Stream Restoration Plan

UNNAMED TRIBUTARY TO MARYS CREEK

Alamance County, NC

APRIL 2003

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Alamance County, NC

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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

The North Carolina Wetlands Restoration Program (NCWRP) identified two Unnamed Tributaries (UTs) to Marys Creek as a potential stream restoration site. The proposed site is on the Dixon Farm, located southeast of Saxapahaw, in Alamance County, North Carolina.

The main channel running through the farm receives drainage from a second channel that will also be restored. The completed length of the proposed stream restoration will be 2,084 feet.

Cattle have heavily impacted the proposed restoration reach. Due to numerous cattle crossings, the banks of both UTs are severely eroded and unstable with little or no riparian buffer. Bank slumpage and sheared banks are evident along the reach. Bare soil is exposed in many sections. The channels' riffle-to-pool sequences have been diminished, thus hampering energy dissipation and causing the banks to become undercut in many areas. The riparian vegetation has been altered by the harvest of large hardwood trees and from grazing cattle.

The North Carolina Division of Water Quality (NCDWQ) has classified Marys Creek as a "Nutrient Sensitive Water (NSW)" and a "Class C" waterbody. The creek is also included on the North Carolina 303(d) list of impaired waterbodies (NCDWQ, 2000). The water quality of the UTs has been severely affected by the presence of cattle within and around the streams. Urine and manure odors were prevalent in the channels. Algal blooms were present at numerous locations within the UTs.

The project can be divided into three segments: upstream main channel (MC), downstream main channel (MC), and secondary channel (SC), based upon differences in drainage areas and topography. The downstream segment experiences greater amounts of runoff, which influences design parameters. All of the segments will be designed as a C4 stream type. A majority of this restoration plan consists of a Priority 1 restoration (Rosgen, 1997), in which the restored channel meanders across the existing floodplain.

The proposed channel will be slightly entrenched with a moderate width-to-depth ratio and moderate sinuosity. The bankfull channel will have a meandering pattern on a well-developed floodplain. 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 existing floodplain. The completed design profile will detail a riffle, run, pool, and glide sequence.

The proposed project provides an excellent opportunity for restoration of severely degraded stream and buffer conditions. The goals of restoring the UTs to Marys Creek include improving water quality and providing aquatic and terrestrial habitats through the stabilization of the UTs and the creation of a riparian buffer. The following table summarizes acreages and footages for the site.

COMPONENT	BEFORE RESTORATION	AFTER RESTORATION
Stream (feet)	2,103	2,084
Riparian Buffer (acres)	NA	5.5

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SECTION 1

INTRODUCTION

1.0 INTRODUCTION

The North Carolina Wetlands Restoration Program (NCWRP) identified two Unnamed Tributaries (UTs) to Marys Creek as a potential stream restoration site. The proposed site is on the Dixon Property, located southeast of Saxapahaw, in Alamance County, North Carolina (Exhibit 1.1.1).

The main channel running through the property receives drainage from a second channel that will also be restored. For the purposes of this report, the two UTs have been termed Main Channel (MC) and Secondary Channel (SC), respectively. This mitigation plan also details three separate designs for this restoration project, which are referred to as the upstream MC, downstream MC, and SC designs. The NCWRP has determined that these UTs should be restored using natural channel design methods. The completed length of the stream restoration will be 2,084 feet.

1.1 PROJECT DESCRIPTION

The Marys Creek restoration site is located off Dixon Lamb Road (SR 2336), east of Lindley Mill Road (SR 1003) and northwest of the Eli Whitney community (Exhibit 1.1.2). The entire site is enclosed within the Dixon property.

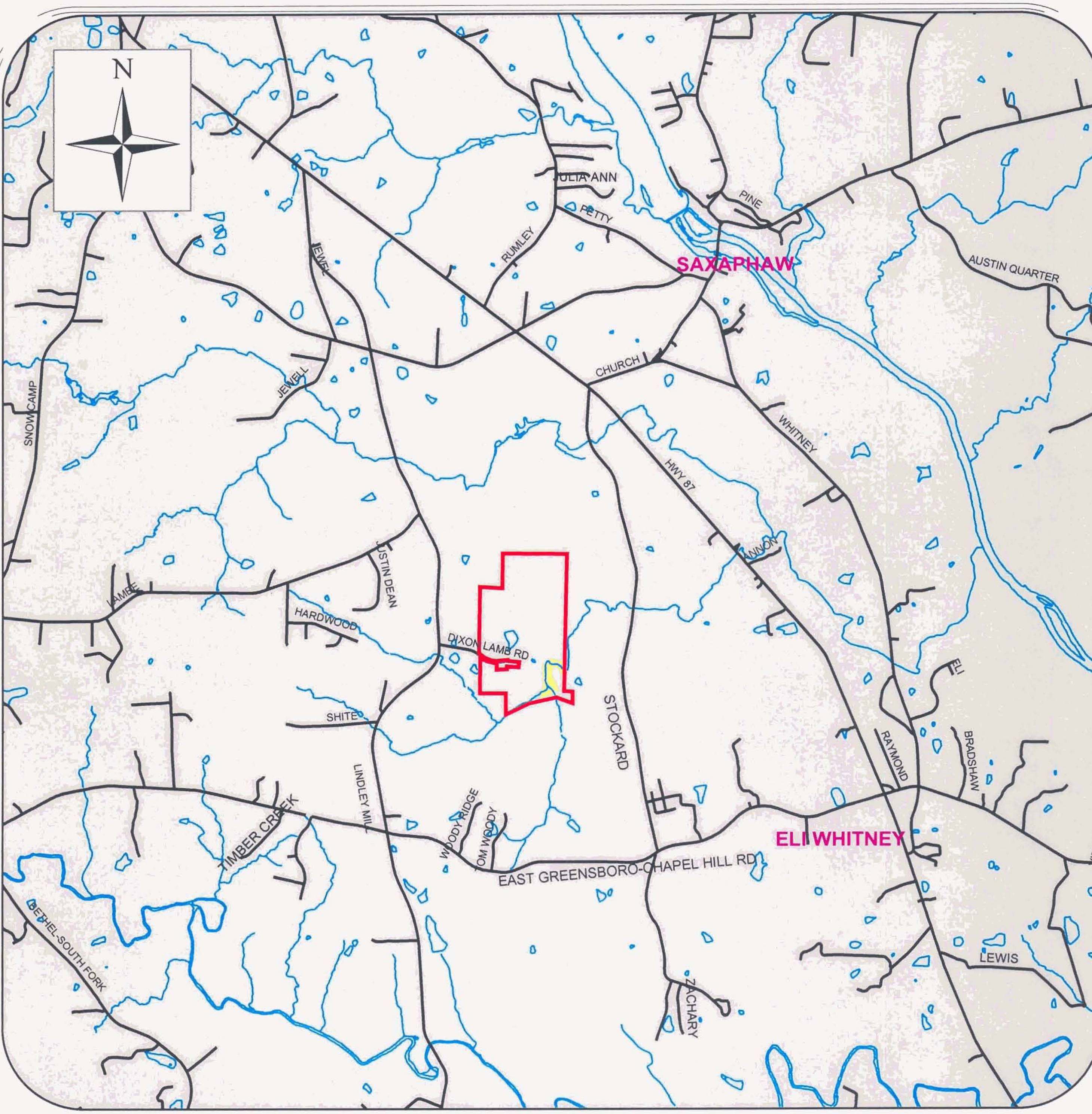
Cattle have heavily impacted the proposed restoration reach. The animals have unfettered access to the UTs and have created numerous crossings through the stream channel. The streambanks are severely eroded at these locations, adding to the degraded water quality conditions within the reach.

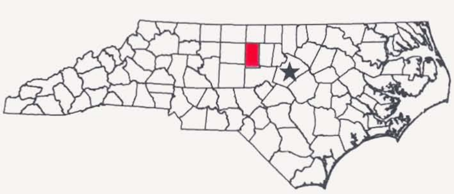
The location of this reach is strongly influenced by the local topography. Numerous rock outcrops can be found within the channel and in the adjacent riparian areas. The upper reach is more sinuous, slightly entrenched, and degrading. Valley walls and bedrock features confine the middle reach, transitioning into a straight and wide lower reach with long pools. The riparian vegetation has been altered by the harvest of large hardwood trees and from grazing cattle.

1.2 PROJECT GOALS AND OBJECTIVES

There are several goals and objectives for this stream restoration. The goals and objectives of restoring the UTs to Marys Creek include:

1. Improve water quality;
2. Provide wildlife habitat through the creation of a riparian zone;
3. Improve aquatic habitat by the use of natural material stabilization structures and a riparian buffer;
4. Prevent cattle from accessing the stream;
5. Reduce nutrient loads from entering the stream via the buffer acting as a filter and the removal of cattle;
6. Enhance the function of the existing floodplain; and,
7. Reduce erosion and sedimentation.





NC Wetlands Restoration Program

UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Project Vicinity

1" = 2500'

Exhibit 1.1.1

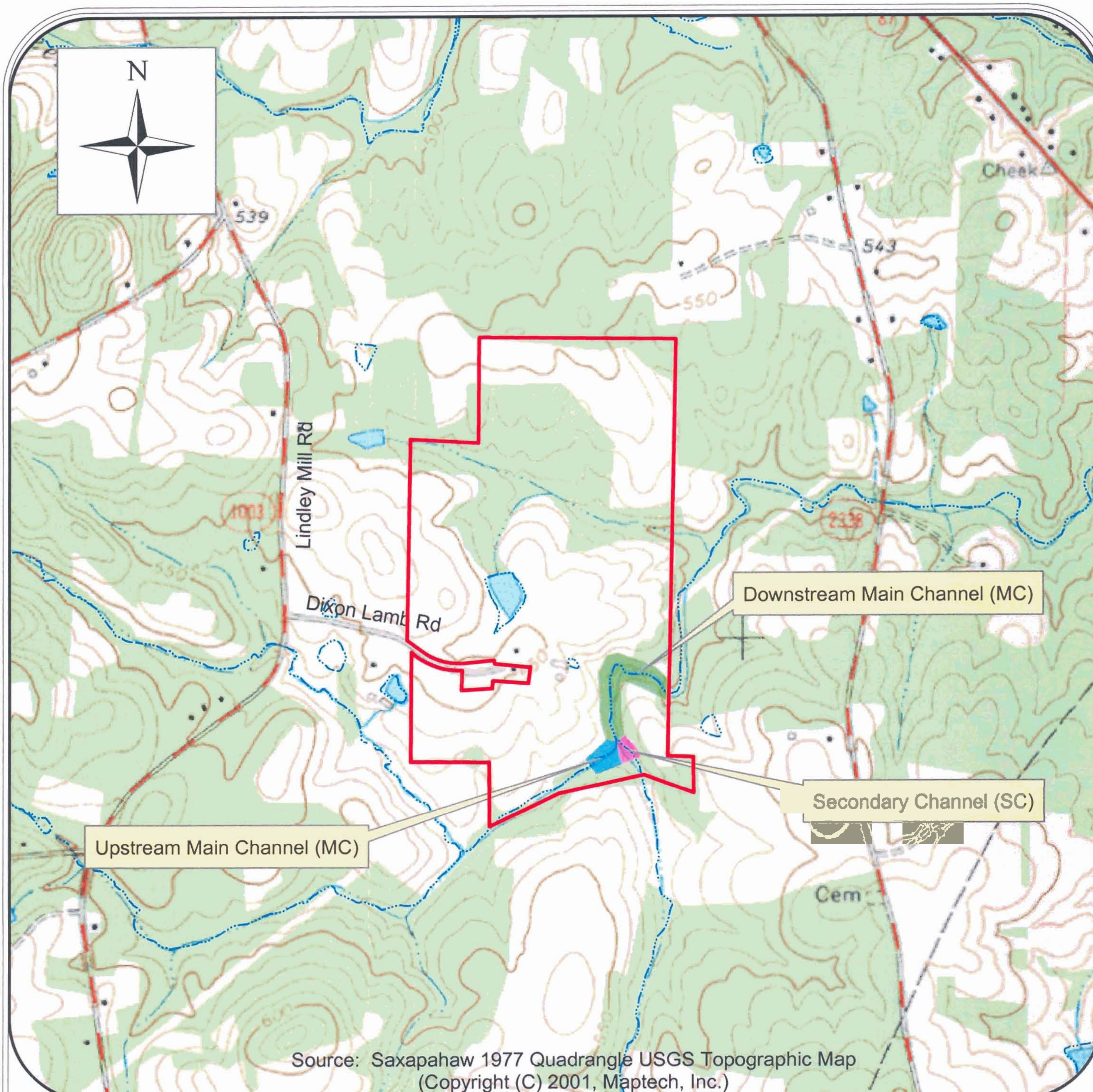
Legend

Dixon Parcel

Restoration Reach

Hydrography

Roads



Legend

- Dixon Parcel
- Downstream Main Channel (MC)
- Upstream Main Channel (MC)
- Secondary Channel (SC)
- Hydrography

NC Wetlands Restoration Program

UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Project Location

1" = 1200'

Exhibit 1.1.2

SECTION 2

EXISTING CONDITIONS

2.0 EXISTING CONDITIONS

2.1 WATERSHED

The proposed restoration site is located within the northern portion 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. Marys Creek and its tributaries are located within NCDWQ Subbasin 03-06-04.

2.1.1 Hydrology

The MC originates at an elevation of 660 feet near the Chatham County line. At the restoration site, the channel starts at an elevation of approximately 520 feet and ends near 490 feet. The MC is a classified as a third order stream, which flows north into Marys Creek, joining the Haw River and then the Cape Fear River. There are several small tributaries that enter the MC upstream of the site. Several of these tributaries to the UTs have farm ponds on them. One small UT joins the MC within the project reach. The drainage area for the entire site covers 1,145 acres. Exhibit 2.1.1 shows the watershed limits.

2.1.2 Soils and Geology

The proposed restoration project 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 valleys that contain major streams (USDA, 1960).

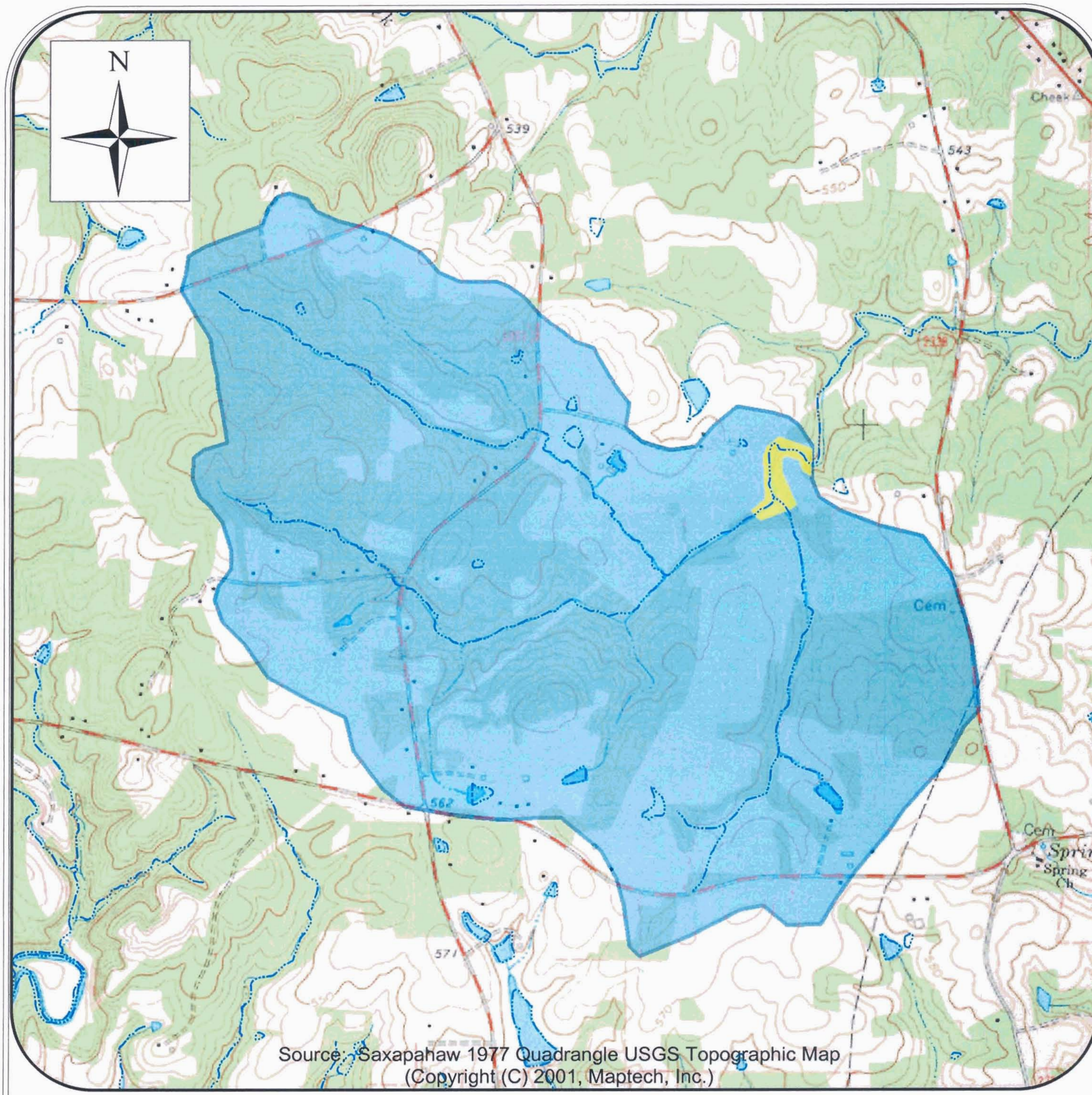
2.1.3 Land Use

The majority of the watershed is used for livestock and poultry operations. The remaining portions are a combination of pasture, cropland, and forest. There are few roads within the watershed and impervious surfaces comprise less than 5% of the watershed. Most of the land within the Dixon property is currently used for a cattle operation. Approximately 90% of the land use on-site consists of maintained pastureland. The Dixon residence and the buildings for housing property equipment and animals occupy the remaining areas. The UTs enter the site from a thin forest line that runs along the outside of the property. Exhibit 2.1.2 shows the current land use within the Dixon property.

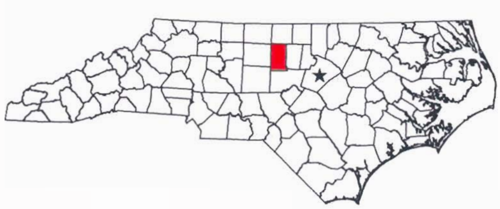
2.2 RESTORATION SITE

2.2.1 Site Description

The banks of both UTs are severely eroded and unstable with little or no riparian buffer. Bank slumpage and sheared slopes are evident along the reach. The streambanks are exposed in many sections; the MC has degraded to the natural slate bedrock substrate and has begun a widening trend in response. A June 17, 2002 site visit revealed that the channels' riffle-to-pool sequences had been diminished, preventing energy dissipation and causing the degrading process. During the September 10, 2002 site visit, the deepest pools had water depths of 1 to 2 feet and there was evidence that the stream had recently peaked about 2 feet above its current elevation. Photographs from the two site visits are shown in Exhibit 2.2.1.



Source: Saxapahaw 1977 Quadrangle USGS Topographic Map
(Copyright (C) 2001, Maptech, Inc.)



Legend

- Watershed Area
- Restoration Reach
- Hydrography

NC Wetlands Restoration Program

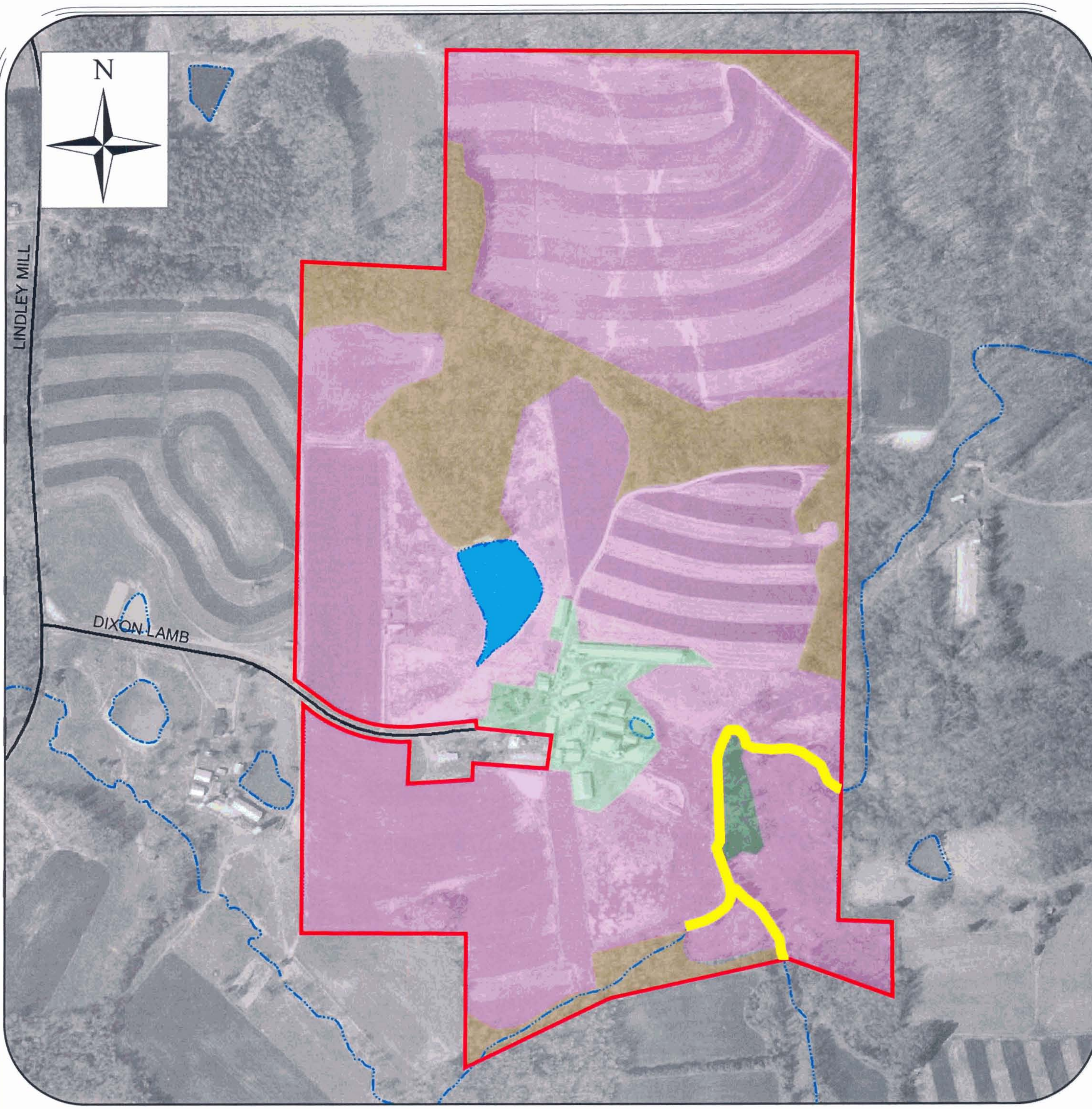
UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Watershed Area

1" = 1700'

Exhibit 2.1.1



Legend

- Dixon Parcel
- Forest
- Pasture/Cropland
- Residential/Structures
- Pond
- Wooded Pasture
- Restoration Reach
- Hydrography
- Roads

NC Wetlands Restoration Program

UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

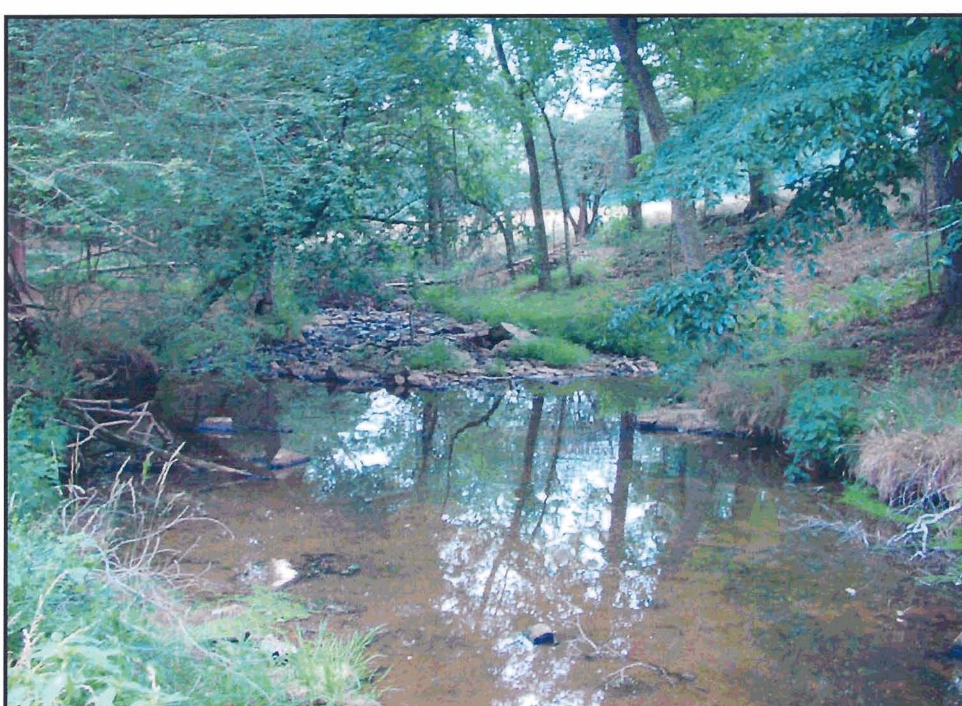
Land Use

Not to Scale

Exhibit 2.1.2

Exhibit 2.2.1 Site Photographs

Cattle paths, undercut banks, and sedimentation in the channel.



Widened section of stream with undercut banks.

Severe bank degradation is evident on both the MC and SC. 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, 30 cattle trails were observed crossing the UTs. 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, numerous wading pools for cattle were also observed. 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.

The lack of deeply rooted plants and trees on the streambanks has led to bank destabilization during high flow events. Evidence of this can be seen on the banks where sheared walls, bank slumpage, and bare soil are visible. The trees that are currently on the banks are being undercut, leaving bare roots overhanging the channel. In many cases trees have collapsed into the channel.

2.2.2 Soils

The Soil Survey for Alamance County North Carolina (USDA, 1960) identifies two soil series along the stream restoration site (Exhibit 2.2.3). Starr loam is found throughout the site primarily along the downstream MC. These are non-hydric soils found on gently sloping (2-6%) bottomlands along streams and drainage ways. Soils of the Starr series are well to moderately drained soils. They have a moderate water-holding capacity and are permeable.

The second soil series is local alluvial land is found along the upstream MC and SC. This soil series generally has a high water table and is poorly drained.

2.2.3 Macro-invertebrates

Upon inspection, neither the main channel nor secondary channel produced many specimens. Few dobsonflies (Corydalidae) and beetle larva (Coleoptera) were found under rocks and undercut banks in the main channel and secondary channel. Other aquatic life identified was one crayfish in the main stem, water snails (Gastropoda) in both the main channel and secondary channel, and pockets of tadpoles throughout the main channel.

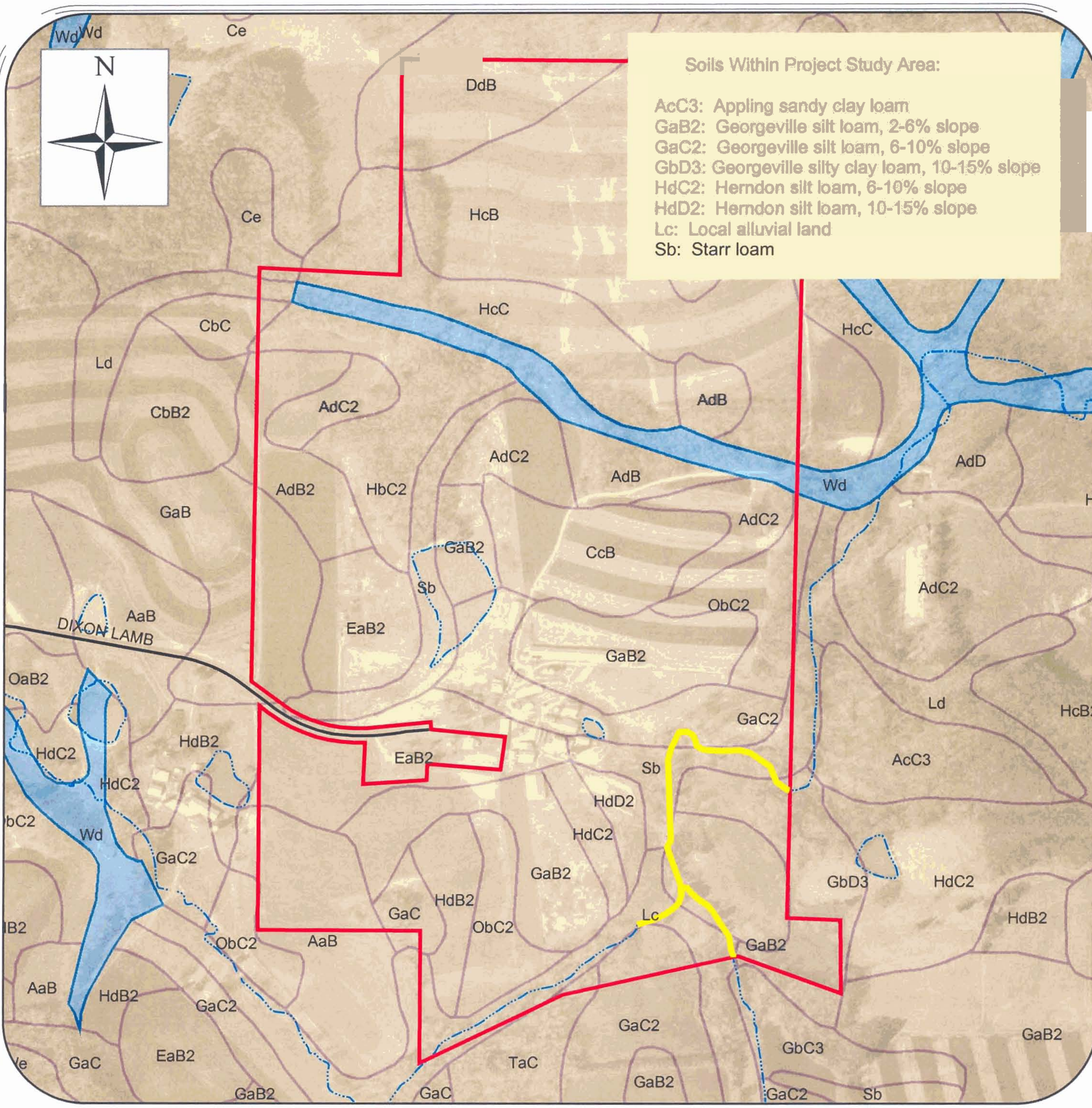
2.2.4 Plant Communities

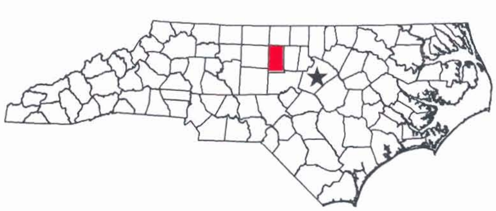
The vegetated riparian community found throughout the site is dominated by red cedar (*Juniperus virginiana*) and is only one to two trees wide. Only one section of the main channel exhibits a wide riparian community. Vegetation found in this section is almost entirely red cedar, but is severely impacted by cattle. Other tree species found in the riparian community include muscle wood (*Carpinus caroliniana*), American beech (*Fagus grandifolia*), sweet gum (*Liquidambar styraciflua*), green ash (*Fraxinus pennsylvanica*), and red maple (*Acer rubrum*). The dominant shrub is Chinese privet (*Ligustrum sinense*).

Exhibit 2.2.2 Cattle Impacts on the MC

Rut created by cattle with sediment deposition in channel.

Ruts created by cattle in and evidence of increased sedimentation.





Legend

Dixon Parcel	Restoration Reach
Non-hydric Soils	Hydrography
Hydric Soils	Roads

NC Wetlands Restoration Program

UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Soils

Not To Scale

Exhibit 2.2.3

2.2.5 Fish and Wildlife

During all site visits, turbid water conditions greatly hampered observations of aquatic animals. No minnows or fish were observed in the main channel or the secondary channel. Slow flowing areas of the stream contained tadpoles.

2.2.6 Endangered/Threatened Species

No endangered or threatened species are listed for Alamance County. There are several Federal Species of Concern (FSC) 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 water quality of the UTs has been severely affected by the presence of cattle within and around the streams. Urine and manure odors were prevalent in and around the channels. Algal blooms were observed during the summer site visits.

Marys Creek is classified by the NCDWQ as a "Nutrient Sensitive Water (NSW)." These are waters that experience, or are subject to, excessive growths of microscopic and macroscopic vegetation. The creek is also classified as a "Class C" waterbody, which is considered suitable for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, and agriculture.

Marys Creek is also included in Part 2 of the North Carolina 303(d) list of impaired waterbodies (NCDWQ, 2000). The sources of pollution for waterbodies listed in Part 2 are defined as "man-made or man-induced" alterations and include sediment as a contributor to habitat degradation through effects such as turbidity, channel erosion, and sediment deposition.

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 used for this project.

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 Society (USGS) Saxapahaw Quadrangle for North Carolina. Field verification of the watershed was conducted on September 10, 2002.

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 for classifying the stream. These values were used in the design process. Once the values have been determined, a design will be proposed based on the geomorphic processes occurring with the channel.

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 a 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 observations of macrobenthos aquatic life, terrestrial life, and plant community identification. This information assists in the development of the restoration plan and may 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 do not accumulate in high amounts and that there is not a high amount of suspended sediment. The stream has to be able to move its sediment load without causing detrimental affects to living things. Therefore, the proposed stream will greatly improve the biotic community

3.2 EXISTING STREAM CLASSIFICATION AND CONDITIONS

The existing conditions discussed below are also included in Table 3.2.1 along with additional morphological characteristics. Exhibit 3.2.1 shows photographs of the existing conditions. The existing channel survey data is contained in Appendix A. NCDWQ stream classification forms for the existing channel are contained in Appendix B.

Upstream MC and SC

The upstream MC and SC sections both begin near the southern end of the site and end at the confluence of the MC and SC. The drainage area for the upstream MC is 794 acres and the drainage area for the SC is 330 acres. Design constraints for these sections include initial elevations approaching the site, valley slope and valley width at the confluence.

Using Rosgen classification, the upstream channels were classified as a C4 stream type. The relatively high entrenchment ratio, a moderate to high width-to-depth ratio, and moderate to high sinuosity are characteristic of a C type stream. A typical C channel is one that is fairly wide, meandering through the valley with alternating point bars. The 4 in the classification indicates that the channel is predominantly comprised of gravel.

Although the channels classify as a C channel, both systems are experiencing adjustments, which are indicative of unstable conditions. Erosion has down cut the channel and created unstable, sloughing, and bare banks. Additionally, the channels' alternating point bars have been eroded which has straightened the channels. This straightened pattern is not normally found in stable streams. These deteriorating processes are expected to continue unless restoration practices are implemented.

Table 3.2.1 Existing Conditions

Mitigation Plan: UTs to Marys Creek Proposed Design Design by: Ryan Smith Checked by: Kathleen McKeithan, PE, CPESC R. Kevin Williams, PE, PLS, CPESC		
PARAMETER	**UPSTREAM**	**DOWNSTREAM**
STREAM TYPE	C4	F4
DRAINAGE AREA (acres)	794	813
BANKFULL WIDTH (ft)	15.7	34.5
BANKFULL MEAN DEPTH (ft)	1.4	0.7
WIDTH/DEPTH RATIO	11	50
BANKFULL X-SECTION AREA (ft^2)	22.7	24.1
BANKFULL MEAN VELOCITY (ft/s)	4.6	4.4
BANKFULL DISCHARGE (cfs)	104	106
BANKFULL MAX DEPTH (ft)	2.1	1.0
WIDTH OF FLOOD-PRONE AREA (ft)	47	37
ENTRENCHMENT RATIO	3.0	1.1
MEANDER LENGTH (ft)	212 – 287	330 – 840
RATIO OF MEANDER LENGTH TO BANKFULL WIDTH	13.5 – 18.9	10 – 24.3
RADIUS OF CURVATURE (ft)	15.2 – 16.0	n/a
RATIO OF RADIUS OF CURVATURE TO BANKFULL WIDTH	1.0	n/a
BELT WIDTH (ft)	35	105
MEANDER WIDTH RATIO	2.2	3.0
SINUOSITY (K)	1.14	1.03
VALLEY SLOPE (ft/ft)	0.0096	0.0096
AVERAGE SLOPE (ft/ft)	0.0026	0.0057
POOL SLOPE (ft/ft)	0.0004	0.0018
RATIO OF POOL SLOPE TO AVERAGE SLOPE	0.0 – 0.3	0.2 – 0.4
MAX POOL DEPTH (ft)	2.7	2.7
RATIO OF POOL DEPTH TO AVERAGE BANKFULL DEPTH	1.9	3.9
POOL WIDTH (ft)	19.2	27.6
RATIO OF POOL WIDTH TO BANKFULL WIDTH	1.2	0.8
POOL TO POOL SPACING (ft)	16 – 64	28 – 148
RATIO OF POOL TO POOL SPACING TO BANKFULL WIDTH	1.0 – 4.0	0.8 – 4.3

Exhibit 3.2.1a Existing Stream Conditions

View of Upstream MC looking north (downstream).

View of SC looking south (upstream).

Exhibit 3.2.1b Existing Stream Conditions

View of MC.

The survey of the upstream section of the MC determined that the average bankfull width is 15.7 feet with a mean depth of 1.4 feet. Based on these numbers, the width-to-depth ratio is 10.9. The bankfull cross-sectional area is 22.7 square feet (ft^2). Bankfull mean velocity is 4.6 feet per second (ft/s) and the bankfull discharge is 104 cubic feet per second (cfs). The bankfull maximum depth is 2.1 feet and the width of the flood-prone area is 47 feet.

Downstream MC

This reach, which represents the bulk of the project, begins at the confluence of the MC and SC and extends northeast to the end of the property. The drainage area for this section is 1151 acres. Constraints for this section of the design include the confluence and downstream elevations, valley slope, valley width, and bedrock outcroppings.

The lower section of the MC is classified as a F4. The entrenched channel with a moderate to high width-to-depth ratio, moderate sinuosity, and low slope signifies an F type stream. A typical F channel is wide and deep (Rosgen, 1994).

The average bankfull width for the downstream reach of the MC is 34.5 feet. The bankfull mean depth is 0.7 feet. From this data, the width-to-depth ratio is calculated to be 49.5. The bankfull cross-sectional area is 24.1 ft^2 and the bankfull mean velocity is 4.4 ft/s. The bankfull discharge is 106 cfs. The bankfull maximum depth is 1.0 foot. The width of the flood-prone area for this reach is 37 feet.

The channel has down cut to bedrock and large cobble outcrops and has begun overwidening the channel's dimensions. These processes are expected to continue unless restoration practices are utilized.

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, 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. The inspection is performed to ensure that the contributing watershed was not adversely affecting the condition of the reach. A biotic survey is also conducted.

Using the above criteria, suitable reference reaches were identified for this project. Once sites were identified, survey teams performed longitudinal profile and cross-sectional surveys. The data discussed in Section 3.1 were also surveyed. The data were then used to calculate dimensionless ratios that were utilized in the design.

Due to an unstable geometry the upstream and downstream portions of the MC, the channel 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). The two streams identified as reference reaches for the MC and SC are an UT to Cabin Branch in Durham County and Landrum Creek in Chatham County. Exhibit 3.3.1 shows the locations of the two streams. Table 3.3.1 contains the morphological characteristics of the reference reaches. Appendix B contains the NCDWQ stream classification forms for the reference reaches.

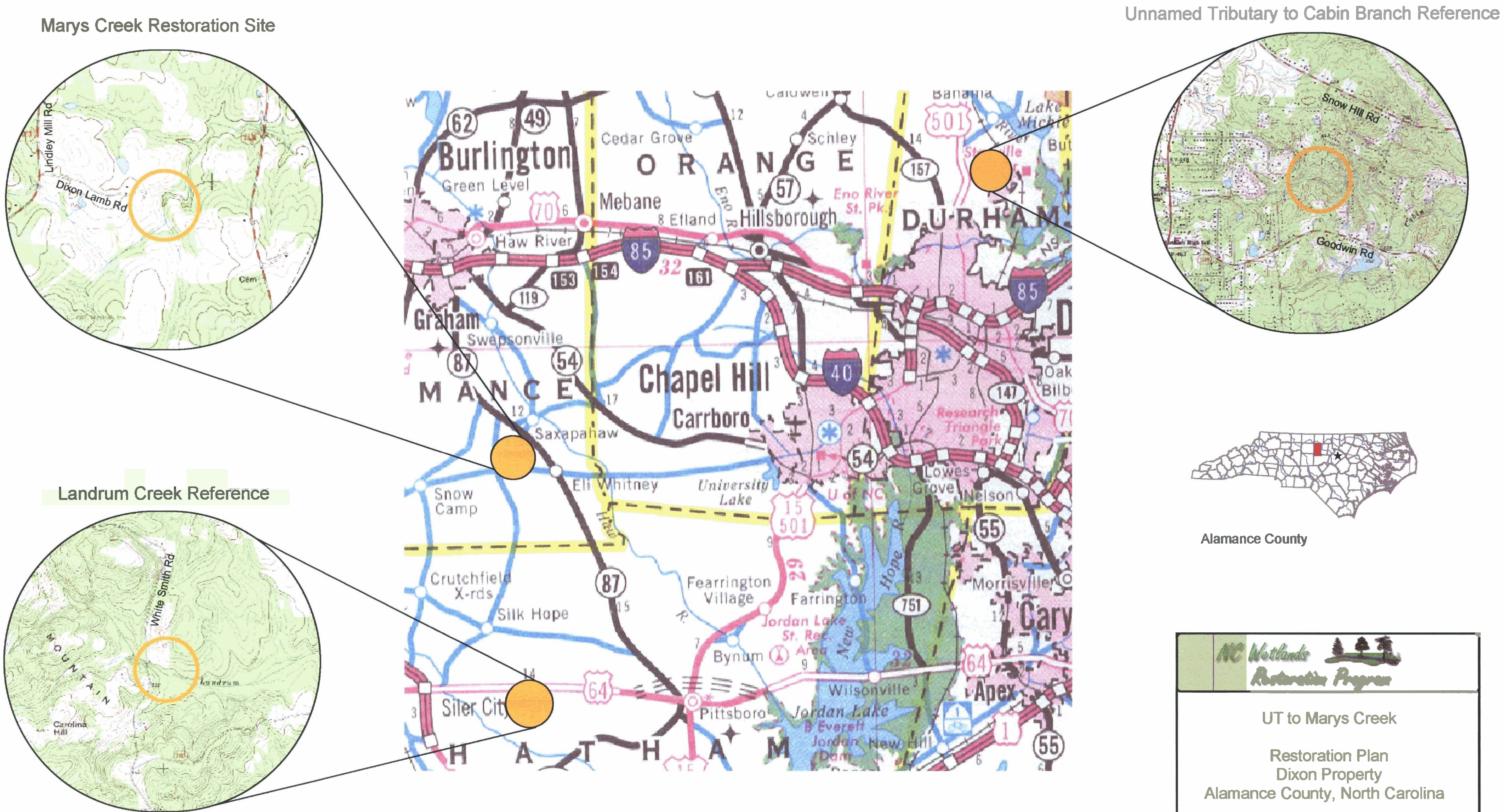
3.3.1 UT to Cabin Branch

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 Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Reference Reach Locations

Not To Scale Exhibit 3.3.1

Table 3.3.1 Reference Conditions

Mitigation Plan: UT's to Marys Creek Proposed Design 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 (Looking 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 sp.*) 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 2^{nd} 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 power line 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.

Exhibit 3.3.3: Landrum Creek Reference Reach

Facing downstream

Facing Upstream

The width-to-depth ratio of 22.8 is moderate and the entrenchment 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 sp.*). 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, rock-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 long-term 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 Proposed Channel Classification

The restoration project was divided into three segments: upstream MC, downstream MC, and SC, based upon differences in drainage areas and topography. The downstream MC segment experiences greater amounts of runoff, which influences design parameters. All of the segments will be designed as C4 streams. A majority of this restoration plan consists of a

Priority 1 restoration (Rosgen, 1997), in which the restored channel meanders across the existing floodplain.

3.4.2 Proposed Stream Description

The UTs will be restored from the southern boundary of the property to the eastern boundary of the property. The total length of the restoration will be 2084 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, valley slope width, and bedrock outcroppings.

The restoration will include establishing the proper dimension, pattern, profile, riparian buffer, and 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 2084 feet. 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 three different sections for restoration are discussed in the following paragraphs. 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.

Upstream MC

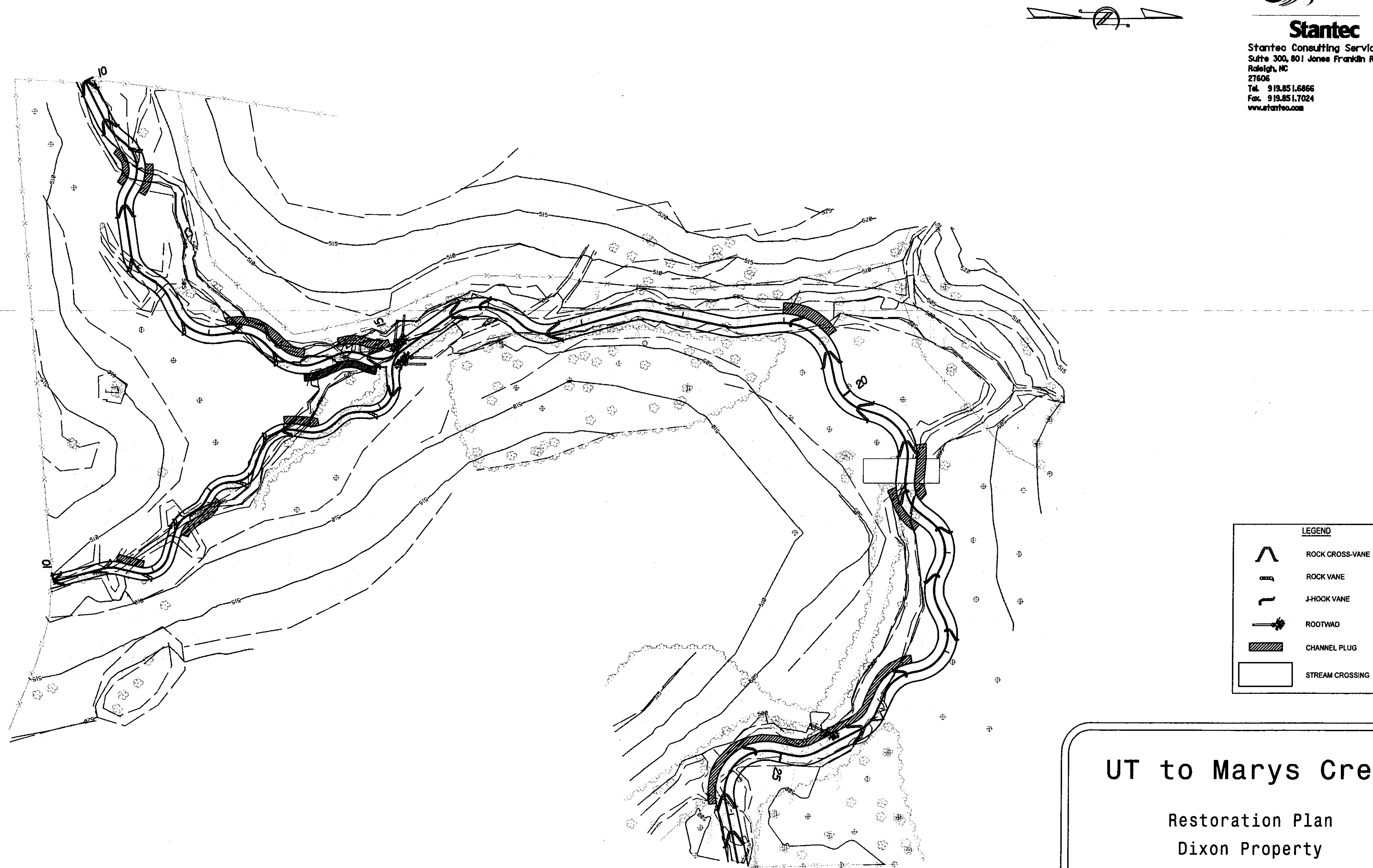
The upstream MC reach is entrenched due to the downcutting and straightening of the unstable reach. The channel also exhibits vertical streambanks. There is evidence of the stream's historical channel existing to the east of the current channel. To remove the channel from the existing sheared bank, the design will mimic the historical pattern and provide an appropriate floodplain; the channel's proposed pattern deviates from the existing alignment. Due to previous downcutting and the horizontal realignment of the channel, the floodplain will be constructed through the middle section of the reach; however, grade control downstream has allowed the channel to continue to use its floodplain. Rock cross-vanes will provide further grade control at the top and bottom of the reach. These structures, along with several rock vanes, provide horizontal alignment, a riffle-pool sequence, habitat diversity, and channel stability with an aesthetically natural appearance.

Downstream MC

The MC begins with several natural bedrock grade control structures that will be utilized within the proposed alignment. A rock cross-vane is proposed below the confluence to provide grade control below this feature and above the 60-foot break in the conservation easement requested by the landowner for a possible future road crossing. Below the break, another rock vane will be installed for grade control and to direct the alignment over the naturally occurring bedrock features. Bank stabilization will be added to this section as well. Below the bedrock reach, the alignment will dramatically deviate from the existing alignment in order to remove shear stress from an eroding valley wall and to provide an area for treatment of runoff before it enters the stream. Runoff from the adjacent agricultural land, which currently flows directly into the stream, will be filtered by a substantial buffer. A permanent stream crossing for cattle and equipment will be provided within this reach. Below the crossing, the channel will be removed from the existing alignment for variability and to increase the floodplain area. The final section of the reach will be aligned over natural occurring bedrock and large cobble features with rock cross-vanes, providing grade control at the downstream end of the site.

SC

The SC's length will be substantially increased by bringing the channel further down the valley before joining the MC. Sinuosity will be increased and a riffle-pool sequence established. The SC and the upstream section of the MC create a triangular piece of property that will be isolated following the completion of the project. This triangular piece of property will be included in the conservation easement. This property will be reforested and will provide both floodplain and upland habitat.



Stantec
Stantec Consulting Services Inc.
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27606
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Fax. 919.851.7024
www.stantec.com

Scale: 1" = 100'

UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Plan View

Exhibit 3.4.1

TYPICAL RIFFLE AND POOL CROSS SECTION

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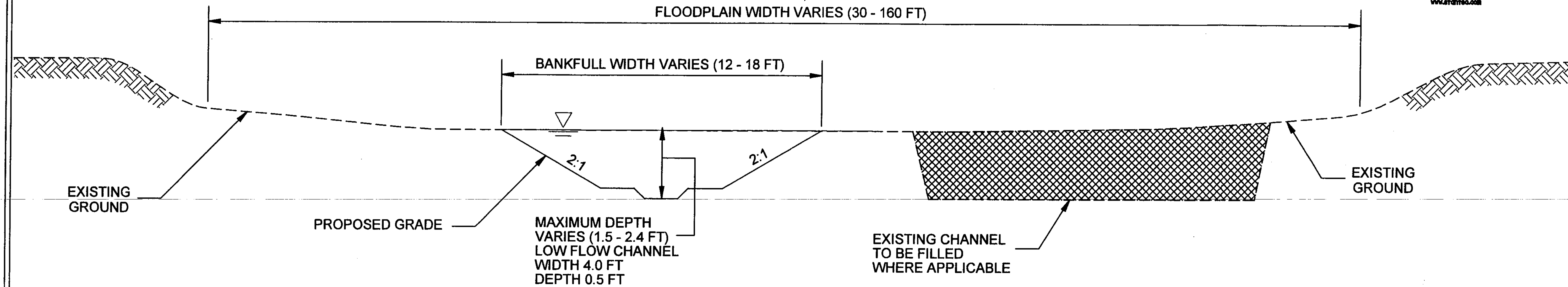
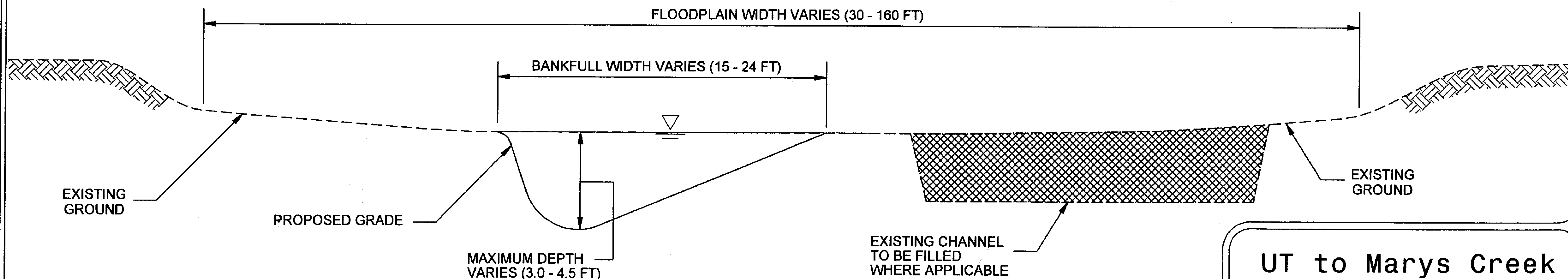
RIFFLE CROSS-SECTION



POOL CROSS-SECTION



NOTE: PROPOSED CHANNEL WILL MEANDER ACROSS FLOODPLAIN

Scale: NTS

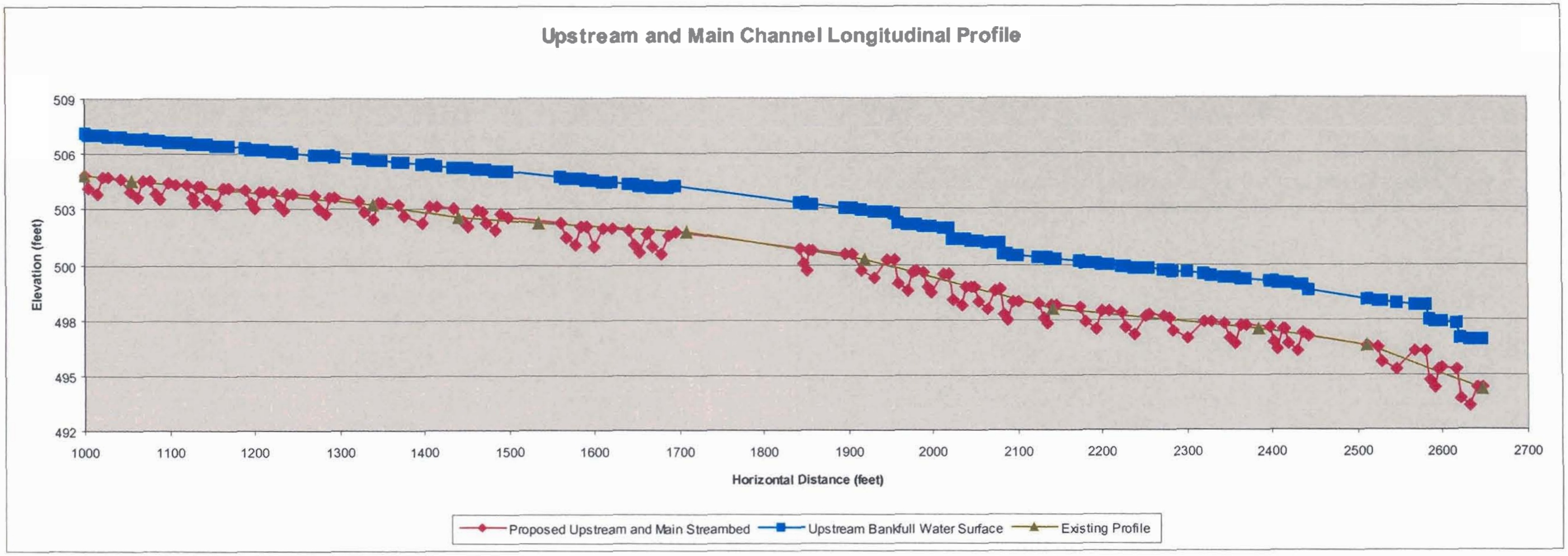
UT to Marys Creek

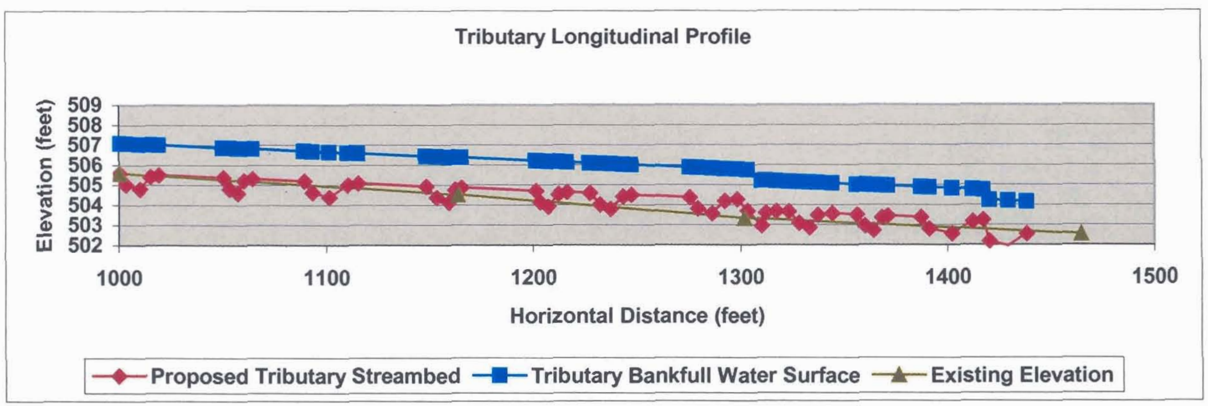
Restoration Plan

Dixon Property
Alamance County, North Carolina

Typical Riffle and Pool Cross Section

Exhibit 3.4.2





UT to Marys Creek

Restoration Plan
McPherson Property
Alamance County, North Carolina

Longitudinal Profiles

Exhibit 3.4.3

Table 3.4.1 Morphological Characteristics

PARAMETER	EXISTING CONDITIONS		DESIGN CONDITIONS			REFERENCE REACH CONDITIONS	
LOCATION	Upstream	Downstream	Secondary Channel (SC)	Upstream Main Channel (MC)	Downstream Main Channel (MC)	UT Cabin Branch	Landrum Creek
STREAM TYPE	C4	F4	C4	C4	C4	C4b	C4
DRAINAGE AREA (acres)	794	813	330	794	1151	806	1619
BANKFULL WIDTH (ft)	15.7	34.5	12.0	16.0	18.0	14.3	27.6
BANKFULL MEAN DEPTH (ft)	1.4	0.7	1.0	1.3	1.5	1.5	1.2
LOW BANK HEIGHT RATIO	1.7	2.9	1.0	1.0	1.0	1.0	1.6
WIDTH/DEPTH RATIO	11	50	12	12	12	10	23
BANKFULL X-SECTION AREA (ft^2)	22.7	24.1	11.0	24.0	28.0	21.4	33.5
BANKFULL MEAN VELOCITY (ft/s)	4.6	4.4	3.4	3.4	4.0	4.9	5.2
BANKFULL DISCHARGE (cfs)	104	106	37	81	112	105	174
BANKFULL MAX DEPTH (ft)	2.1	1.0	1.5	2.1	2.4	2.2	2.0
WIDTH OF FLOOD-PRONE AREA (ft)	47	37	36	48	54	47	140
ENTRENCHMENT RATIO	3.0	1.1	3.0	3.0	3.0	3.3	5.1
MEANDER LENGTH (ft)	212 – 287	330 – 840	36 –96	48 – 128	54 – 144	32 – 92	94 – 100
RATIO OF MEANDER LENGTH TO BANKFULL WIDTH	13.5 – 18.9	10 – 24.3	3.0 – 8.0	3.0 – 8.0	3.0 – 8.0	2.2 - 6.4	3.4 - 3.6
RADIUS OF CURVATURE (ft)	15.2 – 16.0	n/a	24 - 36	32 - 48	36 – 54	9.3 - 29	10 - 13
RATIO OF RADIUS OF CURVATURE TO BANKFULL WIDTH	1.0	n/a	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0	0.7 - 3.0	0.4 - 0.6
BELT WIDTH (ft)	35	105	36 - 72	48 - 96	54 - 108	80	77
MEANDER WIDTH RATIO	2.2	3.0	3.0 – 6.0	3.0 – 6.0	3.0 – 6.0	5.6	2.8
SINUOSITY (K)	1.14	1.03	1.20	1.20	1.20	1.20	1.12
VALLEY SLOPE (ft/ft)	0.0096	0.0096	0.0091	0.0056	0.0092	0.0169	0.0080
AVERAGE SLOPE (ft/ft)	0.0026	0.0057	0.0044	0.0030	0.0031	0.0149	0.0077
RIFFLE SLOPE	0.0234	0.0225	0.0077	0.0052	0.0053	0.0333	0.0145
POOL SLOPE (ft/ft)	0.0004	0.0018	0.0000	0.0000	0.0001	0.0000 - 0.0011	0.0000
RATIO OF POOL SLOPE TO AVERAGE SLOPE	0.0 – 0.3	0.2 – 0.4	0.00	0.00	0.04	0.0 - 0.1	0.0
MAX POOL DEPTH (ft)	2.7	2.7	3.0	4.0	4.5	2.5	2.8
RATIO OF POOL DEPTH TO AVERAGE BANKFULL DEPTH	1.9	3.9	3.0	3.0	3.0	1.7	2.3
POOL WIDTH (ft)	19.2	27.6	15.6	20.8	23.4	14.7	27.4
RATIO OF POOL WIDTH TO BANKFULL WIDTH	1.2	0.8	1.3	1.3	1.3	1.0	1.0
POOL TO POOL SPACING (ft)	16 – 64	28 – 148	28	37	41	9 - 49	25 - 104
RATIO OF POOL TO POOL SPACING TO BANKFULL WIDTH	1.0 – 4.0	0.8 – 4.3	2.3	2.3	2.3	0.6 - 3.4	0.9 - 3.8

3.4.3 Sediment Transport

The proposed stream design must be able to transport its 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.

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 helps ensure the stream will not move too large a particle. Existing grade control including bedrock and large cobble outcroppings will be reinforced with grade controls structures at the upstream and downstream end of the project, and around the confluence of the two channels. The design for each 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

		UPSTREAM MC	DOWNSTREAM MC	SC
	LARGEST PARTICLE FROM BAR SAMPLE [D_i] (mm)	45	45	45
	PARTICLE FROM BAR SAMPLE [D_{100}] (mm)	45	45	45
AGGRADATION ANALYSIS	CRITICAL DIMENSIONLESS SHEAR STRESS [τ^*_{ci}]	0.0177	0.0177	0.0177
	EXISTING STREAM CONDITION BY REQUIRED DEPTH	Stable	Stable	Stable
	EXISTING STREAM CONDITION BY REQUIRED SLOPE	Stable	Stable	Stable
DEGGRADATION ANALYSIS	BANKFULL SHEAR STRESS (lb/ft^2)	0.26	0.28	0.23
	BANKFULL SHEAR STRESS MOVEABLE PARTICLE SIZE (mm)	15	17	14
	STREAM CONDITION BY BANKFULL SHEAR STRESS	Stable	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.

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, 14 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. 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.

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

The bankfull discharge for the site is approximately 112 cfs. The existing bankfull velocity is approximately 4 ft/s. The proposed design will not 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, rock 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, rock vanes, and j-hook vanes will be utilized to direct the flow away from the bank and toward the center of the channel. Root wads 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.

Rock Vanes - The rock vane directs the flow away from the stream bank and into the center of the channel. The rock vane structure creates a scour pool immediately downstream which provides a habitat feature. Boulders are used to build these structures and will be used throughout the Site on the outside meander bend.

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 vane's 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.

Root wads – Root wads will be utilized for streambank protection, habitat for fish and terrestrial insects, cover, and introduction of woody material into the stream. Root wads 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.

4.0 BUFFER RESTORATION

4.1 METHODOLOGY

The buffer along Marys 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 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 buffer along much of Marys Creek consists of pasture dominated by fescue (*Festuca* spp.) and scattered red cedars and an occasional red maple or sweetgum. As described earlier, much of the streambank is unstable and some of the larger trees along the creek have fallen in. Only the middle portion of the project reach has much of a riparian forest remaining, and it has been grazed and trampled by cattle.

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 references. 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 4.1.1 shows the buffer reference reaches.

4.3.1 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, white oak (*Quercus alba*), green ash, red maple, sweetgum, 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* sp.). This 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 UTs to Marys Creek.

4.3.2 Landrum Creek

A typical Piedmont mixed hardwood forest comprises most of the riparian zone along this 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, sweetgum, 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 sp., microstegium sp., 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 4.2.1 shows the planting plan as it will be implemented along the channel. Table 4.4.1 summarizes the vegetation discussed in the following paragraphs. It should be noted that it may be necessary to control fescue prior to or following the planting of the buffer.

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, American sycamore, 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* sp.), and beautyberry (*Callicarpa americana*).

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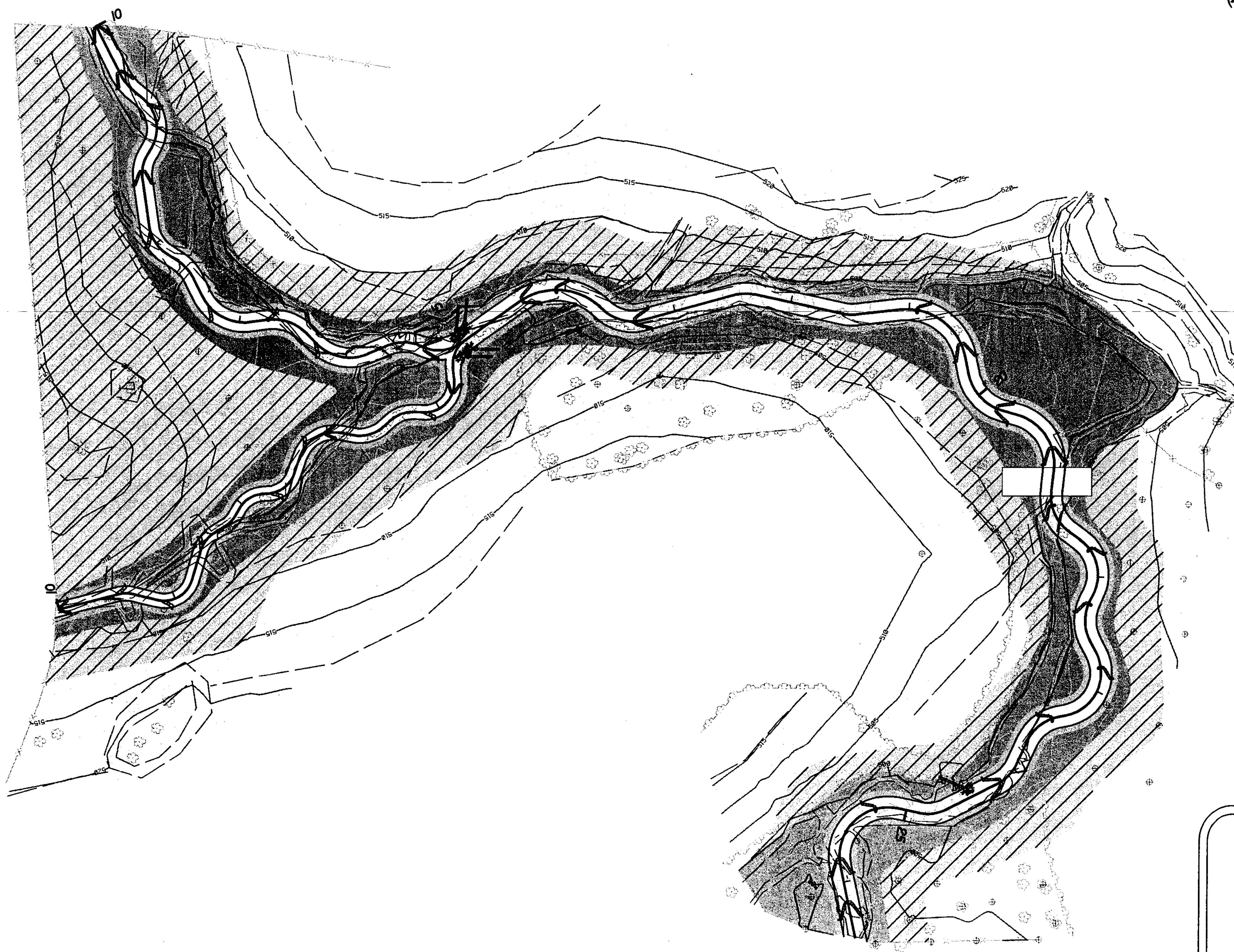

LEGEND

ZONE 1 STREAMBANK

ZONE 2 FLOODPLAIN FOREST

ZONE 3 UPLAND FOREST

UT to Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

Planting Plan

Scale: 1" = 100'

Exhibit 4.4.1

SECTION 5

MONITORING

5.0 <u>MONITORING</u>

5.1 STREAM CHANNEL

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

6.0 SUMMARY

The North Carolina Wetlands Restoration Program (NCWRP) has identified two Unnamed Tributaries (UTs) to Marys Creek as potential stream restoration sites. The proposed site is at the Dixon Property, located southeast of Saxapahaw, in Alamance County, North Carolina.

The main channel running through the property receives drainage from a second channel that will also be restored. The completed length of the stream restoration will be 2,084 feet.

Cattle have heavily impacted the proposed restoration reach. Due to numerous cattle crossings, the banks of both UTs are severely eroded and unstable with little or no riparian buffer. Bank slumpage and sheared walls are evident along the reach. Bare soil is exposed in many sections of the UTs and much of the natural substrate has been covered by sediment that has been washed into the channels. The channels' riffle-to-pool sequences have been eliminated, preventing energy dissipation and causing the banks to become undercut in many areas. The riparian vegetation has been altered by the harvest of large hardwood trees and from grazing cattle.

The North Carolina Division of Water Quality (NCDWQ) has classified Marys Creek as a "Nutrient Sensitive Water (NSW)" and a "Class C" waterbody. The creek is also included on the North Carolina 303(d) list of impaired waterbodies (NCDWQ, 2000). The water quality of the UTs has been severely affected by the presence of cattle within and around the streams. Urine and manure odors were prevalent in the channels. Algal blooms were present at numerous locations within the UTs.

The proposed stream conditions are divided into three segments: upstream MC, downstream MC, and SC, as based upon differences in drainage areas and topography. The downstream segment experiences greater amounts of runoff, which influences design parameters. All of the segments will be designed as a C4 stream type. A majority of this restoration plan consists of a Priority 1 restoration (Rosgen, 1997), in which the channels meander across the floodplain.

The proposed channel will be slightly entrenched with a moderate width-to-depth ratio and moderate sinuosity. The bankfull channel will have a meandering pattern on a well-developed floodplain. 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 constructed floodplain. The completed design profile will detail a riffle, run, pool, and glide sequence.

The proposed project provides an excellent opportunity for restoration of severely degraded stream and buffer conditions. The goals of restoring the UTs to Marys Creek include improving water quality and providing aquatic and terrestrial habitats through the stabilization of the UTs and the creation of a riparian buffer. The following table summarizes acreages and footages for the site.

COMPONENT	BEFORE RESTORATION	AFTER RESTORATION
Stream (feet)	2,103	2,084
Riparian Buffer (acres)	NA	5.5

SECTION 7

REFERENCES

7.0 REFERENCES

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UT to Marys Creek (Upstream) Longitudinal Profile Data

Basin:	Cape Fear	Channel Slope:	0.257444 %
Reach:	Marys Creek (Upstream)	Stream Length:	322.4 ft
Observers:	RKW, KMM, SNR, RVS	Valley Length:	284 ft
Channel Type:	C4	Sinousity:	1.14
Drainage Area (sq mi):	1.24	Meander Length:	212 ft
		Belt Width:	35 ft
		Radius of Curvature:	15.225 ft

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank (RT)	Top of Bank (LT)	Terrace
2.0	93.15	93.49		96.88		
8.1	92.90					
14.8	93.04	93.54				
22.8	93.00	93.54				
33.1	93.15	93.54				
43.5	93.37	93.58				
52.5	93.06	93.55				
61.6	93.17	93.57				
76.8	93.32	93.56		96.93		
87.7	93.35	93.55				
91.6	93.50	93.58				
97.0	93.40	93.53				
106.1	92.90	93.54				
112.0	93.33	93.53				
124.0	93.92					
130.0	93.58			95.96		
132.7	93.17					
136.4	93.17					
140.0	93.45					
145.5	93.55					
151.5	93.52					
156.4	92.93		95.72	96.99	98.72	
162.2	92.70					
166.8	92.79					
167.0	93.09					
172.6	93.12					
176.2	93.07					
177.8	92.72					
182.2	92.68					
187.3	92.44					
190.2	92.55					
197.0	92.81					
200.3	92.92					
207.0	92.75			95.19	97.57	96.27
211.0	92.41	92.65				
214.5	92.04	92.68				
218.9	92.46	92.66				
225.1	92.13	92.64				
228.5	92.21	92.63				
232.9	92.51	92.65				
244.9	92.79					
249.9	92.15	92.65				
256.3	92.28	92.61				
259.2	92.76					
260.0	92.95					
262.1	92.84		95.08			96.43
269.5	92.78					
274.3						
279.3						
289.0	92.52		94.67			
294.1	92.36	92.26				
296.3	91.47	92.26				
301.0	91.63	92.25				
306.7	91.50		94.24	95.95		
310.9	91.52	92.25				
313.5	92.03					
316.3	92.20	92.27				
319.0	92.29					
321.0	92.53					
324.4	92.1	92.4				

UT to Marys Creek (Upstream) - Cross Section Data

Basin: Cape Fear
Reach: Marys Creek (Upstream)
Observers: RKW, KMM, SNR, RVS
Channel Type: C4
Drainage Area (sq mi): 1.24

Riffle

UT to Marys Creek

Station	Elevation Streambed	Elevation Bankfull
0.9	96.46	93.80
7.0	96.11	
11.6	95.31	
12.2	94.65	
14.2	94.04	
14.6	93.78	
15.1	93.60	
15.3	93.15	
16.6	92.88	
17.3	92.56	
18.7	92.30	
19.6	92.08	
20.6	91.95	
22.7	91.89	
23.8	91.74	
24.3	91.69	
25.8	91.69	
27.0	92.02	
27.4	92.23	
28.0	92.18	
28.1	92.51	
28.4	92.52	
28.6	92.86	
29.0	93.27	
29.2	93.41	
30.3	93.80	
32.3	94.06	
43.0	94.03	
44.0	94.18	
48.7	95.35	
55.8	95.56	

Bankfull Area	22.7 sq.ft
Bankfull Width	15.7 ft
Max depth	2.1 ft
Mean depth	1.4 ft
Width/Depth Ratio	10.9
Flood Prone Width	47.0 ft
Entrenchment Ratio	3.0

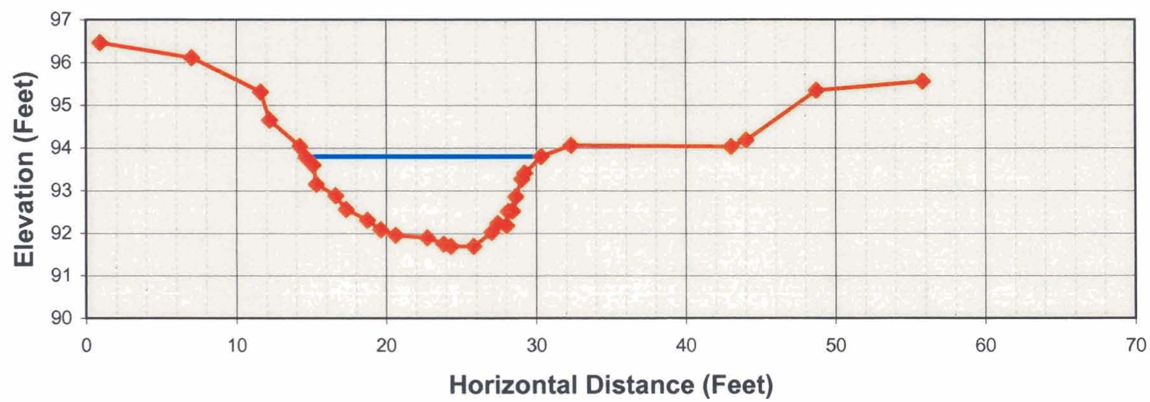
Pool

UT to Marys Creek

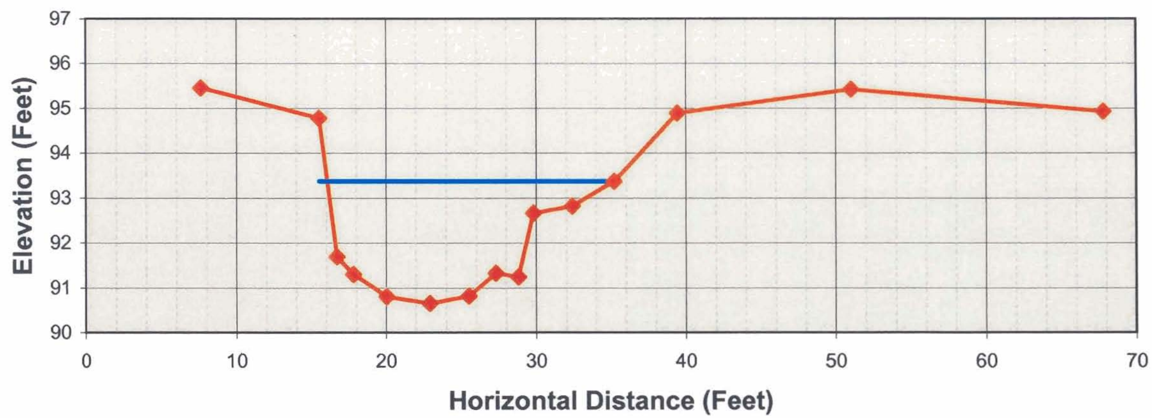
Station	Elevation Streambed	Elevation Bankfull
7.6	95.45	93.37
15.5	94.78	
16.7	91.69	
17.8	91.30	
20.0	90.80	
22.9	90.65	
25.5	90.82	
27.3	91.33	
28.8	91.24	
29.8	92.66	
32.4	92.82	
35.2	93.37	
39.4	94.89	
51.0	95.42	
67.8	94.93	

Bankfull Area	33.3 sq.ft
Bankfull Width	19.2 ft
Max depth	2.7 ft
Mean depth	1.7 ft

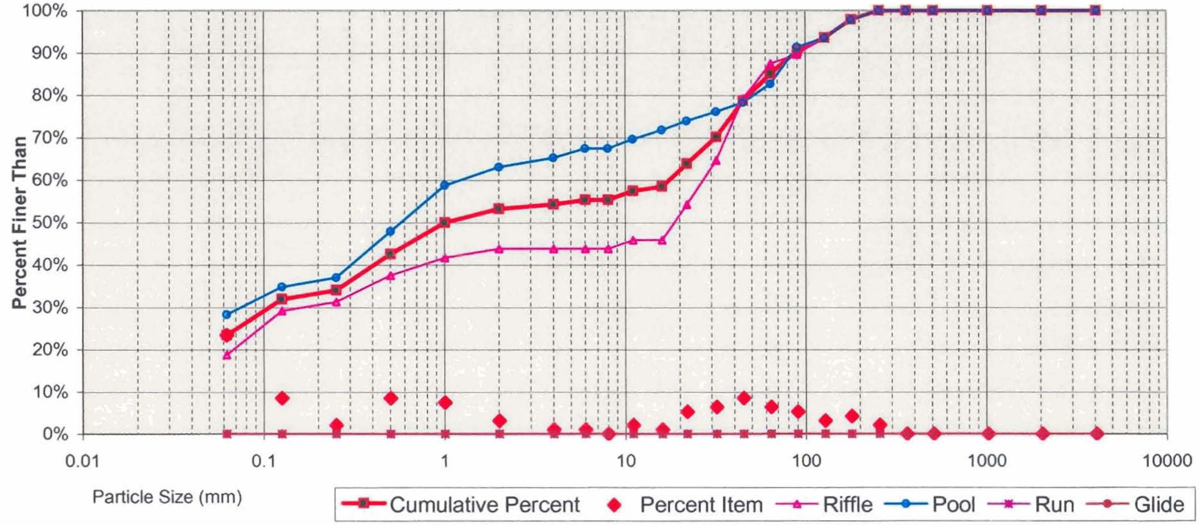
UT to Marys Creek (Upstream) Riffle Cross-Section



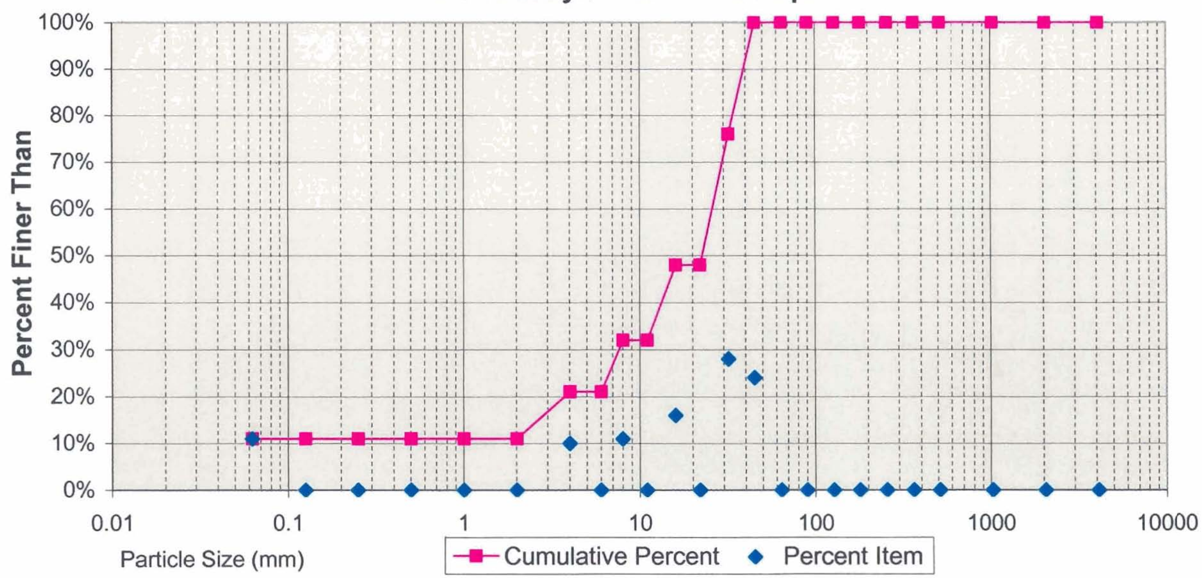
UT to Marys Creek (Upstream) Pool Cross-Section



UT to Marys Creek (Upstream) Pebble Count



UT to Marys Creek Bar Sample



UT to Marys Creek (Downstream) Longitudinal Profile Data

Basin:	Cape Fear	Channel Slope:	0.572634 %
Reach:	Marys Creek (Downstream)	Stream Length:	412 ft
Observers:	RKW, KMM, SNR, RVS	Valley Length:	400 ft
Channel Type:	F4	Sinousity:	1.03
Drainage Area (sq mi):	1.27	Meander Length:	333 ft
		Belt Width:	105 ft
		Radius of Curvature:	0 ft

Station	Elevation Streambed	Elevation Water surface	Elevation Bankfull	Top of Bank (RT)
2.0	92.08	93.41		
6.0	92.02	93.41		96.41
10.2	92.17	93.42		
13.6	91.98	93.43		
22.2	91.94	93.44		
26.3	91.98	93.47		
31.9	91.70	93.42		
38.5	91.86	93.40		96.64
49.0	91.79	93.42		
55.5	91.86	93.40		
64.0	92.14	93.42		
73.2	92.51	93.43		95.61
78.9	92.99	93.42		
82.2	93.25	93.43		
88.7	93.30	93.33		
94.7	93.07	93.32		
100.9	93.03	93.32		
104.7	93.11	93.32		
108.9	93.09	93.31		
111.0	93.09	93.30		
116.2	93.02	93.32		
124.6	93.07	93.33		
128.0	93.10	93.32		
131.1	93.08	93.32		95.23
132.9	93.09	93.31		
139.0	93.09	93.30		
147.0	93.02	93.33		95.00
148.9	93.02	93.32		
152.8	92.87	93.31		
157.4	92.80	93.32		
160.4	93.11	93.32		
163.9	92.98	93.30		
170.0	92.90	93.23		
174.9	92.74	93.24		
177.7	92.79	93.23		
182.7	92.70	93.24		
187.4	93.20	93.22		94.76
192.5	92.00	93.01		
194.9	92.15	93.00		
198.0	91.86	93.00		
204.4	92.21	93.01		
210.5	92.22	93.02		
216.0	92.14	92.99		94.32
223.0	92.60	93.01		
229.8	92.82	93.01		
235.4	92.93	92.96		
241.5	92.09	92.71		
246.1	92.34	92.71		
251.2	92.34	92.71		93.95
257.7	92.55	92.67		
265.7	92.43	92.53		
270.8	92.32	92.56		
275.7	91.71	92.53		
279.0	91.42	92.52		
281.6	91.72	92.52		
288.0	92.32	92.54		
294.0	92.35	92.53		
298.8	91.90	92.33		
303.0	91.54	91.99		
310.6	91.45	91.97		
317.0	91.55	91.99		
329.6	91.52	91.72		
340.2	91.44	91.72		
348.1	91.7	91.7		
355.8	91.7	91.7		
359.0	91.4	91.5		
362.7	91.1	91.5		
368.0	90.8	91.5		
372.3	90.7	91.5		
378.8	90.8	91.5		
386.3	91.0	91.5		
394.0	91.2	91.6		
400.0	91.2	91.5		
408.0	91.2	91.5		
414.0	91.4	91.5		

UT to Marys Creek (Downstream) Cross Section Data

Basin:	Cape Fear
Reach:	Marys Creek (Downstream)
Observers:	RKW, KMM, SNR, RVS
Channel Type:	F4
Drainage Area (sq mi)	1.27

Riffle

UT to Marys Creek

Station	Elevation Streambe	Elevation Bankfull
1.0	99.24	94.63
4.8	97.79	
6.6	94.49	
10.1	94.63	
14.2	94.13	
16.1	93.82	
17.2	93.71	
19.5	93.68	
21.8	93.70	
24.9	93.76	
28.2	93.75	
31.3	93.70	
33.5	93.67	
35.0	93.72	
37.9	93.81	
39.3	93.85	
40.9	94.56	
43.8	96.00	
48.7	96.46	
53.0	96.30	
61.0	96.54	
71.4	97.05	
87.3	98.15	
93.9	98.95	

Bankfull Area	24.1 sq.ft
Bankfull Width	34.5 ft
Max depth	1.0 ft
Mean depth	0.7 ft
Width/Depth Ratio	49.5
Flood Prone Width	36.5 ft
Entrenchment Ratio	1.1

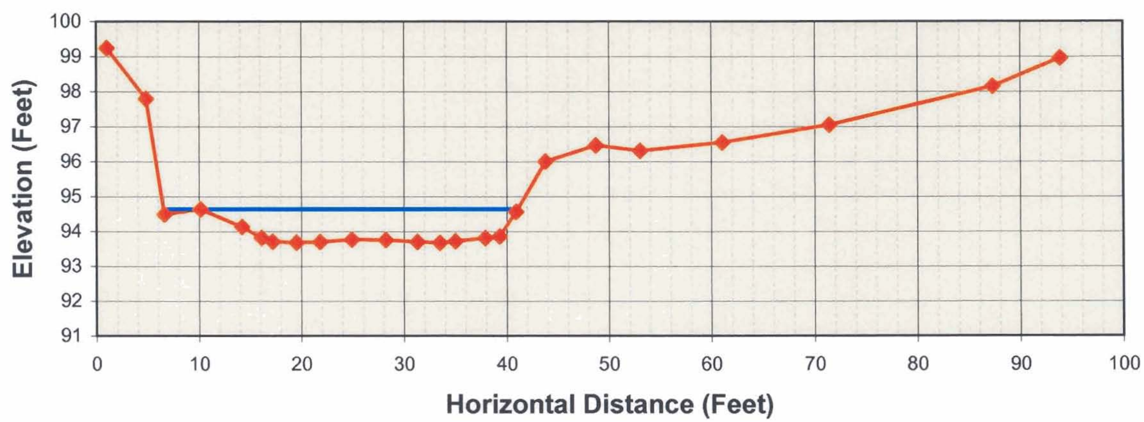
Pool

UT to Marys Creek

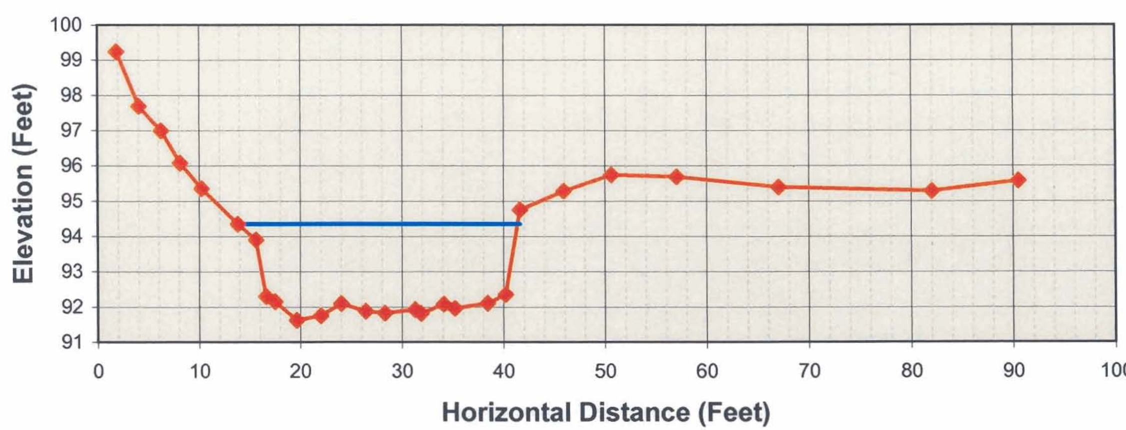
Station	Elevation Streambe	Elevation Bankfull
1.8	99.24	94.35
4.0	97.69	
6.2	96.99	
8.1	96.08	
10.2	95.35	
13.8	94.35	
15.6	93.90	
16.6	92.30	
17.5	92.15	
19.6	91.62	
22.0	91.75	
24.0	92.10	
26.4	91.88	
28.3	91.82	
31.3	91.92	
31.9	91.81	
34.1	92.08	
35.2	91.96	
38.4	92.11	
40.2	92.35	
41.6	94.75	
45.9	95.28	
50.6	95.74	
57.0	95.68	
67.0	95.39	
82.0	95.28	
90.5	95.57	

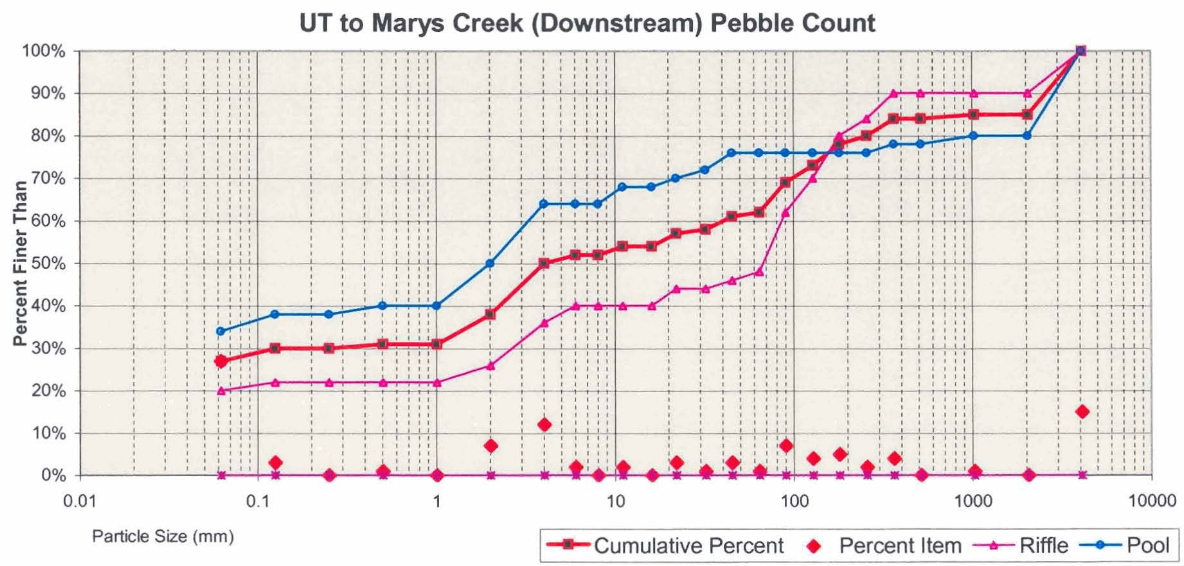
Bankfull Area	59.6 sq.ft
Bankfull Width	27.6 ft
Max depth	2.7 ft
Mean depth	2.2 ft

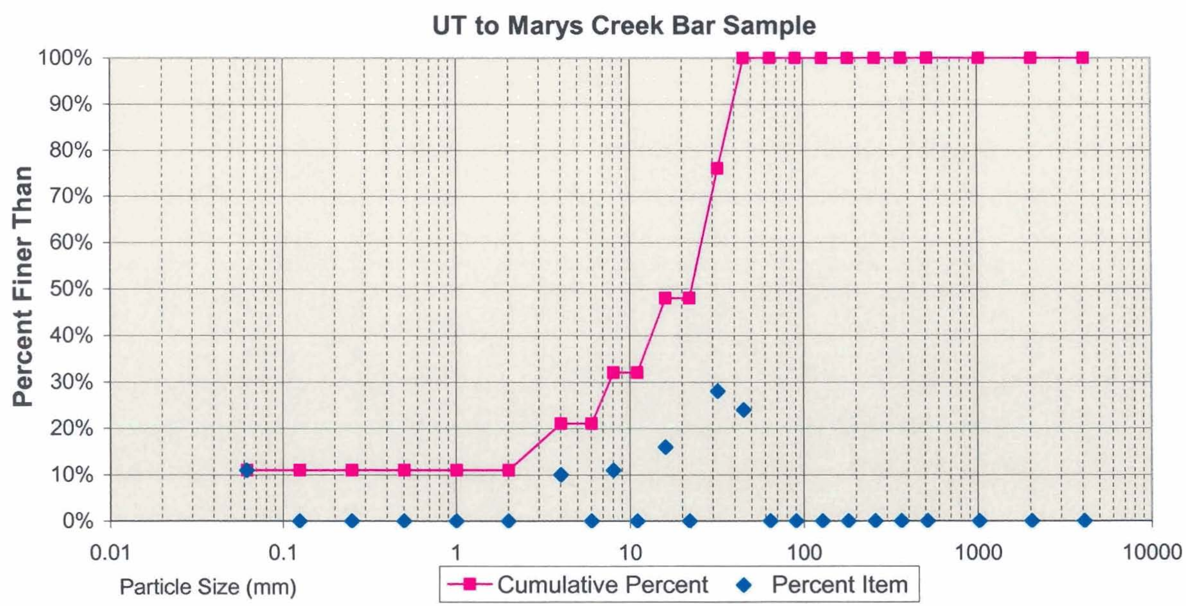
UT to Marys Creek (Downstream) Riffle Cross-Section



UT to Marys Creek (Downstream) Pool Cross-Section




UT to Marys Creek (Downstream) 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 Marys 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 B

NCDWQ STREAM CLASSIFICATION FORMS

NCDWQ Stream Classification Form

Project Name: UT to Marys Creek (Main Channel) River Basin: Cape Fear County: Alamance Evaluator: RVS

DWQ Project Number: N/A Nearest Named Stream: Marys Creek Latitude: 35 54 54.75 Signature:

Date: 9/10/02 USGS QUAD: Saxapahaw Longitude: 79 20 12.16

Location/Directions: Dixon Property – East of Lindley Mill Road off of Dixon Lamb Rd (short private drive), and approximately 2.5 miles southwest of Saxapahaw.

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? *(*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)*	0	1	2	3
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: 16

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: 6

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?	[redacted]	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	.5	[redacted]	1.5
3) Are Wrack Lines Present?	0	.5	[redacted]	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	[redacted]	1.5
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: 7.5

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	[redacted]	.5	1	1.5
2) Are Amphibians Present?	[redacted]	.5	1	1.5
3) Are AquaticTurtles Present?	[redacted]	.5	1	1.5
4) Are Crayfish Present?	0	.5	[redacted]	1.5
5) Are Macrobenthos Present?	0	[redacted]	1	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	[redacted]	.5	1	1.5
7) Is Filamentous Algae Present?	0	[redacted]	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	[redacted]	.75	.5	0	0

SECONDARY BIOLOGY INDICATOR POINTS: 3

TOTAL POINTS (Primary + Secondary)= 37.5 (If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)

NCDWQ Stream Classification Form

Project Name: UT to Marys Creek (Secondary Channel) River Basin: Cape Fear County: Alamance Evaluator: RVS

DWQ Project Number: N/A Nearest Named Stream: Marys Creek Latitude: 35 54 54.75 Signature:

Date: 9/10/02 USGS QUAD: Saxapahaw Longitude: 79 20 12.16

Location/Directions: Dixon Property – East of Lindley Mill Road off of Dixon Lamb Rd (short private drive), and approximately 2.5 miles southwest of Saxapahaw.

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	[redacted]
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	[redacted]
3) Are Natural Levees Present?	0	[redacted]	2	3
4) Is The Channel Sinuous?	0	[redacted]	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	[redacted]	3
6) Is The Channel Braided?	[redacted]	1	2	3
7) Are Recent Alluvial Deposits Present?	0	[redacted]	2	3
8) Is There A Bankfull Bench Present?	[redacted]	1	2	3
9) Is A Continuous Bed & Bank Present?	0	1	2	[redacted]

*(*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*=[redacted]

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: 14

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

PRIMARY HYDROLOGY INDICATOR POINTS: [redacted]

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	2	[redacted]	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: 4

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

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

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: [redacted]

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaf litter Present In Streambed?	[redacted]	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	[redacted]	1.5
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	.5	[redacted]	1.5
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes*=[redacted]		*No*=0

***SECONDARY HYDROLOGY INDICATOR POINTS*: [redacted]**

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	[redacted]	.5	1	1.5
2) Are Amphibians Present?	0	[redacted]	1	1.5
3) Are AquaticTurtles Present?	[redacted]	.5	1	1.5
4) Are Crayfish Present?	0	[redacted]	1	1.5
5) Are Macrobenthos Present?	0	[redacted]	1	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	[redacted]	.5	1	1.5
7) Is Filamentous Algae Present?	[redacted]	.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	[redacted]	.75	.5	0	0

***SECONDARY BIOLOGY INDICATOR POINTS*: [redacted]**

TOTAL POINTS (Primary + Secondary)= 31.5 (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	[redacted]	3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	[redacted]
3) Are Natural Levees Present?	0	[redacted]	2	3
4) Is The Channel Sinuous?	0	1	[redacted]	3
5) Is There An Active (Or Relic) Floodplain Present?	0	[redacted]	2	3
6) Is The Channel Braided?	[redacted]	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	2	[redacted]
8) Is There A Bankfull Bench Present?	0	[redacted]	2	3
9) Is A Continuous Bed & Bank Present?	0	1	2	[redacted]

*(*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)*

10) Is A 2^{nd} Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present? *Yes*=[redacted] *No*=0

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: [redacted]

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

PRIMARY HYDROLOGY INDICATOR POINTS: [redacted]

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	[redacted]	3

PRIMARY BIOLOGY INDICATOR POINTS: [redacted]

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

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

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: [redacted]

II. Hydrology

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaf litter Present In Streambed?	[redacted]	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	.5	[redacted]	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	[redacted]	1.5
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	[redacted]	1	1.5
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes=1.5*		*No=*[redacted]

SECONDARY HYDROLOGY INDICATOR POINTS: [redacted]

III. Biology

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

SECONDARY BIOLOGY INDICATOR POINTS: [redacted]

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	[redacted]
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	[redacted]
3) Are Natural Levees Present?	0	[redacted]	2	3
4) Is The Channel Sinuous?	0	1	[redacted]	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	2	[redacted]
6) Is The Channel Braided?	[redacted]	1	2	3
7) Are Recent Alluvial Deposits Present?	0	[redacted]	2	3
8) Is There A Bankfull Bench Present?	0	1	2	[redacted]
9) Is A Continuous Bed & Bank Present?	0	1	2	[redacted]
*(*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*=[redacted]		*No*=0	

PRIMARY GEOMORPHOLOGY INDICATOR POINTS: 22

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

PRIMARY HYDROLOGY INDICATOR POINTS: [redacted]

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

PRIMARY BIOLOGY INDICATOR POINTS: [redacted]

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

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

SECONDARY GEOMORPHOLOGY INDICATOR POINTS: [redacted]

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaf litter Present In Streambed?	1.5	[redacted]	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	[redacted]	1	1.5
3) Are Wrack Lines Present?	0	.5	[redacted]	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	[redacted]	[redacted]
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes*=[redacted]		*No*=0

SECONDARY HYDROLOGY INDICATOR POINTS: [redacted]

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

TOTAL POINTS (*Primary + Secondary*)= [redacted] *(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

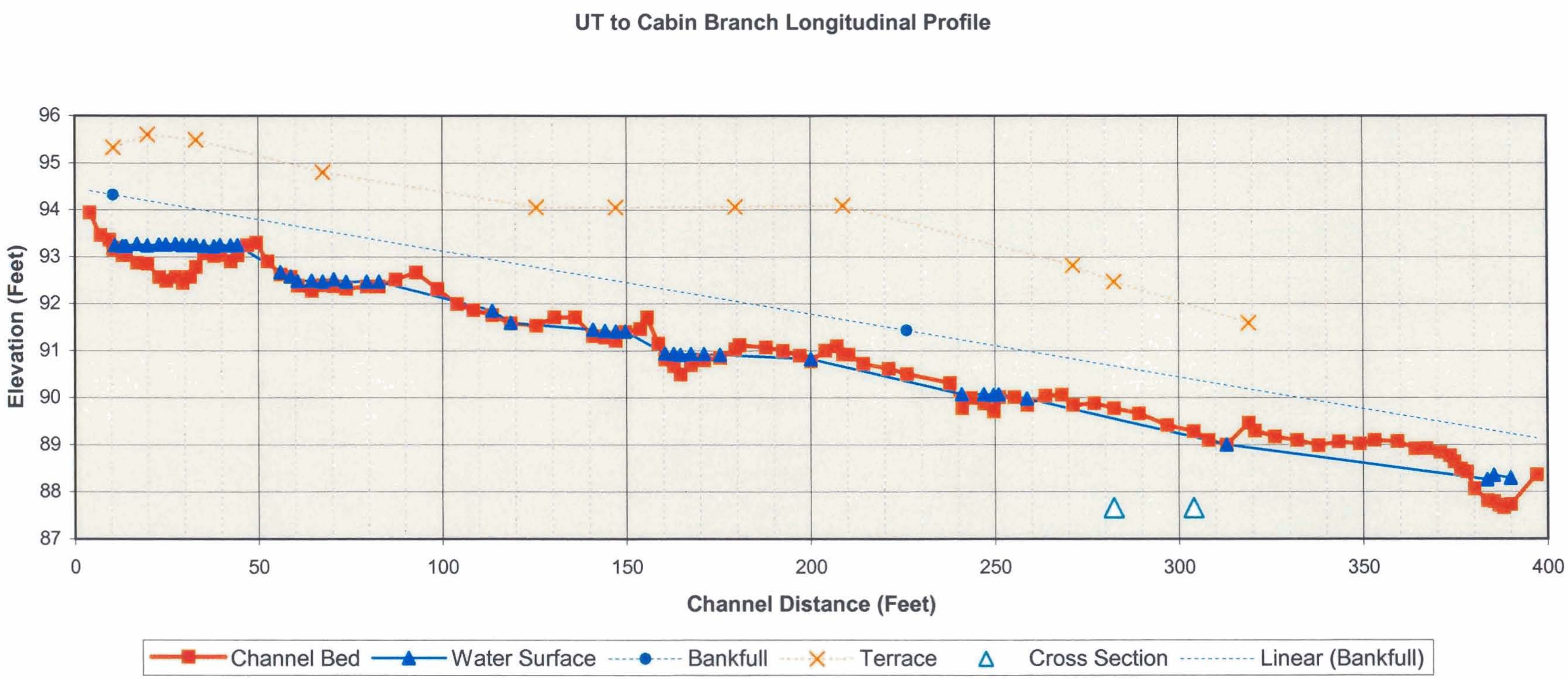
Station	Elevation Streambed	Elevation Bankfull
1.6	96.00	93.83
3.0	95.86	
5.0	95.63	
6.5	95.51	
8.5	95.21	
9.9	95.15	
15.5	94.79	
16.8	94.65	
17.7	93.83	
18.6	93.23	
19.3	92.97	
19.8	92.63	
20.3	92.38	
20.7	91.99	
22.3	91.94	
23.5	91.78	
24.1	91.64	
25.9	91.76	
28.4	91.77	
29.0	91.87	
29.3	92.81	
30.5	93.22	

Bankfull Area	21.4	sq.ft
Bankfull Width	14.3	ft
Max depth	2.2	ft
Mean depth	1.5	ft
Width/Depth Ratio	10	
Flood Prone Width	47.0	ft
Entrenchment Ratio	3.3	

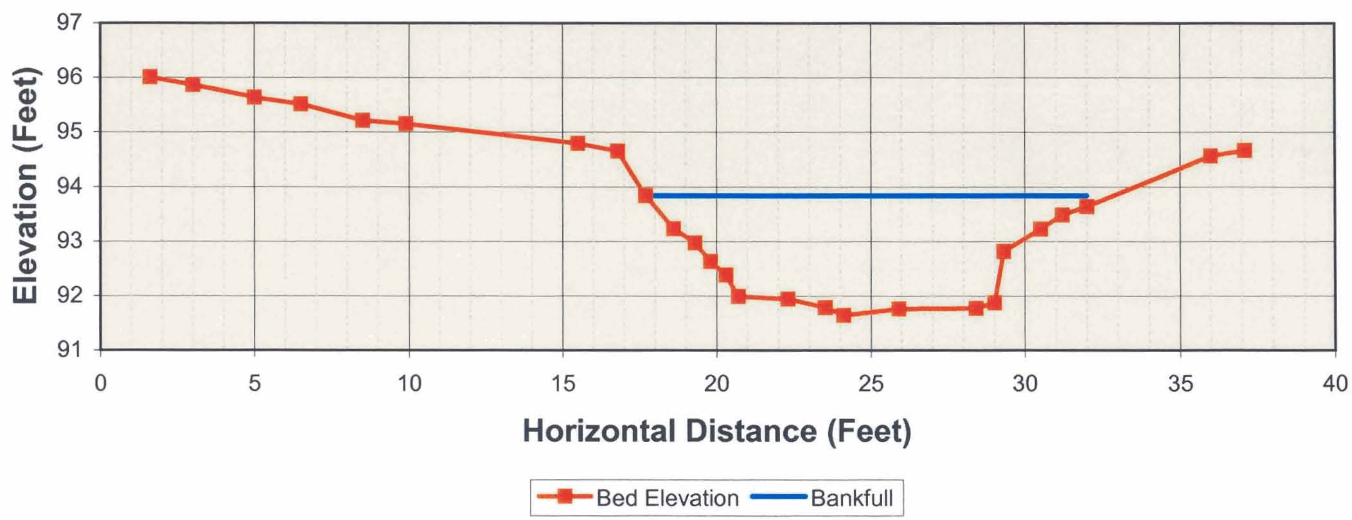
Pool

Station	Elevation Streambed	Elevation Bankfull
2.0	95.30	93.62
3.8	95.06	
5.0	94.93	
6.5	94.97	
8.6	95.08	
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	

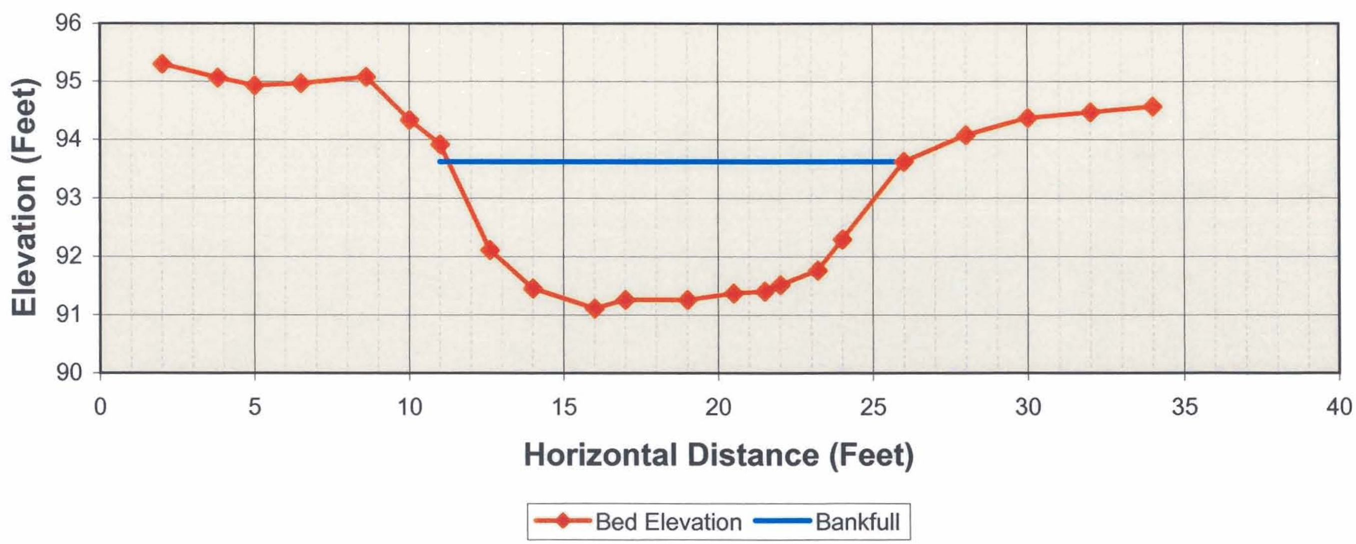
Bankfull Area	27.2	sq.ft
Bankfull Width	14.7	ft
Max depth	2.5	ft
Mean depth	1.8	ft

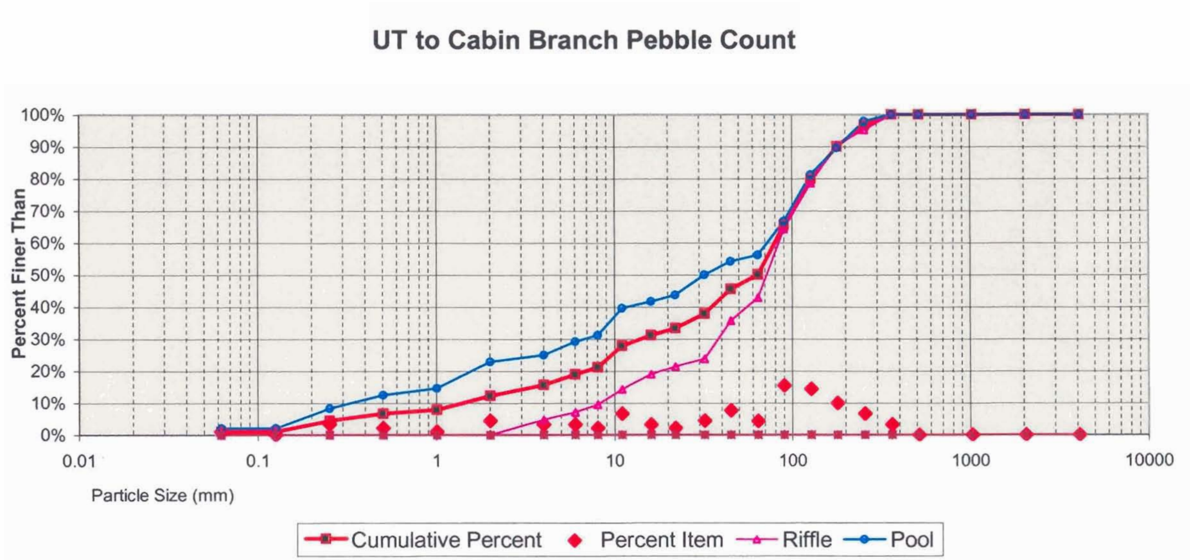

UT to Cabin Branch Longitudinal Profile
Elevation (Feet)
96
95
94
93
92
91
90
89
88
87
0
50
100
150
200
250
300
350
400
Channel Distance (Feet)
Channel Bed
Water Surface
Bankfull
Terrace
Cross Section
Linear (Bankfull)

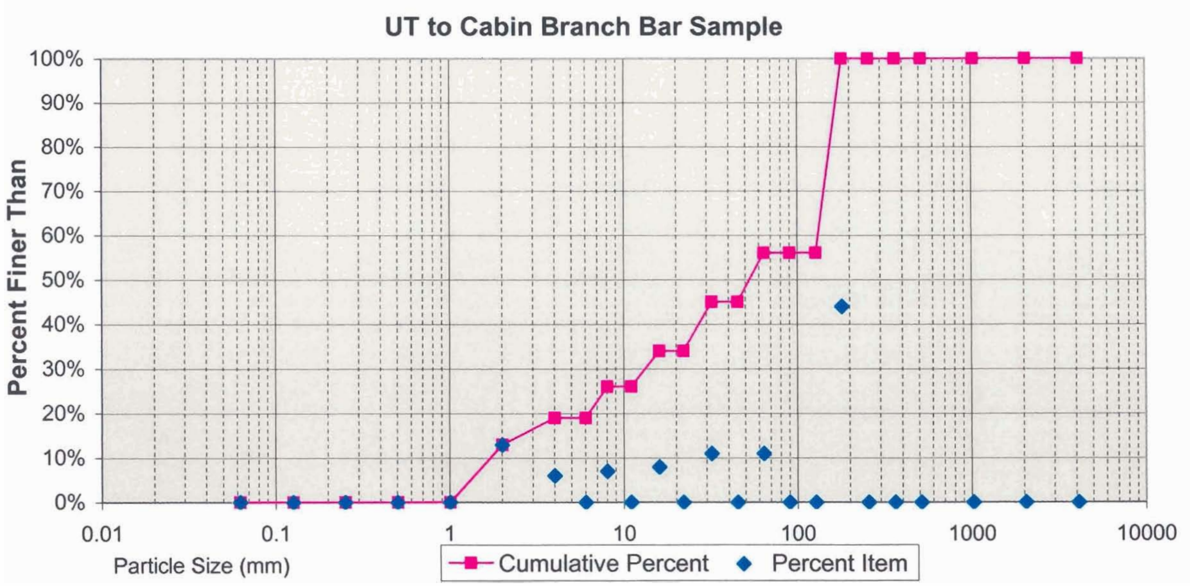
UT to Cabin Branch Riffle Cross-Section



UT to Cabin Branch Pool Cross-Section




UT to Cabin Branch 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 Cabin Branch 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 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

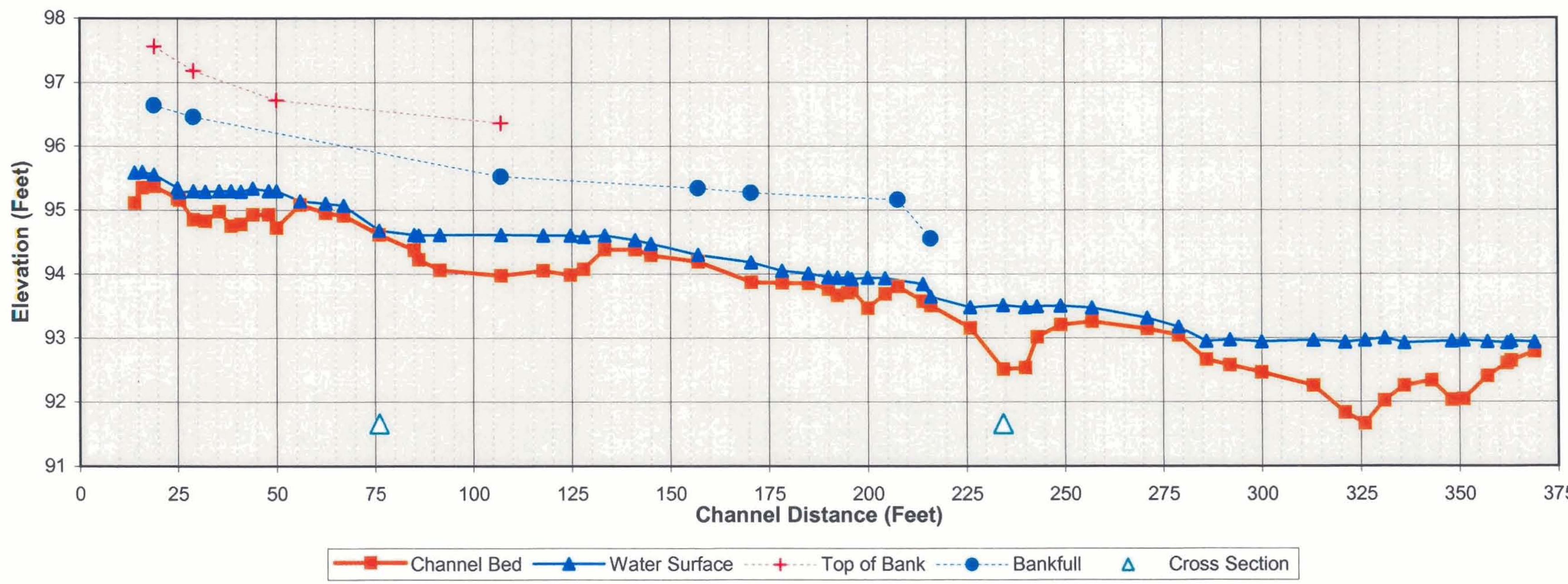
Bankfull Area	33.5	sq.ft
Bankfull Width	27.6	ft
Max depth	2.0	ft
Mean depth	1.2	ft
Width/Depth Ratio	22.8	
Flood Prone Width	140.0	ft
Entrenchment Ratio	5.1	

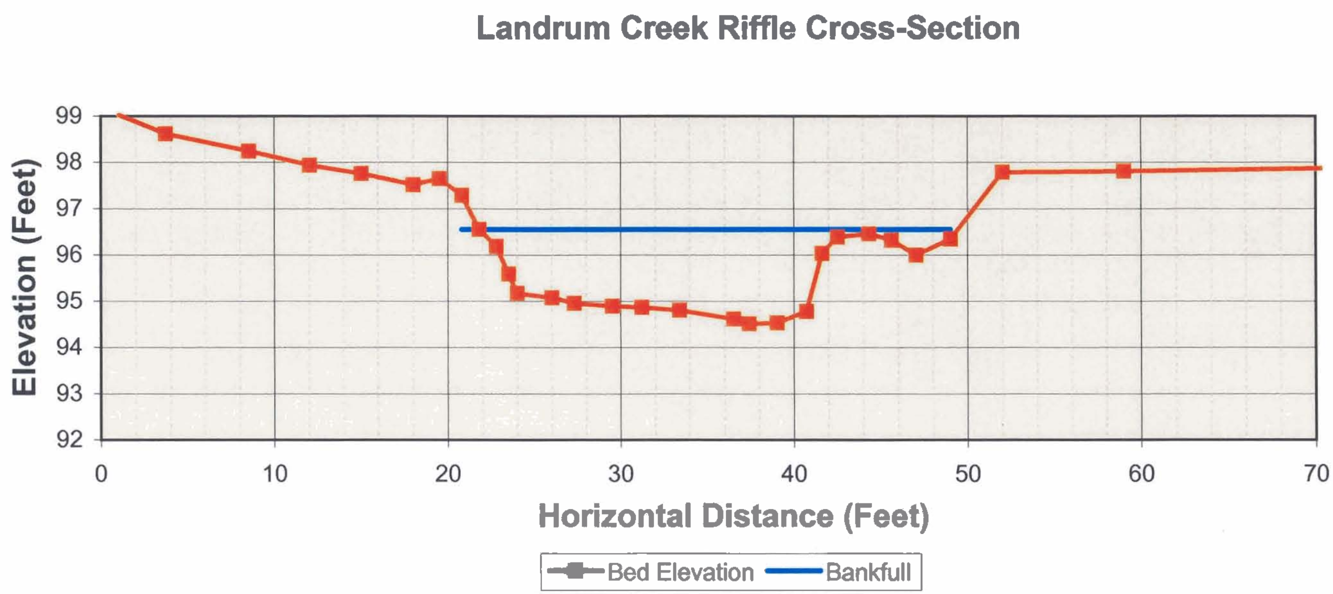
Pool

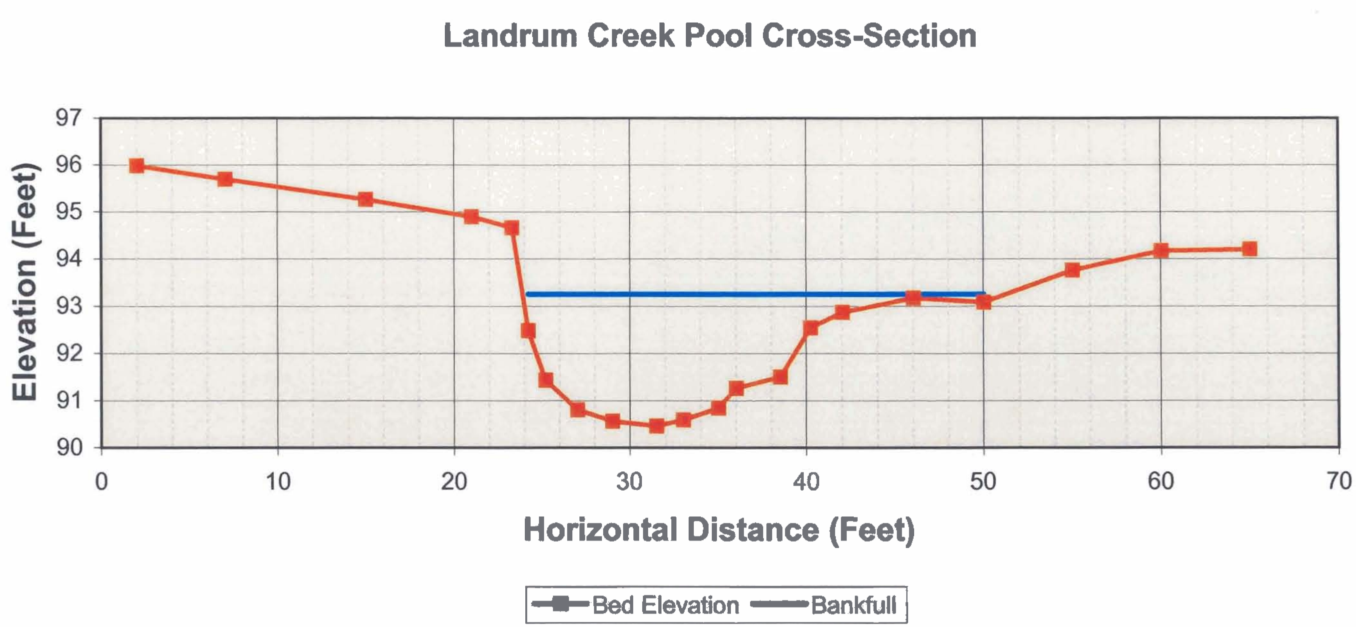
Station	Elevation Streambed
2	95.98
7	95.69
15	95.26
21	94.89
23.3	94.66
24.2	92.48
25.2	91.43
27	90.8
29	90.56
31.5	90.46
33	90.59
35	90.84
36	91.26
38.5	91.5
40.2	92.54
42	92.87
46	93.17
50	93.08
55	93.76
60	94.17
65	94.2

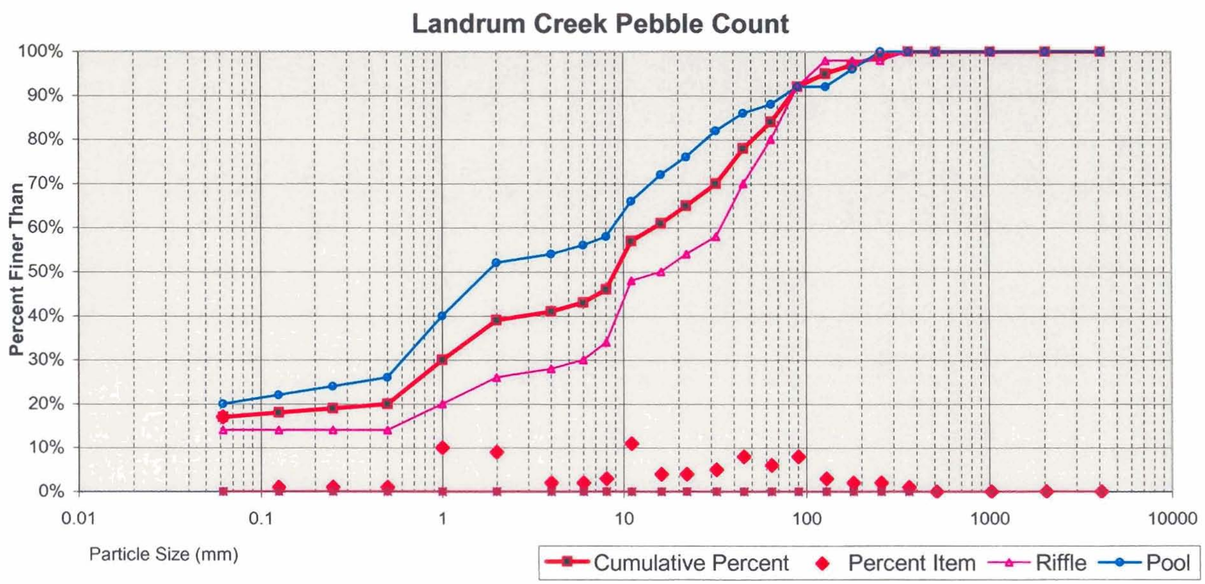
Bankfull Area	37.9	sq.ft
Bankfull Width	27.4	ft
Max depth	2.8	ft
Mean depth	1.4	ft

Landrum Creek Reference Reach Longitudinal Profile

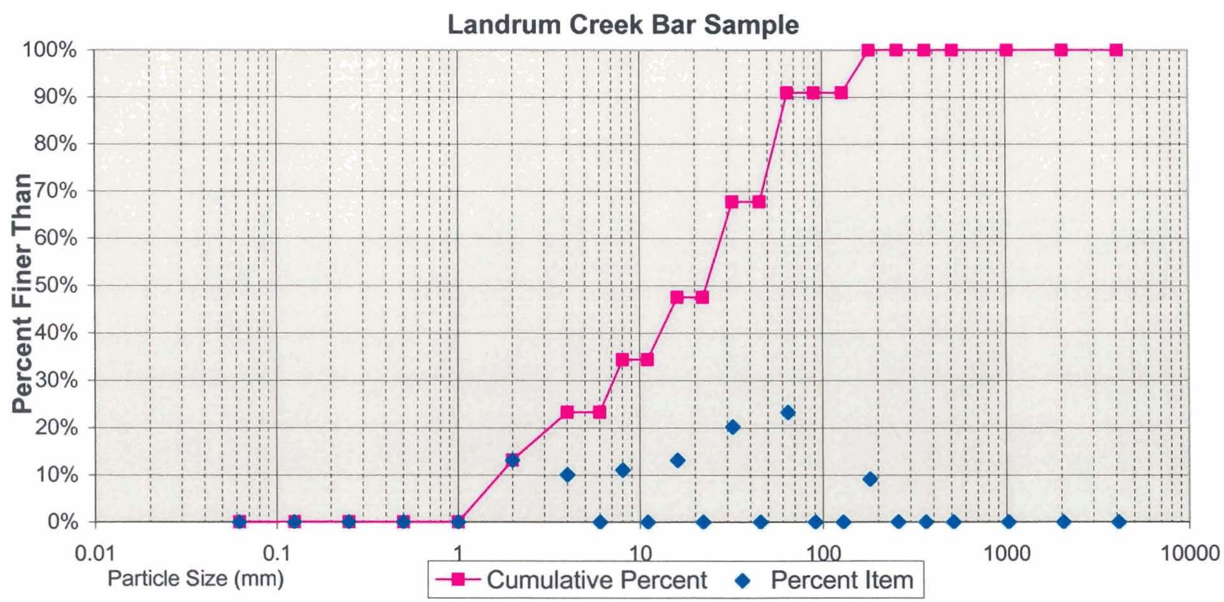



Landrum Creek Riffle Cross-Section
Elevation (Feet)
99
98
97
96
95
94
93
92
0
10
20
30
40
50
60
70
Horizontal Distance (Feet)
Bed Elevation
Bankfull


Landrum Creek Pool Cross-Section
Elevation (Feet)
97
96
95
94
93
92
91
90
0
10
20
30
40
50
60
70
Horizontal Distance (Feet)
Bed Elevation
Bankfull



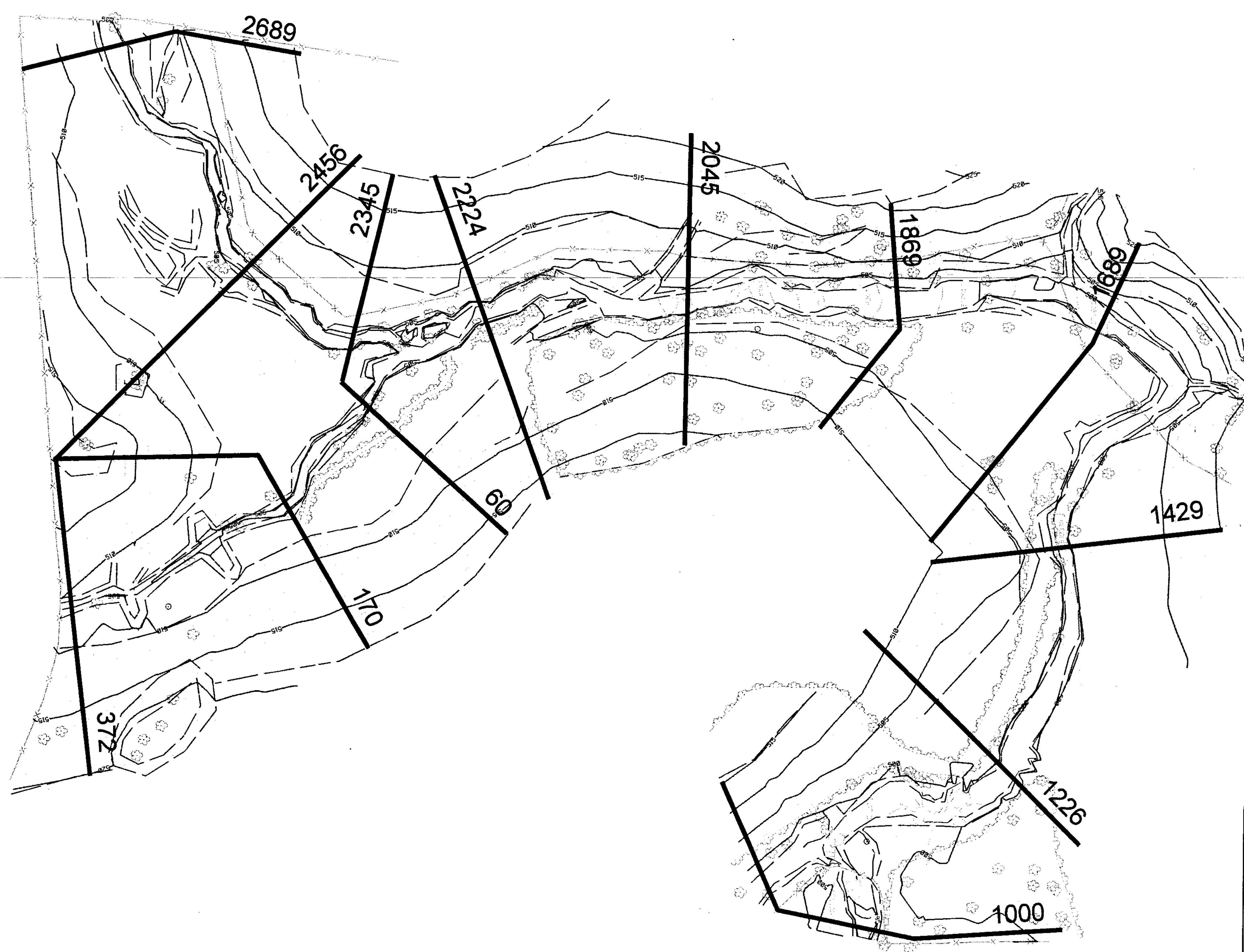
Landrum Creek Pebble Count
Percent Finer Than
Particle Size (mm)
Cumulative Percent
Percent Item
Riffle
Pool



Landrum Creek Bar Sample
Percent Finer Than
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 Marys Creek

Restoration Plan
Dixon Property
Alamance County, North Carolina

HEC-RAS Cross -Section Locations

Scale: 1″ = 100′

APPENDIX D
HEC-RAS ANALYSIS

STATION	STORM	DISCHARGE (cfs)	EXISTING WATER SURFACE ELEVATION (ft)	PROPOSED WATER SURFACE ELEVATION (ft)	BACKWATER (ft)
Downstream Main Channel					
600	Bankfull	112.3	494.93	494.93	0
600	100 yr	1049	499.17	499.17	0
800	Bankfull	112.3	495.53	495.53	0
800	100 yr	1049	499.77	499.77	0
1000	Bankfull	112.3	496.19	496.34	0.15
1000	100 yr	1049	500.38	500.36	-0.02
1231	Bankfull	112.3	498.42	498.84	0.42
1231	100 yr	1049	502.15	502.13	-0.02
1429	Bankfull	112.3	500.53	500.5	-0.03
1429	100 yr	1049	503.8	503.71	-0.09
1689	Bankfull	112.3	501.63	501.58	-0.05
1689	100 yr	1049	505.84	505.19	-0.65
1869	Bankfull	112.3	502.63	502.78	0.15
1869	100 yr	1049	506.11	505.97	-0.14
2045	Bankfull	112.3	504.25	504.35	0.1
2045	100 yr	1049	507.31	507.25	-0.06
2224	Bankfull	112.3	504.94	505.1	0.16
2224	100 yr	1049	509.04	508.91	-0.13
Upstream Main Channel					
2345	Bankfull	80.6	505.18	505.52	0.34
2345	100 yr	826	509.03	509.01	-0.02
2456	Bankfull	80.6	505.7	505.9	0.2
2456	100 yr	826	509.9	509.9	0
2689	Bankfull	80.6	507.37	506.85	-0.52
2689	100 yr	826	510.03	510.02	-0.01
Secondary Channel					
60	Bankfull	36.9	505.26	505.59	0.33
60	100 yr	470	509.52	509.5	-0.02
170	Bankfull	36.9	505.84	505.81	-0.03
170	100 yr	470	509.63	509.59	-0.04

APPENDIX F

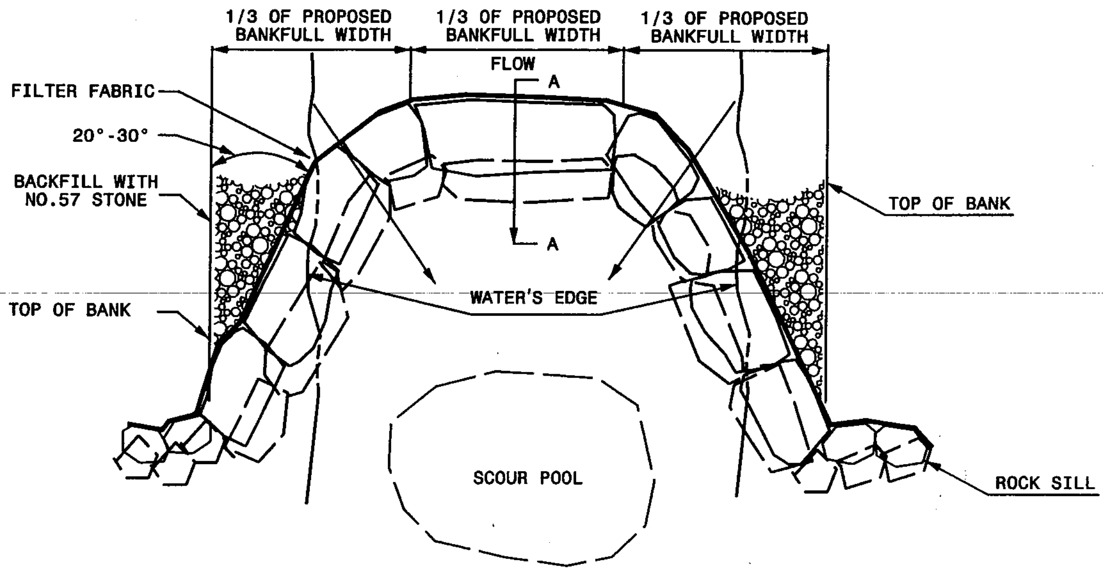
STRUCTURES USED FOR NATURAL CHANNEL DESIGN

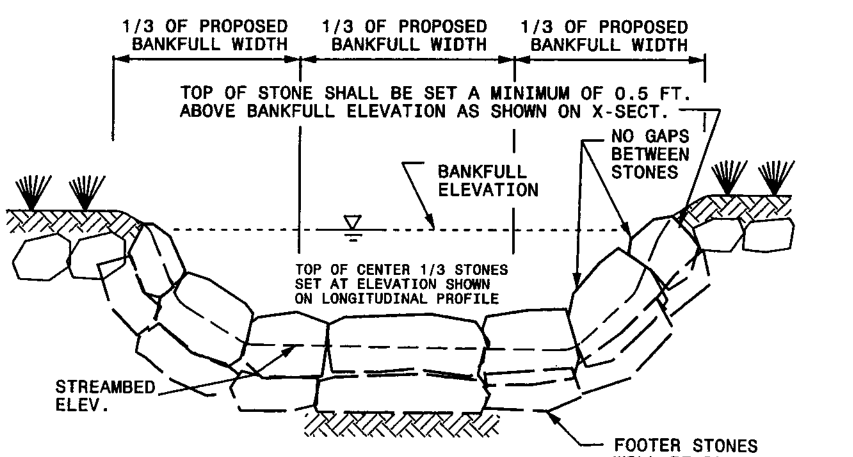
ROCK CROSS VANE

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

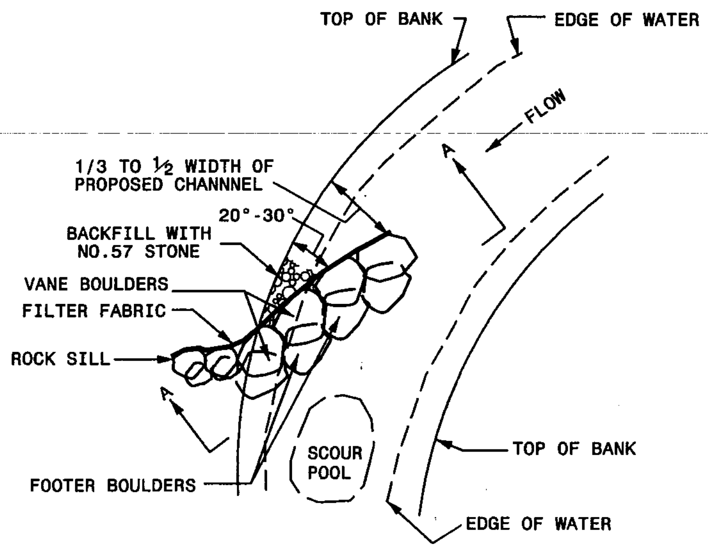
ROCK VANE

SCALE: NTS

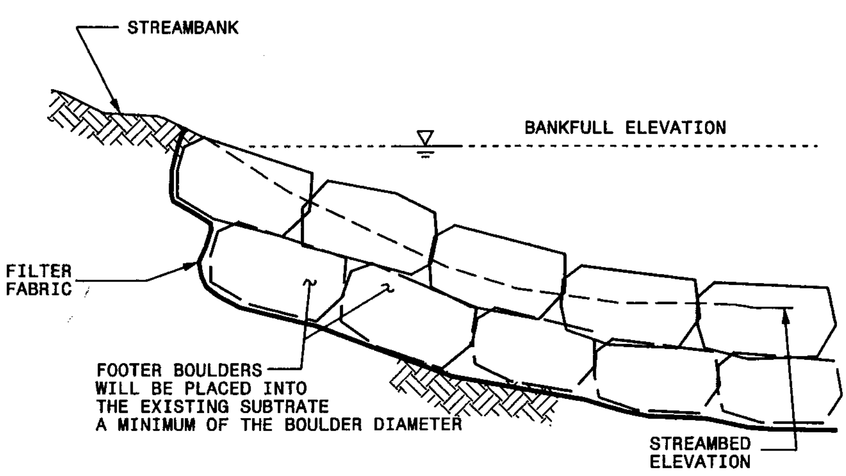
NOTES:
1. ALL STONES ARE TO BE STRUCTURE STONE.
2. GAPS BETWEEN BOULDERS SHALL BE MINIMIZED BY FITTING BOULDERS TOGETHER, PLUGGING WITH STRUCTURE STONE CLASS A AND NO.57 AND LINING WITH FILTER FABRIC.
3. DIMENSIONS AND SLOPES MAYBE ADJUSTED TO FIT BY THE ENGINEER.
4. A DOUBLE FOOTER BOULDER SHALL BE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

SLOPE OF VANE FROM CENTERLINE TO TOP OF BANK SHALL BE 2-7%



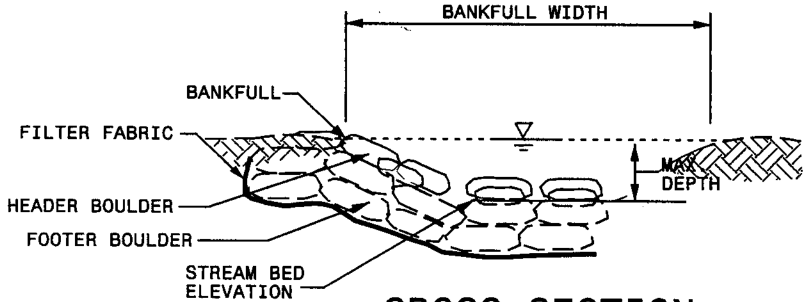
PLAN VIEW



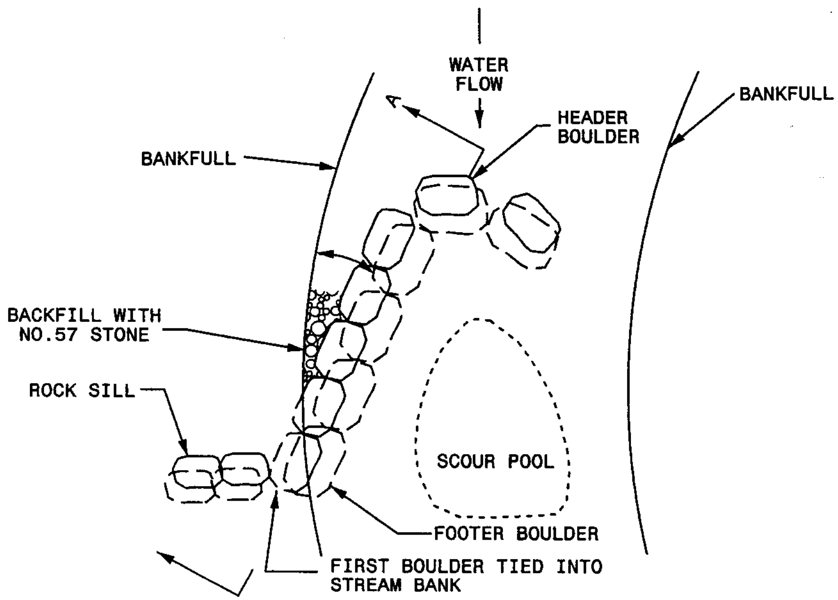
SECTION A-A

J-HOOK VANE

SCALE: NTS



CROSS SECTION

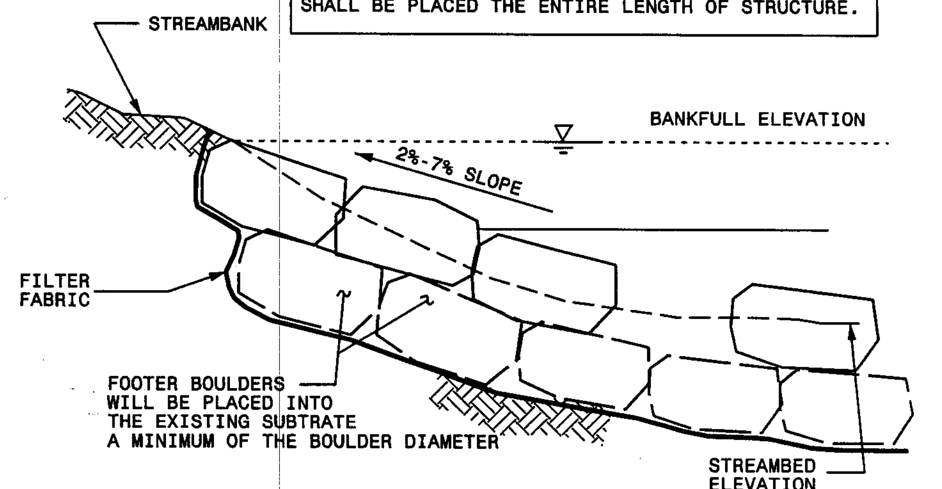


PLAN VIEW

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

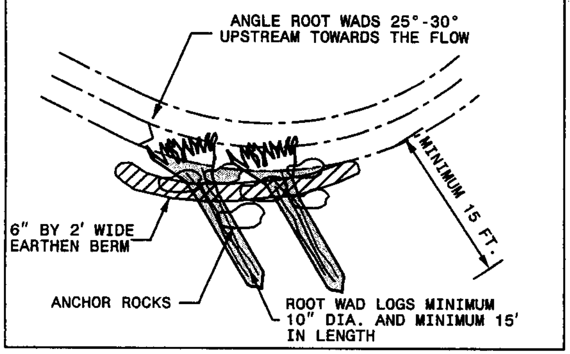
ROOT WAD

SCALE:NTS

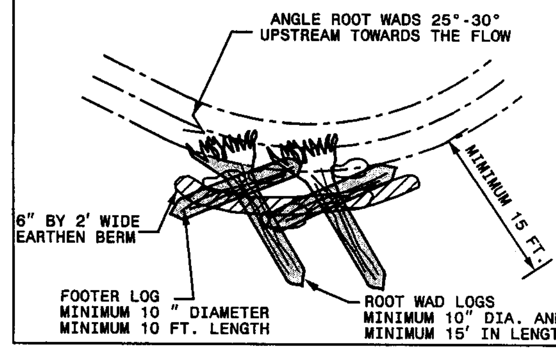
NOTE:
1. ALL STONES ARE TO BE STRUCTURE STONE.
2. SIDE SLOPES WILL BE MATTED
3. 6" BY 2' WIDE EARTHEN BERM LOCATED ATOP ROOT WADS TO DIRECT SHEET FLOW AWAY FROM ROOT WADS.

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

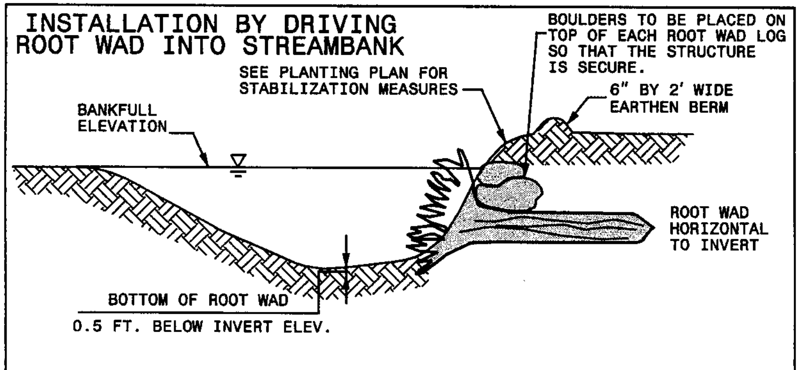


INSTALLATION BY TRENCHING

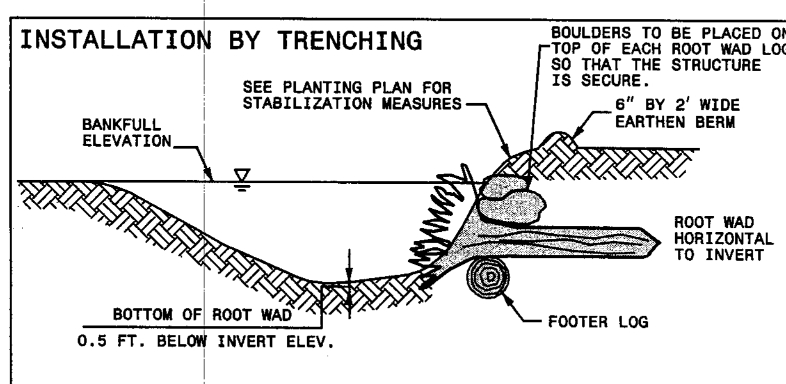


PLAN VIEW

INSTALLATION BY DRIVING ROOT WAD INTO STREAMBANK



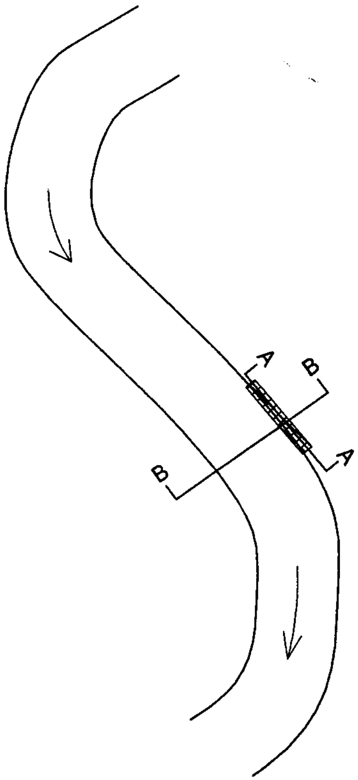
INSTALLATION BY TRENCHING



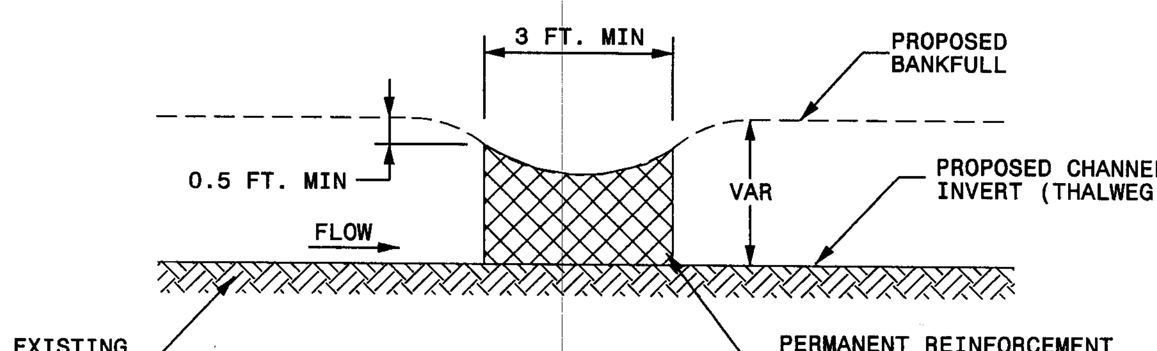
ROOT WADS - CROSS SECTION (CUT)

FLOODPLAIN INTERCEPTOR

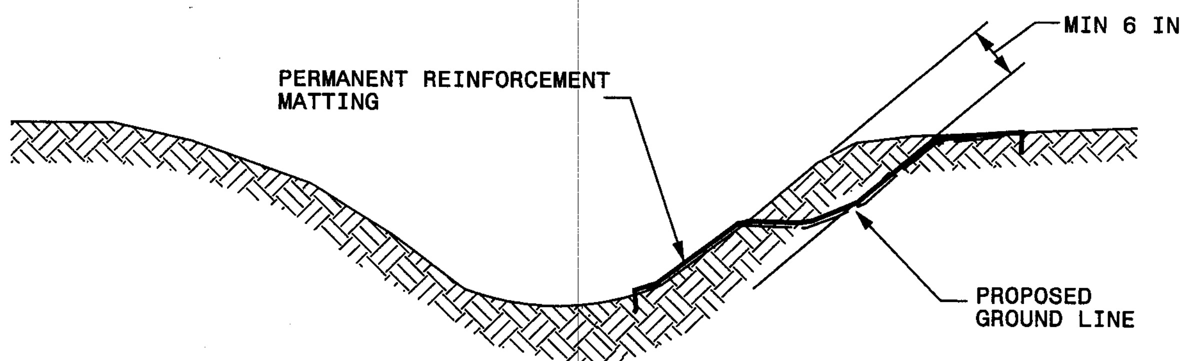
SCALE: NTS



PLAN VIEW



SECTION A-A



KEY IN MATTING A MINIMUM OF 1 FT.

SECTION B-B