12-18 meters..........	4	4
3. width 6-12 meters..........	3	3
4. width < 6 meters..........	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..........	4	4
b. width 12-18 meters..........	3	3
c. width 6-12 meters..........	2	2
d. width < 6 meters..........	1	1
2. breaks common		
a. width > 18 meters..........	3	3
b. width 12-18 meters..........	2	2
c. width 6-12 meters..........	1	1
d. width < 6 meters..........	0	0

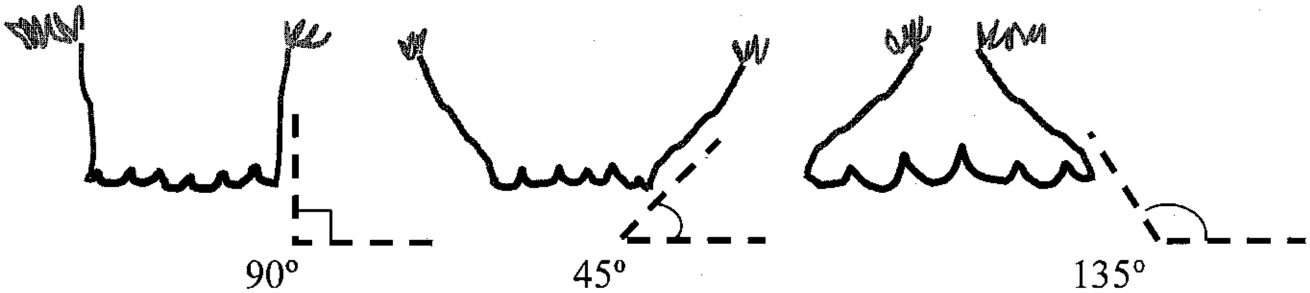
Remarks ______ Total 5

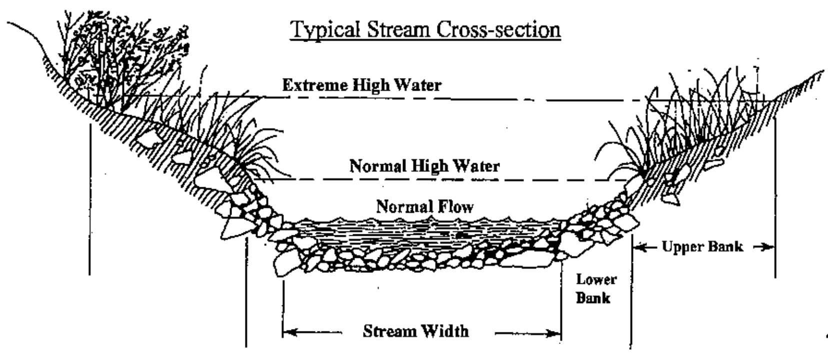
Page Total 37

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE** 75

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

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3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 55

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R3 Location/road: Pierce/Pine (Road Name ______)County Wake

Date 5-21-2013 CC# ______ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKL/BSH Type of Study: ☐ Fish ☐ Benthos ☒ Basinwide ☐ Special Study (Describe) ______

Latitude ______ Longitude ______ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 75 °~~C~~ DO ______ mg/l Conductivity (corr.) ______ µS/cm pH ______

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 50 %Forest 50 %Residential ______ %Active Pasture ______ % Active Crops
______ %Fallow Fields ______ % Commercial ______ %Industrial ______ %Other - Describe: ______

Watershed land use : ☐ Forest ☐ Agriculture ☒ Urban ☐ Animal operations upstream

Width: (meters) Stream 1-1 1/2 Channel (at top of bank) 12 **Stream Depth:** (~~m~~ ft) Avg 0.5' Max 1
☐ Width variable ☐ Large river >25m wide

Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (~~m~~ ft) 5

Bank Angle: 80 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)

☒ Channelized Ditch
☐ Deeply incised-steep, straight banks ☐ Both banks undercut at bend ☐ Channel filled in with sediment
☐ Recent overbank deposits ☐ Bar development ☐ Buried structures ☐ Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐ Green tinge ☐ Sewage smell

Manmade Stabilization: ☐ N ☒ Y: ☒ Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐ Berm/levee

Flow conditions : ☐ High ☒ Normal ☒ Low

Turbidity: ☐ Clear ☐ Slightly Turbid ☐ Turbid ☐ Tannic ☐ Milky ☐ Colored (from dyes)

Good potential for Wetlands Restoration Project?? ☐ **YES** ☒ **NO Details** ______

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed	☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed	☐
C. Water fills 25-75% of available channel, many logs/snags exposed	☐
D. Root mats out of water	☐
E. Very little water in channel, mostly present as standing pools	☒

Weather Conditions: ______ **Photos:** ☐ N ☒ Y ☒ Digital ☐ 35mm

Remarks: Photos 8-10 (olympus) 5-11 (Brian's Photos)

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐ Evidence of desnagging=no large woody debris in stream ☒ Banks of uniform shape/height

Remarks____ Subtotal 2

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

___**Rocks** ___**Macrophytes** ✓**Sticks and leafpacks** ✓**Snags and logs** ___**Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks____ Subtotal 10

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks____ Subtotal 4

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 4

☐ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☒ Silt bottom ☐ Some pools over wader depth

Remarks____

Page Total 20

SB KS

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10 7	3
D. riffles absent...	0	

Channel Slope: ☒Typical for area ☐Steep=fast flow ☐Low=like a coastal stream

Subtotal 7

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy...........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding.................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident...	0	0

Total 14

Remarks____

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal..................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..	2
E. **No canopy** and no shading...	0

Remarks____ Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☒ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters..	3	3
c. width 6-12 meters..	2	2
d. width < 6 meters..	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters..	1	1
d. width < 6 meters..	0	0

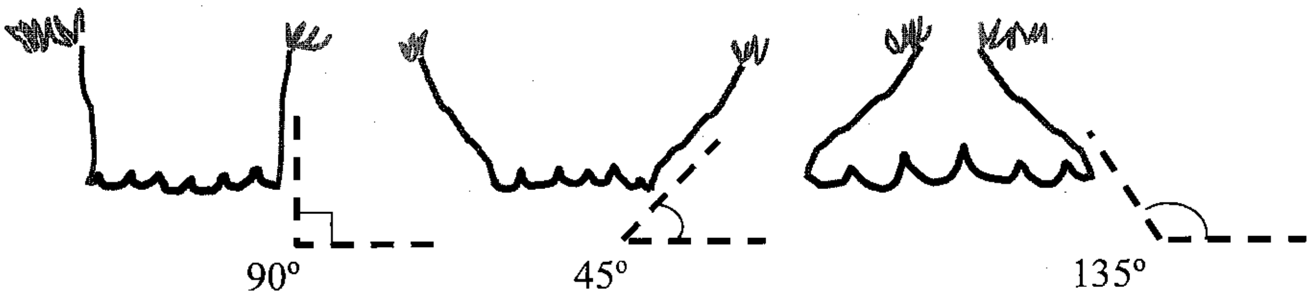
Remarks____ Total 4

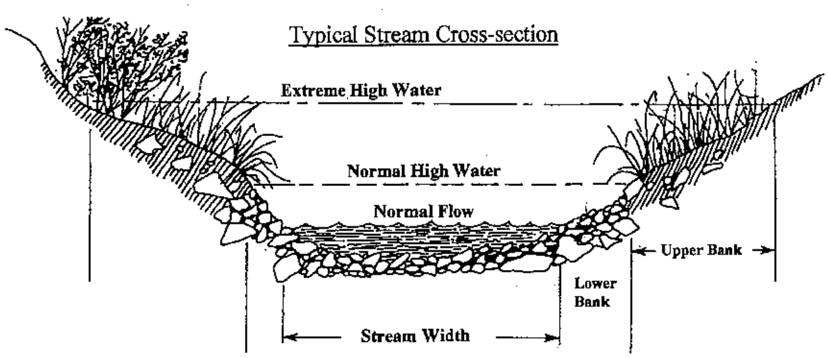
Page Total 35

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE** 55

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

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3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 85

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R 4a Downstream Segment Location/road: Below Deacon Ridge (Road Name __________)County Wake

Date 5-21-2013 CC# __________ Basin Smith Creek Subbasin Spring Branch

Observer(s)________ Type of Study: ☐ Fish ☐Benthos ☒ Basinwide ☐Special Study (Describe) __________

Latitude __________ Longitude __________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 85 °F DO ______ mg/l Conductivity (corr.) ______ µS/cm pH _____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 60 %Forest 40 %Residential _____ %Active Pasture _____ % Active Crops
_____ %Fallow Fields _____ % Commercial _____ %Industrial _____ %Other - Describe: __________

Watershed land use : ☐Forest ☐Agriculture ☒Urban ☐ Animal operations upstream

Width: (meters) Stream 12 Channel (at top of bank) 20 **Stream Depth:** (ft) Avg 0.5 Max 2
☐ Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (ft) 4

Bank Angle: 70 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☐Deeply incised-steep, straight banks ☒Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☒Bar development ☐Buried structures ☒Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☒Y: ☒Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☒Normal ☐Low
Turbidity: ☐Clear ☒ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☐NO Details __________

Channel Flow Status
Useful especially under abnormal or low flow conditions.
A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed........ ☐
C. Water fills 25-75% of available channel, many logs/snags exposed........ ☒
D. Root mats out of water........ ☐
E. Very little water in channel, mostly present as standing pools........ ☐

Weather Conditions: __________ **Photos:** ☐N ☒Y ☒ Digital ☐35mm

Remarks: Photos (29-37 Brian's)
18-22 (Olympus)

I. Channel Modification Score

A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks________________ Subtotal 5

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

X **Rocks** ___ **Macrophytes** X **Sticks and leafpacks** X **Snags and logs** X **Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks________________ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks________________ Subtotal 12

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 10

☒ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks________________

Page Total 43

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V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent....	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream

Subtotal 16

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy....	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding....	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident....	0	0

Total 11

Remarks

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent....	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal....	7
D. Stream with **minimal** canopy - full sun in all but a few areas....	2
E. **No canopy** and no shading....	0

Remarks

Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters....	5	5
2. width 12-18 meters....	4	4
3. width 6-12 meters....	3	3
4. width < 6 meters....	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters....	4	4
b. width 12-18 meters....	3	3
c. width 6-12 meters....	2	2
d. width < 6 meters....	1	1
2. breaks common		
a. width > 18 meters....	3	3
b. width 12-18 meters....	2	2
c. width 6-12 meters....	1	1
d. width < 6 meters....	0	0

Remarks

Total 5

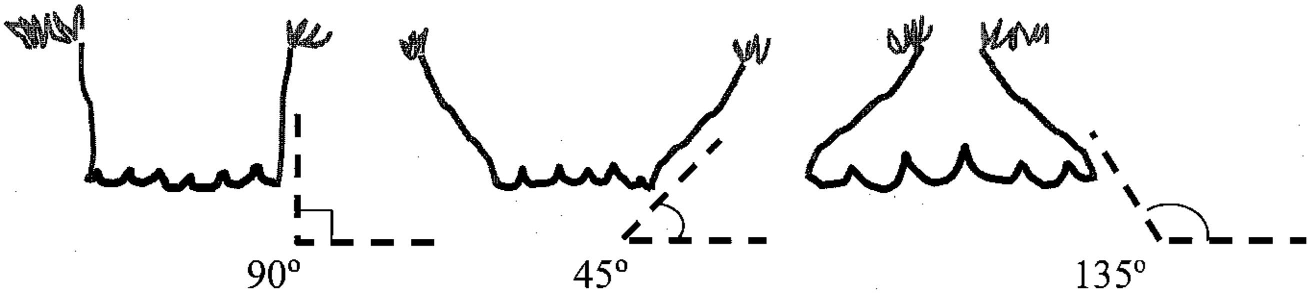
Page Total 42

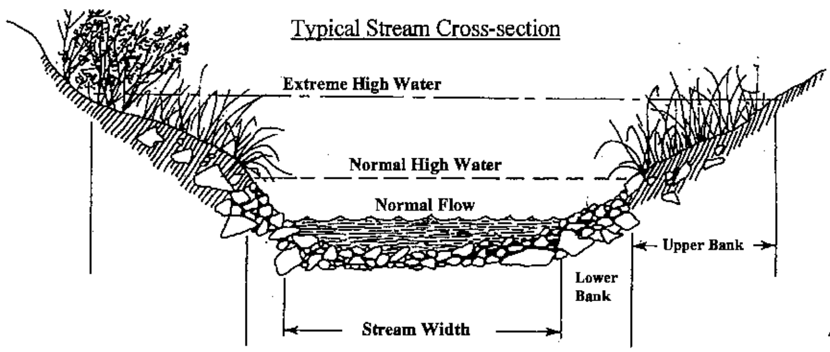
☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream.

TOTAL SCORE 85

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 66

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R 4b Location/road: Above Beacon Ridge (Road Name Cala Lilly Rd)County Wake

Date 5-21-2013 CC#___ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKL/BSH Type of Study: ☐ Fish ☐Benthos ☒ Basinwide ☐Special Study (Describe) ___

Latitude ___ Longitude ___ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 85 °F DO ___ mg/l Conductivity (corr.) ___ µS/cm pH ___

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 60 %Forest 40 %Residential ___ %Active Pasture ___ % Active Crops
___ %Fallow Fields ___ % Commercial ___ %Industrial ___ %Other - Describe: ___

Watershed land use : ☐Forest ☐Agriculture ☒Urban ☐ Animal operations upstream

Width: (meters) Stream 12 Channel (at top of bank) 16 **Stream Depth:** (~~m~~ ft) Avg 0.5 Max 1 1/2
☐ Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (~~m~~ ft) 4'

Bank Angle: 45 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☒ Recent overbank deposits ☒Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☒Normal ☐Low
Turbidity: ☐Clear ☒ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☐NO Details ___

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed........ ☐
C. Water fills 25-75% of available channel, many logs/snags exposed........ ☒
D. Root mats out of water........ ☐
E. Very little water in channel, mostly present as standing pools........ ☐

Weather Conditions: ___ **Photos:** ☐N ☒Y ☒ Digital ☐35mm

Remarks: Photos

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks________________ Subtotal 5

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

X **Rocks** ____**Macrophytes** X **Sticks and leafpacks** ____**Snags and logs** ____**Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks________________ Subtotal 10

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks________________ Subtotal 3

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 4

☐ Pool bottom boulder-cobble=hard ☒ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks________________

Page Total 22

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent..	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream

Subtotal 14

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy...........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding.................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident..	0	0

Total 14

Remarks____

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal.................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..	2
E. **No canopy** and no shading..	0

Remarks____ Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☒ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters..	3	3
c. width 6-12 meters..	2	2
d. width < 6 meters..	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters..	1	1
d. width < 6 meters..	0	0

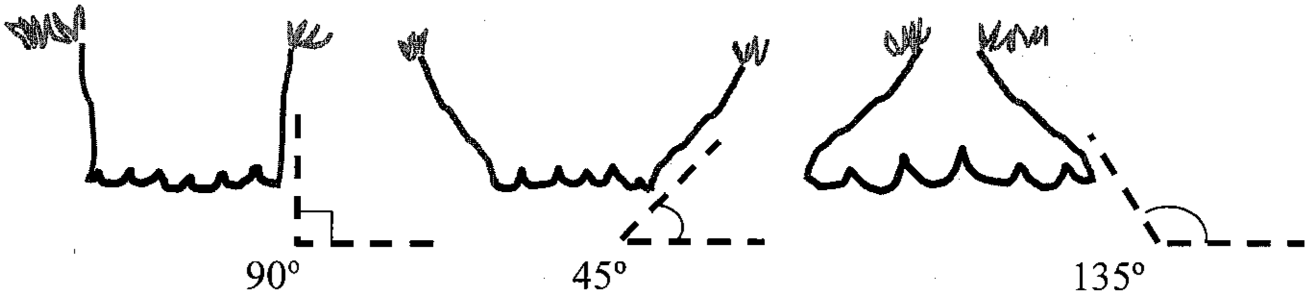
Remarks____ Total 6

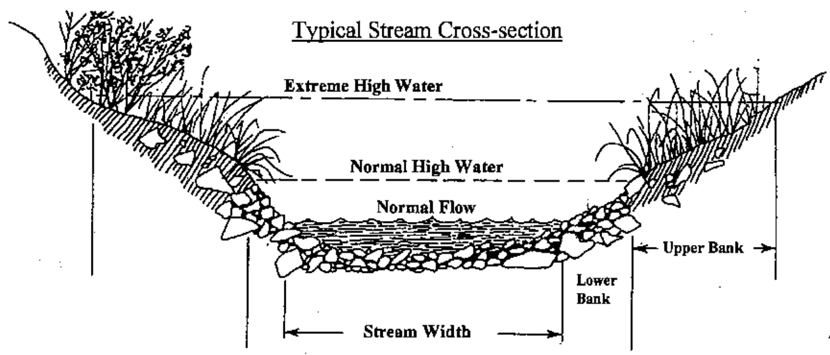
Page Total 44

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE** 66

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:______________________________________
____
____
____
____

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 88

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R4C Location/road: Above Cole Mill lane (Road Name ________)County Wake

Date 5-21-2013 CC# ________ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKL/BSH Type of Study: ☐ Fish ☐Benthos ☒ Basinwide ☐Special Study (Describe) ________

Latitude ________ Longitude ________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 85 °F DO ______ mg/l Conductivity (corr.) ______ µS/cm pH ______

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 60 %Forest 40 %Residential ____ %Active Pasture ____ % Active Crops
____ %Fallow Fields ____ % Commercial ____ %Industrial ____ %Other - Describe: ________

Watershed land use : ☐Forest ☐Agriculture ☒Urban ☐ Animal operations upstream

Width: (meters) Stream 4' Channel (at top of bank) 12' **Stream Depth:** (~~m~~ ft) Avg 0.2' Max 2'
☐ Width variable ☐ Large river >25m wide

Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (~~m~~ ft) 5

Bank Angle: 60 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)

☒ Channelized Ditch
☐Deeply incised-steep, straight banks ☒Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☒Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☒Normal ☐Low
Turbidity: ☐Clear ☒ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☐NO **Details** ________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed........ ☐
C. Water fills 25-75% of available channel, many logs/snags exposed........ ☒
D. Root mats out of water........ ☐
E. Very little water in channel, mostly present as standing pools........ ☐

Weather Conditions: ________ **Photos:** ☐N ☒Y ☒ Digital ☐35mm

Remarks: Photos 44 - 48 (Brian's)

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks ______ Subtotal 4

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

✓ **Rocks** ✓ **Macrophytes** ✓ **Sticks and leafpacks** ✓ **Snags and logs** ✓ **Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks ______ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks ______ Subtotal 11

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 10

☐ Pool bottom boulder-cobble=hard ☒ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks ______

Page Total 41

SB R4C

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent..	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream Subtotal 16

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion.	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident..	0	0

Total 14

Remarks____

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal.................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..	2
E. **No canopy** and no shading..	0

Remarks____ Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters..	3	3
c. width 6-12 meters..	2	2
d. width < 6 meters..	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters..	1	1
d. width < 6 meters..	0	0

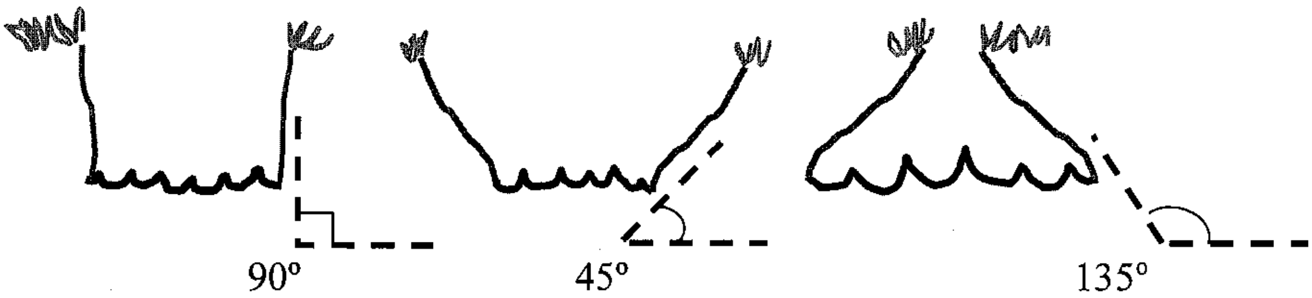
Remarks____ Total 7

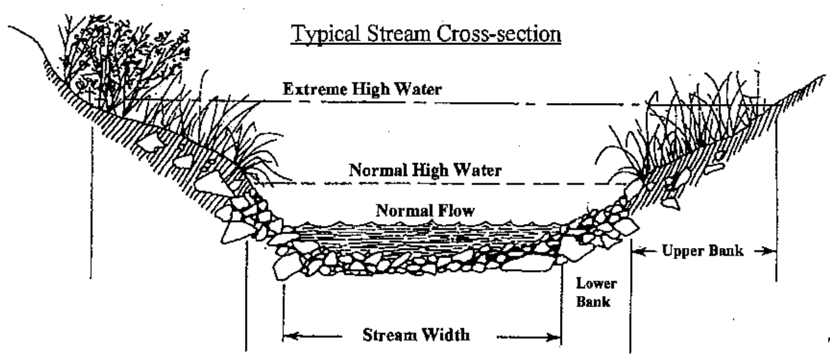
Page Total 47

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE** 88

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 61

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R5 Location/road: west of Franklin (Road Name Hollins Road)County Wake

Date ________ CC# ________ Basin Smith Creek Subbasin Spring Branch

Observer(s) GKG/BSH Type of Study: ☐ Fish ☐Benthos ☒ Basinwide ☐Special Study (Describe) ________

Latitude ________ Longitude ________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 85° °F DO ____ mg/l Conductivity (corr.) ____ µS/cm pH ____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 40 %Forest 30 %Residential ____ %Active Pasture ____ % Active Crops
____ %Fallow Fields 30 % Commercial ____ %Industrial ____ %Other - Describe: ________

Watershed land use : ☐Forest ☐Agriculture ☒Urban ☐ Animal operations upstream

Width: (meters) Stream 3' Channel (at top of bank) 6' **Stream Depth**: (~~m~~ ft) Avg 0.25' Max 0.8'
☒ Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (~~m~~ ft) 3'

Bank Angle: 40 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☒ Recent overbank deposits ☒Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☒Y: ☒Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☐Normal ☐Low
Turbidity: ☐Clear ☒ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☒NO Details ________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed.......... ☒
C. Water fills 25-75% of available channel, many logs/snags exposed.......... ☐
D. Root mats out of water.......... ☐
E. Very little water in channel, mostly present as standing pools.......... ☐

Weather Conditions: ________ **Photos:** ☐N ☒Y ☒ Digital ☐35mm

Remarks: Photos 51-55 (Brian's)

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks______ Subtotal 5

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

✓ **Rocks** ____**Macrophytes** ✓ **Sticks and leafpacks** ____**Snags and logs** ____**Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks______ Subtotal 10

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks______ Subtotal 3

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 10

☐ Pool bottom boulder-cobble=hard ☒ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks______

Page Total 28

SB R5

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent....................	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream

Subtotal 14

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy....................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding....................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident....................	0	0

Total 10

Remarks

VII. Light Penetration

Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent....................	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal....................	7
D. Stream with **minimal** canopy - full sun in all but a few areas....................	2
E. **No canopy** and no shading....................	0

Remarks

Subtotal 7

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters....................	5	5
2. width 12-18 meters....................	4	4
3. width 6-12 meters....................	3	3
4. width < 6 meters....................	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters....................	4	4
b. width 12-18 meters....................	3	3
c. width 6-12 meters....................	2	2
d. width < 6 meters....................	1	1
2. breaks common		
a. width > 18 meters....................	3	3
b. width 12-18 meters....................	2	2
c. width 6-12 meters....................	1	1
d. width < 6 meters....................	0	0

Remarks

Total 2

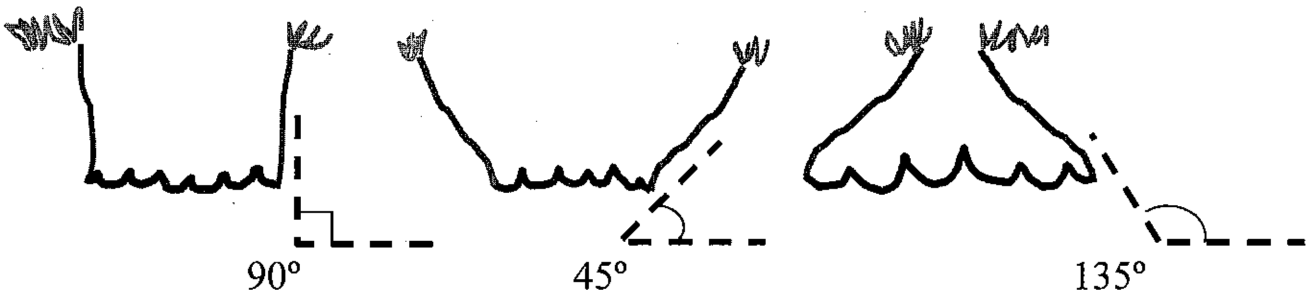
Page Total 33

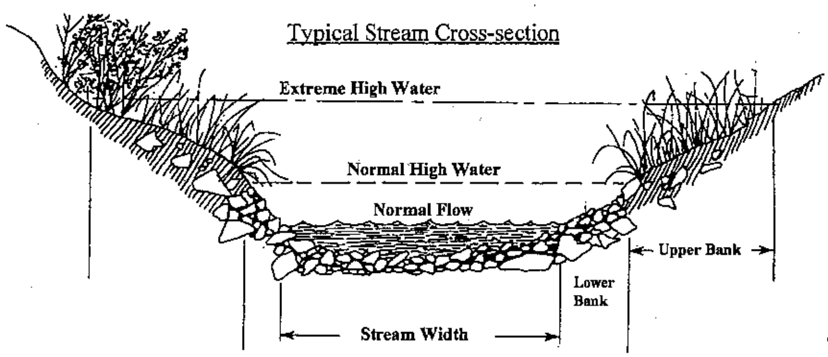
☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream.

TOTAL SCORE 61

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 89

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R6 Location/road: ________ (Road Name ________)County Wake

Date ________ CC# ________ Basin Smith Creek Subbasin Spring Branch

Observer(s) BSH Type of Study: ☐ Fish ☐Benthos ☒ Basinwide ☐Special Study (Describe) ________

Latitude ________ Longitude ________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 75 °F DO ____ mg/l Conductivity (corr.) ____ µS/cm pH ____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 75 %Forest ____ %Residential 25 %Active Pasture ____ % Active Crops
____ %Fallow Fields ____ % Commercial ____ %Industrial ____ %Other - Describe: ________

Watershed land use : ☒Forest ☒Agriculture ☐Urban ☐ Animal operations upstream

Width: (meters) Stream 4 Channel (at top of bank) 12 **Stream Depth**: (ft) Avg 0.3 Max 1
☐ Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (ft) 4

Bank Angle: 60 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☒Deeply incised-steep, straight banks ☒Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☒Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☒Normal ☐Low
Turbidity: ☒Clear ☐ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ **YES** ☒**NO Details** ________

Channel Flow Status
Useful especially under abnormal or low flow conditions.
A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed.......... ☒
C. Water fills 25-75% of available channel, many logs/snags exposed.......... ☐
D. Root mats out of water.......... ☐
E. Very little water in channel, mostly present as standing pools.......... ☐

Weather Conditions: ________ **Photos:** ☐N ☒Y ☐ Digital ☐35mm

Remarks: Photos 2-10 (Brian's)
* Preservation Potential

I. Channel Modification

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks________________________________ Subtotal 5

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

C **Rocks** ____**Macrophytes** ✓ **Sticks and leafpacks** C **Snags and logs** C **Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks________________________________ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks________________________________ Subtotal 12

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 8

☒ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks________________________________

Page Total 41

5B Rb

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent...	0	

Channel Slope: ☐Typical for area ☒Steep=fast flow ☐Low=like a coastal stream Subtotal 16

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding.................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident..	0	0

Total 12

Remarks

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal...................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas...	2
E. **No canopy** and no shading..	0

Remarks Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☒Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters..	3	3
c. width 6-12 meters..	2	2
d. width < 6 meters..	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters..	1	1
d. width < 6 meters..	0	0

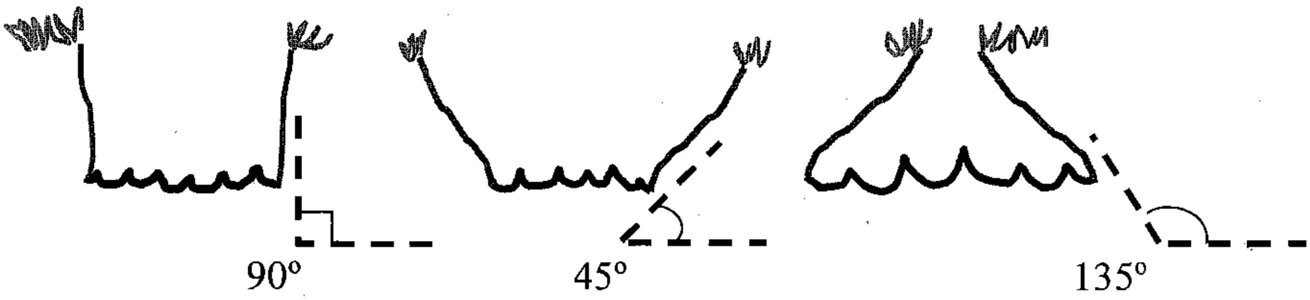
Remarks Total 10

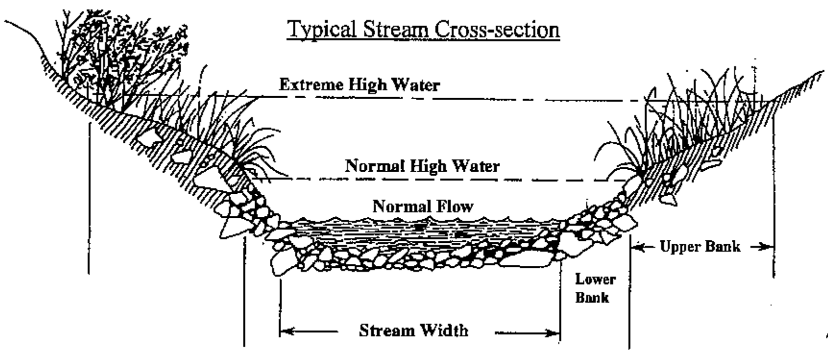
Page Total 48

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE** 89

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____
____
____
____
____

3/06 Revision 6

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE** 90

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream Spring Branch R7 Location/road: ____________ (Road Name ____________)County Wake

Date 5-23-2013 CC# ____________ Basin Smith Creek Subbasin Spring Branch

Observer(s) BSH Type of Study: ☐ Fish ☐Benthos ☒Basinwide ☐Special Study (Describe) ____________

Latitude ____________ Longitude ____________ Ecoregion: ☐ MT ☒ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature 77 °F DO ______ mg/l Conductivity (corr.) ______ µS/cm pH ______

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: 90 %Forest 10 %Residential ______ %Active Pasture ______ % Active Crops
______ %Fallow Fields ______ % Commercial ______ %Industrial ______ %Other - Describe: ____________

Watershed land use : ☒Forest ☐Agriculture ☐Urban ☐ Animal operations upstream

Width: (meters) Stream 6' Channel (at top of bank) 15' **Stream Depth:** (~~m~~ ft) Avg 0.3' Max 2'
☒ Width variable ☐ Large river >25m wide

Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (~~m~~ ft) 6'

Bank Angle: 70 ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)

☐ Channelized Ditch
☒Deeply incised-steep, straight banks ☒Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☒Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☒Normal ☐Low
Turbidity: ☒Clear ☐ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ **YES** ☒**NO Details** ____________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed.................... ☒
C. Water fills 25-75% of available channel, many logs/snags exposed.................... ☐
D. Root mats out of water.................... ☐
E. Very little water in channel, mostly present as standing pools.................... ☐

Weather Conditions: ____________ **Photos:** ☐N ☒Y ☒Digital ☐35mm

Remarks: 11-15 (Brian)

I. Channel Modification Score

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks________________ Subtotal 5

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as Rare, Common, or Abundant.

✓ **Rocks** ✓ **Macrophytes** ✓ **Sticks and leafpacks** ✓ **Snags and logs** ___ **Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks________________ Subtotal 16

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks________________ Subtotal 12

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal 10

☒ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks________________

Page Total 43

SB R7

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent	0	

Channel Slope: ☒Typical for area ☐Steep=fast flow ☐Low=like a coastal stream

Subtotal 16

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow	2	2
5. little or no bank vegetation, mass erosion and bank failure evident	0	0

Remarks________________________ Total 12

VII. Light Penetration

Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent	8
C. Stream with **partial** canopy - sunlight and shading are equally equal	7
D. Stream with **minimal** canopy - full sun in all but a few areas	2
E. **No canopy** and no shading	0

Remarks________________________ Subtotal 10

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☒ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters	5	5
2. width 12-18 meters	4	4
3. width 6-12 meters	3	3
4. width < 6 meters	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters	4	4
b. width 12-18 meters	3	3
c. width 6-12 meters	2	2
d. width < 6 meters	1	1
2. breaks common		
a. width > 18 meters	3	3
b. width 12-18 meters	2	2
c. width 6-12 meters	1	1
d. width < 6 meters	0	0

Remarks________________________ Total 9

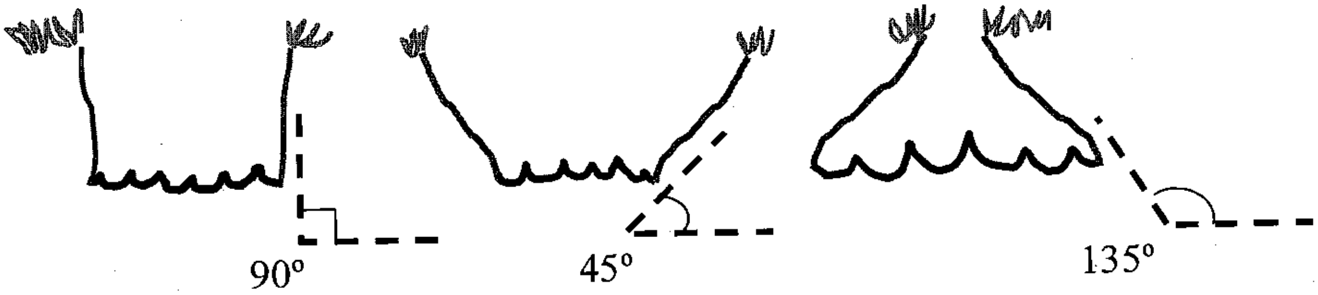
☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream.

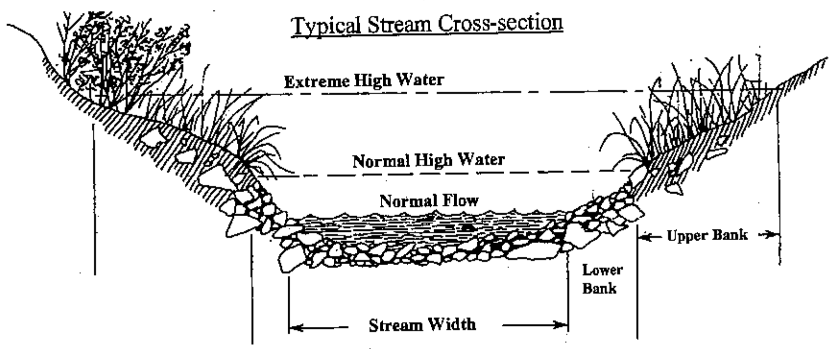
Page Total 47

TOTAL SCORE 90

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:

APPENDIX D.
BMP PHOTOS AND NOTES

	
BMP 0	
	
BMP 1	

BMP 2

BMP 3

BMP 4

BMP 5

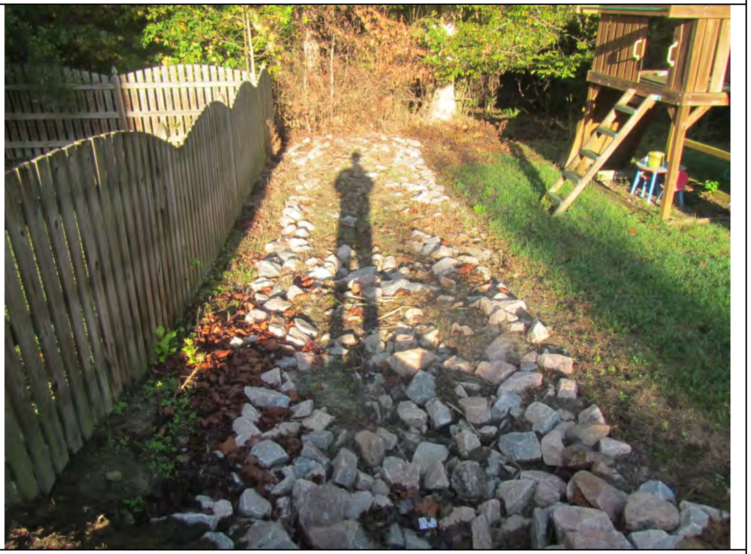

BMP 6


BMP 7


BMP 8


BMP 9


BMP 10

BMP 11

BMP 12

BMP 13

BMP 14

BMP 15


BMP 16


BMP 17


BMP 18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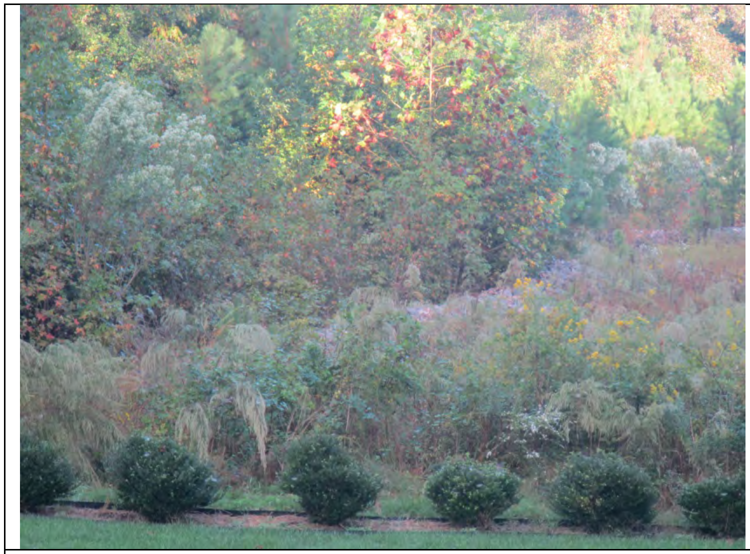
BMP 82

BMP 83



BMP 84

BMP 86


BMP 87

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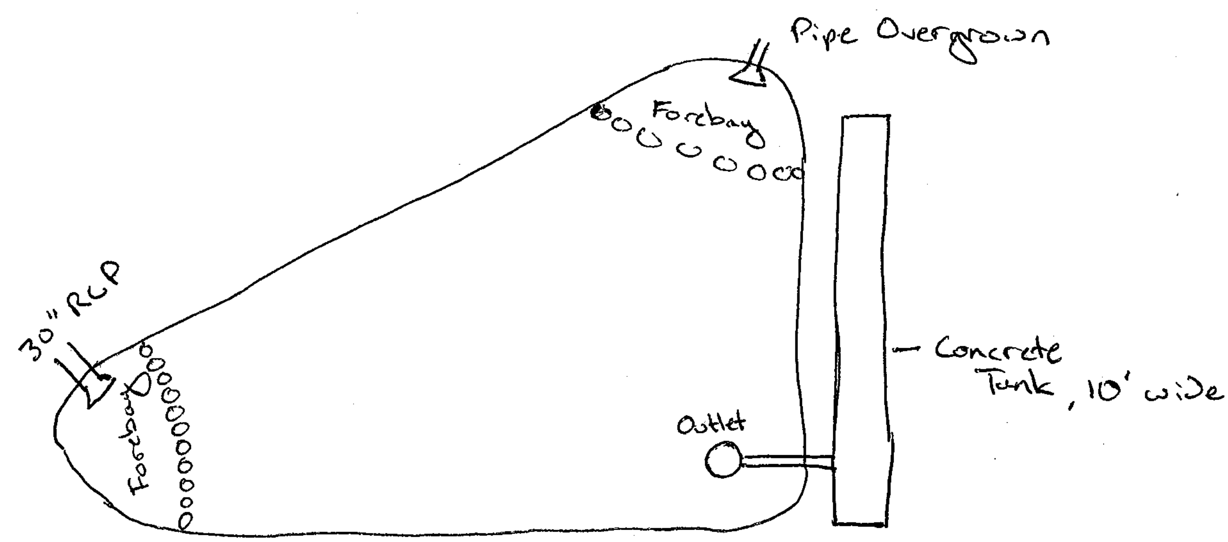
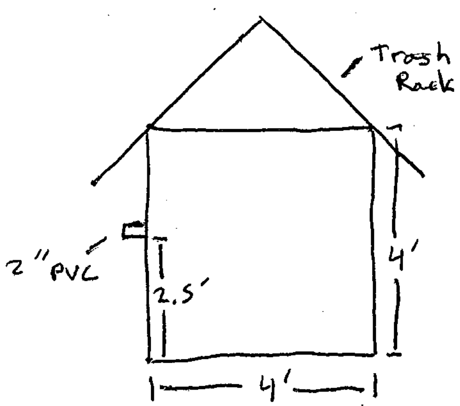
BMP #2 - Wet Detention



Outlet Detail



Note: Upstream parking lot is unpaved. Possible sediment source.

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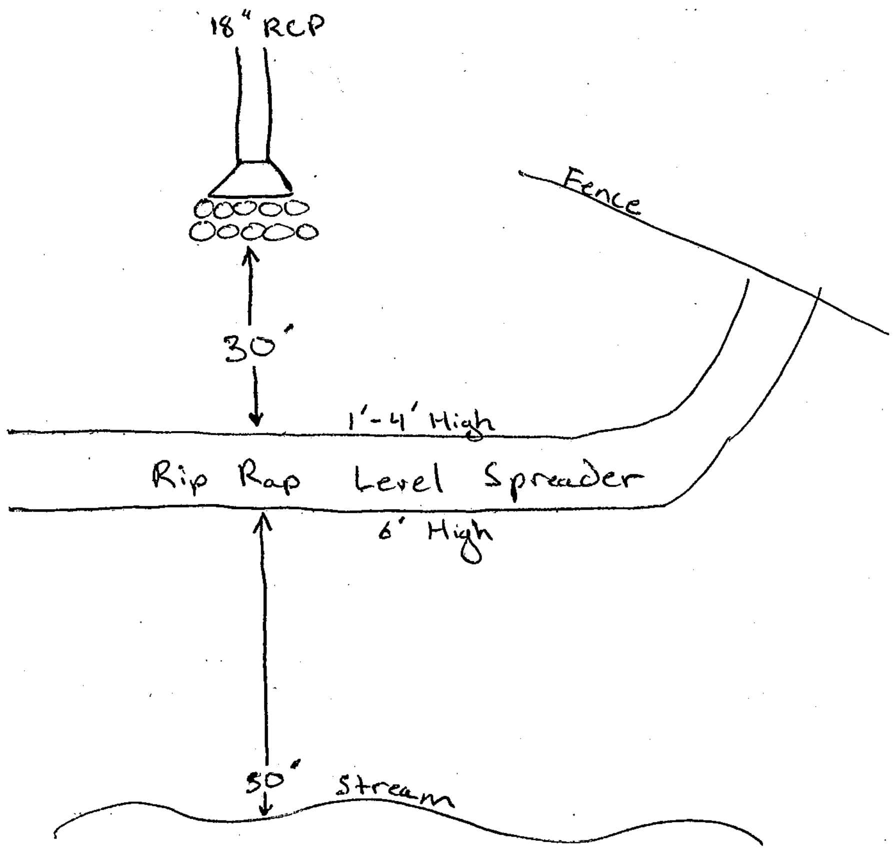
BMP #7 - Level Spreader



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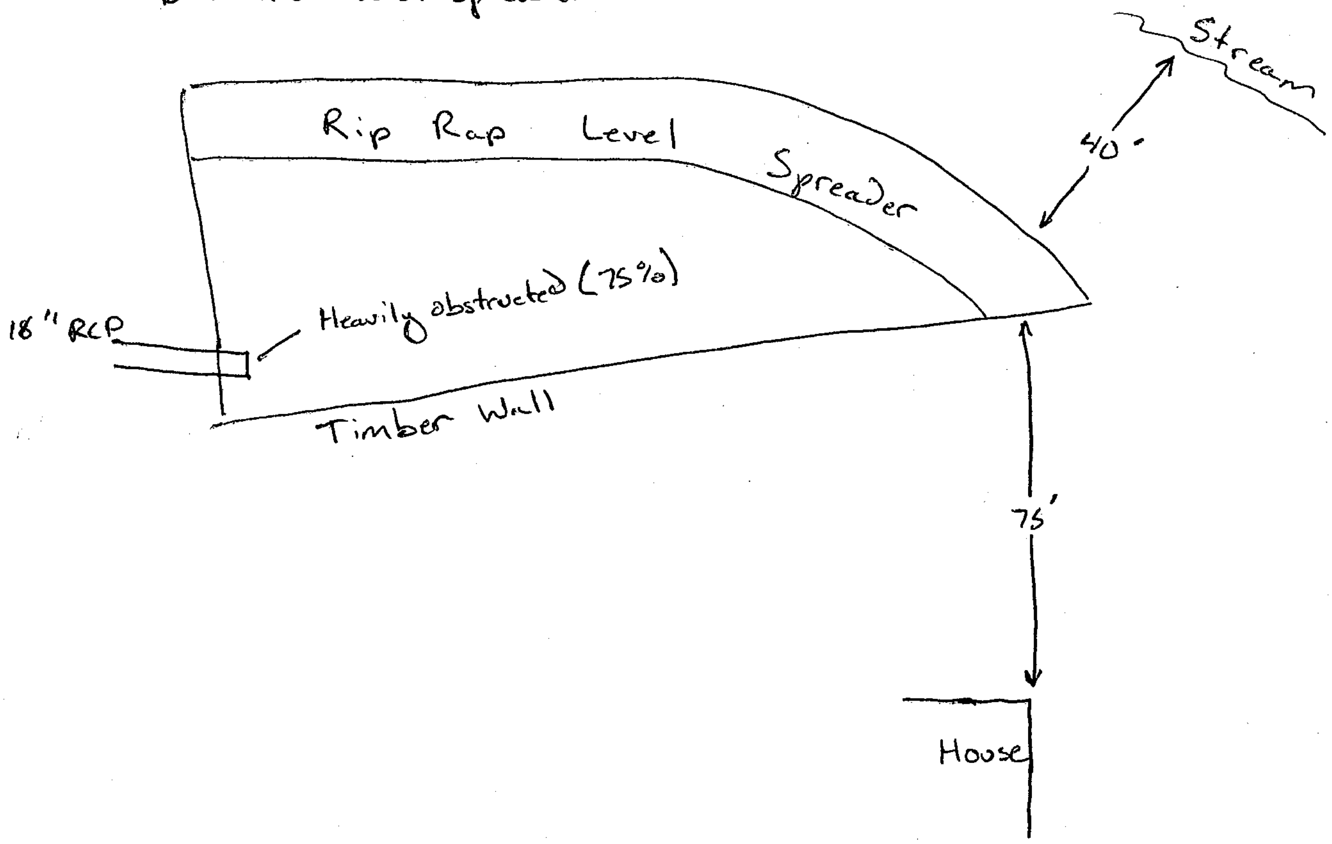
BMP #8 - Level Spreader



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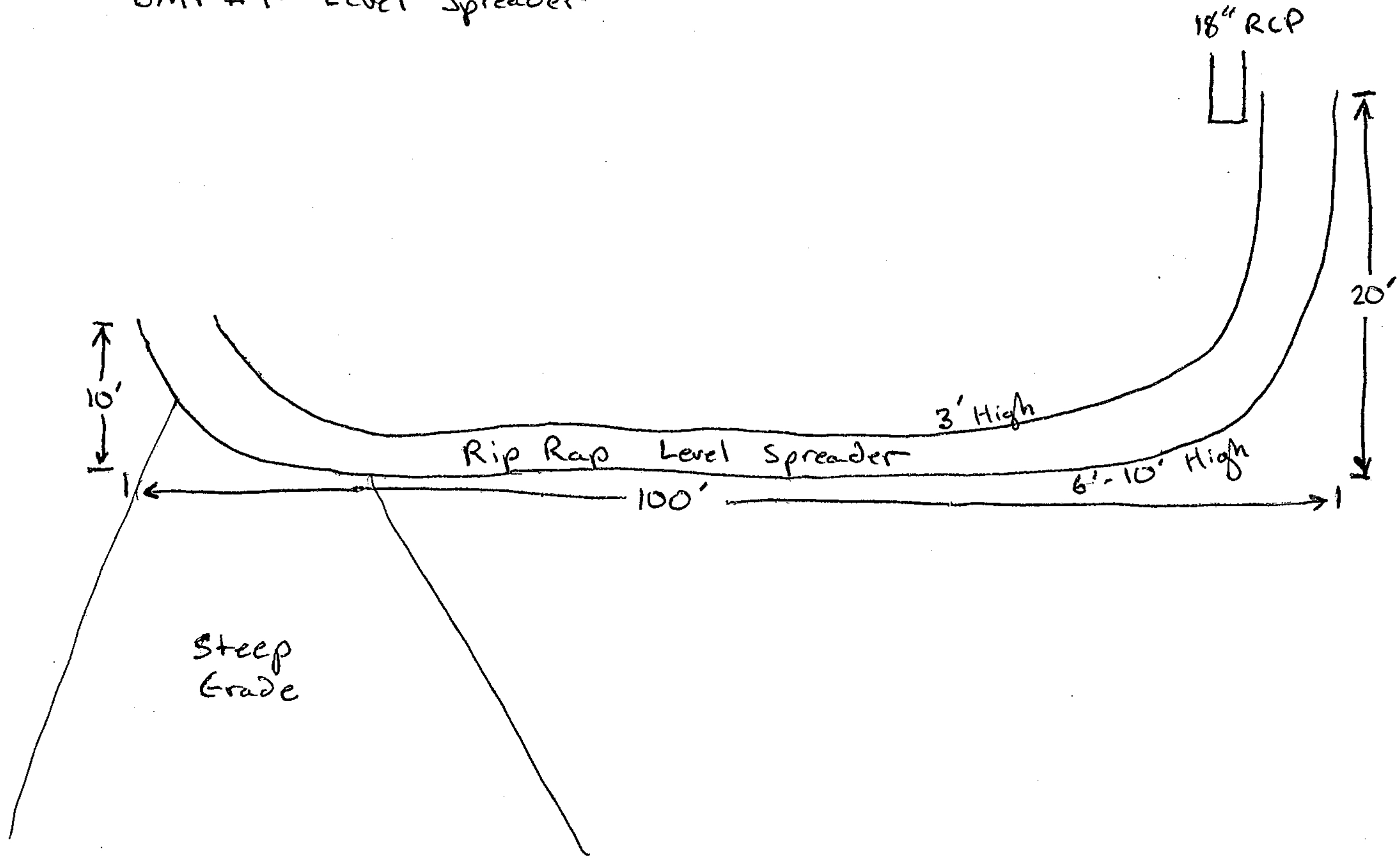
CLIENT ______ CHECKED BY ______ DATE ______

BMP #9 - Level Spreader



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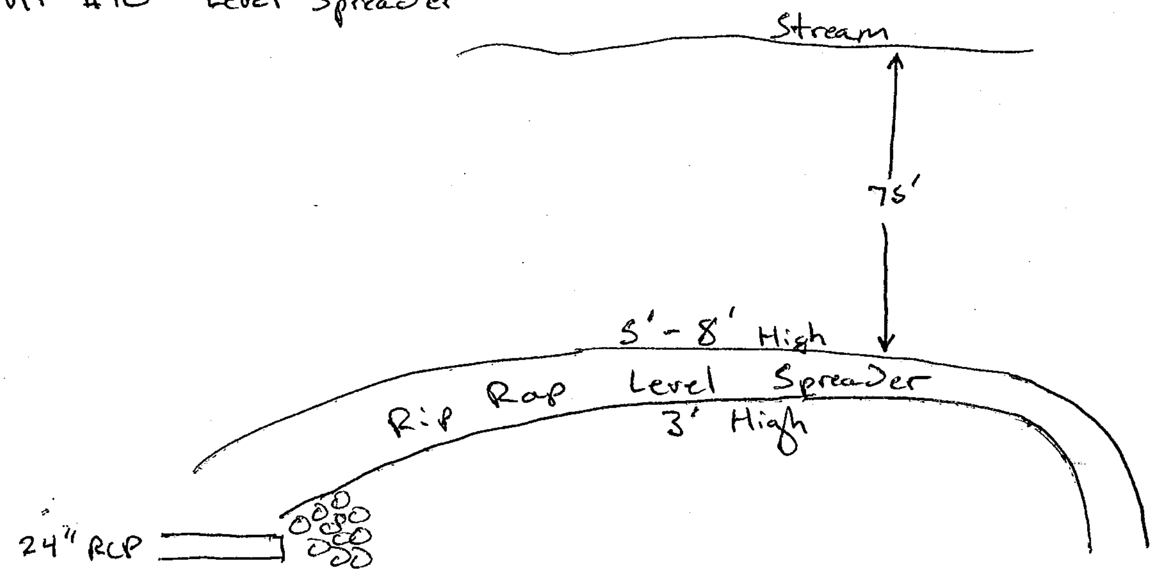
BMP #10 - Level Spreader



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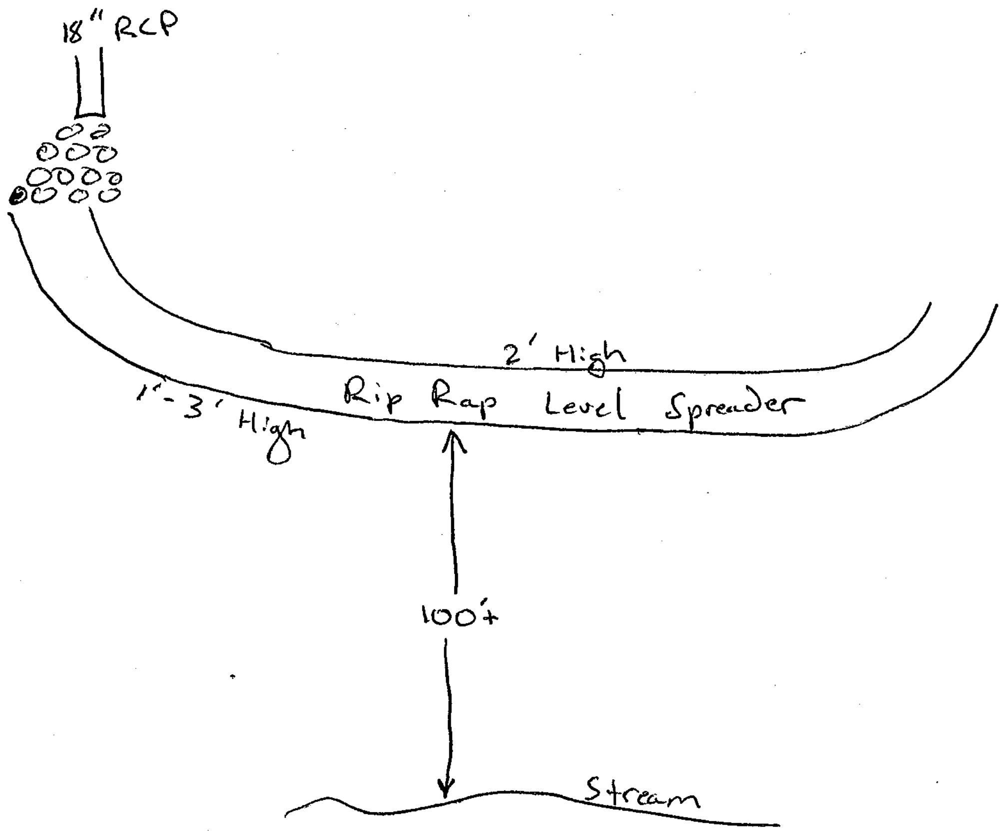
BMP #74 - Level Spreader



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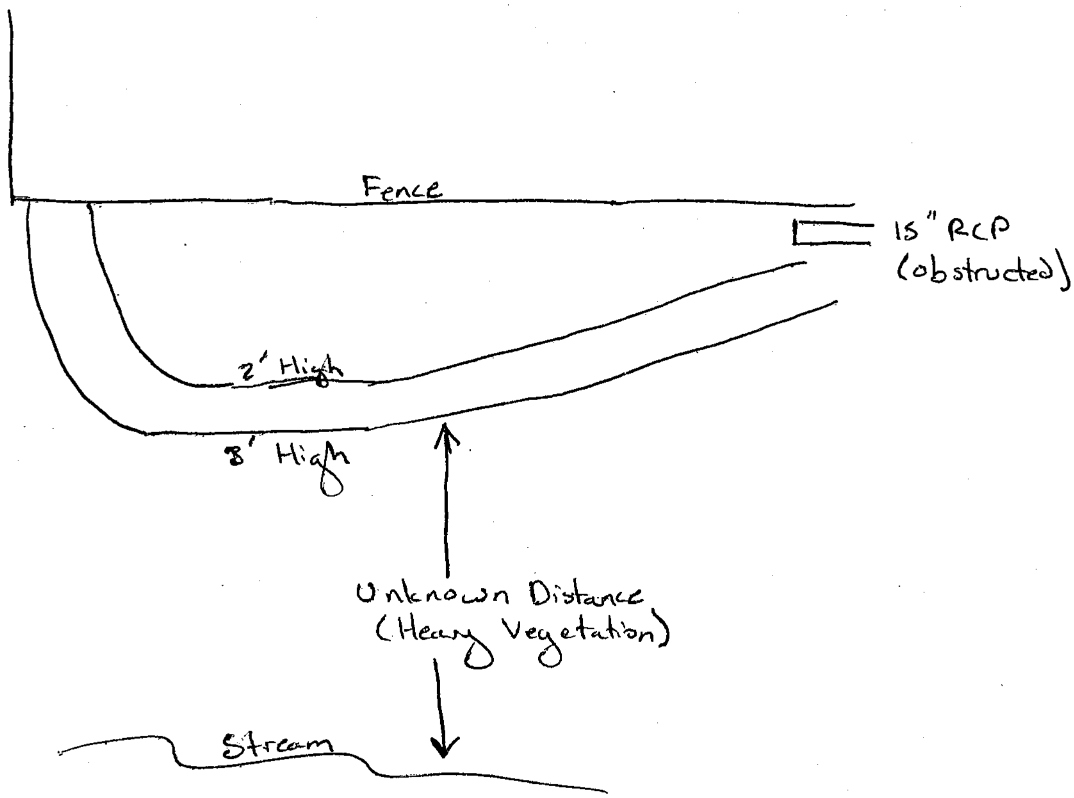
JOB NAME COMPUTED BY DATE

CLIENT CHECKED BY DATE

BMP #76 - Level Spreader



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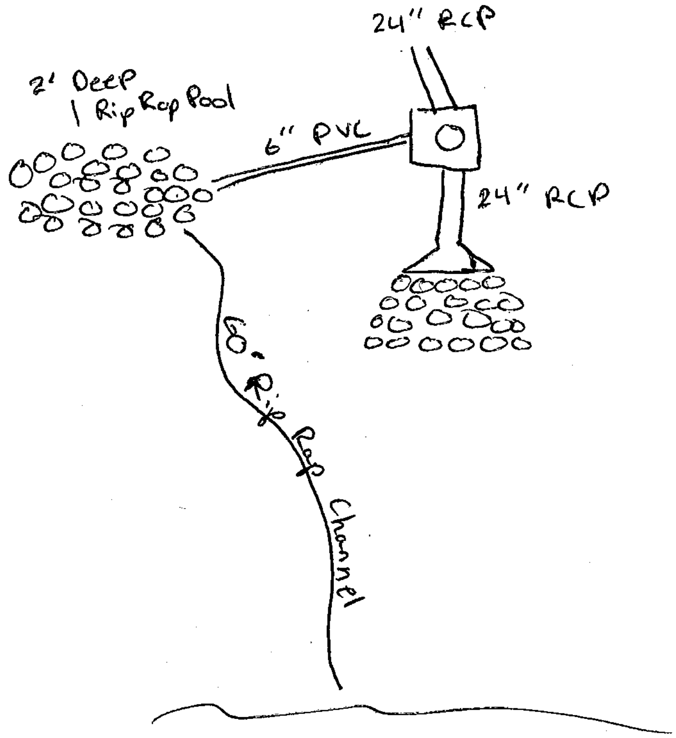
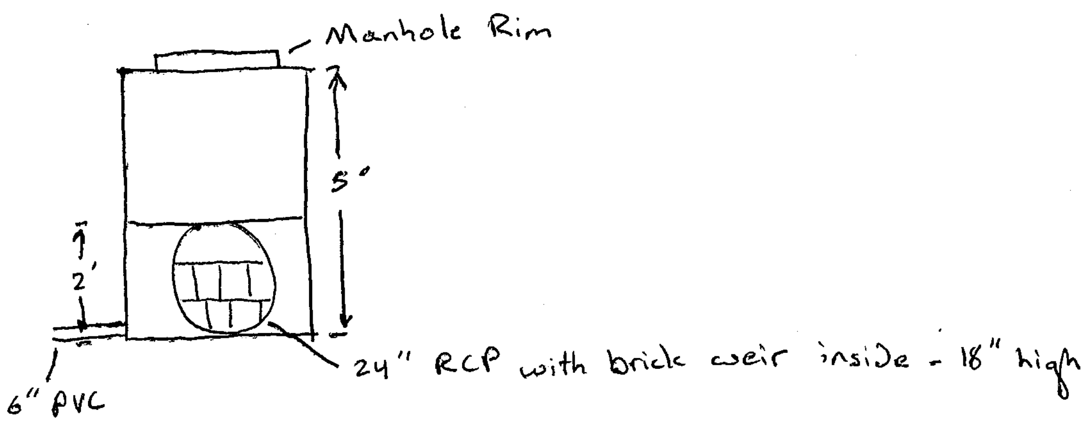
BMP # 17 - Level Spreaders



Junction Box Detail



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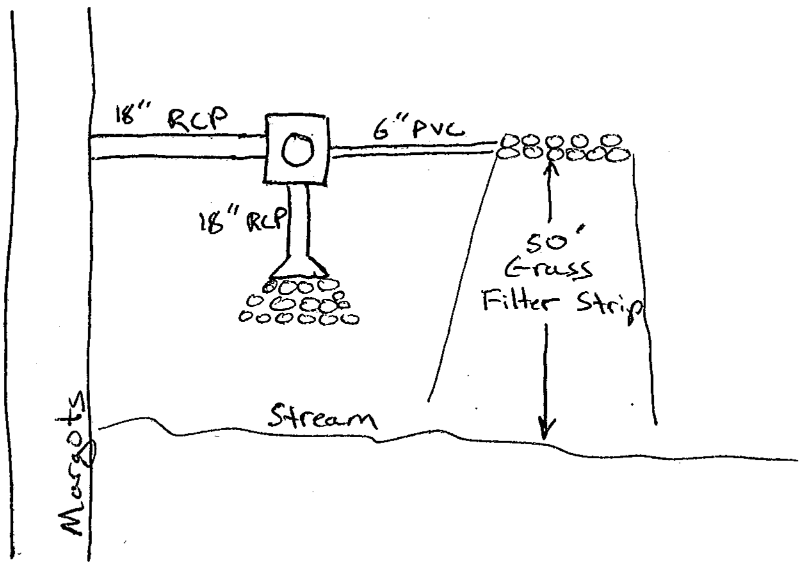
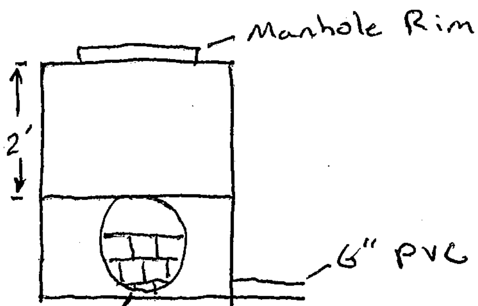
BMP #27 - Level Spreader



Junction Box Detail



18" RCP with brick weir inside pipe - 12" high

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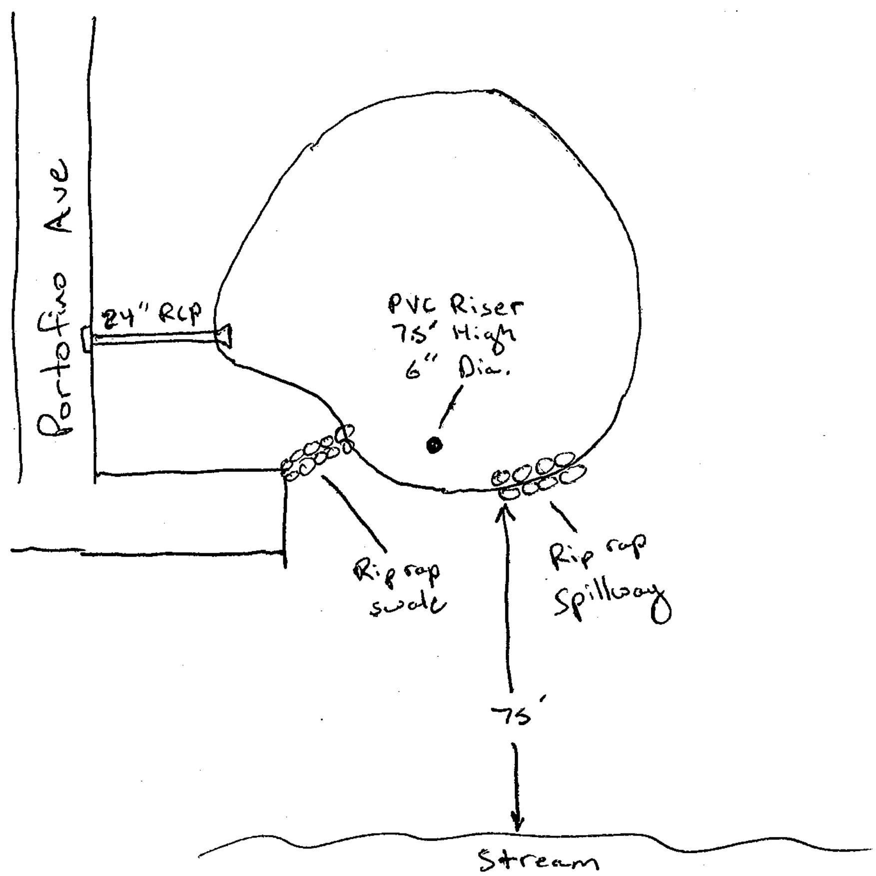
BMP #38 - Level Spreader



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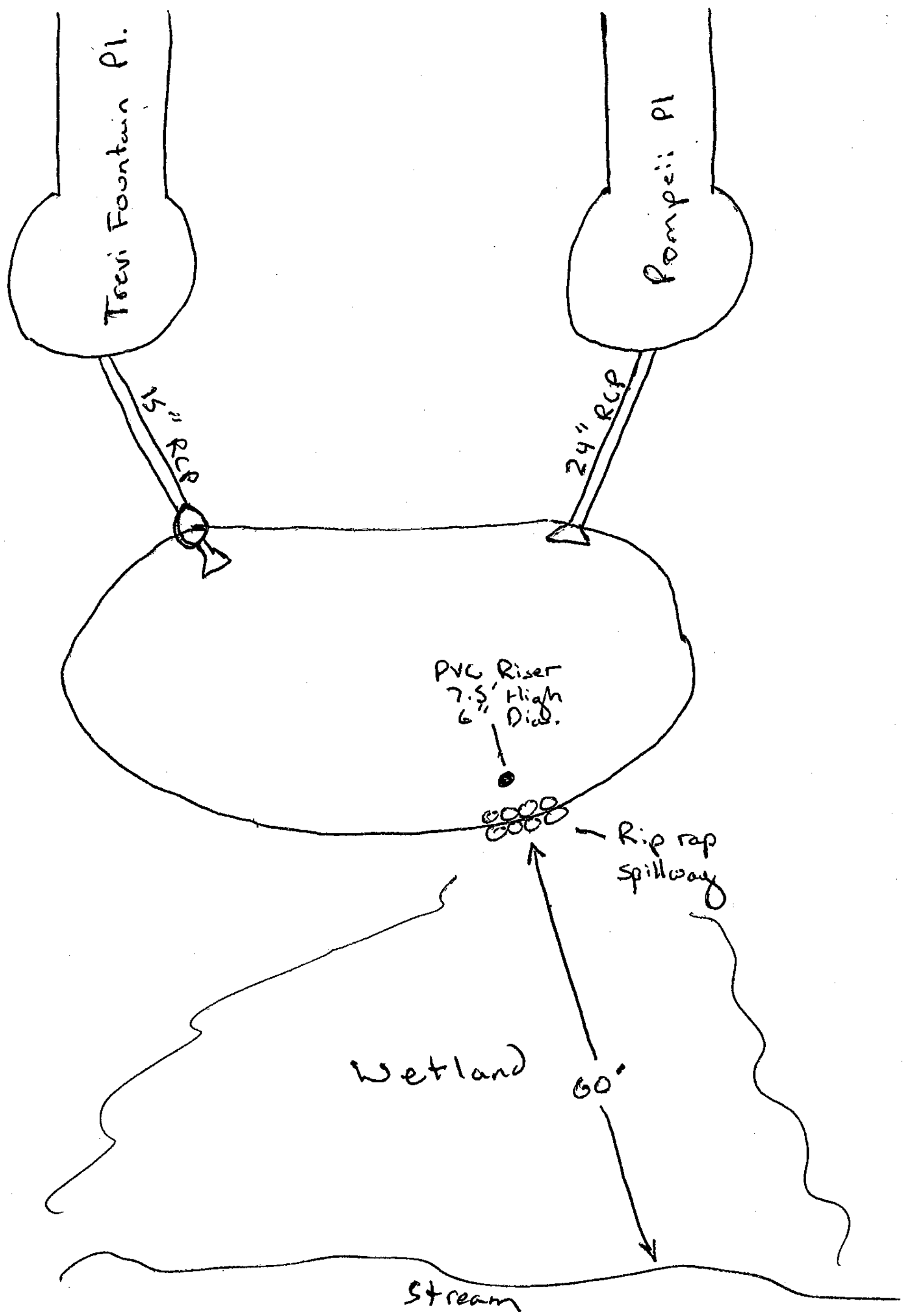
BMP #36 - Dry Pond



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JOB NAME ____________ COMPUTED BY ____________ DATE ________

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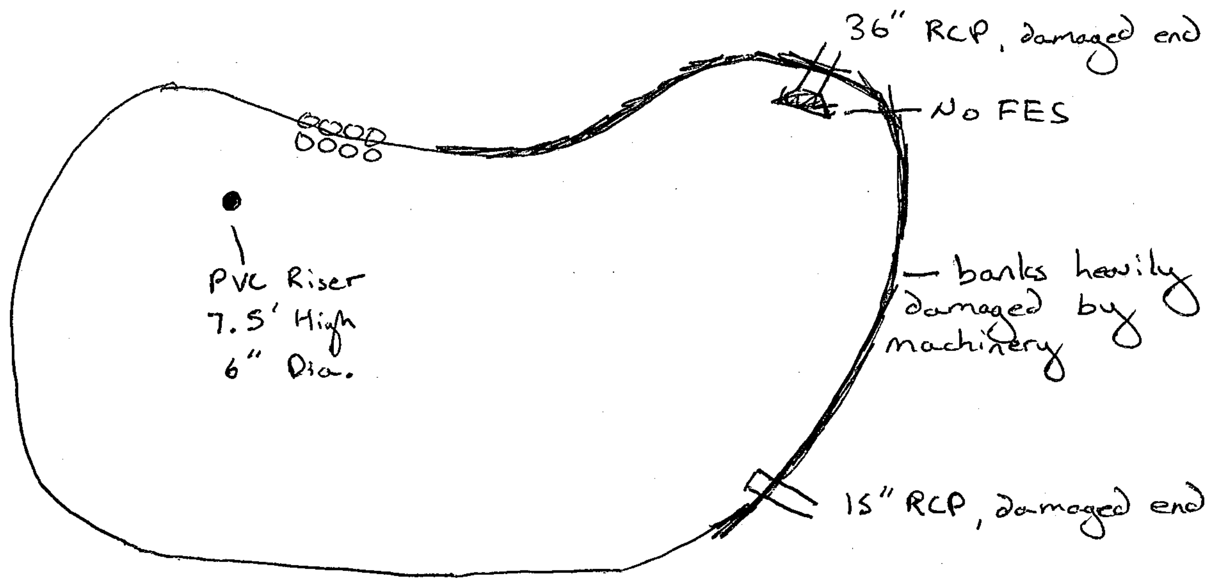
BMP #35 - Dry Detention



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JOB NAME ____ COMPUTED BY ____ DATE ____

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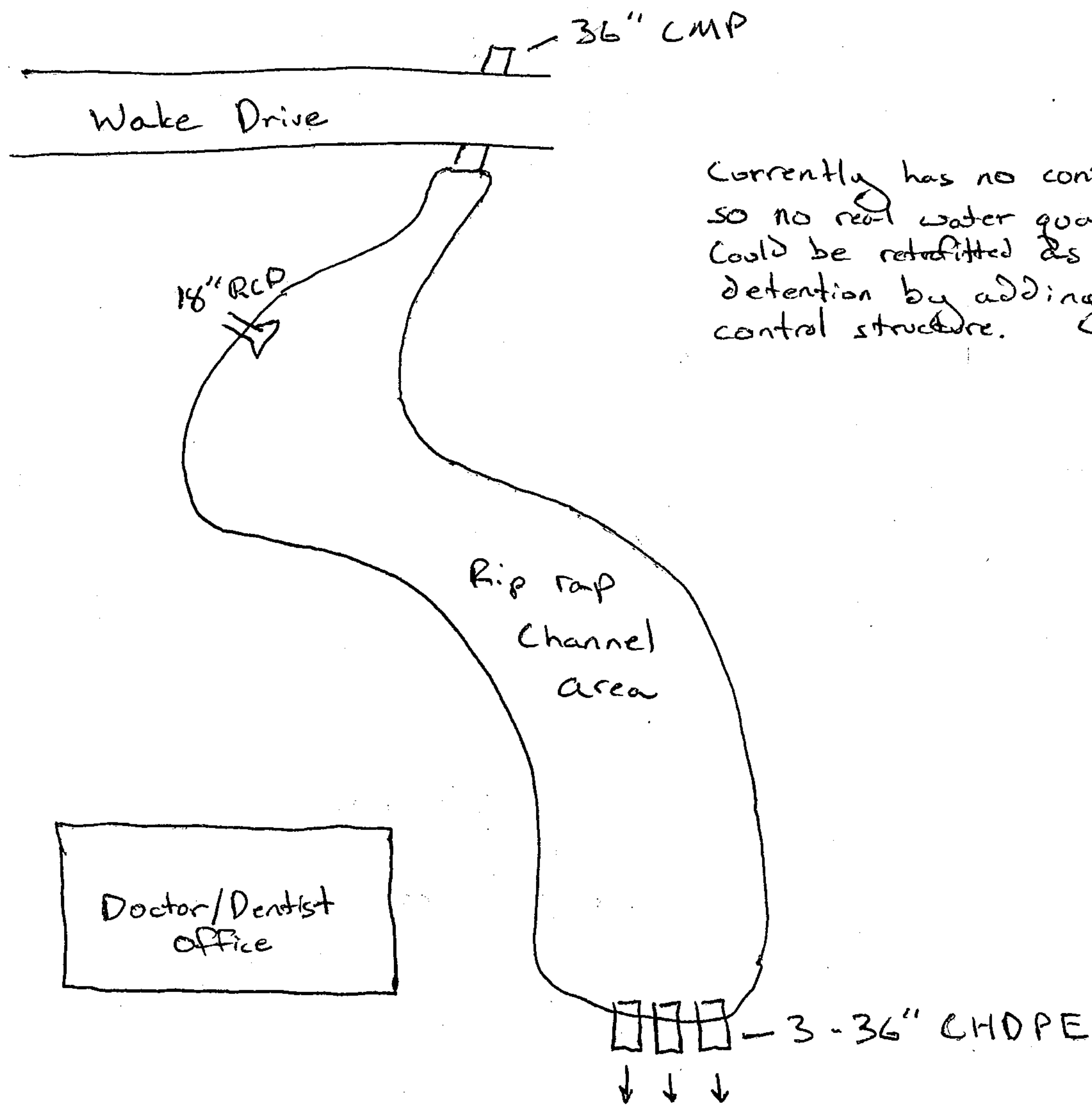
BMP #38 - No current BMP, good retrofit potential



Currently has no control structure, so no real water quality effects. Could be retrofitted as bioretention/detention by adding downstream control structure.

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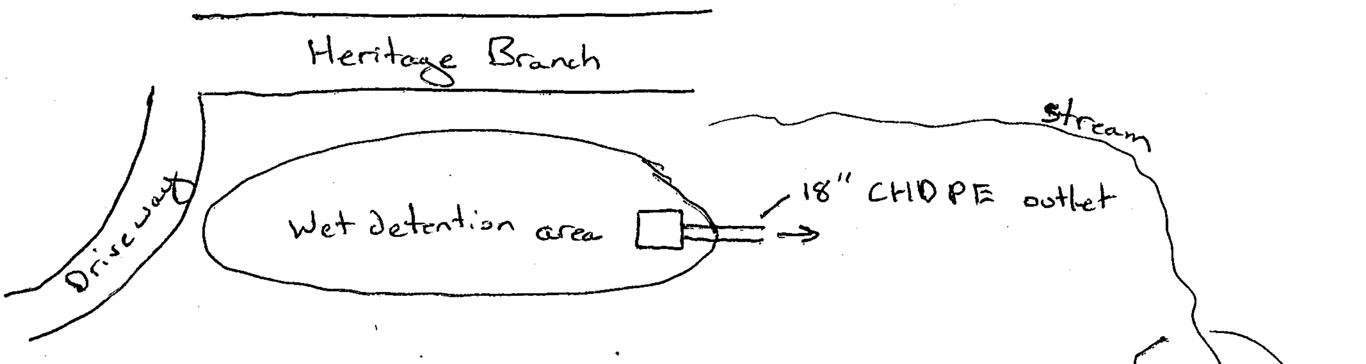
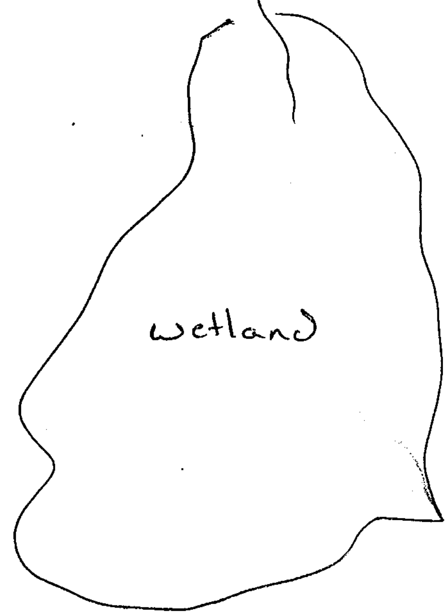
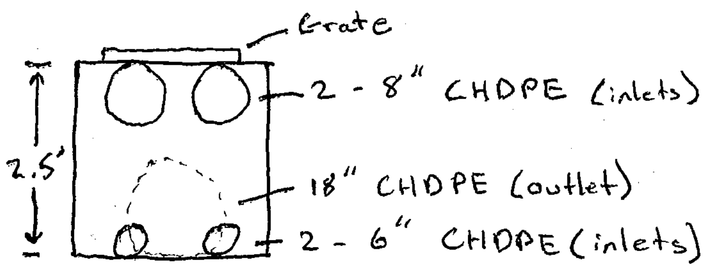
CLIENT ______________ CHECKED BY ______________ DATE ______________

BMP # 82 - wet detention





Control structure Detail



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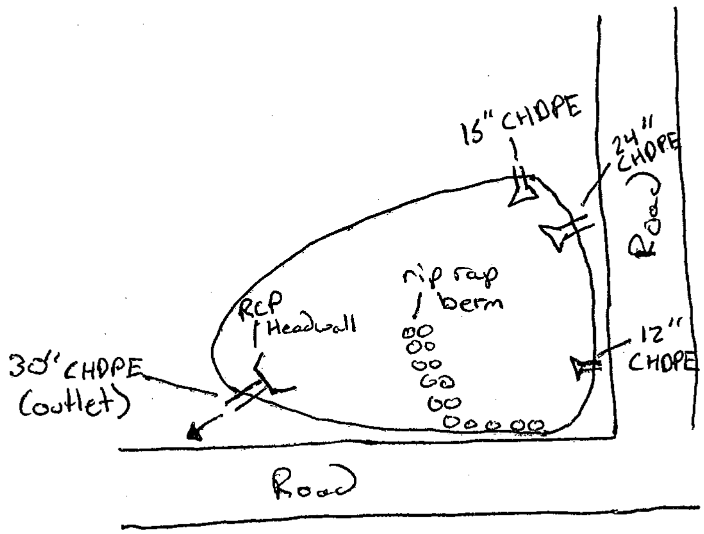
JOB NAME ________ COMPUTED BY ________ DATE ________

CLIENT ________ CHECKED BY ________ DATE ________

BMP # 46 - Wet Detention



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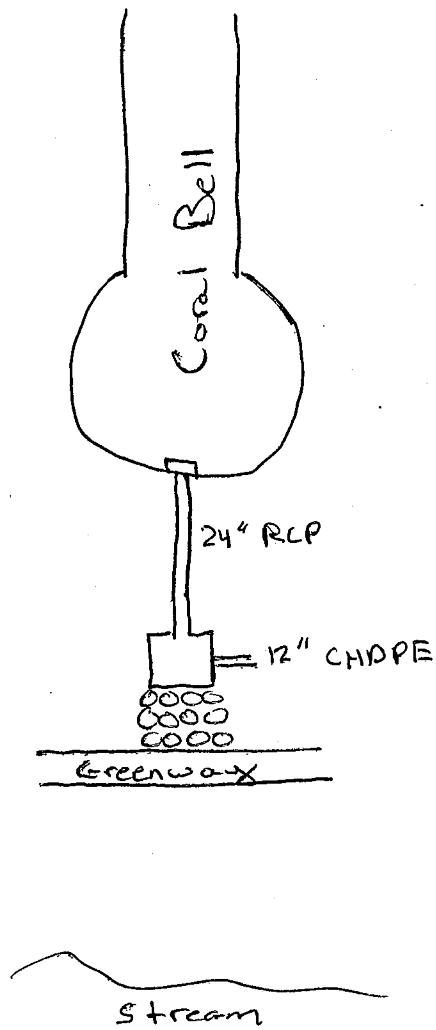
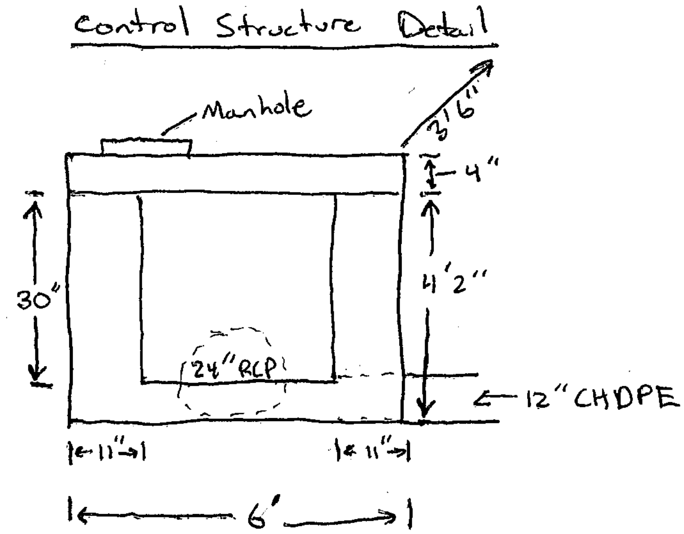
JOB NAME ____ COMPUTED BY ____ DATE ____

CLIENT ____ CHECKED BY ____ DATE ____

BMP # 49 - Level Spreader





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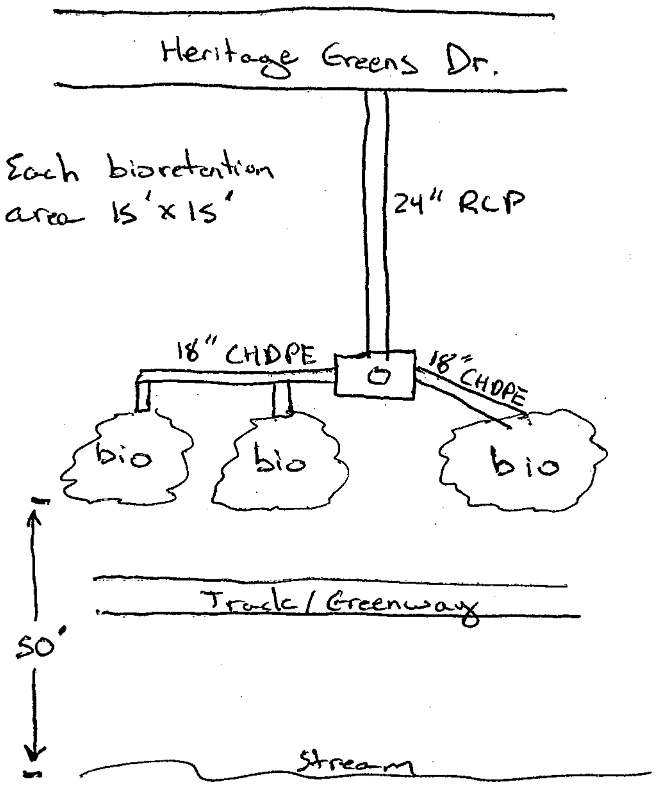
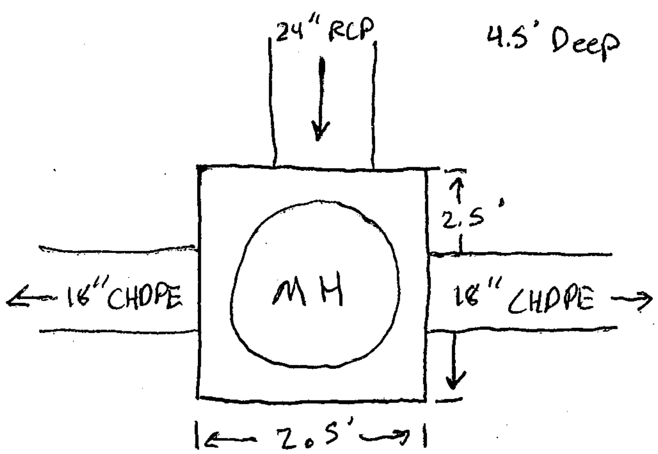
CLIENT ______ CHECKED BY ______ DATE ______

BMP #50 - Bioretention



Control Structure Detail



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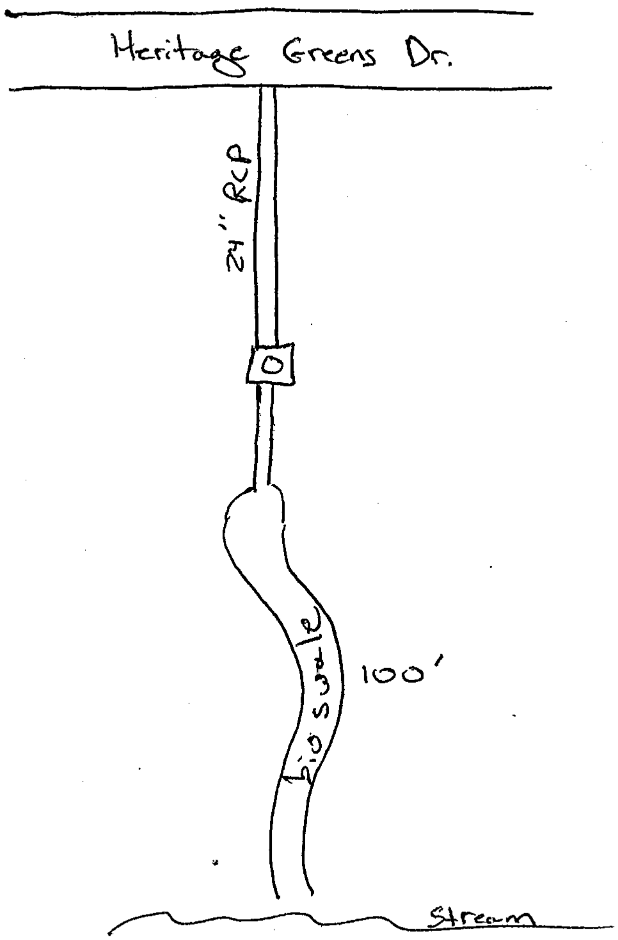
JOB NAME ______ COMPUTED BY ______ DATE ______

CLIENT ______ CHECKED BY ______ DATE ______

BMP #51 - Bioswale



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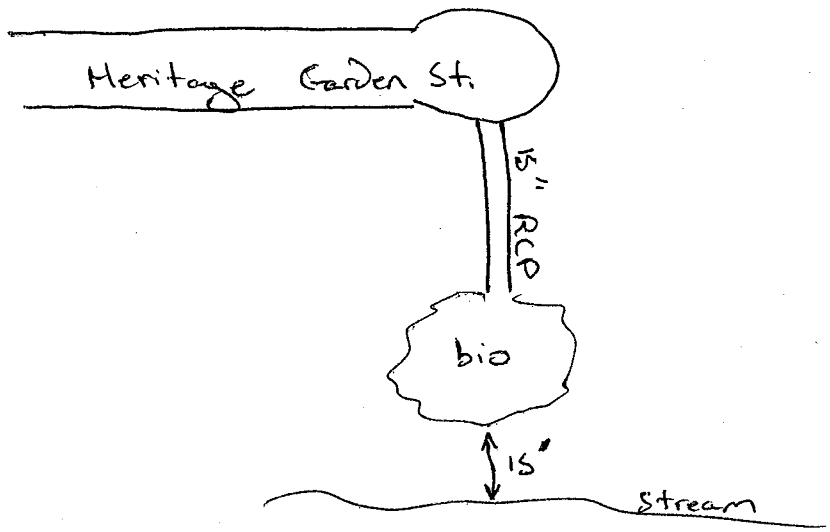
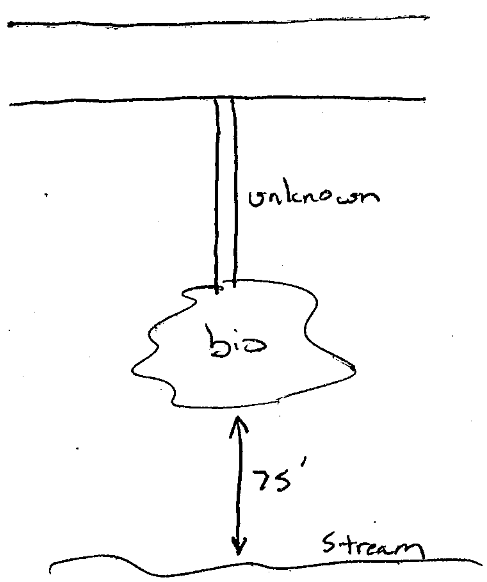
JOB NAME ______ COMPUTED BY ______ DATE ______

CLIENT ______ CHECKED BY ______ DATE ______

BMP #53 - Level spreader/bioretention



BMP #54 - Level spreader/bioretention



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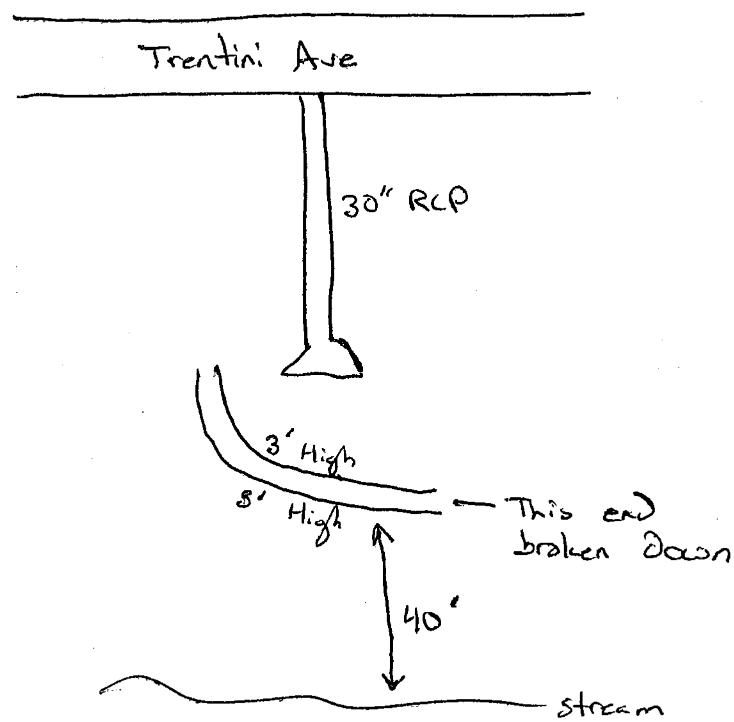
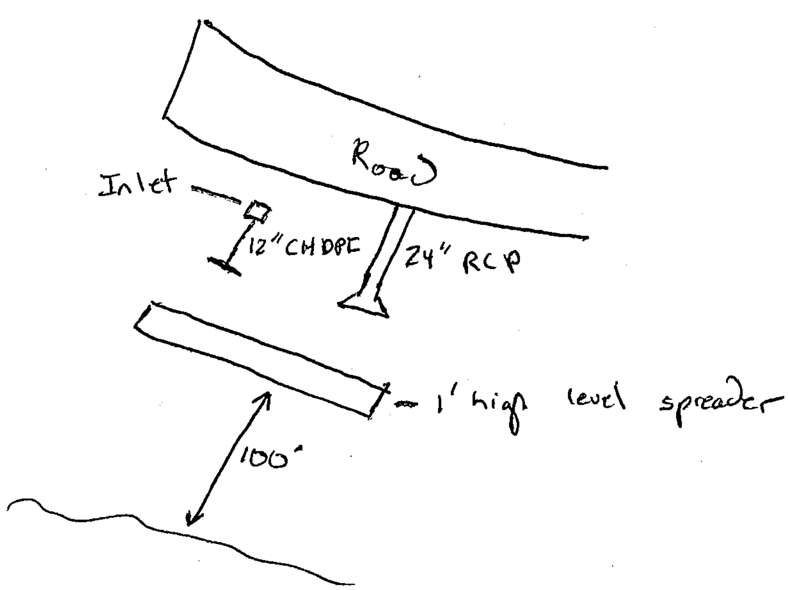
JOB NAME ______ COMPUTED BY ______ DATE ______

CLIENT ______ CHECKED BY ______ DATE ______

BMP # 58 - Level Spreader



BMP # 59 - Level Spreader



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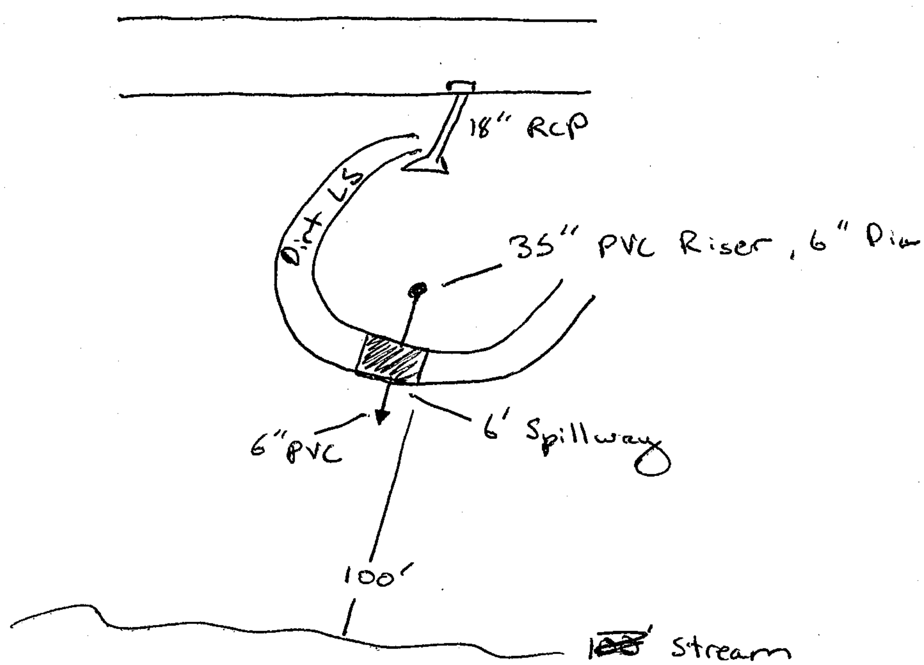
JOB NAME ______ COMPUTED BY ______ DATE ______

CLIENT ______ CHECKED BY ______ DATE ______

BMP # 66 - Level Spreader / Detention



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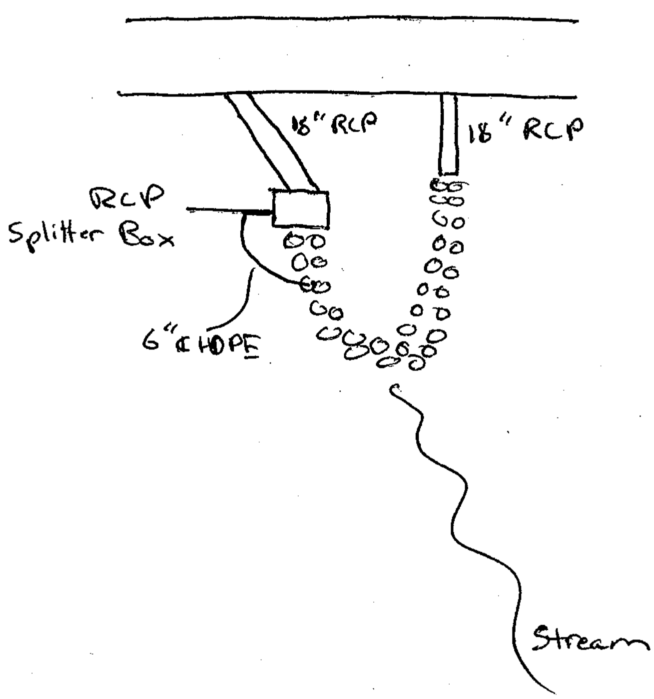
SHEET NO. ______ OF ______

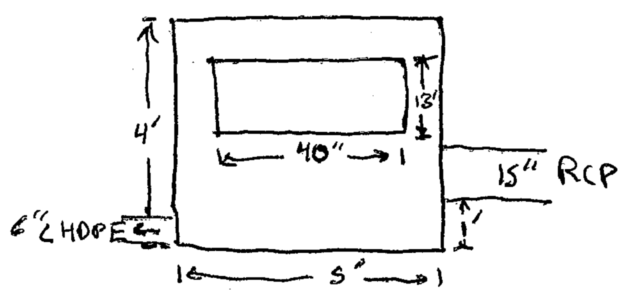
JOB NAME ____________ COMPUTED BY ____________ DATE ____________

CLIENT ____________ CHECKED BY ____________ DATE ____________

BMP #60 - Level Spreader



Splitter Box Detail



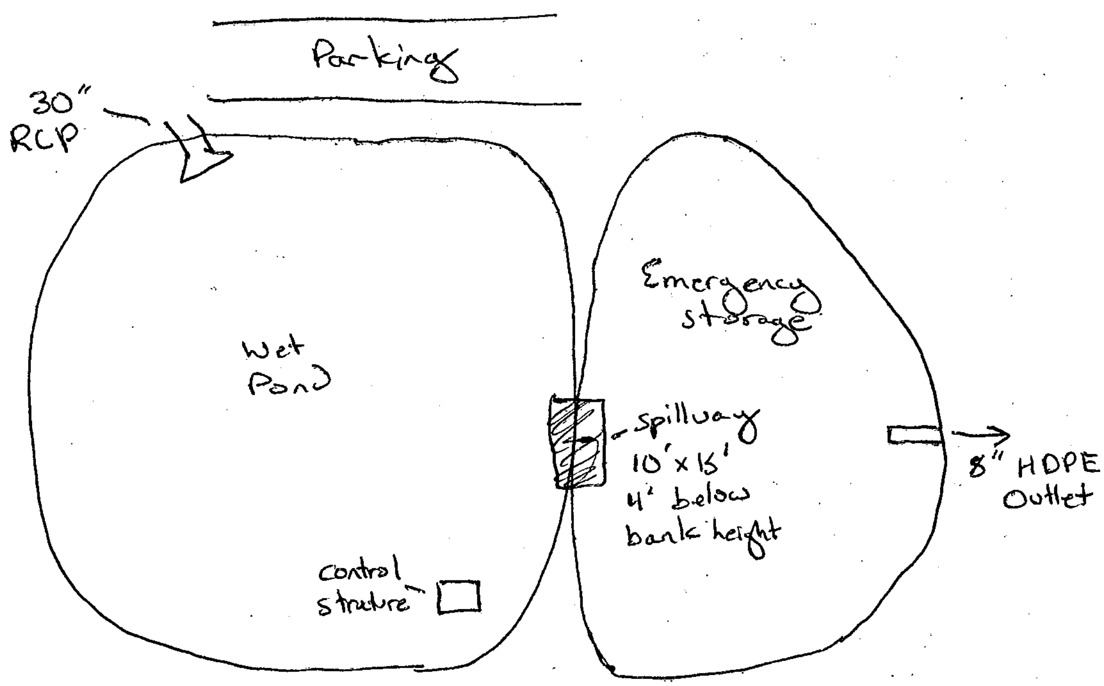
WKD NO.

SHEET NO. ______ OF ______

JOB NAME ______ COMPUTED BY ______ DATE ______

CLIENT ______ CHECKED BY ______ DATE ______

BMP #70 - Wet detention



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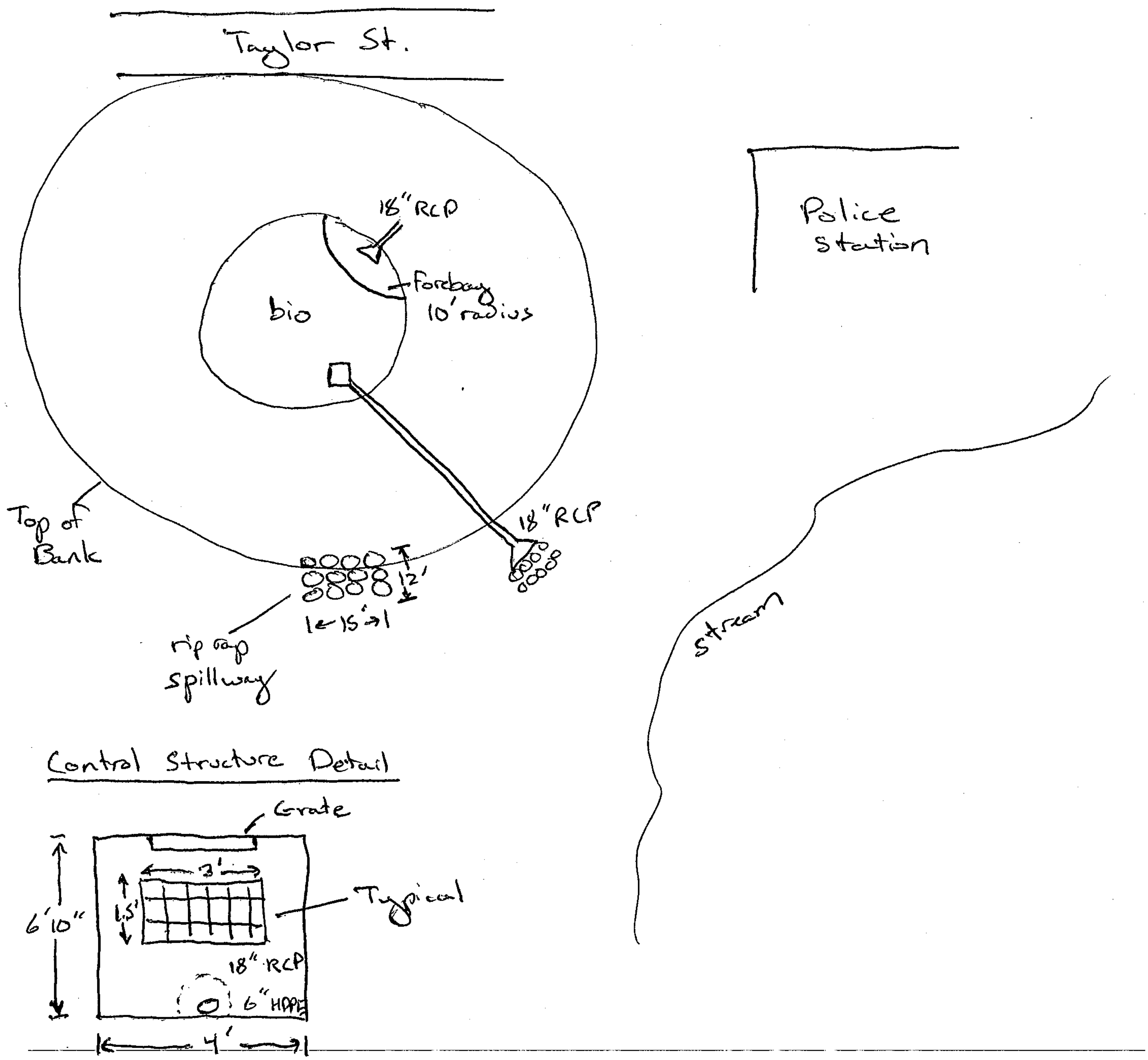
SHEET NO. ______ OF ______

JOB NAME ______ COMPUTED BY ______ DATE ______

CLIENT ______ CHECKED BY ______ DATE ______

BMP # 71 - Bioretention



APPENDIX E.
319 QUARTERLY REPORTS

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Jan. - Mar. 2013, report #1

Project Outputs and Deliverables (*cut and paste from approved workplan*):

1. create stakeholder list

2. contact stakeholders

3. delineate subwatersheds

4. evaluate existing data

5. identify data gaps

6. conduct impervious cover analysis

7. estimate sediment loads

8. create mean annual flood curve

9. establish website

10. begin field assessment using EPA Rapid Habitat Assessment protocol

11. develop environmental education schedule

12. revise website

13. schedule education days

14. conduct initial benthos sampling

New Data/Activities/Project Progress (*insert reporting period*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. complete

2. complete

3. complete

4. complete

5. complete

6. ongoing: preliminary evaluation complete. 2010 false color IR – based impervious data requested from Wake County

7. ongoing: awaiting final impervious data from Wake County

8. ongoing: awaiting USGS data

9. websites are completed with additional data and maps pending specific to the 319 grant.
http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
http://www.wakeforestnc.gov/watershed-education.aspx
http://www.wakeforestnc.gov/adopt-a-stream-1.aspx

10. complete: initial evaluation of 14 sites

11. initial schedule is listed on the Town webpage through Dec. 2014. Additional school education will be scheduled once education program details are complete.

12. ongoing; as data is collected website will be updated with sample locations and values

13. Education days have been scheduled with NC Museum of Science for 5 sessions starting in the summer 2013, conducted stream clean up of Smith Creek at Burlington Mills Road on April 6th (10 bags in 2.5 hours, only ½ mile covered), scheduled tree planting of NRB at Smith Creek Soccer Center for April 24th with 1,000 loblollies from 2 until 5 pm. Also, secured a booth spaces at Town's Meet in the Street Festival on Saturday, May 4th from 10 until 4 pm; with CWEP education booth, Enviroscape, adopt a stream map, and hand out materials.

14. ongoing: awaiting response from DWQ re: acceptable fish and benthos protocols and if data collected can be used to evaluate use support

<u>Additional Required Reporting</u>

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date
2. Lat/Longs all BMPs and project area: none to date
3. Load reductions associated with BMPs: none to date
4. Water quality monitoring data (water chemistry): none to date
5. Map of BMP locations in watershed: ongoing

<u>Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:</u>

none

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: April-June 2013, Quarterly Report #2

Project Outputs and Deliverables (*cut and paste from approved workplan*)**:**

1. create stakeholder list

2. contact stakeholders

3. delineate subwatersheds

4. evaluate existing data

5. identify data gaps

6. conduct impervious cover analysis

7. estimate sediment loads

8. create mean annual flood curve

9. establish website

10. begin field assessment using EPA Rapid Habitat Assessment protocol

11. develop environmental education schedule

12. revise website

13. schedule education days

14. conduct initial benthos sampling

New Data/Activities/Project Progress (*Apr- June 2013*)**:**
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. complete

2. complete

3. complete

4. complete

5. complete

6. complete

7. complete

8. complete

9. complete; websites are completed with additional data and maps, additional webpage to be added for data
http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
http://www.wakeforestnc.gov/watershed-education.aspx
http://www.wakeforestnc.gov/adopt-a-stream-1.aspx

10. complete: initial evaluation of 14 sites

11. complete; schedule is listed on the Town webpage through Dec. 2014. Additional school education will be scheduled in the fall once school reconvenes

12. ongoing; as data is collected website will be updated with sample locations and values

13. complete; Education days have been scheduled with NC Museum of Science for 5 sessions starting in the summer 2013, conducted stream clean up of Smith Creek at Burlington Mills Road on April 6th (10 bags in 2.5 hours, only ½ mile covered), scheduled tree planting of NRB at Smith Creek Soccer Center for April 24th with 1,000 loblollies from 2 until 5 pm. Also, secured a booth spaces at Town's Meet in the Street Festival on Saturday, May 4th from 10 until 4 pm; with CWEP education booth, Enviroscape, adopt a stream map, and hand out materials.

14. complete, QAPP now can be completed

<u>Additional Required Reporting</u>

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date
2. Lat/Longs all BMPs and project area: initiated/ongoing
3. Load reductions associated with BMPs: none to date
4. Water quality monitoring data (water chemistry): initial set complete (Adopt a Stream program)
5. Map of BMP locations in watershed: ongoing

<u>Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:</u>

4/8/13-Jan-Mar 2013, report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: July-Sept 2013, Quarterly Report #3

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan***):**

1. create stakeholder list

2. contact stakeholders

3. delineate subwatersheds

4. evaluate existing data

5. identify data gaps

6. conduct impervious cover analysis

7. estimate sediment loads

8. create mean annual flood curve

9. establish website

10. begin field assessment using EPA Rapid Habitat Assessment protocol

11. develop environmental education schedule

12. revise website

13. schedule education days

14. conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*July-Sept 2013***):**
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. complete

2. complete, ongoing update meetings:
    - July 17, 2013- Smith Creek Watershed Quarterly Stakeholders Meeting #2
    - Oct 30, 2013- Smith Creek Watershed Quarterly Stakeholders Meeting #3

3. complete
4. complete

5. complete

6. complete

7. complete

8. complete

9. complete; websites are completed with additional data and maps, additional webpage to be added for data
http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
http://www.wakeforestnc.gov/watershed-education.aspx
http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
http://www.wakeforestnc.gov/water-quality-data.aspx
http://www.wakeforestnc.gov/backyard-stream-repair.aspx

10. complete: initial evaluation of 14 sites, conducted 3 EPA rapid site assessments. See attached results

11. complete; schedule is listed on the Town webpage through Dec. 2013. Additional school education will be scheduled in the spring of 2014.

- Aug 1, 2013- Reptiles and Amphibians, NC Museum of Natural Sciences
- Sept 7, 2013- Ssnakes, NC Museum of Natural Sciences
- Sept 28, 2013- National Public Lands Day- Reservoir Clean Up
- Oct 5, 2013- Birds of a Feather, NC Museum of Natural Sciences
- Nov 2, 2013- Wonders of Wetlands, NC Museum of Natural Sciences
- Dec 7, 2013- Animal Tracks and Signs, NC Museum of Natural Sciences
- Dec. 13, 2013- Backyard Stream Repair Workshop with NC Co-Op Ext. Repair & replant banks of Miller Park- UT to Spring Branch in Downtown Wake Forest, trib to Smith Creek.

12. ongoing; as data is collected website will be updated with sample locations and values, also see #9

13. complete; Education days have been scheduled with NC Museum of Natural Sciences for 7 sessions thru December 2013, partnered with Greenway Advisory Board to conduct clean up at Town Reservoir thru National Public Lands Day. Over 100 volunteers showed up collecting approximately 1 ton of garbage, also see #11

14. complete, QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010.

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date
2. Lat/Longs all BMPs and project area: ongoing
3. Load reductions associated with BMPs: none to date
4. Water quality monitoring data (water chemistry):
    a. volunteer data obtained from past four months (Adopt a Stream program)- non technical, not lab certified
5. Map of BMP locations in watershed: ongoing, not complete

Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:

07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Oct. -Dec. 2013, Quarterly Report #4

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan*):

1. create stakeholder list

2. contact stakeholders

3. delineate subwatersheds

4. evaluate existing data

5. identify data gaps

6. conduct impervious cover analysis

7. estimate sediment loads

8. create mean annual flood curve

9. establish website

10. begin field assessment using EPA Rapid Habitat Assessment protocol

11. develop environmental education schedule

12. revise website

13. schedule education days

14. conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*Oct - Dec 2013*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. complete

2. complete, ongoing update meetings:
   - Oct 30, 2013- Smith Creek Watershed Quarterly Stakeholders Meeting #3
   - Attended CWEP Meeting

- Attended Watershed Steering Network Meeting
- Completed SEEA Adopt a Stream Grant. Will continue program.

3. complete
4. complete

5. complete

6. complete

7. complete

8. complete

9. complete; websites are completed with additional data and maps:

http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
http://www.wakeforestnc.gov/watershed-education.aspx
http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
http://www.wakeforestnc.gov/water-quality-data.aspx
http://www.wakeforestnc.gov/backyard-stream-repair.aspx
http://www.wakeforestnc.gov/water-quality-data.aspx

10. complete: evaluation of 14 sites, conducted 3 EPA rapid site assessments.

11. complete; schedule is listed on the Town webpage through Dec. 2013. Additional school education will be scheduled in the Spring of 2014.

- Oct 5, 2013- Birds of a Feather, NC Museum of Natural Sciences
- Nov 2, 2013- Wonders of Wetlands, NC Museum of Natural Sciences
- Dec 7, 2013- Animal Tracks and Signs, NC Museum of Natural Sciences
- Dec. 13, 2013- Backyard Stream Repair Workshop with NC Co-Op Ext.
- Jan. 2014- Repair & replant banks of Miller Park- UT to Spring Branch in Downtown Wake Forest, trib. to Smith Creek

12. ongoing; as data is collected website will be updated with sample locations and values, also see #9

13. complete; Education days have been scheduled with NC Museum of Natural Sciences for 7 sessions thru December 2013. Planning 2014 dates and activities

14. complete, QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010.

North Carolina’s Section 319 NPS Program
Quarterly Progress Reporting

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date
2. Lat/Longs all BMPs and project area: ongoing
3. Load reductions associated with BMPs: none to date
4. Water quality monitoring data (water chemistry):
    a. volunteer data obtained from past four months (Adopt a Stream program)- non technical, not lab certified
5. Map of BMP locations in watershed: ongoing, not complete

Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:

10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Jan-Mar 2014, Quarterly Report #5

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan***):**

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*Jan – Mar 2014***):**
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –complete
2. Contact stakeholders-complete, ongoing update meetings

- 1/27/14- Monthly progress mtg with WKD
- 2/26/14- Monthly progress mtg with WKD
- 3/25/14- Monthly progress mtg with WKD

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete

    - Evaluation of 14 sites, conducted 3 EPA rapid site assessments
    - Additional sampling will commence this Spring as in-kind services in the amount of $13,890 to determine catchment area ratings in 6 of the subwatersheds

11. Develop environmental education schedule -complete

    - Schedule is listed on the Town webpage through Dec. 2013

    - Additional school education will be scheduled in the Spring/Fall of 2014

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9
    - Completed SEEA Adopt a Stream Grant. Will continue program through 2016.

13. Schedule education days- ongoing

- 2/18/14- Attended CWEP Steering Committee Meeting- grass clippings next focus
- 3/1/14- Eagle Scout Project to enhance UT to Spring Branch in Miller Park
- 3/5/14- Attended Watershed Steering Network Meeting- group completed logo and started education ideas
- 3/6-3/7/14- Hosted NC Co-op/NCSU BMP Maintenance Training at Town Hall. Conducted field visits to onsite BMP's (bioretention, wetland, scour hole, level spreader with vegetated swale) and stream enhancement project in Miller Park.
- 3/19-3/20/14- Attended WRRI Annual Conference and Symposium. Presented about Small Local Governments involvement in water quality focusing on Smith Creek Restoration and Implementation Project and spoke about Adopt a Stream Program and benthos data acquired to date.
- 3/22/14-Booth at Town's Arbor Day Celebration- enviroscape, adopt a stream, Smith Creek Restoration and Implementation plan handouts and maps.

14. Complete, QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010.

- Additional sampling will commence this Spring as in-kind services in the amount of $13,890 to determine catchment area ratings in 6 of the subwatersheds.

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date, evaluation of potential retrofits complete

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: none to date

4. Water quality monitoring data (water chemistry):
    a. volunteer data obtained from past 8 months (Adopt a Stream program)- non technical, not lab certified

5. Map of BMP locations in watershed: complete

Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:

12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: April - June 2014, Quarterly Report #6

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan*):

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*April - June 2014*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –complete

2. Contact stakeholders-complete, ongoing update meetings

- 4/23/14- Monthly progress mtg with WKD
  Identified potential repair projects:
  Jones Dairy Road 3,000 LF
  Heritage Lake Road old mill dam pond
  Ailey Young Park RSC at end of dam
  Deerfield Crossing
  9500 White Carriage Drive RSC
  9316 Brandon Ct, Song Sparrow
  Trentini Ave/Hope Lutheran Church
  Stroud Circle- sediment repair
- 5/25/14- Monthly progress mtg with WKD
- 6/26/14- Monthly progress mtg with WKD

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

   Additional Hec-Ras data completed on Smith, Dunn, and Sanford Creeks to capture CLOMR/LOMR's and rise. BFE's adjusted to correct development increase. Did not affect homes.

9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete

    - Evaluation of 14 sites, conducted 3 EPA rapid site assessments
    - Additional sampling started April 2014 as in-kind services in the amount of $13,890 to determine catchment area ratings in 6 of the subwatersheds. Results were good/excellent.

11. Develop environmental education schedule -complete

- Schedule is listed on the Town webpage through Dec. 2013

- Additional school education will be scheduled in the late Summer/ early Fall of 2014

12. Revise website - ongoing

- As data is collected website will be updated with sample locations and values, also see #9
- Completed SEEA Adopt a Stream Grant. Will continue program through 2016.

13. Schedule education days- ongoing

- 4/5/14- Booth at Town's Dirt Day Celebration- enviroscape, adopt a stream, Smith Creek Restoration and Implementation plan handouts and maps.
- 4/7/14- Submitted CWMTF grant to acquire 168 acre of headwater stream and drainage of Smith Creek. Also submitted for small 14 acre parcel to protect an unnamed tributary to Smith Creek near Old Crawford Road.
- 4/24/14- Met with residents about stream repair work behind houses. Discussed live staking, slopes, bankfull, buffers and protection.
- 4/24/14- 721 Opposition Way- met with Mitch Woodward and Bill Lord to discuss swale design options in public drainage easement. Design underway, to be installed in the Fall of 2014.
- 5/2/14- 1201 Groves Field Lane- Met with residents about stream repair work behind houses. Discussed live staking, slopes, bankfull, buffers and protection. Large headcut from end of pipe to stream start. Potential repair location. WKD to look into for a possible mitigation site.
- 5/30/14- Conducted 15 grass clipping surveys for CWEP. Data to be used for next round of education promotion and videos.
- 6/7/14- National Trails Day- thank you event for Adopt a Greenway and Adopt a Stream Volunteers. Also had 9 environmental education stations at Joyner Park-Enviroscape/turbidity, invasive species, bugs, raptors, stream repair, snakes, home depot bird houses, tree nursery tours, tree id.
- 6/24/14- Attended NCSU Swale and Filter Strip Design Workshop. Planning on utilizing some of these methods and swale design spreadsheet to calculate pollutant and sediment reduction for BMP installation.
- Completed FY 14/15 Budget for 319 grant
    - Task 1- habitat enhancement and relocation (year 1)
    - Task 2- third party lab certifications of data (year 1)
    - Task 3- third party lab certifications of data (year 2)
    - Task 4- third party lab certifications of data (year 3)
    - Task 5- third party lab certifications of data (year 4)
- July 2014- benthos sampling and habitat enhancement project- 3 locations
    - Burlington – habitat

  - Smith – habitat and seeding
  - Austin/Sanford- habitat and seeding
- Schedule of Fall Workshops and School events to occur in July/August 2014.

14. Complete, QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data will be collected on July 17, 2014.

- Additional sampling will commence this Spring as in-kind services in the amount of $13,890 to determine catchment area ratings in 6 of the subwatersheds.

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date, evaluation of potential retrofits complete, budget pending for FY 14/15, potential grant opportunities being pursued.

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: none to date

4. Water quality monitoring data (water chemistry):
   a. volunteer data obtained from past 11 months (Adopt a Stream program)- non technical, not lab certified

5. Map of BMP locations in watershed: complete

Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:

3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: July-Sept 2014, Quarterly Report #7

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan*):

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*July-Sept 2014*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –complete

2. Contact stakeholders-complete, ongoing update meetings

- 7/28/14- Monthly progress mtg with WKD, benthos seeding project on August 16, 2014
- 8/26/14- Monthly progress mtg with WKD, benthos seeding project part 2 on Sept 20, 2014
- 9/26/14- Monthly progress mtg with WKD- canceled

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete

11. Develop environmental education schedule -complete

    - Visiting schools and conducting water quality education at charter and public schools in community

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9

13. Schedule education days- ongoing

    - Aug 16, 2014 and Sept 20, 2014- benthos sampling and habitat enhancement project at Sanford Creek in Heritage South off of Golden Star Way
    - Scheduled Fall Workshops and School events to occur in 2014/2015

14. Complete, QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data collected on July 17, 2014. Showed slight increase from good-fair to good. More group 1 taxa present.

- Benthic habitat will be installed along Sanford Creek near Heritage South to help determine if benthos population is able to sustain itself.

<u>Additional Required Reporting</u>

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date, evaluation of potential retrofits complete, potential grant opportunities being pursued.

Identified potential repair projects:

- Jones Dairy Road 3,000 LF stream repair- looking into grants or mitigation bank
- Heritage Lake Road old mill dam pond/Stroud Circle/Trentini Ave/Hope Lutheran Church - private property, NCDOT Bridge work to be done in this area 2016 along with 72" culvert extension
- Ailey Young Park RSC at end of dam- checking structural integrity of dam prior to installation
- Deerfield Crossing- private development under bank ownership, towf greenway and dedicated open space not accepted in this area yet
- 9500 White Carriage Drive RSC- will commence with installation of greenway trail in 2016
- 9316 Bramdon Ct, Song Sparrow- will commence with installation of greenway trail in 2016
- Working with Wake Forest garden club to install planting and bank stabilization in watershed

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: none to date

4. Water quality monitoring data (water chemistry):
   a. volunteer data obtained from past 15 months (Adopt a Stream program)- non technical, not lab certified, showed all sites within range for water quality. 13 of 20 sites adopted/readopted since July 2014. Ordering more supplies for quarter 8-12.

5. Map of BMP locations in watershed: complete

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

<u>Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:</u>

6/30/14	Apr- June 2014	Report #6
3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Oct-Dec 2014, Quarterly Report #8

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan*):

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*Oct- Dec 2014*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –complete
2. Contact stakeholders-complete, ongoing update meetings

- 11/3/14- Monthly progress mtg with WKD

3. Delineate subwatersheds – complete
4. Evaluate existing data – complete
5. Identify data gaps- complete
6. Conduct impervious cover analysis – complete
7. Estimate sediment loads – complete
8. Create mean annual flood curve- complete
9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete

11. Develop environmental education schedule -complete

    - Visiting schools and conducting water quality education at charter and public schools in community

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9

13. Schedule education days- ongoing

    - Developing Spring Workshops and School events to occur in 2015

14. QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data collected on July 17, 2014. Showed slight increase from good-fair to good. More group 1 taxa present.

- Benthic habitat will be installed along Sanford Creek near Heritage South to help determine if benthos population is able to sustain itself.

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date, evaluation of potential retrofits complete, potential grant opportunities being pursued. Estimated $25,000 in CIP budget starting in 2016 for the next four years.

Identified potential repair projects:

- Jones Dairy Road 3,000 LF stream repair- looking into grants or mitigation bank
- Heritage Lake Road old mill dam pond/Stroud Circle/Trentini Ave/Hope Lutheran Church - private property, NCDOT Bridge work to be done in this area 2016 along with 72" culvert extension
- Ailey Young Park RSC at end of dam- checking structural integrity of dam prior to installation
- Deerfield Crossing- private development under bank ownership, towf greenway and dedicated open space not accepted in this area yet
- 9500 White Carriage Drive RSC- will commence with installation of greenway trail in 2016
- 9316 Bramdon Ct, Song Sparrow- will commence with installation of greenway trail in 2016
- Working with Wake Forest garden club to install planting and bank stabilization in watershed

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: none to date

4. Water quality monitoring data (water chemistry):
    a. volunteer data obtained from past 18 months (Adopt a Stream program)- non technical, not lab certified, showed all sites within range for water quality. 13 of 20 sites adopted/readopted since July 2014. Ordering more supplies for quarter 8-12.

5. Map of BMP locations in watershed: complete

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

<u>Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:</u>

9/30/14	Aug- Sept 2014	Report #7
6/30/14	Apr- June 2014	Report #6
3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Jan- Mar 2015, Quarterly Report #9

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan***):**

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*Jan- March 2015***):**
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –complete

2. Contact stakeholders-complete, ongoing update meetings

- 3/26/15- Monthly progress mtg with WKD

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete

11. Develop environmental education schedule -complete

    - Visiting schools and conducting water quality education at charter and public schools in community

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9

13. Schedule education days- ongoing

    - Developing Spring Workshops and School events to occur in 2015

14. QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data collected on July 17, 2014. Showed slight increase from good-fair to good. More group 1 taxa present.

- Benthic habitat will be installed along Sanford Creek near Heritage South to help determine if benthos population is able to sustain itself.

<u>Additional Required Reporting</u>

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date, evaluation of potential retrofits complete, potential grant opportunities being pursued. Estimated $25,000 in CIP budget starting in 2016 for the next four years.

Identified potential repair projects:

- Jones Dairy Road 3,000 LF stream repair- looking into grants or mitigation bank
- Heritage Lake Road old mill dam pond/Stroud Circle/Trentini Ave/Hope Lutheran Church - private property, NCDOT Bridge work to be done in this area 2016 along with 72" culvert extension
- Ailey Young Park RSC at end of dam- checking structural integrity of dam prior to installation, looking into grant funding and requested in budget for FY 15-16.
- Deerfield Crossing- private development under bank ownership, towf greenway and dedicated open space not accepted in this area yet
- 9500 White Carriage Drive RSC- will commence with installation of greenway trail in 2016
- 9316 Bramdon Ct, Song Sparrow- will commence with installation of greenway trail in 2016
- Working with Wake Forest garden club to install planting and bank stabilization in watershed
- Groves Field Lane headwater stream repair project
- Smith Creek Soccer Center Buffer replant, fall 2015
- Coir log installation for benthos habitat, summer 2015
- Miller Park Stream rehab fall/winter 2015
- Smith Creek at Burlington Mills to Neuse River bank stabilization and habitat enhancement

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: none to date

4. Water quality monitoring data (water chemistry):
    a. volunteer data obtained from past 18 months (Adopt a Stream program)- non technical, not lab certified, showed all sites within range for water quality, 13 of 20 sites adopted/readopted since July 2014. Ordering more supplies for quarter 8-12.

5. Map of BMP locations in watershed: complete

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

<u>Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:</u>

04/01/15	Jan-March 2015	Report #9
12/31/14	Oct- Dec 2014	Report #8
9/30/14	Aug- Sept 2014	Report #7
6/30/14	Apr- June 2014	Report #6
3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Apr-June 2015, Quarterly Report #10

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan***):**

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*Apr-June 2015***):**
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –completed

2. Contact stakeholders-complete, ongoing update meetings

- 4/27/15 Monthly Progress Meeting
- 5/29/15 Monthly Progress Meeting
- 6/25/15 Monthly Progress Meeting

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete
    Next benthos field assessment site visit scheduled for July 23, 2015

11. Develop environmental education schedule -complete

    - Visiting schools and conducting water quality education at charter and public schools in community

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9

13. Schedule education days- ongoing

    - Developing Spring Workshops and School events to occur in Fall 2015

14. QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data collected on July 17, 2014. Showed slight increase from good-fair to good. More group 1 taxa present. Last sampling July 23, 2015.

- Benthic habitat will be installed along Sanford Creek near Heritage South to help determine if benthos population is able to sustain itself. Relocation conducted April 2015.

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): none to date, evaluation of potential retrofits complete, potential grant opportunities being pursued. Estimated $25,000 in CIP budget starting in 2016 for the next four years.

Identified potential repair projects:

- Jones Dairy Road 3,000 LF stream repair- looking into grants or mitigation bank
- Heritage Lake Road old mill dam pond/Stroud Circle/Trentini Ave/Hope Lutheran Church - private property, NCDOT Bridge work to be done in this area 2016 along with 72" culvert extension
- Ailey Young Park RSC at end of dam- checking structural integrity of dam prior to installation, Duke Energy Water Resources Fund grant applied LOI, CWMTF winter 2016.
- Deerfield Crossing- private development under bank ownership, towf greenway and dedicated open space not accepted in this area yet
- 9500 White Carriage Drive RSC- will commence with installation of greenway trail in 2016
- 9316 Bramdon Ct, Song Sparrow- will commence with installation of greenway trail in 2016
- Working with Urban Forestry Coordinator to install planting and bank stabilization in watershed

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: none to date

4. Water quality monitoring data (water chemistry):
    a. volunteer data obtained from past 24 months (Adopt a Stream program)- non technical, not lab certified, showed all sites within range for water quality. 13 of 20 sites adopted/readopted since July 2014. Ordering more supplies for quarter 11-12.

5. Map of BMP locations in watershed: complete

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

<u>Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:</u>

4/7/15	Jan-Mar 2015	Report #9
12/31/14	Oct- Dec 2014	Report #8
9/30/14	Aug- Sept 2014	Report #7
6/30/14	Apr- June 2014	Report #6
3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: July- Sept 2015, Quarterly Report #11

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan*):

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*July-Sept 2015*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –completed

2. Contact stakeholders-complete, ongoing update meetings, results meeting to be held in final quarter prior to submission of final report. Additional meetings will be held after report approval/acceptance.

   7/24/15- Monthly Progress Meeting- field samples
   8/25/15- Monthly Progress Meeting
   9/28/15- Monthly Progress Meeting

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

9. Establish website – complete

   http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
   http://www.wakeforestnc.gov/watershed-education.aspx
   http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx
   http://www.wakeforestnc.gov/backyard-stream-repair.aspx
   http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete
    Final benthos field assessment site visit July 24, 2015

11. Develop environmental education schedule -complete

    - Visiting schools and conducting water quality education at charter and public schools in community

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9

13. Schedule education days- ongoing

- Workshops and School events to occur in Fall/Winter 2015
- Worked with future Eagle Scout to provide habitat logs in stream along Sanford Creek
- Worked with future Eagle Scout to provide soft trail along Wake Forest Reservoir

14. QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data collected on July 17, 2014. Showed slight increase from good-fair to good. More group 1 taxa present. Last sample taken July 24, 2015. Results pending.

- Benthic habitat installed along Sanford Creek near Heritage South. Benthos population/taxa is able to sustain itself. Relocation conducted April 2015, samples taken in July 2015.

<u>Additional Required Reporting</u>

Associated Project data:

1. BMPs installed (#, Size, area treated): evaluation of potential retrofits complete, and potential grant opportunities being pursued. Estimated $25,000 in CIP budget starting in 2016 for the next four years. Applying for EPA Urban Waters Grant, Duke Energy Water Resources Grant, EEG DOJ Smithfield grant, NC Parks PARTF grant. In addition, many of the locations have nearby development and have retrofitted or added new BMPs to improve water quality.

Identified potential repair projects:

- Jones Dairy Road 3,000 LF stream repair- looking into grants or mitigation bank
- Heritage Lake Road old mill dam pond/Stroud Circle/Trentini Ave/Hope Lutheran Church - private property, NCDOT Bridge work to be done in this area 2016 along with 72" culvert extension. Project to be pursued under mitigation or grant funding.
- Ailey Young Park dam removal and stream repair. Grants applied for to assist with project-Duke Energy Water Resources Fund grant applied (status tbd), USFWS grant applied for fish passage removal (status tbd), CWMTF winter 2016.
- Deerfield Crossing- private development under bank ownership, towf greenway and dedicated open space not accepted in this area yet.
- 9500 White Carriage Drive RSC- will commence with installation of greenway trail in 2016
- 9316 Bramdon Ct, Song Sparrow- will commence with installation of greenway trail in 2016
- Working with Urban Forestry Coordinator to install planting and bank stabilization in watershed- Fall 2015.

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: will conduct additional samples and conclude after BMP's and projects are complete.

4. Water quality monitoring data (water chemistry):
    a. 137 volunteer data samples obtained using LaMotte low cost water quality kits from past 27 months (Adopt a Stream program)- non technical, not lab certified, showed all sites within range for water quality. 13 of 20 sites adopted/readopted since July 2014. Ordered more supplies for quarter 11-12. Will continue program and look at adding additional watersheds.

5. Map of BMP locations in watershed: complete

Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:

7/9/15	Apr-June 2015	Report #10
4/7/15	Jan-Mar 2015	Report #9
12/31/14	Oct- Dec 2014	Report #8
9/30/14	Aug- Sept 2014	Report #7
6/30/14	Apr- June 2014	Report #6
3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

North Carolina's Section 319 NPS Program
Quarterly Progress Reporting

Project Title: Smith Creek Watershed Restoration and Implementation Project

DWQ Contract Number: 5038
Contract Period: Jan. 2013 – Dec. 31, 2015
Project Manager(s): Holly E. Miller, PE, CPESC, CFM
Reporting Period: Oct- Dec 2015, Quarterly Report #12

<u>Project Outputs and Deliverables</u> (*cut and paste from approved workplan*):

1. Create stakeholder list
2. Contact stakeholders
3. Delineate subwatersheds
4. Evaluate existing data
5. Identify data gaps
6. Conduct impervious cover analysis
7. Estimate sediment loads
8. Create mean annual flood curve
9. Establish website
10. Begin field assessment using EPA Rapid Habitat Assessment protocol
11. Develop environmental education schedule
12. Revise website
13. Schedule education days
14. Conduct initial benthos sampling

<u>New Data/Activities/Project Progress</u> (*Oct- Dec 2015*):
Please report activities for each deliverable listed above, following the same numbering system. "No activity" is acceptable if there was no progress made for a given deliverable for the quarter being reported.

1. Create stakeholder list –completed

2. Contact stakeholders-complete, ongoing update meetings, results meeting to be held in final quarter prior to submission of final report. Additional meetings will be held after report approval/acceptance.

    10/26/15- Monthly Progress Meeting
    11/23/15- Monthly Progress Meeting
    12/21/15- Monthly Progress Meeting

3. Delineate subwatersheds – complete

4. Evaluate existing data – complete

5. Identify data gaps- complete

6. Conduct impervious cover analysis – complete

7. Estimate sediment loads – complete

8. Create mean annual flood curve- complete

9. Establish website – complete

    http://www.wakeforestnc.gov/residents-engineering_environmentaleducation.aspx
    http://www.wakeforestnc.gov/watershed-education.aspx
    http://www.wakeforestnc.gov/adopt-a-stream-1.aspx
    http://www.wakeforestnc.gov/water-quality-data.aspx
    http://www.wakeforestnc.gov/backyard-stream-repair.aspx
    http://www.wakeforestnc.gov/water-quality-data.aspx

10. Begin field assessment using EPA Rapid Habitat Assessment protocol – complete
    Final benthos field assessment site visit July 24, 2015

11. Develop environmental education schedule -complete

    - Visiting schools and conducting water quality education at charter and public schools in community

12. Revise website - ongoing

    - As data is collected website will be updated with sample locations and values, also see #9

13. Schedule education days- complete

14. QAPP is complete, first set of benthos sampling conducted on July 22, 2013, data has been evaluated as good-fair, up from fair in 2010. Second set of data collected on July 17, 2014. Showed slight increase from good-fair to good. More group 1 taxa present. Last sample taken July 24, 2015.

   - Benthic habitat installed along Sanford Creek near Heritage South. Benthos population/taxa is able to sustain itself. Relocation conducted April 2015, samples taken in July 2015.

Additional Required Reporting

Associated Project data:

1. BMPs installed (#, Size, area treated): evaluation of potential retrofits complete, and potential grant opportunities being pursued. Estimated $25,000 in CIP budget starting in 2016 for the next four years. Applied for Duke Energy Water Resources Grant, EEG DOJ Smithfield grant, NC Parks PARTF grant. In addition, many of the locations have nearby development and have retrofitted or added new BMPs to improve water quality.

Identified potential repair projects:

- Jones Dairy Road 3,000 LF stream repair- looking into grants or mitigation bank
- Heritage Lake Road old mill dam pond/Stroud Circle/Trentini Ave/Hope Lutheran Church - private property, NCDOT Bridge work to be done in this area 2016 along with 72" culvert extension. Project to be pursued under mitigation or grant funding.
- Ailey Young Park dam removal and stream repair. Grants applied for to assist with project-Duke Energy Water Resources Fund grant applied (status tbd), USFWS grant applied for fish passage removal (status tbd), CWMTF winter 2016.
- Deerfield Crossing- private development under bank ownership, towf greenway and dedicated open space not accepted in this area yet.
- 9500 White Carriage Drive RSC- will commence with installation of greenway trail in 2016
- 9316 Bramdon Ct, Song Sparrow- will commence with installation of greenway trail in 2016
- Working with Urban Forestry Coordinator to install planting and bank stabilization in watershed- Winter 2015.

2. Lat/Longs all BMPs and project area: complete

3. Load reductions associated with BMPs: will conduct additional samples and conclude after BMP's and projects are complete.

4. Water quality monitoring data (water chemistry):
   a. 141 volunteer data samples obtained using LaMotte low cost water quality kits from past 30 months (Adopt a Stream program)- non technical, not lab certified, showed all sites within range for water quality. 13 of 20 sites adopted/readopted

since July 2014. Ordered more supplies for quarter 11-12. Will continue program and look at adding additional watersheds.

5. Map of BMP locations in watershed: complete

Previous Reports Listed in Reverse Chronologic Order by Date of Quarterly Report:

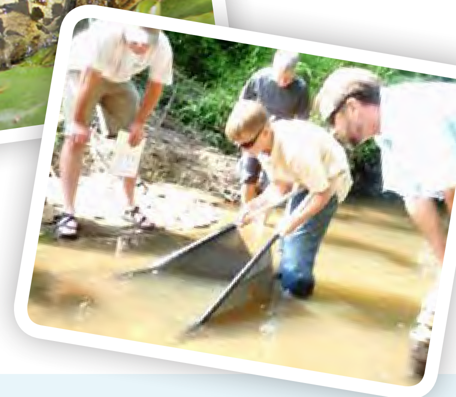
9/24/15	July-Sept 2015	Report #11
7/9/15	Apr-June 2015	Report #10
4/7/15	Jan-Mar 2015	Report #9
12/31/14	Oct- Dec 2014	Report #8
9/30/14	Aug- Sept 2014	Report #7
6/30/14	Apr- June 2014	Report #6
3/31/14	Jan-Mar 2014	Report #5
12/31/13	Oct- Dec 2013	Report #4
10/15/13	July-Sept 2013	Report #3
07/25/13	April-June 2013	Report #2
04/08/13	Jan-Mar 2013	Report #1

APPENDIX F
ADOPT A STREAM PROGRAM MATERIALS

TOWN of WAKE FOREST ADOPT-A-STREAM

Clean Water Begins Here

Adopt-A-Stream volunteers are environmental stewards who play a vital role in keeping Wake Forest's streams healthy. By taking a proactive role, you can help identify problems and repair streams in Wake Forest.



How does the program work?

To adopt a stream, your group agrees to perform one of the following tasks on a section of the stream for a period of one year.

OPTION A:
WATER QUALITY MONITORING

Just like diagnosing a person or pet that is sick, we take all the symptoms of a stream together to determine its health.

By observing the color of the stream we can tell the type of pollutant that might be in the water. Observing fish behavior (or absence of fish) also gives us clues to water quality.

As a water quality monitor, your group will make observations and record what you see in your stream section for a period of one year. You will work from a field data sheet and make monthly observations of algae, insect life, condition of stream bank, appearance of water, odors and stream flow. You will also collect data using monitoring kits.

Your group will be provided with all the equipment you need including nets, kits and safety vests. Each time you collect data, you will submit your findings to the town's Engineering Department so our staff can quickly address any problems.

OPTION B:
STREAM CLEAN-UP

Your group agrees to organize at least two stream clean-ups in the adopted stream section. After each litter collection, you will submit a form to briefly describe the types of trash your group collected such as tires, bottles, paper, etc. Your group may want to schedule the clean-ups to coincide with Earth Day and North Carolina's Big Sweep. Safety vests, bags and gloves will be provided.

OPTION C:
STREAM REPAIR, PLANTING OR DRAIN LABELING

Depending on your interest and abilities, you can choose to help with stream restoration work. Volunteer help is needed planting native trees and shrubs along the stream bank to create a healthy buffer zone.

Help is also needed spray painting a stenciled message on all storm drains. The message reminds citizens that what goes into the storm drain ends up in the stream.

Can anyone volunteer to adopt a stream?

We encourage individuals, families, scout troops, youth groups, schools, churches, community and service organizations, and special interest groups to get involved. Anyone with an interest in healthy streams and the outdoors is welcome to help us preserve and maintain our waterways.

A stream section must be adopted for a period of one year with the option to renew the agreement after the year is completed.

CAN CHILDREN PARTICIPATE?

Minors under age 18 may participate if their parents or guardians sign a *Youth Participation Release* in addition to the *Adopt-A-Stream Release Form*. The parent or guardian must accompany the minor, or must assign responsibility to an adult representative of the Adopt-A-Stream applicant.

ARE VOLUNTEERS COMPENSATED?

As a volunteer you will not be paid, but you will be rewarded.

- Your name and/or group name will appear on the town's website, Community Channel 10 and in *Our Town* newsletter.
- You will receive special recognition at our Volunteer Appreciation Event.
- Most important, you will have the satisfaction of knowing that you're actively protecting and maintaining natural resources.

CAN WE CONTRACT THE WORK TO SOMEONE ELSE?

You may do the work yourself, with other volunteers, or hire a contractor to do the work for you. All volunteers or contractors must first sign an *Adopt-A-Stream Release Form* prior to beginning work.

Where do I sign up?

If you or anyone you know is interested in adopting a Wake Forest stream, please contact the Adopt-a-Stream Program Coordinator:

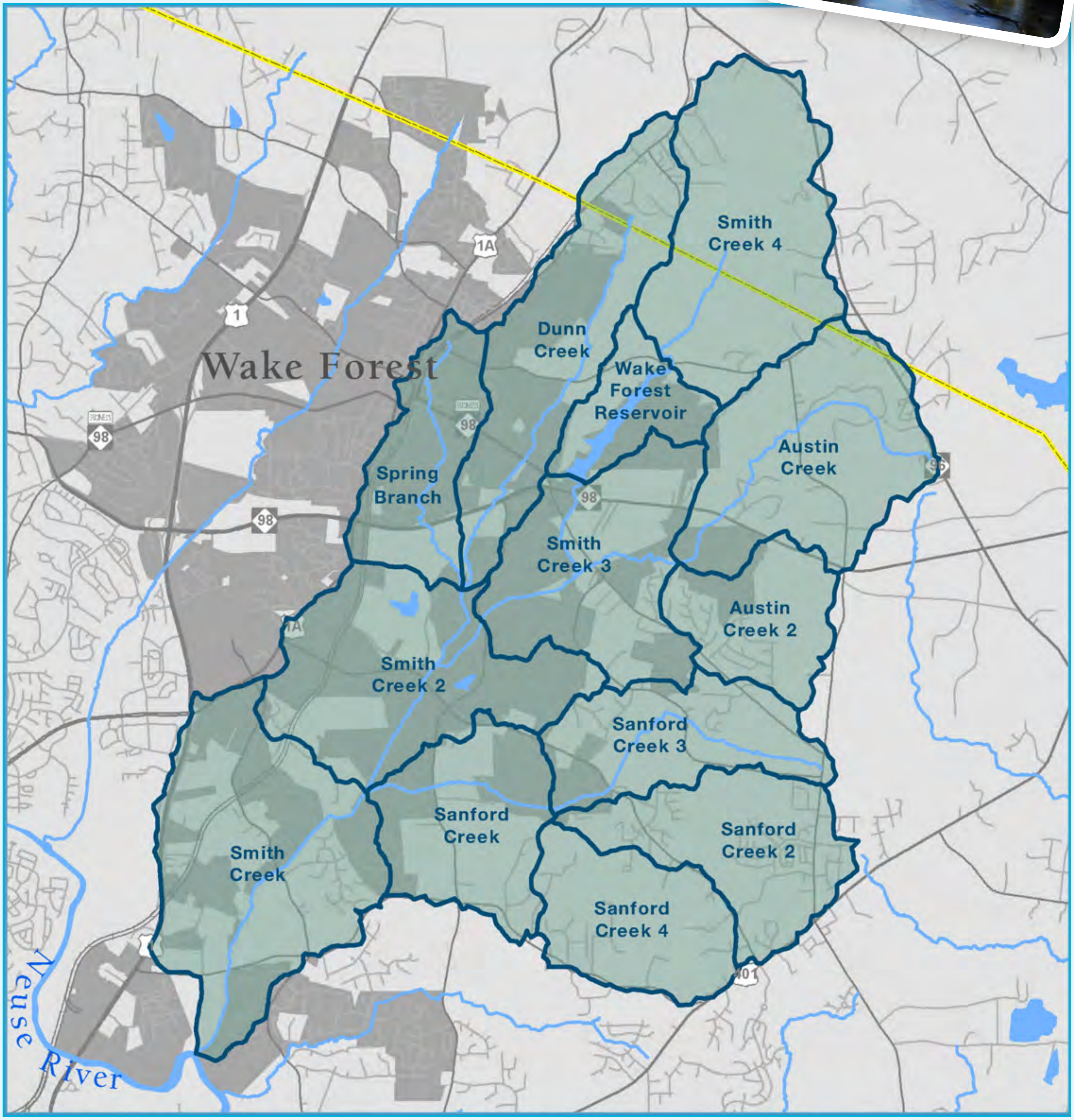
Assistant Town Engineer
Holly Miller
hmiller@wakeforestnc.gov
(919) 435-9443

Before any work is initiated, the volunteering group or individual will sign an *Adopt-A-Stream Agreement* outlining the responsibilities and obligations of adopting a stream, and each participating trail volunteer must sign an *Adopt-A-Stream Release Form* that must be mailed or delivered to Wake Forest Town Hall before any work may begin.

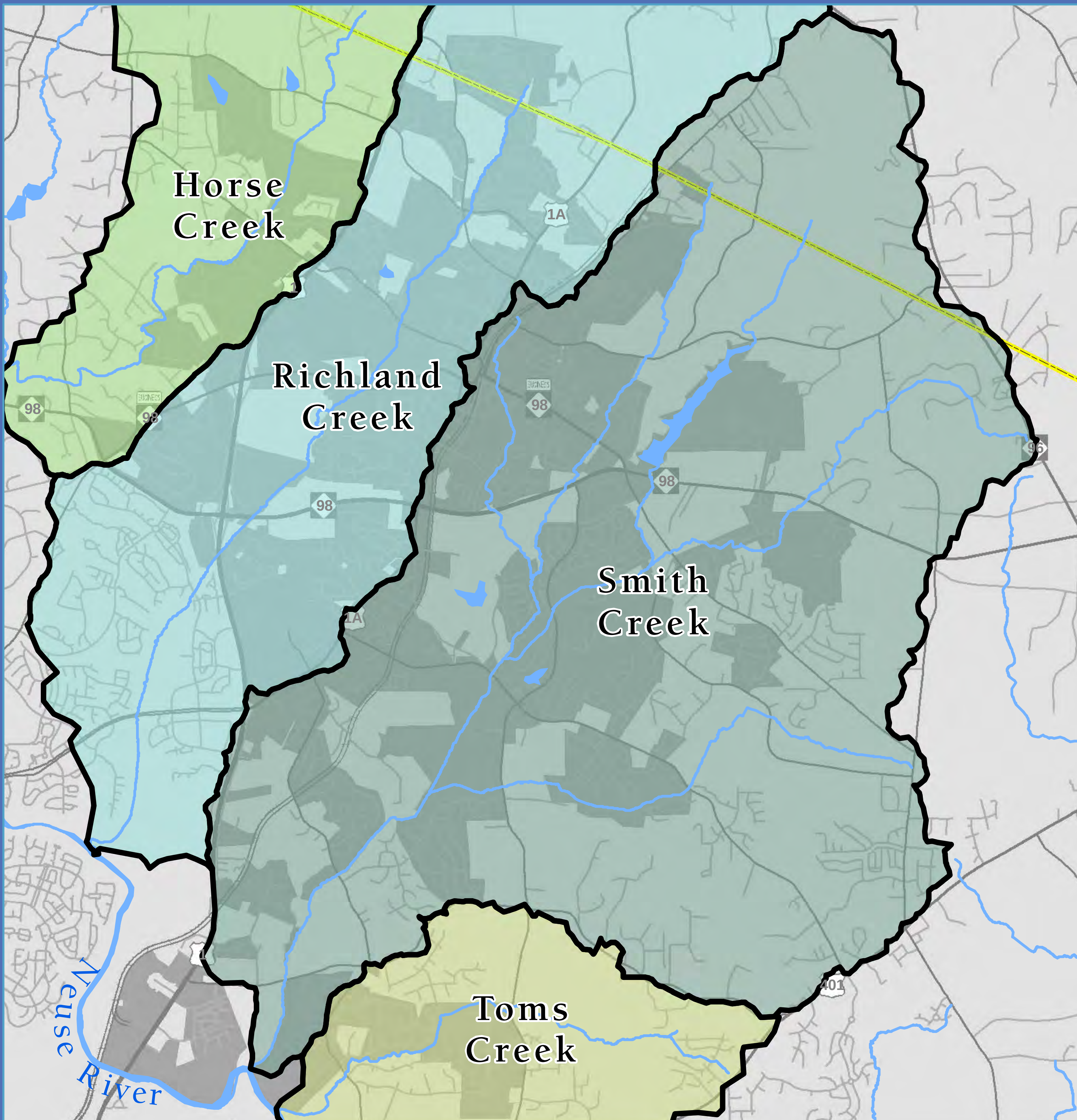
Stream sections that are available in the Adopt-A-Stream program are shown on the next page.

Stream sections for adoption in Wake Forest

The map below shows the different sections of streams in the Adopt-A-Stream program.
When signing up, you may indicate your preference for a specific section.



Watersheds of Wake Forest



Legend

- Major Streams
- Major Water Bodies
- Streets
- Town Limits
- County Boundary

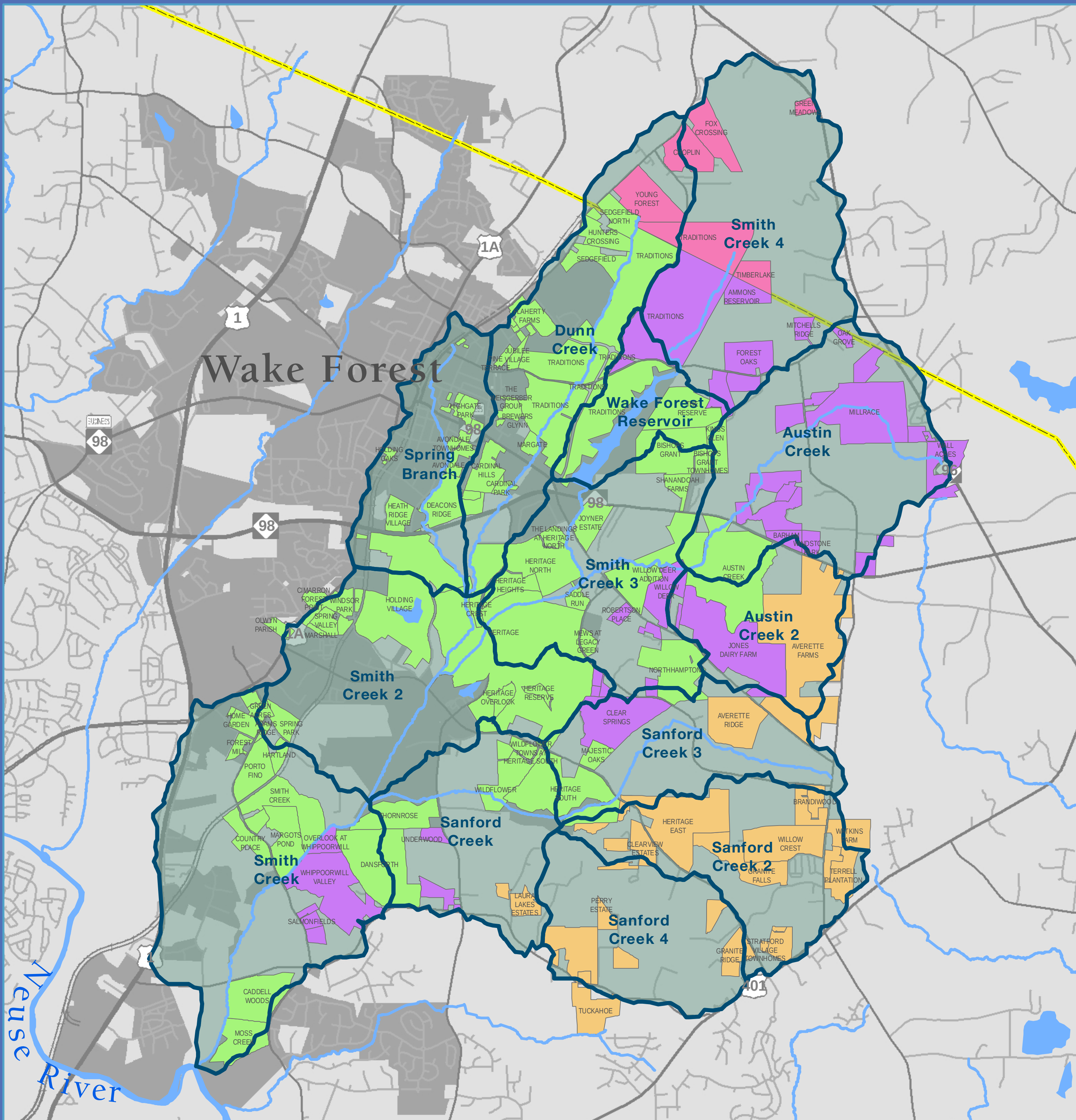
0 0.5 1 2
Miles

N
W E
S

TOWN *of* WAKE FOREST

Please note that this map is intended for illustrative purposes only. For specific inquiries regarding data displayed here, contact the Wake Forest Engineering Department at 919-435-9443.

Subdivisions in Smith Creek Watershed



Legend

Subdivisions

- Franklin County
- Rolesville
- Wake County
- Wake Forest
- Major Streams
- Major Water Bodies
- Streets
- Town Limits
- County Boundary

0 0.5 1 2

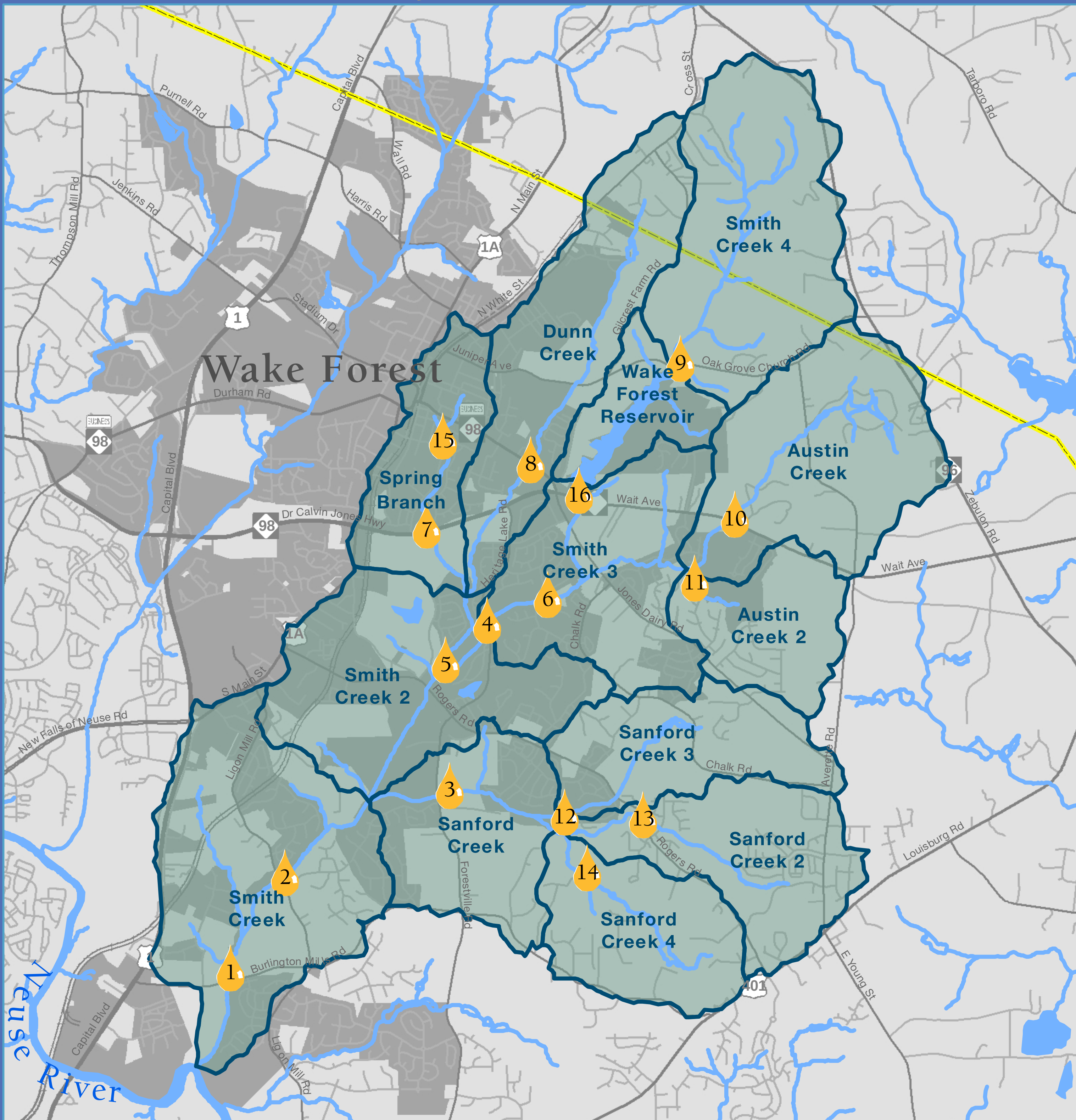
Miles

N W E S

TOWN of WAKE FOREST

Please note that this map is intended for illustrative purposes only. For specific inquiries regarding data displayed here, contact the Wake Forest Engineering Department at 919-435-9443.

Turbidity Sample Sites



Sample Sites

Major Streams

Major Water Bodies

Streets

Town Limits

County Boundary

Smith Creek Watershed Project

0 0.5 1 2

Miles

N E S W

TOWN of WAKE FOREST

Please note that this map is intended for illustrative purposes only. For specific inquiries regarding data displayed here, contact the Wake Forest Engineering Department at 919-435-9443.

Stream Buffer

TREE PLANTING

Wednesday

2 pm - 5 pm

TOWN of WAKE FOREST
ADOPT-A-STREAM
Clean Water Begins Here

TOWN *of*
WAKE FOREST

Stream Buffer

TREE PLANTING

TODAY

2 pm - 5 pm

TOWN *of* WAKE FOREST

TOWN of WAKE FOREST
ADOPT-A-STREAM

Clean Water Begins Here

think green WAKE FOREST

The Town of Wake Forest is planting the seeds for a greener, cleaner community.

Tree Planting and Preservation

Wake Forest demonstrates tremendous support for the urban forest and our green canopy. The town has proudly been designated a Tree City USA for over 30 years. Additionally, Wake Forest has received the Tree City USA Growth Award 14 times – virtually unprecedented in the United States.

wakeforestnc.gov/parksrecreation_urbanforestry.aspx

Rainwater Harvesting

Wake Forest installed a rainwater harvesting system at the Public Works Operations Center in 2009. The setup includes a series of 10" gutters that drain into two 5,000-gallon cisterns and one 1,200-gallon cistern. The water collected in these tanks is used in the town's street sweeper, boring machine and the brine system. The saved water is also used to clean storm drains. The rain-water harvesting system is expected to save over 100,000 gallons of water per year.

Great Grass Giveaway

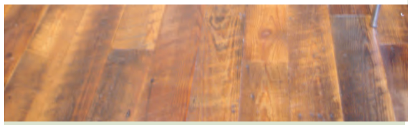
In May 2009, the Town of Wake Forest introduced a new program designed to promote water conservation by giving away drought-tolerant Bermuda grass seed for those willing to convert their Fescue lawns. Any Wake Forest homeowner willing to reseed his/her lawn is eligible for free seed during the annual Great Grass Giveaway. The event is held on the fourth Saturday of April each year at the Public Works Operations Center.

wakeforestnc.gov/greatgrassgiveaway.aspx
919-435-9570

Street Light Pollution Standards

Lighting regulations minimize light pollution with stringent standards for fully-shielded, full cutoff, and flat lenses for lighting on and off of buildings to preserve the night sky and light levels that eliminate light intrusion onto neighboring properties.

The town has applied for a grant to install up to 4,000 LED lights throughout Wake Forest. LED street lights use between 35 and 67 percent of the energy required for a comparable standard high pressure light.



Environmentally Responsible Town Hall

The new Wake Forest Town Hall was constructed with sustainability as a top priority. The building achieved LEED Platinum certification, the highest level possible, for its many green features which include daylighting, ultra low-flow water fixtures, low VOCs and the use of recycled building products.

wakeforestnc.gov/newtownhall.aspx

Green Transportation

Wake Forest received grants for and adopted a Pedestrian Plan in 2006 and a Bicycle Plan in 2008. The town also introduced transit service in 2009 that includes a local bus route, park & ride lot, and a limited stop connector to downtown Raleigh, an enviable accomplishment for a town our size. Wake Forest placed a main gateway road into downtown on a "road diet" by installing landscaped medians, two roundabouts, bike lanes, and pedestrian-scale street lighting.

Curbside Recycling

Wake Forest became the first municipality in Wake County to offer roll-out comingled curbside community recycling utilizing a 48-gallon cart. Our program has been cited nationally for its high customer participation rate and rate of recycling and is recognized as a "Model City" by the Climate Group.

wakeforestnc.gov/residents-publicworks_recycling.aspx
919-435-9570

Sustainable Energy Policy

In January 2009 Wake Forest adopted an internal sustainable energy policy in order to establish the town's overall energy baseline usage with a goal of reducing energy consumption in all its facilities. Wake Forest set ambitious energy reduction goals, made necessary improvements, and provided all town staff with practical energy awareness educational materials.

Open Space & Greenways

Our Open Space and Greenways Plan is being implemented through partnerships with the City of Raleigh, Wake County, North Carolina, and the federal government to maximize land acquisition, trail construction, and connectivity. Our trails will someday be part of a system of interconnected trails extending from Maine to Florida and across the state. Greenways improve water quality and preserve wildlife habitat and biodiversity.

wakeforestnc.gov/residents-parksrecreation.greenways.aspx

think green
WAKE FOREST

Top ways you can help keep Wake Forest a clean and green place to live

To see more ideas, visit:
wakeforestnc.gov/think-green.aspx.

Plant a tree and become a Tree Steward

Pick up a free tree seedling at the town's annual Tree Seedling Giveaway and plant it in your yard. Native trees provide shade and habitat for birds and animals. Residents with a passion for trees can join the Tree Steward program to become a certified volunteer. Tree Stewards can plant new trees in public areas and educate citizens on proper tree care.

wakeforestnc.gov/tree-steward-program.aspx
919-435-9565

Collect rain for watering plants

Collecting rainwater runoff to water landscapes and gardens ensures healthier plants that are less susceptible to disease. It also increases the amount of treated water that is available for drinking, cooking and bathing. As a service, the Town of Wake Forest offers 65-gallon rain barrels to area residents for $95 each. Rain barrels can be purchased at town hall.

wakeforestnc.gov/rainbarrels.aspx
919-435-9570

Switch to a drought tolerant lawn

Most lawns in our area are planted with Fescue grass. Fescue is a cool season grass that will turn brown in the summer if it is not watered regularly. If you prefer a lush green lawn in the summer, switch to Bermuda grass which requires one third the water of Fescue. Free Bermuda seed is available at the town's annual Great Grass Giveaway.

wakeforestnc.gov/greatgrassgiveaway.aspx
919-435-9570

Use energy-efficient appliances

When shopping for home appliances, pay attention to the energy saving features and design. Products with superior energy efficiency will have the Energy Star logo. In addition, use the clothes dryer only with a full load and clean the dryer filter after every use. When washing clothes, use cold water when possible and run it with a full load of clothes.

wakeforestnc.gov/energy-conservation-tips.aspx

Switch to Pay-As-You-Go electric service

Wake Forest Power customers that switch to Pay-As-You-Go electric service can log in and see how much electricity they are using on any given day. Adjust the thermostat a few degrees and see what happens to your costs. It's all in your hands.

wakeforestnc.gov/pay-as-you-go.aspx
919-435-9400

Use fuel efficient vehicles

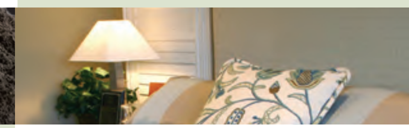
By choosing the most fuel efficient vehicle that meets your needs, you can help reduce greenhouse gas emissions from burning gasoline and diesel and reduce our country's oil dependence. Choose cars with better gas mileage and walk, bike, carpool or take public transit more often.

www.fueleconomy.gov

Compost your kitchen waste

Reduce your garbage output and create a rich (and free!) soil conditioner for your garden. Compost is created by mixing grass cuttings and fallen leaves with fruit and vegetable spoils. The Town of Wake Forest offers the Earth Machine, an 80-gallon compost bin to area residents for $45. Purchase the bin at town hall.

wakeforestnc.gov/compostbins.aspx
919-435-9570

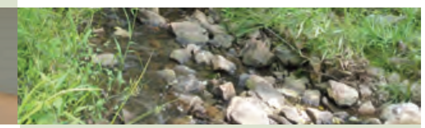


Sign up for a free energy audit

If you are a Wake Forest Power customer, you qualify for a free energy audit. Upon, request, the town's residential energy auditor will visit your residence and help uncover the most cost-effective ways to save energy and lower your energy costs. Assistance in weatherizing your home is available for citizens that qualify.

wakeforestnc.gov/homeenergyaudits.aspx.
919-435-9472

wakeforestnc.gov/weatherization-assistance-program.aspx
919-435-9466



Become an Adopt-A-Stream volunteer

Adopt-A-Stream volunteers are environmental stewards who play a vital role in keeping Wake Forest's streams healthy. By taking a proactive role, you can help identify problems and repair streams in your town. Volunteers help with monitoring water quality, stream clean-up and planting trees in the stream buffer.

wakeforestnc.gov/adopt-a-stream-1.aspx
919-435-9443

STREAM CLEAN-UP

SATURDAY

9 am - noon

TOWN of WAKE FOREST
ADOPT-A-STREAM

Clean Water Begins Here

TOWN *of*
WAKE FOREST

STREAM CLEAN-UP

TODAY

9 am - noon

TOWN of WAKE FOREST
ADOPT-A-STREAM

Clean Water Begins Here

TOWN *of*
WAKE FOREST

Release Form

This release is executed on _______________, 20____, by ______________________________(name of group) (the "Group") and its members, whose signatures appear below (hereinafter referred to collectively as "Releasors").

In consideration of being permitted to participate in the Town of Wake Forest's Adopt-A-Stream Program (the "Program") for the section of the trail identified in the Group's Adopt-A-Trail Program Agreement (the "Agreement") with the Town of Wake Forest, Releasors, being of lawful age, for themselves and their personal representatives, heirs, and next of kin, hereby release and forever discharge the Town of Wake Forest and its officials, employees, and/or agents (hereinafter referred to collectively as the "Town"), from any and every claim, demand, action or right of action, of whatsoever kind or nature, either in law or in equity arising from or by reason of any bodily injury or personal injuries known or unknown, death and/or property damage resulting or to result from any accident that may occur as a result of participation in the Program.

Releasors acknowledge that participation in the Program is voluntary and that the work to be performed and the work environment may be hazardous. Releasors agree that they will follow all Town of Wake Forest safety guidelines and directives and that they will wear and use all required items of safety gear and equipment for the performance of their volunteer duties. Releasors assume full responsibility for and assume the risk of bodily injury, death or property damage while picking up litter, debris, or loose brush and otherwise participating in the Program. Releasors agree to indemnify the Town from any loss, liability, damage or cost the Town may incur due to the presence of Releasors in, on or near those sections of the trail referenced in the Group's Agreement.

Releasors acknowledge their likeness may be captured by the Town for use in promotional, news, or informational media. Participation in this activity implies consent. If any Releasor does not wish for such a photo to be used, please contact the Engineering Department at (919) 435-9510.

In no event shall the Releasors be considered the agents or employees of the Town.

Releasors agree that this release, waiver, and indemnity agreement is intended to be as broad and inclusive as permitted by the laws of the State of North Carolina and that if any portion of the agreement is held invalid, it is agreed that the balance shall, notwithstanding, continue in full legal force and effect.

A participating child's parent or guardian is required to sign a "Youth Participation Release" in the form attached hereto for each volunteer less than 18 years of age.

No one may participate in the Program without first having signed below as a Releasor, and no one under the age of 18 may participate without having signed as a Releasor and having a parent or guardian sign the Youth Participation Release.

This Release contains the entire agreement between the parties to this agreement, and the terms of this Release are contractual and not a mere recital.

RELEASORS:

SIGNATURE	PRINT NAME	DATE

TOWN of WAKE FOREST ADOPT-A-STREAM

Clean Water Begins Here

Youth Participation Release

To be signed for each child volunteer under the age of 18

As the parent/guardian (the “Parent”) of the minor child named below (the “Child,” and together with the Parent, the “Releasors”), I hereby give permission for the Child to participate in one or more Adopt-A-Stream Programs. By my signature I release the Town of Wake Forest for the Child, the Parent, and his or her personal representatives, heirs, and next of kin, hereby release and forever discharge the Town of Wake Forest and its officials, employees, and/or agents (hereinafter referred to collectively as the “Town”), from any and every claim, demand, action or right of action, of whatsoever kind or nature, either in law or in equity arising from or by reason of any bodily injury or personal injuries known or unknown, death and/or property damage resulting or to result from any accident which may occur as a result of the Child’s participation in the Adopt-A-Stream Program.

The undersigned acknowledges that participation in the Adopt-A-Stream Program is voluntary and that work on trails may include exposure to numerous hazards. Releasors assume full responsibility for and assume the risk of bodily injury, death or property damage. Releasors agree to indemnify the Town from any loss, liability, damage or cost the Town may incur due to the participation of the Child in the Adopt-A-Stream Program.

In no event shall the Child be considered the agent or employee of the Town.

The Parent agrees that this release, waiver, and indemnity agreement is intended to be as broad and inclusive as permitted by the laws of the State of North Carolina and that if any portion of the agreement is held invalid, it is agreed that the balance shall, notwithstanding, continue in full legal force and effect.

The Parent realizes that transportation to and from the program is the Parent’s responsibility, and that if anyone connected with the program transports the Child on Parent’s behalf, Parent will hold that party blameless for any accident or injury that may occur. Such absolution is to be binding when the above individuals are acting within the scope of the activity. Parent hereby accepts the instructor, supervision, facilities, and equipment, as being satisfactory for the program activity named above. Parent understands that insurance coverage is Parent’s responsibility, and Parent certifies that Parent has read and agreed to the terms stated above and that all information provided is correct to the best of Parent’s knowledge.

The Parent further states that it has carefully read this Release and knows the contents of the Release and signs this Release as his or her own free act, on the Parent’s behalf and on behalf of the Child. The Parent hereby represents and warrants to the Town that he or she is the parent or legal guardian of the Child, with full legal authority to execute this Release on the Child’s behalf.

____

PRINT NAME OF MINOR CHILD

____

SIGNATURE OF PARENT OR GUARDIAN DATE

____

PRINT NAME OF PARENT OR GUARDIAN

____

STREET ADDRESS CITY STATE ZIP

____

TELEPHONE

Program Agreement

The Town of Wake Forest (the "Town") and ____
(name of participating business, organization or individual) (the "Participating Entity") recognize the need and desirability of litter-free and environmentally healthy streams. The Adopt-A-Stream Program (the "Program") has been established for community and civic organizations as well as private businesses and industry to contribute toward the effort of monitoring and maintaining cleaner waterways.

The Participating Entity agrees to not hold the Town responsible for any injuries it, its participants, representatives, employees or agents may suffer or damages that it, its participants, representatives, employees, or agents may cause or suffer as a result of participation in the program.

The Participating Entity agrees to require all participants to sign a Town Adopt-A-Stream Program Release Form and/or a Youth Participation Release (the "Release Form"), as applicable, as a condition to any individual participant's participation in the program. The Participating Entity agrees to deliver a completed Release Form to the Engineering Department prior to each time that it performs work pursuant to this Program Agreement.

The Participating Entity agrees to indemnify and hold harmless the Town and its employees, officers, agents and representatives with respect to any liability, costs or expenses incurred by the town in connection with the failure of a participant to sign the required waiver.

If the Participating Entity enters into a contract with a business, organization or individual to clean its adopted section of the trail, it agrees to notify [________________________________] in writing within ten (10) calendar days of entering into its agreement (whether written or verbal) with the contractor and acknowledges that failure to notify such person of such action may result in termination of the agreement.

The Town recognizes the Participating Entity as the adopting organization for:

____

STREAM SECTION

The Participating Entity volunteers to (check one):

☐ **Monitor Water Quality—**make monthly observations and record what you see in your stream section. You will work from a field data sheet and record your observations. You will also collect data using monitoring kits.

☐ **Clean-up Streams—**pick up litter at least two (2) times a year along the adopted section of stream.

☐ **Repair Streams, Plant Trees or Label Drains—**assist with stream buffer restoration projects and/or labeling of storm drains.

This agreement shall be valid for a period beginning ________________, 20____, and ending __________________, 20_____.
The Participating Entity may cancel this agreement upon 30 days written notice to the Town of Wake Forest.

Non-Discrimination Policy: The Town of Wake Forest does not discriminate on the basis of race, color, national, origin, sex, religion, age, sexual orientation or disability in employment opportunities or the provision of services, programs, or activities. A participant alleging discrimination on the basis of any of the aforementioned areas may file a complaint with the Director of the Wake Forest Engineering Department or the Office of Equal Opportunity, US Department of the Interior, Washington, DC 20240.

Registration Process

1. Complete and sign the *Program Agreement* and *Adopting Group Contact Persons*
2. Prior to performing work, return completed *Release Form* in person or mail to:
   Town of Wake Forest | 301 S. Brooks Street | Wake Forest, NC 27587

INSECTS AND STREAM QUALITY

How clean is your stream?

You can answer that question by counting the insects in your stream. Many stream-dwelling organisms are sensitive to changes in water quality. Their presence or absence can serve as indicators of environmental conditions. Macro invertebrates (visible, spineless animals), especially insects, are easy to find. By following the technique below and filling out the Aquatic Survey Sheet, you can diagnose your stream's water quality.

Kick-Net

The equipment required includes a kick-net (a fine mesh net with a supporting pole on each side) or an old window screen with no holes, forceps, a clear plastic container, several jars for collecting, and a microscope or magnifying glass.

1. Select a riffle typical if the stream, that is, a shallow, fast-moving area with a depth of 3 – 12 inches and stones which are cobble-sized (2 – 10 inches) or larger.

2. Place the kick-seine or screen at the downstream edge of the riffle. Be sure that the bottom of the seine or screen fits tightly against the stream bed (you may want to use rocks to hold the net down tightly), so no insets can escape along this point. Also, don't allow any water to flow over the screen top. This too could allow insects to escape.

3. Disturb the streambed for a distance of 3 feet upstream of the kick-seine. Brush your hands over all rock surface to dislodge any attached insects. Stir up the bed with hands and feet until the entire 3 foot square area has been worked over (Remember to be careful of your hands. Watch for objects that might cut). All detached insects will be carried into the net. For 60 seconds, and no longer, kick the streambed with a sideways motion of the net. This may bring up a few ground dwellers.

4. When step 3 is completed, remove the net with a forward scooping motion. The idea is to remove the net or screen without allowing any of the critters to be washed from its surface.

5. Place the new on a flat, light-colored area. Using forceps, pick all of the creatures from the net and place them in a pan, or just wash the creatures into a light-colored bucket where they may be easily seen. Any creatures moving, even if it looks like a worm, is

part of the sample. (Do not miss snails and clams.) Look closely since most of these organisms are only a fraction of an inch long.

6. Once all animals have been removed from the net (excluding any fish or other vertebrates – throw these back quickly so they might survive the stress of being out of their habitat), count the total number. Then separate them into look-alike groups. Use body shape and number of legs and tails primarily since the same family can vary some in size and color.

7. If the stream seems to have a problem, for example, no bugs are found, take a quick second sample from another spot, preferably a riffle. If your results are similar, you might want to check another spot about a quarter mile upstream. When you find a place where the variety of benthic creatures is greater and the numbers are more balanced, then you know the problem occurs between that spot and where you last tested downstream.

8. Sometimes, it can be difficult to locate a riffle. For example, in an area where there is excessive sand, boulders and rocks are often completely covered. In these cases, remember that a riffle is an area of turbulence. It may be composed of rocks, logs, or even an old car! Look for large stationary objects. Things which have "weathered" in the stream a while. (The critters need time to make these objects home.) Then kick around them much as you would rocks. However, if the substrate is covered with sand or composed entirely of bedrock and a "kickable" riffle does not exist, you can use the bank habitats. For example, place your net downstream of a submerged tree or grass roots and kick in and around them. Make sure it is an area where water is flowing or there is current.

Sweep Net Survey

Most people are familiar with the dip nets used for fishing, A sweep net is similar in construction, but the mesh of the net is smaller. In fact, the net mesh found on a sweep net is smaller than the mesh net used on most kick-nets.

If your group has the money, you can order sweep nets from scientific supply houses, however, a very adequate net can be simply and inexpensively constructed by arranging screen mesh over an old dip net frame. This net will not be ideally correct, but it will be useful for collecting a wide variety of creatures. **Small aquarium dip nets can be used for sampling an area many times in a short period (i.e. student sampling over several periods during a week).**

To perform a sweep net survey, take your net and sweep around the banks of your stream. Sweep in and around tree roots and vegetation. Then, stir the sediment near the stream bank with your foot and use the sweep net to scoop up the creatures jarred loose. Dragonflies, damselflies, mayflies, and snails will often be found in a sweep net sample.

Smith Creek

TOWN of WAKE FOREST

ADOPT-A-STREAM

Clean Water Begins Here

Visual Stream Diagnosis

"How can I tell what is wrong with my stream?" Just like diagnosing a person or pet that is sick, you take all the symptoms and signs together and try to hazard a guess. These tables are to help you know what kind of problems you might have in your area and the obvious signs of those problems. Read each table several times allowing you to get a feel for threats to streams. You may want to take these tables with you when you visit your stream.

Characteristics of Surrounding Area Draining Into Stream

Forests	Check for sedimentation (cloudy or muddy water) from erosion caused by logging, road building, or any clearcutting.
Farmland (crops, pastures, feedlots)	Check for excessive algae growth caused by fertilizer or manure draining into stream. Also watch for sedimentation caused by poor farming practices and possible pesticides.
Urban Settings	Urban run-off can carry with it all sorts of pollution including metals, salts, chemicals, and oil. Insect counts may indicate the presence of one of the above, but chemical analysis may be needed to pinpoint it.
Industries	Because the variety of by-products of industry, the stream should be tested for both organic and toxic substances. Keep an eye out for excessive algae and absence of animal life, such as insects and fish.
Sewage (treatment plants or pipelines)	Look for organic pollution indicated by absence of some aquatic organisms and/or extreme abundance of others.
Mining	Check for sedimentation and acid drainage. Acid drainage can be detected by a low pH. A yellowish-orange deposit may be present on bottom.

Construction	Land disturbing activities such as development and road building are the leading cause of erosion and sedimentation, so watch for cloudy or dirty water.
Residential (homes)	Lawn fertilizer, detergents used for washing clothes or cars, oils drained from autos and grass clippings are common forms of residential pollution. Keep an eye open for excessive algae growth, white foam greater than 3 inches high, color sheet on surface or absence of organisms in select counts.

Physical Indicators of Water Pollution

Color of Stream

Green	If the stream is excessively green, this could be an indication of nutrients being released into stream, feeding algae. What To Do: Check watershed for possible fertilizer or manure run-off areas.
Orange-red	Orange to red deposits could be cause by acid drainage. What To Do: Check watershed for mining and watch for industrial waste draining into the stream.
Light brown (muddy or cloudy)	Sedimentation deposition caused by erosion. What To Do: Search upstream for disturbed ground left open to rainfall. Remember, if the source is a drainpipe, don't stop there.
Yellow coating on stream bed	Indication of sulfur entering the stream. What To Do: Check upstream for industrial waste or coal-using operation.
Multi-color reflection	Indicates oil floating in stream. What To Do: Check closely upstream for source – waste oil may have been dumped along the stream.
Yellow-brown to dark-brown water	Acids released from decaying plants What To Do: Naturally occurs each fall when dead leaves collect in the stream. Also common in stream draining marsh or swampland.
White, cottony masses on stream bed	Could be "sewage fungus" What To Do: The presence of this growth indicates sewage or other organic pollution.

Stream Odor:

Rotten egg odor	Indicates sewage pollution. Odor may also be present in marsh or swampy land.
Musky odor	May indicate presence of untreated sewage, livestock waste, algae or other conditions.
Chlorine	This may mean that a sewage treatment plant is over chlorinated their effluent.
Chemical	May indicate the presence of an industrial plant or the spraying on nearby agricultural land.
Foaming	When white and greater than 3 inches high, it may be due to detergents.
	What To Do: Check upstream for industrial or residential waste entering the stream.

Fish as Biological Indicators of Water Quality

Odd Behavior	Jumping out or non-responsive action of fish may indicate toxic substance in the stream.
	What To Do: Chemical analysis is needed to find the source, but check upstream to see where it begins.
Absence of Fish	This is a good indication of a badly stressed stream. The cause could be urban run-off, sewage seepage or toxics entering the stream.
	What To Do: Chemical analysis is needed to find the source. Again, check upstream to find where it begins.

Stream Survey Data Sheet

Stream Subwatershed and location:

____

Sample Number ________ of _________

Date______________

Time______________

Weather___________

Please make sure you have the forms on file prior to starting:

___ Waiver form
___ Monitoring agreement
___ Current contact data

Please forward a copy of this form via email to Holly Miller at hmiller@wakeforestnc.gov or drop off/mail to:

Town of Wake Forest
Engineering Department
301 South Brooks Street
Wake Forest, NC 27587

If you have any questions please contact Holly Miller at 919-435-9443.

Type of monitoring (place a ✓ on the appropriate line):

___________ Visual monitoring

___________ Macro invertebrate count

___________ Chemical test (check which parameters taken)

_____Temperature
_____pH
_____Dissolved Oxygen
_____Nitrogen
_____Phosphorus
_____Turbidity
_____Conductivity

___________ Stream clean up

(Optional)

You should select a riffle where the water is not running too fast (ideal depth is 3-6 inches), and the stream bed consists of coddle sized stones or larger if possible. Try to select a 3 square foot area if possible.

Width of study area	
Pool section ____________	Pool section ____________
Riffle section __________	Riffle section ___________
Depth of Study area	

Speed of stream flow (velocity in meters/sec) _________________

Use tennis ball method or multi parameter unit

Water Temp (degrees Celsius) ________________

Visual Monitoring

(place a ✓ on the appropriate line that matches the condition)

Water Appearance	Stream Bed Coating	Odor
______ Scum	______ Orange/red	______ Rotten egg
______ Foam	______ Yellowish	______ Musky
______ Muddy	______ Black	______ None
______ Clear	______ Brown	______ Other
______ Tea	______ Gravel	
______ Milky	______ None	
______ Oil sheen		
______ Brownish		
______ Other		

Bank Cover

Look at the stream bank on both sides and visually determine % of ground cover in several spots (if different mark left bank or right bank looking downstream)

______ Good (70-100% of bank soil covered by plants, rocks, logs)

______ Fair (30-70% of bank soil covered by plants, rocks, logs)

______ Poor (0-30% of bank soil covered by plants, rocks, logs)

Stability of Stream Bank

Stand on the bank and determine if the material sinks below your feet in several locations (5-10)

______ no spots ______few spots ______many spots

Bed Composition of Riffle

Use sand cards to determine size

_____ % silt
_____ % sand (1/16-1/4”)

_____ % gravel (1/4- 2”)
_____ % cobbles (2-10”)
_____ % boulders (> 10” stones)

Algae color
_____ light green
_____ dark green
_____ brown coat
_____ matted on stream bed
_____ hairy looking

Algae location
_____ widespread
_____ localized
_____ % bedcover

Land use near stream reach/section
(place a ✓ on the appropriate line that matches the condition, if more than one use is nearby check all that match)

_____ stores/commercial
_____ woods
_____ farm fields (cows/horses)
_____ agriculture (crops)
_____ other:
____

_____ factories/industrial
_____ residential
_____ golf course/playing field
_____ construction

Please answer the following questions regarding point source pollution with a yes or no

________ Are there any direct discharge pipes (stormwater, grey water, other) into creek?

If yes, note pipe size, qty, type (RCP, plastic, other), discharge color:
Pipe size (interior diameter in inches) ________
Quantity________
Type (RCP-concrete, HDPE-black plastic, PVC- white)_________
Discharge Color ___________

________ Did you test below and above discharge to determine any chances in water quality?

If yes, please note differences:

Upstream Downstream

Temp ___________ ___________
pH ___________ ___________
DO ___________ ___________
Nitrogen ___________ ___________
Phoshorus ___________ ___________
Turbidity ___________ ___________
Conductivity ___________ ___________

Water elevation drop

Note structures causing water level differences of 1 foot or more by placing a ✓ on the appropriate line that matches the condition, if more than one condition exists in the reach/section check all that apply

______ Waterfalls (including rock weirs in stream restorations, stream crossings, etc…)
______ Down trees, log jams
______ Beaver dams
______ Pipe structures that have undermined
______ None
______ Other:
____

Barrier to fish passage

Note structures limiting/prohibiting fish passage by placing a ✓ on the appropriate line that matches the condition, if more than one condition exists in the reach/section check all that apply

______ Waterfalls (including rock weirs in stream restorations, stream crossings, etc…)
______ Down trees, log jams
______ Beaver dams
______ Pipe structures that have undermined
______ None
______ Other:
____

Aquatic Life

In this section, we will be searching the stream for macro invertebrates who are indicators of water quality. Use the leaf pack cards, macro books and kicknets to find organisms record your results by tolerant level. This should be done in 3 times in a riffle section of the creek with in a 24 foot area. For each test, multiply the groups I, II, and III by the appropriate value, then add up to get the stream index value. This value then gives us a range for water quality and stream support value based on your field counts.

Excellent (> 22)	Fair (11 – 16)
Good (17 – 22)	Poor (< 11)

Circle the macro species that was found

Group I- intolerant	Group II- moderate	Group III- tolerant
Caddis fly larvae	beetle fly larvae	aquatic worms
Dobson fly larvae	clam	black fly larvae
Mayfly nymph	crane fly larvae	leech
other snails	crayfish	midge larvae
riffle beetle (adult)	damselfly nymph	pouch snail
stonefly nymph	dragonfly nymph	
water penny larvae	scud	

Count number of circles from each group and write number on each line, then multiply by the correct number and add up to get the stream index value

	Group I	Group II	Group III
	____________	______________	_____________
Tolerant Multiplier	x 3 =	x 2 =	x 1 =
	_________	+ _________	+ _________

Sum of tolerant multipliers = _________ Stream Index value

(place a ✓ on the appropriate line that matches the condition, if more than one group is nearby check all that match)

Fish

_____ Scattered individuals

_____ Scattered schools

Crayfish

_____ scarce

_____ abundant

Please use the space below to describe other interesting finds (turtles, frogs, great blue heron, hawk, deer, snakes, spiders, etc…):

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

Chemical and Physical Parameters

Sample _____ of _______

Date ______________

Time taken: ________

Location ____

Weather today _______________________

Rain fall within 24 hours, if so how much? ______________

48 hours? _____________

72 hours? _____________

Air Temperature (degrees C/degrees F) ___________

Water Temperature (degrees C/degrees F) ___________

pH ________________ Testing Method: ___________

DO ________________ mg/L Notes:

Conductivity __________

Turbidity ____________

Nitrogen _____________

Phosphorus ___________

Stream Flow __________ cfs

Litter Cleanup

Date _______________

Length of stream cleaned _________________________

Group ____

Number of participants ___________________________

Describe % and type of litter collected around stream

____
____
____

Average number of small and large items collected

Small, paper, trash	cans and bottles	tires, carts, etc…
______ 0 – 5	______ 0 – 5	______ 0 – 5
______ 5 – 10	______ 5 – 10	______ 5 – 10
______ 10 – 50	______ 10 – 50	______ 10 – 50
______ 50 +	______ 50 +	______ 50 +

Total number of trash bags ________________

Unusual items

____
____
____