STREAM RESTORATION PLAN

City of Fayetteville Property
Cross Creek and Little Cross Creek
Cumberland County, North Carolina

N.C. Wetlands Restoration Program
NCDENR_DWQ

October 2002

EARTH TECH

A tyco INTERNATIONAL LTD. COMPANY

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1.0 INTRODUCTION

The North Carolina Wetlands Restoration Program (NCWRP), in conjunction with the City of Fayetteville, North Carolina, has identified portions of Cross Creek and Little Cross Creek for stream restoration. Both portions of the streams identified are on property owned by the City of Fayetteville. Combined the two streams total 2,065 feet of potential restoration. Both streams have undergone a multitude of alterations in an effort to accommodate development and improve stormwater carrying capacity. Currently, the land use surrounding the restoration area is residential, institutional, and commercial. Fayetteville has plans to turn the property into a park for surrounding residents.

Restoration will require determining how far the streams have departed from their natural stability, and what the stable forms of the streams (channel dimension, pattern, and profile) are under the current hydrologic conditions within the drainage area. It has been determined that Cross Creek and Little Cross Creek both have good restoration potential, and the techniques listed below will be incorporated into their restorations:

- Alteration of channel dimension, pattern, and profile to achieve stream stability.
- Placement of natural material structures in the stream to reduce erosion and enhance aquatic habitat.
- Stabilization of stream banks with herbaceous and woody vegetation.

1.1 PROJECT DESCRIPTION

The property is located in Fayetteville, North Carolina off of the Martin Luther King Freeway (formerly the C.B.D. Loop), between Murchison Road and Bragg Boulevard (Figure 1). Washington Drive and Blue Street, both off of Murchison Road, surround the project site. The potential restoration area can be accessed from either Washington Drive or Blue Street. The current reaches to be restored are approximately 2,065 feet in length.

The 2,065 feet is divided into to three reaches. Reach 1 consists of 560 feet of Cross Creek downstream of its convergence with Little Cross Creek. Reach 2 is the remaining 800 feet of Cross Creek upstream of the convergence. Reach 3 is 705 feet of Little Cross Creek. Although historical mapping was not obtained for this site, the existing conditions provide strong evidence that the stream has been altered.

The main factors in the degradation and impairment of the streams are hydrologic changes in their watersheds, past straightening of the channels, and the filling of their floodplains. Both streams have attempted to adjust to the alterations through bed profile and pattern changes. Along all three reaches, downcutting has progressed until reaching a consolidated sandy clay medium that is acting as temporary grade control. However, this control is not stable and continues to erode. The streams will continue to adjust until they reach equilibrium. These reaches have no woody vegetation along the majority of their banks, allowing for further erosion. The eastern bank of Reach 1 is entirely covered with kudzu (*Pueraria lobata*). A photo log on the site is included in Appendix A.

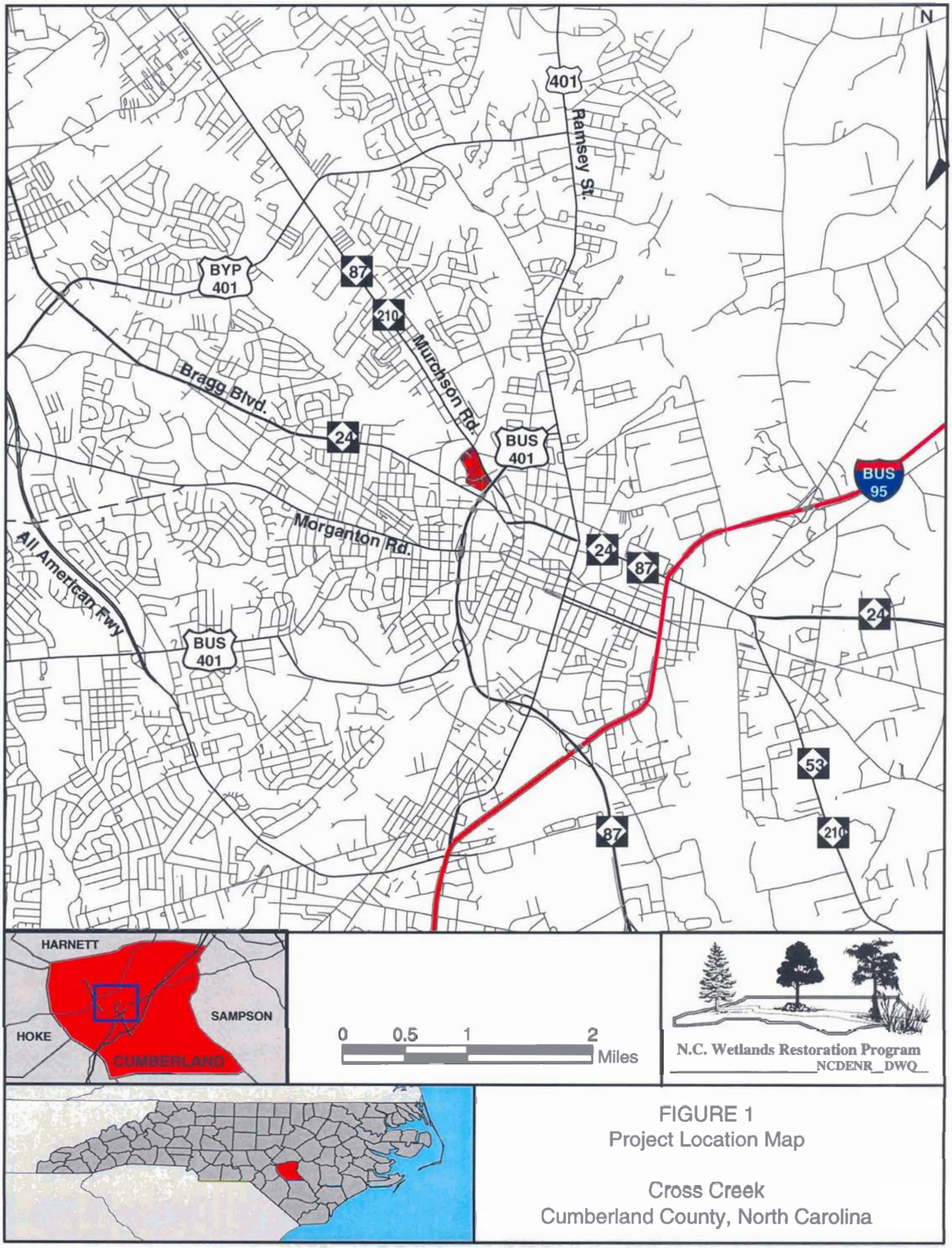


FIGURE 1
Project Location Map

Cross Creek
Cumberland County, North Carolina

1.2 GOALS AND OBJECTIVES

The goals and objectives of the Cross Creek and Little Cross Creek restorations are listed below.

1. Provide a stable stream channel that neither aggrades nor degrades while maintaining its dimension, pattern, and profile with the capacity to transport its watershed's water and sediment load.
2. Provide the stream with a floodplain at the stream's current elevation.
3. Improve aquatic habitat with the use of natural material stabilization structures such as root wads, rock vanes, woody debris, and a riparian buffer.
4. Provide wildlife habitat and bank stability through the creation of a riparian zone.

1.3 STREAM SURVEY METHODOLOGY

"General Technical Report RM-245, Stream Channel Reference Sites: An Illustrated Guide to Field Technique", a US Forest Service publication, is used as a guide when taking field measurements. Accurate field measurements are critical to determine the present condition of the existing channel, conditions of the floodplain, and watershed drainage patterns.

Earth Tech contracted surveyors with 4D Site Solutions, in Raeford, to conduct a topographic survey of the restoration site in June 2002. This mapping was used to evaluate present conditions, new channel alignment, and grading volumes. Mapping also provided locations of property pins, large trees, vegetation lines, culverts, utilities, roads, and elevation contours.

A walkover of the property was conducted to better evaluate the drainage properties of the area surrounding the restoration site. A windshield survey was also conducted to determine the existing conditions within the watershed. During the site visits, six cross-sections were taken using standard differential leveling techniques. These cross-sections were used to gather detail on the present dimension and condition of the channel. Cross-sectional area was calculated using the bankfull features. See Appendix B for a copy of the existing condition surveys.

1.3.1 Stream Delineation Criteria - Classification

Dave Rosgen developed his stream classification system in order to accomplish the following:

1) Predict a river's behavior
2) Develop specific hydraulic and sediment relationships for a given stream type and its state
3) Provide a mechanism to extrapolate site-specific data to stream reaches having similar characteristics

4) Provide a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines and interested parties

The Rosgen Stream Classification System is based on five criteria: width/depth ratio, entrenchment ratio, slope, sinuosity, and channel materials. All cross-sections were classified using this system.

1.3.2 Bankfull Verification

The foundation of Dave Rosgen's classification system is the concept of bankfull stage, which is the point of incipient flooding. The width/depth and entrenchment ratios described above depend on the correct assessment of bankfull. If bankfull is incorrectly determined in the field, the entire restoration effort will be based on faulty data. It is important to verify the physical indicators observed in the field with either gage data or a regional curve to ensure the correct assessment of the bankfull stage.

The bankfull stage is determined in the field using physical indicators. The following is a list of commonly used indicators that define bankfull (Rosgen, 1996):

- The presence of a floodplain at the elevation of incipient flooding.
- The elevation associated with the top of the highest depositional feature (*e.g.*, point bars, central bars within the active channel). These depositional features are especially good stage indicators for channels in the presence of terrace or adjacent colluvial slopes.
- A break in slope of the bank and/or a change in the particle size distribution, since finer material is associated with deposition by overflow, rather than deposition of coarser material within the active channel.
- Evidence of an inundation feature such as small benches below bankfull.
- Staining of rocks.

The dominant bankfull indicators along both Cross Creek and Little Cross Creek are high scour lines and breaks in slope along the backs of alternate bars. The most common method of verifying bankfull stage is to compare the field-determined bankfull stage with measured stages at a stream gaging station. This calibration can be performed if there is a stream gage within the study area's hydrophysiographic region.

In ungaged areas, Dave Rosgen recommends verifying bankfull with the development of regional curves. The regional curves normally plot bankfull discharge (Q_{bkf}), cross-sectional area, width, and depth as a function of drainage area. There are efforts currently underway to develop Coastal Plain Regional Curves, but none have been published at the time of this plan's development. Preliminary findings of stream restoration professionals working on the Coastal Plain Curve were studied and used as a comparison to the data Earth Tech obtained.

2.0 EXISTING CONDITIONS

2.0 WATERSHED

2.1.1 General Description of the Watershed

Cross Creek and its tributary, Little Cross Creek, are located within the Coastal Plain Physiographic Province of the Cape Fear River Basin. Portions of the northwestern areas of the watershed are located within the Sandhills Physiographic Province. The headwaters of Cross Creek originate about 7.5 miles north-northwest of the project area. The headwaters of Little Cross Creek originate 6.0 miles north-northeast of the project area. Both streams enter the site as third-order streams before joining to form a fourth-order stream. Cross Creek (NCDWQ Stream Index Number 18-27-(3)) and Little Cross Creek (18-27-4-(2)) both have a WS-IV classification, which is assigned to water supplies in moderately to highly developed watersheds in North Carolina. Cross Creek and Little Cross Creek account for forty percent of Fayetteville's water supply.

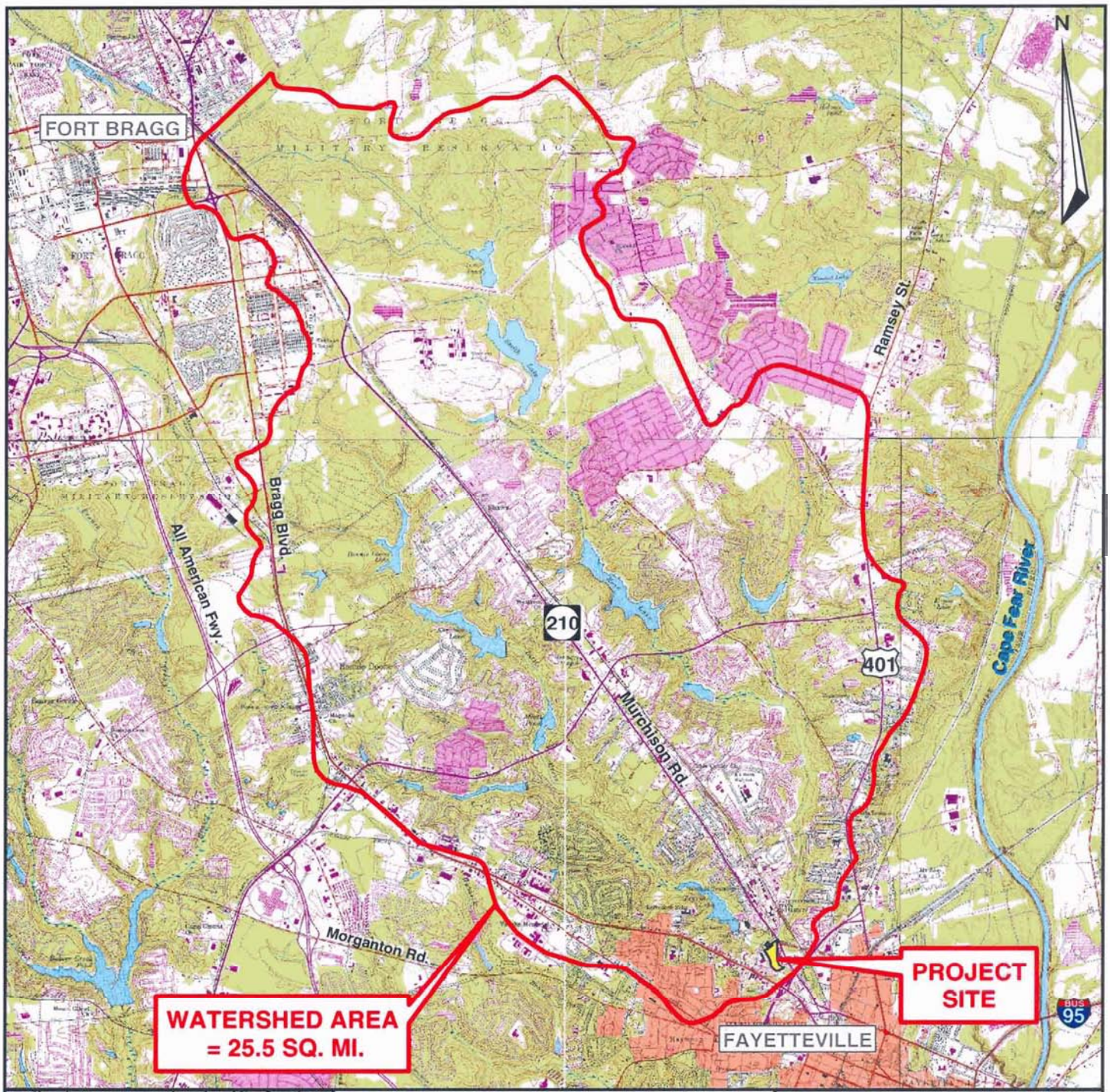
The watershed is approximately 16,300 acres or 25.5 square miles (Figure 2). Approximately 15.5 square miles (9,920 acres) drain into Cross Creek and the remaining 10.0 square miles (6,380 acres) drain into Little Cross Creek. Murchison Road is located along the ridgeline separating the two watersheds.

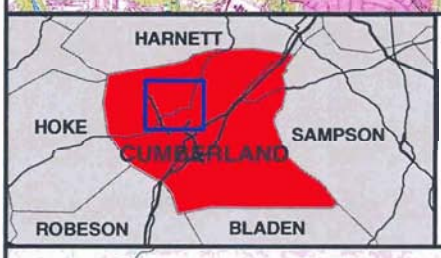
Topography of the area is characterized as gently undulating with relatively low slopes. Streams in this region tend to cut deeply into the landscape over time, so that the steepest terrain commonly is found along the stream banks. This pattern is evident in the Cross Creek Basin. In addition, slopes are steep in localized areas along manmade berms, roadside ditches, and embankments. The watershed gradient is approximately 0.45 percent. Over sixty percent of the watershed area has slopes below five percent. Land surface elevations range from approximately 300 feet to 100 feet above mean sea level. The floodplain near the project site is flat, but has been modified for development.

2.1.2 Soils of the Watershed

The soils found in the watershed and adjacent to the stream can help determine the bed and bank materials occurring in the stream. The Rosgen stream classification system uses average particle size within the bankfull channel to help classify the stream. Knowing the make up of the soils in the watershed assists in understanding the anticipated bedload and sediment transport capacity of the stream.

The majority of soils in upland areas of the watershed are Urban land (Ur) or Urban land complexes. Blaney loamy sand (BaB) or Blaney-Urban land complex (BdB,D) is mapped along the banks of Cross Creek and Little Cross Creek upstream of the project area. The Urban land unit consists of areas with more than 85% impervious cover. This results in the rapid runoff of nearly all precipitation that falls. The Faceville-Urban land complex (FcB) consists of units of Faceville soil intermingled with 30-40% cover of Urban land.





Source: USGS Quadrangles:
Fayetteville, NC, 1957, Photorevised 1987;
Manchester, NC, 1957, Photorevised 1987;
Slocomb, NC, 1948, Photorevised 1981;
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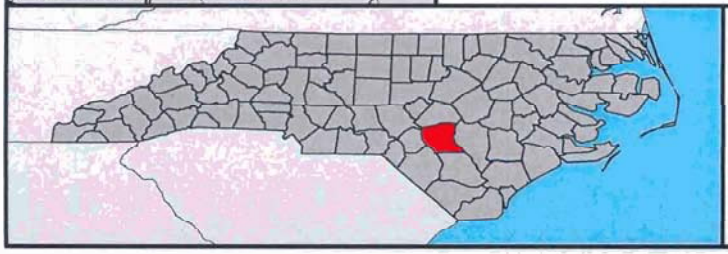


FIGURE 2
Site Location Map

Cross Creek
Cumberland County, North Carolina

Faceville soils are loamy sands found on upland flats or side slopes. They were formed in clayey upland sediments and are moderately permeable. The seasonal high water table is greater than 6 feet deep. The Blaney-Urban land complex consists of units of Blaney loamy sand intermingled with 30-40% cover of Urban land. Blaney loamy sands formed in sandy and loamy upland sediments and are moderately permeable. Brittle subsoils result in a perched water table after heavy rains.

2.1.3 Land Use/Cover and Development/Stability

Land uses within the Little Cross Creek watershed area have been identified in a 2001 Water-Resources Investigations Report published by The United States Geological Survey (Giorgino, M.J. and Silvia Terziotti, 2001). The Cross Creek watershed has very similar characteristics to the Little Cross Creek, and the percentages are assumed to be similar for both watersheds. The following is a table of landcover percentages within the watershed.

Table 1 Landcover Percentages

Landcover	Percentage
Forested	25
Water/Wetlands	3
Grassed	2
Low-intensity residential	31
High-intensity residential	9
Commercial/Industrial/Paved	28
Transitional	3

The current landcover percentages show that the watersheds are highly urbanized. Although some development continues, the majority of the watersheds are built to capacity. Redevelopment of the watershed's impervious areas accounts for the most significant ongoing development. For example, Fort Bragg, established in 1917, is undergoing extensive barracks facility renovations and additions, and residential developments continue to be built along Highway 401. It should also be noted that three percent of the watershed area is covered in water or wetlands. There are numerous impoundments located upstream of the project area, some of which serve as Fayetteville's water supply. These impoundments have significantly altered the natural hydrology of the site. The impoundments serve as detention basins for both of the watersheds, lowering the streamflow peaks. The restoration design of the two streams will assume that the watersheds are almost built to capacity and the existing impoundments will remain in operation to serve as detention basins.

2.2 RESTORATION SITE

The following sections provide a description of existing site conditions. This includes the current stream conditions, soils, and surrounding plant communities.

2.2.1 Site Description

This site is located in the central part of Fayetteville off of Murchison Road. The Glenville Water Treatment Plant is located to the north and the Martin Luther King Freeway to the south. Murchison Road is located to the east and Bragg Boulevard is located to the west. Residential lots surround the site on the north and east sides (Figure 3). Washington Drive borders the property on the west, and Blue Street borders the property on the south. Cross Creek follows the eastern boundary of the property. Little Cross Creek travels between two residential lots and across a small portion of another before flowing into the center of the City's property and joining with Cross Creek.

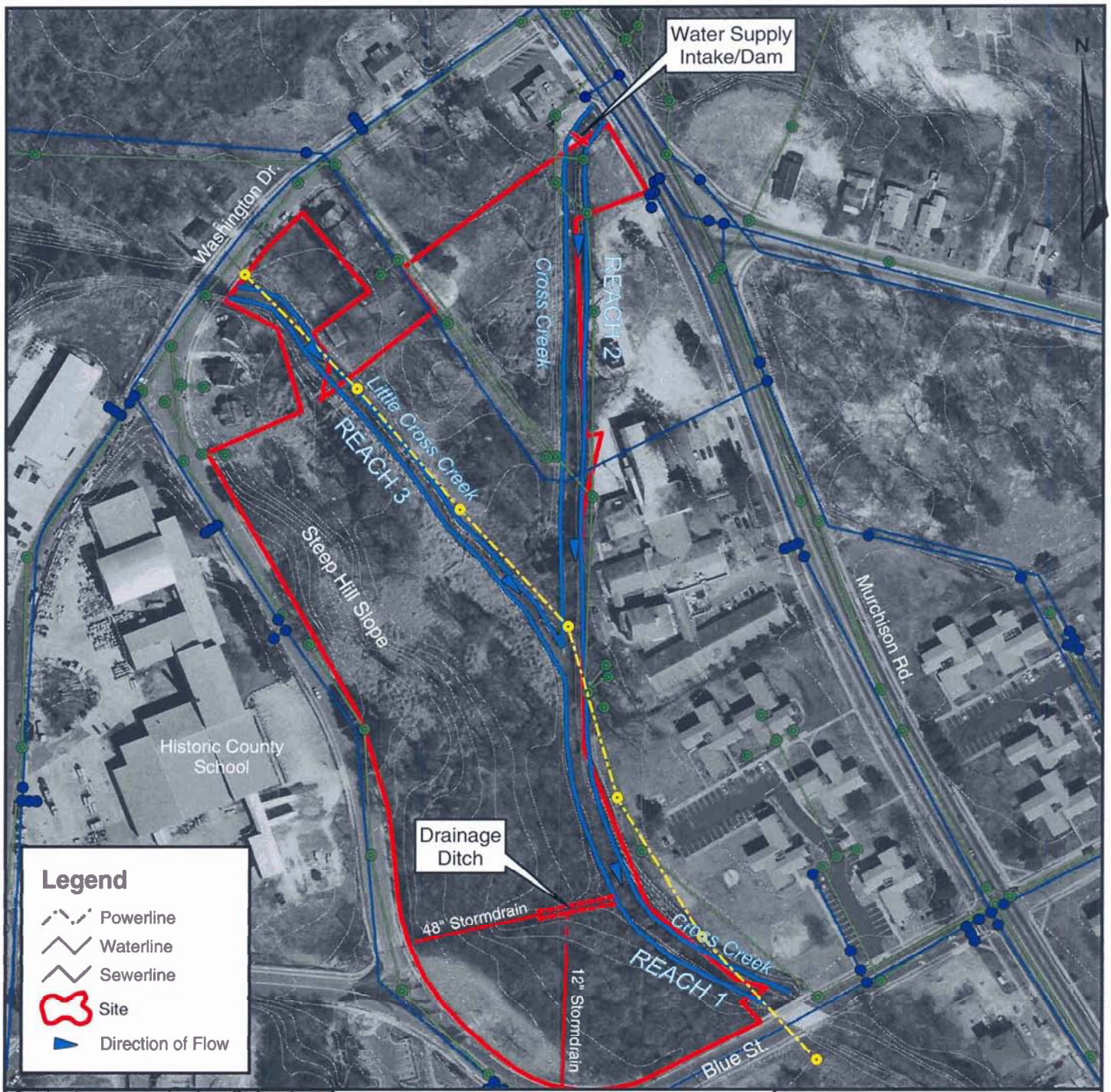
The main drainage on the property is Cross Creek (Figure 3). Reach 1 has an existing riffle bankfull width of 28.2 feet and mean depth of 2.5 feet with a channel substrate consisting of sand and consolidated sandy clay. Reach 2 has an existing riffle bankfull width of 26.5 feet and mean depth of 2.8 feet with a channel substrate consisting of sand and consolidated sandy clay. Cross Creek enters the site at the northeast corner of the property and flows approximately 800 linear feet before converging with Little Cross Creek (Reach 3). Reach 3 has an existing riffle bankfull width of 20.2 feet and mean depth of 1.9 feet with a channel substrate consisting of trash, construction rubble, sand, and consolidated sandy clay.

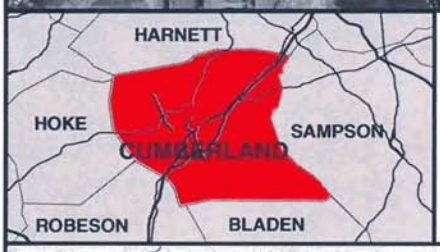
Conversations with the Fayetteville Public Works Commission revealed that the County had once used the western side of the property as a landfill. Trash and debris were visible during the initial site visit. There were large amounts in the channel bed and banks of Little Cross Creek and a large drainage channel on the south end of the property. The soils investigation, performed during a subsequent visit, indicates that the rubble is primarily within the first foot of soil throughout the property.

The topography of the site consists of a gently undulating floodplain with a steep hill slope on the northwest side of the site. The hill slope was modified to facilitate the construction of Washington Drive. Therefore, much of the hill consists of fill material. The floodplain available for relocation ranges from 400 feet wide adjacent to Reach 2 and 3 to 200 feet wide adjacent to Reach 1. A local engineer recalls that a large portion of the floodplain adjacent to Murchison Road was filled to accommodate the current development. Based on to Cumberland County mapping, the entire floodplain is designated as the FEMA 100-year floodplain.

A large drainage channel that carries runoff from a 48" reinforced concrete pipe empties into Cross Creek approximately 300 feet from the end of Reach 1. The pipe has many failed sections (refer to picture 13 in Photo Log). A large headcut that led to the failure of the pipe gives evidence that the elevation of the Cross Creek was once higher than it is now. The headcut began on Cross Creek and is working its way up the drainage channel.

Many utilities for the City of Fayetteville are present on the property. Overhead electrical lines run along the eastern banks of Reach 1 and 3 toward a sub-station to the north. A sanitary sewer line parallels the eastern banks of Reach 1 and 2. Both sewer and





0 100 200 400 Feet

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FIGURE 3
Existing Conditions

Cross Creek
Cumberland County, North Carolina

water lines run between Reach 2 and 3 before aerially crossing Reach 2. A water supply intake line and a small dam are located at the upstream end of Reach 2 near the Murchison Road culvert (refer to picture 7 in Photo Log). Although many utilities are located on the property, there are no utilities located on the western side of Reach 1 or 3.

2.2.2 Existing Stream Characteristics

Field surveys of the site and the existing stream's channels were conducted on October 11, 2001, May 29, 2002, and June 4, 2002. Photographs of the site were taken and are provided in Appendix A. The Cross Creek Restoration Site can be typically defined as a straight channel with no habitat and highly erodible banks. Flows larger than bankfull are contained within the channel, due to the lack of accessible floodplain, and therefore near-bank stresses are very high.

The following is a table of average values taken from the existing three stream reaches. Reach 2 and Reach 3 converge to form Reach 1. Refer to Appendix B for the complete set of field data.

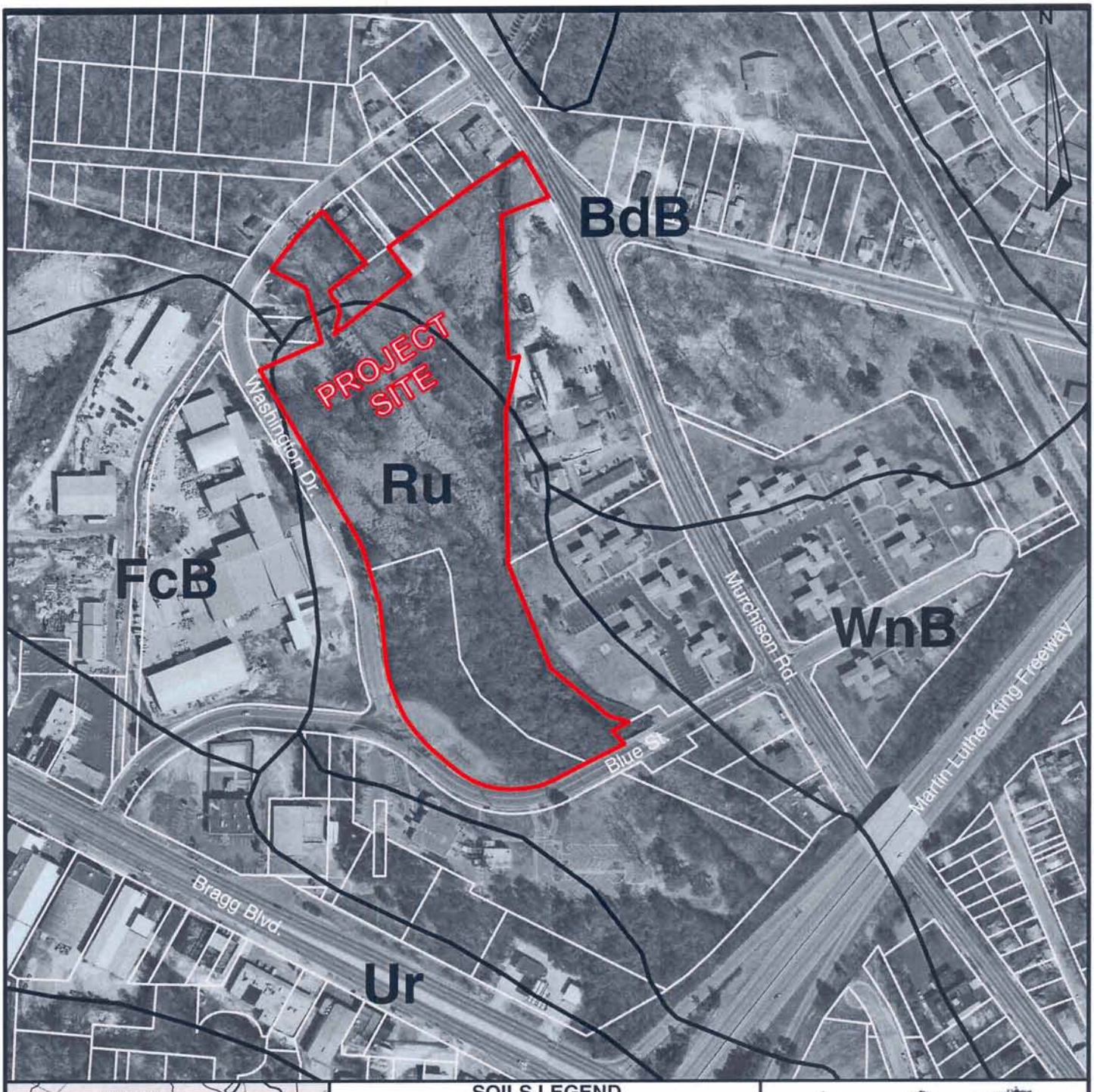
Table 2 Existing Stream Dimensions

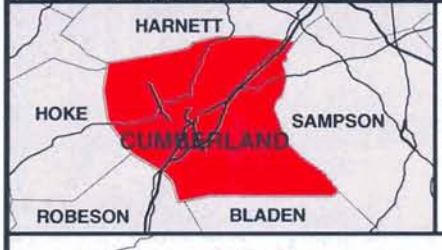
	Cross Creek	Cross Creek	Little Cross Crk
Channel Parameter	**Reach1**	**Reach 2**	**Reach 3**
Stream type	G5	G5	G5
Bankfull width (ft)	28.2	26.5	20.2
Cross-sectional Area (ft^3)	71.4	74.9	38.6
Mean depth (ft)	2.5	2.8	1.9
Maximum depth (ft)	3.5	3.9	2.7
Avg. Water Slope (%)	0.22	0.22	0.37
Entrenchment Ratio	1.25	1.9	1.6
Sinuosity	1.0	1.0	1.0
Bank Height Ratio	2.1	2.1	2.2
BEHI	Extreme	High	High

It should be noted that the bankfull flows of Little Cross Creek do not correspond to the bankfull flows of Cross Creek due to the detention of flows by impoundments along Little Cross Creek. This accounts for the lack of increase in bankfull area between Reach 2 and Reach 1. The hydrology of Cross Creek dominates the system's dimensions.

2.2.3 Soils of the Restoration Site

Based on the *Soil Survey of Cumberland and Hoke Counties, North* Carolina (USDA 1984) the majority of the soils within the project area are mapped as Roanoke-Urban land complex (Ru) (Figure 4). The upper portion of Reach 2 of Cross Creek falls within the Blaney-Urban land complex (BdB) described in Section 2.1.2. The Roanoke-Urban land complex consists of about 40-50 percent Roanoke soils, and 30-40 percent Urban land, and small inclusions of Altavista, Dogue, Wahee, and Wickham soils. Roanoke soils are





SOILS LEGEND

SYMBOL	*SOIL NAME, SLOPE*
BdD, B	Blaney - Urban Land Complex, 8-15%, 2-8%
FcB	Faceville - Urban Land Complex, 0-6%
Ru	Roanoke - Urban Land Complex
Ur	Urban Land
WnB	Wickham - Urban Land Complex, 1-6%

0 165 330 660 Feet

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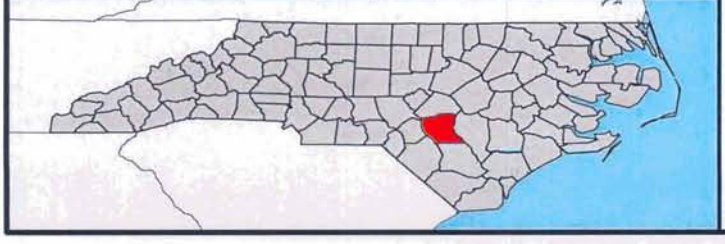


FIGURE 4
Soils Map

Cross Creek
Cumberland County, North Carolina

nearly level, poorly drained soils with slow permeability and high clay content. The water table is at or near the surface for extended periods during the winter and early spring. Roanoke is classified as a hydric soil by the NRCS.

Hand-augered soil profiles along the banks were impossible to obtain because of the presence of glass and brick fill material. A boring made about 50 feet from the right bank of Little Cross Creek in a depression at the base of a slope yielded the following partial profile, suggestive of Roanoke soils:

0-8 inches	10 YR 5/3 fine sandy loam streaks of 10 YR 3/1 and 5 YR 5/6
8-10 inches	10 YR 2/1 clay loam
10+ inches	fill material

Although the soil was dry the day of the site visit, a sparse cover of rushes (*Juncus* sp.), cattail (*Typha latifolia*), and lady's thumb (*Polygonum persicaria*) suggest that standing water had been present in this area. Another boring made in a grove of white oaks (*Quercus alba*) on a topographic high spot between the two creeks yielded the following partial profile:

0-2 inches	2.5 Y 4/1 fine sandy loam
2-14 inches	2.5 Y 6/3 fine sandy loam

The soil was extremely dry and unconsolidated, which hindered the extraction of soil for examination beyond a depth of 14 inches. A detailed subsurface analysis of the site was conducted by Froehling and Robertson, Inc. to determine the extent of fill and help evaluate the engineering capabilities of the site. The results of this study are included in Appendix C.

2.2.4 Plant Communities

The following sections describe the existing plant communities on and adjacent to the restoration site. Three plant communities are described, all of which are highly managed or disturbed: Remnant Forest, Maintained Grass Cover, and Streambank Cover. Nomenclature follows Radford *et al.* (1968).

2.2.3.1 Remnant Forest

A forest remnant occupies the downstream end of the project. The whole site was probably previously covered by a bottomland hardwood forest. The few trees remaining in this downstream area are a depauperate mix of pioneer species, which suggests that the stand is probably second growth. Tree species include hackberry (*Celtis laevigata*), sweetgum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis*), and mulberry (*Morus rubra*). There is a dense growth of herbs and vines including kudzu, English ivy (*Hedera helix*), dog fennel (*Eupatorium capillifolium*), and Johnson grass (*Sorghum halepense*).

2.2.3.2 Maintained Grass Cover

A maintained landscape dominates the floodplain. It consists mainly of managed grasses that are mown regularly. A few trees and shrubs are scattered across the area including sweetgum (*Liquidambar styraciflua*), pecan (*Carya illinoiensis*), mulberry (*Morus rubra*), water oak (*Quercus nigra*), hackberry (*Celtis laevigata*), white oak (*Quercus alba*), box elder (*Acer negundo*), and shining sumac (*Rhus copallina*). The herbaceous species include Bermuda grass (*Cynodon dactylon*), centipede grass (*Eremochloa* sp.), Johnson grass (*Sorghum halepense*) and a mixture of other species. Invasive species found throughout the floodplain include kudzu (*Pueraria lobata*), mimosa (*Albizia julibrissin*), and Chinese privet (*Ligustrum sinense*).

2.2.3.3 Streambank Cover

The streambanks throughout the project area are covered with dense herbaceous vegetation consisting of a mixture of weedy and invasive species and common streambank vegetation. The banks of Cross Creek have a higher percentage of invasive cover than Little Cross Creek. Shrubs and vines include tag alder (*Alnus serrulata*), kudzu (*Pueraria lobata*), elderberry (*Sambucus canadensis*), trumpet creeper (*Campsis radicans*), Japanese honeysuckle (*Lonicera japonica*), blackberry (*Rubus* sp.), wild grape (*Vitis rotundifolia*), and autumn olive (*Elaeagnus umbellata*). Herbaceous species include, horseweed (*Erigeron canadensis*), dog fennel (*Eupatorium capillifolium*), soft rush (*Juncus effusus*), New York ironweed (*Vernonia noveboracensis*), spotted jewelweed (*Impatiensis capensis*), Venus' looking-glass (*Specularia perfoliata*), chickweed (*Stellaria media*), a sedge (*Carex albolutescens*), a rush (*Juncus acuminatus*), a beaksedge (*Rhynchospora inundata*), tearthumb (*Polygonum hastatum*), a St. John's-wort (*Hypericum* sp.), cattail (*Typha latifolia*), lurid sedge (*Carex lurida*), a spikerush (*Eleocharis* sp.), pickerelweed (*Pontederia cordata*), vervain (*Verbena tenuisecta*), and lady's thumb (*Polygonum persicaria*).

2.2.5 Wildlife Observations

Wildlife and signs of wildlife were noted during on-site visits; however, a formal wildlife survey was not performed. Frogs, snails and small fish were observed in the stream channel. Asiatic clams (*Corbicula* sp.), an invasive mollusk species, were found in the stream channel. A variety of small birds were observed in the thickets and shrubs surrounding the stream channel and forest.

The USFWS lists 8 species under federal protection and 28 species of federal concern for Cumberland County as of July 2002 (USFWS 2002). These species are listed in Tables 3 and 4.

Table 3 Species Under Federal Protection in Cumberland County

Common Name	Scientific Name	Status
Vertebrates		
American alligator	*Alligator mississippiensis*	T(S/A)
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Invertebrates		
Saint Francis' satyr	*Neonympha mitchellii francisci*	Endangered
Vascular Plants		
American chaffseed	*Schwalbea americana*	Endangered
Michaux's sumac	*Rhus michauxii*	Endangered
Pondberry (=Southern spicebush)	*Lindera melissifolia*	Endangered
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Endangered
Small-whorled pogonia	*Isotria medeoloides*	Threatened*

Endangered - A taxon "in danger of extinction throughout all or a significant portion of its range."
Threatened - A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
***Historic record** - the species was last observed in the county more than 50 years ago.

Table 4 Federal Species of Concern in Cumberland County

Common Name	Scientific Name	Habitat Present
Vertebrates		No
Bachman's sparrow	*Aimophila aestivalis*	No
Carolina gopher frog	*Rana capito capito*	No
Northern pine snake**	*Pituophis melanoleucus melanoleucus*	No
Southern hognose snake*	*Heterodon simus*	No
Invertebrates		No
Atlantic pigtoe	*Fusconaia masoni*	No
Yellow lampmussel	*Lampsilis cariosa*	No
Vascular Plants		No
Awned meadowbeauty	*Rhexia aristosa*	No
Bog spicebush	*Lindera subcoriacea*	No
Boykin's lobelia	*Lobelia boykinii*	No
Carolina asphodel	*Tofieldia glabra*	No
Carolina goldenrod	*Solidago pulchra*	No
Carolina grass-of-parnassus	*Parnassia caroliniana*	No
Conferva pondweed	*Potamogeton confervoides*	No
Georgia indigo-bush (=Georgia leadplant)	*Amorpha georgiana* var. *georgiana*	No
Loose watermilfoil	*Myriophyllum laxum*	No
Pickering's dawnflower	*Stylisma pickeringii* var. *pickeringii*	No
Pondspice	*Litsea aestivalis*	No
Resinous boneset	*Eupatorium resinosum*	No
Roughleaf yellow-eyed grass	*Xyris scabrifolia*	No
Sandhills bog lily	*Lilium iridollae*	No
Sandhills milkvetch	*Astragalus michauxii*	No
Sandhills pyxie-moss	*Pyxidanthera barbulata* var. *brevistyla*	No
Savanna cowbane	*Oxypolis ternata*	No
Spiked medusa	*Pteroglossaspis ecristata*	No
Spring-flowering goldenrod	*Solidago verna*	No
Venus flytrap	*Dionea muscipula*	No
White wicky	*Kalmia cuneata*	No
Wavyleaf wild quinine	*Parthenium radfordii*	No
***Historic record** - the species was last observed in the county more than 50 years ago. ****Obscure record** - the date and/or location of observation is uncertain.		

No Threatened, Endangered or Species of Federal Concern were observed during the site visit, and none are recorded at NC National Heritage Program as occurring within 2 miles (3.2 km) of the project area. No habitat exists at the site for any of the species listed above.

3.0 REFERENCE REACHES

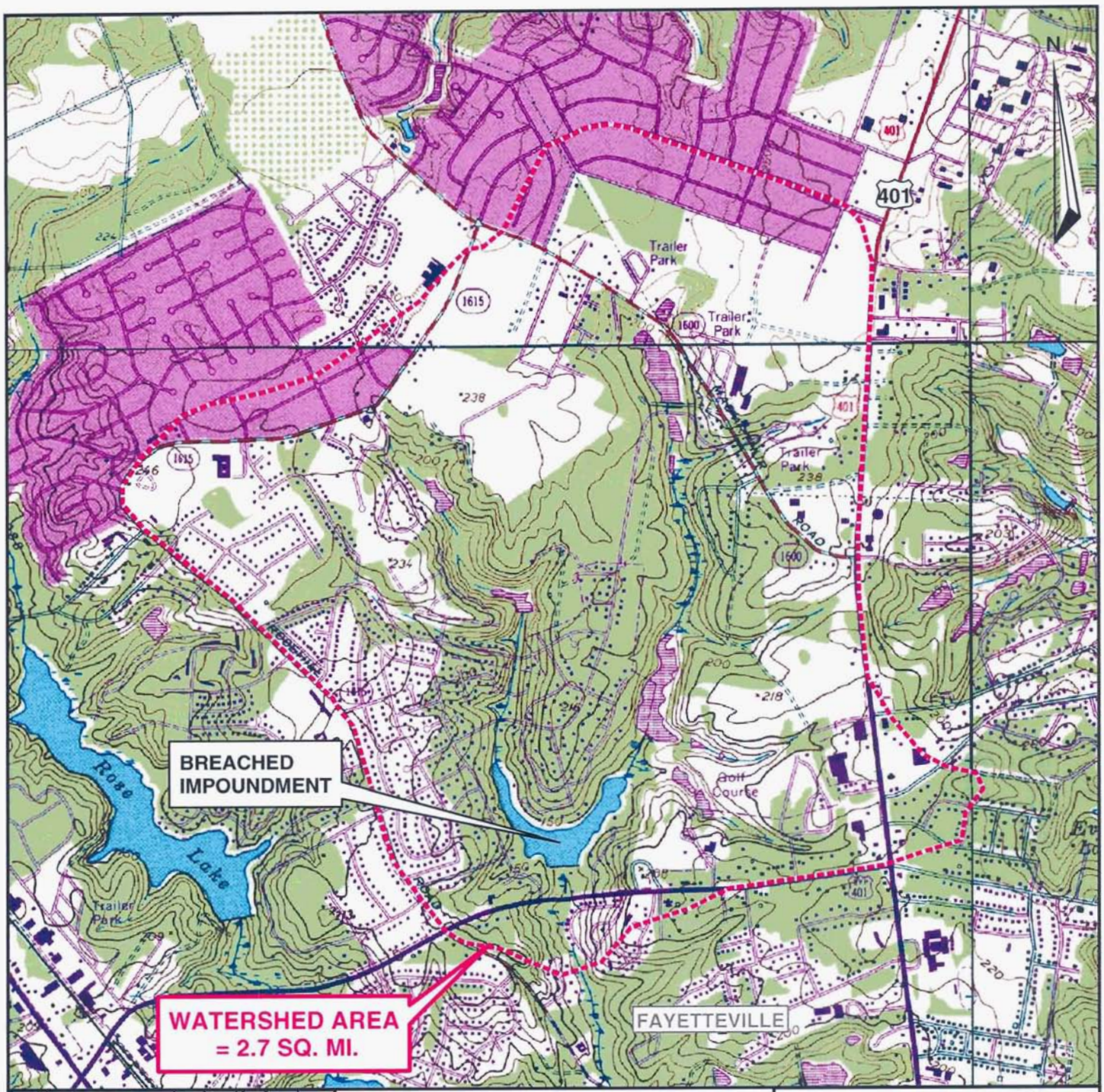
Two reference reaches were surveyed for this project. Both are in Cumberland County, and one is within the watershed of the project. Every effort was made to locate streams within the urban areas of Fayetteville, but only two potential reference reaches were located in the City. Most of the evaluated streams were highly incised as a result of development and the erosive nature of the soils. One reach found within Fayetteville was considered too small for use as a reference stream for the project. When no other streams within Fayetteville could be located, the search area was widened and two additional reference reaches were located. Of these two, only one could serve as an adequate reference reach for the restoration work. Descriptions of the two reference sites being used in the design of Cross Creek are listed below.

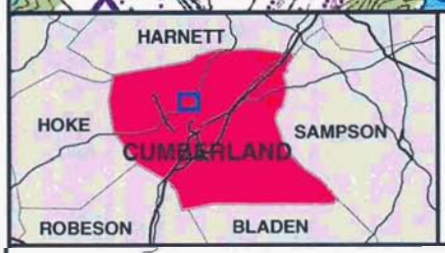
3.1 COUNTRY CLUB BRANCH

Country Club Branch, a second-order stream, is located within the Cross Creek watershed, 2.4 miles northeast of the restoration site (Figure 5). Country Club Branch flows into Cross Creek approximately 12,000 feet upstream of project site. The reach surveyed is located approximately 2,300 feet upstream from the mouth of Country Club Branch. The stream reach has a drainage area of 1,749 acres or 2.7 square miles. The watershed is mildly sloped (1.0 percent) with residential and commercial areas throughout. The floodplain surrounding the creek is forested and relatively flat on either side.

The floodplain forest consists of mostly medium-aged canopy trees with a dense subcanopy and understory. Species include swamp blackgum (*Nyssa biflora*), red maple (*Acer rubrum*), yellow poplar (*Liriodendron tulipifera*), eastern red cedar (*Juniperus virginiana*), sweetbay magnolia (*Magnolia virginiana*), American holly (*Ilex opaca*), tag alder (*Alnus serrulata*), Chinese privet (*Ligustrum sinense*), Virginia willow (*Itea virginica*), elderberry (*Sambucus canadensis*), netted chain-fern (*Woodwardia areolata*), royal fern (*Osmunda regalis*), cinnamon fern (*Osmunda cinnamomea*), arrowhead (*Sagittaria latifolia*), lady's thumb, greenbrier (*Smilax rotundifolia*), wild grape, wild raisin (*Viburnum nudum*), poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and lurid sedge (*Carex lurida*).

The stream was surveyed on June 27, 2002. Channel dimension, pattern, and profile were measured for 306 linear feet of stream. The beginning of the survey is located approximately 700 feet downstream of the Country Club Drive (401 Bypass) culvert. The stream had an average bankfull channel width of 21 feet and a bankfull mean depth of 1.2 feet. Country Club Branch is a C5 stream type from the Rosgen Classification system. A longitudinal profile, cross-sections, and a pebble count for this reference reach are located in Appendix D.





Source: USGS Quadrangles:
Fayetteville, NC, 1957, Photorevised 1987;
Manchester, NC, 1957, Photorevised 1987;
Slocomb, NC, 1948, Photorevised 1981;
Vander, NC, 1957, Photorevised 1987.

0 1,000 2,000 4,000 Feet

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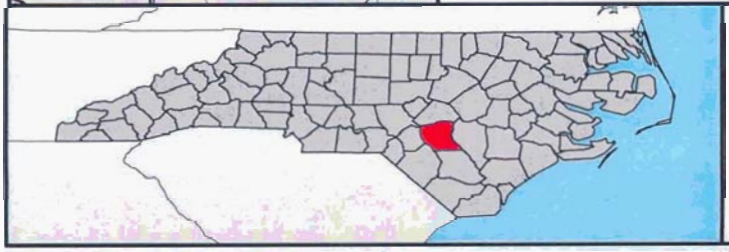


FIGURE 5
Country Club Branch Watershed

Cross Creek
Cumberland County, North Carolina

3.2 LITTLE ROCKFISH CREEK

Little Rockfish Creek, a second-order stream, is located 10 miles west-southwest of the project site off of Highway 401 South (Figure 6). The reach surveyed is located approximately 200 feet downstream of Gillis Hill Farm Road. The drainage area for the reach surveyed is 10,550 acres or 16.5 square miles. The watershed is mildly sloped (0.5 percent) with a mix of medium density residential and forested areas. Sixty percent of the watershed is located in the Fort Bragg Military Reservation.

The stream flows through a forest of medium- to large-diameter canopy trees with a dense understory. Red maple dominates the canopy. There is some swamp blackgum on the banks, and water oak (*Quercus nigra*) and willow oak (*Quercus phellos*) are scattered throughout the floodplain. The understory is dominated by dense growth of doghobble (*Leucothoe axillaris*), Virginia willow, and netted chain-fern.

The stream was surveyed on July 2, 2002. Channel dimension, pattern, and profile were measured for 620 linear feet of stream. The beginning of the survey is located approximately 200 feet downstream of the Gillis Farm Hill Road (South of Raeford Rd or 401 South) culvert. The stream had an average bankfull channel width of 20 feet and a bankfull mean depth of 2.3 feet. Little Rockfish Creek is an E5 stream type from the Rosgen Classification system. Although the stream classifies as an E-type stream, it functions much like a C-type stream. The width-to-depth ratios are close to 12, the ratio of a C-type stream. A longitudinal profile, cross-sections, and a pebble count for this reference reach are located in Appendix E.

4.0 STREAM CHANNEL DESIGN

This restoration will classify as a Priority 2 restoration (Rosgen, 1997). The floodplain will be re-established at a lower elevation, so that it can be accessed during storm events above bankfull. The new stream will essentially have the same profile as the existing stream, but with a bank height ratio of one. The current bank height ratios (> 2.0 for all reaches) reveal that the existing channels contain flows above the bankfull stage. Table 5 describes and summarizes the four priorities of incised river restoration (Rosgen, 1997). The proposed stream restoration will restore the natural meander pattern, modify channel cross-section, restore bedform, improve sediment transport capacity, enhance habitat, and re-establish a floodplain for the stream.

The design was based upon Dave Rosgen's natural channel design methodology. As described in Section 3.0, Country Club Branch and Little Rockfish Creek were utilized as reference reaches on which the morphological characteristics were measured to determine a range of values for the stable dimension, pattern, and profile of the proposed channel. The measured and proposed morphological characteristics are shown in Table 6. A conceptual design was developed from the range of values listed in Table 6. This stream restoration project will result in approximately 1,639 restored linear feet (as measured from the thalweg) of Cross Creek and 691 restored linear feet of Little Cross Creek.

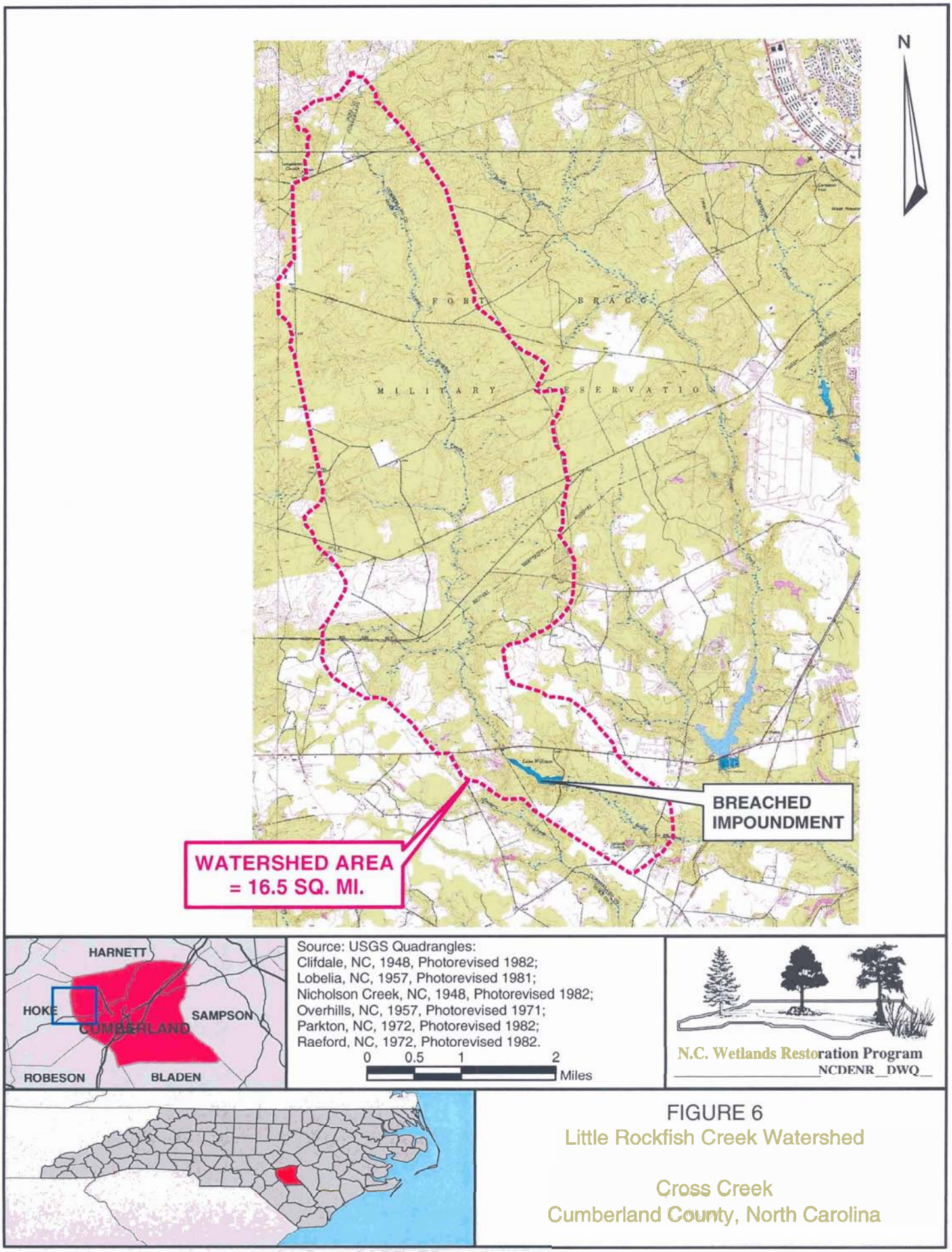


FIGURE 6

Little Rockfish Creek Watershed

Cross Creek

Cumberland County, North Carolina

Table 5 Priorities and Summary for Incised River Restoration

Description	Methods	Advantage	Disadvantage
PRIORITY 1 Convert G and/or F stream types to C and/or E at previous elevation w/floodplain	Re-establish channel on previous floodplain using relic channel or construction of new bankfull discharge channel. Design new channel for dimension, pattern and profile characteristic of stable form. Fill in existing incised channel or with discontinuous oxbow lakes level with new floodplain elevation.	Re-establishment of floodplain and stable channel: 1) reduces bank height and streambank erosion 2) reduces land loss 3) raises water table 4) decreases sediment 5) improves aquatic and terrestrial habitats 6) improves land productivity, and 7) improves aesthetics.	1) floodplain re-establishment could cause flood damage to urban agricultural and industrial development. 2) downstream end of project could require grade control from new to previous channel to prevent head-cutting.
PRIORITY 2 Convert G and/or F stream types to C or E. Re-establishment of floodplain at existing or higher, but not at original level	If belt width provides for the minimum meander width ratio for C or E stream types, construct channel in bed of existing channel, convert existing bed to new floodplain. If belt width is too narrow, excavate streambank walls. End-hall material or place in streambed to raise bed elevation and create new floodplain in the deposition.	1) decreases bank height and streambank erosion 2) allows for riparian vegetation to help stabilize banks 3) establishes floodplain to help take stress of channel during flood 4) improves aquatic habitat 5) prevents wide-scale flooding of original land surface 6) reduces sediment 7) downstream grade transition for grade control is easier.	1) does not raise water table back to previous elevation 2) shear stress and velocity higher during flood due to narrower floodplain 3) upper banks need to be sloped and stabilized to reduce erosion during flood.
PRIORITY 3 Convert to a new stream type without an active floodplain, but containing a floodprone area. Convert G to B stream type, or F to Bc	Excavation of channel to change stream type involves establishing proper dimension, pattern and profile. To convert G to B stream involves an increase in width/depth and entrenchment ratio, shaping upper slopes and stabilizing both bed and banks. A conversion from F to Bc stream type involves a decrease in width/depth ratio and an increase in entrenchment ratio.	1) reduces the amount of land needed to return the river to a stable form. 2) developments next to river need not be re-located due to flooding potential 3) decreases flood stage for the same magnitude flood 4) improves aquatic habitat.	1) high cost of materials for bed and streambank stabilization 2) does not create the diversity of aquatic habitat 3) does not raise water table to previous levels.
PRIORITY 4 Stabilize channel in place	A long list of stabilization materials and methods have been used to decrease stream bed and bank erosion, including concrete, gabions, boulders and bio-engineering methods	1) excavation volumes reduced 2) land needed for restoration is minimal	1) high cost for stabilization 2) high risk due to excessive shear stress and velocity 3) limited aquatic habitat depending on nature of stabilization methods used.

Source: Rosgen, 1997, "A Geomorphological Approach to Restoration of Incised Rivers"

Table 6 Morphological Characteristics: Existing, Reference, and Proposed Reaches

Variables	Little Cross Creek (Flow Controlled)	Cross Creek	Reference Reach-Country Club Branch	Reference Reach-Little Rockfish Creek	Proposed Little Cross Creek (Flow Controlled)	Proposed Cross Creek
Stream Type (Rosgen)	G5	G5/E5	C5	E5	C5	C5
Drainage Area (sq. mi.)	10.0	25.5	2.7	16.5	10.0	25.5
Bankfull Width (W_{bkf}, ft)	17.3-23.0	26.0-30.0	14.5-27.4	19.5-21.0	24.7	34.2
MEAN	20.2	27.4	21	20.3		
Bankfull Mean Depth (d_{bkf}, ft)	1.9	2.5-3.0	0.8-1.5	2.3	1.54	2.14
MEAN	1.90	2.65	1.2	2.3		
Width/depth Ratio (W_{bkf}/d_{bkf})	8.9-12.1	8.8-10.0	10-34	8.4-9.0	16	16
MEAN	10.5	10.3	22	8.7		
Bankfull Cross-sectional Area (A_{bkf} sq. ft.)	33.5-43.6	68.8-77.1	21.1-21.9	45.4-49.1	38	73
MEAN	38.6	73.2	21.5	47.3		
Bankfull Mean Velocity (V_{bkf} fps) (Manning)	3.3	3.3	2.0	2.6	3.3	3.3
Bankfull Discharge (Q_{bkf} cfs) (Manning)	130	240	40	120	130	240
Bankfull Maximum Depth (d_{max} ft)	2.5-2.9	3.3-4.1	2.1-3.0	3.0-3.5	2.3	3.2
MEAN	2.7	3.7	2.6	3.3		
Ratio Bankfull Maximum Depth to Mean Bankfull Depth (d_{max}/d_{bkf})	1.4	1.4	2.2	1.3-1.5	1.5	1.5
Lowest Bank Height to Bankfull Maximum Depth Ratio	2.6	2.3	1.0	1.0	1.0	1.0
Width of Flood Prone Area (W_{fpa} ft)	27-37	32-65	200	300	>50	>70
MEAN	32	43	200	300		
Entrenchment Ratio (W_{fpa}/W_{bkf})	1.6	1.6	10.5	14.9	>2.2	>2.2
Meander Length (L_m ft)	0	0	32-58	119-325	173-346	240-479
MEAN	0	0	43	212		
Ratio of Meander Length to Bankfull Width (L_m/W_{bkf})	0	0	1.9-3.2	6-16	7-14	7-14
MEAN	0	0	2.3	11		
Radius of Curvature (R_c ft)	0	0	7-21	22-36	50-86	70-120
MEAN	0	0	14	30		
Ratio of Radius of Curvature to Bankful Width (R_c/W_{bkf})	0	0	0.48-1.5	1.1-1.8	2.0-3.5	2.0-3.5
MEAN	0	0	0.67	1.5		
Belt Width (W_{blt} ft)	20.2	27.4	20-23	25-36	50-124	70-170
MEAN	20.2	27.4	21	29		
Meander Width Ratio (W_{blt}/W_{bkf})	1.0	1.0	0.67-1.6	1.2-1.8	2.0-5.0	2.0-5.0
MEAN	1.0	1.0	1.0	1.5		
Sinuosity (Stream Length/Valley Length, k - ft/ft)	1.0	1.0	1.5	1.3	1.12	1.10
Valley Slope (S_{valley}) ft/ft	0.0037	0.0022	0.0007	0.0012	0.0037	0.0022
Average Water Surface Slope (S_{avg})	0.0037	0.0022	0.0011	0.0016	0.0033	0.0024
Pool Slope (S_{pool})	0.00-0.0017	0.000-0.0012	0	0.00-0.0091	0.0004	0.0004
MEAN	0.00047	0.00038	0	0.00032	0.0004	0.0004
Ratio of Pool Slope to Average Slope (S_{pool}/S_{avg})	0.12	0.18	0	0.00-0.58	0.12	0.17
Riffle Slope (S_{riff} ft/ft)	0.0031-.014	0.0020-0.023	0.0017-0.0033	0.0011-0.0083	0.0055	0.004
MEAN	0.0082	0.0078	0.0024	0.0031	0.0055	0.004
Ratio of Riffle Slope to Average Slope (S_{riff}/S_{avg})	0.83-3.6	0.91-10.6	1.5-3.1	0.68-5.3	1.67	1.67
MEAN	2.2	3.5	2.2	2.0	1.67	1.67
Maximum Pool Depth (d_{pool} ft)	2.6	5.3	4.4	5.8	3.9	5.3
Ratio of pool depth to mean bankfull depth (d_{pool}/d_{bkf})	1.4	2.0	3.7	2.5	2.5	2.5
Pool Width (W_{pool} ft)	20.2	27.4	26.7	16	32.1	44.4
Ratio of Pool Width to Bankful Width (W_{pool}/W_{bkf})	1.0	1.0	1.3	0.8	1.3	1.3
Pool to Pool Spacing (P-P ft)	36-131	77-167	19-57	66-123	90-172	152-228
MEAN	83	132	36	89	118	187
Ratio of P-P to Bankfull Width (P-P/W_{bkf})	1.8-6.5	2.9-6.3	0.61-1.8	3.4-6.2	3.6-6.9	4.5-6.7
MEAN	4.1	4.9	1.2	4.4	4.7	5.5

*Rosgen recommends keeping the Rc/Wbkf >2.0 (4.0-6.0 for C type streams) for stability.
The reference reaches are in stable hardwood forests => lower Rc/Wbkf are possible and maintain stability

4.1 RESTORATION TECHNIQUES

Stream dimension, pattern, and profile will be adjusted so the new stream channel can maintain stability while transporting its water and sediment load. The Priority 2 restoration (Table 5) will involve modifying the existing channel at its existing elevation to create a stable channel (Figure 7). The new streams are designed to carry the existing bankfull flows with a newly created floodplain surrounding the bankfull channel.

Vegetation will be utilized to provide stability and habitat along the stream banks and in the riparian area. The greatest advantage of this Priority 2 restoration will be to create a floodplain that the active channel can actively access. Other advantages of a Priority 2 restoration include improving aesthetics, improving habitat, reduction of bank height and streambank erosion, and lowering of the in-channel shear stress.

4.1.1 Dimension

Cross Creek's present bankfull channel width ranges from 26.0 to 30.0 feet with a cross-sectional area ranging from 68.8 to 77.1 square feet. The design channel will be constructed to bankfull target dimensions that are based on a combination of reference reach surveys, HEC RAS modeling, and field measurements. Typical cross-sections can be seen in Figure 8.

A design width of 34 feet will be applied to the Cross Creek portion of the restoration. This width was back-calculated from the cross-sectional area taken from field measurements and a width-to-depth ratio of 16. Required mean depth of the channel was verified using critical dimensionless shear stress relationships to ensure there is enough design depth to transport the channel bedload without aggrading or degrading. These characteristics will provide a stream channel that classifies as a C-type channel. The proposed Cross Creek channel will be able to access a floodplain and effectively transport the sediment load.

Little Cross Creek's present bankfull channel width ranges from 17.3 to 23.0 feet with a cross-sectional area ranging from 33.5 to 43.6 square feet. The design channel will be constructed to bankfull target dimensions that are based on a combination of reference reach surveys, HEC RAS modeling, and field measurements.

A design width of 25 feet will be applied to the Little Cross Creek portion of the restoration. This width was back-calculated from the cross-sectional area taken from field measurements and a width-to-depth ratio of 16. Required mean depth of the channel was verified using critical dimensionless shear stress relationships to ensure there is enough design depth to transport the channel bedload without aggrading or degrading. These characteristics will provide a stream channel that classifies as a C-type channel. The proposed Little Cross Creek channel will be able to access a floodplain and effectively transport the sediment load.

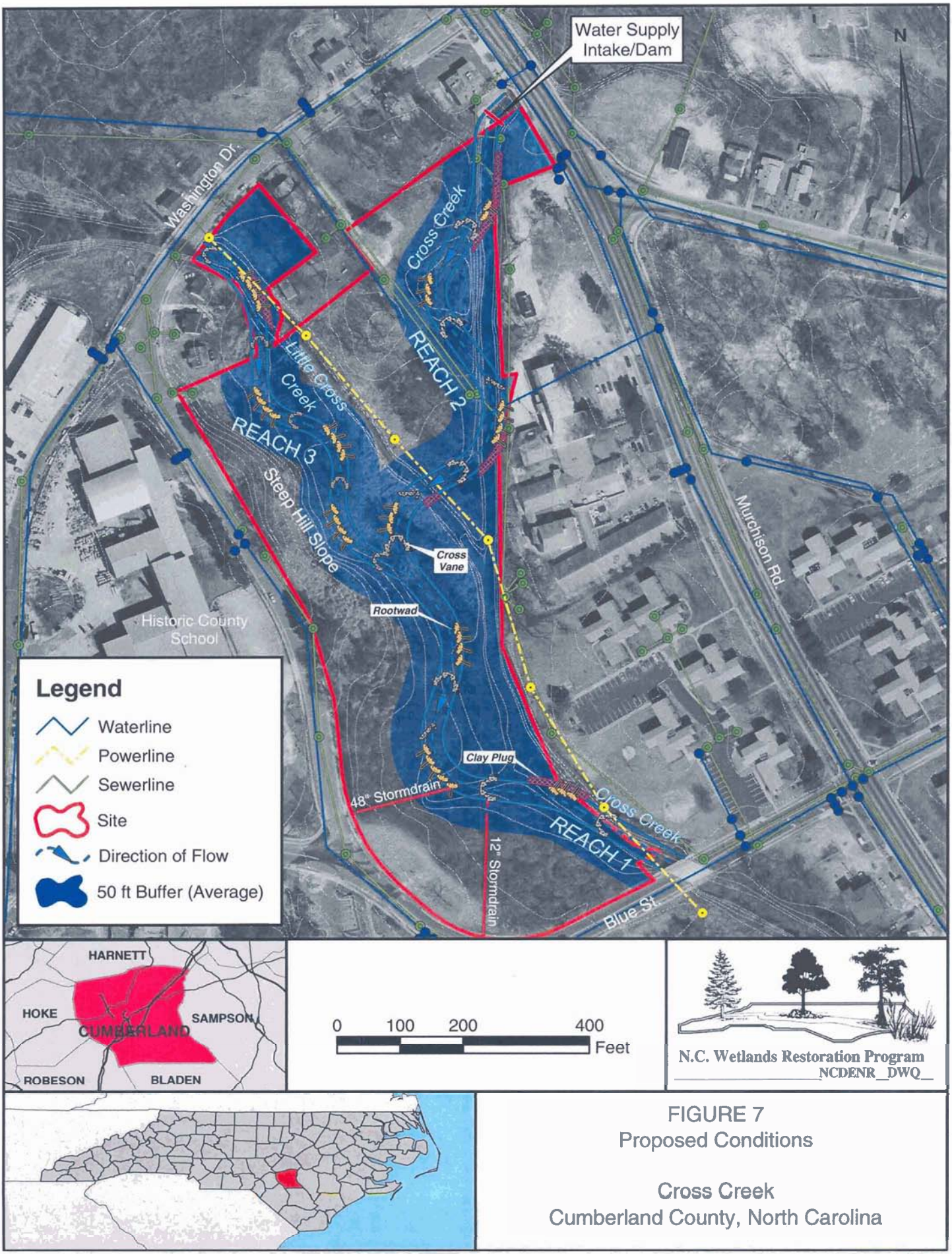
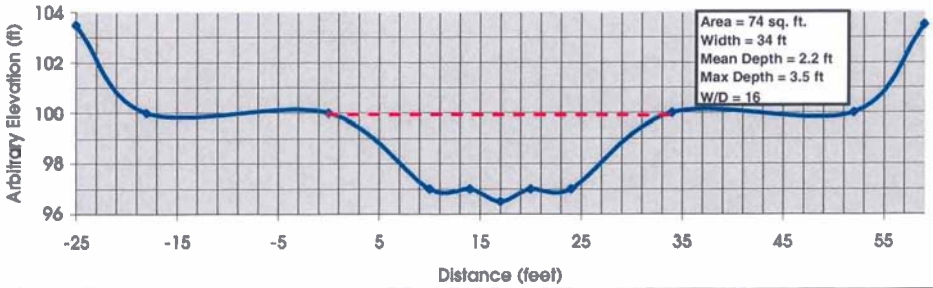


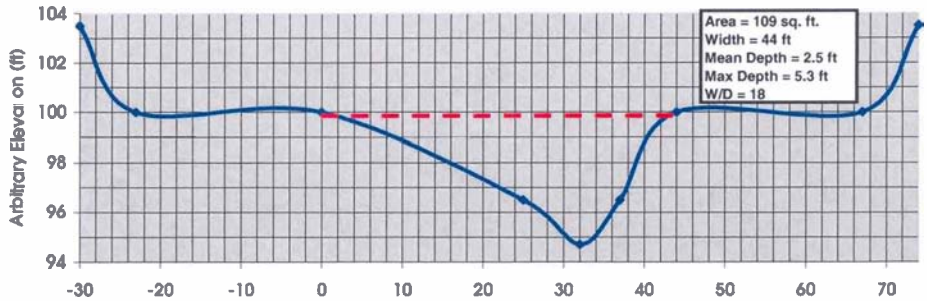
FIGURE 7
Proposed Conditions

Cross Creek
Cumberland County, North Carolina

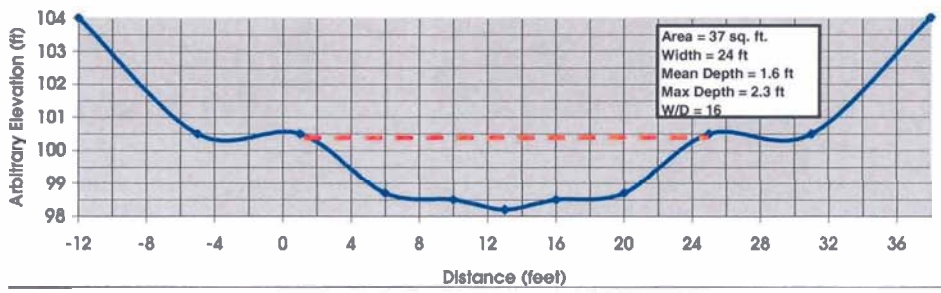
Proposed Cross Creek Riffle
'C' Type Stream



Proposed Cross Creek Pool
'C' Type Stream



Proposed Little Cross Creek Riffle
'C' Type Stream



Proposed Little Cross Creek Pool
'C' Type Stream

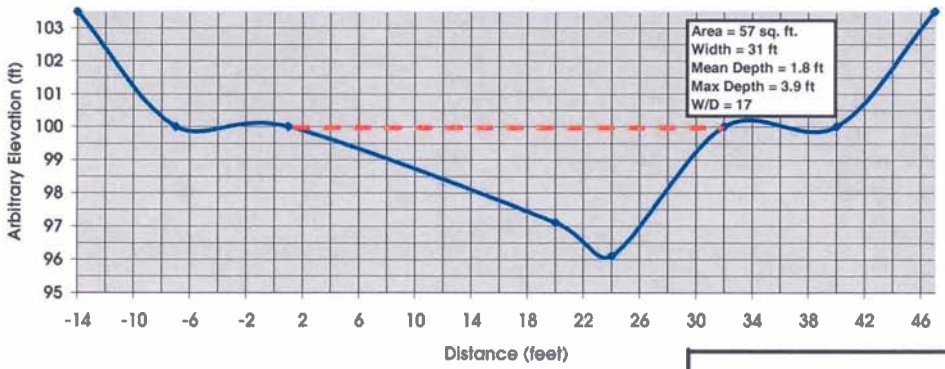


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FIGURE 8
Typical Cross Sections

Cross Creek
Cumberland County, North Carolina

4.1.2 Pattern

The existing pattern of Cross Creek and Little Cross Creek can be described as long straight reaches with no meanders. The current sinuosity of both channels is 1.0. The proposed channels will have meanders added with appropriate radius of curvatures and lengths based on reference reach data and existing constraints. Although the sinuosities are not that of the measured reference reaches, the maximum sinuosities have been designed into the new channels based on project constraints. The constraints consist of utilities, existing trees, existing structures, and property lines. Introduction of these meanders will improve habitat while lowering slope and shear stress.

4.1.3 Bedform

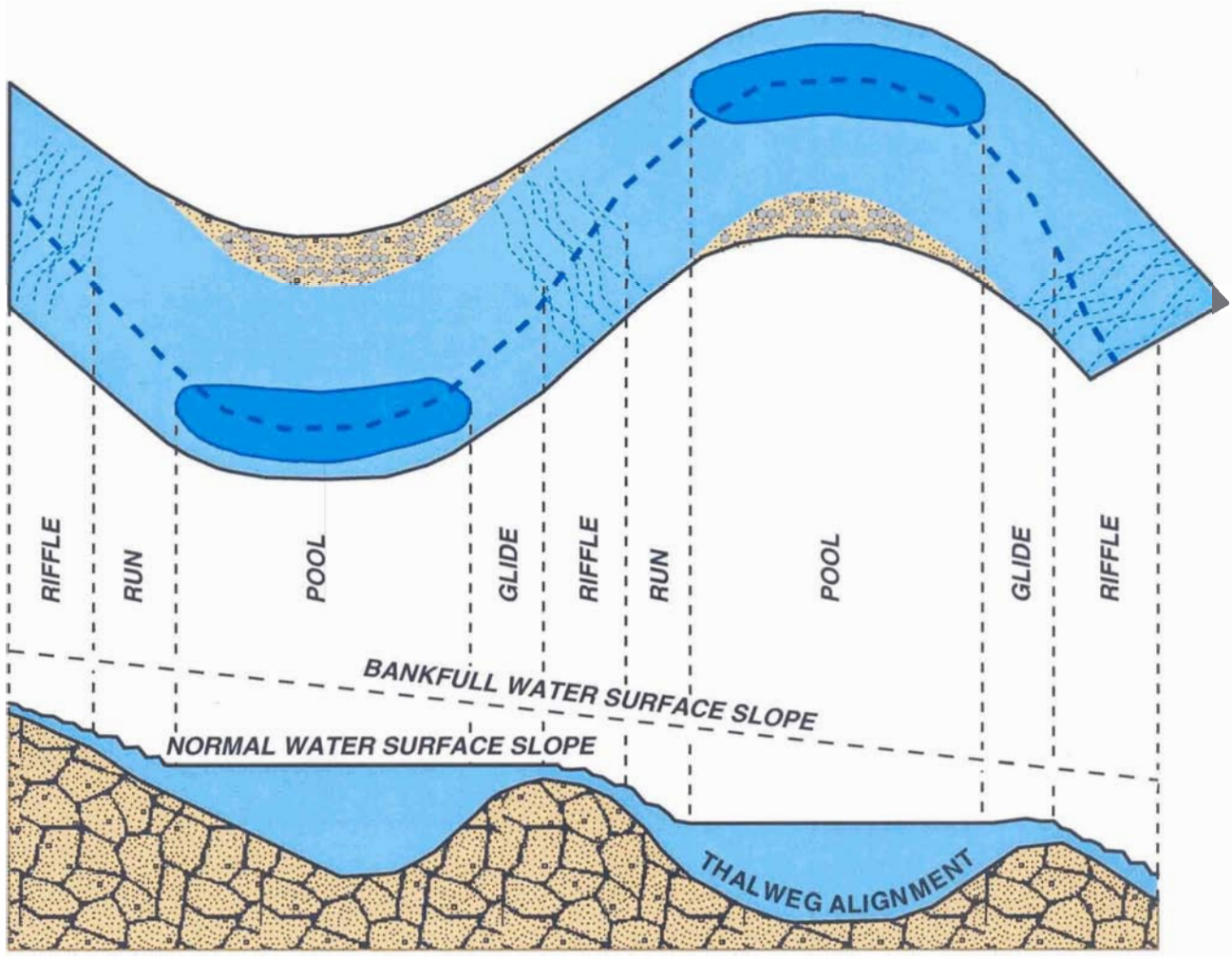
The existing bedform along Cross Creek and Little Cross Creek is in poor condition. Long, straight sections of the channel consist of predominantly run bedform features while others are very steep riffles with no habitat. The design channel will incorporate riffles and pools to provide bedform common to C5 stream types with sand substrate (Figure 9). Pools will be located in the outside of meander bends with riffles in the inflection points between meanders. Cross Creek's and Little Cross Creek's riffles will have thalweg depths of 3.2 feet and 2.3 feet, respectively, while the pools will be deeper with a maximum depths of 5.3 feet and 3.9 feet, respectively. A graph of the proposed profiles can be seen in Figure 10. The profiles may be adjusted slightly during the final design phase of the project.

Cross-vanes will be utilized as grade control structures and to tie the relocated sections back into the existing channel. The cross vanes will be constructed out of natural materials such as boulders and wood. Every effort will be made to use wood structures where feasible. When boulder cross-vanes must be used, the wings will be tied into the channel banks at half bankfull so the stream will appear more natural in its Coastal plain setting where rock outcroppings are not usually found.

Bedform will also be addressed through the strategic placement of natural material structures such as rock cross vanes, root wads and large woody debris. Placement of large woody debris will be a key to these streams' restoration success since the current channels have no woody debris present, which is needed for aquatic habitat. Modifications to the bedform will provide stability and habitat to the channel.

4.1.4 Riparian Areas

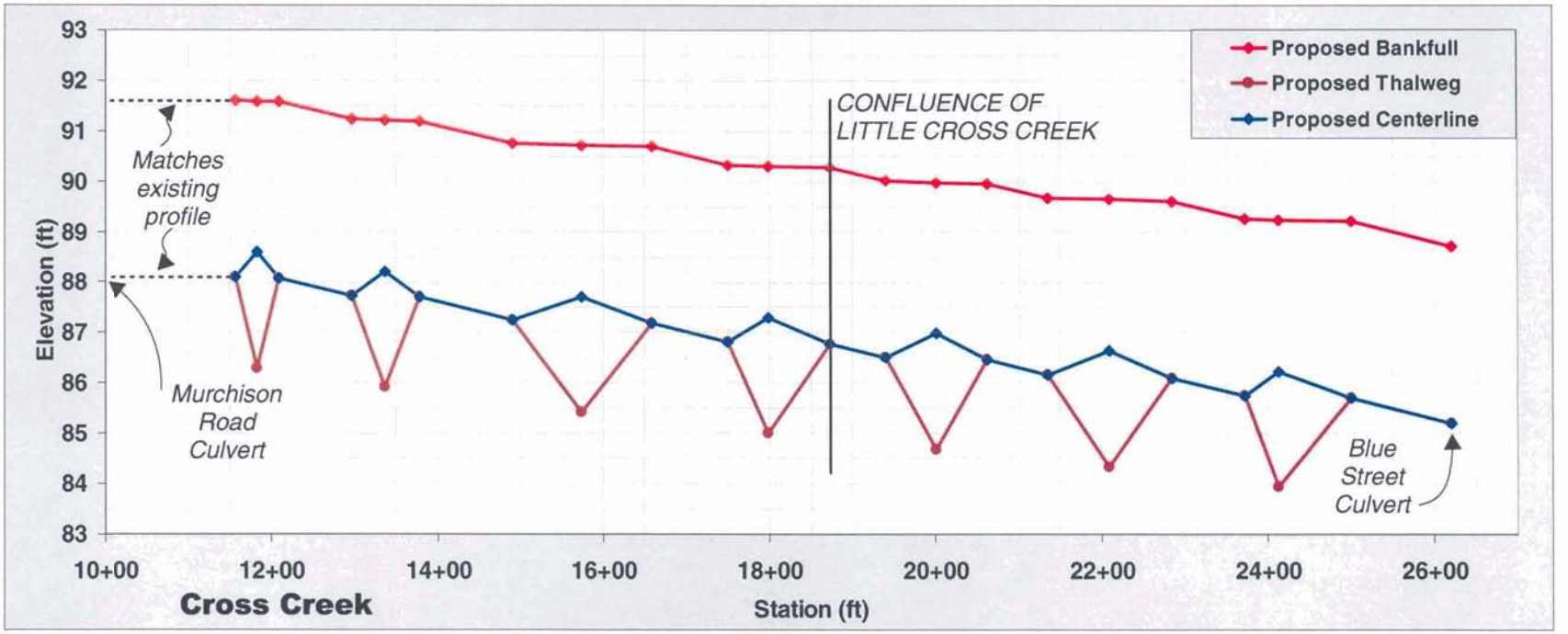
A riparian zone will be created around the new proposed stream channel to enhance both aquatic and terrestrial habitat as well as stabilize the stream channel. The riparian zone will extend at least 50 feet on either side of the channel from the top of bank (Figure 7). These areas will be planted with appropriate riparian vegetation as described in Section 6.0 Habitat Restoration.

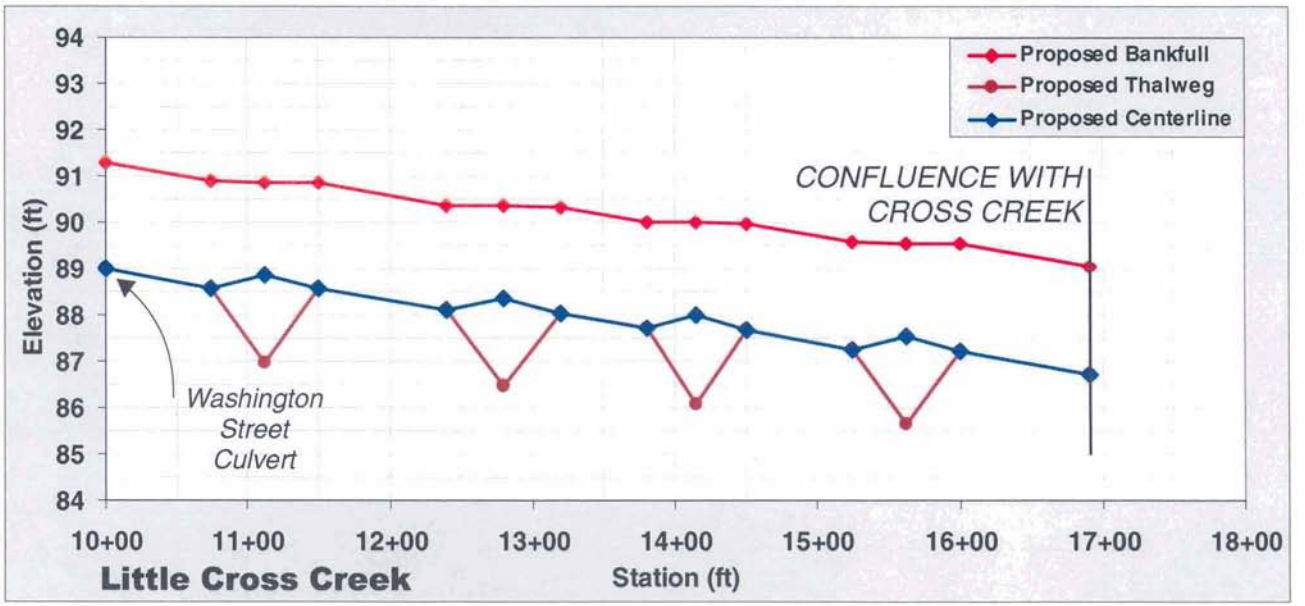


N.C. Wetlands Restoration Program
NCDENR DWQ

FIGURE 9
Typical Bedform

Cross Creek
Cumberland County, North Carolina





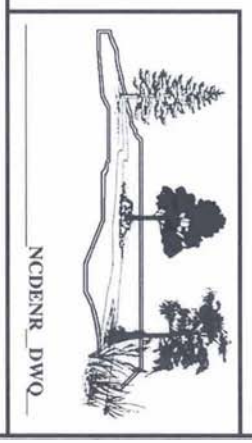


FIGURE 10
Proposed Profile

Cross Creek
Cumberland County, North Carolina

4.2 SEDIMENT TRANSPORT

A stable stream has the capacity to move its sediment load without aggrading or degrading. The total load of sediment can be divided into bedload and wash load. Wash load is normally composed of fine sands, silts and clay and transported in suspension at a rate that is determined by availability and not hydraulically controlled. Bedload is transported by rolling, sliding, or hopping (saltating) along the bed. At higher discharges, some portion of the bedload can be suspended, especially if there is a sand component in the bedload. Bed material transport rates are essentially controlled by the size and nature of the bed material and hydraulic conditions (Hey 1997).

Critical dimensionless shear stress ($\tau *_{ci}$) can be calculated using a surface and subsurface particle sample from a representative riffle in the reach. Since taking a subsurface sample is difficult, it is often estimated using the average grain size from a point bar sample or riffle sample. The sample is taken on the point bar face halfway between the thalweg and bankfull or to the right or left of the thalweg in a riffle.

$$\tau *_{ci} = 0.0834\left(\frac{d_i}{\hat{d}_{50}}\right)^{-0.872}$$

where, τ^*_{ci}=critical dimensionless shear stress
d_i=d_{50} of riffle bed surface from pebble count (mm)
$\hat{d}_{50}$=subpavement d_{50} or bar d_{50} (mm)

A riffle bed surface pebble count was taken at a riffle on both Cross Creek and Little Cross Creek using a method developed by Wildland Hydrology and the Natural Resources Conservation Service. Particles were randomly selected along the wetted area throughout the entire length of the riffles. The riffle bed surface d50's for Cross Creek and Little Cross Creek were then calculated to be 4 mm and 11 mm respectively. Subsurface samples were then taken at the same riffles and sieved to determine the subsurface d50's. Cross Creek's and Little Cross Creek's subpavement d50's were then calculated to be 1 mm and 1.8 mm respectively. The data and particle distribution graphs can be found in Appendix B.

The critical dimensionless shear stress is then calculated as follows:

$$\text{Cross Creek } \tau *_{ci} = 0.0834\left(\frac{4mm}{1mm}\right)^{-0.872} = 0.025$$

$$\text{Little Cross Creek } \tau *_{ci} = 0.0834\left(\frac{11mm}{1.8mm}\right)^{-0.872} = 0.017$$

Critical dimensionless shear stress can then be used to predict the minimum bankfull mean depth required for entrainment of the largest particles found within each of the

active channels, which is 38 mm or 0.12 ft for Cross Creek and 35 mm or 0.11 ft for Little Cross Creek. This minimum bankfull mean depth is calculated by the following equation:

$$d = \frac{(\tau^*_{ci})(\rho_{sand} - \rho_{water})(D_i)}{s}$$

where, d=water depth (ft)
τ^*_{ci}=critical dimensionless shear stress
ρ_{sand}=density of sand (2.65 lb/ft^3)
ρ_{water}=density of water (1.0 lb/ft^3)
D_i=largest particle found in the bar sample (ft)
s=average bankfull slope

Thus,

$$\text{Cross Creek } d = \frac{(0.025)(2.65\frac{lb}{ft^3} - 1.0\frac{lb}{ft^3})\left(\frac{38mm}{25.4\frac{mm}{in} * 12\frac{in}{ft}}\right)}{0.0024\frac{ft}{ft}} = 2.13ft$$

$$\text{Little Cross Creek } d = \frac{(0.017)(2.65\frac{lb}{ft^3} - 1.0\frac{lb}{ft^3})\left(\frac{35mm}{25.4\frac{mm}{in} * 12\frac{in}{ft}}\right)}{0.0033\frac{ft}{ft}} = 0.99ft$$

Cross Creek has a critical dimensionless shear stress value of 0.025, so the minimum mean depth of water required to move a 38-mm particle was predicted to be 2.13 ft. Little Cross Creek has a critical shear stress of 0.017, so the minimum mean depth of water required to move a 35 mm particle was predicted to be 0.99 ft. Cross Creek's proposed channel dimensions have an average bankfull depth of 2.1 ft, with a maximum depth of 3.2 ft. Little Cross Creek's proposed channel dimensions have an average bankfull depth of 1.5 ft, with a maximum depth of 2.3 ft. Both designs provide at least the minimum depth required to move the largest particles found in the riffle samples. The channels' dimensions will provide sufficient shear stress to accommodate sediment transport.

Shear stress at the riffle was also checked using Shield's Curve. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by the following equation:

$$\tau = \gamma Rs$$

where, τ=shear stress (lb/ft^2)
γ=specific gravity of water (62.4 lb/ft^3)
R=hydraulic radius (ft)
s=average bankfull slope (ft/ft)

Hydraulic radius is calculated by:

$$R = \frac{A}{P}$$

where, R=hydraulic radius
A=cross-sectional area (ft^2)
P=wetted perimeter (ft)

Thus,

$$\text{Cross Creek } R = \frac{73 ft^2}{35 ft} = 2.1 ft$$

$$\text{Little Cross Creek } R = \frac{38 ft^2}{18 ft} = 2.1 ft$$

Wetted perimeters were measured off of the typical riffle cross-sections drawn to scale.

Therefore,

$$\text{Cross Creek } \tau = (62.4 \frac{lb}{ft^3})(2.1 ft)(0.0024 \frac{ft}{ft}) = 0.31 lb / ft^2$$

$$\text{Little Cross Creek } \tau = (62.4 \frac{lb}{ft^3})(2.1 ft)(0.0033 \frac{ft}{ft}) = 0.43 lb / ft^2$$

The critical shear stresses for the proposed Cross Creek and Little Cross Creek channels have to be sufficient to move the D_{84}'s of the riffles' bed material, which are 6 mm and 10 mm respectively. Based on shear stresses of 0.31 lb/ft^2 and 0.43 lb/ft^2, Shield's Curve predicts that these streams can move particles that are, on average, greater than 15 mm and 20 mm. Since the D_{84}'s for both streams are less than the Shield's Curve predictions, the proposed streams have the capability to move their bedload.

4.3 FLOODING ANALYSIS

The hydrology of the project's watershed is very complex. Cross Creek and Little Cross Creek are highly urbanized, and as a result, influenced by numerous human factors. Impoundments throughout the watershed form the largest manmade structures that affect

the hydrology of the streams. Storm drains form the second largest hydrologic factor. Storm peaks vary substantially as a result of impoundments and stormdrains found throughout the watershed. While the impoundments lower peak flows, stormdrains tend to increase them. Storm drains in the project watershed also carry additional runoff from outside the watershed. The locations of these watershed transfers are often difficult to find making it difficult to determine watershed size. The third hydrologic factor relates to the use of the streams for forty percent of Fayetteville's water supply. Water supply demand varies seasonally and annually making withdrawal predictions difficult.

In an effort to overcome the above circumstances various assumptions have been made to estimate design discharges. Limitations in time and resources prohibit modeling the two complex watersheds effectively; so three watershed studies of Cumberland County were reviewed for useful relationships and data. The studies revealed that the majority of the available land in the watershed has been developed, so it is assumed that stream discharges will not increase significantly from their present values. The studies also reveal that estimated flood frequency values and discharges developed from gaged storms do seem to be reasonable and generally agree with estimates developed previously by the U.S. Army Corps of Engineers.

The studies also reveal that streams in the Sandhills have flows that are considerably lower than those found in the Coastal Plain. These reports substantiate why the estimates of bankfull discharge from the Draft Rural Coastal Plain Regional Curve are considerably higher than what was measured in the field.

This restoration site is in a FEMA/regulatory floodway zone and, therefore, is subject to FEMA regulations. The Priority 2 restoration of the stream will leave the stream's existing profile elevations essentially the same. A new floodplain will be established at this elevation so that the active stream will be able to access it during larger storm events. Considering the type of restoration, it is assumed that for smaller events (less than 2-year), the water surface elevations along the stream shall remain the same. During storms where the stream accesses the newly established floodplain (greater than 2-year) the new water surface elevations are expected to be lower than the existing water surface elevations of storms of the same magnitude. The restoration will create neither positive nor negative water surface elevation changes during the larger storm events (greater than 10-year). The 100-year floodplain elevation and boundary will not be altered, but the floodway will be shifted slightly. Due to the small shift in the floodway a Conditional Letter of Map Revision (CLOMR) will be required. HEC-RAS will be used to analyze both existing and proposed conditions once the design is completed. Sheer stress and flood stages will be compared between the two conditions to evaluate the design.

4.4 STRUCTURES

Several different structures made of natural materials will be installed along Cross Creek and Little Cross Creek. These structures include cross vanes, J-hook vanes, and root wads. Natural materials such as boulders, rocks, and trees will be used to create these structures from off-site sources. Every effort will be made to design wood structures for

each stream, since it is the more native material, but some rock grade control structures will need to be installed to insure the integrity of the new streams.

4.4.1 Cross Vane

A cross vane structure serves to maintain the grade of the stream. The design shape is roughly that of the letter "U" with the apex located on the upstream side at the foot of the ripple. Footer rocks are placed in the channel bottom for stability. During onsite subsurface analysis a solid mudstone layer was located at the typical depth of footer rock installation. This solid foundation will provide a solid footing for all structures. When this layer is not present a minimum of a four-foot boulder foundation will be built.

Wood or rocks are then placed on these footer rocks in the middle of the channel at approximately the same elevation as the ripple. On either side of the channel, wood or rocks are placed at an angle to the stream bank, gradually inclining in elevation until they are located approximately half the bankfull depth directly adjacent to the stream bank. Water flowing downstream is directed over the vane towards the middle of the channel. Wood or rocks placed at the apex determine the bed elevation upstream. A cross vane is primarily used for grade control and to protect the stream banks. A median weight filter-cloth will be placed upstream of the cross vane along the perimeter to minimize piping through the rocks. Smaller rocks will be used to chink gaps around the boulders to also minimize piping.

4.4.2 Root Wads

The objectives of these structure placements are as follows: (1) protect the stream bank from erosion; (2) provide in-stream and overhead cover for fish; (3) provide shade, detritus, terrestrial insect habitat; (4) look natural, and (5) provide diversity of habitats (Rosgen 1996). A footer log and boulder are placed on the channel bottom abutting the stream bank along an outside meander that will provide support for the root wad and additional stability to the bank. A large tree root wad is then placed on the stream bank with additional boulders and rocks on either side for stability. Flowing water is deflected away from the bank and towards the center of the channel.

4.4.3 J-Hook Vanes

A j-hook vane is essentially half of a cross-vane with a rock cluster added to the upstream end. It redirects water in the downstream direction, thus reducing the near-bank stresses. A j-hook structure can include a combination of boulders, logs, and rootwads. J-hook vanes will be placed near the beginning of meander bends to protect the steeper sloped banks along the outside of pools. Specific location of these structures will be determined during final design.

5.0 HABITAT RESTORATION

The restoration plan requires the establishment of riparian vegetation at the site. The proposed vegetation is described in the following sections.

5.1 VEGETATION

Vegetation that quickly develops a canopy, has an extensive root system, and a substantial aboveground plant structure is needed to help stabilize the banks of a restored stream channel in order to reduce scour and runoff erosion. In natural riparian environments, pioneer plants that often provide these functions are alder, river birch, silky dogwood, and willow. Once established, these trees and shrubs create an environment that allows for the succession of other riparian species including ashes, black walnuts, red maples, sycamores, oaks and other riparian species.

In the newly restored stream channel, revegetation will be vital to help stabilize the stream banks and establish a riparian zone around the restored channel. Revegetation efforts on this project will emulate natural vegetation communities found along relatively undisturbed stream corridors. To quickly establish dense root mass along the channel bank, a native herb/grass mixture will be planted on the streambed and bank. Shrubs and vines will be utilized on the stream bank and along the floodplain to provide additional root mass. Extra care will be given to the outside of the meander bends to ensure a dense root mass in those areas of high stress. Coir matting will be used to provide erosion protection until vegetation can be established. Trees, shrubs and a native grass mixture will be planted along the tops of the channel banks.

A combination of seeds, livestakes, bare root nursery stock, and transplants will be utilized to stabilize the banks. Species proposed for planting are listed below.

Trees
American holly (*Ilex opaca*)
green ash (*Fraxinus pennsylvanica*)
hackberry (*Celtis laevigata*)
ironwood (*Carpinus caroliniana*)
swamp blackgum (*Nyssa biflora*)
swamp white oak (*Quercus michauxii*)
sweetbay magnolia (*Magnolia virginiana*)
water oak (*Quercus nigra*)
willow oak (*Quercus phellos*)
bald cypress (taxodium distichum)

Shrubs and Vines
blaspheme vine (*Smilax laurifolia*)
dog-hobble (*Leucothoe axillaris*)
elderberry (*Sambucus canadensis*)
silky willow (*Salix sericea*)
tag alder (*Alnus serrulata*)
ti-ti (*Cyrilla racemiflora*)

trumpet creeper (*Campsis radicans*)
Virginia willow (*Itea virginica*)
wild raisin (*Viburnum nudum*)
yellow jessamine (*Gelsemium sempervirens*)

Herbs and Grasses
arrowhead (*Sagittaria latifolia*)
cinnamon fern (*Osmunda cinnamomea*)
false stinging-nettle (*Boehmeria cylindrica*)
giant cane (*Arundinaria gigantea*)
lady's thumb (*Polygonum persicaria*)
lurid sedge (*Carex lurida*)
netted chain-fern (*Woodwardia areolata*)
royal fern (*Osmunda regalis*)
slender spikegrass (*Chasmanthium laxum*)

Woody vegetation will be planted between November and March to allow plants to stabilize during the dormant period and set root during the spring season. In the areas where invasive and exotic species are located, control by removal or appropriate herbicides will be implemented during construction and monitoring to prevent competition with the revegetation efforts.

5.2 Temporary Seeding

A temporary seed mixture will be applied to all disturbed areas immediately after construction activities have completed. This temporary seed mixture will provide erosion control until permanent seed can become established.

5.3 Kudzu Control

Kudzu is present along the stream banks throughout the project area and reaches into the canopy of the forest remnant at the downstream end. With roots that can extend to 9 feet below the soil surface and a potential growth rate of one foot per day, kudzu has the potential to overwhelm a newly planted site if not adequately controlled. Regular, aggressive management of this exotic invasive vine will be required. Management should begin with the site preparation stage and continue through the 5-year monitoring period at a minimum. An additional 5 years of aggressive management may be necessary to completely eradicate the viable propagules. Management techniques may include an initial site preparation burn, painting cut stumps with an appropriate herbicide such as glyphosate, sifting stockpiled soil to remove root fragments, and monitoring the project area monthly April through November to spray sprouts with glyphosate.

6.0 MONITORING

6.1 STREAM CHANNEL

Monitoring the stability of the channel is recommended approximately 6 months after restoration is complete or after bankfull (or greater) events and should continue annually for a period of 3 to 5 years. Monitoring practices may include, but are not limited to, installing bank erosion pins and a toe pin, monumented cross-sections, scour chains, macroinvertebrate studies, longitudinal profiles, conducting the bank erosion hazard rating guide and establishing photo reference points. The purpose of monitoring is to determine bank stability, bed stability, morphological stability and overall channel stability. The table below can be used for selecting practices.

Table 7 Stream Monitoring Practices

Practice	Stability Assessment
Bank Erosion Pins with Toe Pin	-Lateral or bank stability
Monumented Cross-Section	-Vertical or bed stability -Lateral or bank stability
Scour Chains	-Vertical or bed stability -Scour depth for a particular storm
Scour Chain w/ Monumented Cross-Section	-Vertical or bed stability -Sediment transport relations -Biological interpretations
Longitudinal Profile	-Channel profile stability
Bank Erosion Hazard Guide	-Bank erosion potential
Photo Reference Points	-Overall channel stability
Macroinvertebrate Studies	-Biological indication of water quality

6.2 VEGETATION

Prior to planting, the site will be inspected and checked for proper elevation and suitability of soils. Availability of acceptable, good quality plant species will be determined. The site will be inspected at completion of planting to determine proper planting methods, including proper plant spacing, density, and species composition.

Competition control will be implemented if determined to be necessary during the early stages of growth and development of the tree species. Quantitative sampling of the vegetation will be performed between August 1 and November 30 at the end of the first year and after each growing season until the vegetation criteria is met.

In preparation for the quantitative sampling, 0.05-acre vegetative plots will be established in the reforested area. Plots will be evenly distributed throughout the site. For each plot, species composition and density will be reported. Photo points will be taken within each zone. Monitoring will take place once each year for five years.

Success will be determined by survival of target species within the sample plots. At least six different representative tree species should be present on the entire site. If the vegetative success criteria are not met, the cause of failure will be determined and appropriate corrective action will be taken.

6.3 MACROINVERTEBRATES

A monitoring period of 3 to 5 years is commonly suggested to determine changes in macroinvertebrate populations within a newly restored stream. The North Carolina Wetlands Restoration Program will determine a macroinvertebrate monitoring policy.

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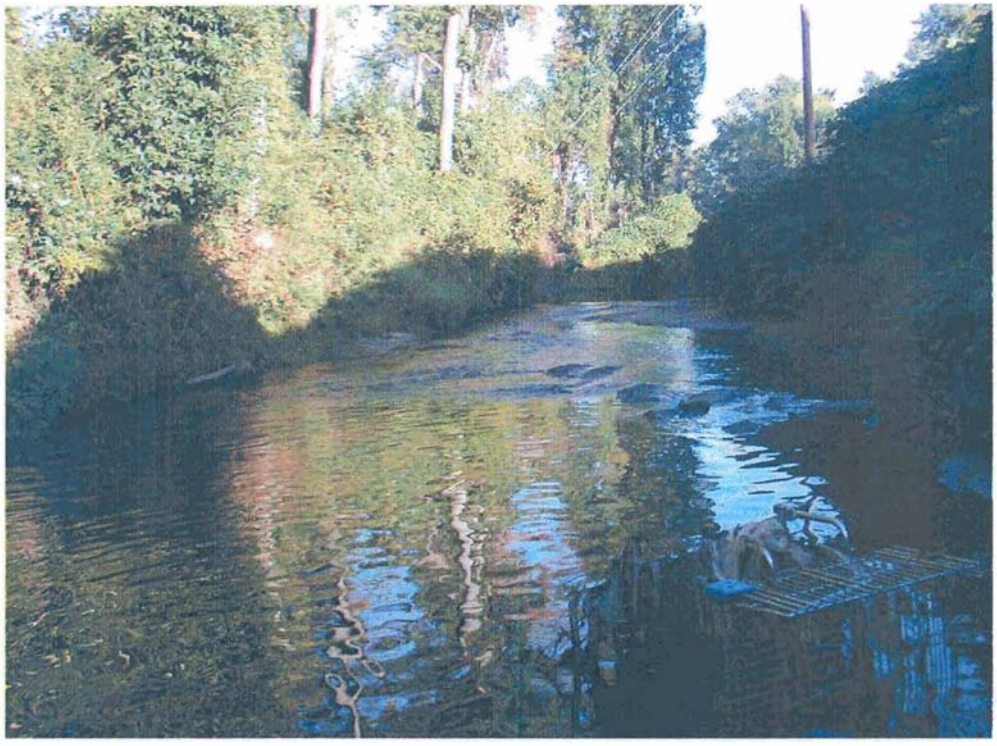
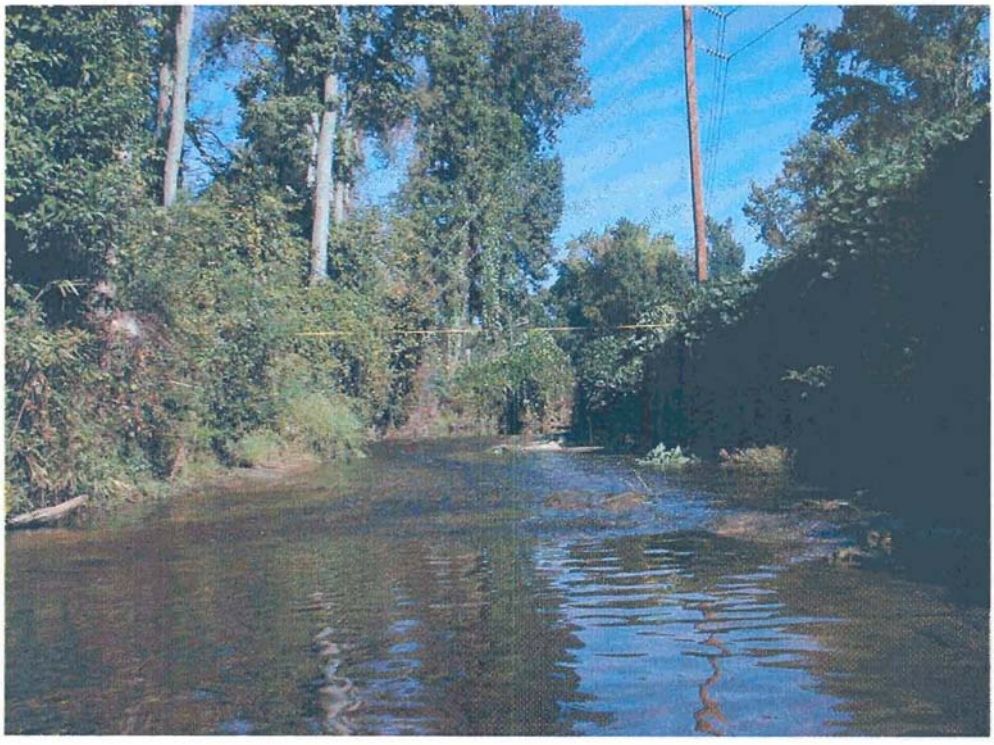
Photo Log
Cross Creek and Little Cross Creek
Stream Restoration Plan

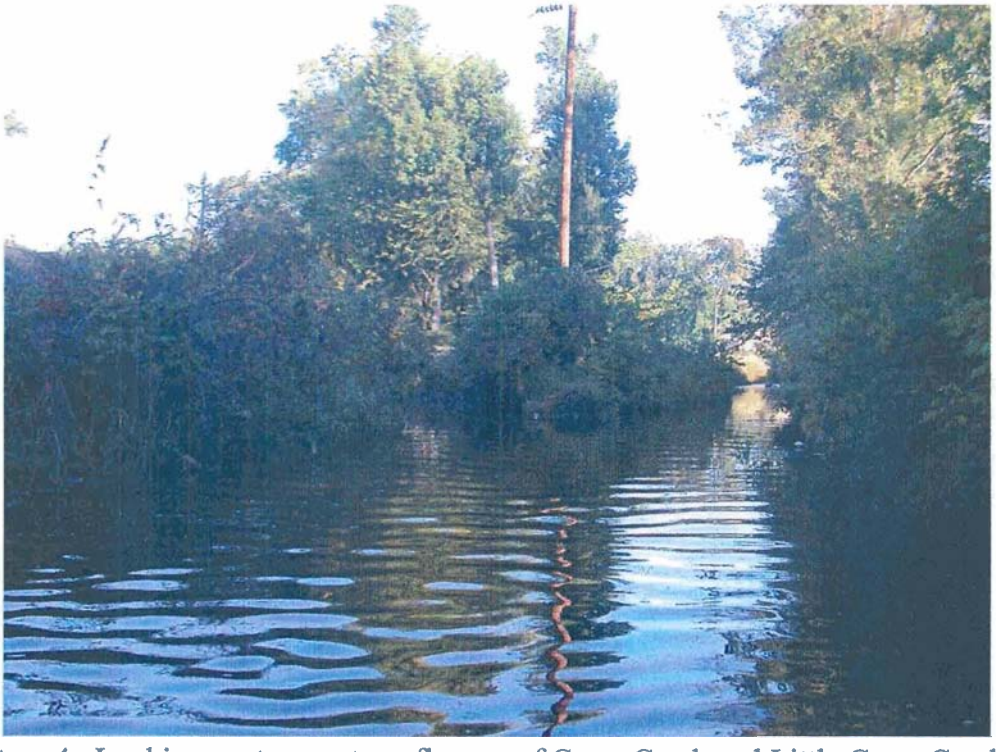


Picture 1. Looking upstream at Riffle Cross-section #1. Trash in foreground.

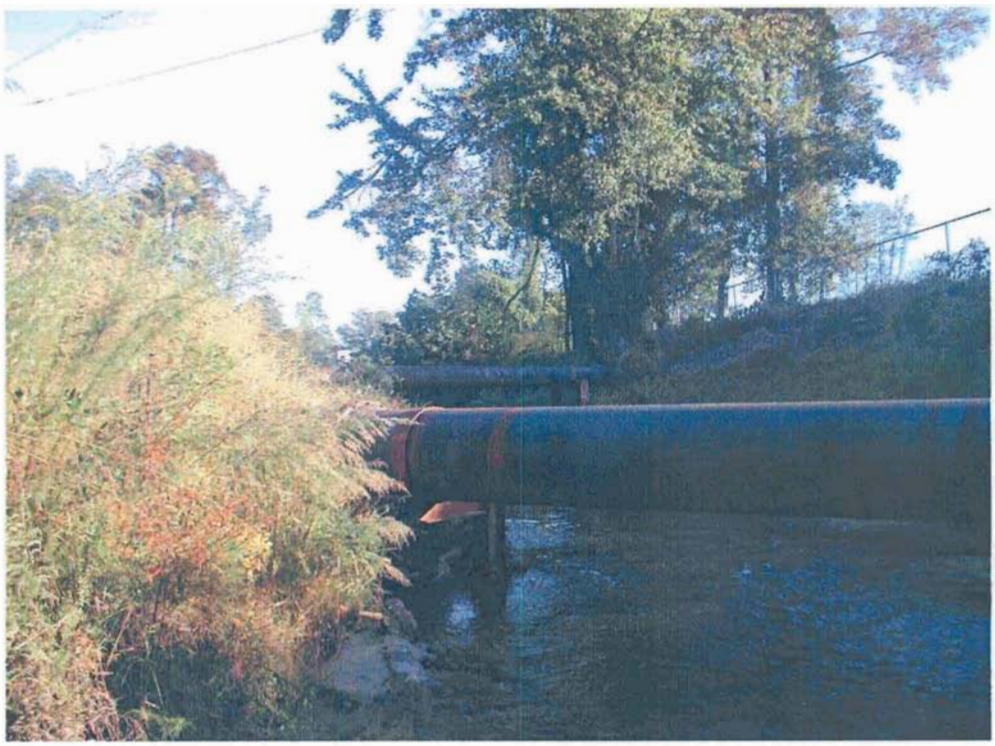


Picture 2. Tape stretched across Cross-section #1. Sandstone on the right.

Picture 3. Sandstone at Riffle Cross-section #1. Kudzu along right bank.

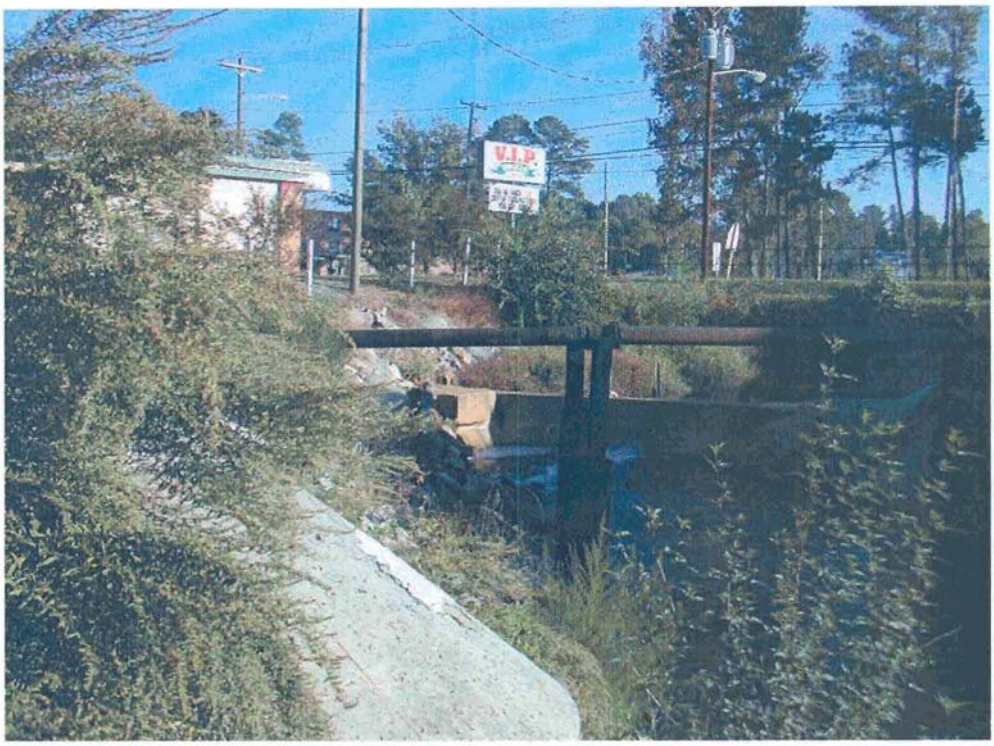


Picture 4. Looking upstream at confluence of Cross Creek and Little Cross Creek.

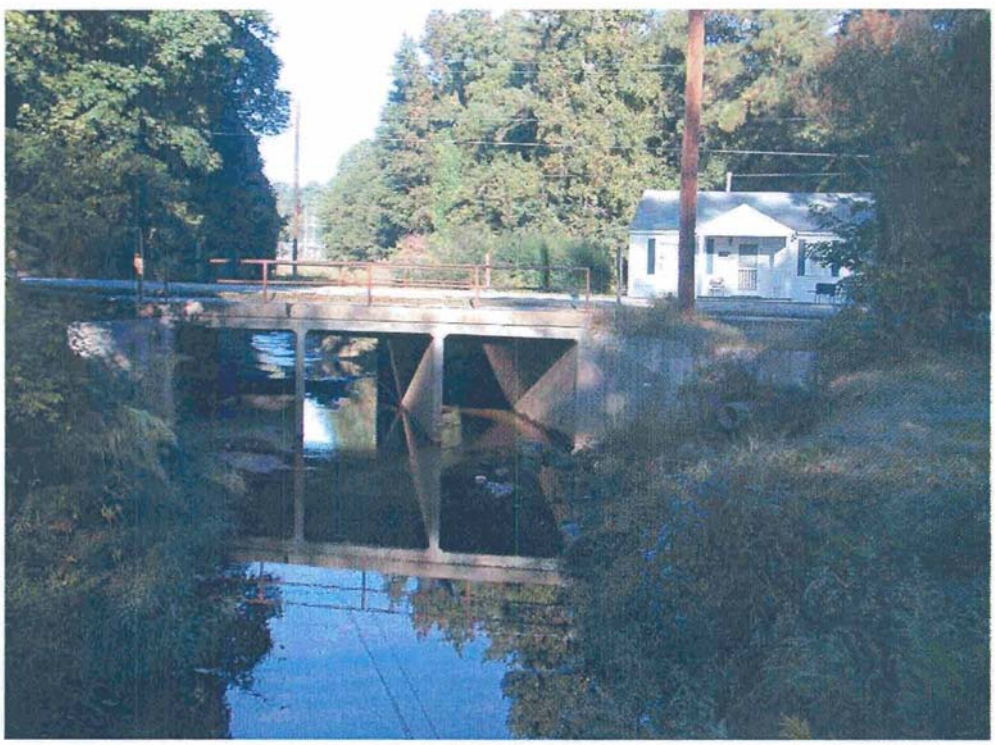


Picture 5. Water and sewer line crossing along Reach 2, Cross Creek.

Picture 6. Looking downstream at Riffle Cross-section #2. Tape stretched across stream.



Picture 7. Water supply intake dam located at upstream end of Reach 2, Cross Creek.



Picture 8. Culvert at beginning of Reach 3, Little Cross Creek.

Picture 9. Looking downstream along Reach 3, Little Cross Creek, from culvert.

Picture 10. Looking upstream at Riffle Cross-section #3 on Little Cross Creek.

Picture 11. Hill slope along Washington Drive on west side of floodplain.

Picture 12. Remnant forest at south end of project site.

Picture 13. Large drainage ditch at south end of property. 48" pipe has failed.

Picture 14. Small drainpipe from Blue Street on south side of property.

Fayetteville Property
Cross Creek
Cumberland County, NC

SUMMARY OF CROSS SECTION DATA

Prepared By:	**Ben Goetz**		
River Basin:	**Cape Fear**		
Watershed:	**Cross Creek & Little Cross Creek**		
Stream Reach:	**Project Site - Reach 1, 2, & 3**		
Date:	**7/22/2002**		
Reach:	**Reach 1**	**Reach 2**	**Reach 3**
Drainage Area (sq. mi.):	**25.5**	**15.5**	**10.0**
Total Stream Length:	**600**	**760**	**705**

	Reach 1	**Reach 2**	**Reach 3**
	CS#1	**CS#2**	**CS#3**
Channel Feature	**Riffle**	**Riffle**	**Riffle**
Cross Sect. Area, A (sq ft)	68.8	77.1	33.5
Top Width, W(ft)	26.4	26.0	17.3
Maximum Depth, Dmax (ft)	3.3	4.1	2.9
Mean Depth, D (ft)	2.6	3.0	1.9
W/D Ratio	10.1	8.8	8.9

	Reach 1	**Reach 2**	**Reach 3**
	CS#6	**CS#5**	**CS#4**
Channel Feature	**Riffle**	**Riffle**	**Riffle**
Cross Sect. Area, A (sq ft)	74.1	72.6	43.6
Top Width, W(ft)	30.0	27.0	23.0
Maximum Depth, Dmax (ft)	3.6	3.7	2.5
Mean Depth, D (ft)	2.5	2.7	1.9
W/D Ratio	12.1	10.0	12.1

AVERAGE VALUES	**Reach 1**	**Reach 2**	**Reach 3**
Channel Feature	**Riffle**	**Riffle**	**Riffle**
Cross Sect. Area, A (sq ft)	71.4	74.9	38.6
Top Width, W(ft)	28.2	26.5	20.2
Maximum Depth, Dmax (ft)	3.5	3.9	2.7
Mean Depth, D (ft)	2.5	2.8	1.9
W/D Ratio	11.1	9.4	10.5

Fayetteville Property
Cross Creek
Cumberland County, NC

Field Crew:	Ben Goetz, Jan Patterson
River Basin:	Cape Fear
Watershed:	Cross Creek downstream ofconvergence
Stream Reach:	Cross Creek- Reach 1
Drainage Area:	25.5 sq mi (16,315 acres)
Date:	10/11/2001
Location:	~300' upstream of Washington Dr Culvert ~95' upstream of 48' storm drain outlet ditch
Feature:	Riffle CS#1

*Special Note: Streamflow affected by impoundments upstream

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
0+00.0	104.73	4.73	100.00	2' from fence
0+03.0	104.73	5.15	99.58	
0+06.0	104.73	5.98	98.75	LTOB
0+06.7	104.73	6.26	98.47	
0+07.4	104.73	8.27	96.46	
0+08.0	104.73	9.18	95.55	
0+08.8	104.73	9.85	94.88	LBKF
0+09.5	104.73	10.60	94.13	
0+10.2	104.73	11.50	93.23	
0+12.0	104.73	11.59	93.14	
0+14.0	104.73	12.05	92.68	
0+16.0	104.73	12.44	92.29	
0+18.0	104.73	12.50	92.23	
0+19.3	104.73	12.57	92.16	
0+20.6	104.73	12.50	92.23	
0+22.0	104.73	12.73	92.00	LEW
0+24.3	104.73	13.08	91.65	
0+25.0	104.73	13.05	91.68	
0+25.8	104.73	13.08	91.65	
0+27.5	104.73	13.13	91.60	
0+29.0	104.73	13.17	91.56	TW
0+30.5	104.73	13.15	91.58	
0+31.8	104.73	13.15	91.58	
0+33.5	104.73	12.87	91.86	
0+34.4	104.73	12.14	92.59	REW
0+34.5	104.73	10.81	93.92	
0+35.2	104.73	9.65	95.08	RBKF
0+35.9	104.73	8.07	96.46	
0+36.4	104.73	7.61	97.12	
0+38.8	104.73	5.87	98.86	
0+39.8	104.73	5.69	99.04	RTOB
0+42.0	104.73	5.42	99.31	
0+45.0	104.73	5.43	99.30	
0+48.0	104.73	5.66	99.07	
0+50.0	104.73	5.91	98.82	
0+54.0	104.73	6.21	98.52	berm after then drops into field

Bankfull Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	0.7	0.8	0.3
	0.7	1.7	0.8
	1.8	1.7	3.1
	2.0	2.2	3.9
	2.0	2.6	4.8
	2.0	2.7	5.2
	1.3	2.7	3.5
	1.3	2.7	3.5
	1.4	2.9	3.9
	2.3	3.2	7.0
	0.7	3.2	2.3
	0.8	3.2	2.6
	1.7	3.3	5.5
	1.5	3.3	5.0
	1.5	3.3	5.0
	1.3	3.3	4.3
	1.7	3.0	5.4
	0.9	2.3	2.4
	0.1	1.0	0.2
	0.7	-0.2	0.3
TOTAL	26.4		68.8

Top of Bank Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	0.7	0.3	0.1
	0.7	2.3	0.9
	0.6	3.2	1.6
	0.8	3.9	2.8
	0.7	4.6	3.0
	0.7	5.5	3.5
	1.6	5.6	10.0
	2.0	6.1	11.7
	2.0	6.5	12.5
	2.0	6.5	13.0
	1.3	6.6	8.5
	1.3	6.5	8.5
	1.4	6.8	9.3
	2.3	7.1	15.9
	0.7	7.1	5.0
	0.8	7.1	5.7
	1.7	7.1	12.1
	1.5	7.2	10.8
	1.5	7.2	10.8
	1.3	7.2	9.3
	1.7	6.9	12.0
	0.9	6.2	5.9
	0.1	4.8	0.5
	0.7	3.7	3.0
	0.7	2.3	2.1
	0.5	1.6	1.0
	2.4	0.0	2.0
	1.0	0.0	0.0
TOTAL	33.8		181.4

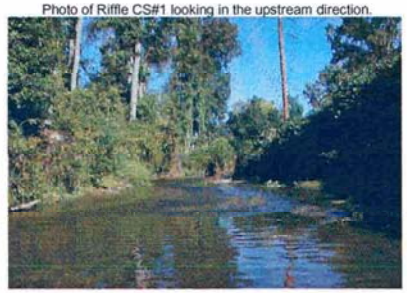
SUMMARY DATA (BANKFULL)

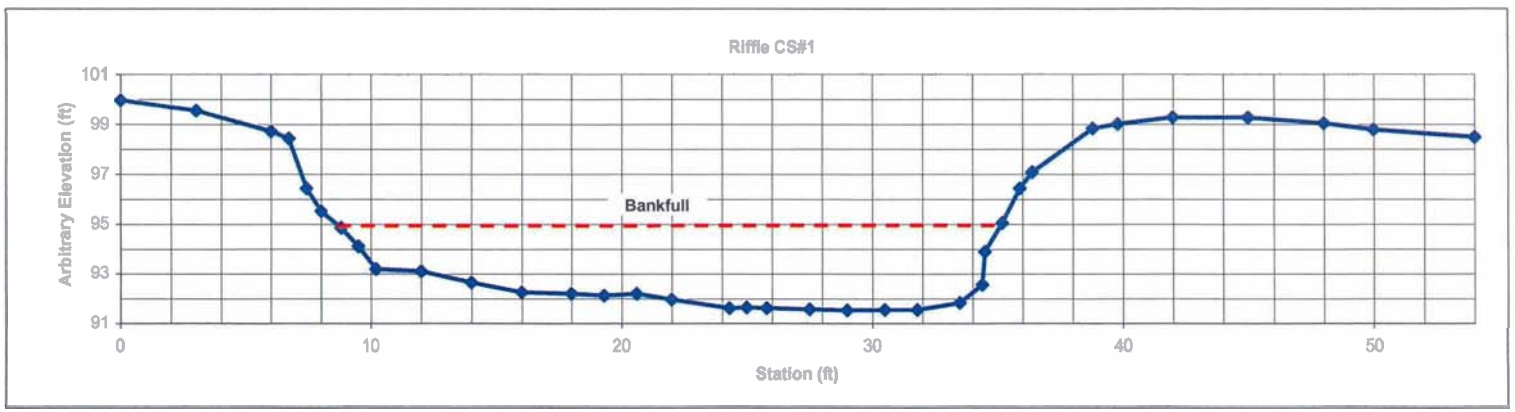
A(BKF)	68.8	W(FPA)	32
W(BKF)	26.4	Slope	0.0022
Max d	3.3	Sinuosity	1
Mean d	2.6	Area=	A
W/D	10.1	Width=	W
Entrenchment	1.2	Depth=	D
Stream Type	G5	Bankfull=	BKF
Area from Rural Regional Curve			490

Bank Erosion Hazard Index (BEHI

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	2.2	1.3	Very Low
Root Depth/Bank Ht	0.33	4.3	Moderate
Root Density (%)	10	8.6	Very High
Bank Angle (Degrees)	57	3.8	Low
Surface Protection (%)	5	10	Extreme
Bank Materials	Sand	10	
		38	High

Photo of Riffle CS#1 looking in the upstream direction.





Fayetteville Property
Cross Creek
Cumberland County, NC

Field Crew:	Ben Goetz, Jan Pattersor
River Basin:	Cape Fear
Watershed:	Cross Creek downstream of convergence
Stream Reach:	Cross Creek- Reach 1
Drainage Area:	25.5 sq mi (16,315 acres
Date:	10/11/2001
Station:	~120' upstream of Washington Dr Culver
	~80 downstream of 48' storm drain outlet ditc
Feature:	Riffle CS#6

*Special Note: Streamflow affected by impoundments upstrean

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
0+00.0	106.44	6.44	100.00	2' from fence
0+03.0	104.73	6.44	98.29	LTOB
0+04.0	104.73	8.85	95.88	
0+06.0	104.73	10.88	93.85	
0+07.0	104.73	12.30	92.43	LBKF
0+09.5	104.73	12.76	91.97	
0+11.5	104.73	13.11	91.62	
0+13.0	104.73	13.76	90.97	
0+15.5	104.73	14.79	89.94	LEW/WS
0+18.5	104.73	15.19	89.54	
0+20.5	104.73	15.22	89.51	
0+24.0	104.73	15.10	89.63	
0+28.0	104.73	15.36	89.37	
0+35.0	104.73	15.80	88.93	
0+37.0	104.73	15.89	88.84	TW
0+37.0	104.73	12.30	92.43	RBKF
0+37.0	104.73	12.13	92.60	
0+42.0	104.73	9.13	95.60	RTOB

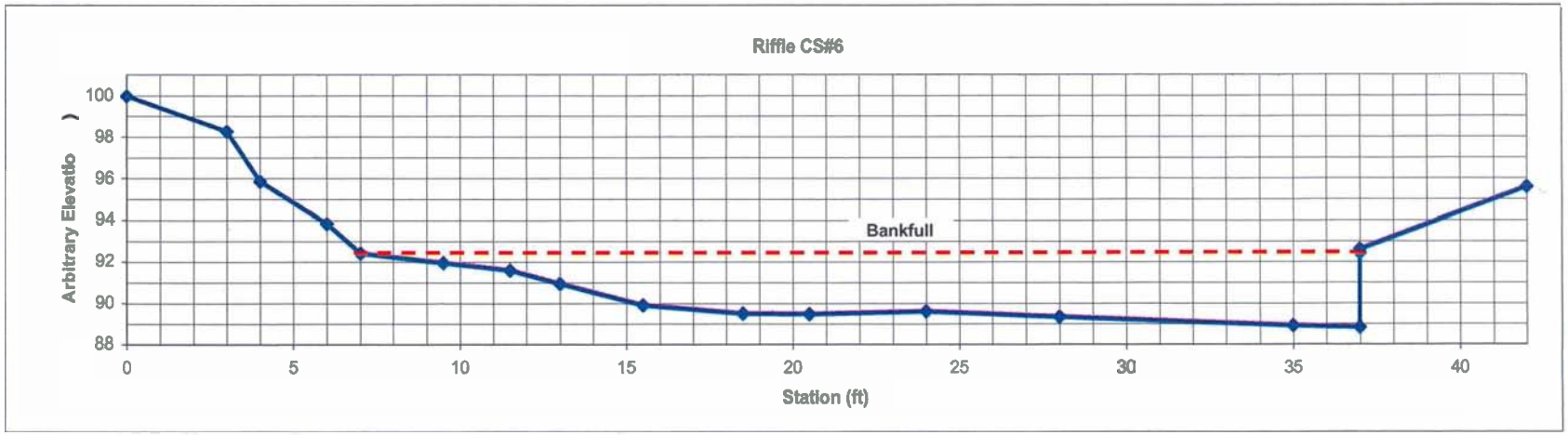
Bankfull Geometry	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	2.5	0.5	0.6
	2.0	0.8	1.3
	1.5	1.5	1.7
	2.5	2.5	4.9
	3.0	2.9	8.1
	2.0	2.9	5.8
	3.5	2.8	10.0
	4.0	3.1	11.7
	7.0	3.5	23.0
	2.0	3.6	7.1
	0.0	0.0	0.0
TOTAL	30.0		74.1

Top of Bank Geometry	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	1.0	2.4	1.2
	2.0	4.4	6.8
	1.0	5.9	5.2
	2.5	6.3	15.2
	2.0	6.7	13.0
	1.5	7.3	10.5
	2.5	8.4	19.6
	3.0	8.8	25.7
	2.0	8.8	17.5
	3.5	8.7	30.5
	4.0	8.9	35.2
	7.0	9.4	64.0
	2.0	9.5	18.8
	0.0	5.9	0.0
	0.0	5.7	0.0
	5.0	2.7	21.0
TOTAL	39.0		284.1

SUMMARY DATA (BANKFULL)			
A(BKF)	74.1	W(FPA)	40
W(BKF)	30.0	Slope	0.0022
Max d	3.6	Sinuosity	1
Mean d	2.5	Area= A	
W/D	12.1	Width= W	
Entrenchment	1.3	Depth= D	
Stream Type	G5	Bankfull= BKF	
Area from Rural Regional Curve			490

Bank Erosion Hazard Index (BEHI			Bank Erosion
Criteria	Value	Index	Potential
Bank Ht/Bkf Ht	2	7.9	High
Root Depth/Bank Ht	0.5	3.9	Low
Root Density (%)	10	8.6	Very High
Bank Angle (Degrees)	90	7.9	High
Surface Protection (%)	5	10	Extreme
Bank Materials	Sand	10	
		48.3	Extreme

Photo of Riffle CS#6 looking in the upstream direction.



Fayetteville Property
Cross Creek
Cumberland County, NC

LONGITUDINAL PROFILE

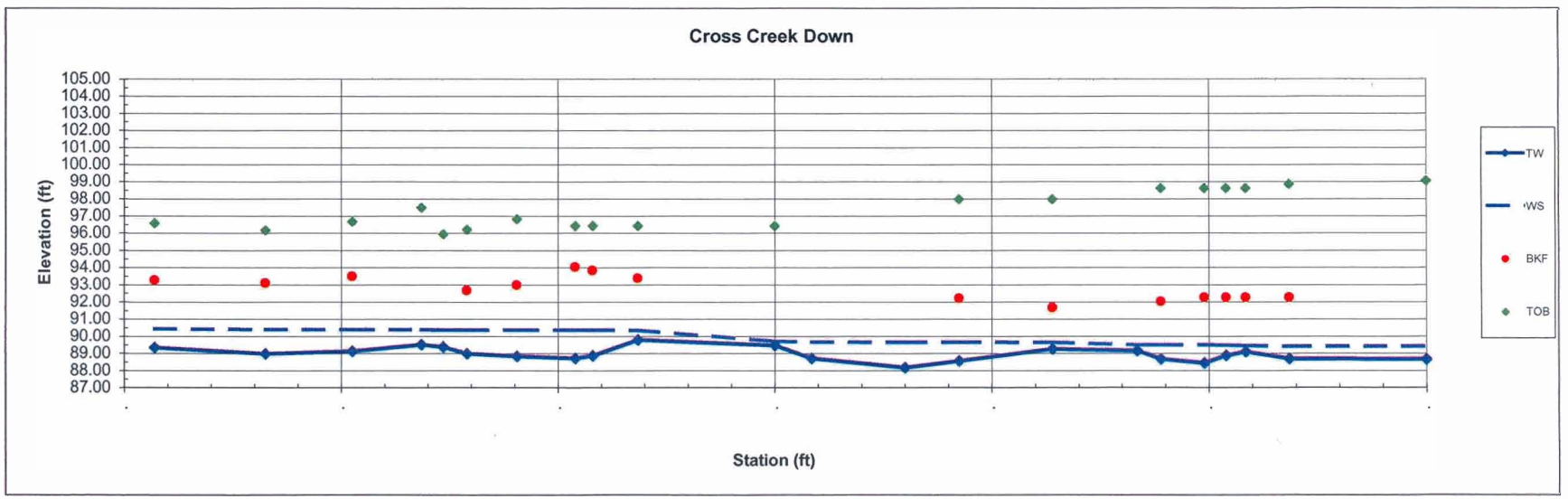
River Basin:	Cape Fear
Watershed:	Cross Creek
Stream Reach:	Cross Creek Down
DA (sq mi):	25.5 sq.mi.
Date:	6/4/2002

REF PT	BS	HI	FS	ELEV	NOTES
TBM	1.40	101.40		100.00	manhole
TP#1	14.90	104.46	11.84		

Station	REF PT	HI	TW(FS)	TW	WS(FS)	WS	BKF(FS)	BKF	TOB(FS)	TOB	Notes
0+14.0	TBM	101.40	12.06	89.34	10.97	90.43	8.14	93.26	4.80	96.60	Head of Pool
0+65.0	TBM	101.40	12.42	88.98	11.00	90.40	8.31	93.09	5.21	96.19	Max Pool
1+05.0	TBM	101.40	12.26	89.14	11.00	90.40	7.90	93.50	4.70	96.70	Head of Glide
1+37.0	TBM	101.40	11.88	89.52	11.00	90.40			3.88	97.52	Head of Riffle
1+47.0	TBM	101.40	12.01	89.39	11.00	90.38			5.42	95.98	Head of Run
1+58.0	TBM	101.40	12.40	89.00	11.00	90.38	8.72	92.68	5.15	96.25	Head of Pool
1+81.0	TBM	101.40	12.55	88.85	11.00	90.38	8.40	93.00	4.55	96.85	IM
2+08.0	TBM	101.40	12.66	88.74	11.00	90.38	7.35	94.05	4.93	96.47	Max Pool
2+16.0	TBM	101.40	12.52	88.88	11.02	90.38	7.55	93.85	4.93	96.47	Head of Glide
2+37.0	TBM	101.40	11.59	89.81	11.04	90.36	8.00	93.40	4.93	96.47	Head of Riffle
3+00.0	TBM	101.40	11.90	89.50	11.67	89.73			4.93	96.47	Head of Run
3+17.0	TBM	101.40	12.67	88.73	11.70	89.70					Head of Pool
3+60.0	TP#1	104.46	16.26	88.20	14.79	89.67					Max Pool
3+85.0	TP#1	104.46	15.87	88.59	14.79	89.67	12.24	92.22	6.44	98.02	Head of Glide
4+28.0	TP#1	104.46	15.19	89.27	14.80	89.66	12.80	91.66	6.44	98.02	Head of Riffle
4+67.0	TP#1	104.46	15.28	89.18	14.95	89.51					Head of Run
4+78.0	TP#1	104.46	15.78	88.68	14.95	89.51	12.45	92.01	5.80	98.66	Head of Pool
4+98.0	TP#1	104.46	16.01	88.45	14.95	89.51	12.20	92.26	5.80	98.66	Max Pool
5+08.0	TP#1	104.46	15.58	88.88	14.97	89.49	12.20	92.26	5.80	98.66	Head of Glide
5+17.0	TP#1	104.46	15.36	89.10	15.00	89.46	12.20	92.26	5.80	98.66	Head of Riffle
5+37.0	TP#1	104.46	15.76	88.70	15.04	89.42	12.20	92.26	5.57	98.89	Head of Run
6+00.0	TP#1	104.46	15.80	88.66	15.04	89.42			5.37	99.09	Culvert

Average Water Surface Slope 0.22

	Bk Ht/Bkf Ht.	P-P	Pool Length	Max Pool Depth	Pool Slope	Riffle Length	Riffle Slope
	1.9						
	1.8			4.11			
	1.7		91.0		0.03		
						10.0	0.20
	2.0	144.0					
	1.9						
	1.5			5.31			
	1.5		58.0		0.00		
	1.9					63.0	1.00
		159.0					
	2.6		68.0		0.04		
	3.7					39.0	0.38
	3.0	161.0					
	2.7			3.81			
	2.9		30.0		0.07		
	3.0					20.0	0.20
	2.9						
max	3.7	161.0	91.0	5.3	0.0667	63	1.0000
min	1.5	144	30	3.81	0.0000	10	0.2000
avg	2.3	154.7	61.8	4.4	0.0359	33	0.4462
Max ratio	0.13	5.71	3.23	0.19	0.30	2.23	4.55
Min ratio	0.05	5.11	1.06	0.14	0.00	0.35	0.91
avg ratio	0.08	5.48	2.19	0.16	0.16	1.17	2.03



Fayetteville Property
Cross Creek
Cumberland County, NC

Field Crew:	Ben Goetz, Jan Patterson
River Basin:	Cape Fear
Watershed:	Cross Creek upstream of convergence
Stream Reach:	Cross Creek- Reach 2
Drainage Area:	15.5 sq mi (9,812 acres)
Date:	10/11/2001
Station:	~400' downstream of Murchison Rd Culvert ~20' upstream of double manholes
Feature:	Riffle CS#2

*Special Note: Streamflow affected by impoundments upstream

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
0+00.0	106.63	6.63	100.00	fence
0+08.5	106.63	6.94	99.69	
0+11.0	106.63	6.67	99.96	
0+14.0	106.63	5.61	101.02	LTOB/berm
0+16.0	106.63	6.76	99.87	
0+19.0	106.63	8.80	97.83	
0+20.5	106.63	10.30	96.33	LBKF
0+22.0	106.63	10.63	96.00	
0+23.5	106.63	11.52	95.11	
0+24.0	106.63	13.00	93.63	
0+26.0	106.63	13.43	93.20	
0+26.7	106.63	13.62	93.01	LEW/WS
0+28.5	106.63	14.25	92.38	
0+30.5	106.63	14.39	92.24	TW
0+33.0	106.63	14.25	92.38	
0+35.0	106.63	14.18	92.45	
0+37.5	106.63	14.02	92.61	
0+38.0	106.63	13.50	93.13	
0+39.8	106.63	13.53	93.10	
0+41.2	106.63	13.93	92.70	
0+43.8	106.63	13.44	93.19	REW
0+45.0	106.63	11.56	95.07	
0+46.5	106.63	10.30	96.33	RBKF
0+48.0	106.63	9.03	97.60	
0+51.0	106.63	6.94	99.69	
0+56.0	106.63	4.15	102.48	RTOB
0+60.0	106.63	3.50	103.13	
0+66.0	106.63	3.83	102.80	
0+77.0	106.63	4.15	102.48	
0+87.0	106.63	4.36	102.27	
1+00.0	106.63	4.94	101.69	

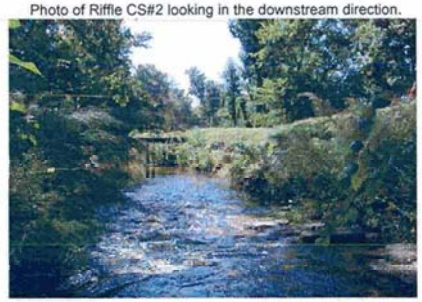
Bankfull Geometry		
Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
0.0	0.0	0.0
1.5	0.3	0.2
1.5	1.2	1.2
0.5	2.7	1.0
2.0	3.1	5.8
0.7	3.3	2.3
1.8	4.0	6.5
2.0	4.1	8.0
2.5	4.0	10.1
2.0	3.9	7.8
2.5	3.7	9.5
0.5	3.2	1.7
1.8	3.2	5.8
1.4	3.6	4.8
2.6	3.1	8.8
1.2	1.3	2.6
1.5	0.0	0.9
TOTAL 26.0		77.1

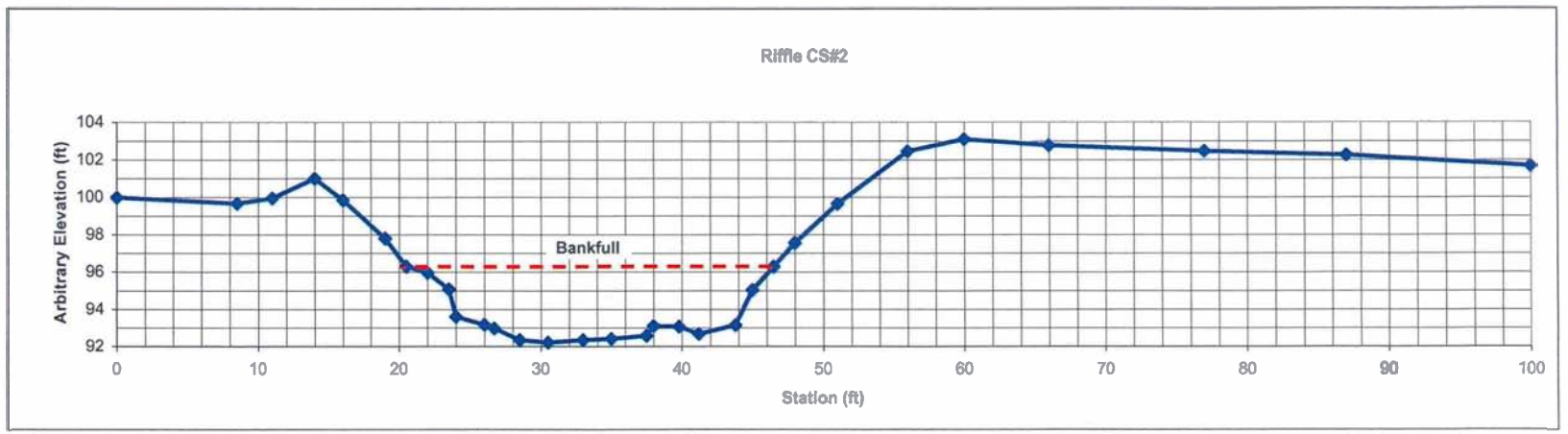
Top of Bank Geometry		
Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
0.0	0.0	0.0
2.0	1.2	1.2
3.0	3.2	6.5
1.5	4.7	5.9
1.5	5.0	7.3
1.5	5.9	8.2
0.5	7.4	3.3
2.0	7.8	15.2
0.7	8.0	5.5
1.8	8.6	15.0
2.0	8.8	17.4
2.5	8.6	21.8
2.0	8.6	17.2
2.5	8.4	21.2
0.5	7.9	4.1
1.8	7.9	14.2
1.4	8.3	11.4
2.6	7.8	21.0
1.2	6.0	8.3
1.5	4.7	8.0
1.5	3.4	6.1
3.0	1.3	7.1
5.0	0.0	3.3
TOTAL 42.0		229.2

SUMMARY DATA (BANKFULL)			
A(BKF)	77.1	W(FPA)	65
W(BKF)	26.0	Slope	0.0022
Max d	4.1	Sinuosity	1
Mean d	3.0	Area=	A
W/D	8.8	Width=	W
Entrenchment	2.5	Depth=	D
Stream Type	E5	Bankfull=	BKF
Area from Rural Regional Curve			350

Bank Erosion Hazard Index (BEHI)			
Criteria	Value	Index	Bank Erosion
Bank Ht/Bkf Ht	1.06	1.6	Very Low
Root Depth/Bank Ht	1	1	Very Low
Root Density (%)	55	2	Low
Bank Angle (Degrees)	52	3.5	Low
Surface Protection (%)	65	2.8	Low
Bank Materials	Sand	10	
			Moderate

Photo of Riffle CS#2 looking in the downstream direction.





Fayetteville Property
Cross Creek
Cumberland County, NC

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	**Cross Creek upstream of convergence**
Stream Reach:	Cross Creek- Reach 2
Drainage Area:	15.5 sq mi (9,812 acres)
Date:	5/29/2002
Station:	~600' downstream of Murchison Rd Culvert ~30' downstream of last aerial crossing
Feature:	Riffle CS#5

***Special Note: Streamflow affected by impoundments upstream**

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
0+00.0	102.12	2.12	100.00	
0+07.0	102.12	4.45	97.67	LTOB
0+12.0	102.12	7.90	94.22	LBKF
0+14.0	102.12	8.50	93.62	
0+16.0	102.12	9.16	92.96	
0+16.5	102.12	11.10	91.02	LEW/WS
0+17.0	102.12	11.39	90.73	
0+20.0	102.12	11.15	90.97	
0+22.5	102.12	11.15	90.97	
0+24.5	102.12	11.53	90.59	
0+27.0	102.12	11.64	90.48	TW
0+29.5	102.12	11.26	90.86	
0+32.5	102.12	11.04	91.08	REW
0+36.0	102.12	10.65	91.47	
0+38.0	102.12	8.80	93.32	
0+39.0	102.12	7.90	94.22	RBKF
0+42.0	102.12	4.74	97.38	RTOB
0+43.0	102.12	3.80	98.32	
0+63.0	102.12	4.23	97.89	
0+70.0	102.12	4.57	97.55	

Bankfull Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	2.0	0.6	0.6
	2.0	1.3	1.9
	0.5	3.2	1.1
	0.5	3.5	1.7
	3.0	3.3	10.1
	2.5	3.3	8.1
	2.0	3.6	6.9
	2.5	3.7	9.2
	2.5	3.4	8.9
	3.0	3.1	9.7
	3.5	2.8	10.3
	2.0	0.9	3.6
	1.0	0.0	0.4
TOTAL	27.0		72.6

Top of Bank Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	5.0	3.5	8.6
	2.0	4.1	7.5
	2.0	4.7	8.8
	0.5	6.6	2.8
	0.5	6.9	3.4
	3.0	6.7	20.5
	2.5	6.7	16.8
	2.0	7.1	13.8
	2.5	7.2	17.8
	2.5	6.8	17.5
	3.0	6.6	20.1
	3.5	6.2	22.4
	2.0	4.3	10.6
	1.0	3.5	3.9
	3.0	0.3	5.6
TOTAL	35.0		180.0

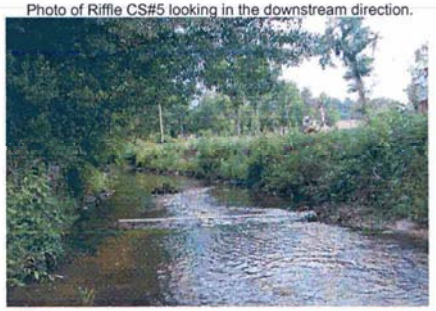
SUMMARY DATA (BANKFULL)

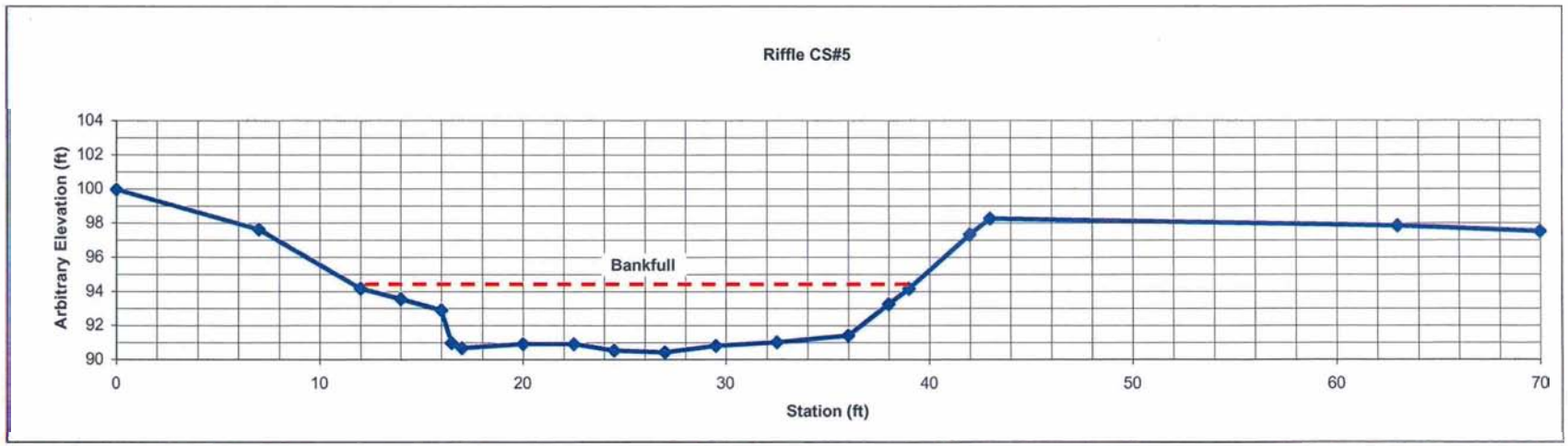
A(BKF)	72.6	W(FPA)	36
W(BKF)	27.0	Slope	0.0022
Max d	3.7	Sinuosity	1
Mean d	2.7	Area=	A
W/D	10.0	Width=	W
Entrenchment	1.3	Depth=	D
Stream Type	G5	Bankfull=	BKF
Area from Rural Regional Curve			350

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion
Bank Ht/Bkf Ht	2.1	8	Very High
Root Depth/Bank Ht	1	1	Very Low
Root Density (%)	54	4	Moderate
Bank Angle (Degrees)	45	2.7	Low
Surface Protection (%)	25	6.5	High
Bank Materials	Sand	10	
		32.2	High

Photo of Riffle CS#5 looking in the downstream direction.





Fayetteville Property
Cross Creek
Cumberland County, NC

LONGITUDINAL PROFILE

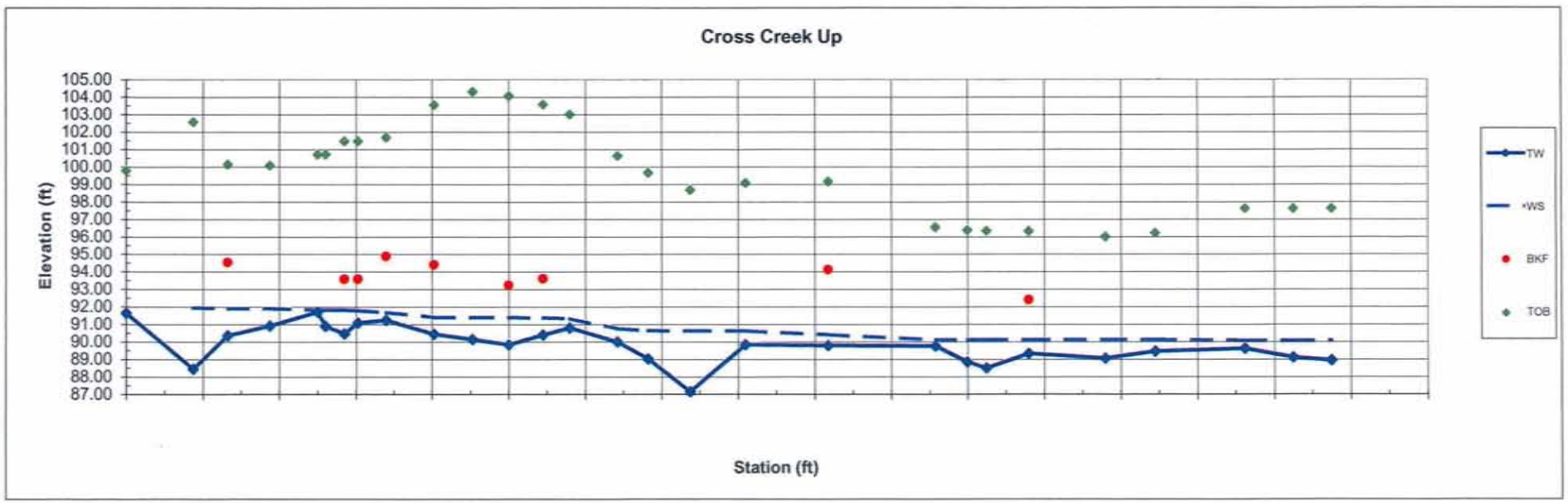
River Basin:	Cape Fear
Watershed:	Cross Creek
Stream Reach:	Cross Creek Upstream
DA (sq mi):	15.5 sq.mi.
Date:	5/29/2002

REF PT	BS	HI	FS	ELEV	NOTES
BM	9.15	109.15		100.00	manhole
TP#1	1.30	101.30			

Station	REF PT	HI	TW(FS)	TW	WS(FS)	WS	BKF(FS)	BKF	TOB(FS)	TOB	Notes
0+00.0	BM	109.15	17.48	91.67	17.10				9.34	99.81	Head of Pool
0+35.0	BM	109.15	20.66	88.49	17.16	91.99			6.56	102.59	Max Pool
0+53.0	BM	109.15	18.75	90.40	17.20	91.95	14.59	94.56	8.98	100.17	Head of Glide
0+75.0	BM	109.15	18.19	90.96	17.20	91.95			9.03	100.12	Head of Riffle
1+00.0	BM	109.15	17.40	91.75	17.29	91.86			8.42	100.73	Head of Run
1+04.0	BM	109.15	18.22	90.93	17.29	91.86			8.42	100.73	Head of Pool
1+14.0	BM	109.15	18.64	90.51	17.33	91.86	15.56	93.59	7.65	101.50	Max Pool
1+21.0	BM	109.15	18.03	91.12	17.33	91.84	15.58	93.59	7.65	101.50	Head of Glide
1+36.0	BM	109.15	17.87	91.28	17.42	91.73	14.25	94.90	7.45	101.70	Head of Riffle
1+61.0	BM	109.15	18.67	90.48	17.70	91.45	14.73	94.42	5.59	103.56	Head of Run
1+81.0	BM	109.15	18.95	90.20	17.70	91.45			4.83	104.32	Head of Pool
2+00.0	BM	109.15	19.27	89.88	17.70	91.45	15.90	93.25	5.07	104.08	Max Pool
2+18.0	BM	109.15	18.70	90.45	17.71	91.44	15.53	93.62	5.54	103.61	Head of Glide
2+32.0	BM	109.15	18.30	90.85	17.76	91.39			6.11	103.04	Head of Riffle
2+57.0	BM	109.15	19.09	90.06	18.34	90.81			8.48	100.67	Head of Run
2+73.0	BM	109.15	20.07	89.08	18.44	90.71			9.45	99.70	Head of Pool
2+95.0	BM	109.15	21.95	87.20	18.45	90.70			10.43	98.72	Max Pool
3+24.0	TP#1	101.30	11.40	89.90	10.60	90.70			2.19	99.11	Head of Glide
3+67.0	TP#1	101.30	11.45	89.85	10.83	90.47	7.15	94.15	2.10	99.20	Head of Riffle
4+23.0	TP#1	101.30	11.48	89.82	11.12	90.18			4.70	96.60	Head of Run
4+40.0	TP#1	101.50	12.40	89.90	11.13	90.17			4.87	96.43	Head of Pool
4+50.0	TP#1	101.30	12.74	88.56	11.13	90.17			4.91	96.39	Max Pool
4+72.0	TP#1	101.30	11.92	89.38	11.13	90.17	8.88	92.42	4.93	96.37	Head of Glide
5+12.0	TP#1	101.30	12.20	89.10	11.13	90.17			5.25	96.05	N/A
5+38.0	TP#1	101.30	11.79	89.51	11.13	90.17			5.05	96.25	N/A
5+85.0	TP#1	101.30	11.65	89.65	11.18	90.12			3.65	97.65	N/A
6+10.0	TP#1	101.30	12.15	89.15	11.18	90.12			3.65	97.65	N/A
6+30.0	TP#1	101.30	12.32	88.98	11.18	90.12			3.65	97.65	N/A

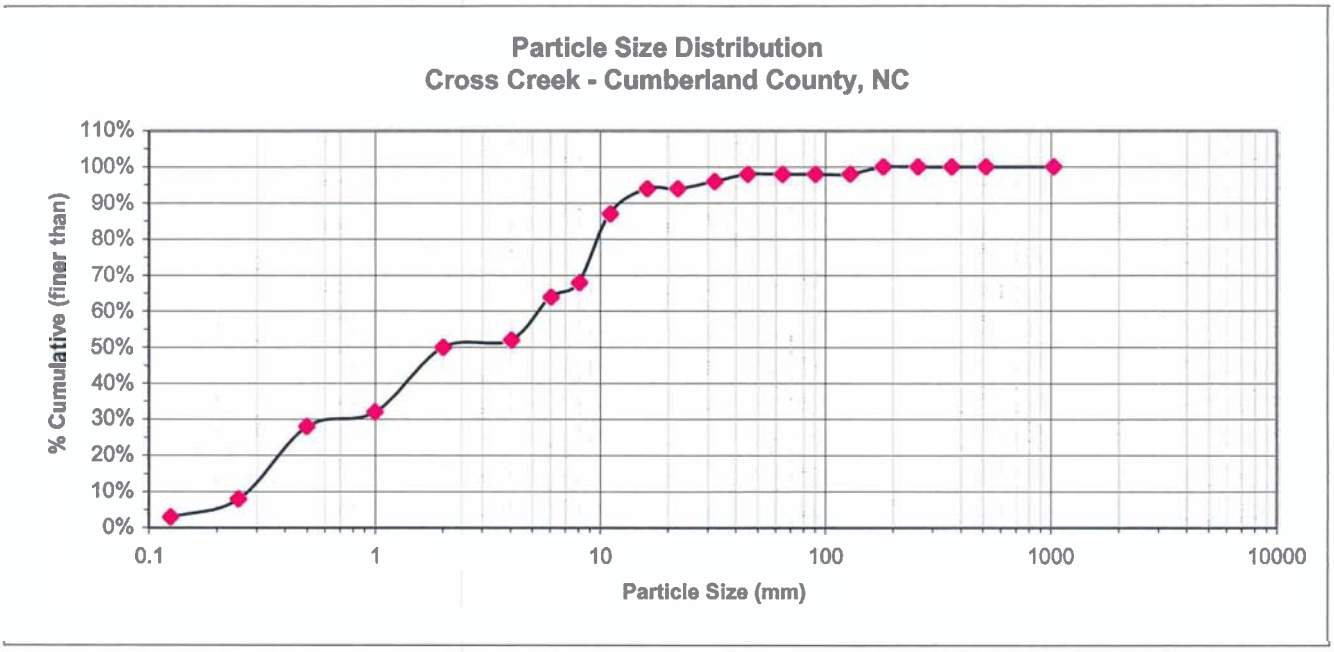
Average Water Surface Slope 0.22

	Bk Ht/Bkf Ht.	P-P	Pool Length	Max Pool Depth	Pool Slope	Riffle Length	Riffle Slope
	2.3		53.0				
						25.0	0.36
		104.0					
	3.6			3.08			
	4.2		17.0		0.12		
	2.9					25.0	1.12
	3.3						
		77.0					
	4.2			3.37			
	4.2		37.0		0.03		
						25.0	2.32
		92.0					
			51.0		0.02		
	2.2					56.0	0.52
		167.0					
	2.3		32.0		0.00		
max	4.2	167.0	53.0	3.4	0.1176	56	2.3200
min	2.2	77	17	3.08	0.0000	25	0.3600
avg	3.2	110.0	38.0	3.2	0.0411	33	1.0795
Max ratio	0.16	6.30	2.00	0.13	0.53	2.11	10.55
Min ratio	0.08	2.91	0.64	0.12	0.00	0.94	1.64
avg ratio	0.12	4.15	1.43	0.12	0.19	1.24	4.91



Fayetteville Property
Cross Creek
Cumberland County, NC

PEBBLE COUNT									
Site: Cross Creek							5/29/2002		
Party: Ben Goetz, Jan Patterson, Jane Almon							Cross Creek		
				Particle Count					
Inches	Particle	Millimeter		Riffle	Run/Pool		Total No.	Item %	% Cumulativ
	Silt/Clay	< 0.062	S/C	0	0		0	0%	0%
	Very Fine	.062 - .125	S	0	3		3	3%	3%
	Fine	.125 - .25	A	4	1		5	5%	8%
	Medium	.25 - .50	N	14	6		20	20%	28%
	Coarse	.50 - 1.0	D	2	2		4	4%	32%
.04 -.08	Very Coarse	1.0 - 2.0	S	0	18		18	18%	50%
.08 - .16	Very Fine	2.0 - 4.0		0	2		2	2%	52%
.16 - .22	Fine	4.0 - 5.7	G	10	2		12	12%	64%
.22 - .31	Fine	5.7 - 8.0	R	1	3		4	4%	68%
.31 - .44	Medium	8.0 - 11.3	A	11	8		19	19%	87%
.44 - .63	Medium	11.3 - 16.0	V	3	4		7	7%	94%
.63 - .89	Coarse	16.0 - 22.6	E	0	0		0	0%	94%
.89 - 1.26	Coarse	22.6 - 32.0	L	2	0		2	2%	96%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S	1	1		2	2%	98%
1.77 - 2.5	Very Coarse	45.0 - 64.0		0	0		0	0%	98%
2.5 - 3.5	Small	64 - 90	C	0	0		0	0%	98%
3.5 - 5.0	Small	90 - 128	O	0	0		0	0%	98%
5.0 - 7.1	Large	128 - 180	B	2	0		2	2%	100%
7.1 - 10.1	Large	180 - 256	L	0	0		0	0%	100%
10.1 - 14.3	Small	256 - 362	B	0	0		0	0%	100%
14.3 - 20	Small	362 - 512	L	0	0		0	0%	100%
20 - 40	Medium	512 - 1024	D	0	0		0	0%	100%
40 - 80	rg- Very Lr	1024 - 2048	R	0	0		0	0%	100%
	Bedrock		BDRK	0	0		0	0%	100%
			Totals	50	50		100	100%	100%



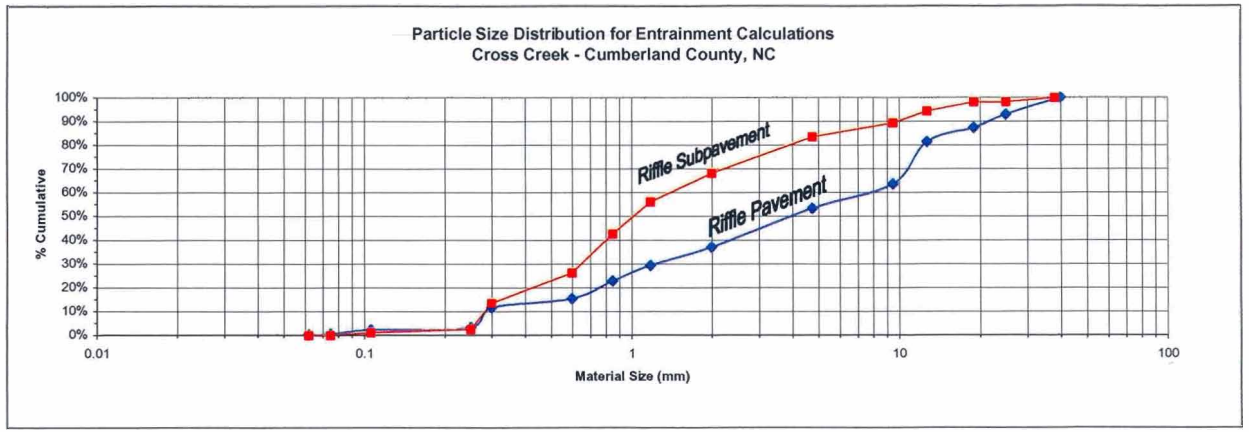
Fayetteville Property
Cross Creek
Cumberland County, NC

RIFFLE SAMPLE	
River Basin:	Cape Fear
Watershed:	Cross Creek
Stream Reach:	Cross Creek (Reaches 1 & 2)
DA (sq mi):	25.5 sq.mi.
Date:	5/29/2002

Sieve Size (mm)	0.062	0.075	0.106	0.25	0.3	0.6	0.85	1.18	2	4.75	9.5	12.7	19	25	
micro		75	106	250	300	600	850								
Tare Weight(lbs)	0.81	0.74	0.77	0.81	0.82	0.87	0.95	0.95	1.03	1.12	1.2	1.22	1.28	1.28	
Pave Sample Weight (lbs)	0.81	0.75	0.84	0.85	1.16	1.02	1.25	1.21	1.34	1.78	1.61	1.94	1.52	1.5	
Subpav Sample Weight (lbs)	0.82	0.75	0.95	1.01	2.43	2.77	3.39	2.93	2.82	3.37	2.06	1.96	1.83	1.28	
Pave Net Weight (lbs)	0.01	0.01	0.07	0.04	0.34	0.15	0.3	0.26	0.31	0.66	0.41	0.72	0.24	0.22	4.03
Subpave Net Weight(lbs)	0.01	0.01	0.18	0.2	1.61	1.9	2.44	1.98	1.79	2.25	0.86	0.74	0.55	0	14.78
% Pavement	0%	0%	2%	1%	8%	4%	7%	6%	8%	16%	10%	18%	6%	5%	
% Cumulative Pavement	0%	0%	2%	3%	12%	15%	23%	29%	37%	53%	64%	81%	87%	93%	100%
% Subpavement	0%	0%	1%	1%	11%	13%	17%	13%	12%	15%	6%	5%	4%	0%	
% Cumulative Subpavement	0%	0%	1%	3%	14%	26%	43%	56%	68%	84%	90%	95%	98%	98%	100%

	LP1	LP2
dia	40	37
weight	0.18	0.11
weight	0.17	0.09
dia	38	35

D50 Subpavement (mm)	1	
D50 Riffle Pavement (mm)	4	
D50/D50^	4	
Tc	0.025	
Largest Particle (mm)	38.00	0.12 ft
Slope	0.002	
Depth required (mm)	650	2.13 ft
Area Required (sq. ft.)	73	
Width/Depth Ratio	16	
Bankfull Width (ft)	34.2	
Actual mean depth (ft)	2.14	



Fayetteville Property
Cross Creek
Cumberland County, NC

Field Crew:	Ben Goetz, Jan Patterson
River Basin:	Cape Fear
Watershed:	Little Cross Creek upstream of convergence
Stream Reach:	Little Cross Creek- Reach 3
Drainage Area:	10.0sq.mi (6,503 acres)
Date:	10/11/2001
Station:	~200' upstream of convergence
Feature:	Riffle CS#3

*Special Note: Streamflow affected by impoundments upstream

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
0+00.0	104.88	4.88	100.00	
0+07.0	104.88	4.50	100.38	
0+15.0	104.88	4.79	100.09	
0+20.0	104.88	5.07	99.81	
0+22.0	104.88	5.32	99.56	LTOB
0+24.0	104.88	6.37	98.51	
0+26.5	104.88	7.47	97.41	
0+27.2	104.88	8.16	96.72	LBKF
0+27.7	104.88	9.35	95.53	
0+29.0	104.88	10.13	94.75	
0+30.2	104.88	10.64	94.24	LEW/WS
0+32.5	104.88	10.86	94.02	
0+33.5	104.88	10.97	93.91	
0+35.5	104.88	10.94	93.94	
0+36.8	104.88	11.04	93.84	TW
0+38.4	104.88	10.68	94.20	REW
0+39.0	104.88	10.32	94.56	
0+40.0	104.88	9.31	95.57	
0+42.0	104.88	8.83	96.05	
0+44.0	104.88	8.69	96.19	
0+44.5	104.88	8.16	96.72	RBKF
0+44.7	104.88	8.07	96.81	
0+45.8	104.88	7.73	97.15	
0+47.5	104.88	5.93	98.95	
0+49.5	104.88	3.95	100.93	RTOB
0+54.0	104.88	3.08	101.80	
0+62.5	104.88	2.10	102.78	
0+67.0	104.88	2.22	102.66	
0+75.5	104.88	3.59	101.29	
0+82.0	104.88	4.11	100.77	

Bankfull Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	0.5	1.2	0.3
	1.3	2.0	2.1
	1.2	2.5	2.7
	2.3	2.7	6.0
	1.0	2.8	2.8
	2.0	2.8	5.6
	1.3	2.9	3.7
	1.6	2.5	4.3
	0.6	2.2	1.4
	1.0	1.2	1.7
	2.0	0.7	1.8
	2.0	0.5	1.2
	0.5	0.0	0.1
TOTAL	17.3		33.5

Top of Bank Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	2.0	1.1	1.1
	2.5	2.2	4.0
	0.7	2.8	1.7
	0.5	4.0	1.7
	1.3	4.8	5.7
	1.2	5.3	6.1
	2.3	5.5	12.5
	1.0	5.7	5.6
	2.0	5.6	11.3
	1.3	5.7	7.4
	1.6	5.4	8.9
	0.6	5.0	3.1
	1.0	4.0	4.5
	2.0	3.5	7.5
	2.0	3.4	6.9
	0.5	2.6	1.6
	0.2	2.6	0.6
	1.1	2.4	2.8
	1.7	0.6	2.9
	2.0	0.0	0.6
TOTAL	27.5		96.3

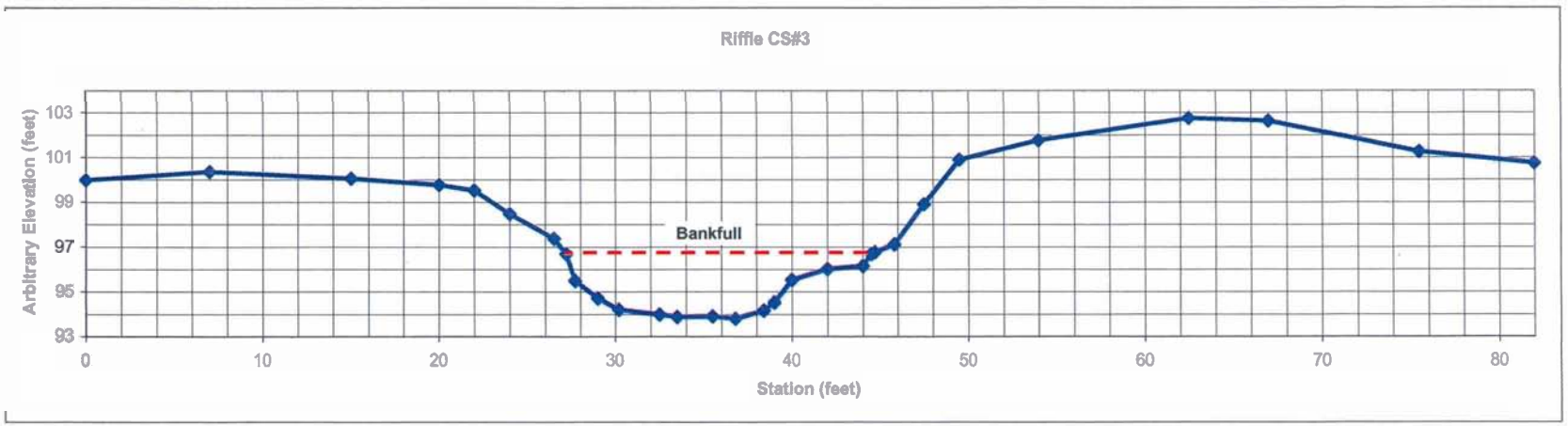
SUMMARY DATA (BANKFULL)

A(BKF)	33.5	W(FPA)	27
W(BKF)	17.3	Slope	0.0037
Max d	2.9	Sinuosity	1.1
Mean d	1.9	Area=	A
W/D	8.9	Width=	W
Entrenchment	1.6	Depth=	D
Stream Type	G5c	Bankfull=	BKF
Area from Rural Regional Curve			270

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion
Bank Ht/Bkf Ht	1.03	1.3	Very Low
Root Depth/Bank Ht	0.75	3.2	Low
Root Density (%)	55	2	Low
Bank Angle (Degrees)	50	3.4	Low
Surface Protection (%)	50	3.6	Moderate
Bank Materials	Sand	10	
		23.5	Moderate

Photo of Riffle CS#3 looking in the upstream direction



Fayetteville Property
Cross Creek
Cumberland County, NC

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	**Little Cross Creek upstream of convergence**
Stream Reach:	Little Cross Creek- Reach 3
Drainage Area:	10.0 sq mi (6,503 acres)
Date:	5/29/2002
Station:	~100' upstream of convergence
Feature:	Riffle CS#4

***Special Note: Streamflow affected by impoundments upstream**

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
-0+05.0	107.72	7.72	100.00	
0+00.0	107.72	8.19	99.53	LTOB
0+04.0	107.72	8.82	98.90	
0+09.0	107.72	11.00	96.72	
0+15.0	107.72	11.76	95.96	LBKF
0+16.5	107.72	12.48	95.24	
0+17.5	107.72	13.13	94.59	
0+19.5	107.72	13.92	93.80	LEW/WS
0+22.5	107.72	14.16	93.56	
0+24.5	107.72	14.25	93.47	TW
0+26.5	107.72	14.16	93.56	
0+28.5	107.72	13.98	93.74	REW
0+31.0	107.72	13.75	93.97	
0+32.5	107.72	13.88	93.84	
0+33.5	107.72	14.40	93.32	ponded area to side
0+35.0	107.72	13.80	93.92	toe of bank
0+38.0	107.72	11.76	95.96	
0+43.0	107.72	8.19	99.53	
0+45.0	107.72	6.99	100.73	
0+47.0	107.72	7.12	100.60	
0+51.0	107.72	5.17	102.55	RTOB

Bankfull Geometry	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	1.5	0.7	0.5
	1.0	1.4	1.0
	2.0	2.2	3.5
	3.0	2.4	6.8
	2.0	2.5	4.9
	2.0	2.4	4.9
	2.0	2.2	4.6
	2.5	2.0	5.3
	1.5	2.1	3.1
	1.0	2.6	2.4
	1.5	2.0	3.5
	3.0	0.0	3.1
TOTAL	23.0		43.6

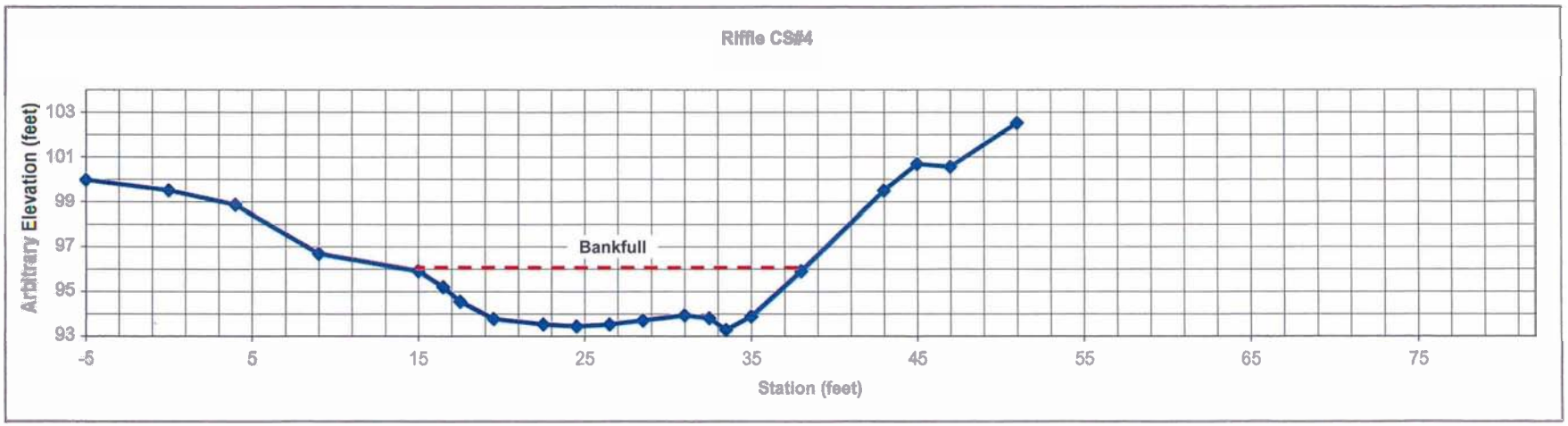
Top of Bank Geometry	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	4.0	0.6	1.3
	5.0	2.8	8.6
	6.0	3.6	19.1
	1.5	4.3	5.9
	1.0	4.9	4.6
	2.0	5.7	10.7
	3.0	6.0	17.6
	2.0	6.1	12.0
	2.0	6.0	12.0
	2.0	5.8	11.8
	2.5	5.6	14.2
	1.5	5.7	8.4
	1.0	6.2	6.0
	1.5	5.6	8.9
	3.0	3.6	13.8
	5.0	0.0	8.9
TOTAL	43.0		163.7

SUMMARY DATA (BANKFULL)			
A(BKF)	43.6	W(FPA)	37
W(BKF)	23.0	Slope	0.0037
Max d	2.5	Sinuosity	1.1
Mean d	1.9	Area=	A
W/D	12.1	Width=	W
Entrenchment	1.6	Depth=	D
Stream Type	G5	Bankfull=	BKF
Area from Rural Regional Curve			270

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion
Bank Ht/Bkf Ht	2.4	8.5	Very Low
Root Depth/Bank Ht	0.8	3.6	Low
Root Density (%)	45	5.2	Low
Bank Angle (Degrees)	26	2.2	Low
Surface Protection (%)	80	1.9	Very Low
Bank Materials	Sand	5	
		26.4	Moderate

Photo of Riffle CS#4 looking in the upstream direction.



Fayetteville Property
Cross Creek
Cumberland County, NC

LONGITUDINAL PROFILE

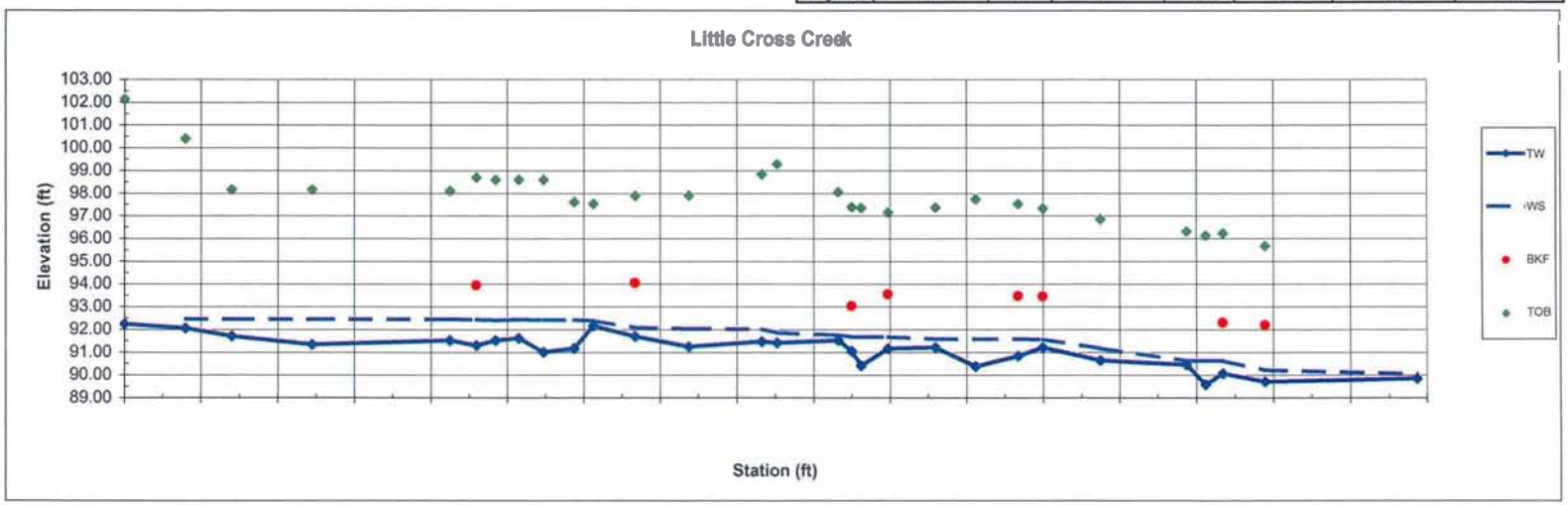
River Basin:	Cape Fear
Watershed:	Little Cross Creek
Stream Reach:	Little Cross Creek
DA (sq mi):	10 sq mi
Date:	5/29/2002

REF PT	BS	HI	FS	ELEV	NOTES
BM	5.38	105.38		100.00	manhole

Station	REF PT	HI	TW(FS)	TW	WS(FS)	WS	BKF(FS)	BKF	TOB(FS)	TOB	Notes
0+00.0	BM	105.38	13.11	92.27					3.22	102.16	culvert invert
0+32.0	BM	105.38	13.29	92.09	12.88	92.50			4.95	100.43	Head of Run
0+56.0	BM	105.38	13.63	91.75	12.88	92.50			7.18	98.20	Head of Pool
0+98.0	BM	105.38	14.00	91.38	12.88	92.50			7.18	98.20	Max Pool
1+70.0	BM	105.38	13.81	91.57	12.94	92.50			7.23	98.15	Head of Pool
1+84.0	BM	105.38	14.04	91.34	12.89	92.49	11.42	93.96	6.64	98.74	Max Pool
1+94.0	BM	105.38	13.82	91.56	12.92	92.46			6.74	98.64	Head of Glide
2+06.0	BM	105.38	13.72	91.66	12.89	92.49			6.74	98.64	Head of Pool
2+19.0	BM	105.38	14.33	91.05	12.91	92.47			6.74	98.64	Max Pool
2+35.0	BM	105.38	14.16	91.22	12.91	92.47			7.72	97.66	Head of Glide
2+45.0	BM	105.38	13.17	92.21	12.94	92.44			7.79	97.59	Head of Riffle
2+67.0	BM	105.38	13.63	91.75	13.24	92.14	11.30	94.08	7.44	97.94	Head of Pool
2+95.0	BM	105.38	14.08	91.30	13.29	92.09			7.43	97.95	Max Pool
3+33.0	BM	105.38	13.85	91.53	13.30	92.08			6.49	98.89	Head of Glide
3+41.0	BM	105.38	13.91	91.47	13.46	91.92			6.05	99.33	Head of Riffle
3+73.0	BM	105.38	13.80	91.58	13.56	91.82			7.27	98.11	Head of Run
3+80.0	BM	105.38	14.26	91.10	13.65	91.73	12.32	93.06	7.93	97.45	Head of Pool
3+85.0	BM	105.38	14.92	90.46	13.65	91.73			7.97	97.41	Max Pool
3+99.0	BM	105.38	14.16	91.22	13.65	91.73	11.80	93.58	8.17	97.21	Head of Riffle
4+24.0	BM	105.38	14.12	91.26	13.74	91.64			7.96	97.42	Head of Pool
4+45.0	BM	105.38	14.96	90.42	13.74	91.64			7.60	97.78	Max Pool
4+67.0	BM	105.38	14.50	90.88	13.74	91.64	11.89	93.49	7.80	97.58	Head of Glide
4+80.0	BM	105.38	14.12	91.26	13.76	91.62	11.90	93.48	8.00	97.38	Head of Riffle
5+10.0	BM	105.38	14.69	90.69	14.16	91.22			8.48	96.90	IM Riffle
5+55.0	BM	105.38	14.89	90.49	14.70	90.68			9.02	96.36	Head of Pool
5+65.0	BM	105.38	15.76	89.62	14.70	90.68			9.20	96.18	Max Pool
5+74.0	BM	105.38	15.28	90.10	14.70	90.68	13.08	92.30	9.10	96.28	Head of Riffle
5+96.0	BM	105.38	15.64	89.74	15.12	90.26	13.19	92.19	9.66	95.72	Head of Run
6+75.0	BM	105.38	15.50	89.88	15.29	90.09					Confluence

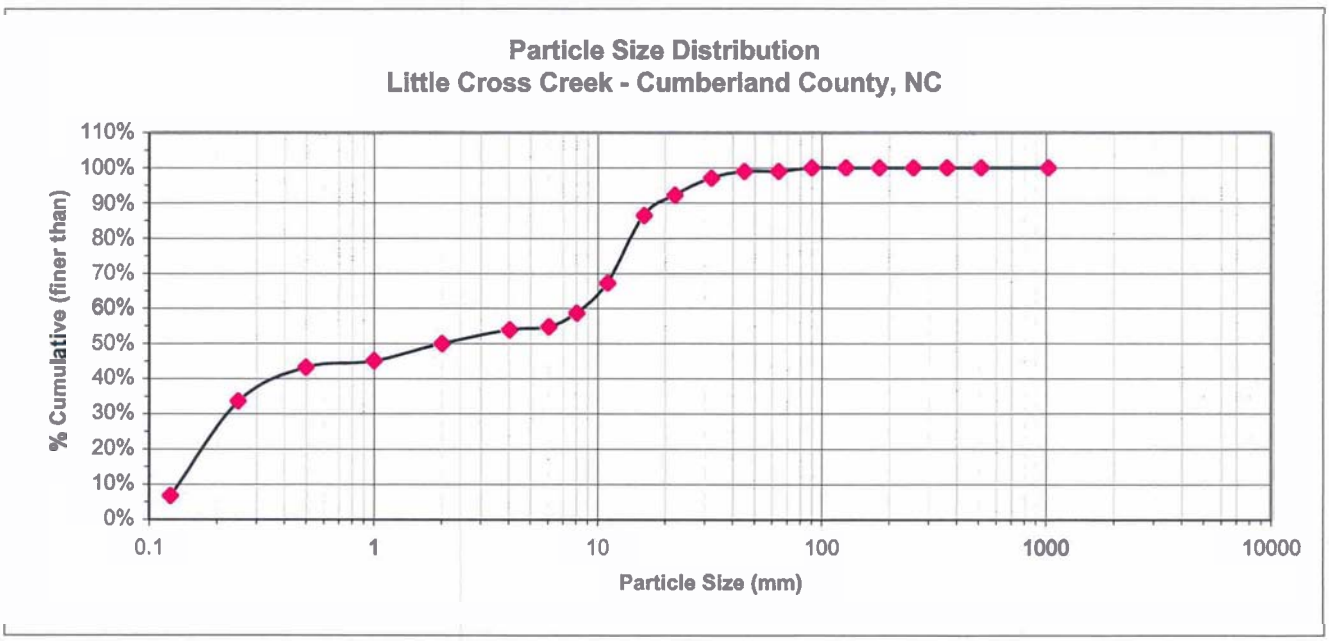
Average Water Surface Slope 0.37

	Bk Ht/Bkf Ht.	P-P	Pool Length	Max Pool Depth	Pool Slope	Riffle Length	Riffle Slope
						32.0	
		114.0	114.0		0.00		
	2.8			2.62			
			24.0		0.17		
		36.0					
			29.0		0.07		
						22.0	1.36
	2.7	61.0					
			66.0		0.09		
						32.0	0.31
	3.2	113.0					
	2.5		19.0		0.00	26.0	0.36
		44.0					
	2.6		43.0		0.00		
	2.8					75.0	1.25
		131.0					
			19.0		0.00	22.0	1.91
max	3.2	131.0	114.0	2.6	0.1667	75	1.3636
min	2.5	36	19	2.62	0.0000	22	0.3125
avg	2.8	83.2	44.9	2.6	0.0466	35	0.8224
Max ratio	0.14	6.50	5.66	0.13	0.44	3.72	3.64
Min ratio	0.01	1.79	0.94	0.13	0.00	1.09	0.83
avg ratio	0.00	4.13	2.23	0.13	0.12	1.72	2.19



Fayetteville Property
Cross Creek
Cumberland County, NC

PEBBLE COUNT									
Site: Little Cross Creek							5/29/2002		
Party: Ben Goetz, Jan Patterson, Jane Almon							Little Cross Creek		
Particle Count									
Inches	Particle	Millimeter		Riffle			Total No.	Item %	% Cumulativ
	Silt/Clay	< 0.062	S/C	2			2	2%	2%
	Very Fine	.062 - .125	S	5			5	5%	7%
	Fine	.125 - .25	A	28			28	27%	34%
	Medium	.25 - .50	N	10			10	10%	43%
	Coarse	.50 - 1.0	D	2			2	2%	45%
.04 -.08	Very Coarse	1.0 - 2.0	S	5			5	5%	50%
.08 - .16	Very Fine	2.0 - 4.0		4			4	4%	54%
.16 - .22	Fine	4.0 - 5.7	G	1			1	1%	55%
.22 - .31	Fine	5.7 - 8.0	R	4			4	4%	59%
.31 - .44	Medium	8.0 - 11.3	A	9			9	9%	67%
.44 - .63	Medium	11.3 - 16.0	V	20			20	19%	87%
.63 - .89	Coarse	16.0 - 22.6	E	6			6	6%	92%
.89 - 1.26	Coarse	22.6 - 32.0	L	5			5	5%	97%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S	2			2	2%	99%
1.77 - 2.5	Very Coarse	45.0 - 64.0		0			0	0%	99%
2.5 - 3.5	Small	64 - 90	C	1			1	1%	100%
3.5 - 5.0	Small	90 - 128	O	0			0	0%	100%
5.0 - 7.1	Large	128 - 180	B	0			0	0%	100%
7.1 - 10.1	Large	180 - 256	L	0			0	0%	100%
10.1 - 14.3	Small	256 - 362	B	0			0	0%	100%
14.3 - 20	Small	362 - 512	L	0			0	0%	100%
20 - 40	Medium	512 - 1024	D	0			0	0%	100%
40 - 80	rg- Very Lr	1024 - 2048	R	0			0	0%	100%
	Bedrock		BDRK	0			0	0%	100%
			Totals	104			104	100%	100%



K:\57036

Fayetteville Property
Cross Creek
Cumberland County, NC

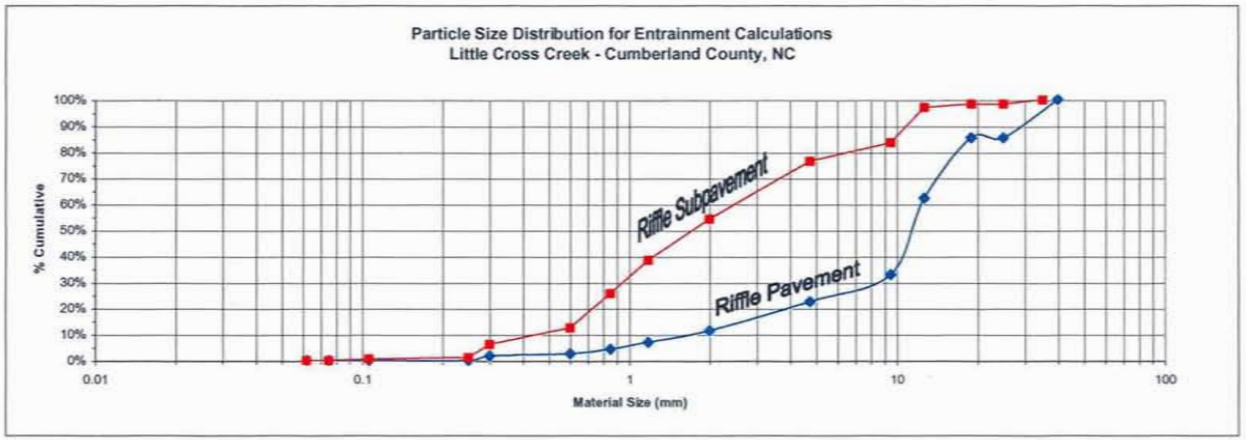
RIFFLE SAMPLE

River Basin:	Cape Fear
Watershed:	Little Cross Creek
Stream Reach:	Little Cross Creek (Reach 3)
DA (sq mi):	10.0 sq.mi.
Date:	5/29/2002

Sieve Size (mm)	0.062	0.075	0.106	0.25	0.3	0.6	0.85	1.18	2	4.75	9.5	12.7	19	25	
micro		75	106	250	300	600	850								
Tare Weight(lbs)	0.81	0.74	0.77	0.81	0.82	0.87	0.95	0.95	1.03	1.12	1.2	1.22	1.28	1.28	
Pave Sample Weight (lbs)	0.81	0.74	0.77	0.81	0.84	0.88	0.97	0.98	1.08	1.25	1.32	1.56	1.55	1.28	
Subpav Sample Weight (lbs)	0.81	0.74	0.82	0.85	1.26	1.42	2.09	2.07	2.4	3.04	1.81	2.39	1.39	1.28	
Pave Net Weight (lbs)	0	0	0	0	0.02	0.01	0.02	0.03	0.05	0.13	0.12	0.34	0.27	0	**1.16**
Subpave Net Weight(lbs)	0	0	0.05	0.04	0.44	0.55	1.14	1.12	1.37	1.92	0.61	1.17	0.11	0	**8.66**
% Pavement	0%	0%	0%	0%	2%	1%	2%	3%	4%	11%	10%	29%	23%	0%	
% Cumulative Pavement	0%	0%	0%	0%	2%	3%	4%	7%	11%	22%	33%	62%	85%	85%	**100%**
% Subpavement	0%	0%	1%	0%	5%	6%	13%	13%	16%	22%	7%	14%	1%	0%	
% Cumulative Subpavement	0%	0%	1%	1%	6%	12%	26%	39%	54%	77%	84%	97%	98%	98%	**100%**

D50 Subpavement (mm)	1.8	
D50 Riffle Pavement (mm)	11	
D50/D50^	6.1	
Tc	0.017	
Largest Particle (mm)	35.00	**0.11 ft**
Slope	0.0033	
Depth required (mm)	301	**0.99 ft**
Area Required (sq. ft.)	38	
Width/Depth Ratio	16	
Bankfull Width (ft)	24.7	
Actual mean depth (ft)	1.54	

	LP1	LP2
dia	40	32
weight	0.12	0.05
weight	0.12	0.02
dia	35	20



Country Club Branch
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Country Club Branch
Reach:	Hickory Hill/Elk Lodge
DA:	2.7 sq mi (1,740 ac)
Date:	6/27/2002
Station:	0+92
Feature:	CS #2, Pool

STATION (FEET)	HI (FEET)	FS (FEET)	ELEVATION (FEET)	NOTES
0+00.0	104.42	4.42	100.00	
0+04.0	104.42	4.51	99.91	LBKF/TOB
0+05.0	104.42	4.75	99.67	
0+06.0	104.42	5.12	99.30	
0+07.0	104.42	5.35	99.07	
0+07.5	104.42	6.18	98.24	
0+07.5	104.42	6.80	97.62	
0+08.0	104.42	8.21	96.21	
0+09.0	104.42	8.69	95.73	
0+10.0	104.42	8.00	96.42	LEW/WS
0+11.5	104.42	7.76	96.66	
0+12.5	104.42	7.20	97.22	TW
0+13.5	104.42	6.49	97.93	
0+14.0	104.42	6.03	98.39	REW
0+15.0	104.42	5.14	99.28	
0+17.0	104.42	4.95	99.47	
0+18.5	104.42	4.65	99.77	
0+19.0	104.42	4.50	99.92	RBKF/TOB
0+20.0	104.42	4.61	99.81	

BANKFULL Hydraulic Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	1.0	0.2	0.1
	1.0	0.6	0.4
	1.0	0.8	0.7
	0.5	1.7	0.6
	0.0	2.3	0.0
	0.5	3.7	1.5
	1.0	4.2	3.9
	1.0	3.5	3.8
	1.5	3.3	5.1
	1.0	2.7	3.0
	1.0	2.0	2.3
	0.5	1.5	0.9
	1.0	0.6	1.1
	2.0	0.4	1.1
	1.5	0.1	0.4
	0.5	0.0	0.0
TOTALS	15.0		25.0

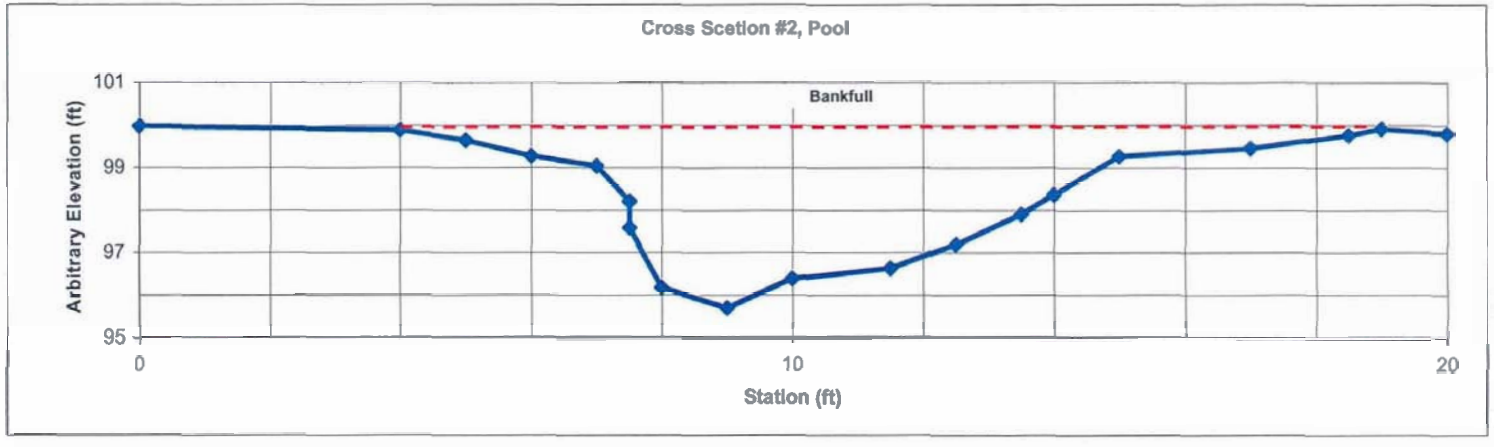
SUMMARY DATA (BANKFULL)

A(BKF)	25.0
W(BKF)	15.0
Max d	4.2
Mean d	1.7

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	90	1.5	very low
Bank Angle (Degrees)	90	7.9	high
Surface Protection (%)	90	1.5	very low
Bank Materials	silt	0	
		12.9	low

Photo of CS#2, pool looking in the upstream direction.



Country Club Branch
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Country Club Branch
Reach:	Hickory Hill/Elk Lodge
DA:	2.7 sq mi (1,740 ac)
Date:	6/27/2002
Station:	0+78
Feature:	CS #1, Riffle

STATION (FEET)	HI (FEET)	FS (FEET)	ELEVATION (FEET)	NOTES
0+00.0	104.85	4.85	100.00	
0+03.5	104.85	4.58	100.27	
0+05.0	104.85	4.59	100.26	LBKF
0+06.0	104.85	4.69	100.16	
0+07.0	104.85	5.21	99.64	
0+07.5	104.85	5.53	99.32	
0+08.0	104.85	5.95	98.90	
0+08.5	104.85	6.15	98.70	LEW/WS
0+09.5	104.85	6.59	98.26	
0+10.5	104.85	6.98	97.87	
0+11.5	104.85	6.84	98.01	
0+12.5	104.85	7.45	97.40	
0+13.5	104.85	7.56	97.29	
0+14.5	104.85	6.83	98.02	TW
0+15.0	104.85	7.14	97.71	
0+16.0	104.85	6.07	98.78	REW
0+16.5	104.85	5.12	99.73	
0+18.0	104.85	4.93	99.92	
0+19.5	104.85	4.61	100.24	RBKF
0+21.5	104.85	4.60	100.25	

BANKFULL Hydraulic Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	1.0	0.1	0.0
	1.0	0.6	0.4
	0.5	0.9	0.4
	0.5	1.4	0.6
	0.5	1.6	0.7
	1.0	2.0	1.8
	1.0	2.4	2.2
	1.0	2.3	2.3
	1.0	2.9	2.6
	1.0	3.0	2.9
	1.0	2.2	2.6
	0.5	2.6	1.2
	1.0	1.5	2.0
	0.5	0.5	0.5
	1.5	0.3	0.7
	1.5	0.0	0.3
TOTALS	14.5		21.1

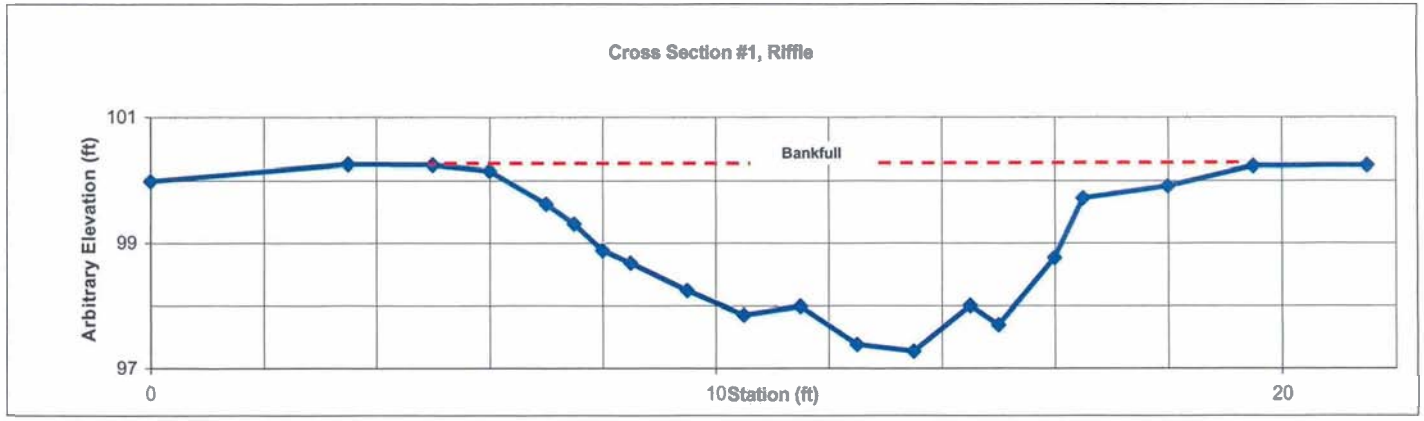
SUMMARY DATA (BANKFULL)

A(BKF)	21.1	W(FPA)	200
W(BKF)	14.5	Slope	n/a
Max d	3.0	Sinuosity	1.5
Mean d	1.5	Area=	A
W/D	10.0	Width=	W
Entrenchment	13.8	Depth=	D
Stream Type	C5	Bankfull=	BKF
Area from Rural Regional Curve			44

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	90	1.5	very low
Bank Angle (Degrees)	35	2.7	low
Surface Protection (%)	70	2.7	low
Bank Materials	sand	5	
		13.9	low

Photo of CS#1, riffle looking in the upstream direction.



Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Country Club Branch
Reach:	Hickory Hill/Elk Lodge
DA:	2.7 sq mi (1,740 ac)
Date:	6/27/2002
Station:	1+20
Feature:	CS #3, Pool

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
-0+10.0	104.69	4.48	100.21	LBKF
0+02.0	104.69	4.69	100.00	
0+08.5	104.69	4.74	99.95	
0+14.0	104.69	5.05	99.64	
0+17.0	104.69	5.06	99.63	
0+20.0	104.69	4.89	99.80	
0+23.0	104.69	5.04	99.65	
0+24.0	104.69	5.24	99.45	
0+27.0	104.69	5.66	99.03	
0+28.0	104.69	5.85	98.84	
0+29.5	104.69	6.18	98.51	LEW/WS
0+30.5	104.69	6.39	98.30	
0+31.5	104.69	7.12	97.57	
0+32.3	104.69	7.33	97.36	
0+33.0	104.69	7.17	97.52	
0+33.3	104.69	7.58	97.11	TW
0+34.0	104.69	5.18	99.51	
0+35.5	104.69	4.82	99.87	
0+36.0	104.69	4.66	100.03	
0+37.0	104.69	4.58	100.11	
0+39.0	104.69	4.48	100.21	RBKF
0+43.0	104.69	4.69	100.00	
0+48.0	104.69	4.68	100.01	

BANKFULL
Hydraulic Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	12.0	0.2	1.3
	6.5	0.3	1.5
	5.5	0.6	2.3
	3.0	0.6	1.7
	3.0	0.4	1.5
	3.0	0.6	1.5
	1.0	0.8	0.7
	3.0	1.2	2.9
	1.0	1.4	1.3
	1.5	1.7	2.3
	1.0	1.9	1.8
	1.0	2.6	2.3
	0.8	2.8	2.2
	0.7	2.7	1.9
	0.3	3.1	0.9
	0.7	0.7	1.3
	1.5	0.3	0.8
	0.5	0.2	0.1
	1.0	0.1	0.1
	2.0	0.0	0.1
TOTALS	49.0		28.4

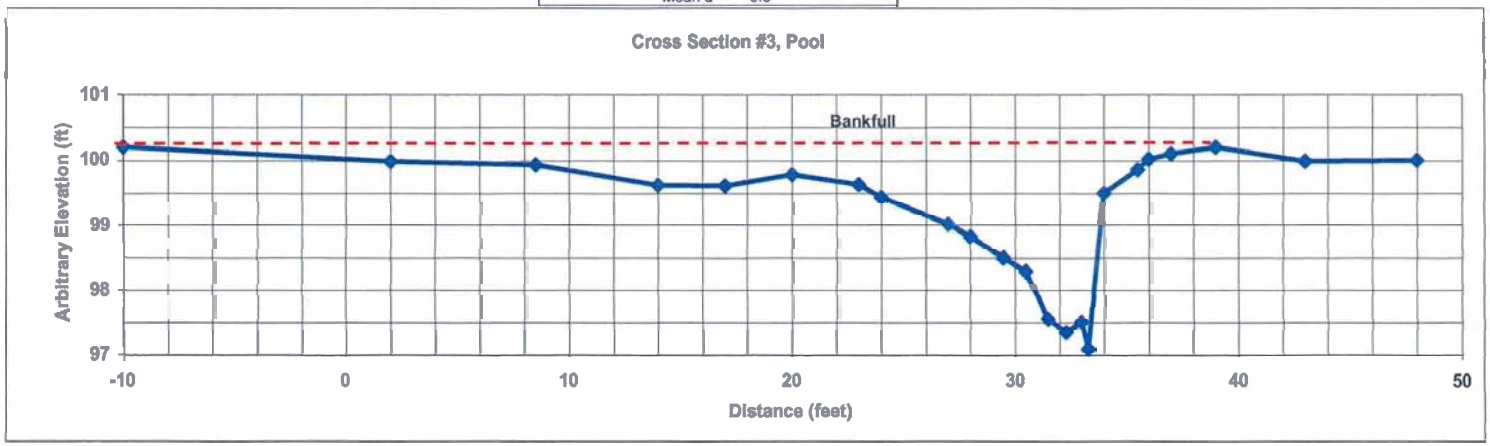
SUMMARY DATA (BANKFULL)

A(BKF)	28.4
W(BKF)	49.0
Max d	2.8
Mean d	0.6

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	90	1.5	very low
Bank Angle (Degrees)	80	5.9	moderate
Surface Protection (%)	75	3.6	low
Bank Materials	silt	0	
		13	low

Photo of Pool, CS#3 looking in the upstream direction.



Country Club Branch
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Country Club Branch
Reach:	Hickory Hill/Elk Lodge
DA:	2.7 sq mi (1,740 ac)
Date:	6/27/2002
Station:	1+73
Feature:	CS #4, Riffle

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
-0+30.0	105.20	4.94	100.26	
0+06.0	105.20	5.2	100.00	
0+07.5	105.20	5.39	99.81	
0+08.0	105.20	5.59	99.61	
0+08.5	105.20	6.30	98.90	
0+08.8	105.20	6.60	98.60	LTOB
0+10.0	105.20	6.54	98.66	
0+12.0	105.20	6.65	98.55	LBKF
0+14.0	105.20	6.67	98.53	
0+15.5	105.20	6.50	98.70	LEW
0+16.5	105.20	6.65	98.55	TW
0+17.2	105.20	6.34	98.86	REW
0+18.0	105.20	6.12	99.08	
0+19.0	105.20	5.25	99.95	
0+20.0	105.20	4.94	100.26	RBKF
0+22.0	105.20	5.11	100.09	
0+25.0	105.20	4.87	100.33	
0+29.0	105.20	4.50	100.70	

BANKFULL
Hydraulic Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	36.0	0.3	4.7
	1.5	0.5	0.5
	0.5	0.7	0.3
	0.5	1.4	0.5
	0.3	1.7	0.5
	1.2	1.6	2.0
	2.0	1.7	3.3
	2.0	1.7	3.4
	1.5	1.6	2.5
	1.0	1.7	1.6
	0.7	1.4	1.1
	0.8	1.2	1.0
	1.0	0.3	0.7
	1.0	0.0	0.2
TOTALS	50.0		22.3

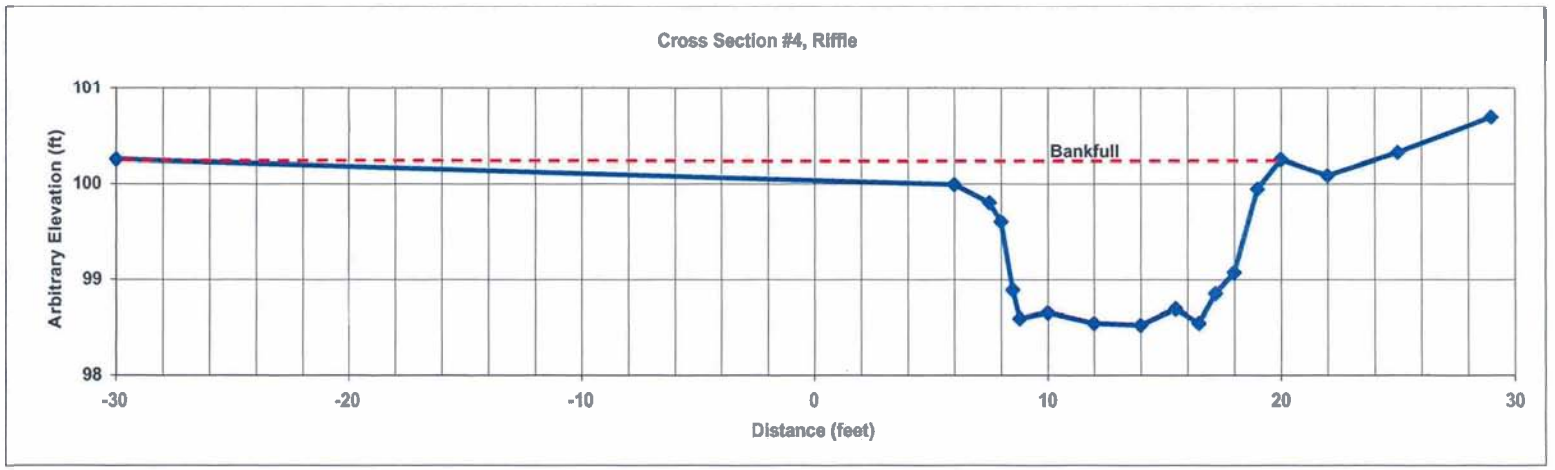
SUMMARY DATA (BANKFULL)

A(BKF)	22.3	W(FPA)	125
W(BKF)	50.0	Slope	0.0025
Max d	1.7	Sinuosity	1.5
Mean d	0.4	Area= A	
W/D	112.2	Width= W	
Entrenchment	2.5	Depth= D	
Stream Type	C5	**Bankfull= BKF**	
Area from Rural Regional Curve			44

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	70	2.7	low
Bank Angle (Degrees)	60	3.9	low
Surface Protection (%)	54	4	moderate
Bank Materials	silt	0	
		12.6	low

Photo of CS#4, riffle looking in the upstream direction.



Country Club Branch
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Country Club Branch
Reach:	Hickory Hill/Elk Lodge
DA:	2.7 sq mi (1,740 ac)
Date:	6/27/2002
Station:	2+35
Feature:	CS #5, Riffle

STATION (FEET)	HI (FEET)	FS (FEET)	ELEVATION (FEET)	NOTES
-0+60.0	102.15	2.15	100.00	
-0+57.0	102.15	2.87	99.28	
-0+54.0	102.15	3.78	98.37	
-0+21.0	102.15	5.03	97.12	
0+00.0	102.15	5.12	97.03	LBKF
0+03.2	102.15	5.33	96.82	
0+05.3	102.15	6.11	96.04	
0+07.0	102.15	6.20	95.95	
0+08.2	102.15	6.02	96.13	
0+09.9	102.15	5.35	96.80	
0+14.0	102.15	5.31	96.84	
0+16.0	102.15	5.13	97.02	
0+17.0	102.15	5.24	96.91	
0+17.5	102.15	5.46	96.69	
0+18.1	102.15	6.50	95.65	
0+18.7	102.15	6.59	95.56	LEW/WS
0+20.1	102.15	6.88	95.27	
0+21.6	102.15	6.89	95.26	
0+23.1	102.15	7.10	95.05	
0+23.7	102.15	7.27	94.88	TW
0+24.7	102.15	7.06	95.09	
0+24.9	102.15	6.94	95.21	REW
0+25.3	102.15	6.30	95.85	
0+26.3	102.15	6.21	95.94	
0+27.4	102.15	5.17	96.98	RBKF
0+28.4	102.15	4.85	97.30	
0+34.0	102.15	5.15	97.00	
0+38.0	102.15	5.32	96.83	
0+40.3	102.15	5.48	96.67	
0+41.5	102.15	5.35	96.80	
0+42.5	102.15	5.76	96.39	
0+43.5	102.15	6.00	96.15	
0+44.5	102.15	5.73	96.42	
0+46.0	102.15	5.52	96.63	
0+50.0	102.15	5.90	96.25	
0+54.0	102.15	6.10	96.05	
0+57.0	102.15	6.40	95.75	
0+60.0	102.15	6.30	95.85	
0+67.0	102.15	5.75	96.40	
0+72.0	102.15	5.85	96.30	
0+77.0	102.15	5.84	96.31	
0+79.0	102.15	6.20	95.95	
0+83.0	102.15	6.10	96.05	
0+90.0	102.15	6.07	96.08	
0+93.0	102.15	6.19	95.96	
0+97.0	102.15	6.00	96.15	
1+10.0	102.15	5.60	96.55	
1+22.0	102.15	4.50	97.65	
1+35.0	102.15	2.15	100.00	

BANKFULL Hydraulic Geometry

Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
0.0	0.0	0.0
3.2	0.2	0.3
2.1	1.0	1.3
1.7	1.1	1.8
1.2	0.9	1.2
1.7	0.2	1.0
4.1	0.2	0.9
2.0	0.0	0.2
1.0	0.1	0.1
0.5	0.3	0.1
0.6	1.4	0.5
0.6	1.5	0.9
1.4	1.8	2.3
1.5	1.8	2.6
1.5	2.0	2.8
0.6	2.1	1.2
1.0	1.9	2.0
0.2	1.8	0.4
0.4	1.2	0.6
1.0	1.1	1.1
1.1	0.0	0.6
TOTALS 27.4		21.9

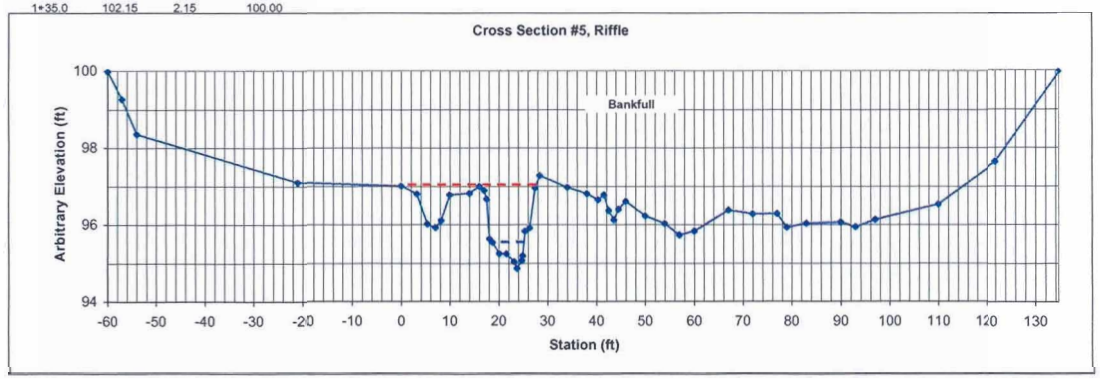
SUMMARY DATA (BANKFULL)

A(BKF)	21.9	W(FPA)	200
W(BKF)	27.4	Slope	0.0017
Max d	2.1	Sinuosity	1.5
Mean d	0.8	Area=	A
W/D	34.3	Width=	W
Entrenchment	7.3	Depth=	D
Stream Type	C5	Bankfull=	BKF
Area from Rural Regional Curve			44

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	70	2.7	low
Bank Angle (Degrees)	60	3.9	low
Surface Protection (%)	54	4	moderate
Bank Materials	silt	0	
		12.6	low

Photo of CS#5, riffle looking in the upstream direction.



Country Club Branch
Cumberland County

LONGITUDINAL PROFILE	
River Basin:	Cape Fear
Watershed:	Country Club Branch
Stream Reach:	Country Club branch
DA (sq mi):	2.7 sq.mi.
Date:	########

REF PT	BS	HI	FS	ELEV	NOTES
BM (AM)	3.31	103.31		100.00	SS MH
BM (AM)		103.31	3.31	100.00	Error=0.00
BM (PM)	3.34	103.34		100.00	
BM (PM)		103.34	3.34	100.00	Error=0.00

PATTERN DATA FOR COUNTRY CLUB BRANCH

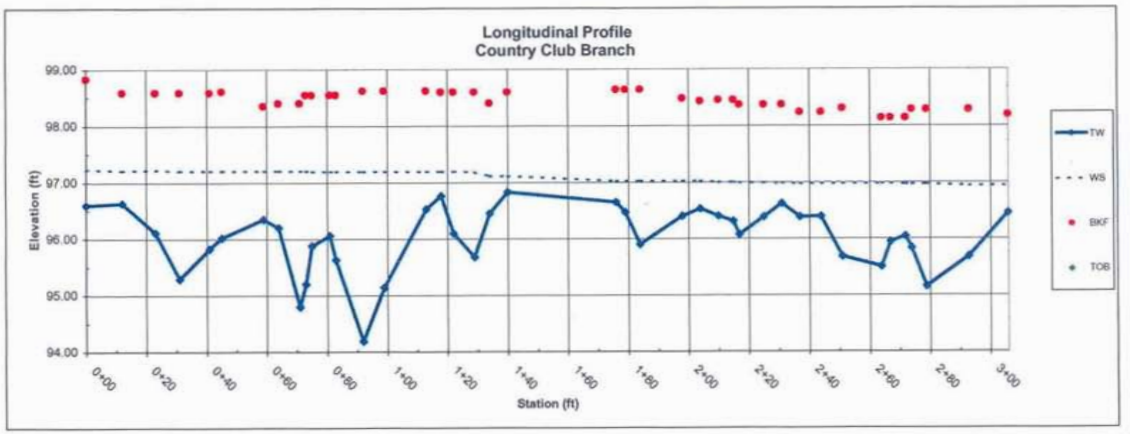
Curve	Chord L	Mid	Radius of C	Beltwidth	Wavelength
1	12	1.3	14		47
2	11	3	7	21	51
3	17	5	10	20	50
4	32	7.5	21	23	
5	14	1.5	17	21	
Ave			14	21	49
Min			7	20	47
Max			21	23	51

Station	REF PT	HI	TW(FS)	TW	WS(FS)	WS	BKF(FS)	BKF	Notes
0+00.0	BM (AM)	103.31	6.70	96.61	6.07	97.24	4.47	98.84	Head of Riffle
0+12.0	BM (AM)	103.31	6.67	96.64	6.09	97.22	4.71	98.60	Head of Run
0+23.0	BM (AM)	103.31	7.19	96.12	6.06	97.25	4.71	98.60	Head of Pool
0+31.0	BM (AM)	103.31	8.01	95.30	6.10	97.21	4.71	98.60	Max Pool
0+41.0	BM (AM)	103.31	7.47	95.84	6.10	97.21	4.71	98.60	Head of Glide
0+45.0	BM (AM)	103.31	7.26	96.03	6.10	97.21	4.69	98.62	Head of Riffle
0+59.0	BM (AM)	103.31	6.95	96.36	6.10	97.21	4.95	98.36	Head of Run
0+64.0	BM (AM)	103.31	7.10	96.21	6.10	97.21	4.90	98.41	Head of Pool
0+71.0	BM (AM)	103.31	8.50	94.81	6.10	97.21	4.90	98.41	Max Pool
0+73.0	BM (AM)	103.31	8.10	95.21	6.10	97.21	4.75	98.56	Head of Glide
0+75.0	BM (AM)	103.31	7.42	95.89	6.11	97.20	4.75	98.56	Head of Riffle
0+81.0	BM (AM)	103.31	7.24	96.07	6.11	97.20	4.75	98.56	Head of Run
0+83.0	BM (AM)	103.31	7.07	96.04	6.11	97.20	4.75	98.56	Head of Pool
0+92.0	BM (AM)	103.31	9.11	94.20	6.11	97.20	4.68	98.63	Max Pool
0+99.0	BM (AM)	103.31	8.16	95.15	6.11	97.20	4.68	98.63	Head of Glide
1+13.0	BM (AM)	103.31	8.77	96.54	6.11	97.20	4.68	98.63	Head of Riffle
1+18.0	BM (AM)	103.31	6.54	96.77	6.11	97.20	4.70	98.61	Head of Run
1+29.0	BM (AM)	103.31	7.20	96.11	6.11	97.20	4.70	98.61	Head of Pool
1+29.0	BM (AM)	103.31	7.62	95.69	6.12	97.19	4.70	98.61	Max Pool
1+34.0	BM (AM)	103.31	6.85	96.46	6.19	97.12	4.90	98.41	Head of Glide
1+60.0	BM (AM)	103.31	6.47	96.84	6.19	97.12	4.70	98.61	Head of Riffle
1+76.0	BM (PM)	103.34	6.68	96.66	6.31	97.03	4.69	98.65	Head of Run
1+79.0	BM (PM)	103.34	9.86	93.48	6.31	97.03	4.69	98.65	Head of Pool
1+84.0	BM (PM)	103.34	7.43	95.91	6.31	97.03	4.69	98.65	Max Pool
1+98.0	BM (PM)	103.34	6.93	96.41	6.31	97.03	4.85	98.49	Head of Glide
2+04.0	BM (PM)	103.34	6.80	96.54	6.31	97.03	4.90	98.44	Head of Riffle
2+10.0	BM (PM)	103.34	6.93	96.41	6.33	97.01	4.88	98.46	Head of Run
2+15.0	BM (PM)	103.34	7.02	96.32	6.33	97.01	4.88	98.46	Head of Pool
2+17.0	BM (PM)	103.34	7.26	96.08	6.34	97.00	4.96	98.38	Max Pool
2+25.0	BM (PM)	103.34	6.96	96.39	6.34	97.00	4.96	98.38	Head of Glide
2+31.0	BM (PM)	103.34	6.71	96.63	6.36	96.98	4.90	98.38	Head of Riffle
2+37.0	BM (PM)	103.34	6.95	96.39	6.36	96.98	5.10	98.24	Head of Run
2+44.0	BM (PM)	103.34	6.94	96.40	6.36	96.98	5.10	98.24	Head of Pool
2+51.0	BM (PM)	103.34	7.65	95.69	6.36	96.98	5.03	98.31	Max Pool
2+64.0	BM (PM)	103.34	7.83	95.51	6.36	96.98	5.20	98.14	Head of Glide
2+67.0	BM (PM)	103.34	7.39	95.95	6.36	96.98	5.20	98.14	Head of Riffle
2+72.0	BM (PM)	103.34	7.29	96.05	6.37	96.97	5.20	98.14	Head of Run
2+74.0	BM (PM)	103.34	7.50	95.84	6.37	96.97	5.05	98.29	Head of Pool
2+79.0	BM (PM)	103.34	8.18	95.16	6.37	96.97	5.05	98.29	Max Pool
2+93.0	BM (PM)	103.34	7.85	95.69	6.40	96.94	5.05	98.29	Head of Glide
3+06.0	BM (PM)	103.34	6.88	96.46	6.40	96.94	5.15	98.19	Head of Riffle

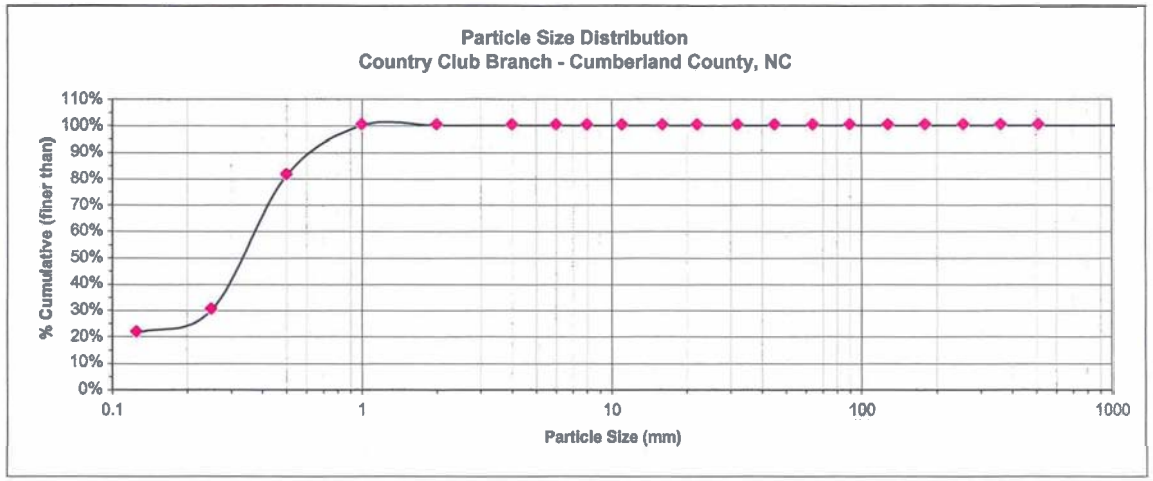
Average Slope 0.1084

P-P	Pool Length	Max Pool Depth	Pool Slope	Riffle Length	Riffle Slope
				12.0	0.17
	18.0				
		3.30	0.00		
				14.0	0.00
41.0	9.0				
		3.60	0.00		
				6.0	0.00
19.0	16.0				
		4.43	0.00		
				5.0	0.00
39.0	12.0				
		2.92	0.00		
				36.0	0.25
57.0	10.0				
		2.74	0.00		
				6.0	0.33
38.0	10.0				
		2.30	0.00		
				6.0	0.17
29.0	20.0				
		2.62	0.00		
				5.0	0.20
30.0	19.0				
		3.13	0.00		

max	57	20	4.43	0.0000	36	0.3333
min	19	9	2.30	0.0000	5	0.1667
avg	36	15	3.13	0.0000	11	0.2375
Max ratio	1.84	0.65	0.14	0.00	1.16	3.07
Min ratio	0.61	0.29	0.07	0.00	0.16	1.54
avg ratio	1.16	0.50	0.10	0.00	0.36	2.19



PEBBLE COUNT										
Site: Country Club Branch								3/25/2002		
Party: Ben Goetz, Jan Patterson								Country Club Branch		
				Particle Count						
Inches	Particle	Millimeter		Riffle	Pool	Riffle	Pool	Total No.	Item %	% Cumulative
	Silt/Clay	< 0.062	S/C	2	0	1	7	10	13%	13%
	Very Fine	.062 - .125	S	2	2	2	1	7	9%	21%
	Fine	.125 - .25	A	1	3	1	2	7	9%	30%
	Medium	.25 - .50	N	11	10	13	7	41	51%	81%
	Coarse	.50 - 1.0	D	4	5	3	3	15	19%	100%
.04 -.08	Very Coarse	1.0 - 2.0	S					0	0%	100%
.08 - .16	Very Fine	2.0 - 4.0						0	0%	100%
.16 - .22	Fine	4.0 - 5.7	G					0	0%	100%
.22 - .31	Fine	5.7 - 8.0	R					0	0%	100%
.31 - .44	Medium	8.0 - 11.3	A					0	0%	100%
.44 - .63	Medium	11.3 - 16.0	V					0	0%	100%
.63 - .89	Coarse	16.0 - 22.6	E					0	0%	100%
.89 - 1.26	Coarse	22.6 - 32.0	L					0	0%	100%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S					0	0%	100%
1.77 - 2.5	Very Coarse	45.0 - 64.0						0	0%	100%
2.5 - 3.5	Small	64 - 90	C					0	0%	100%
3.5 - 5.0	Small	90 - 128	O					0	0%	100%
5.0 - 7.1	Large	128 - 180	B					0	0%	100%
7.1 - 10.1	Large	180 - 256	L					0	0%	100%
10.1 - 14.3	Small	256 - 362	B					0	0%	100%
14.3 - 20	Small	362 - 512	L					0	0%	100%
20 - 40	Medium	512 - 1024	D					0	0%	100%
40 - 80	Lrg- Very Lrg	1024 - 2048	R					0	0%	100%
	Bedrock		BDRK					0	0%	100%
			Totals	20	20	20	20	80	100%	100%



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FROEHLING & ROBERTSON, INC.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS
ENGINEERS • LABORATORIES
"OVER ONE HUNDRED YEARS OF SERVICE"
310 Hubert Street, Raleigh, NC 27603
Telephone: (919) 828-3441
Facsimile: (919) 828-5751

July 15, 2002

Mr. Ben Goetz
Earth Tech of North Carolina, Inc.
701 Corporate Center Drive, Suite 475
Raleigh, North Carolina 27607

Re: Report of Subsurface Exploration
Stream Restoration Project
Cross Creek - Fayetteville, NC
F&R Project No. D66-073

Dear Mr. Goetz:

Froehling & Robertson, Inc. (F&R) has completed the subsurface exploration for the referenced stream restoration project. The purpose of this exploration was to define the subsurface conditions in the areas where the stream will be relocated and provide geotechnical recommendations regarding the stability of the stream banks. It is F&R's understanding that the subsurface information will also be used by Earth Tech to determine if the materials are suitable to support wetland and other vegetation.

PROJECT INFORMATION

Based on information provided to F&R, it is our understanding that a section of Cross Creek and Little Cross Creek will be relocated and restored (see attached Figure No. 1). The new stream bed will be relocated to create a meandering stream. It is F&R's understanding that the stream bed elevation will be similar to the existing stream bed levels.

The subsurface conditions in the area of the relocated stream were determined by performing a series of test pit excavations. F&R retained Horne Brother's Construction to provide a conventional rubber-tired backhoe to perform the test pit excavations. A total of nine (9) test pits were performed at locations depicted on Figure No. 1. The test pit locations were determined by Mr. Ben Goetz of Earth Tech. Ground surface elevations at each test pit locations were interpolated from a topographic site plan provided by Earth Tech. Given the method of

determination, the test pit locations and ground surface elevations should only be considered approximate.

SUBSURFACE CONDITIONS

Topsoil was encountered in TP-1, TP-2 and TP-4 from the ground surface to a depth of approximately 12 inches; the topsoil consisted of silty sand with roots and vegetation. In the remaining test pits (TP-3 and TP-5 to TP-9), earth fill material was encountered from the ground surface to depths ranging from 1 to 5 feet. The earth fill material consisted of silty sand with varying amounts of bottles, brick, scrap metal and other similar junk.

Underlying the topsoil or earth fill, the native soils consisted of loose silty sand and slighlty silty sand to depths ranging from 5 to 8 feet. Underlying this sand layer, another slightly silty sand layer with coarse sand and rounded gravel was encountered in a zone from approximately 6.5 to 9 feet in TP-1, TP-2, TP-3, TP-5, TP-6 and TP-7. The silty sands appeared to be relatively loose based on the ease of excavation. Test pits TP-1, TP-2 and TP-7 were terminated in the silty sand layer. Beneath the silty sand layer, a more dense/firm sandy clay or clayey sand layer was encountered to test pit termination at depths 8 to 9.5 feet in TP-3 to TP-6, TP-8 and TP-9.

Groundwater was noted in most of the test pits at depths ranging from 6.5 to 7 feet. These groundwater levels correspond well with the water levels in the stream.

GEOTECHNICAL RECOMMENDATIONS

The soils encountered in the test pits that will form the new stream banks predominantly consist of loose silty sand and slightly silty sand. Based on the estimated stream bed elevations, it is anticipated that the stream bed will consist of slightly silty sand or a more dense clayey sand/sandy clay. Earth fill material was encountered in several of the borings in the upper 1 to 5 feet of the soil profile, with the deeper fill material being encountered in an area along the west side of Little Cross Creek.

Due to the apparently loose condition of the native sands, F&R recommends that the stream banks generally be graded no steeper than 3 Horizontal to 1 Vertical (3H:1V) for slope stability considerations. Following excavation, the slopes should be vegetated as soon as possible to stabilize the surface and prevent erosion and surface sloughing. It is our understanding that the type of vegetation and method of placement will be determined by Earth Tech. Due to the random composition of the earth fill materials, F&R recommends that the earth fill materials be

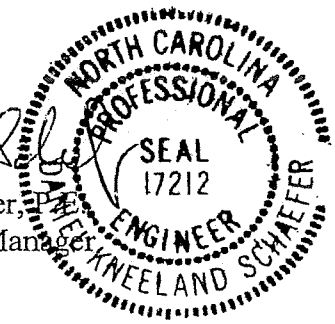
removed from final slope surfaces and be replaced with compacted structural fill prior to vegetation activities.

Please do not hesitate to contact us if you have any questions regarding this report or require additional geotechnical information.

Sincerely,
FROEHLING & ROBERTSON, INC.

Christopher T. Keenan, P.E.
Geotechnical Engineer

Daniel K. Schaefer, P.E.
Raleigh Branch Manager



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TEST PIT FIELD RECORDS

Client: Earth Tech of North Carolina, Inc. F&R Record No: D66-073
Project: Stream Restoration Project - Fayetteville, NC

TEST PIT NO.: TP-1			Location: See attached Site Plan		
Approx. Surface Elev: 95			Plan Subgrade Elev*: 88.5'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL DESCRIPTION AND COMMENTS		
From	To				
0'	1'	94	Topsoil: Grayish-brown silty Sand with roots		
1'	2.5'	92.5	Gray and brown silty Sand		
2.5'	8'	87	Gray and brown slightly silty Sand		
8'	8.5'	86.5	Gray and brown slightly silty Sand with rounded gravel		
			- TEST PIT WAS TERMINATED AT 8.5 FEET - Groundwater encountered at 6.5'		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

TEST PIT NO.: TP-2			Location: See attached Site Plan		
Approx. Surface Elev: 94'			Plan Subgrade Elev*: 88.5'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL DESCRIPTION AND COMMENTS		
From	To				
0'	1'	93	Topsoil: Grayish-brown silty Sand with roots		
1'	7'	87	Gray and Black slighty silty Sand		
7'	7.5'	86.5	Gray slighty silty Sand with rounded gravel		
			- TEST PIT WAS TERMINATED AT 7.5 FEET - Groundwater encountered at 7'		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

TEST PIT NO.: TP-3			Location: See attached Site Plan		
Approx. Surface Elev: 94'			Plan Subgrade Elev*: 87.5'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL DESCRIPTION AND COMMENTS		
From	To				
0'	1'	93	FILL: silty Sand with bottles		
1'	7.5'	86.5	Gray and brown silty Sand		
7.5'	9'	85	Gray and brown silty Sand with rounded gravel		
9'	9.5'	84.5	Greenish gray sandy Clay		
			- TEST PIT WAS TERMINATED AT 9.5 FEET - Groundwater encountered at 7'		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

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TEST PIT FIELD RECORDS

Client: Earth Tech of North Carolina, Inc.
Project: Stream Restoration Project - Fayetteville, NC

F&R Record No: D66-073

TEST PIT NO.: TP-4			Location: See attached Site Plan		
Approx. Surface Elev: 93'			Plan Subgrade Elev*: 86.5'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL DESCRIPTION AND COMMENTS		
From	To				
0'	1'	92	Topsoil: Grayish-brown silty Sand with grass		
1'	5'	88	Gray and tan slightly silty Sand		
5'	8'	85	Greenish gray clayey Sand		
			TEST PIT WAS TERMINATED AT 8 FEET -		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

TEST PIT NO.: TP-5			Location: See attached Site Plan		
Approx. Surface Elev: 95'			Plan Subgrade Elev*: 86.5'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL DESCRIPTION AND COMMENTS		
From	To				
0'	1'	94	FILL: Brown silty Sand with bottles and scrap metal		
1'	6.5'	88.5	Grayish brown silty Sand		
6.5'	8'	87	Slightly silty Sand with coarse sand and gravel		
8'	9'	86	Greenish gray clayey Sand		
			- TEST PIT TERMINATED AT 9 FEET -		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit.					

TEST PIT NO.: TP-6			Location: See attached Site Plan		
Approx. Surface Elev: 94'			Plan Subgrade Elev*: 86'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL DESCRIPTION AND COMMENTS		
From	To				
0'	1.5'	92.5	FILL: Brown silty Sand with bottles and junk		
1'	3'	91	Dark black sandy Silt		
3'	7'	87	Light grayish tan slightly silty Sand		
7'	8'	86	Light grayish tan slightly silty Sand with rounded gravel		
8'	8.5'	85.5	Greenish gray clayey Sand		
			- TEST PIT WAS TERMINATED AT 8.5 FEET - Groundwater encountered at 7'		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

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TEST PIT FIELD RECORDS

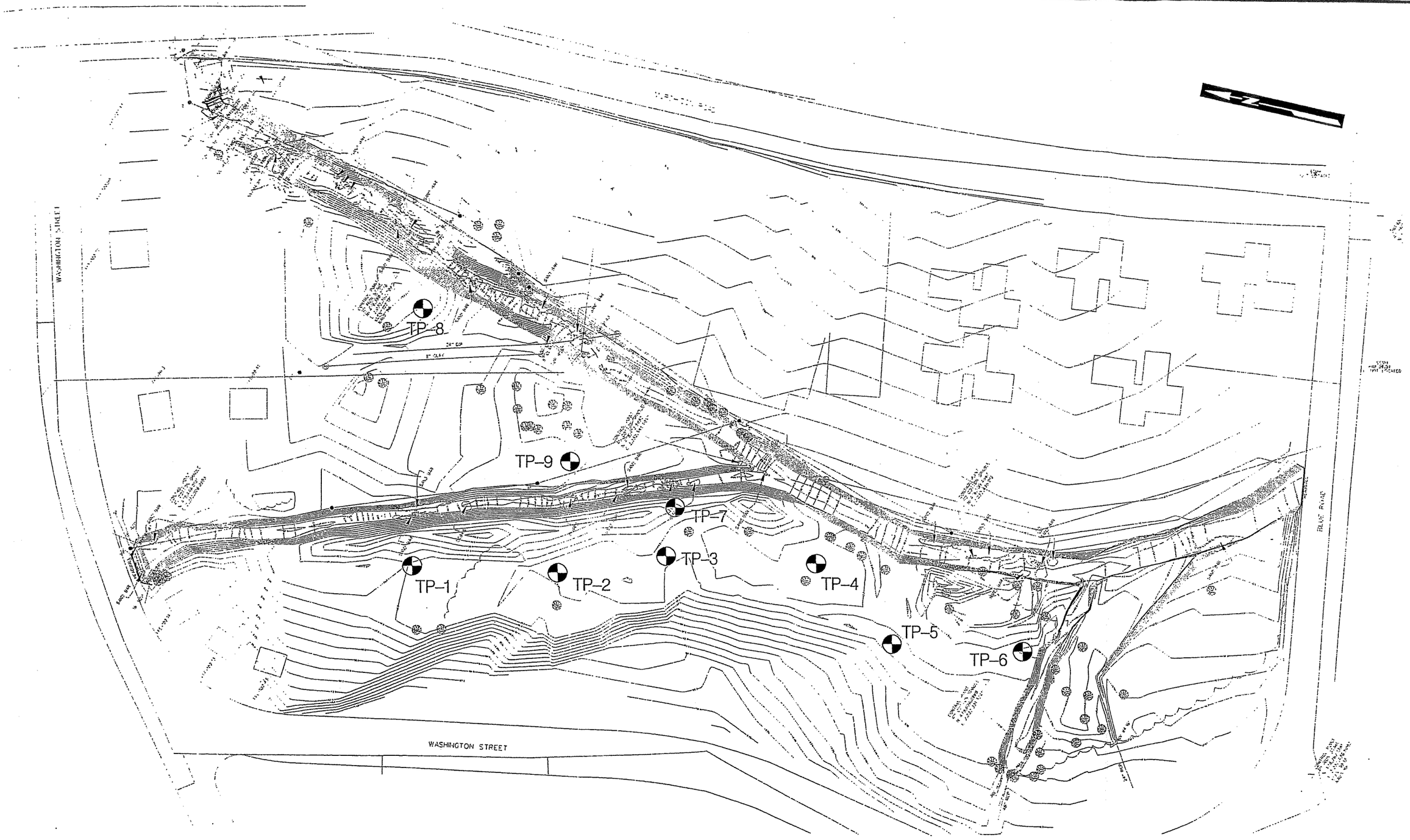
Client: Earth Tech of North Carolina, Inc.
Project: Stream Restoration Project - Fayetteville, NC

F&R Record No: D66-073

TEST PIT NO.: TP-7			Location: See attached Site Plan		
Approx. Surface Elev: 96'			Plan Subgrade Elev*: 87.5'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL STRATA DESCRIPTION AND COMMENTS		
From	To				
0'	5'	91	FILL: Topsoil with bottles and junk		
			- TEST PIT WAS TERMINATED AT 5 FEET -		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

TEST PIT NO.: TP-8			Location: See attached Site Plan		
Approx. Surface Elev: 101'			Plan Subgrade Elev*: 88'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL STRATA DESCRIPTION AND COMMENTS		
From	To				
0'	3'	98	FILL: Silty Sand Topsoil with trace brick		
3'	7'	94	Tan and orangish brown silty Sand		
7'	8'	93	Tan clayey Sand		
			- TEST PIT WAS TERMINATED AT 8 FEET -		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					

TEST PIT NO.: TP-9			Location: See attached Site Plan		
Approx. Surface Elev: 94'			Plan Subgrade Elev*: 87'	Observer: C. Keenan	Date: 6/26/2002
Strata Depth		Approx. Elevation (ft)	VISUAL SOIL STRATA DESCRIPTION AND COMMENTS		
From	To				
0'	1.5'	92.5	FILL: Orangish tan silty Sand with brick and bottles		
1.5'	7'	87	Gray slightly silty Sand		
7'	8'	86	Gray slightly silty Sand with rounded gravel		
8'	9'	85	Greenish gray clayey Sand		
			- TEST PIT WAS TERMINATED AT 9 FEET - Groundwater encountered at 7'		
NOTE: *Plan subgrade is estimated to be the approximate existing stream bed elevation nearest the test pit					



TEST PIT LOCATION PLAN

LEGEND
APPROX. F&R TEST PIT LOCATION

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310 Hubert Street
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(919) 828-3441; Fax: (919) 828-5751

CLIENT: Earth Tech of North Carolina, Inc.		
PROJECT: Stream Restoration Project		
LOCATION: Fayetteville, NC		
F&R PROJECT No.: D66-073		
DATE: 7/2002	SCALE: 1"=100'	FIGURE No.: 1

Little Rockfish Creek
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Little Rockfish Creek
Reach:	Gillis Farm
DA:	16.5 sq mi (10,550 ac)
Date:	7/2/2002
Station:	1+53
Feature:	CS #1, Riffle

STATION (FEET)	HI (FEET)	FS (FEET)	ELEVATION (FEET)	NOTES
0+00.0	104.71	4.71	100.00	
0+04.0	104.71	4.46	100.25	
0+10.0	104.71	4.33	100.38	
0+12.5	104.71	4.37	100.34	
0+14.0	104.71	4.68	100.03	
0+15.0	104.71	4.87	99.84	
0+15.5	104.71	5.86	98.85	LBKF
0+16.0	104.71	7.09	97.62	
0+17.0	104.71	7.76	96.95	LEW/WS
0+18.5	104.71	8.57	96.14	
0+20.0	104.71	8.87	95.84	
0+23.5	104.71	8.09	96.62	
0+27.0	104.71	8.19	96.52	
0+30.5	104.71	8.53	96.18	
0+32.5	104.71	8.54	96.17	TW
0+34.5	104.71	8.23	96.48	
0+35.5	104.71	7.83	96.88	REW
0+36.5	104.71	5.86	98.85	RBKF
0+39.0	104.71	4.70	100.01	
0+41.0	104.71	4.61	100.10	
0+47.0	104.71	4.83	99.88	

BANKFULL Hydraulic Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	0.5	1.2	0.3
	1.0	1.9	1.6
	1.5	2.7	3.5
	1.5	3.0	4.3
	3.5	2.2	9.2
	3.5	2.3	8.0
	3.5	2.7	8.8
	2.0	2.7	5.4
	2.0	2.4	5.1
	1.0	2.0	2.2
	1.0	0.0	1.0
TOTALS	21.0		49.1

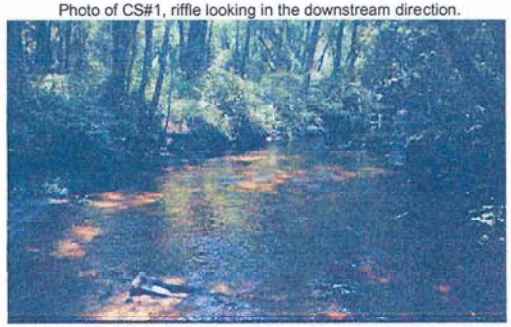
SUMMARY DATA (BANKFULL)

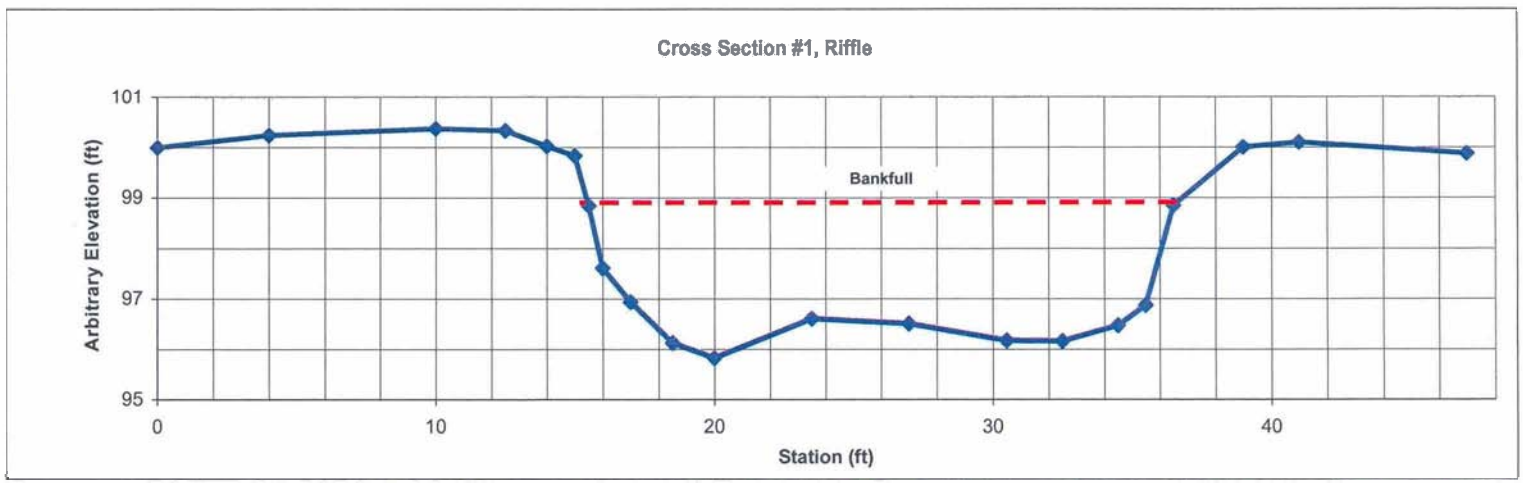
A(BKF)	49.1	W(FPA)	300
W(BKF)	21.0	Slope	0.0042
Max d	3.0	Sinuosity	1.3
Mean d	2.3	Area=	A
W/D	9.0	Width=	W
Entrenchment	14.3	Depth=	D
Stream Type	E5	Bankfull=	BKF
Area from Draft Rural Reg. Curve			122

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1.4	5.7	moderate
Root Depth/Bank Ht	1	1	very low
Root Density (%)	25	7.6	high
Bank Angle (Degrees)	85	6.9	high
Surface Protection (%)	10	9	very high
Bank Materials	sand	5	
		35.2	high

Photo of CS#1, riffle looking in the downstream direction.





Little Rockfish Creek
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Little Rockfish Creek
Reach:	Gillis Farm
DA:	16.5 sq mi (10,550 ac)
Date:	7/2/2002
Station:	3+73
Feature:	CS #2, Pool

STATION (FEET)	HI (FEET)	FS (FEET)	ELEVATION (FEET)	NOTES
0+00.0	105.70	5.70	100.00	
0+04.0	105.70	5.62	100.08	
0+06.5	105.70	5.36	100.34	LBKF
0+07.5	105.70	5.80	99.90	
0+08.5	105.70	6.63	99.07	
0+08.7	105.70	7.82	97.88	
0+09.0	105.70	10.02	95.68	
0+10.0	105.70	10.65	95.05	
0+11.0	105.70	10.73	94.97	
0+12.0	105.70	10.65	95.05	LEW/WS
0+14.0	105.70	10.31	95.39	
0+15.0	105.70	10.09	95.61	TW
0+17.0	105.70	9.44	96.26	
0+18.0	105.70	8.98	96.72	REW
0+19.7	105.70	7.92	97.78	
0+21.0	105.70	7.45	98.25	
0+21.2	105.70	6.23	99.47	
0+22.0	105.70	5.75	99.95	
0+22.5	105.70	5.36	100.34	RBKF
0+24.5	105.70	4.97	100.73	
0+28.5	105.70	5.01	100.69	

BANKFULL Hydraulic Geometry

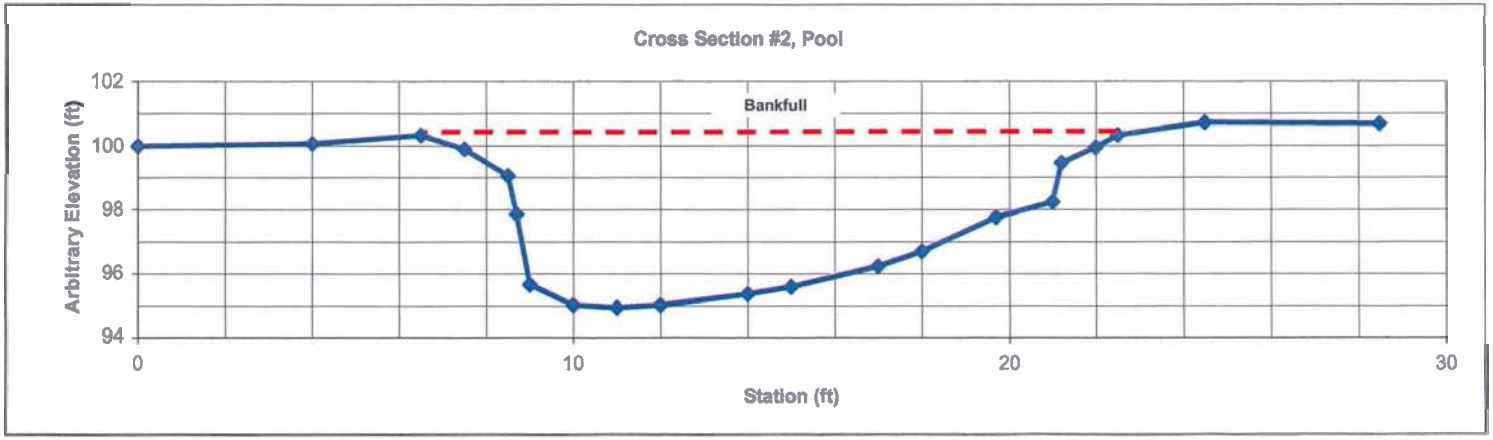
	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	1.0	0.4	0.2
	1.0	1.3	0.9
	0.2	2.5	0.4
	0.3	4.7	1.1
	1.0	5.3	5.0
	1.0	5.4	5.3
	1.0	5.3	**5.3**
	2.0	**5.0**	**10.2**
	1.0	4.7	**4.8**
	2.0	4.1	**8.8**
	1.0	3.6	**3.9**
	1.7	2.6	**5.3**
	1.3	2.1	**3.0**
	0.2	0.9	**0.3**
	0.8	0.4	0.5
	0.5	0.0	0.1
TOTALS	16.0		55.1

Mean d

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	80	1.9	very low
Bank Angle (Degrees)	85	6.9	high
Surface Protection (%)	95	1.2	very low
Bank Materials	sand	5	

Photo of CS#2, pool looking in the downstream direction.



Little Rockfish Creek
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Little Rockfish Creek
Reach:	Gillis Farm
DA:	16.5 sq mi (10,550 ac)
Date:	7/2/2002
Station:	4+49
Feature:	CS #3, Riffle

STATION (Feet)	HI (Feet)	FS (Feet)	ELEVATION (Feet)	NOTES
0+00.0	106.33	5.62	100.71	
0+00.5	106.33	7.16	99.17	
0+05.0	106.33	7.13	99.20	
0+07.0	106.33	6.42	99.91	
0+10.5	106.33	6.48	99.85	
0+15.5	106.33	6.52	99.81	
0+18.0	106.33	5.96	100.37	
0+20.0	106.33	6.00	100.33	
0+21.0	106.33	6.37	99.96	LBKF
0+22.5	106.33	6.74	99.59	
0+23.5	106.33	7.00	99.33	
0+24.6	106.33	9.44	96.89	LEW
0+26.5	106.33	9.89	96.44	TW
0+29.0	106.33	9.68	96.65	
0+31.0	106.33	9.39	96.94	
0+35.0	106.33	8.89	97.44	
0+37.7	106.33	8.77	97.56	REW/WS
0+38.8	106.33	8.41	97.92	
0+40.0	106.33	6.5	99.83	
0+40.5	106.33	6.37	99.96	RBKF
0+41.0	106.33	6.27	100.06	
0+43.0	106.33	6.19	100.14	
0+45.2	106.33	6.28	100.05	
0+47.7	106.33	6.00	100.33	
0+50.0	106.33	5.62	100.71	
0+55.0	106.33	5.58	100.75	
0+70.0	106.33	5.14	101.19	
0+90.0	106.33	4.38	101.95	

BANKFULL
Hydraulic Geometry

	Width (Feet)	Depth (Feet)	Area (Sq. Ft.)
	0.0	0.0	0.0
	1.5	0.4	0.3
	1.0	0.6	0.5
	1.1	3.1	2.0
	1.9	3.5	6.3
	2.5	3.3	8.5
	2.0	3.0	6.3
	4.0	2.5	11.1
	2.7	2.4	6.6
	1.1	2.0	2.4
	1.2	0.1	1.3
	0.5	0.0	0.0
TOTALS	19.5		45.4

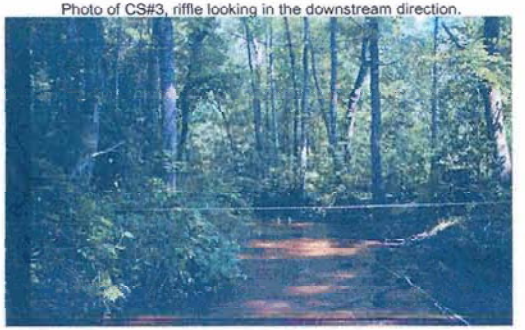
SUMMARY DATA (BANKFULL)

A(BKF)	45.4	W(FPA)	300
W(BKF)	19.5	Slope	0.0028
Max d	3.5	Sinuosity	1.3
Mean d	2.3	Area=	A
W/D	8.4	Width=	W
Entrenchment	15.4	Depth=	D
Stream Type	E5	Bankfull=	BKF
Area from Draft Rural Reg. Curve			122

Bank Erosion Hazard Index (BEHI)

Criteria	Value	Index	Bank Erosion Potential
Bank Ht/Bkf Ht	1	1	very low
Root Depth/Bank Ht	1	1	very low
Root Density (%)	90	1.5	very low
Bank Angle (Degrees)	75	5.4	moderate
Surface Protection (%)	80	1.9	very low
Bank Materials	sand	5	
		15.8	low

Photo of CS#3, riffle looking in the downstream direction.



Little Rockfish Creek
Cumberland County

Field Crew:	Ben Goetz, Jan Patterson, Jane Almon
River Basin:	Cape Fear
Watershed:	Little Rockfish Creek
Reach:	Gillis Farm
DA:	16.5 sq mi (10,550 ac)
Date:	7/2/2002

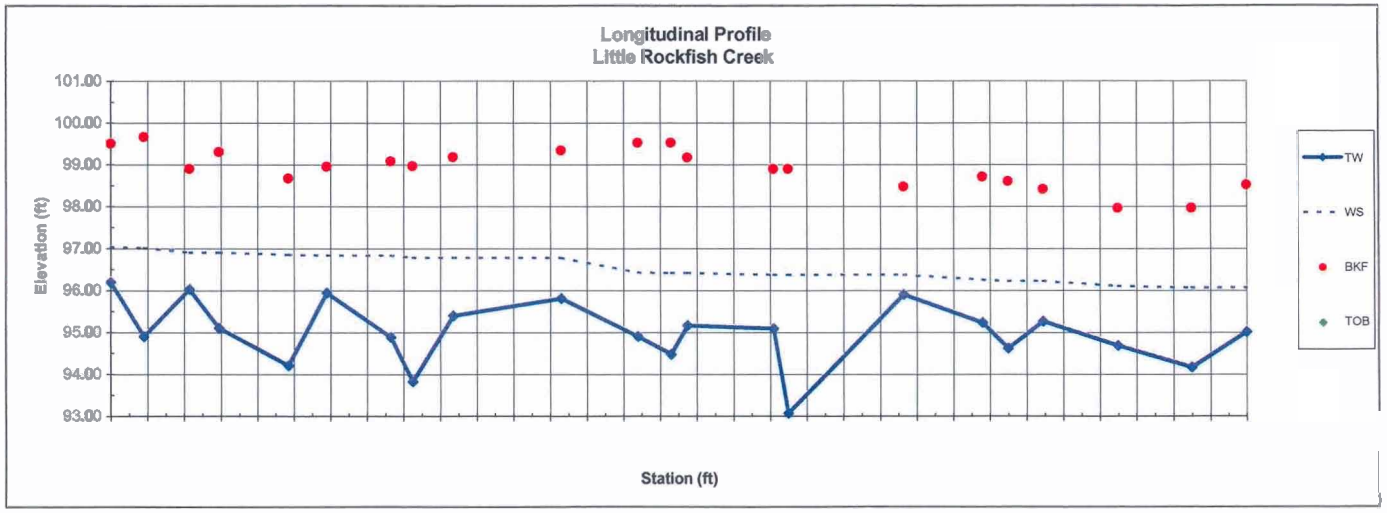
REF PT	BS	HI	FS	ELEV	NOTES
BM (AM)	4.55	104.55		100.00	PIN
BM (AM)		100.00	4.55	100.00	Error=0.00
BM (PM)	4.28	104.28		100.00	
TP #2	6.05	103.03	7.30	96.98	
TP #3	7.07	105.07	5.03	98.00	
TP #4	7.03	104.08	8.02	97.05	
BM (PM)		100.00	4.08	100.00	Error=0.00

PATTERN DATA FOR LITTLE ROCKFISH CREEK

Curve	Chord L	Mid	Radius of C	Beltwidth	Wavelength
1	42	7	35		325
2	41	8.2	30	36	119
3	38	8	27		184
4	45	8	36	27	220
5	30	6	22		
6	35	6	29	25	
Avg			30	29	212
Min			22	25	119
Max			36	36	325

Station	REF PT	HI	TW(FS)	TW	WS(FS)	WS	BKF(FS)	BKF	Notes	P-P	Pool Length	Max Pool Depth	Pool Slope	Riffle Length	Riffle Slope
0+00.0	BM (AM)	104.55	8.34	96.21	7.50	97.05	5.03	99.52	Head of Riffle					18.0	0.11
0+18.0	BM (AM)	104.55	9.63	94.92	7.52	97.03	4.87	99.68	Head of Pool		41.0		0.00		
0+43.0	BM (AM)	104.55	8.51	96.04	7.63	96.92	5.63	98.92	Max Pool			2.88			
0+59.0	BM (AM)	104.55	9.43	95.12	7.66	96.92	5.23	99.32	Head of Riffle					38.0	0.13
0+97.0	BM (AM)	104.55	10.32	94.23	7.68	96.87	5.86	98.69	Head of Pool	79.0	56.0		0.04		
1+18.0	BM (AM)	104.55	8.59	95.96	7.70	96.85	5.58	98.97	Max Pool			3.01			
1+53.0	BM (AM)	104.55	9.64	94.91	7.74	96.85	5.45	99.10	Head of Riffle					12.0	0.42
1+65.0	BM (AM)	104.55	10.70	93.85	7.75	96.80	5.56	98.99	Head of Pool	68.0	81.0		0.00		
1+87.0	BM (AM)	104.55	9.13	95.42	7.75	96.80	5.35	99.20	Max Pool			3.78			
2+46.0	BM (AM)	104.55	8.72	95.83	7.95	96.80	5.19	99.36	Head of Riffle					42.0	0.83
2+88.0	BM (AM)	104.55	9.62	94.93	8.10	96.45	5.01	99.54	Head of Pool	123.0	27.0		0.04		
3+06.0	BM (AM)	104.55	10.05	94.50	8.11	96.44	5.01	99.54	Max Pool			5.04			
3+15.0	BM (PM)	104.28	9.09	95.19	7.89	96.44	5.09	99.19	Head of Riffle					47.0	0.11
3+62.0	BM (PM)	104.28	9.17	95.11	7.92	96.39	5.36	98.92	Head of Pool	74.0	71.0		0.00		
3+70.0	BM (PM)	104.28	11.19	93.09	7.89	96.39	5.36	98.92	Max Pool			5.83			
4+33.0	BM (PM)	104.28	8.36	95.92	7.95	96.39	5.79	98.49	Head of Riffle					43.0	0.28
4+76.0	BM (PM)	104.28	9.03	95.25	8.01	96.27	5.55	98.73	Head of Pool	114.0	33.0		0.09		
4+90.0	BM (PM)	104.28	9.64	94.64	8.04	96.24	5.66	98.62	Max Pool			3.98			
5+09.0	BM (PM)	104.28	9.00	95.28	8.08	96.24	5.85	98.43	Head of Riffle					41.0	0.29
5+50.0	TP #2	103.03	8.33	94.70	6.91	96.12	5.06	97.97	Head of Pool	74.0	70.0		0.06		
5+90.0	TP #2	103.03	8.85	94.18	6.95	96.08	5.06	97.97	Max Pool			3.79			
6+20.0	TP #2	103.03	8.00	95.03	7.00	96.08	4.50	98.53	Head of Riffle						
										max	123.0	81.0	5.8	0.0909	47.0000	0.8333
										min	68	27	2.88	0.0000	12.0000	0.1064
										avg	88.7	54.1	4.0	0.0315	34.4286	0.3101
										Max ratio	6.2	4.1	0.3	0.58	300.41	5.33
										Min ratio	3.4	1.4	0.1	0.00	76.70	0.68
										avg ratio	4.4	2.7	0.2	0.20	220.06	1.98

Average Water Surface Slope 0.16



Little Rockfish Creek
Cumberland County

PEBBLE COUNT							
Site: Gillis Farm					6/2/2002		
Party: Ben Goetz, Jan Patterson					Little Rockfish Creek		
				Particle Count			
Inches	Particle	Millimeter		Riffle	Total No.	Item %	% Cumulative
	Silt/Clay	< 0.062	S/C	12	12	6%	6%
	Very Fine	.062 - .125	S	31	31	16%	22%
	Fine	.125 - .25	A	59	59	30%	52%
	Medium	.25 - .50	N	43	43	22%	73%
	Coarse	.50 - 1.0	D	7	7	4%	77%
.04 - .08	Very Coarse	1.0 - 2.0	S	18	18	9%	86%
.08 - .16	Very Fine	2.0 - 4.0		2	2	1%	87%
.16 - .22	Fine	4.0 - 5.7	G	10	10	5%	92%
.22 - .31	Fine	5.7 - 8.0	R	5	5	3%	94%
.31 - .44	Medium	8.0 - 11.3	A	9	9	5%	99%
.44 - .63	Medium	11.3 - 16.0	V	2	2	1%	100%
.63 - .89	Coarse	16.0 - 22.6	E				100%
.89 - 1.26	Coarse	22.6 - 32.0	L				100%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S				100%
1.77 - 2.5	Very Coarse	45.0 - 64.0					100%
2.5 - 3.5	Small	64 - 90	C				100%
3.5 - 5.0	Small	90 - 128	O				100%
5.0 - 7.1	Large	128 - 180	B				100%
7.1 - 10.1	Large	180 - 256	L				100%
10.1 - 14.3	Small	256 - 362	B				100%
14.3 - 20	Small	362 - 512	L				100%
20 - 40	Medium	512 - 1024	D				100%
40 - 80	Lrg- Very Lrg	1024 - 2048	R				100%
	Bedrock		BDRK				100%
			Totals	**198**	**198**	**100%**	**100%**