Stream Restoration Plan

UNNAMED TRIBUTARY TO
CANE CREEK
Alamance County, NC

APRIL 2003

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Prepared for:

NC Wetlands Restoration Program

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I HEREBY CERTIFY THAT THE REPORT CONTAINED HEREIN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION.

SIGNED SEALED, AND DATED THIS 22nd DAY OF APRIL 2003.
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EXECUTIVE SUMMARY

Restoration and preservation of the environment leads to many benefits and improvements to the communities that depend upon it. Restoration of a stream and its associated buffer helps to restore a degraded system to its stable state or a state that mimics the conditions prior to anthropogenic influences. Preservation of the existing buffer ensures the continued existence of the ecosystem and acts as a wildlife corridor.

The Unnamed Tributary (UT) to Cane Creek Restoration Site on the McPherson properties in Alamance County provides opportunities for stream restoration and buffer restoration. The following table summarizes acreages and footages for the site.

COMPONENT	BEFORE RESTORATION	AFTER RESTORATION
Stream (feet)	2301	2330
Riparian Buffer (acres)	NA	5.4

This site consists of a channel that is classified as a C4, which is not entrenched. However, due to agricultural development within its watershed, the channel has become unstable, downcut to bedrock, and is now overwidening. Restoration of this channel to a stable C type stream will help to improve biological integrity of the system, reduce energy of the stream, reduce erosion, and increase habitat. The existing buffer consists of a disturbed and cutover Piedmont Mesic Mixed Hardwood Forest. Restoration and preservation of the riparian buffer along the stream will help to improve aquatic and terrestrial habitats.

The restoration site on the McPherson properties provides an excellent opportunity for restoration of the stream and buffer. Restoring stream and buffer functions at this site will:

1) Improve floodwater levels;
2) Improve water quality;
3) Increase aquatic and terrestrial habitat and diversity;
4) Provide stream geomorphologic restoration opportunities;
5) Improve the biological integrity of the system;
6) Reduce the amount of sediment and pollutants entering the stream; and
7) Provide landscape continuity.

Overall, the site will provide a variety of habitats from aquatic to uplands. The site will greatly increase the future habitat and food sources for a variety of wildlife species. Restoration of the stream channel and buffer will help improve water quality for the unnamed tributary to Cane Creek and downstream bodies of water including Cane Creek, the Haw River, and thus the Cape Fear River.

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SECTION 1

INTRODUCTION

1.0 INTRODUCTION

The North Carolina Wetlands Restoration Program (NCWRP) has identified the UT to Cane Creek as a potential stream restoration site. The proposed site is located on the McPherson properties, south of Snow Camp, in Alamance County, North Carolina (Exhibit 1.1.1). The NCWRP has determined that the UT and surrounding riparian buffer should be restored using natural channel design methods. The completed length of the stream restoration will be 2330 feet.

1.1 PROJECT DESCRIPTION

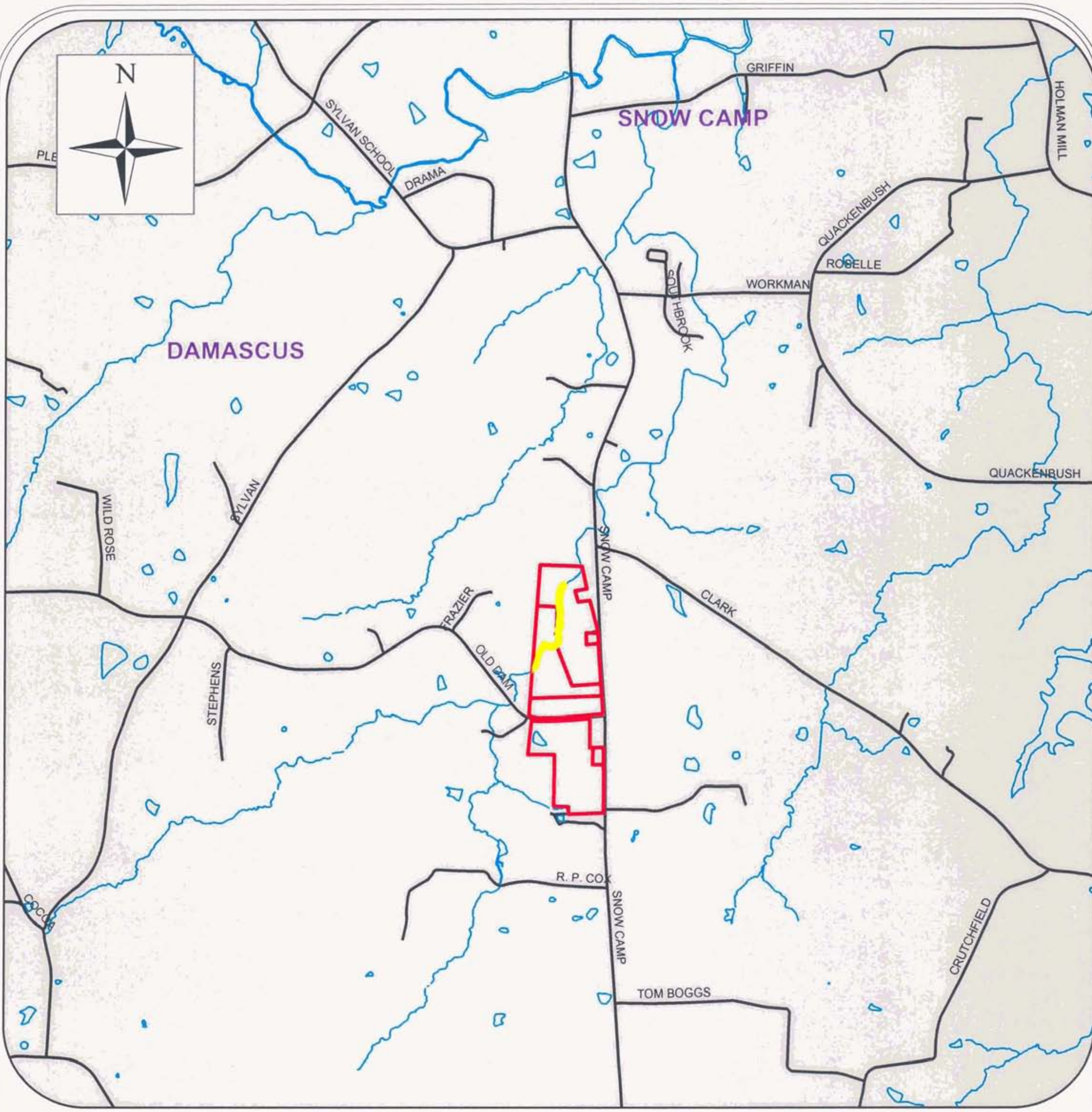
The proposed restoration site is located on the Stephen and Tammy McPherson and Herbert and Yvonne McPherson properties off Snow Camp Road (SR 1004) (Exhibit 1.1.2). The reach is enclosed within the properties boundaries of the McPherson properties.

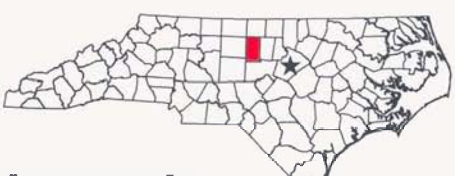
Cattle have heavily impacted the proposed restoration reach. The animals have unfettered access to the stream and have created numerous crossings through the channel. The lower portion of the reach is straight and wide signaling that it may have been channelized in the past. The upper reach is more sinuous; however has downcut. Numerous rock outcrops can be found within the channel and in the adjacent riparian areas. The riparian vegetation has been altered by the harvest of larger hardwood trees and from cattle grazing and trampling.

1.2 PROJECT GOALS AND OBJECTIVES

There are several goals and objectives for the stream restoration site on the McPherson Farms. The goals and objectives of restoring UT to Cane Creek include:

1. Improving water quality;
2. Providing wildlife habitat through the creation of a riparian zone;
3. Improving aquatic habitat with the use of natural material stabilization structures and a riparian buffer;
4. Excluding the cattle from the stream;
5. Reducing nutrient loads from entering the stream via the buffer acting as a filter and exclusion of cattle;
6. Increasing the stream's access to its floodplain; and
7. Reducing erosion and sedimentation.





Legend

- McPherson Parcels
- Restoration Reach
- Hydrography
- Roads

NC Wetlands Restoration Program

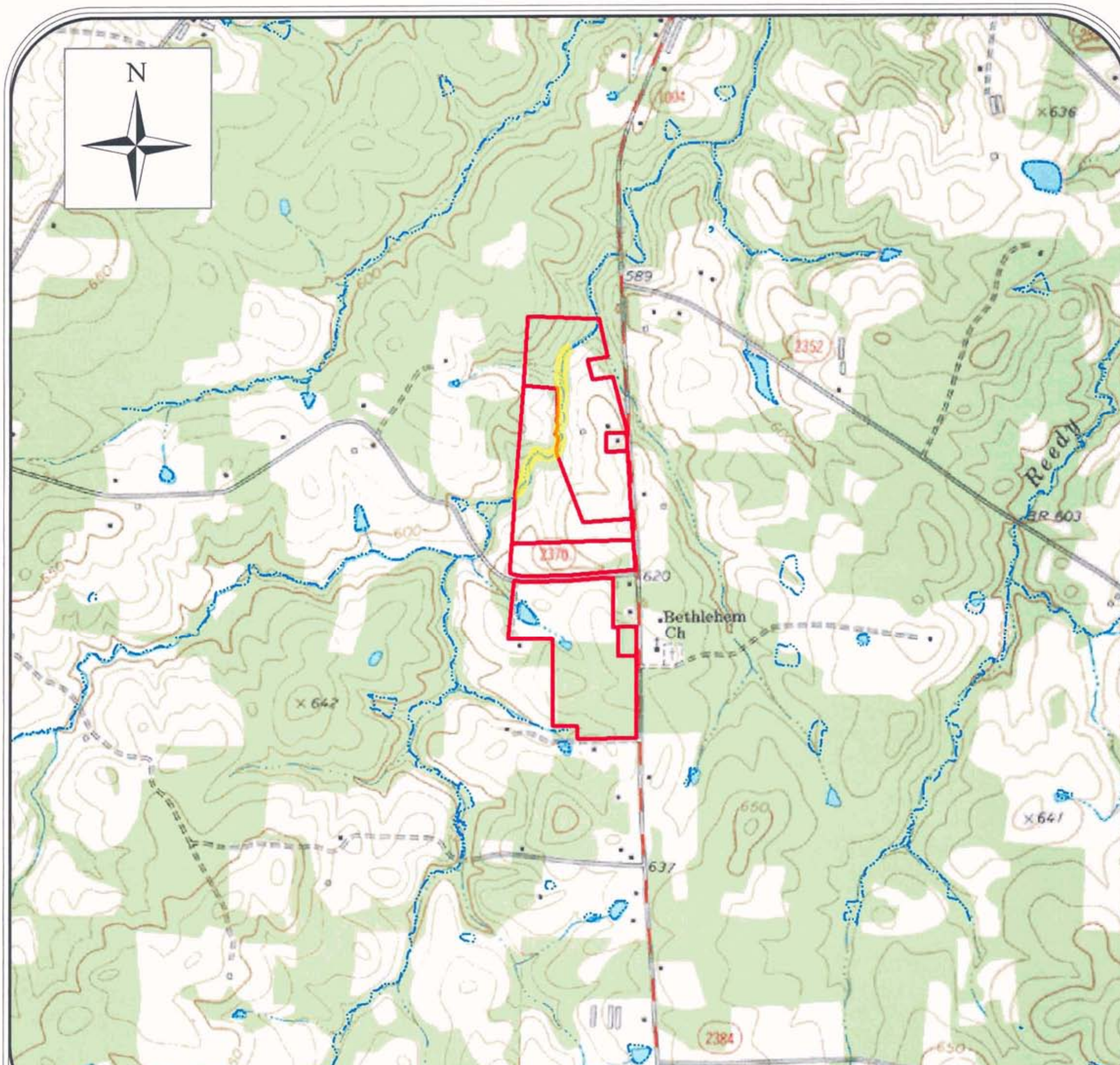
UT to Cane Creek

Restoration Plan
McPherson Properties
Alamance County, North Carolina

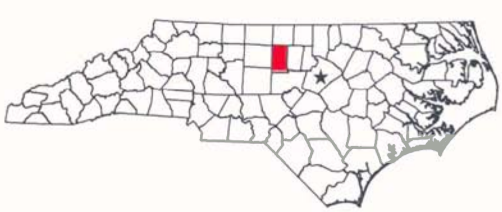
Project Vicinity

1" = 2500'

Exhibit 1.1.1



Source: Crutchfield Crossroads 1974 Quadrangle USGS Topographic Map
(Copyright (C) 2001, Maptech, Inc.)



NC Wetlands Restoration Program

UT to Cane Creek

Restoration Plan
McPherson Properties
Alamance County, North Carolina

Project Location

1" = 1500' Exhibit 1.1.2

Legend

- McPherson Parcels
- Restoration Reach
- Hydrography

SECTION 2

EXISTING CONDITIONS

2.0 EXISTING CONDITIONS

2.1 WATERSHED

The proposed restoration site is located within the northern region of the Cape Fear River Basin. The USGS has divided this river basin into six 8-dight Hydrologic Units (HUs). The project is located within HU 03030002. Its main waterbodies are the Haw River and the B. Everett Jordan Reservoir. The North Carolina Division of Water Quality (NCDWQ) has further divided the USGS HUs into smaller subbasins. Cane Creek and its tributaries are located within NCDWQ Subbasin 03-06-04.

2.1.1 Hydrology

The UT to Cane Creek starts at an elevation of 670 feet near the Chatham County line. The restoration project area is at an elevation of 570 feet. There are several small tributaries upstream of the site. Many of these tributaries have farm ponds located on them. The drainage area for the entire site covers 2003 acres. Exhibit 2.1.1 shows the watershed limits.

2.1.2 Soils and Geology

The proposed restoration site is located in the Piedmont physiographic province of North Carolina, within the Carolina Slate Belt. This belt consists of heated and deformed volcanic sedimentary rocks and was the site of oceanic volcanic islands approximately 550-650 million years ago. The topography is predominantly rolling with some steep and rugged areas such as the Uwharrie Mountains. The streams tend to have trellised drainage patterns and dry up fast due to the rocks beneath the soil. Silty clay loams are prevalent in the region (USDA, 1960). The predominate soil series in this region are Herndon and Georgeville soils.

2.1.3 Land Use

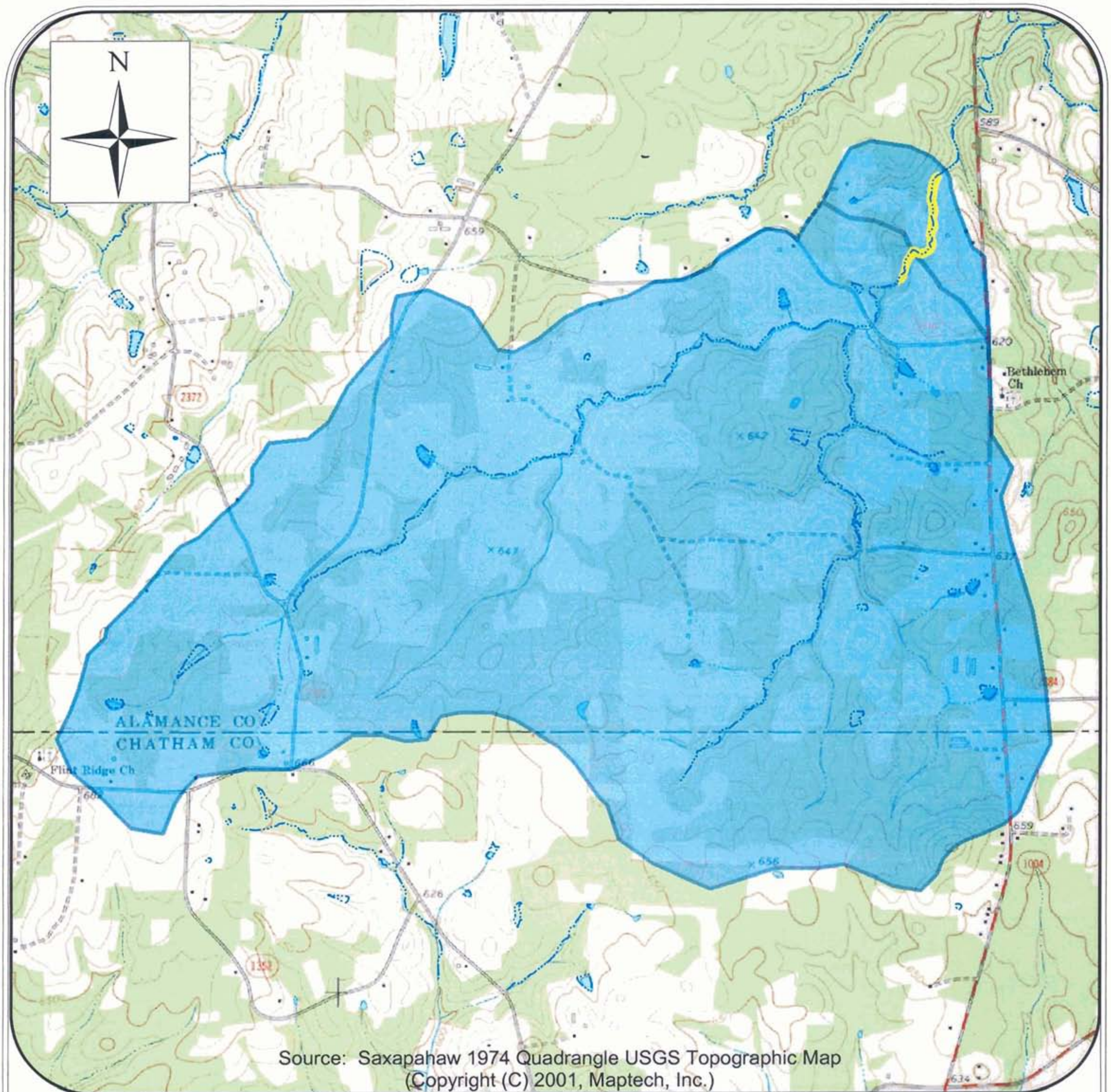
A majority of the land within the watershed is used for agricultural purposes (Exhibit 2.1.2). The remaining land use consists of forested land and scattered home sites along the county roads. There are scattered forest areas near the headwaters of the UT to Cane Creek. Land use within the watershed is not expected to change in the near future.

2.2 RESTORATION SITE

2.2.1 Site Description

The proposed restoration reach is typical of a Carolina Slate Belt stream. The upper reach is fairly sinuous. There is an abundance of cobble material present in the channel and along the channel banks.

Bank erosion is prevalent in the upper and middle reach due to the highly erosive soils and lack of vegetation that helps to stabilize an area. The lower reach of the restoration site has been straightened in the past and is dominated by straight, shallow pools.



Legend

Watershed Area

Restoration Reach

Hydrography

NC Wetlands Restoration Program

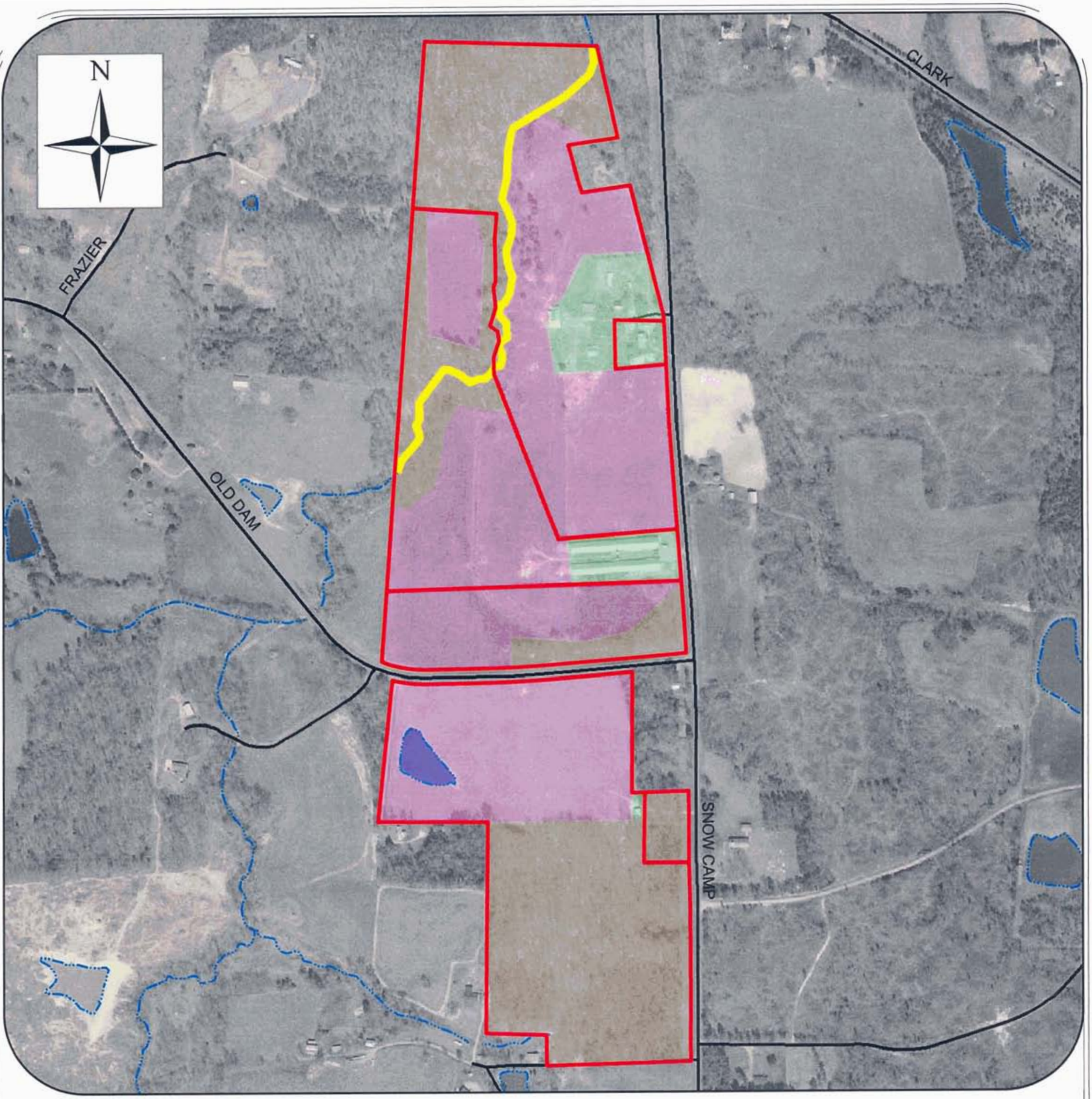
UT to Cane Creek

Restoration Plan
McPherson Properties
Alamance County, North Carolina

Watershed Area

1" = 1700'

Exhibit 2.1.1



Legend

- McPherson Parcels
- Restoration Reach
- Pasture/Cropland
- Pond
- Forest/Clearcut
- Residential/Structures
- Hydrography
- Roads

NC Wetlands Restoration Program

UT to Cane Creek

Restoration Plan
McPherson Properties
Alamance County, North Carolina

Land Use

Not to Scale

Exhibit 2.1.2

Based on the July 17, 2002 site visit, extreme drought conditions prevailed such that minimal aquatic species could survive in the shallow pools and dry riffles. During the site visit on September 5, 2002, the deepest pools had water depths of 1 to 2 feet. On this site visit, there was also evidence that the stream is accessing the existing floodplain. Wrack lines indicated that the stream had recently peaked about 2 feet above its current elevation. Photographs from two site visits on July 17, 2002 and September 5, 2002 are shown in Exhibit 2.2.1.

Bank degradation at this site can be attributed to the unlimited access that the cattle have to the channel and to the lack of a vegetated riparian buffer. During reach surveys, many cattle trails were observed entering the UT. The cattle have repeatedly trod through these areas, destroying the vegetation and causing gullies and ruts to form on the banks (Exhibit 2.2.2). These conditions have created highly erosive areas where sediment can enter the channel and cover the natural substrate. Additionally, the cattle are utilizeing the hannel as a wading pool. These areas are low, mucky depressions that host seasonal vegetation during summer droughts. Further, cattle have urinated and defecated in the stream channel adding to the mucky conditions, increasing nutrient levels and creating conditions for bacteria to flourish.

2.2.2 Soils

The Soil Survey for Alamance County North Carolina (USDA, 1960) identifies four soil series along the restoration site (Exhibit 2.2.3). Most of the soils are loams or silt loams. Only one soil series identified on-site is classified as hydric but is located only in the northern most tip of the McPherson properties; therefore, it is not feasible to propose wetland restoration for this site.

Colfax sandy loam is found at the upper end of the project reach. These are non-hydric soils found on gently sloping saddlelike areas in the landscape. Soils of the Colfax series are very deep and somewhat poorly drained. They have a moderate water-holding capacity and moderate permeability. They are found on uplands and formed in materials weathered from granitic rocks.

The Herndon silt loam (6-10% and 10-15% slope) series is found on the adjacent slopes along the UT to Cane Creek. The Herndon series consists of very deep, well-drained, moderately permeable soils. Herndon soils are typically found on gently sloping to moderately steep Piedmont Uplands. The Herndon series formed in material mostly weathered from fine-grained metavolcanic rock in the Carolina Slate Belt region.

The soil series along most of the stream reach consists of mixed alluvial land. It is described as being found along meandering streams that have shallow banks. The land is typically somewhat poorly drained to poorly drained and medium to strongly acidic. Local alluvial land is also found at the site. This soil series generally has a high water table and is poorly drained.

Worsham silt loam is found along a small tributary at the lower end of the reach. This is a poorly drained soil found on foot slopes and saddles in low, wet depressions and is considered to be a hydric soil series. Worsham silt loam is described as developing from local alluvial material that was washed from volcanic slate found in the Carolina Slate Belt region.

Exhibit 2.2.1b Site Photographs

Vegetation growing in channel from dry summer conditions

Long straight, shallow pool feature common throughout site

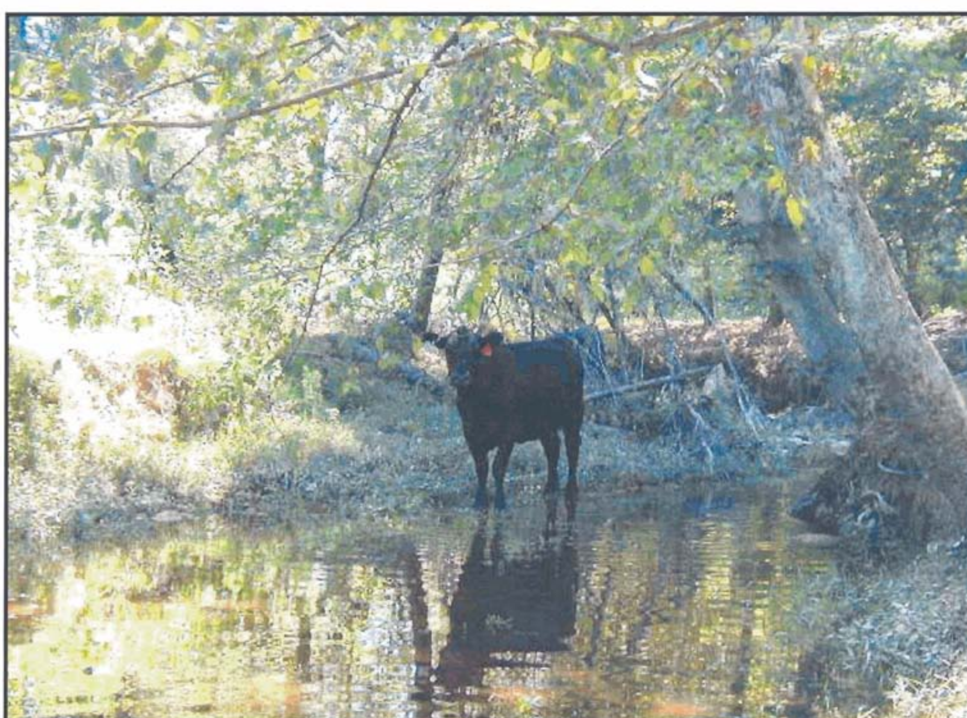
Exhibit 2.2.1b Site Photographs

Vegetation growing in channel from dry summer conditions

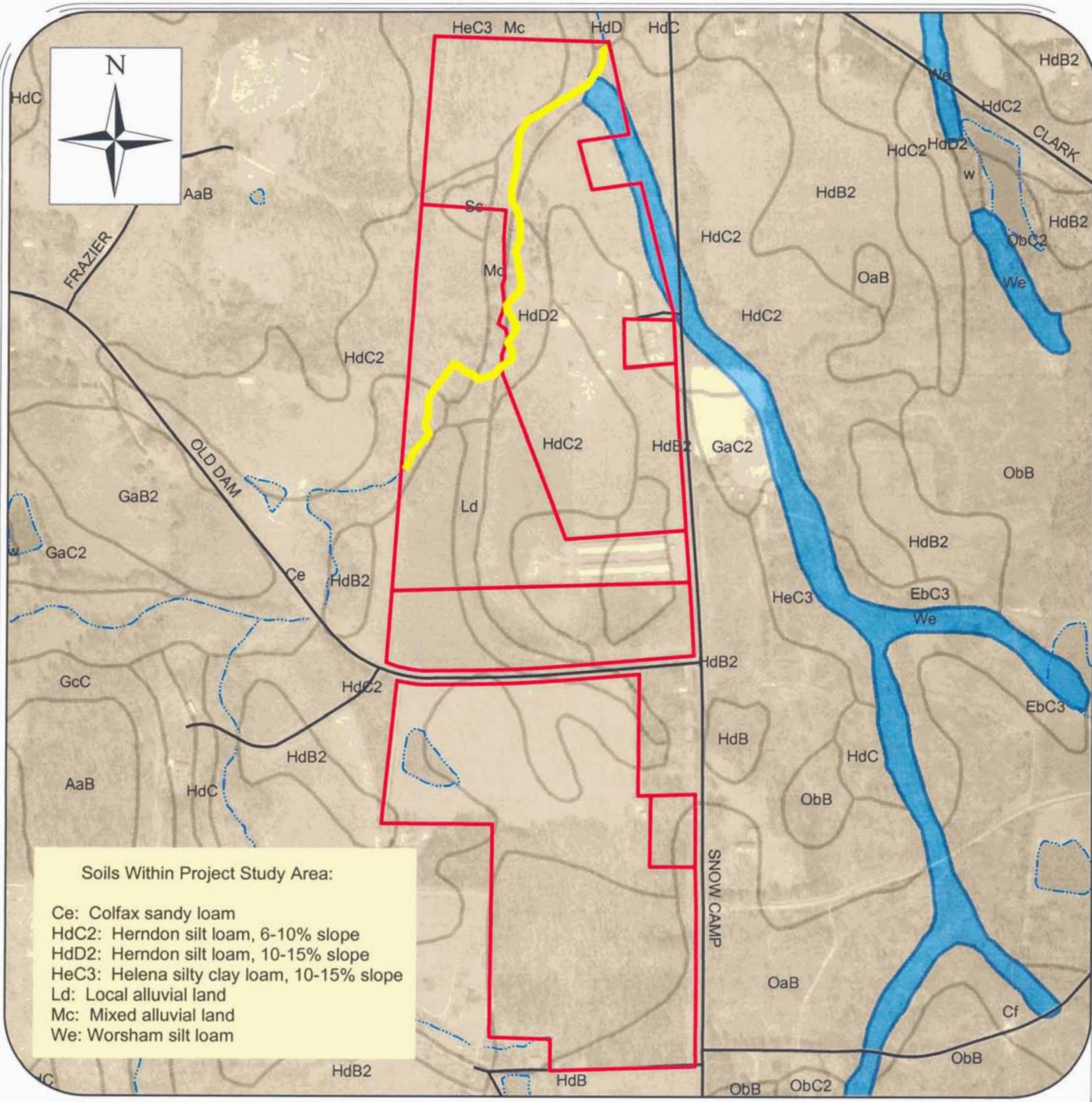
Long straight, shallow pool feature common throughout site

Exhibit 2.2.2 Cattle Impacts to the UT to Cane Creek

Ruts created by cattle moving through the area



One of many cattle that have access to the stream



NC Wetlands Restoration Program

UT to Cane Creek

Restoration Plan
McPherson Properties
Alamance County, North Carolina

Soils

Not to Scale

Exhibit 2.2.3

Legend

McPherson Parcels
Non-hydric Soils
Hydric Soils
Hydrography
Roads
Restoration Reach

2.2.3 Macro-invertebrates

A preliminary biological survey using a dip net and visual observation was made of the proposed stream restoration reach on September 5, 2002 and again on November 19, 2002. During the September survey, under very dry conditions, no benthic macroinvertebrates were found under rocks in the channel. One dragonfly larva (Suborder Anisoptera) was caught in debris around logs in the channel. A number of adult water beetles and bugs (Order Coleoptera and Hemiptera) were caught in areas of logs in the deeper pools. These included the diving beetles (Family Dytiscidae), riffle beetles (Family Elmidae), water boatmen (Family Corixidae), and a water scorpion (Family Nepidae). For the November survey, the stream flow was back to normal. The November sampling found a black fly larva (Family Simulidae), a few aquatic worms (Class Oligochaeta), some amphipods (Order Ampipoda), and a few juvenile crayfish (Order Decapoda).

2.2.4 Plant Communities

The existing riparian community consists of a mixed hardwood forest in which most of the larger trees have been cut in the last couple of years leaving some areas open, encouraging the growth of a dense herbaceous layer. The dominant tree species that are left include sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandiflora*), and red maple (*Acer rubrum*). A few white oaks (*Quercus alba*), northern red oak (*Quercus rubra*), slippery elm (*Ulmus rubra*), persimmon (*Diospyros virginiana*), and green ash (*Fraxinus pennsylvanica*) can also be found along the stream. Under story species include ironwood (*Carpinus caroliniana*) and eastern red cedar (*Juniperous virginiana*). Herbaceous species that have come in with the opening of the forest include wingstem (*Verbesina alterniflora*), ironweed (*Vernonia noveboracensis*), dog fennel (*Anthemis* spp.), ragweed (*Ambrosia* spp.), and microstegium (*Microstegium vimineum*). Cardinal flower (*Lobelia cardinalis*) and false nettle (*Boehmeria cylindrica*) were observed along the stream banks in a few areas.

2.2.5 Fish and Wildlife

The turbid water conditions greatly hampered observations of aquatic animals during both surveys. In September, slow moving areas of the stream were filled with mosquito larvae (Family Culicidae). A few minnows (possibly *Gambusia affinis*) were observed in one of the deeper pools. Minnows were more numerous during the November site visit. A number of Pickerel frogs (*Rana palustris*) and a few tadpoles were observed along the channel in September.

2.2.6 Endangered/Threatened Species

No endangered or threatened species are listed for Alamance County. There are several federal species of concern including: Carolina darter (*Etheostoma collies lepidinion*), Carolina redhorse (*Moxostoma* sp.), yellow lampmussel (*Lampsilis cariosa*), Carolina creekshell (*Villosa vaughaniana*), and sweet pinesap (*Monotropsis odorata*).

2.2.7 Water Quality

The main water quality concern at the proposed restoration reach is from the defecating and urinating of cattle and the sediment that enters the stream. This concern is due to the cattle having unlimited access to the stream on the McPherson properties and farther upstream on other farms. The destabilization of the banks by erosive water forces and cattle trails leads to excessive erosion and thus sedimentation downstream, which destroys the habitat of many aquatic organisms by removing and then filling areas between cobble and around large rocks in the stream. Several of the large cobbles are covered in algae as well as the sand material in the bottom of the channel. These algae may be an indication of excessive nutrients in the water as well as a lack of shading.

Cane Creek is classified by the NCDWQ as a "Water Supply II (WS-II)" and a "High Quality Water (HQW)." Cane Creek's status as a HQW typically occurs in conjunction with being a WS-II, or a water supply in a predominantly undeveloped watershed. Any water quality benefits created through this restoration project will help protect the water quality of all downstream waters.

SECTION 3

STREAM RESTORATION

3.0 STREAM RESTORATION

For a stream restoration project to be successful there are several key items that must be included. It is important that the designer(s) understand the processes that are degrading the stream, the characteristics of the stream and its watershed, and what design elements may be employed to repair the stream. This enables those involved to develop a plan for a holistic approach to restoration of the system. The following sections detail the stream restoration design process.

3.1 METHODOLOGY

The *Stream Channel Reference Sites: An Illustrated Guide to Field Technique, US Forest Service General Technical Report RM-245* (Harrelson *et al.*, 1994), was used as a guide for taking stream survey measurements. Information and techniques on stream classification and morphology in *Applied River Morphology* (Rosgen, 1996) were also used for classifying the stream and reference reaches.

The existing conditions of the UTs and surrounding area were observed and analyzed to better understand the behavior of the watershed. This allowed for the development of a restoration plan that encompasses the entire system. The watershed area was delineated from the United States Geological Survey (USGS) Crutchfield Crossroads Quadrangle for North Carolina.

In addition to documenting the information contained in Section 2, quantitative measurements were taken for the existing conditions and reference reach conditions. These measurements were used to determine the proposed conditions for the restoration. Elevation measurements for the longitudinal profile survey and cross-sectional surveys (one pool and one riffle) included but were not limited to: thalweg, water surface, bankfull, low bank, and terrace elevation. The bank slope, width of flood prone area, belt width, valley length, straight length, pool-to-pool spacing, and composition of channel material were also measured and calculated.

The survey also identified materials such as trees and boulders that could be used in constructing in-stream structures for the restoration. Design constraints (*e.g.*, existing bedrock, crossings, and valley walls) were also identified during the survey.

3.1.1 Stream Classification

The stream channel was classified by five criteria: width-to-depth ratio, entrenchment ratio, slope, sinuosity, and channel materials. Width-to-depth ratio is the ratio of the bankfull width to the mean depth of the bankfull channel. The width-to-depth ratio indicates the channel's ability to dissipate energy and transport sediment. The entrenchment ratio is the vertical containment of the stream and the degree to which the channel is incised in the valley floor. The flood-prone width divided by the bankfull width yields the entrenchment ratio. The entrenchment ratio indicates if the stream is able to access its floodplain. The slope of the channel is the change in water surface elevation per unit of stream length. The slope can be analyzed over the entire reach to determine if the slope is stable with the existing channel material, or the slope can be calculated over sections, to determine the condition of pools and riffles. Sinuosity is the ratio of stream length to valley length. Low sinuosity typically indicates that the channel has been straightened. The amount and type of bed and bank material present indicate the channel's resistance to hydraulic stress and its ability to transport sediment (Rosgen, 1996). All five criteria are interrelated and were used to determine the current condition of the channel and also used for classifying the stream. These values helped to classify the stream and are used in the design process. Once the values were determined, a design process based on the geomorphic processes occurring with the channel was used.

3.1.2 Sediment Transport

A stream's stability is dependent upon its ability to transport sediment without aggrading or degrading. A stable stream can transport both the suspended load and the bedload without accumulating sediment or eroding sediment over long periods of time. The suspended load is the fine sand, silt, and clay particles collectively found within the water column. The bedload is comprised of the course sand, gravels, and cobbles along the stream bottom. The critical dimensionless shear stress is the force required to initiate the general movement of particles in a streambed. This entrainment of particles must have the ability to move the largest particle from the bar sample (D_i) to prevent aggradation of particles. In order to move the D_i particle the stream design must exceed a critical depth and slope. The critical dimensionless shear stress analysis described above indicates whether a stream has the ability to move its bedload and thus will not be susceptible to aggradation.

In conjunction with the aggradation analysis, a degradation analysis was performed to insure the design parameters would resist scour and bed cutting. As mentioned above, the shear stress is the force witch entrains and moves the particles. Here the boundary shear stress of the proposed cross section is plotted on Rosgen's revised Shield's Curve to assure the stream will not move too large of particle. If the shear stress has the ability to move the D_{100}, a potential for degradation exist. Existing and proposed grade controls bring further confidence to the analysis.

3.1.3 Flood Analysis

With any modification to a stream channel, it is important to analyze the modification's effect on flood elevations. Floodwater elevations were analyzed using the United States Army Corps of Engineers (USACE) *Hydrologic Engineering Center's River Analysis System* (HEC-RAS Version 3.01). This is a software package designed to perform one-dimensional, steady flow, analysis of water surface profiles for a network of natural and constructed channels.

HEC-RAS uses two equations, energy and/or momentum, depending upon the water surface profile. The site's model is generally based on the energy equation. The energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is used in situations where the water surface profile rapidly varies, such as hydraulic jumps and stream junctions. The 100-year discharges were taken from the USGS guidance document, *Estimating the Magnitude and Frequency of Floods in Rural Basins of North Carolina – Revised* (USGS, 2001).

Backwater analysis was performed for the existing and proposed conditions for both bankfull and 100-year discharges. In addition to steady flow data, geometric data is also required to run HEC-RAS. Geometric data consists of establishing the connectivity of the river system, which includes: cross-section data, reach lengths, energy loss coefficients (friction losses, contraction, and expansion losses), and stream junction information. The HEC-RAS model portrays how the proposed conditions will accommodate bankfull and 100-year discharges.

3.1.4 Discharge Analysis

The hydrologic analysis of the existing conditions required the quantification of the bankfull elevation and corresponding bankfull area. In degraded systems, bankfull indicators such as the inner berm or top of bank are often absent or are unreliable. As a result, the existing bankfull elevations and bankfull cross-sectional areas were determined by evaluating the North Carolina Rural Piedmont Discharge Curve (Harman *et al.*, 1999).

The HEC-RAS software was used to evaluate how the discharge flows within the proposed channel geometry. This evaluation verifies that the proposed plan, dimension, and profile would adequately carry the discharge at the bankfull stage, the point where water begins to overflow onto the floodplain (USACE, 2001).

3.1.5 Biotic Survey

A survey of the biotic community was conducted prior to restoration. The surveys include observing macrobenthos, aquatic life, and terrestrial life and plant community identification. This information assists in the development of the restoration plan and will provide a means to measure the success of the restoration as it relates to aquatic, wildlife, and buffer habitat. For life to flourish in streams, it is important that high quantities of sediment are not eroded and then allowed to accumulate in substantial amounts and that there is not a high quantity of suspended sediment. The stream has to be able to move its sediment load without causing detrimental affects to living things. Therefore, the proposed restoration of the stream will greatly improve the quality of its biotic community.

3.2 EXISTING STREAM CLASSIFICATION

Using Rosgen classification, the proposed restoration reach of the UT to Cane Creek is classified as a "C4" stream type (Rosgen, 1994). The slight entrenchment ratio, moderate to high width-to-depth ratio, and moderate to high sinuosity signifies a "C" in the Rosgen Stream classification. The typical "C" channel is one that is fairly wide and has point bars. The channel is mainly composed of gravel, which is denoted by the "4". The combination of maintenance practices and cattle access has encouraged the stream to downcut to its current elevation and then to widen out due to bedrock holding the grade of the stream. Although the stream is classified as a "C" type stream, it is severely eroding the banks due to overwidening and trees are falling into the stream. Exhibit 3.2.1 shows photographs of the existing conditions. The conditions discussed below are also included in Table 3.2.1 along with additional morphological characteristics. The existing channel survey data is in Appendix A. The NCDWQ Stream Classification Form is in Appendix B.

Two reaches were surveyed and classified using Rosgen's Natural Channel Design Classification scheme. The downstream reach has a bankfull width of 44.5 feet, bankfull mean depth of 1.0 feet, and a bankfull width-to-depth ratio of 42.5. The cross-sectional area for the downstream reach is 46.5 square feet (ft^2) and has a flood prone area of 88 feet. The bankfull mean velocity is at 4.3 ft/s and the bankfull discharge is 202 cfs for the downstream reach. The calculated entrenchment ratio for the downstream reach is 2.0 and with all of the above numbers for the downstream reach, the stream is classified as a C type channel. The upstream reach has a bankfull width of 24.6 feet, bankfull mean depth of 1.8 feet, and a bankfull width-to-depth ratio of 13.5. The cross-sectional area for the upstream reach is 45.0 square feet and has a flood prone area of 76 feet. The upstream bankfull mean velocity is at 4.4 ft/s and the bankfull discharge is 196 cfs.

Exhibit 3.2.1a Existing Stream Conditions

Eroded banks with trees falling in channel

Eroded banks

Table 3.2.1 Existing Conditions

Mitigation Plan: UTs to Cane Creek Design by: Ryan Smith Checked by: Kathleen McKeithan, PE, CPESC R. Kevin Williams, PE, PLS, CPESC		
PARAMETER	**UPSTREAM**	**DOWNSTREAM**
STREAM TYPE	C4	C4
DRAINAGE AREA (acres)	2000	1914
BANKFULL WIDTH (ft)	44.5	24.6
BANKFULL MEAN DEPTH (ft)	1.0	1.8
WIDTH/DEPTH RATIO	43	13
BANKFULL X-SECTION AREA (ft^2)	46.5	45.0
BANKFULL MEAN VELOCITY (ft/s)	4.3	4.4
BANKFULL DISCHARGE (cfs)	202	196
BANKFULL MAX DEPTH (ft)	2.3	2.3
WIDTH OF FLOOD-PRONE AREA (ft)	88	76
ENTRENCHMENT RATIO	2.0	3.1
MEANDER LENGTH (ft)	218	217.5
RATIO OF MEANDER LENGTH TO BANKFULL WIDTH	4.9	8.8
RADIUS OF CURVATURE (ft)	24	19
RATIO OF RADIUS OF CURVATURE TO BANKFULL WIDTH	0.5	0.8
BELT WIDTH (ft)	63	63
MEANDER WIDTH RATIO	1.4	2.5
SINUOSITY (K)	1.00	1.15
VALLEY SLOPE (ft/ft)	0.0056	0.0063
AVERAGE SLOPE (ft/ft)	0.0056	0.0055
POOL SLOPE (ft/ft)	0.0001	0.0001
RATIO OF POOL SLOPE TO AVERAGE SLOPE	0.0	0.0
MAX POOL DEPTH (ft)	5.7	3.2
RATIO OF POOL DEPTH TO AVERAGE BANKFULL DEPTH	5.5	1.7
POOL WIDTH (ft)	61	25
RATIO OF POOL WIDTH TO BANKFULL WIDTH	1.4	1.0
POOL TO POOL SPACING (ft)	355	61
RATIO OF POOL TO POOL SPACING TO BANKFULL WIDTH	5.5 –10.5	9.9 –19.9

The calculated entrenchment ratio for the upstream reach is 3.1 and combined with the above numbers for the upstream reach, the stream is also classified as a C type channel. The D_{50} for the two reaches is 18 millimeters.

3.3 STREAM REFERENCE REACH SITE SEARCH AND CLASSIFICATION

Restoration designs use reaches of stable channels and buffers within the same physiographic region for design guidance. These reference reaches provide natural channel design dimensionless ratios that are based on measured morphological relationships from stable channels. A search for suitable reference reaches was conducted based upon specific criteria between the UTs and the reference reach. The criteria for a reference reach include: the current land use, drainage area size, stream order, the absence of man-made alterations within the immediate reach, the absence of beaver dams, stream classification, and current stream condition. Additionally, visual inspections were conducted along each potential reference reach and notes were taken on the vegetative cover, bank stability, and channel condition. For suitable reference reaches, the survey data discussed in Section 3.1 was also measured.

Due to an unstable geometry the upstream and downstream portions of the UT to Cane Creek, the stream does not provide a stable dimension, pattern, and profile that can be used to design the proposed channel. Reference streams in the area were found in order to provide guidance in designing a stable stream with proper dimensions, patterns, and profiles based on the bankfull stage (Rosgen, 2001). Two streams were identified to use as reference reaches for the design. Exhibit 3.3.1 shows the locations of the two streams. Appendix B contains the NCDWQ stream classification forms for the reference reaches.

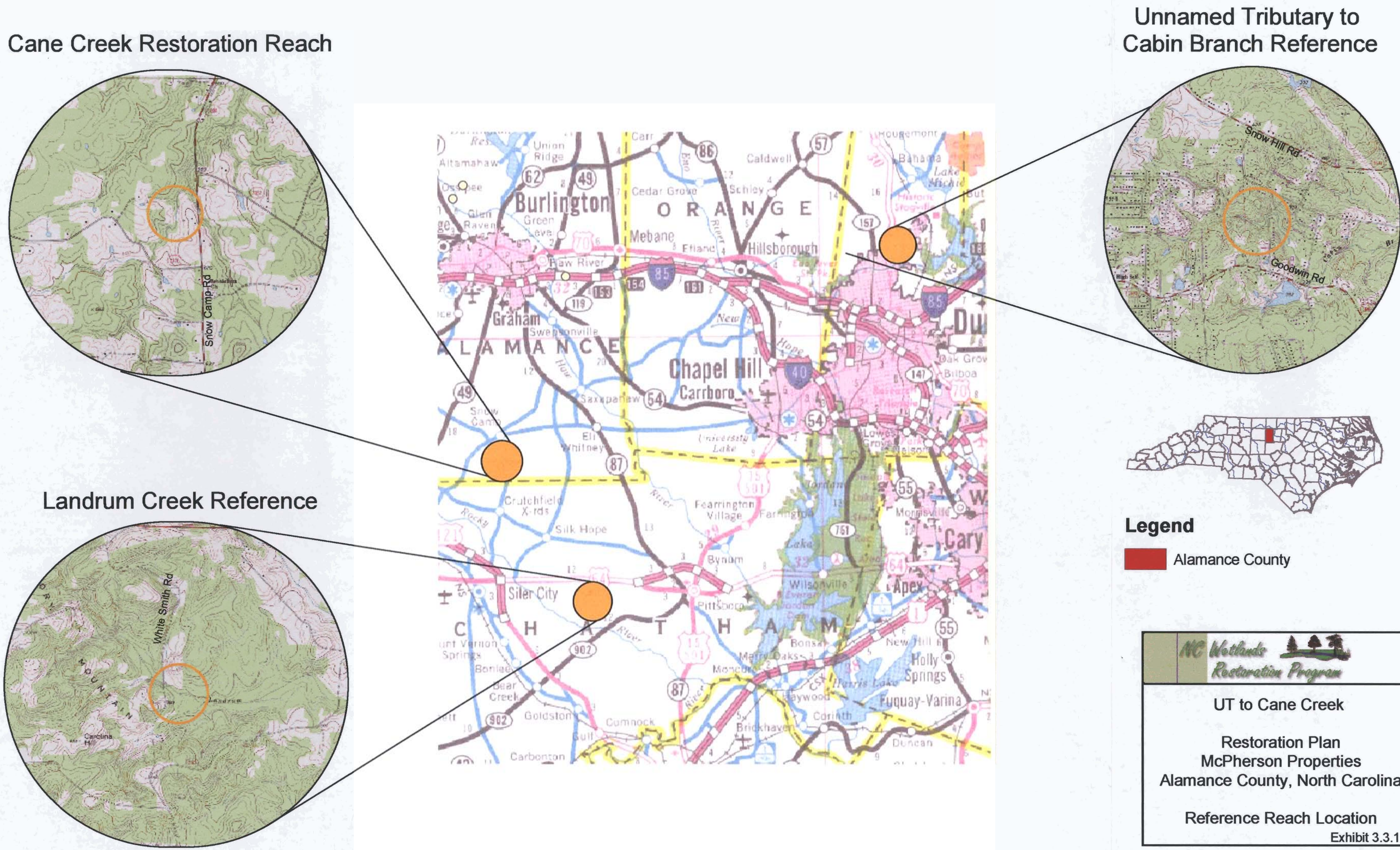
3.3.1 UT to Cabin Branch

Stream Conditions

The UT to Cabin Branch, which flows east into the Eno River, is located approximately four miles north of Durham at the end of Earl Road (SR 2625). This stream is a second order stream with a watershed area of 806 acres. Photographs of the UT to Cabin Branch are presented in Exhibit 3.3.2.

The stream channel is 8 to 15 feet wide with 2-foot high banks. At the time of the site survey (August 6, 2002) there was water only in the deepest pools due to an extended drought during the summer of 2002. The channel substrate is gravel, with a considerable amount of bedrock. The channel meanders through a well-established buffered floodplain within a U shaped valley. Although the floodplain is not extensively wide and the sinuosity is not extremely high, the floodplain, valley structure, and sinuosity provide a template of a system which can be constructed within the constraints of the project site. A WRP and a DWQ representative inspected and approved the site as a reference reach.

The reference reach survey was initiated near the end of Earl Road (SR 2625). The stream reach used for the survey totaled 397 feet. The survey included a longitudinal profile, cross-sections, bed material evaluation, buffer assessments, and system stability evaluation. The UT



NC Wetlands Restoration Program

UT to Cane Creek

Restoration Plan
McPherson Properties
Alamance County, North Carolina

Reference Reach Location

Exhibit 3.3.1

Table 3.3.1 Reference Conditions

Mitigation Plan: UT's to Cane Creek
Design by: Ryan Smith
Checked by: Kathleen McKeithan, PE, CPESC
R. Kevin Williams, PE, PLS, CPESC

PARAMETER	REFERENCE REACH	REFERENCE REACH
LOCATION	UT Cabin Branch	Landrum Creek
STREAM TYPE	C4b	C4
DRAINAGE AREA (acres)	806	1619
BANKFULL WIDTH (ft)	14.3	27.6
BANKFULL MEAN DEPTH (ft)	1.5	1.2
WIDTH/DEPTH RATIO	10	23
BANKFULL X-SECTION AREA (ft^2)	21.4	33.5
BANKFULL MEAN VELOCITY (ft/s)	4.9	5.2
BANKFULL DISCHARGE (cfs)	105	174
BANKFULL MAX DEPTH (ft)	2.2	2.0
WIDTH OF FLOOD-PRONE AREA (ft)	47	140
ENTRENCHMENT RATIO	3.3	5.1
MEANDER LENGTH (ft)	32 - 92	94 - 100
RATIO OF MEANDER LENGTH TO BANKFULL WIDTH	2.2 - 6.4	3.4 - 3.6
RADIUS OF CURVATURE (ft)	9.3 - 29	10 - 13
RATIO OF RADIUS OF CURVATURE TO BANKFULL WIDTH	0.7 - 3.0	0.4 - 0.6
BELT WIDTH (ft)	80	77
MEANDER WIDTH RATIO	5.6	2.8
SINUOSITY (K)	1.20	1.12
VALLEY SLOPE (ft/ft)	0.0169	0.0080
AVERAGE SLOPE (ft/ft)	0.0149	0.0077
POOL SLOPE (ft/ft)	0.0000 - 0.0011	0.0000
RATIO OF POOL SLOPE TO AVERAGE SLOPE	0.0 - 0.1	0.0
MAX POOL DEPTH (ft)	2.5	2.8
RATIO OF POOL DEPTH TO AVERAGE BANKFULL DEPTH	1.7	2.3
POOL WIDTH (ft)	14.7	27.4
RATIO OF POOL WIDTH TO BANKFULL WIDTH	1.0	1.0
POOL TO POOL SPACING (ft)	9 - 49	25 - 104
RATIO OF POOL TO POOL SPACING TO BANKFULL WIDTH	0.6 - 3.4	0.9 - 3.8

Exhibit 3.3.2 UT to Cabin Branch

View of Downstream Section (Facing Upstream)

View of Upstream Section

to Cabin Branch reference reach was classified as a C4b stream type based upon the survey data (Appendix C) (Rosgen, 1994). The C indicates a meandering channel with a moderate width-to-depth ratio and sinuosity. The b designates that the channel has characteristics of a B type channel such as: increased slope and less distinguished point bar features. The reach is transporting its sediment supply without aggrading or degrading while maintaining its dimension, pattern, and profile. Bankfull width of the reach is approximately 14.3 feet and bankfull depth is approximately 1.5 feet. The reference reach has a sinuosity of 1.2 and a radius of curvature of 9-29 feet. The width-to-depth ratio of 10 is on the low borderline for a C type stream; however, the stream portrays many C features such as the moderate to high sinuosity, meandering pattern, and the entrenchment ratio. The streambed material for both the UT to Cabin Branch and the site are dominated by gravel. Within the constraints of the project site, the proposed design will portray these same features.

Wildlife and Aquatic Life Observed

A preliminary biological survey using a dip net and visual observation was made of the reference reach. Due to the extended drought conditions, no flow was observed in the channel. However, aquatic life was observed in the water remaining in the deepest pools. Numerous crayfish (Order Decapoda), tadpoles, and minnows (*Gambusia* spp.) were observed. Aquatic snails (Class Gastropoda), small bivalve shells (Class bivalvia), and one-dragonfly larva (Suborder Anisoptera) were also found, but very few other macro invertebrates were observed. Wildlife or wildlife sign observed along the reach included raccoon (*Procyon lotor*), gray squirrel (*Sciurus carolinensis*), white-tailed deer (*Odocoileus virginianus*), blue jay (*Cyanocitta cristata*), and common crow (*Corvus brachyrhynchos*). Since the deepest pools were holding aquatic life through the season, species diversity and richness is expected to increase dramatically outside of drought conditions.

3.3.2 Landrum Creek

The reference reach on Landrum Creek is located approximately seven miles east of Siler City near Pleasant Hill Church Road (SR 1506) in Chatham County. This site was surveyed on September 30, 2002. The creek flows northwest to southeast crossing Pleasant Hill Church Road and flows to the Rocky River several miles below the reference reach. The reference reach is located approximately 200 feet east (downstream) of Pleasant Hill Church Road. A large pond is located within the watershed. The channel substrate is very rocky through the riffles with medium to large coble and some boulders; however, gravel dominates the substrate. The pools along the reach have a silt/sand bottom. The banks are two to three feet high and fairly stable. A number of fallen trees bridge the channel. There is also woody debris and leaf litter in the channel. Exhibit 3.3.3 contains photographs of Landrum Creek.

Landrum Creek is a 2nd order stream with a watershed of 1619 acres. The reach used for the detailed survey totaled 369 feet. The survey length of this reference reach was shortened due to the presence of a maintained powerline easement. The survey included a longitudinal profile, cross-sections, bed material evaluation, buffer establishment, and system stability evaluation. Four riffle and pool sequences were surveyed within this reach. The Landrum Creek reference reach was classified as a C4 stream type based upon the survey data (Appendix D). The reach is transporting its sediment supply without aggrading or degrading, while maintaining its dimension, pattern, and profile. Bankfull width of the branch is approximately 28 feet and bankfull depth is 1.2 feet. The reference reach has a sinuosity of 1.12 and a radius of curvature of 10 to 13 feet. Due to limited topographical data, the valley slope of 0.0074 ft/ft was calculated from the USGS quadrangle. The width-to-depth ratio of 22.8 is moderate and the entrenchment

Exhibit 3.3.3: Landrum Creek Reference Reach

Facing downstream

Facing Upstream

ratio of 5.1 is slightly entrenched as expected for a C type stream. The streambed material for Landrum Creek and the site are both dominated by gravel.

Wildlife and Aquatic Life Observed at Landrum Creek

A number of small fish were observed in the stream. Although none were captured for positive identification, it is likely that the population contains creek chubs (*Semotilus atromaculatus*) and other small minnows (*Gambusia* spp.). Several crayfish (Order Decapoda) were found in the rocky substrate. Brief sampling for benthic macroinvertabrates found only scattered individuals including caddisfly larvae, mayfly larvae, dragonfly larvae, and fishfly larvae. Wildlife or wildlife signs observed along the reach included raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), hummingbird (*Archilochus colubris*), red-bellied woodpecker (*Melanerpes carolinus*), American crow (*Corvus brachyrhynchos*), and red-tailed hawk (*Buteo jamaicensis*).

3.4 NATURAL CHANNEL DESIGN

The stream channel was designed using Rosgen's Natural Channel Design principles and practices (Rosgen, 1996). Typical morphological characteristics were obtained from stable reference reaches and used for designing the streams dimension, pattern, and profile. Using information from the reference reach surveys, dimensionless ratios were calculated in order to determine stable dimension, pattern, and profile ranges for the stream restoration site. The stream design parameters also include the stream's ability to transfer sediment through the reach without aggrading or degrading. The longitudinal profile was prepared using slopes from the reference reach's features. To make sure that the design is constructible, the existing profile was compared to the proposed profile. Flood analysis was conducted to ensure that the stream restoration project would not increase the flood stage following construction. Instream and bank stabilizing structures were added to the design layout.

Structures, matting, and plantings will be used to stabilize the restored channel. Structures may include rock cross-vanes, j-hook vanes, root wads, and floodplain interceptors. These structures are described further in Section 3.4.6. Grade control structures such as rock cross-vanes will be placed at the top and bottom of the mitigation reach. Additional structures will be used to stabilize the streambank and form the channel's pattern, profile, and dimensions. These stabilization structures will also provide habitat within the stream. In addition, the streambanks will be stabilized with matting material and tree/shrub plantings. Matting will be composed of material that withstands the maximum shear stress at bankfull velocity and is biodegradable. Plantings will be placed on the outside of meander bends and along the sides of riffle areas. Plant material will be comprised of native tree/shrub species that will provide bank stabilization and enhance ecological value.

In addition to detailing the proposed restoration, this section also contains the results of the sediment analysis, flood analysis, discharge analysis, and the structures used in the channel design.

3.4.1 <u>Proposed Channel Classification</u>

The proposed stream conditions are designed as a C4 stream type. The stream mitigation consists of a Priority 1 restoration and will be restored within the existing floodplain. The historical floodplain is also the current, existing floodplain.

3.4.2 Proposed Stream Description

The UT to Cane Creek will be restored from the property line on the west side of the site to the forest line near the north property line. The total length of the restoration will be 2330 feet. The restoration and establishment of hydraulic geometry, floodplain, and riparian buffer will contribute to water quality improvements within the watershed. Design aspects considered in this design were the location of the existing channel (to minimize cut and fill) and the elevations at the upstream and downstream control points, and the valley width and slope.

The restoration will include establishing the proper dimension, pattern, profile, and riparian buffer. Because the bedrock has held the grade at the site, the existing channel will be designed to meander across the original floodplain. The appropriate hydrologic geometry will be constructed for the reach along with a more natural, variable sinuosity. The stream channel's dimension, pattern, and profile design is based upon morphological parameters of the reference reaches.

The proposed channel will have an entrenchment ratio greater than 2.2 with a moderate width-to-depth ratio and a moderate sinuosity. The bankfull channel will have a meandering pattern on a well-developed floodplain. Based on the designed sinuosity, the new channel will have a total length of 2330 feet, adding 29 feet to the total length. A low flow channel is incorporated into the design to handle average daily flows. The bankfull channel is designed to handle larger flows. Flood flows will be able to access the floodplain. The completed design profile will detail a riffle, run, pool, and glide sequence. Exhibit 3.4.1 shows the plan view sheets for the entire proposed restoration. Exhibit 3.4.2 shows a typical cross-section of a riffle and pool for the designed channel. The longitudinal profile for the designed channel is contained in Exhibit 3.4.3. The restoration designs are discussed in the following paragraph. Table 3.4.1 shows each reach's design parameters and dimensions. This data is also included in the morphological characteristics table contained in Section 3.2.1.

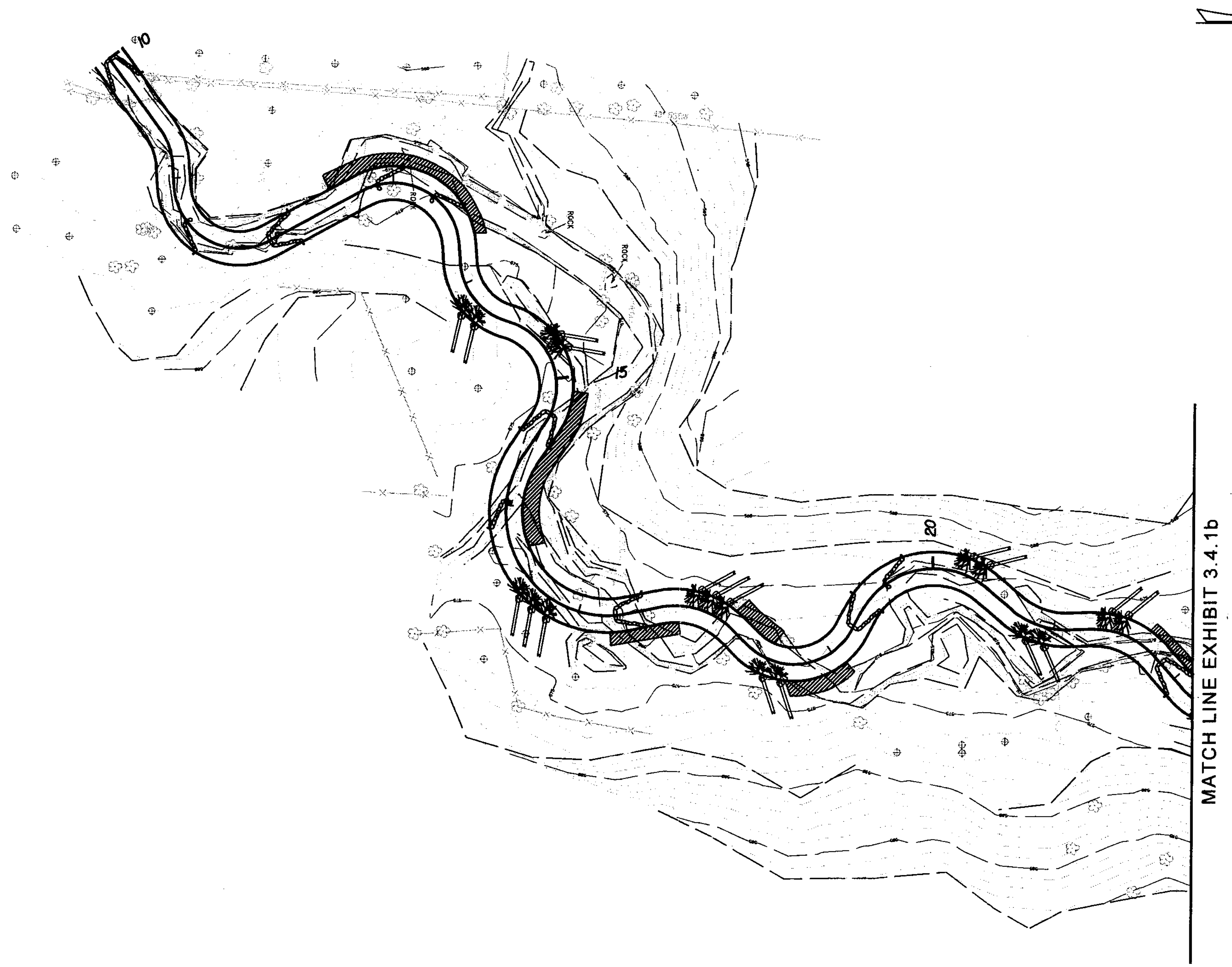
The proposed design calls for a shift in the alignment of the upper portion of the stream. By moving the stream back to its original location, the design will eliminate the active erosion of the valley wall. In the middle portion of the project, the proposed channel meanders back and forth across the existing channel within a fairly narrow valley. At the bottom of the project where the valley widens out, the restored channel is moved to visit west side of the valley to eliminate erosion of the valley wall.

3.4.3 Sediment Transport

The proposed stream design must be able to transport the sediment load without aggrading or degrading. The critical dimensionless shear stress is the force required to initiate the general movement of particles in a streambed. To prevent aggrading of particles, the entrainment of particles must be able to move the largest particle from the bar sample (D_i). In order to move the D_i particle the stream design must exceed the critical depth and slope, thus the proposed depths will allow the stream to move its bedload and not be susceptible to aggradation.

Table 3.4.1 Morphological Characteristics

PARAMETER	EXISTING CONDITIONS		DESIGN CONDITIONS	REFERENCE CONDITIONS	
LOCATION	Upstream	Downstream	---	UT Cabin Branch	Landrum Creek
STREAM TYPE	C4	C4	C4	C4b	C4
DRAINAGE AREA (acres)	2000	1914	2003	806	1619
BANKFULL WIDTH (ft)	44.5	24.6	24.0	14.3	27.6
BANKFULL MEAN DEPTH (ft)	1.0	1.8	2.0	1.5	1.2
LOWEST BANK HEIGHT RATIO	0.8	4.3	1.0	1.0	1.6
WIDTH/DEPTH RATIO	43	13	12	10	23
BANKFULL X-SECTION AREA (ft^2)	46.5	45.0	47.7	21.4	33.5
BANKFULL MEAN VELOCITY (ft/s)	4.3	4.4	4.2	4.9	5.2
BANKFULL DISCHARGE (cfs)	202	196	202	105	174
BANKFULL MAX DEPTH (ft)	2.3	2.3	3.2	2.2	2.0
WIDTH OF FLOOD-PRONE AREA (ft)	88	76	72	47	140
ENTRENCHMENT RATIO	2.0	3.1	3.0	3.3	5.1
MEANDER LENGTH (ft)	218	217.5	53 - 192	32 – 92	94 – 100
RATIO OF MEANDER LENGTH TO BANKFULL WIDTH	4.9	8.8	2.0 – 3.0	2.2 - 6.4	3.4 - 3.6
RADIUS OF CURVATURE (ft)	24	19	48 - 72	9.3 - 29	10 - 13
RATIO OF RADIUS OF CURVATURE TO BANKFULL WIDTH	0.5	0.8	2.0 – 3.0	0.7 - 3.0	0.4 - 0.6
BELT WIDTH (ft)	63	63	105	80	77
MEANDER WIDTH RATIO	1.4	2.5	4.4	5.6	2.8
SINUOSITY (K)	1.00	1.15	1.14	1.20	1.12
VALLEY SLOPE (ft/ft)	0.0056	0.0063	0.0029	0.0169	0.0080
AVERAGE SLOPE (ft/ft)	0.0056	0.0055	0.0023	0.0149	0.0077
RIFFLE SLOPE	0.0162	0.0116	0.0034	0.0333	0.0145
POOL SLOPE (ft/ft)	0.0001	0.0001	0.0000	0.0000 - 0.0011	0.0000
RATIO OF POOL SLOPE TO AVERAGE SLOPE	0.0	0.0	0.0	0.0 - 0.1	0.0
MAX POOL DEPTH (ft)	5.7	3.2	5.0	2.5	2.8
RATIO OF POOL DEPTH TO AVERAGE BANKFULL DEPTH	5.5	1.7	2.5	1.7	2.3
POOL WIDTH (ft)	61	25	29	14.7	27.4
RATIO OF POOL WIDTH TO BANKFULL WIDTH	1.4	1.0	1.2	1.0	1.0
POOL TO POOL SPACING (ft)	355	61	82	9 - 49	25 - 104
RATIO OF POOL TO POOL SPACING TO BANKFULL WIDTH	5.5 –10.5	9.9 –19.9	3.4	0.6 - 3.4	0.9 - 3.8



Stantec
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LEGEND

- ROCK CROSS-VANE
- J-HOOK VANE
- ROOTWAD
- CHANNEL PLUG

Scale: 1" = 100'

UT to Cane Creek

Restoration Plan
McPherson Property
Alamance County, North Carolina

Plan View

Exhibit 3.4.1a

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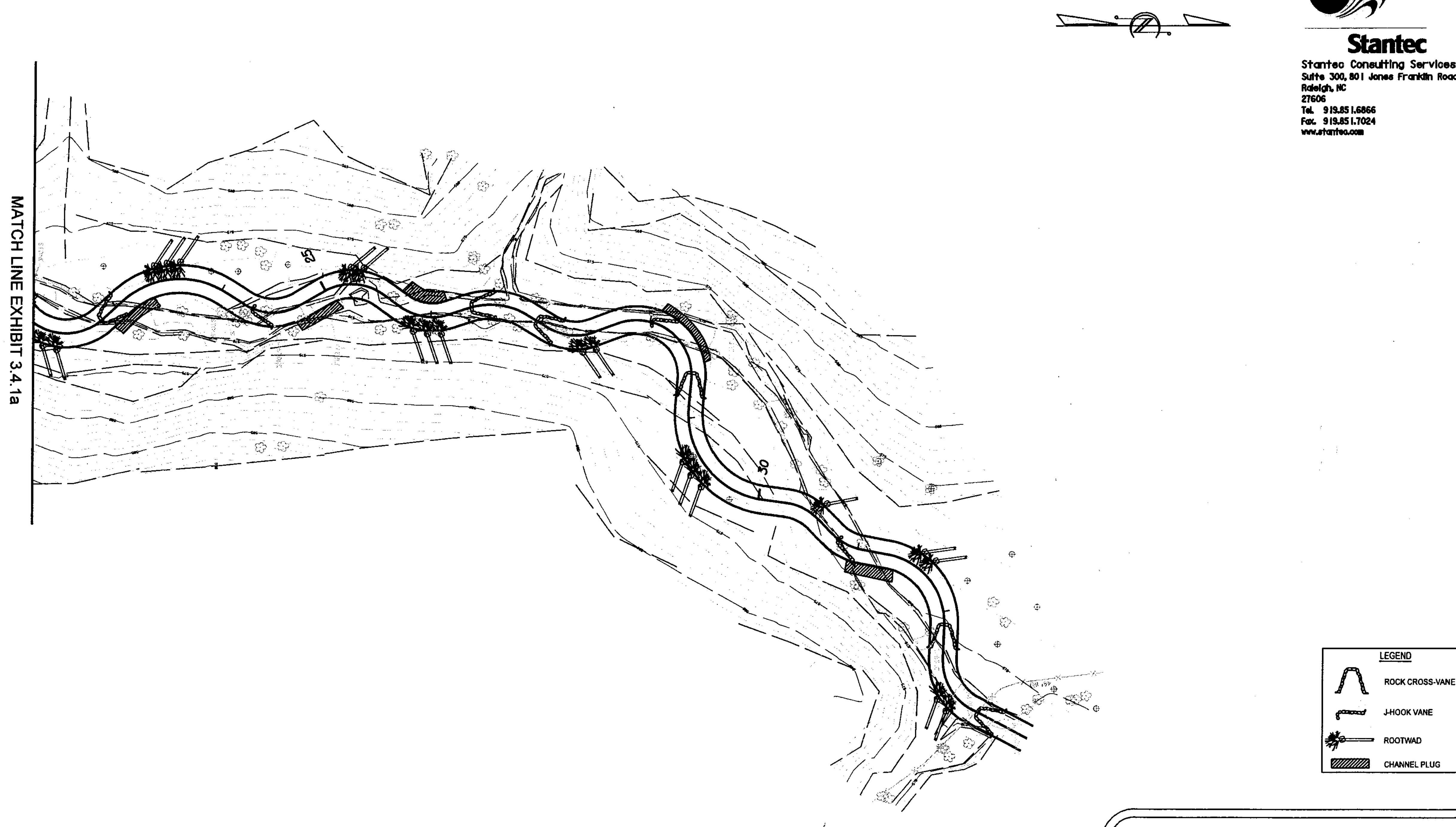

Scale: 1" = 100'

UT to Cane Creek

Restoration Plan

McPherson Property

Alamance County, North Carolina

Plan View

Exhibit 3.4.1b

TYPICAL RIFFLE AND POOL CROSS SECTION

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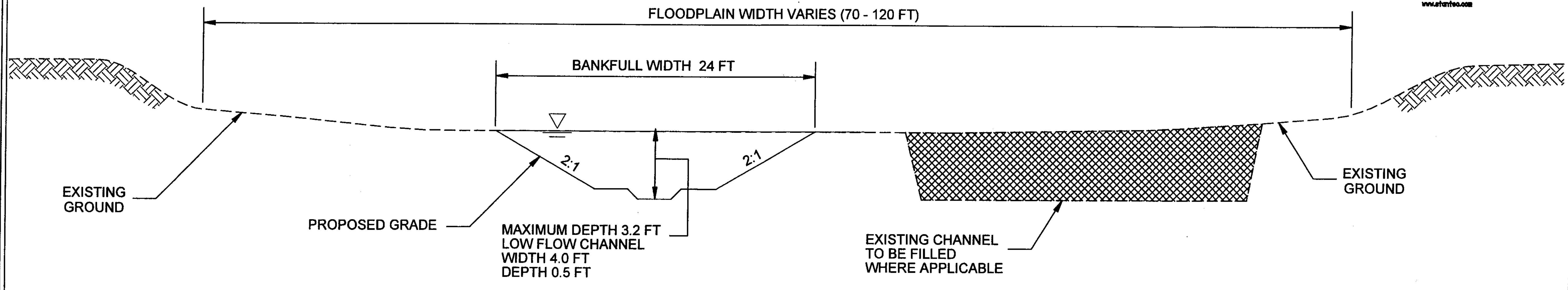
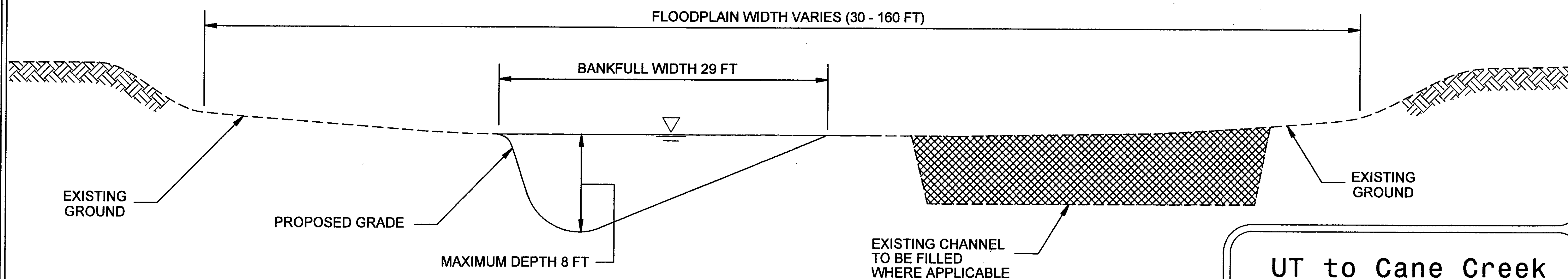
RIFFLE CROSS-SECTION



POOL CROSS-SECTION



NOTE: PROPOSED CHANNEL WILL MEANDER ACROSS FLOODPLAIN

Scale: NTS

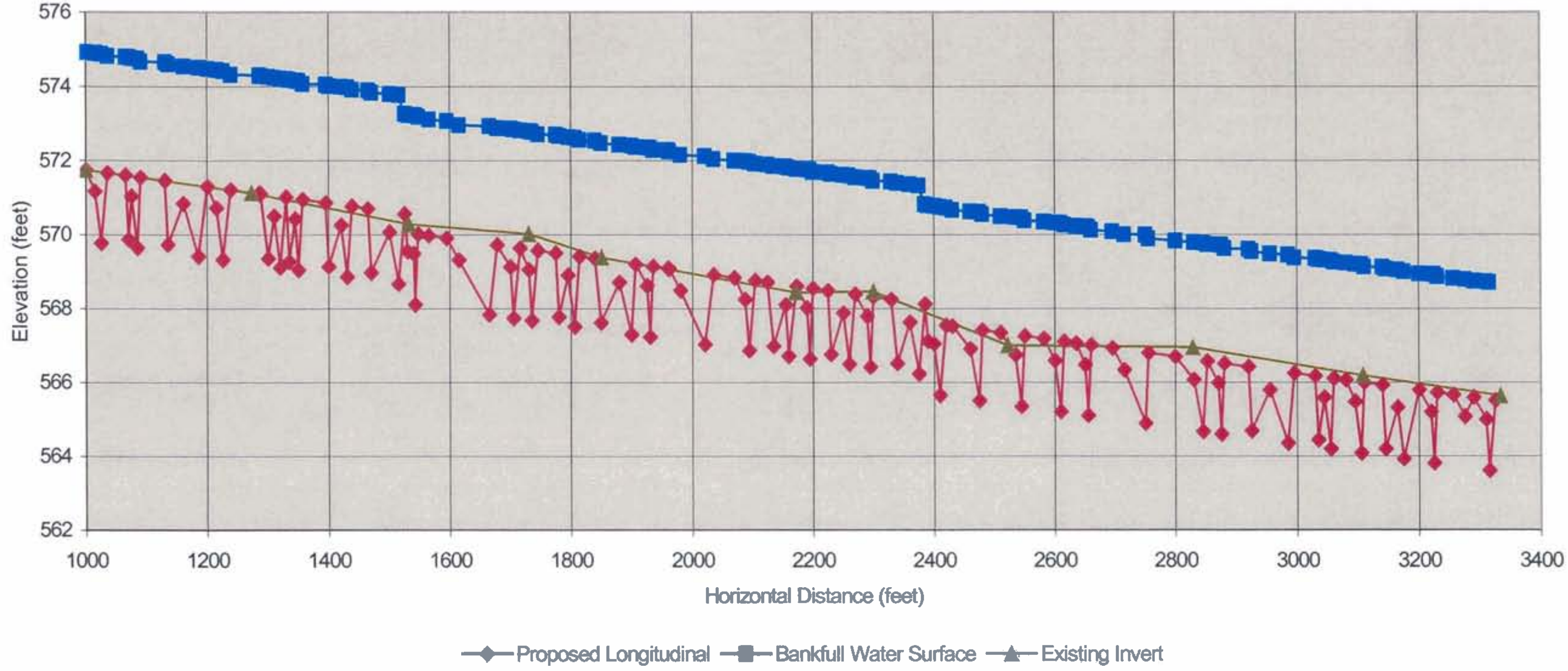
UT to Cane Creek

McPherson Property

Alamance County, North Carolina

Typical Riffle and Pool Cross Section

Exhibit 3.4.2



UT to Cane Creek

Restoration Plan
McPherson Property
Alamance County, North Carolina

Longitudinal Profile

Exhibit 3.4.3

The degradation analysis was performed to insure the design parameters would result in scour and bed cutting. As mentioned above, the shear stress is the force that entrains and moves the particles. Plotting the boundary shear stress of the proposed cross section on Rosgen's Revised Shield's Curve assures the stream will not move too large of particle.

Existing grade control including bedrock and cobble outcroppings will be reinforced with grade controls structures throughout the project and at the downstream end of the stream restoration. The design for the reach has the ability to transport the sediment load without aggrading or degrading. Table 3.4.2 contains the results of the sediment transport analysis.

Table 3.4.2 Sediment Transport Analysis

		EXISTING CONDITIONS	PROPOSED CONDITIONS
	LARGEST PARTICLE FROM BAR SAMPLE [D_i] (mm)	55	55
	PARTICLE FROM BAR SAMPLE [D_{100}] (mm)	55	55
AGGRADATION ANALYSIS	CRITICAL DIMENSIONLESS SHEAR STRESS [t^*_{ci}]	0.0166	0.0166
	EXISTING STREAM CONDITION BY REQUIRED DEPTH	Degrading	Stable
	EXISTING STREAM CONDITION BY REQUIRED SLOPE	Degrading	Stable
DEGGRADATION ANALYSIS	BANKFULL SHEAR STRESS (lb/ft^2)	0.54	0.26
	BANKFULL SHEAR STRESS MOVEABLE PARTICLE SIZE (mm)	40	15
	STREAM CONDITION BY BANKFULL SHEAR STRESS	Stable	Stable

Particle samples were taken from bar features rather than riffle features due to the presence of large cobble outcroppings within the riffle sections. These areas were not considered to be indicative of the channel's typical bed load. The sediment transport analysis portrays an existing channel that has a critical dimensionless shear stress with the ability to degrade the channel and bankfull shear stress that is limited by the bedrock and cobble outcroppings. The proposed design adjusts the channel geometry, patter, and profile such that the stream has the ability to transfer sediment without degrading or aggrading. The bedrock and cobble outcroppings will continue to provide vertical grade control.

3.4.4 Flood Analysis

The HEC-RAS model was used to evaluate the effect of the design on flood elevations and to ensure that the project would not increase flooding. For the study reach, 11 geometric cross-sections were modeled along the length of the existing and proposed channels. Two models, one for existing conditions and one for proposed conditions, were developed and executed to determine the water surface elevations for both the bankfull and 100-year events. The results of the analysis are contained in Appendix E. It was determined that the proposed channel will adequately carry the bankfull stage.

The analysis also indicates that the proposed channel geometry will not increase the 100-year flood elevations within the project area. In fact, the water surface elevation will be reduced at the downstream end of the project for the 100-year flow. The bankfull discharge is kept within the proposed channel for the entire reach. Section 3.4.5 contains further discussion of the calculated discharge values.

3.4.5 Discharge Analysis

The discharge analysis required the evaluation of the existing stream's watershed area, bankfull area and corresponding bankfull discharge. Discharge rates for the bankfull event used in the design of this project were calculated using the North Carolina Rural Piedmont Discharge Curve.

$$Q_{bkf} = 89.04x^{0.72}; (R^2 = 0.97)$$ (Harman *et al.*, 1999).

The bankfull discharge for the site is approximately 202 cfs. The existing bankfull velocity is approximately 4.2 ft/s. The proposed design will not greatly reduce the velocity; however, the proposed geometry, pattern and profile will reduce the shear stress and stream power from the existing condition. The existing and proposed geometries were evaluated at the bankfull discharge rates to determine if the bankfull discharge can be carried in the proposed channel's geometry. This evaluation verifies that the proposed plan, dimension, and profile would adequately carry the discharge at the bankfull stage, the point where water begins to overflow onto the floodplain.

3.4.6 Structures Used for Natural Channel Design

A number of different structures and methods will be used to control grade and stabilize the channel. These structures and methods may include, but are not limited to: rock cross-vanes, j-hook vanes, root wads, floodplain interceptors, matting, and planting materials. These structures provide grade control and bank stabilization; such that the proper dimension, pattern, and profile is maintained while providing various habitats for aquatic organisms. Benthic macroinvertebrates are able to feed on, hide under, and attach to these structures. They also provide shelter and create eddies for fish to rest and feed near. The majority of the materials for the structures will come from off site. Diagrams of these structures are located in Appendix F.

Rock cross-vanes and j-hook vanes will be utilized to direct the flow away from the bank and toward the center of the channel. Rootwads will be used for bank stabilization and to introduce woody material into the channel. Without this introduction it would be many years before the planted saplings would be able to provide the stream with this habitat feature.

Rock Cross-Vanes - Rock cross-vanes direct the flow away from the streambanks into the middle of the channel. The structure creates a scour pool below, while maintaining the grade for the upstream portion. These structures will also provide a stable drop in the stream profile throughout the Site. Boulders are used to build these structures and filter fabric and smaller rock will be used to further strengthen it by solidifying gaps between the boulders.

J-Hook Vanes - J-hook vanes are built with boulders and placed in the stream to direct flow away from the streambanks. The structure has the appearance of a "J" since it consists of one rock vane with boulders placed in the center of the channel curving back around to form a hook. In addition to the vanes scour pool, the openings between the extra boulders create a variety of flow patterns. These flow patterns help move insects that fish feed on and the fish and aquatic organisms hold in the calm water behind the boulders to catch food.

Rootwads - Rootwads will be utilized for streambank protection, habitat for fish, habitat for terrestrial insects, cover and introduction of woody material into the stream. Rootwads act as a deflection device to the stream's flow. The roots buffer the streambank and aid in turning the stream's erosive forces away from the streambank.

Floodplain Interceptor - Floodplain interceptors will provide water on the floodplain with a stabilized access point to flow back into the channel. The floodplain interceptors shall be placed in low swale type areas on the floodplain where floodwater is expected to re-enter the stream channel.

Matting and Planting - Matting, live staking, and vegetation planting will be utilized to stabilize the project. Matting will provide immediate protection to the streambanks while the plantings develop a root mass and aid in protecting against shear stress. Vegetation transplanting will not be used on the Site due to the lack of existing appropriate plant materials. The plantings will develop into mature trees that will be capable of providing the stream with shade and wildlife habitat. The streambed and point bars of the stream channel will not be matted or planted. The detailed planting plan is discussed in Section 4.2.

SECTION 4

BUFFER RESTORATION

4.0 BUFFER RESTORATION AND PRESERVATION

4.1 METHODOLOGY

The buffer along Cane Creek will be restored to a typical Piedmont mixed hardwood / floodplain forest. The riparian buffers along the reference reaches were used to help guide in the development of a planting plan. The dominant species from the canopy, understory, shrub, and herbaceous layers of each buffer reference site were identified and their landscape position noted. The planting plan is a combination of these species in accordance with their position along the streambank, within the floodplain, or the adjacent upland forest.

4.2 EXISTING CONDITIONS

The existing riparian community consists of a mixed hardwood forest in which most of the larger trees have been cut in the last couple of years leaving some areas open to dense herbaceous growth. The dominant tree species that are left include sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandiflora*), and red maple (*Acer rubrum*). A few white oaks (*Quercus alba*), northern red oak (*Quercus rubra*), slippery elm (*Ulmus rubra*), persimmon (*Diospyros virginiana*), and green ash (*Fraxinus pennsylvanica*) can also be found along the stream. Under story species include ironwood (*Carpinus caroliniana*) and eastern red cedar (*Juniperous virginiana*). Herbaceous species that have come in with the opening of the forest include wingstem (*Verbesina alterniflora*), ironweed (*Vernonia noveboracensis*), dog fennel (*Anthemis* spp.), ragweed (*Ambrosia* spp.), and microstegium (*Microstegium vimineum*). Cardinal flower (*Lobelia cardinalis*) and false nettle (*Boehmeria cylindrica*) were observed along the stream banks in a few areas.

4.3 BUFFER REFERENCE REACHES

Once the existing conditions of the site had been assessed, appropriate buffer reference reaches were located. The stream reference reaches had suitable buffer communities that could also be used as buffer reference reaches. Information was collected from these buffer reference reaches as to the type of forest community and vegetation present. This information was used as guidance for the planting plan. Exhibit 4.3.1 shows the buffer reference reaches.

4.3.1 UT to Cane Creek

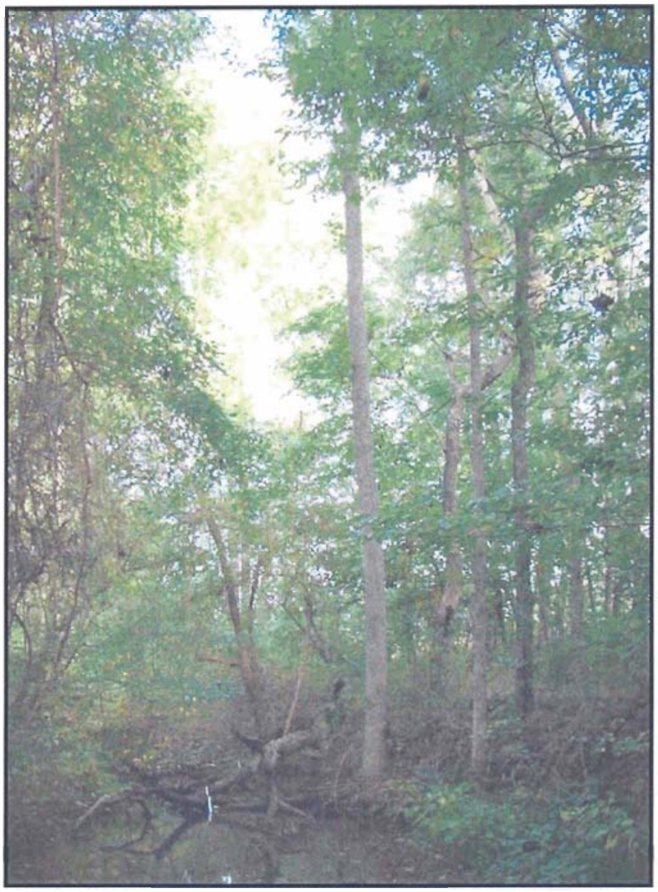
Just downstream of the project reach, the riparian forest remains intact. The dominant plant species within the riparian buffer were noted for comparison with the other reference sites in developing the planting plan. The dominant tree species along the stream include white (Quercus alba), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), sweetgum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*). The understory includes canopy species plus ironwood (*Carpinus carolineana*) and flowering dogwood (*Cornus florida*). Highbush blueberry (*Vaccinium corymbosum*) and witch hazel (*Hamamelis virginiana*) were found in the shrub layer. The sparse herbaceous species included Christmas fern (*Polystichum acrostichoides*).

Exhibit 4.3.1a Buffer Reference Reaches

Cane Creek Buffer

UT to Cabin Branch Buffer

Exhibit 4.3.1b Buffer Reference Reaches



Landrum Creek Buffer

4.3.2 UT to Cabin Branch

The riparian buffer consists of a well-developed Piedmont hardwood forest as defined by Schafale and Weakley (1990). The canopy is dominated by mature yellow poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), white oak (*Quercus alba*), green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and mockernut hickory (*Carya tomentosa*). The understory consisted of the above species as well as sourwood (*Oxydendrum arboreum*), flowering dogwood (*Cornus florida*), and ironwood (*Carpinus carolineana*). The shrub layer contained tag alder (*Alnus serrulata*), silky dogwood (*Cornus amonum*), highbush blueberry (*Vaccinium corymbosum*), elderberry (*Sambucus canadensis*), and witch hazel (*Hamamelis virginiana*). Herbaceous species included Christmas fern (*Polystichum acrostichoides*), Asiatic dayflower (*Commelina communis*), clearweed (*Pilea pumila*), jewelweed (*Impatiens capensis*), and panic grass (*Panicum* spp.). The reference buffer is good example of an upland riparian zone in the Central Piedmont. The degree of underlying rock and other features of the reference reach are very similar to the riparian conditions at the Cane Creek site.

4.3.3 Landrum Creek

A typical Piedmont mixed hardwood forest comprises most of the riparian zone along the reference reach. A fenced pasture is located 20 to 60 feet off the stream channel on the north side. The forest on the south side has been partially cleared and has a dense herbaceous coverage. Vegetation along the banks and bankfull benches of the stream are dominated by clearweed (*Pilea pumila*), false nettle (*Boehmeria cylindrica*), jewelweed (*Impatiens capensis*), and Polygonum species (*P. sagittatum*, tearthumb, and *P. persicaria*). Cardinal flower (*Lobelia cardinalis*) and Asiatic dayflower (*Commelina communis*) were also observed. The forest vegetation between the stream channel and the pasture on the north side consisted of the following canopy trees: swamp chestnut oak (*Quercus michauxii*), chestnut oak (*Quercus prinus*), willow oak (*Quercus phellous*), white oak (*Quercus alba*), northern red oak (*Quercus rubra*), American elm (*Ulmus americana*), American sycamore (*Platanus occidentalis*), yellow poplar (*Liriodendron tulipifera*), green ash (*Fraxinus pennsylvanica*), sweetgum (*Liquidambar styraciflua*), box elder (*Acer negundo*), pignut hickory (*Carya glabra*), and hackberry (*Celtis occidentalis*). The understory contained many of the canopy species along with ironwood (*Carpinus caroliniana*), dogwood (*Cornus florida*), and redbud (*Cercis canadensis*). The shrub layer consists of scattered spicebush (*Lindera benzoin*), buckeye (*Aesculus pavia*), and small thickets of multilora rose. The vines and sparse herbaceous cover contained Christmas fern, (*Polystichum acrostichoides*), microstegium spp., poison ivy (*Rhus radicans*), greenbriar (*Smilax* spp.), and muscadine grape (*Vitis rotundifolia*). The cleared forest area south of the stream channel is dominated by herbaceous species such polygonum spp., microstegium spp., wingstem (*Actinomeris alternifolia*), large-flowered leaf cup (*Polymnia uvedalia*), and various grasses such as bottle-brush grass (*Hystrix patula*).

The riparian forest on the north side of Landrum Creek is more of typical Piedmont floodplain forest with somewhat "wetter" species than was found along the UT to Cabin Branch. Therefore, the Landrum Creek buffer provides a good reference for the floodplain forest in the planting plan.

4.4 PLANTING PLAN

The planting plan is divided into three zones. Zone 1 is along the streambanks and Zone 2 is the floodplain. Zone 3 is the upland area outside the floodplain. Exhibit 4.4.1 shows the planting plan as it will be implemented along the channel.

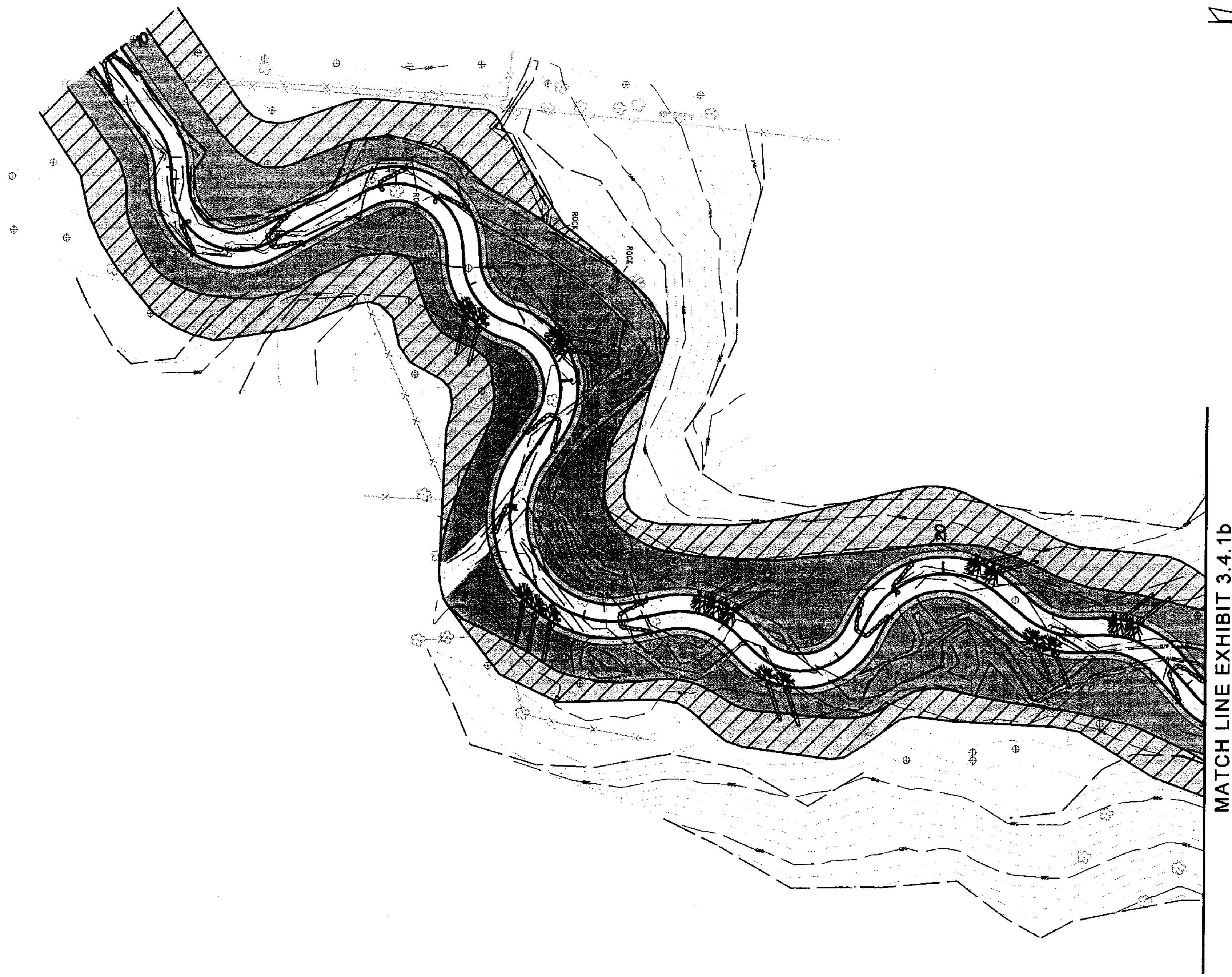
Zone 1 consists of a mix of fast growing woody shrubs that will quickly stabilize the streambanks and begin to provide some shade to the stream. These shrubs may include silky dogwood (*Cornus amonum*), tag alder (*Alnus serrulata*), Virginia willow (*Itea virginica*), silky willow (*Salix sericea*), and buttonbush (*Cephalanthus occidentalis*).

Zone 2 will be planted with a mix of tree species that will provide future shading for the stream as well as food, cover, and habitat for wildlife species. Zone 2 may include river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), American sycamore (*Platanus* occidentalis), willow oak (*Quercus phellos*), and overcup oak (*Quercus lyrata*). Zone 2 may also be enhanced by typical floodplain shrubs such as elderberry (*Sambucus canadensis*), red chokeberry (*Aronia arbutifolia*), doghobble (*Leucothoe axillaris*), inkberry (*Ilex glabra*), and male-berry (*Lyonia ligustrina*).

Zone 3 will consist of disturbed upland areas outside the floodplain. Trees and shrubs that may be planted in this zone include American elm (*Ulmus americana*), American holly (*Ilex opaca*), white oak (*Quercus alba*), chestnut oak (*Quercus prinus*), winterberry (*Ilex verticillata*), highbush blueberry (*Vaccinium corymbosum*), rhododendron (*Rhododendron* spp.), and beautyberry (*Callicarpa americana*).

Table 4.4.1 Planting Plan Summary Table

ZONE 1: STREAMBANK	
SHRUBS	**TREES**
Silky dogwood (*Cornus amonum*)	---
Tag alder (*Alnus serrulata*)	---
Virginia willow (*Itea virginica*)	---
Silky willow (*Salix sericea*)	---
Buttonbush (*Cephalanthus occidentalis*)	---
ZONE 2: FLOODPLAIN FOREST	
SHRUBS	**TREES**
Elderberry (*Sambucus Canadensis*	River birch (*Betula nigra*)
Red chokeberry (*Aronia arbutifolia*	Green ash (*Fraxinus pennsylvanica*)
Doghobble (*Leucothoe axillaries*	American sycamore (*Platanus occidentalis*)
Inkberry (*Ilex glabra*),	Willow oak (*Quercus phellos*)
Male-berry (*Lyonia ligustrina*)	Overcup oak (*Quercus lyrata*)
ZONE 3: UPLAND FOREST	
SHRUBS	**TREES**
Winterberry (*Ilex verticillata*)	American elm (*Ulmus americana*),
Highbush blueberry (*Vaccinium corymbosum*)	American holly (*Ilex opaca*)
Rhododendron (*Rhododendron* spp.)	White oak (*Quercus alba*)
Beautyberry (*Callicarpa americana*).	Chestnut oak (*Quercus prinus*)



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LEGEND

ZONE 1		STREAMBANK
ZONE 2		FLOODPLAIN FOREST
ZONE 3		UPLAND FOREST

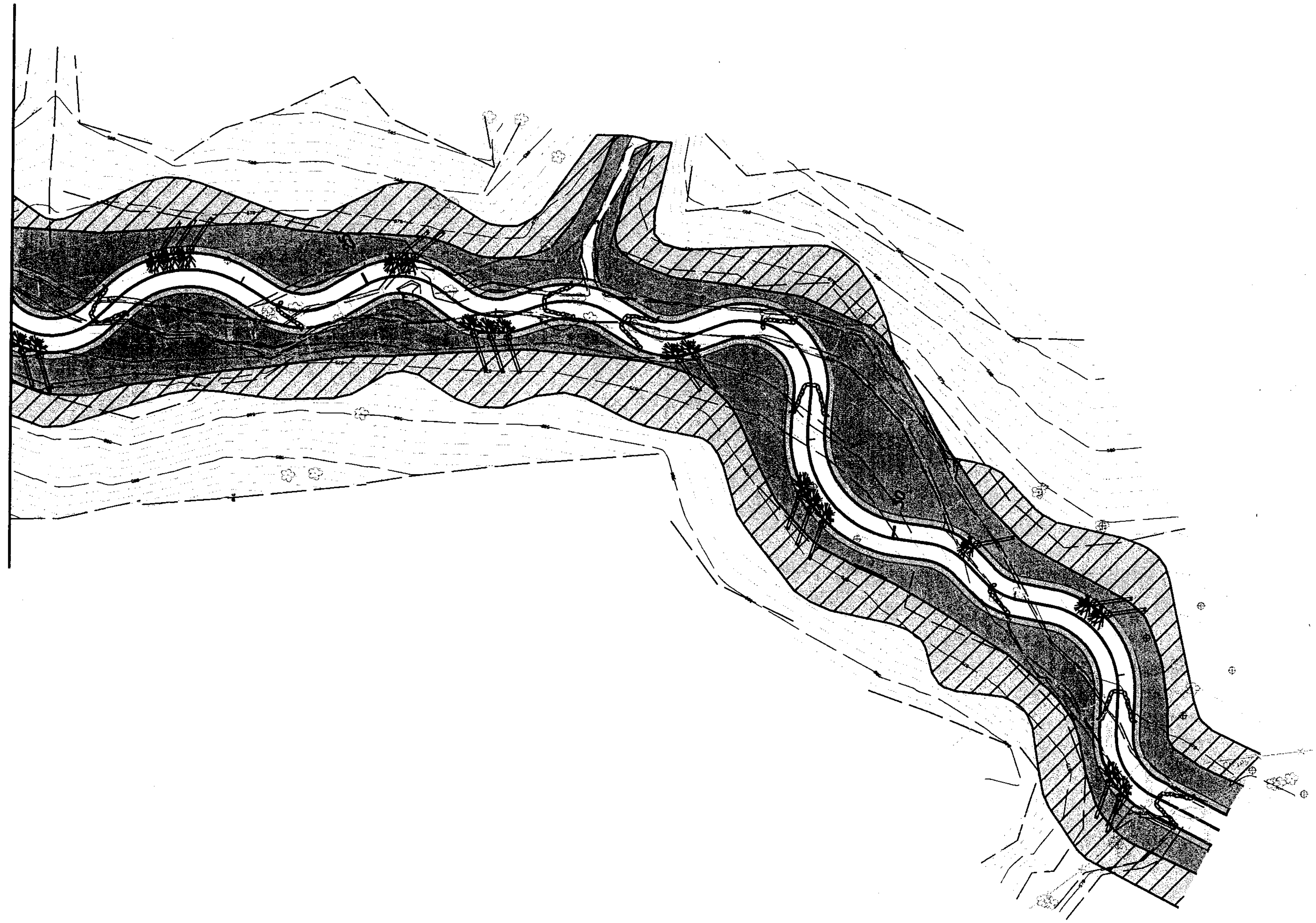
UT to Cane Creek

Restoration Plan
Mcpherson Property
Alamance County, North Carolina

Planting Plan

Scale: 1" = 100'

Exhibit 4.4.1a



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Tel. 919.851.6866
Fax. 919.851.7024
www.stantec.com

LEGEND

ZONE 1		STREAMBANK
ZONE 2		FLOODPLAIN FOREST
ZONE 3		UPLAND FOREST

Scale: 1″ = 100′

UT to Cane Creek

Restoration Plan
McPherson Property
Alamance County, North Carolina

Planting Plan

Exhibit 4.4.1b

SECTION 5

MONITORING

5.0 <u>MONITORING</u>

5.1 STREAM CHANNEL AND VEGETATION

The stability of the stream channel will be monitored according to current regulatory guidelines.

SECTION 6

SUMMARY

6.0 SUMMARY

Restoration and preservation of the environment leads to many benefits and improvements to the communities that depend upon it. Restoration of a stream and its associated buffer helps to restore a degraded system to its stable state or a state that mimics the conditions prior to anthropogenic influences. Preservation of the existing buffer ensures the continued existence of the ecosystem and acts as a wildlife corridor.

The Unnamed Tributary (UT) to Cane Creek Restoration Site on the McPherson properties in Alamance County provides opportunities for stream restoration and buffer restoration. The following table summarizes acreages and footages for the site.

COMPONENT	BEFORE RESTORATION	AFTER RESTORATION
Stream (feet)	2301	2330
Riparian Buffer (acres)	NA	5.4

This site consists of a channel that is classified as a C4, which is not entrenched. However, due to agricultural development within its watershed, the channel has become unstable, downcut to bedrock, and is now overwidening. Restoration of this channel to a stable C type stream will help to improve biological integrity of the system, reduce energy of the stream, reduce erosion, and increase habitat. The existing buffer consists of a disturbed and cutover Piedmont Mesic Mixed Hardwood Forest. Restoration and preservation of the riparian buffer along the stream will help to improve aquatic and terrestrial habitats.

The restoration site on the McPherson properties provides an excellent opportunity for restoration of the stream and buffer. Restoring stream and buffer functions at this site will:

1) Improve floodwater levels;
2) Improve water quality;
3) Increase aquatic and terrestrial habitat and diversity;
4) Provide stream geomorphologic restoration opportunities;
5) Improve the biological integrity of the system;
6) Reduce the amount of sediment and pollutants entering the stream; and
7) Provide landscape continuity.

Overall, the site will provide a variety of habitats from aquatic to uplands. The site will greatly increase the future habitat and food sources for a variety of wildlife species. Restoration of the stream channel and buffer will help improve water quality for the unnamed tributary to Cane Creek and downstream bodies of water including Cane Creek, the Haw River, and thus the Cape Fear River.

SECTION 7

REFERENCES

7.0 REFERENCES

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APPENDIX A

MAIN CHANNEL SURVEY DATA FOR EXISTING CONDITIONS

UT to Cane Creek (McPherson Upstream) Longitudinal Profile Data

Basin:	Cape Fear	**Channel Slope:**	0.26 %	**Meander Length:**	217.5 ft
Reach:	UT to Cane Creek (McPherson Upstream)	**Stream Length:**	2362 ft	**Belt Width:**	62.5 ft
Observers:	KMM, PBC, JRR, SNR	**Valley Length:**	2057 ft	**Radius of Curvature:**	18.6114 ft
Channel Type:	C4	**Sinousity:**	1.15		
Drainage Area (sq mi):	2.99				

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank (LT)	Top of Bank (RT)
3.0	571.30	571.50			
7.0	571.32	571.55			
17.0	571.04				
21.2	570.77	571.57			
23.6	570.66	571.57			
27.7	570.98	571.52		576.18	
33.0	570.81	571.56			
38.3	570.93	571.56			
48.3	570.77	571.57			
53.2	570.45	571.56			
58.0	570.40	571.58			
64.6	570.52	571.56			
71.0	570.85	571.56			
76.0	571.14	571.56			575.63
85.0	571.25	571.56			
91.0	571.23	571.57		576.84	
97.0	571.24	571.54			
103.3	571.38	571.55			
111.3	571.52				
119.2	571.65				
127.9	571.58				
136.0	571.73				
141.5	571.87				
144.3	571.07	571.31			
150.0	571.00	571.36			
156.0	571.09	571.32			
164.0	571.20	571.24			
167.0	571.10		6.87		
173.0	571.17	571.18			575.25
179.6	570.98	571.07			
184.8	570.33	571.08			
192.5	570.18	571.08			
203.6	570.22	571.07			
211.4	570.39	571.07			
221.4	570.57	571.08			
227.2	570.19	571.09			
232.5	570.11	571.08			
233.0	570.33		6.77		
237.2	570.04	571.08			574.06
243.0	570.29	571.05			
251.0	570.00	571.08			
259.0	570.31	571.06			
269.0	570.08	571.08			574.90
278.0	570.03	571.08			
284.7	570.11	571.08			
291.0	570.20	571.05			
303.5	570.41	571.08			
310.0	570.59	571.08			574.64
314.0	570.59	571.08			
322.0	570.73	571.08			
330.0	570.94	571.08			
335.0	570.91	571.06			
340.0	570.69	570.83			
346.3	570.46	570.67			
348.5	570.57	570.59		574.08	

UT to Cane Creek (McPherson Upstream) Cross-Section Data

Basin: Cape Fear
Reach: UT to Cane Creek (McPherson Upstream)
Observers: KMM, PBC, JRR, SNR
Channel Type: C4
Drainage Area (sq mi): 2.99

Riffle Cross-Section

Station	Elevation Streambed	Elevation Bankfull
0.0	576.06	573.39
30.0	575.00	
34.7	575.09	
48.0	574.88	
54.1	574.93	
55.1	573.61	
57.5	572.32	
60.1	571.62	
62.8	571.28	
65.3	571.21	
66.8	571.10	
70.0	571.13	
72.9	571.20	
75.8	571.39	
78.6	571.68	
81.8	575.25	
88.4	575.43	
95.0	575.89	
102.0	576.59	
108.0	577.72	

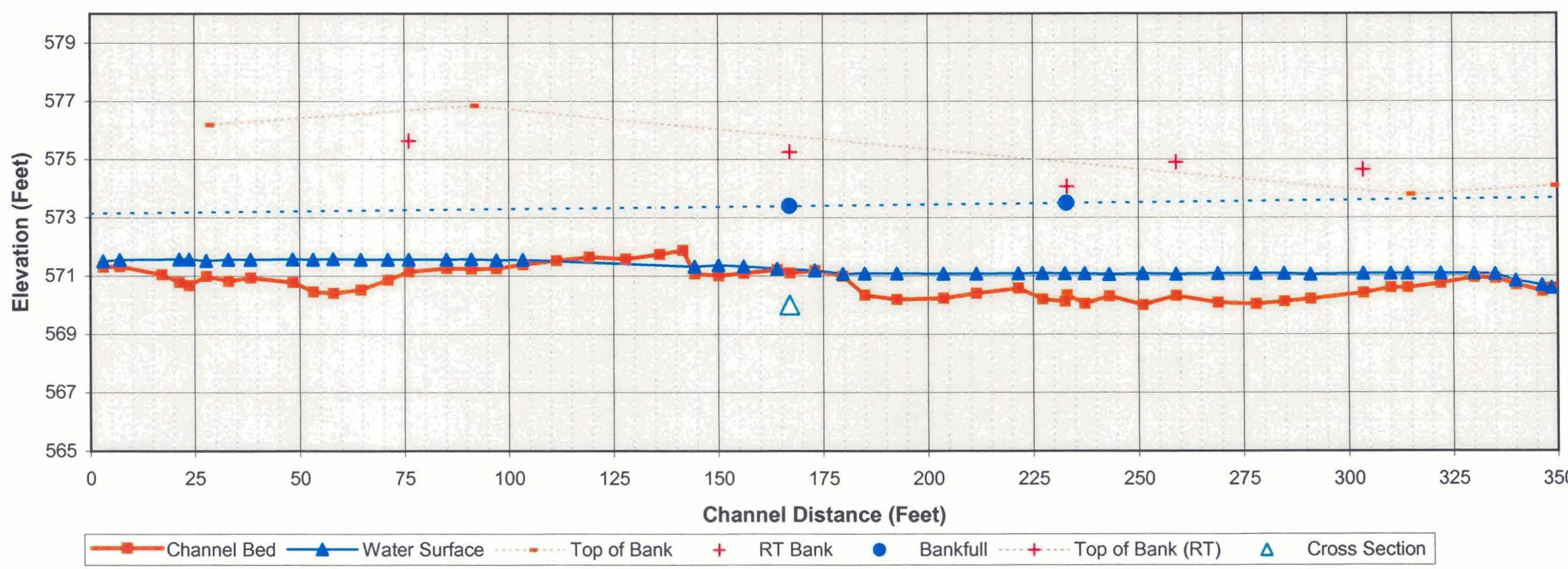
Riffle Cross-Section		
Bankfull Area	45.0	sq.ft
Bankfull Width	24.6	ft
Max depth	2.3	ft
Mean depth	1.8	ft
Width/Depth Ratio	13.5	
Flood Prone Width	76.0	ft
Entrenchment Ratio	3.1	

Pool Cross-Section

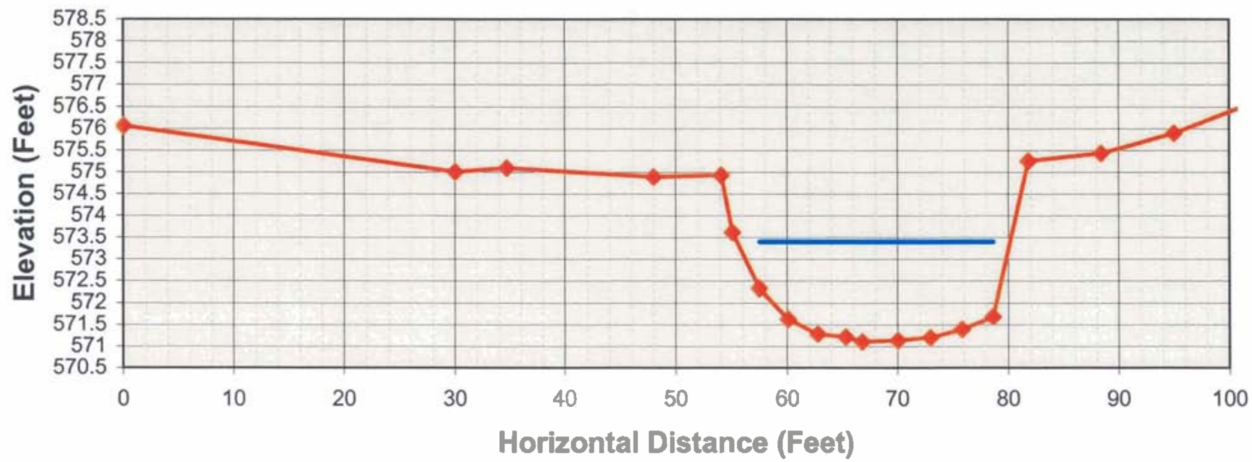
Station	Elevation Streambed	Elevation Bankfull
4.5	575.62	573.21
10.0	574.96	
15.0	574.30	
18.0	573.21	
20.0	572.18	
22.3	570.87	
25.0	570.44	
28.4	570.17	
31.5	570.09	
34.2	570.05	
36.5	570.21	
40.1	570.34	
41.6	572.24	
44.0	573.78	
47.0	574.39	
51.8	574.24	
57.4	573.65	
61.8	574.42	
66.0	574.70	
72.0	574.72	
79.0	575.04	
85.4	575.64	
88.4	576.03	

Pool Cross-Section		
Bankfull Area	61.0	sq.ft
Bankfull Width	25.1	ft
Max depth	3.2	ft
Mean depth	2.4	ft

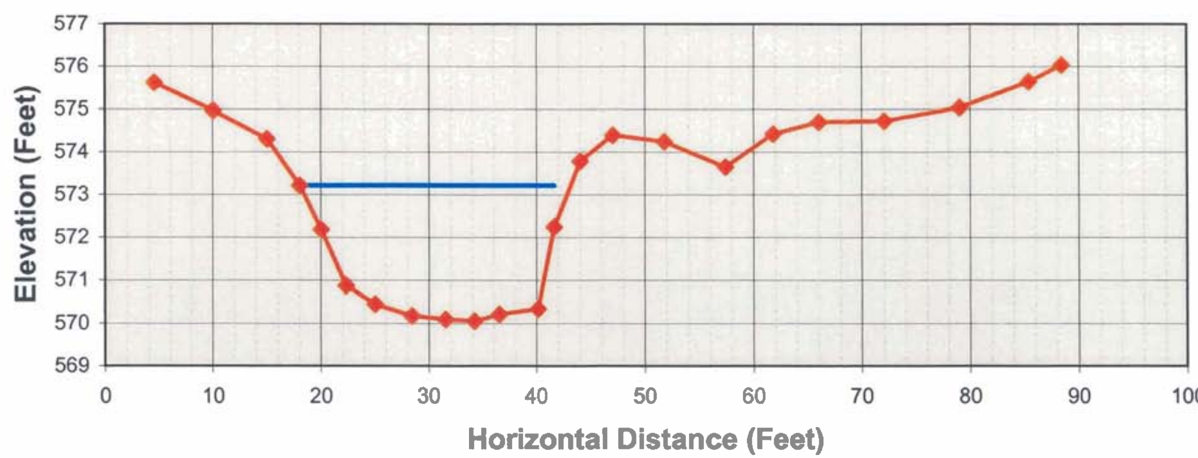
UT to Cane Creek (Upstream) Longitudinal Profile

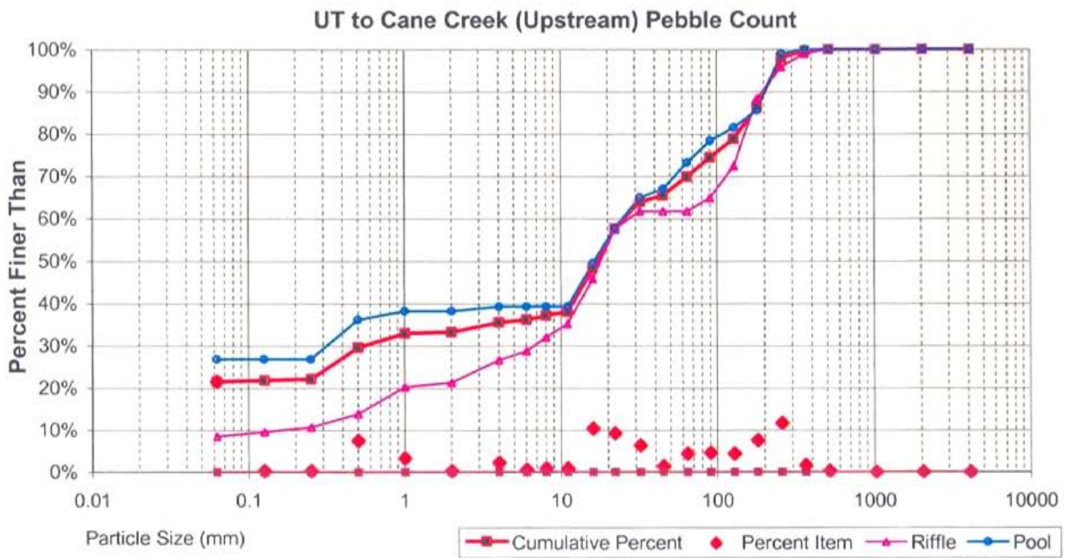


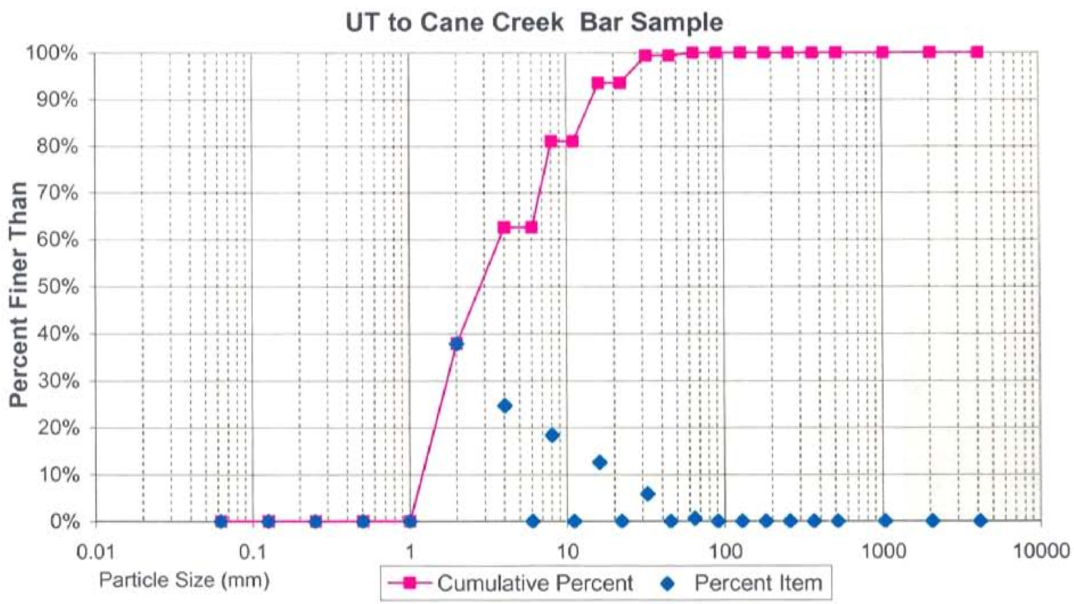
UT to Cane Creek (Upstream) Riffle Cross-Section



UT to Cane Creek (Upstream) Pool Cross-Section




UT to Cane Creek (Upstream) Pebble Count
Percent Finer Than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
Cumulative Percent
Percent Item
Riffle
Pool


UT to Cane Creek Bar Sample
Percent Finer Than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
Cumulative Percent
Percent Item

UT to Cane Creek (Downstream) Longitudinal Profile Data

Basin:	Cape Fear	**Channel Slope:**	0.56 %	**Meander Length:**	217.5 ft
Reach:	UT to Cane Creek (McPherson Downstream)	**Stream Length:**	573.5 ft	**Belt Width:**	62.5 ft
Observers:	KMM, PBC, JRR, SNR	**Valley Length:**	573.5 ft	**Radius of Curvature:**	23.6 ft
Channel Type:	C4	**Sinousity:**	1.00		
Drainage Area (sq mi):	3.13				

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank (LT)	Island	Top of Bank (RT)
6	568.75	569.24				
12	568.86	569.23				
16	569.04	569.19				
19.7	569.03	569.24				
25.4	568.76	569.23				
30.3	568.79	569.23				
35.3	568.95	569.21				
42.5	569.02	569.23				
49	569.08	569.23				
56.6	569.03	569.13				
62.9	568.97	569.07	#N/A			
66.2	568.88	568.91				
73	568.47	568.82				
77.5	568.46	568.83				
84.5	568.50	568.81				
91.2	568.60	568.67				
97.7	568.42	568.50				
101.5	567.81	568.20				
103.6	567.72	568.22				
110	568.01	568.24				
120.2	567.81	568.01				
127.6	567.52	568.03		572.24		
134	567.38	568.03		570.20		
141	567.32	567.99				
146.4	566.93	568.01				
151.5	567.06	568.01				
156.7	567.34	568.01				
162	567.43	568.02		570.52	570.44	
166.5	567.28					
172	566.94	567.99				
175	566.89	567.99				
180	566.78	568.03				
186	567.39	568.01				
191	567.24	568.01				571.39
192.8	567.32	568.02				
201	567.52	568.02				
206	567.30	568.01				
210.8	567.26	568.04				
220.4	567.12	568.02				
236	567.54	568.00		570.82		571.15
251	567.23	568.03				
260	567.26					
275	566.90	568.00				
287	566.76	567.93				
298	566.99	567.99				
300	566.93					
327	566.97	568.02				
338	566.82	568.00		570.38		
358	566.93	567.93				
374	566.66	568.01				
383	566.61	568.01				
406	566.67					
424	566.53	567.99				
439	566.08	568.00				
454	566.53	568.03				
467	567.07	567.99				
483	567.66	567.96				
502	566.87	566.90				
511.4	566.38	566.55				
517.6	566.26	566.54				
537	566.39	566.43				
551.3	565.83					
558	565.87	566.07				
573.5	565.53	566.06				

UT to Cane Creek (Downstream) Cross-Section Data

Basin:	Cape Fear	**Channel Type:**	C4
Reach:	UT to Cane Creek (McPherson Downstream)	**Drainage Area (sq mi):**	3.13
Observers:	KMM, PBC, JRR, SNR		

Riffle Cross-Section

Station	Elevation Streambed	Elevation Bankfull
4.0	572.96	567.70
7.0	572.38	
10.0	572.07	
15.0	571.50	
19.0	570.75	
21.0	569.49	
24.0	568.11	
27.0	568.25	
29.0	565.57	
31.7	565.47	
35.0	565.54	
37.5	565.42	
39.2	565.39	
42.2	565.45	
44.0	565.52	
46.7	567.11	
50.0	566.39	
52.0	566.56	
54.2	567.98	
59.5	567.33	
62.1	567.67	
65.0	568.24	
68.0	568.76	
72.0	569.51	
75.0	569.25	
78.6	569.15	
82.0	569.09	
87.6	569.12	
94.0	568.81	
98.0	568.78	
120.0	570.91	
130.0	572.53	
135.0	572.84	

Riffle Cross-Section

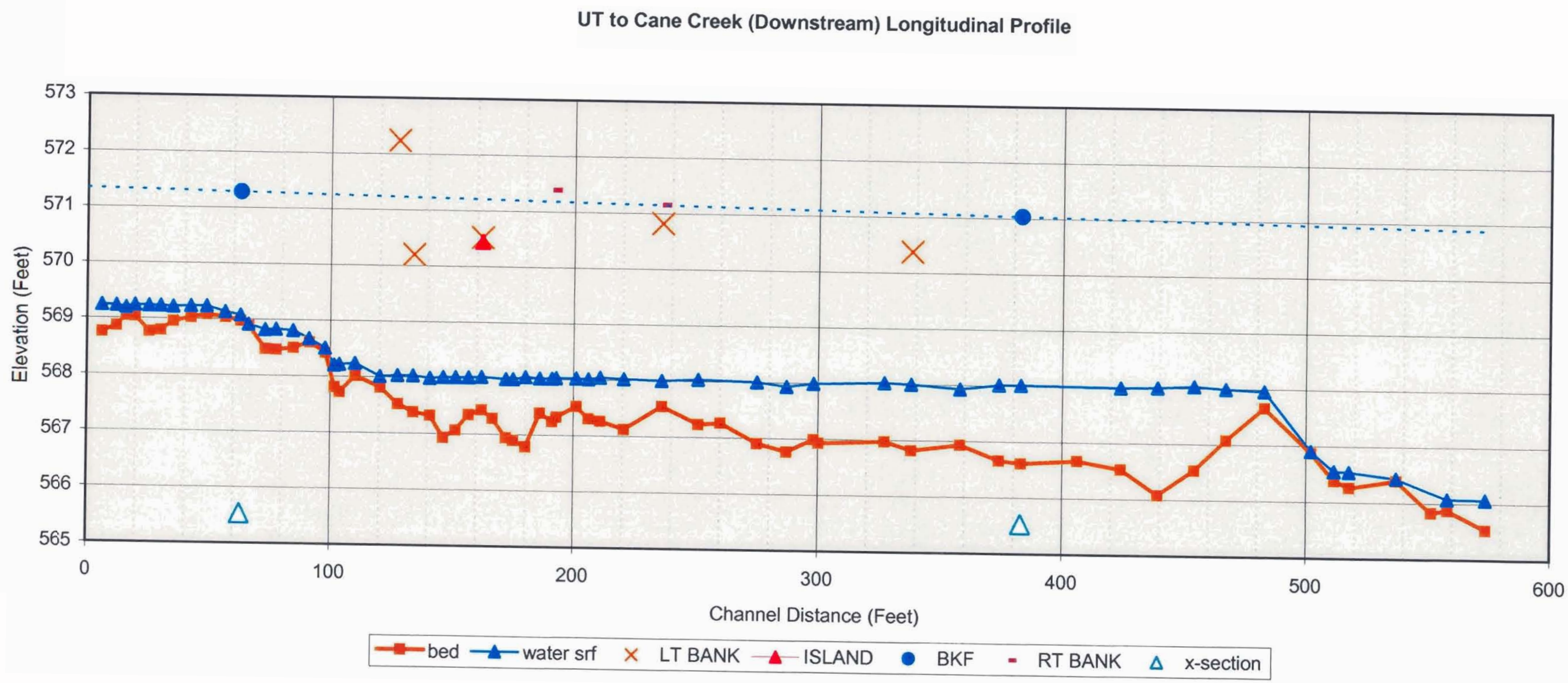
Bankfull Area	46.5 sq.ft
Bankfull Width	32.1 ft
Max depth	2.3 ft
Mean depth	1.4 ft
Width/Depth Ratio	22.2
Flood Prone Width	52.0 ft
Entrenchment Ratio	1.6

Pool Cross-Section

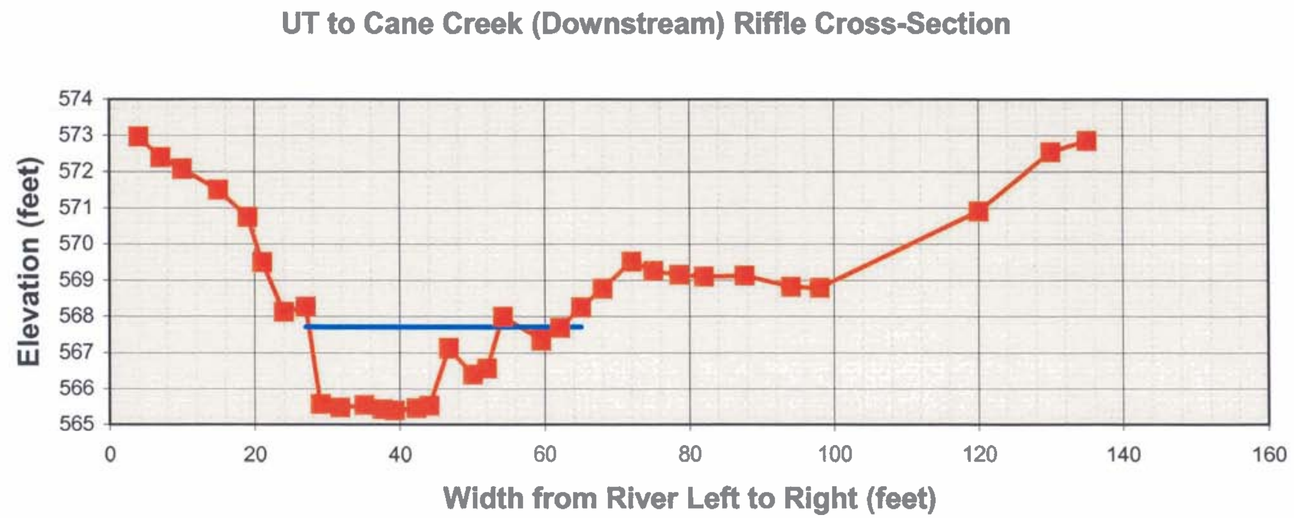
Station	Elevation Streambed	Elevation Bankfull
2.0	569.73	566.91
7.2	569.14	
12.0	569.09	
20.8	568.11	
27.0	567.76	
32.0	567.82	
36.0	567.35	
41.0	566.91	
44.0	566.15	
46.2	563.43	
50.3	562.76	
53.0	562.63	
57.6	562.56	
61.0	562.57	
63.6	563.10	
65.0	566.23	
68.0	567.26	
72.0	567.92	
80.0	568.27	
84.0	568.51	
90.0	568.83	
95.0	569.28	
99.0	569.83	
114.0	572.51	

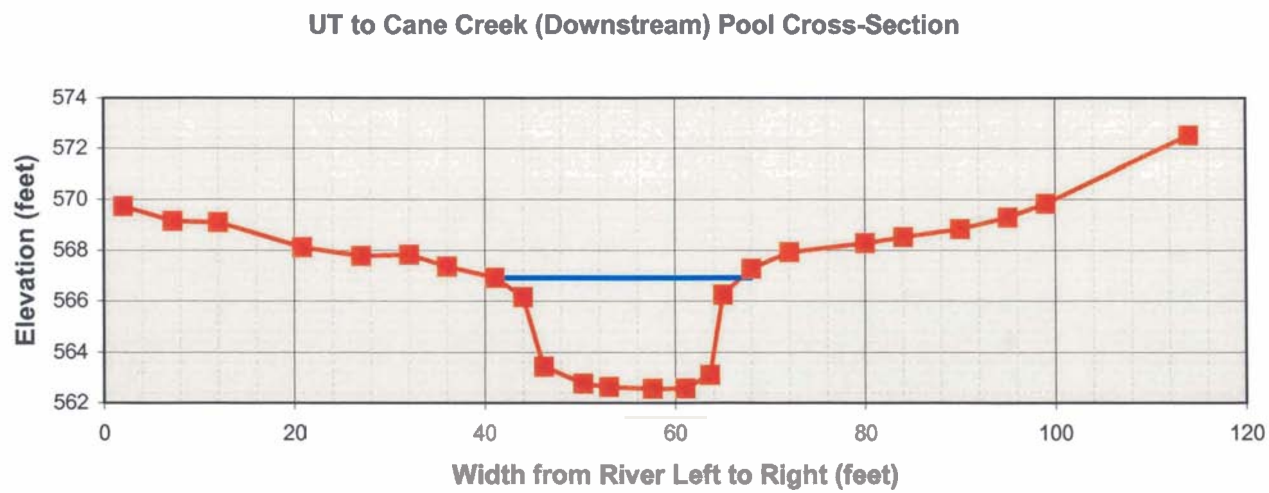
Pool Cross-Section

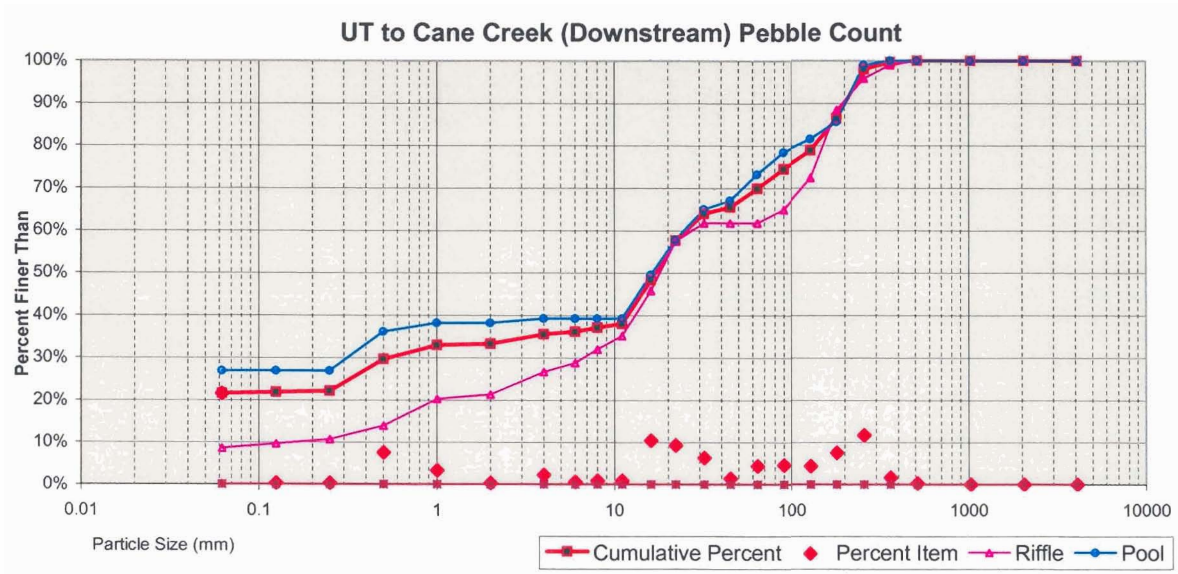
Bankfull Area	81.9 sq.ft
Bankfull Width	26.0 ft
Max depth	4.3 ft
Mean depth	3.2 ft



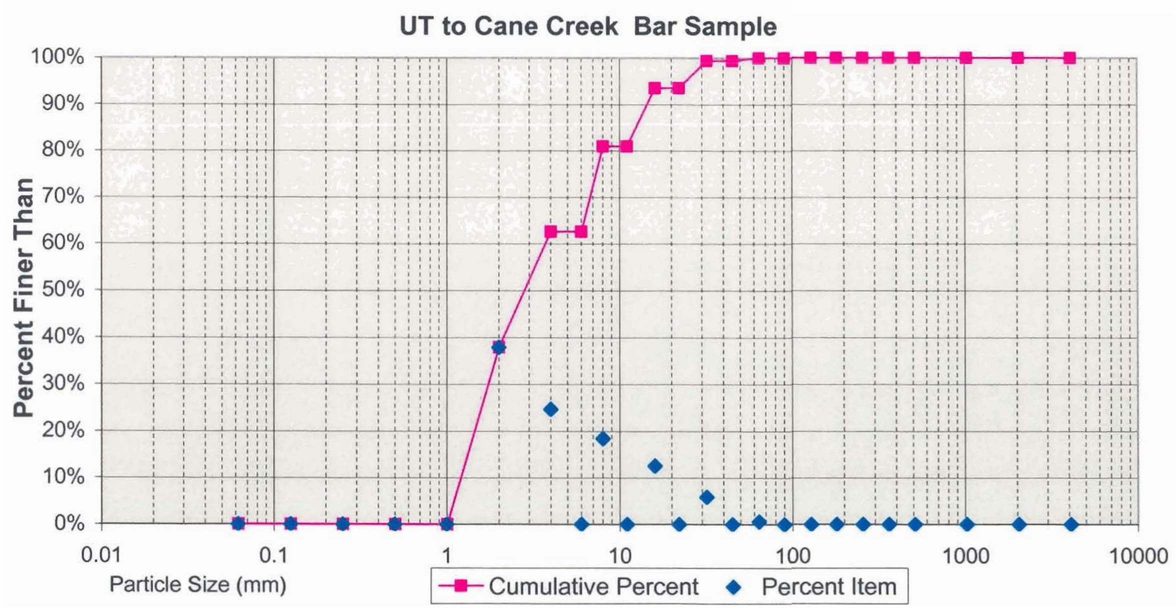
UT to Cane Creek (Downstream) Longitudinal Profile
573
572
571
570
569
568
567
566
565
Elevation (Feet)
0
100
200
300
400
500
600
Channel Distance (Feet)
bed
water srf
LT BANK
ISLAND
BKF
RT BANK
x-section


UT to Cane Creek (Downstream) Riffle Cross-Section
Elevation (feet)
574
573
572
571
570
569
568
567
566
565
0
20
40
60
80
100
120
140
160
Width from River Left to Right (feet)


UT to Cane Creek (Downstream) Pool Cross-Section
Elevation (feet)
574
572
570
568
566
564
562
0
20
40
60
80
100
120
Width from River Left to Right (feet)



UT to Cane Creek (Downstream) Pebble Count
Percent Finer Than
Particle Size (mm)
Cumulative Percent
Percent Item
Riffle
Pool



UT to Cane Creek Bar Sample
Percent Finer Than
Particle Size (mm)
Cumulative Percent
Percent Item

APPENDIX B

NCDWQ STREAM CLASSIFICATION FORMS

NCDWQ Stream Classification Form

Project Name: UT Cane Creek River Basin: Cape Fear County: Alamance Evaluator: PBC

DWQ Project Number: N/A Nearest Named Stream: Cane Creek Latitude: 35 05 52 Signature:

Date: 10/09/01 USGS QUAD: Longitude: 77 28 01

Location/Directions: Brock Property – North of NC 58, approximately 6.5 miles west of Trenton (Existing channel between Brock/Dail culvert crossing and Chinquapin Branch).

PLEASE NOTE:** ***If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used*

Primary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	1	2	3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	3
3) Are Natural Levees Present?	0	1	2	3
4) Is The Channel Sinuous?	0	1	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	2	3
6) Is The Channel Braided?	0	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	2	3
8) Is There A Bankfull Bench Present?	0	1	2	3
9) Is A Continuous Bed & Bank Present?	0	1	2	3
*(*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)*				
10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present?	*Yes=3*		*No=0*	

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: 18

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	1	2	3

PRIMARY HYDROLOGY INDICATOR POINTS: 1

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	2	1	0
2) Are Rooted Plants Present In Streambed?	3	2	1	0
3) Is Periphyton Present?	0	1	2	3
4) Are Bivalves Present?	0	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS: 3

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	0	.5	1	1.5
2) Is There A Grade Control Point In Channel?	0	.5	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	.5	1	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: 3

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaf litter Present In Streambed?	1.5	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	.5	1	1.5
3) Are Wrack Lines Present?	0	.5	1	1.5
4) Is Water In Channel *And* >48 Hrs. Since Last *Known* Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	[redacted]
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	.5	1	1.5
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes*=1.5		*No*=0

SECONDARY HYDROLOGY INDICATOR POINTS: 7

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	0	.5	1	1.5
2) Are Amphibians Present?	0	.5	1	1.5
3) Are AquaticTurtles Present?	0	.5	1	1.5
4) Are Crayfish Present?	0	.5	1	1.5
5) Are Macrobenthos Present?	0	.5	1	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	0	.5	1	1.5
7) Is Filamentous Algae Present?	0	.5	1	1.5

8) Are Wetland Plants In Streambed? N/A	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step UNLESS SAV Present*).*	2	1	.75	.5	0	0

SECONDARY BIOLOGY INDICATOR POINTS: 3.25

TOTAL POINTS (Primary + Secondary)= 35.25 *(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)*

NCDWQ Stream Classification Form

Project Name: UT to Cabin Branch Reference Reach River Basin: Neuse County: Durham Evaluator: PBC
DWQ Project Number: N/A Nearest Named Stream: Cabin Branch Latitude: 36°6' Signature:
Date: 8/6/02 USGS QUAD: NW Durham Longitude: 78°53'

Location/Directions: End of (SR 2625) Earl Road in Durham.

PLEASE NOTE:** ***If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used*

Primary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	1	2	3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	3
3) Are Natural Levees Present?	0	1	2	3
4) Is The Channel Sinuous?	0	1	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	2	3
6) Is The Channel Braided?	0	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	2	3
8) Is There A Bankfull Bench Present?	0	1	2	3
9) Is A Continuous Bed & Bank Present?	0	1	2	3
*(*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)*				
10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present?	*Yes*=3		*No*=0	

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: 19

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	1	2	3

PRIMARY HYDROLOGY INDICATOR POINTS: 2

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	2	1	0
2) Are Rooted Plants Present In Streambed?	3	2	1	0
3) Is Periphyton Present?	0	1	2	3
4) Are Bivalves Present?	0	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS: 8

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	0	.5	1	1.5
2) Is There A Grade Control Point In Channel?	0	.5	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	.5	1	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: 3.5

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaf litter Present In Streambed?	1.5	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	.5	1	1.5
3) Are Wrack Lines Present?	0	.5	1	[redacted]
4) Is Water In Channel *And* >48 Hrs. Since Last *Known* Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	1.5
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	.5	1	1.5
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes=1.5*		*No=*[redacted]

SECONDARY HYDROLOGY INDICATOR POINTS: 5.5

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	0	.5	1	1.5
2) Are Amphibians Present?	0	.5	1	[redacted]
3) Are AquaticTurtles Present?	0	.5	1	1.5
4) Are Crayfish Present?	0	.5	1	1.5
5) Are Macrobenthos Present?	0	.5	1	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	0	.5	1	1.5
7) Is Filamentous Algae Present?	0	.5	1	1.5

8) Are Wetland Plants In Streambed? N/A	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step UNLESS SAV Present*).*	2	1	.75	.5	0	0

SECONDARY BIOLOGY INDICATOR POINTS: 4.25

TOTAL POINTS **(*Primary + Secondary*)** = ***42.25*** *(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)*

NCDWQ Stream Classification Form

Project Name: Landrum Creek Reference Reach | River Basin: Cape Fear | County: Chatham | Evaluator: PBC

DWQ Project Number: N/A | Nearest Named Stream: Landrum Creek | Latitude: 35°43' | Signature:

Date: 9/30/02 | USGS QUAD: Siler City NE | Longitude: 79°21'

Location/Direction: Pleasant Hill Church Rd.

PLEASE NOTE:** ***If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used*

Primary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	1	2	3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	3
3) Are Natural Levees Present?	0	1	2	3
4) Is The Channel Sinuous?	0	1	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	2	3
6) Is The Channel Braided?	0	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	2	3
8) Is There A Bankfull Bench Present?	0	1	2	3
9) Is A Continuous Bed & Bank Present?	0	1	2	3
*(*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)*				
10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present?	*Yes*=3		*No*=0	

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: 22

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	1	2	3

PRIMARY HYDROLOGY INDICATOR POINTS: 1

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	2	1	0
2) Are Rooted Plants Present In Streambed?	3	2	1	0
3) Is Periphyton Present?	0	1	2	3
4) Are Bivalves Present?	0	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS: 7

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	0	.5	1	1.5
2) Is There A Grade Control Point In Channel?	0	.5	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	.5	1	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: 2

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaf litter Present In Streambed?	1.5	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	.5	1	1.5
3) Are Wrack Lines Present?	0	.5	1	1.5
4) Is Water In Channel *And* >48 Hrs. Since Last *Known* Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	[redacted]
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	.5	1	[redacted]
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes=1.5*		*No*=0

SECONDARY HYDROLOGY INDICATOR POINTS: 7

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	0	.5	1	1.5
2) Are Amphibians Present?	0	.5	1	1.5
3) Are AquaticTurtles Present?	0	.5	1	1.5
4) Are Crayfish Present?	0	.5	1	1.5
5) Are Macrobenthos Present?	0	.5	1	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	0	.5	1	1.5
7) Is Filamentous Algae Present?	0	.5	1	1.5

8) Are Wetland Plants In Streambed? N/A	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step UNLESS SAV Present*).*	2	1	.75	.5	0	0

SECONDARY BIOLOGY INDICATOR POINTS: 3

TOTAL POINTS (Primary + Secondary)= *42* *(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)*

APPENDIX C

SURVEY DATA FOR THE UNNAMED TRIBUTARY TO CABIN BRANCH

Unnamed Tributary to Cabin Branch Longitudinal Profile Data

Basin:	Neuse		Channel Slope:	1.49 %
Reach:	UT to Cabin Branch		Stream Length:	397 ft
Observers:	KMM, PBC, JRR, SNR		Valley Length:	330 ft
Channel Type:	C3		Sinousity:	1.20
Drainage Area (sq mi):	1.26		Meander Length:	52 ft
			Belt Width:	80 ft
			Radius of Curvature:	15.2 ft

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank (RT)	Top of Bank (LT)	Terrace
4.0	93.94					
7.0	93.46					
9.5	93.36					
10.5	93.15		94.32		94.84	95.33
11.0	93.19	93.25				
13.0	93.03	93.23				
14.0	93.08	93.23				
17.0	92.87	93.27				
19.8	92.85	93.24		94.76		95.60
23.0	92.56	93.26				
24.9	92.48	93.26				
27.5	92.57	93.27				
29.4	92.44	93.25				
31.4	92.57	93.25				
33.0	92.78	93.25		94.29		95.49
35.2	93.07	93.23				
38.0	93.01	93.22				
39.6	93.04	93.25				
42.5	92.90	93.24				
44.4	93.03	93.25				
47.0	93.24					
49.4	93.30					
52.5	92.90					
56.0	92.62	92.67				
58.7	92.57	92.58				
60.6	92.38	92.48				
64.4	92.27	92.49				
67.4	92.39	92.47		93.92		94.80
70.4	92.37	92.52				
73.7	92.31	92.46				
79.3	92.36	92.47				
82.7	92.36	92.47				
87.3	92.51					
92.8	92.66					
98.6	92.31					
104.0	91.99					
108.4	91.86					
113.5	91.75	91.85				
118.6	91.58	91.59				
125.5	91.53			94.41		94.05
130.4	91.71					
136.0	91.71					
140.8	91.31	91.45				
144.1	91.28	91.42				
147.0	91.21	91.41		93.22		94.05
149.5	91.40	91.41				
153.6	91.46					
155.5	91.71					
158.6	91.15					
160.4	90.81	90.94				
162.8	90.67	90.93				
164.6	90.49	90.91				
167.4	90.69	90.93				
171.0	90.79	90.93				
175.3	90.85	90.91				
179.4	91.03			93.47		94.06

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank (RT)	Top of Bank (LT)	Terrace
180.6	91.1					
187.7	91.1					
192.4	91.0					
197.0	90.9					
200.0	90.8	90.8				
203.9	91.0			92.6		94.1
207.1	91.1					
208.7	90.9					
210.2	90.9					
214.2	90.7					
221.0	90.6					
226.0	90.5		91.4	93.7		
237.7	90.3					
241.0	89.8	90.1				
243.4	90.0					
247.0	89.9	90.1				
249.6	89.7	90.1				
251.0	90.0	90.1				
255.2	90.0					
258.7	89.8	90.0				
263.6	90.0					
268.1	90.1					
271.2	89.8			91.3		92.8
277.0	89.9					
282.4	89.8				91.3	92.5
289.2	89.7					
296.8	89.4					
304.0	89.3					
308.0	89.1					
313.0	89.0	89.0				
319.0	89.5			92.3	90.7	91.6
320.7	89.3					
326.0	89.2					
332.0	89.1					
337.8	89.0					
343.3	89.1					
349.0	89.0					
353.0	89.1					
359.2	89.1					
364.0	88.9					
367.1	88.9					
370.8	88.8					
373.4	88.8					
374.6	88.6					
376.3	88.5					
378.0	88.4					
380.0	88.1					
383.6	87.8	88.3				
385.4	87.8	88.4				
386.7	87.7					
388.0	87.7					
390.0	87.7	88.3				
397.0	88.4					

Unnamed Tributary to Cabin Branch - Cross Section Data

Basin:	Neuse
Reach:	UT to Cabin Branch
Observers:	KMM, PBC, JRR, SNR
Channel Type:	C3
Drainage Area (sq mi):	1.26

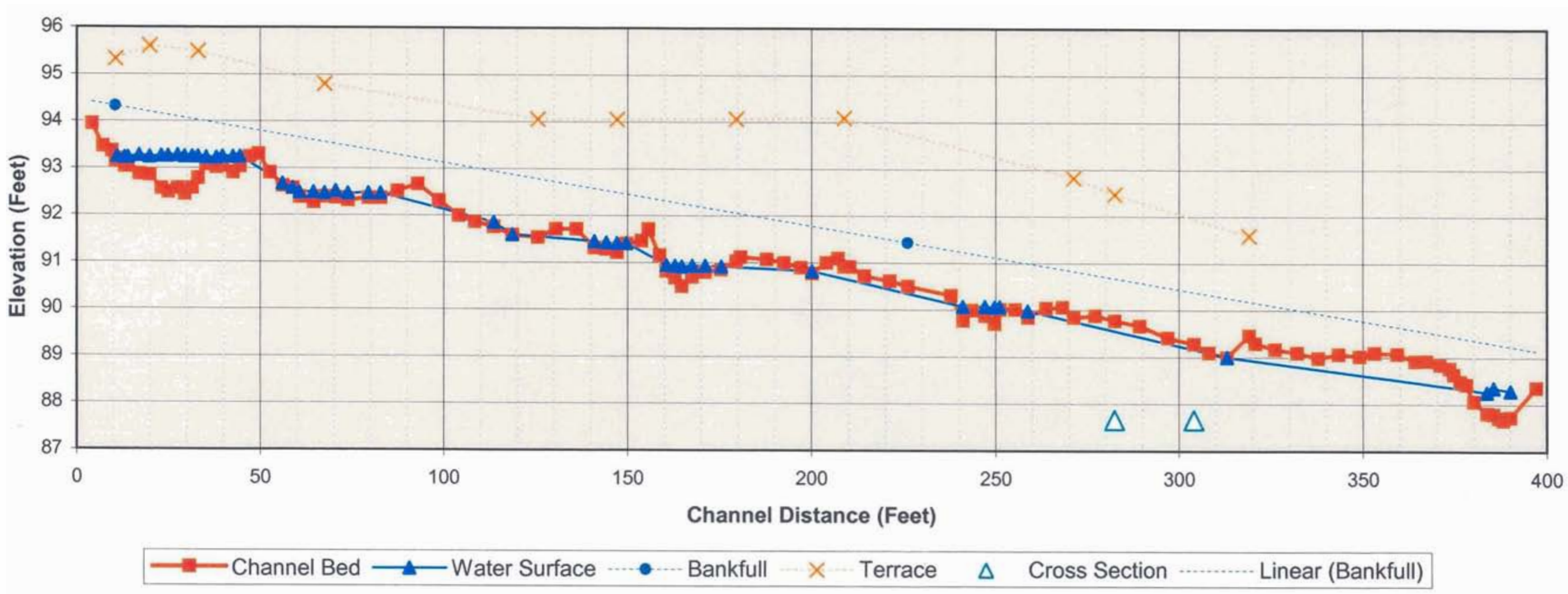
Riffle

Station	Elevation Streambed	Elevation Bankfull		
1.6	96.00	93.83		
3.0	95.86			
5.0	95.63			
6.5	95.51		Bankfull Area	21.4 sq.ft
8.5	95.21		Bankfull Width	14.3 ft
9.9	95.15		Max depth	2.2 ft
15.5	94.79		Mean depth	1.5 ft
16.8	94.65		Width/Depth Ratio	10
17.7	93.83		Flood Prone Width	47.0 ft
18.6	93.23		Entrenchment Ratio	3.3
19.3	92.97			
19.8	92.63			
20.3	92.38			
20.7	91.99			
22.3	91.94			
23.5	91.78			
24.1	91.64			
25.9	91.76			
28.4	91.77			
29.0	91.87			
29.3	92.81			
30.5	93.22			

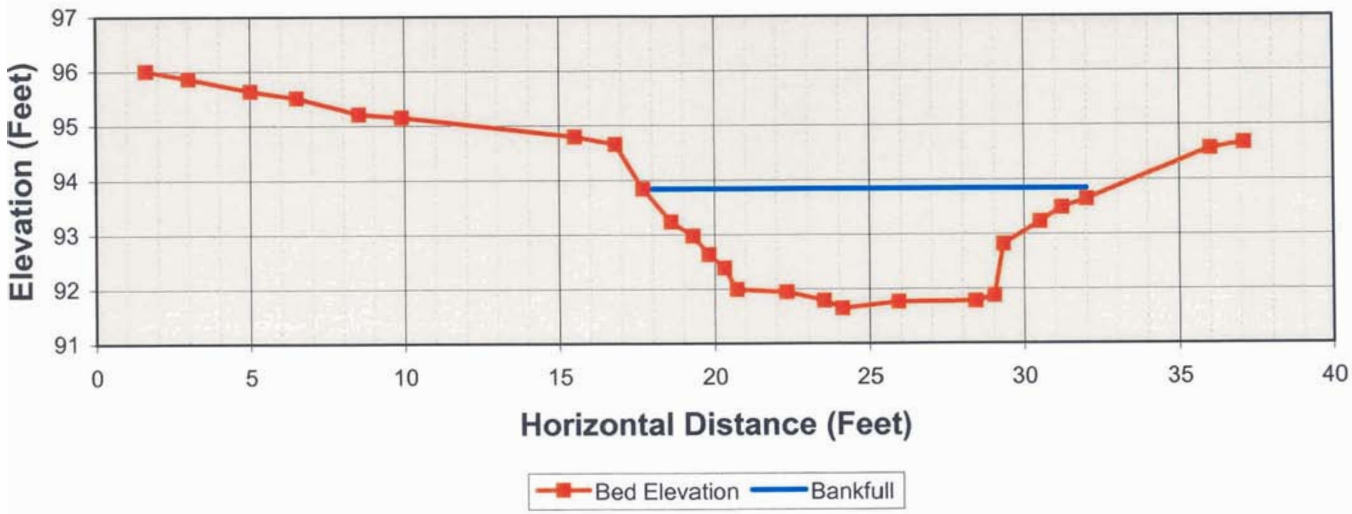
Pool

Station	Elevation Streambed	Elevation Bankfull		
2.0	95.30	93.62		
3.8	95.06		Bankfull Area	27.2 sq.ft
5.0	94.93		Bankfull Width	14.7 ft
6.5	94.97		Max depth	2.5 ft
8.6	95.08		Mean depth	1.8 ft
10.0	94.34			
11.0	93.92			
12.6	92.11			
14.0	91.45			
16.0	91.11			
17.0	91.26			
19.0	91.26			
20.5	91.37			
21.5	91.40			
22.0	91.51			
23.2	91.76			
24.0	92.29			
26.0	93.62			
28.0	94.08			
30.0	94.37			
32.0	94.47			

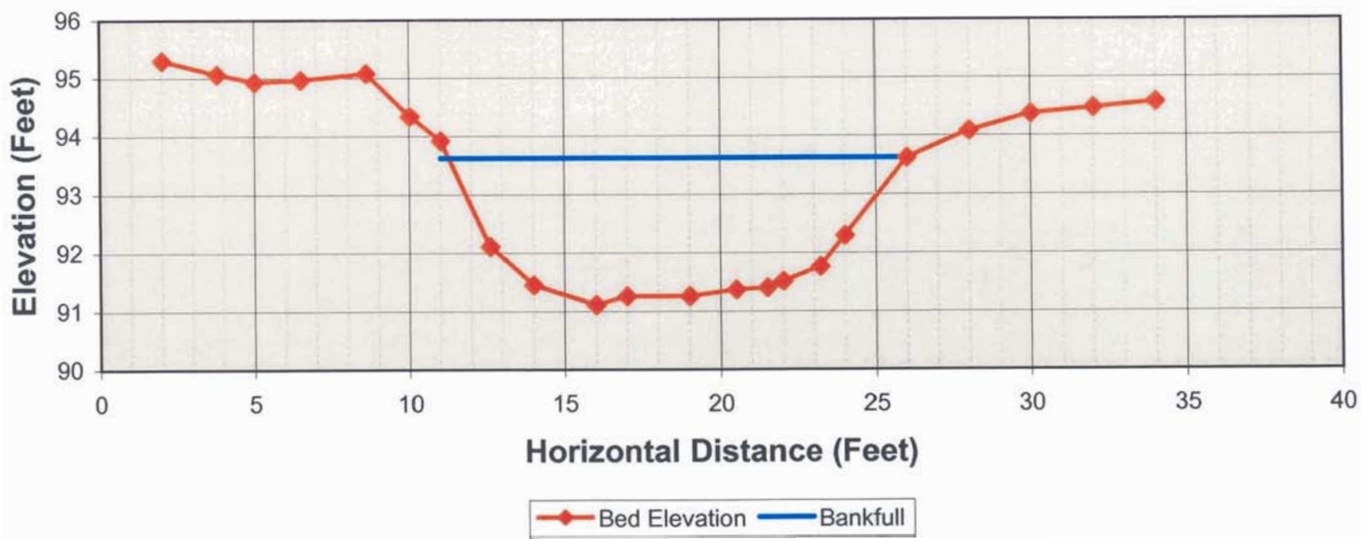
UT to Cabin Branch Longitudinal Profile



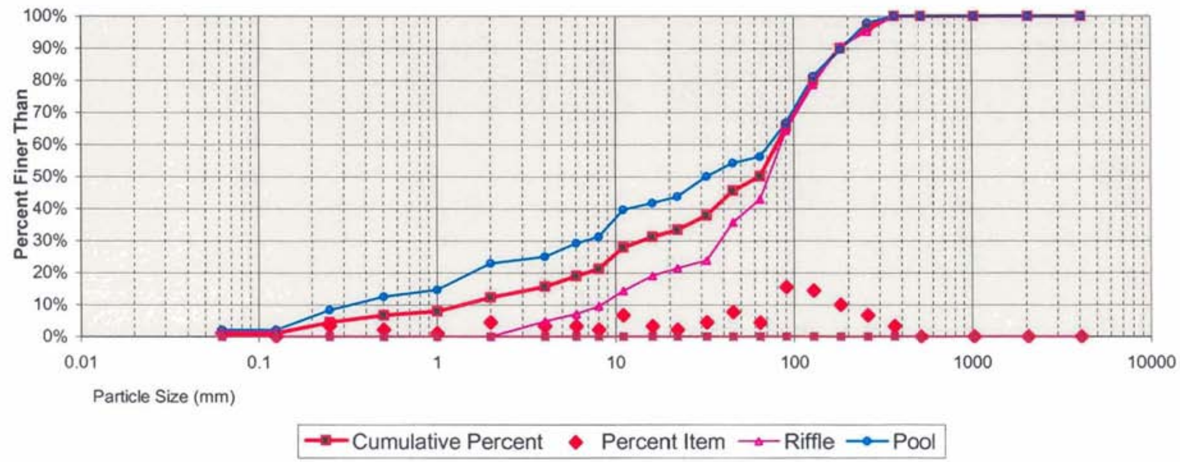
UT to Cabin Branch Riffle Cross-Section



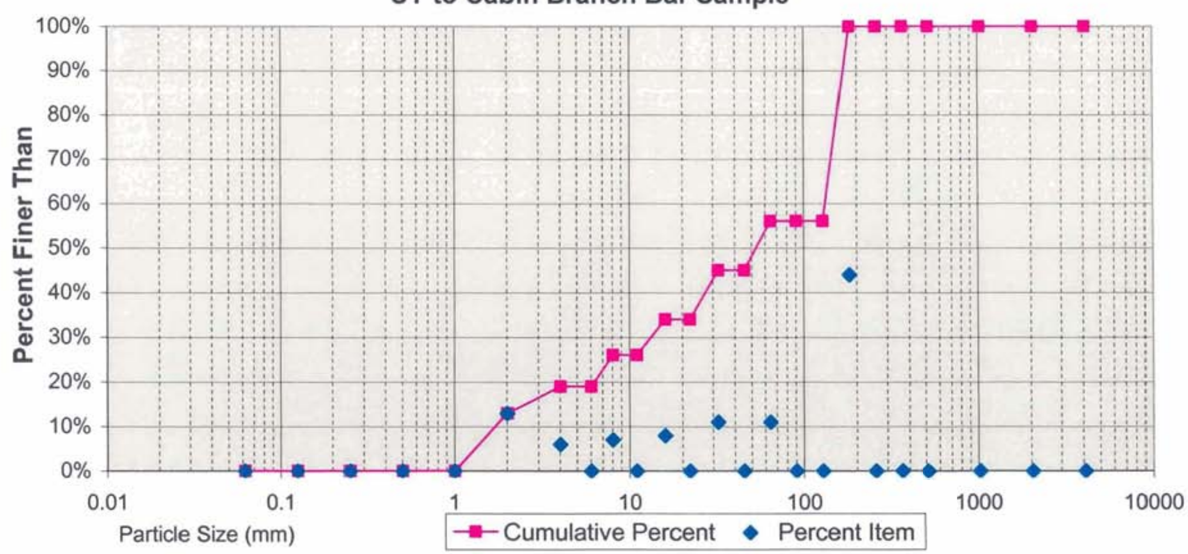
UT to Cabin Branch Pool Cross-Section



UT to Cabin Branch Pebble Count



UT to Cabin Branch Bar Sample



APPENDIX D

SURVEY DATA FOR LANDRUM CREEK

Landrum Creek Longitudinal Profile

Basin:	Cape Fear	**Channel Slope:**	0.77 %
Reach:	Landrum Creek	**Stream Length:**	369 ft
Observers:	KMM, PBC, AJT JRR	**Valley Length:**	330 ft
Channel Type:	C4	**Sinousity:**	1.12
Drainage Area (sq mi):	2.53	**Meander Length:**	NA ft
		Belt Width:	77 ft
		Radius of Curvature:	12 ft

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank	Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank
25.5	95.16	95.28			196	93.75	93.92		
29	94.85	95.30			200	93.46	93.94		
32	94.83	95.29	96.64	97.56	204.4	93.68	93.93	95.27	
35.5	94.98	95.30			207.6	93.80			
38.5	94.75	95.30			214	93.57	93.84		
41	94.78	95.29	96.46	97.18	216	93.50			
44	94.93	95.34			226	93.15	93.48		
48	94.93	95.30			234.4	92.51	93.51		
50	94.72	95.30			240	92.53	93.48		
56	95.08	95.14			243	93.01	93.49		
62.5	94.95	95.10			249	93.20	93.50		
67	94.91	95.07			257	93.25	93.47	95.16	
76	94.61	94.68		96.72	271	93.14	93.31		
85	94.37	94.61			279	93.04	93.17	94.55	
86.2	94.22	94.60			286	92.66	92.95		
91.5	94.06	94.61			292	92.57	92.97		
107	93.97	94.61			300	92.46	92.94		
117.7	94.05	94.60			313	92.25	92.96		
124.6	93.98	94.60			321	91.83			
128	94.07	94.58			326	91.66	92.96		
133.3	94.38	94.60	95.52	96.36	331	92.02	93.00		
141	94.38	94.53			336	92.25	92.94		
170.5	93.87	94.18			343	92.33			
178.3	94.13	94.32			348	92.03	92.95		
185	93.85	94.01			351	92.04	92.96		
190	93.76	93.95			357	92.40	92.94		
192.3	93.66	93.94			362	92.60	92.92		
195	93.70	93.94	95.34		363	92.64	92.95		
					369	92.78	92.93		

Landrum Creek Cross-Sectional Data

Basin: Cape Fear
Reach: Landrum Creek
Observers: KMM, PBC, AJT JRR
Channel Type: C4
Drainage Area (sq mi): 2.53

Riffle

Station	Elevation Streambed
1	99.02
3.7	98.61
8.5	98.24
12	97.93
15	97.75
18	97.51
19.5	97.64
20.8	97.28
21.8	96.55
22.8	96.18
23.5	95.58
24	95.17
26	95.07
27.3	94.95
29.5	94.89
31.2	94.86
33.4	94.8
36.5	94.61
37.4	94.51
39	94.53
40.7	94.77
41.6	96.03
42.5	96.38
44.3	96.45
45.6	96.31
47	95.99
49	96.34
52	97.78
59	97.8
76	97.9
140	98.59

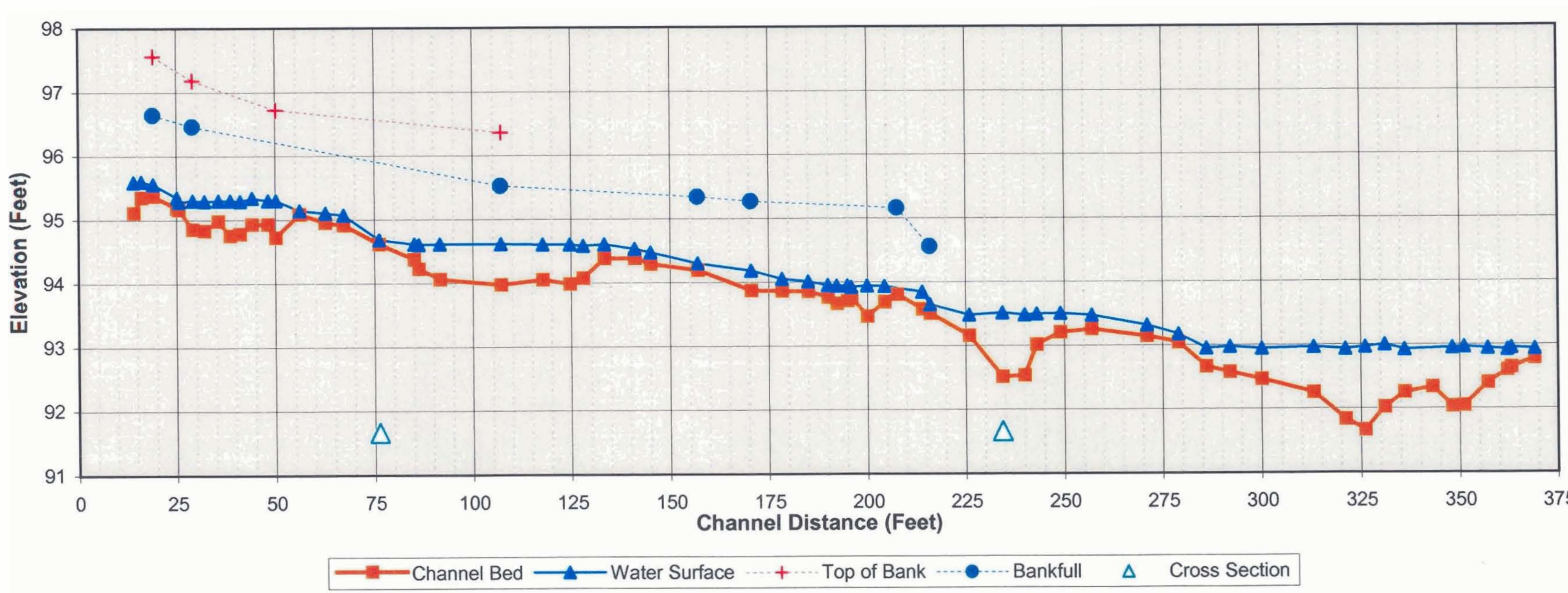
Bankfull Area	33.5	sq.ft
Bankfull Width	27.6	ft
Max depth	2.0	ft
Mean depth	1.2	ft
Width/Depth Ratio	22.8	
Flood Prone Width	140.0	ft
Entrenchment Ratio	5.1	

Pool

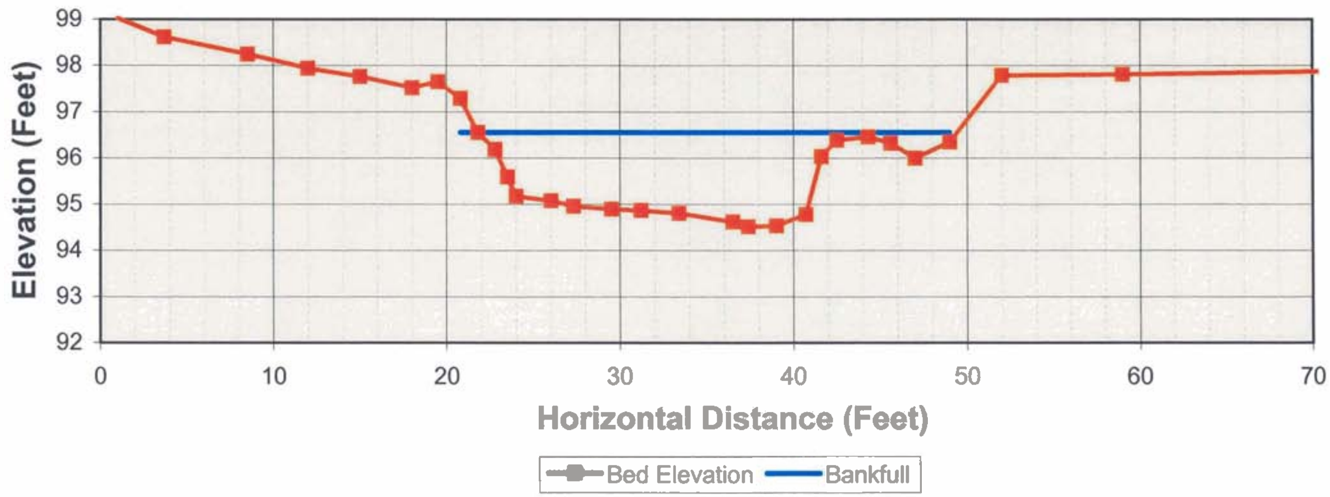
Station	Elevation Streambed
2	95.98
7	95.69
15	95.26
21	94.89
23.3	94.66
24.2	92.48
25.2	91.43
27	90.8
29	90.56
31.5	90.46
33	90.59
35	90.84
36	91.26
38.5	91.5
40.2	92.54
42	92.87
46	93.17
50	93.08
55	93.76
60	94.17
65	94.2

Bankfull Area	37.9	sq.ft
Bankfull Width	27.4	ft
Max depth	2.8	ft
Mean depth	1.4	ft

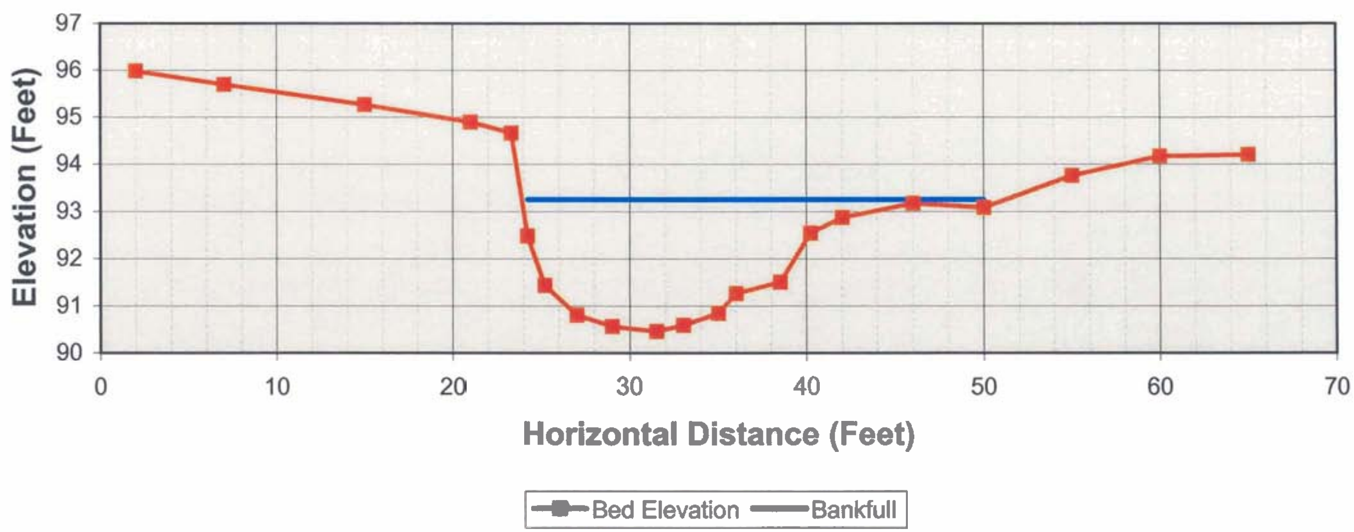
Landrum Creek Reference Reach Longitudinal Profile

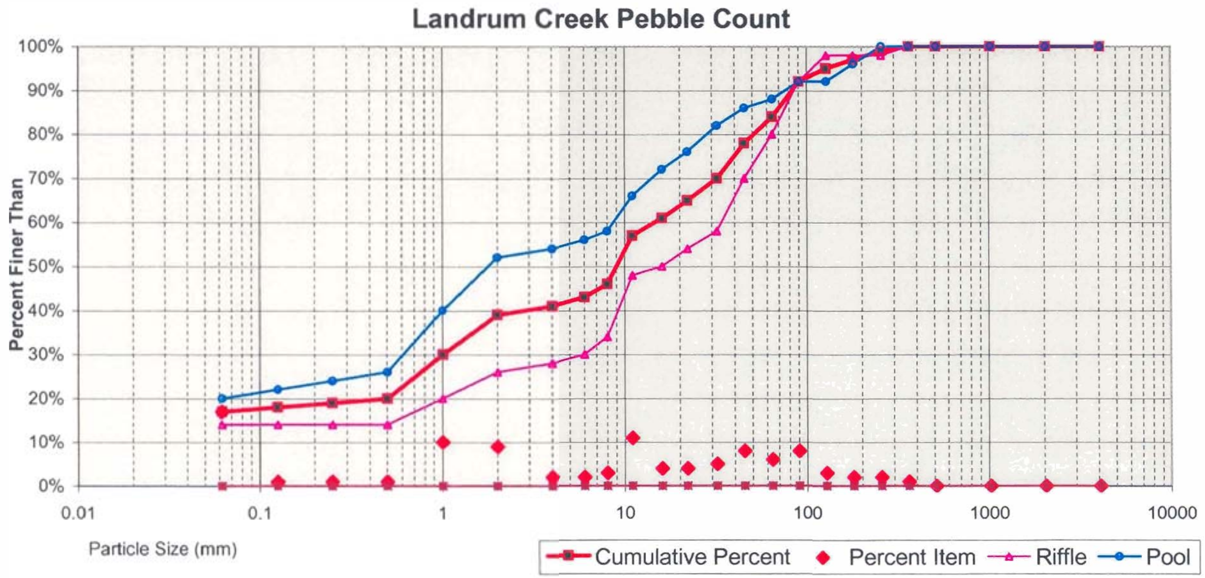


Landrum Creek Riffle Cross-Section

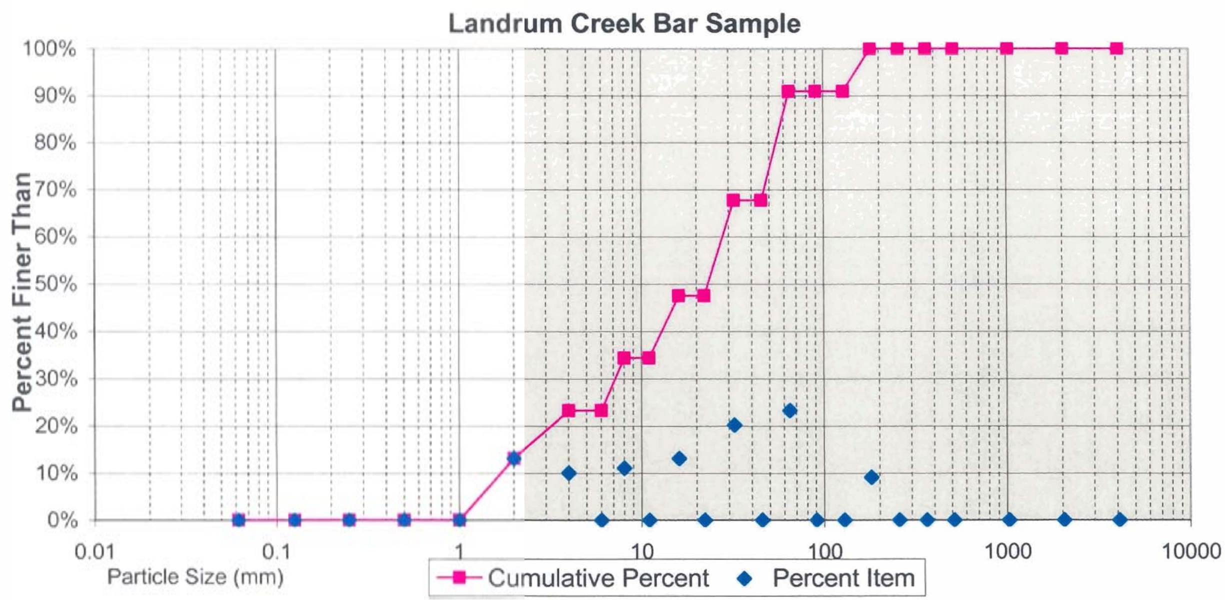


Landrum Creek Pool Cross-Section





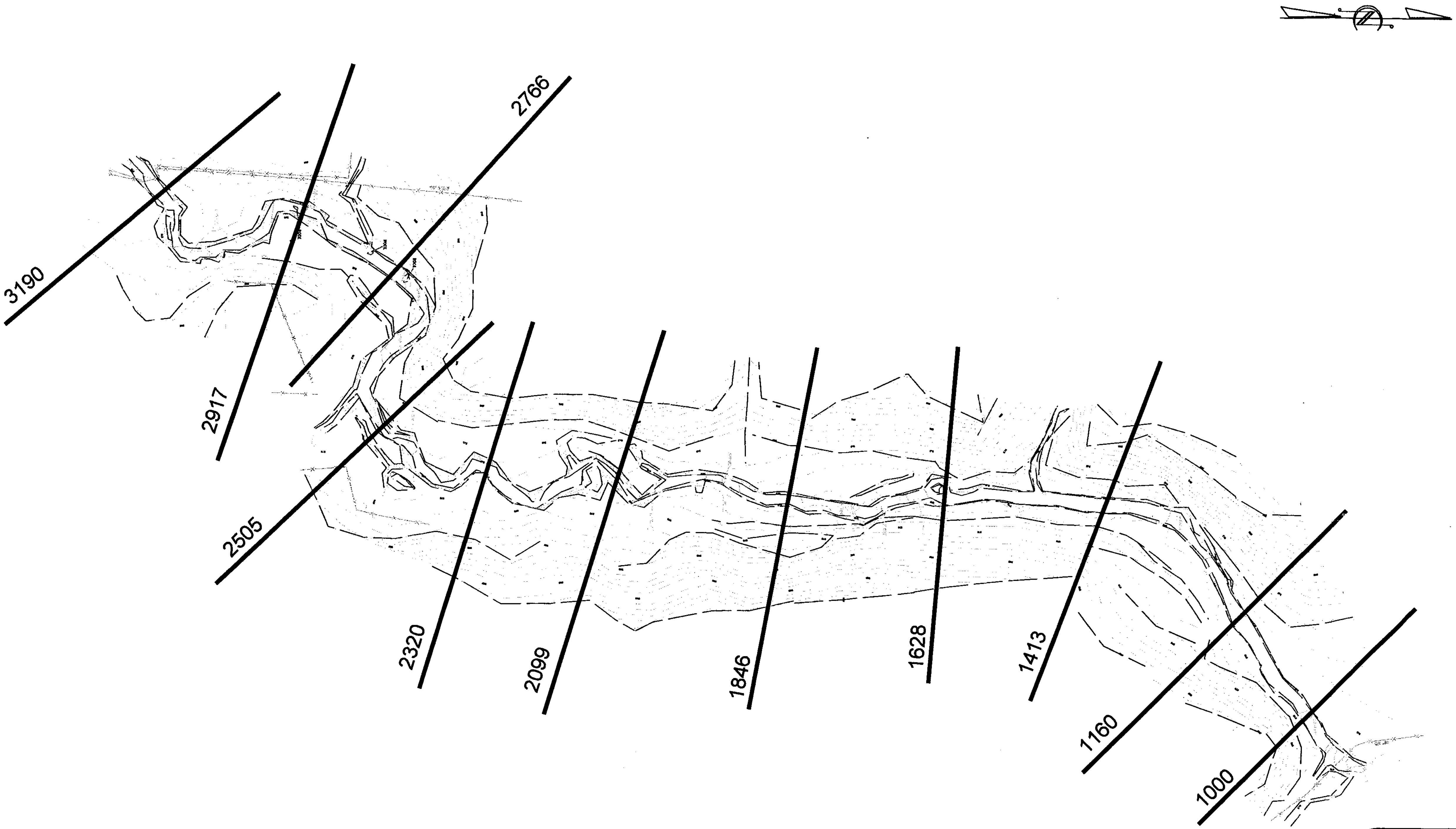
Landrum Creek Pebble Count
Percent Finer Than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
Cumulative Percent
Percent Item
Riffle
Pool



Landrum Creek Bar Sample
Percent Finer Than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
Cumulative Percent
Percent Item

APPENDIX E

HEC-RAS DATA



Stantec
Stantec Consulting Services Inc.
Suite 300, 801 Jones Franklin Road
Raleigh, NC
27606
Tel. 919.851.6866
Fax. 919.851.7024
www.stantec.com

UT to Cane Creek

Restoration Plan
McPherson Property
Alamance County, North Carolina

HEC-RAS Cross-Section Locations

Scale: 1″ = 150′

APPENDIX D
HEC-RAS ANALYSIS

STATION	STORM	DISCHARGE (cfs)	EXISTING WATER SURFACE ELEVATION (ft)	PROPOSED WATER SURFACE ELEVATION (ft)	BACKWATER (ft)
600	Bankfull	202.5	569.02	569.02	0.00
600	100-Year	1520.0	573.63	573.63	0.00
800	Bankfull	202.5	569.48	569.48	0.00
800	100-Year	1520.0	574.09	574.09	0.00
1000	Bankfull	202.5	569.94	569.94	0.00
1000	100-Year	1520.0	574.55	574.54	-0.01
1160	Bankfull	202.5	570.29	570.22	-0.07
1160	100-Year	1520.0	574.85	574.73	-0.12
1413	Bankfull	202.5	570.64	570.67	0.03
1413	100-Year	1520.0	575.44	575.28	-0.16
1628	Bankfull	202.5	571.09	571.14	0.05
1628	100-Year	1520.0	576.03	575.88	-0.15
1846	Bankfull	202.5	571.64	571.75	0.11
1846	100-Year	1520.0	576.53	576.53	0.00
2099	Bankfull	202.5	572.43	572.72	0.29
2099	100-Year	1520.0	577.16	577.16	0.00
2320	Bankfull	202.5	573.28	573.23	-0.05
2320	100-Year	1520.0	577.80	577.66	-0.14
2505	Bankfull	202.5	573.92	573.64	-0.28
2505	100-Year	1520.0	578.59	578.30	-0.29
2766	Bankfull	202.5	574.69	574.30	-0.39
2766	100-Year	1520.0	579.00	578.74	-0.26
2917	Bankfull	202.5	574.99	574.77	-0.22
2917	100-Year	1520.0	579.26	579.01	-0.25
3190	Bankfull	202.5	575.59	575.46	-0.13
3190	100-Year	1520.0	579.94	579.80	-0.14

APPENDIX F

STRUCTURES USED FOR NATURAL CHANNEL DESIGN

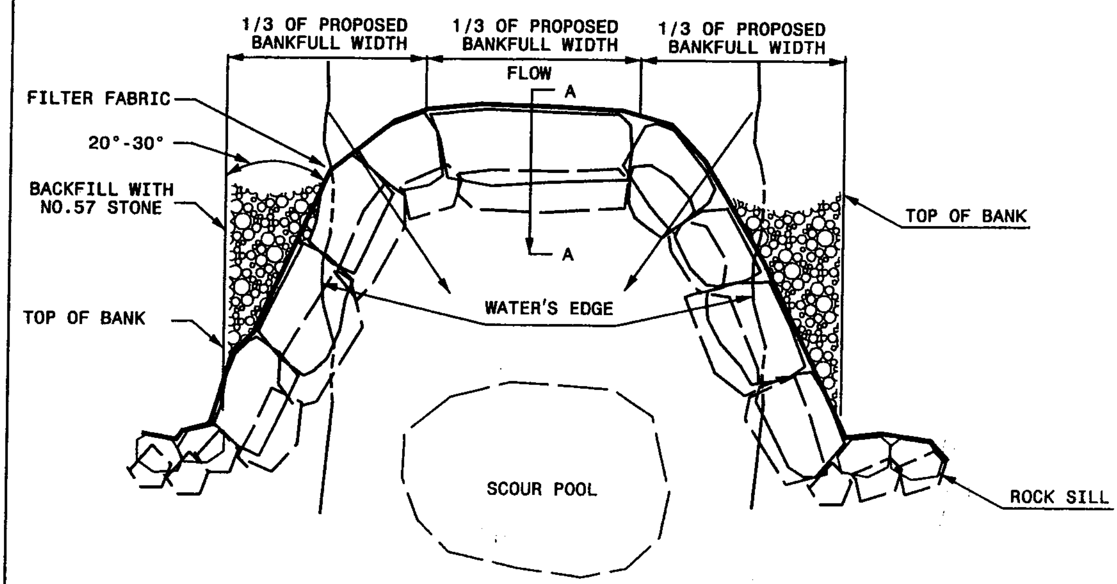
ROCK CROSS VANE

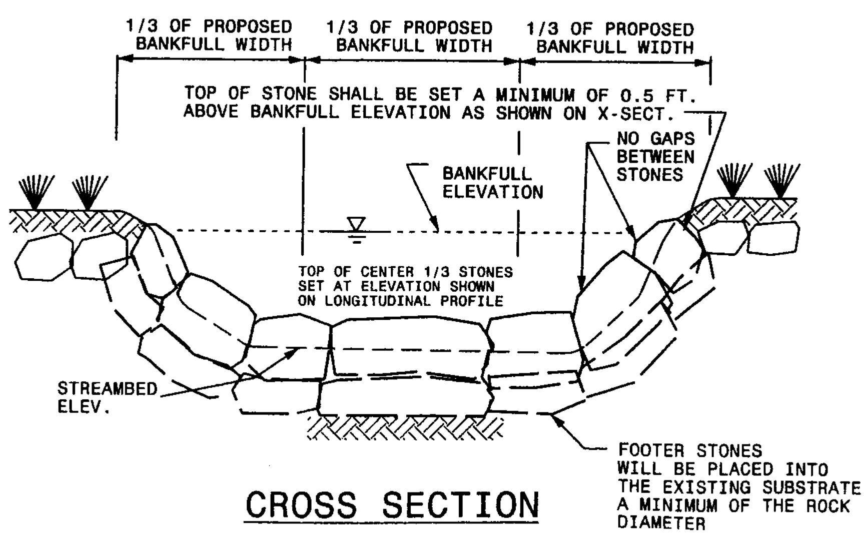
SCALE:NTS

NOTES:

1. ALL STONES ARE TO BE STRUCTURE STONE.
2. GAPS BETWEEN BOULDERS SHALL BE MINIMIZED BY FITTING BOULDERS TOGETHER, PLUGGING WITH STRUCTURE STONE CLASS A AND NO.57 AND LINING WITH FILTER FABRIC.
3. DIMENSIONS AND SLOPES MAYBE ADJUSTED TO FIT BY THE ENGINEER.
4. A DOUBLE FOOTER BOULDER SHALL BE UTILIZED IN SAND BED MATERIAL.

FILTER FABRIC SHALL BE PLACED ON THE UPSTREAM SIDE OF THE STRUCTURE TO PREVENT WASHOUT OF SEDIMENT THROUGH BOULDER GAPS. FILTER FABRIC SHALL EXTEND FROM THE BOTTOM OF THE FOOTER BOULDER TO THE FINISHED GRADE ELEVATION AND SHALL BE PLACED THE ENTIRE LENGTH OF STRUCTURE.

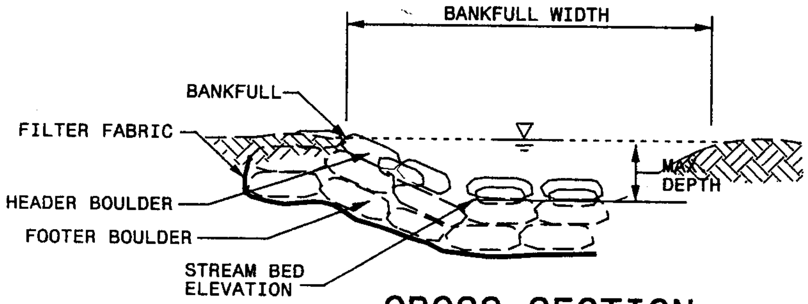




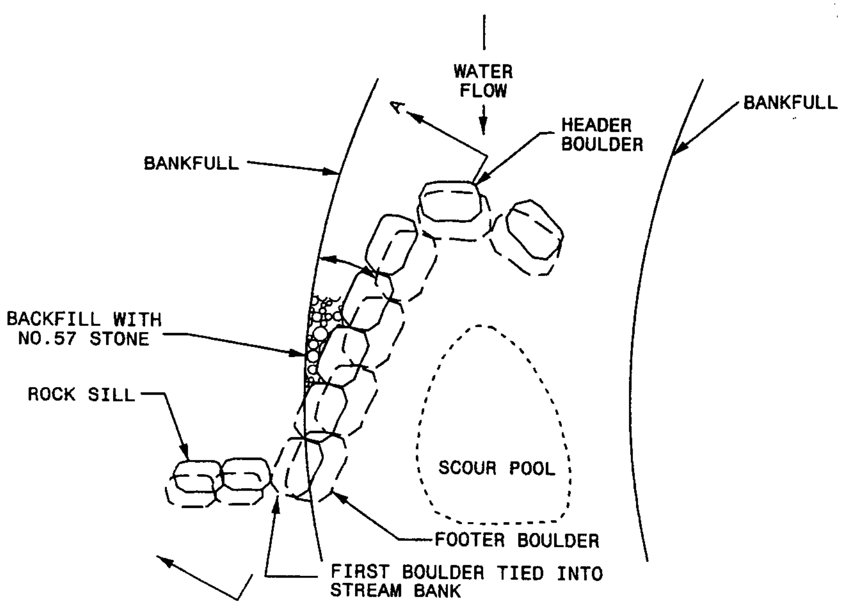
CROSS SECTION

J-HOOK VANE

SCALE: NTS



CROSS SECTION

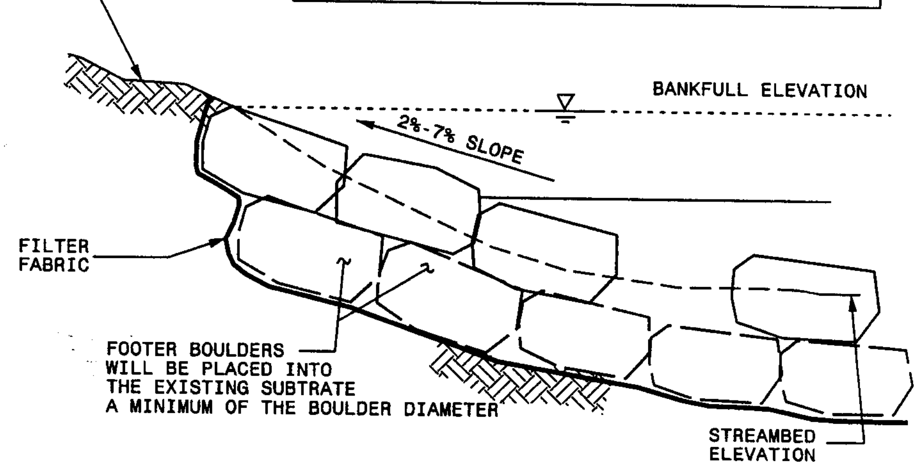


PLAN VIEW

INSTALLATION OF J-HOOK VANE

A TRENCH SHALL BE DUG IN SUCH A MANNER THAT THE FOOTER BOULDERS AND A MINIMUM OF 2/3 OF THE HEADER BOULDERS ARE BURIED BENEATH THE BED SURFACE ELEVATION. AN EXCAVATOR, WITH A BUCKET THAT CONTAINS A HYDARULIC THUMB, SHALL BE USED TO PLACE BOULDERS WITH THE SUPERVISION OF THE RESIDENT ENGINEER. SEE SPECIAL PROVISIONS FOR HEADER AND FOOTER DIMENSIONS. FOOTER BOULDERS SHALL BE PLACED FIRST WITH HEADER BOULDERS PLACED ON TOP PRIOR TO BACKFILLING THE TRENCH. IN THE CENTER OF THE CHANNEL, THE HEADER BOULDERS SHALL BE PLACED JUST ABOVE THE BED ELEVATION, WHILE THE HEADER BOULDERS ON THE BANK SHALL BE PLACED HALFWAY BETWEEN THE THALWEG AND BANKFULL ELEVATION. HEADER BOULDERS SHALL SLOPE FROM THE BED ELEVATION, AT THE HEAD OF THE VANE, TO BANKFULL ELEVATION AT A SLOPE OF 2%-7%. HEADER AND FOOTER BOULDERS SHALL BE TIED SECURELY INTO THE BANK IN SUCH A WAY THAT ELIMINATES THE POSSIBILITY OF STREAMFLOW DIVERTING AROUND THEM. ANY SOIL DISTURBED DURING THE PLACEMENT OF ROCK VANES SHALL BE SEEDED USING TEMPORARY AND PERMANENT SEEDING METHODS.

FILTER FABRIC SHALL BE PLACED ON THE UPSTREAM SIDE OF THE VANE STRUCTURE TO PREVENT WASHOUT OF SEDIMENT THROUGH BOULDER GAPS. FILTER FABRIC SHALL EXTEND FROM THE BOTOM OF THE FOOTER BOULDER TO THE FINISHED GRADE ELEVATION AND SHALL BE PLACED THE ENTIRE LENGTH OF STRUCTURE.



SECTION A-A

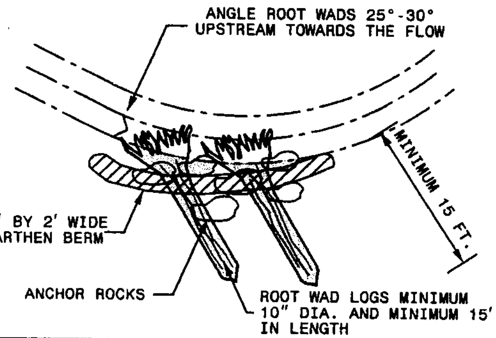
ROOT WAD

SCALE:NTS

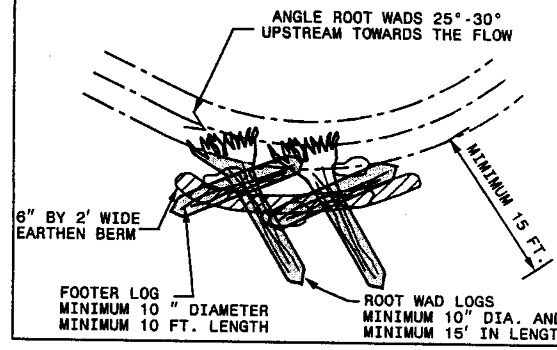
NOTE:
1. ALL STONES ARE TO BE STRUCTURE STONE.
2. SIDE SLOPES WILL BE MATTED
3. 6" BY 2' WIDE EARTHEN BERM LOCATED ATOP ROOT WADS TO DIRECT SHEET FLOW AWAY FROM ROOT WADS.

WHEN BACKFILLING OVER AND AROUND ROOT WAD LOGS PACK STONE BETWEEN ALL WADS TO FIRMLY SECURE ALL CONNECTIONS AND GAPS. ROOT WADS TO OVERLAP. STONE PLACED BETWEEN ROOT WADS. NO GAP BETWEEN BOTTOM OF ROOT WAD & STREAMBED. ROOT WADS ARE HARDWOOD. SEE SPECIAL PROVISIONS FOR STONE SIZE.

INSTALLATION BY DRIVING ROOT WAD INTO STREAMBANK

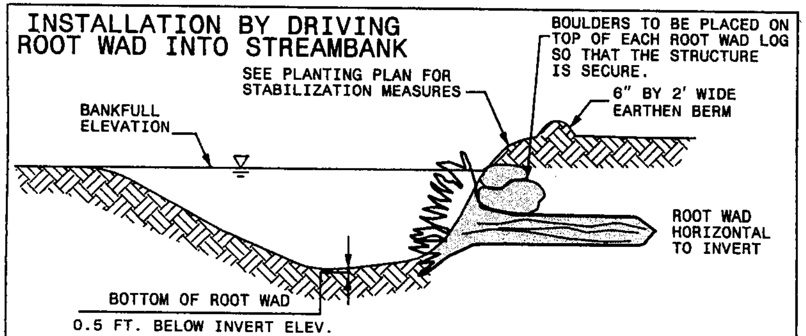


INSTALLATION BY TRENCHING

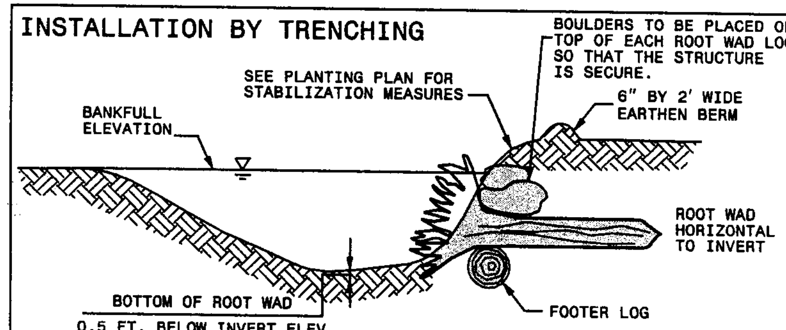


PLAN VIEW

INSTALLATION BY DRIVING ROOT WAD INTO STREAMBANK



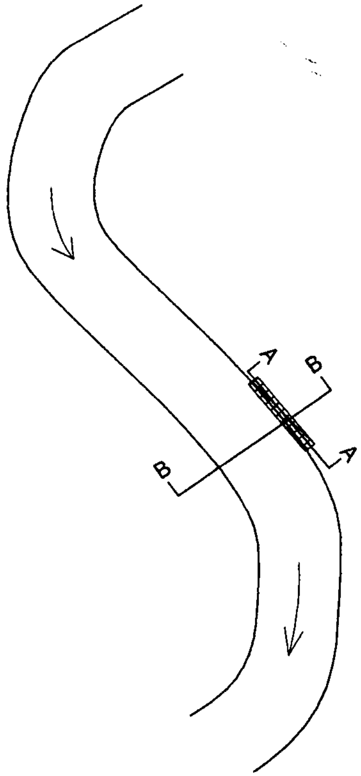
INSTALLATION BY TRENCHING



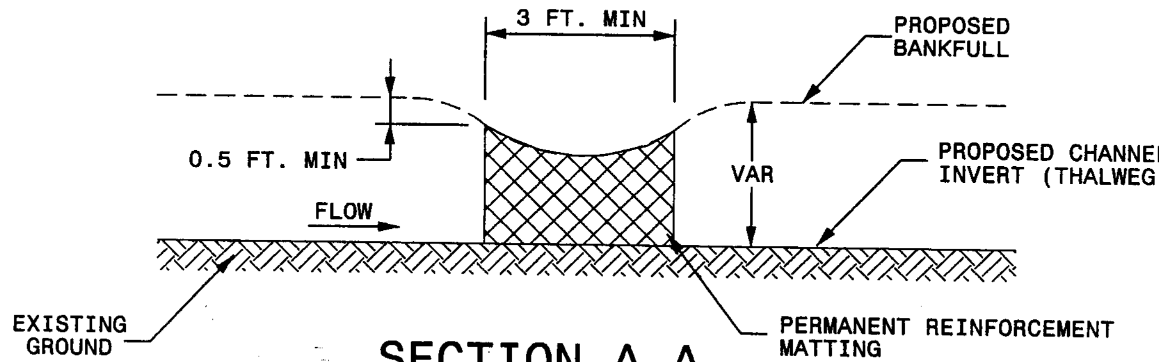
ROOT WADS - CROSS SECTION (CUT)

FLOODPLAIN INTERCEPTOR

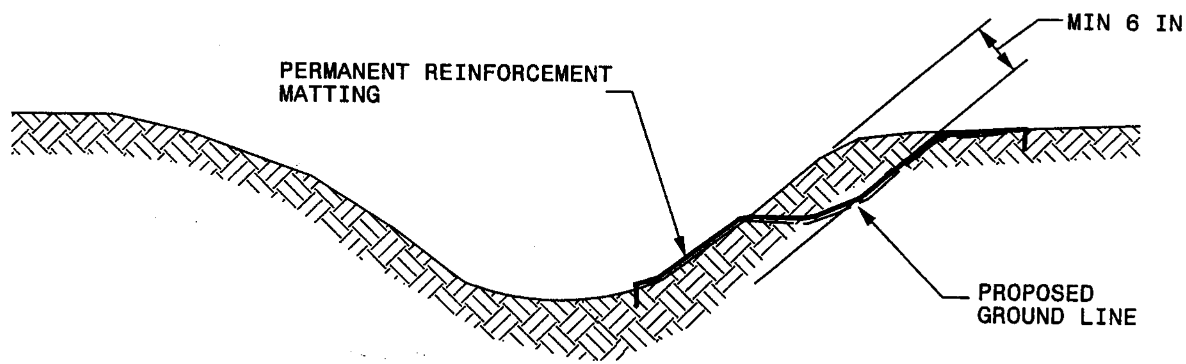
SCALE: NTS



PLAN VIEW



SECTION A-A



KEY IN MATTING A MINIMUM OF 1 FT.

SECTION B-B