STREAM RESTORATION PLAN

HATCHET'S GROVE TRIBUTARY

WAKE COUNTY, NC
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NC Wetlands Restoration Program

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Table of Contents

List of Tables

List of Figures and Sheets

List of Appendices

Hatchet's Grove Tributary Stream Restoration Plan
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1.0 Introduction

An unnamed tributary of Crabtree Creek, locally known as Hatchet's Grove Tributary, located within the confines of the Prestonwood Country Club property has been selected by the North Carolina Wetland Restoration Program (WRP) to be restored after securing the conservation easement. Preliminarily, it has been estimated that over 3,700 linear feet of stream channel and approximately 4.0 acres of riparian buffer (Zone 1) will be restored following the implementation of the proposed restoration plan.

The site has been chosen because of the current degraded state of Hatchet's Grove Tributary. The current conditions of the channel are mainly the result of historical channel modifications such as channelization and periodic dredging, past and present day vegetation maintenance practices, existing channel constraints (golf cart bridges), and the incremental increase of stormwater runoff onto the site from adjacent impervious sources.

The majority of the stream banks are nearly vertical and exposed, with minimal vegetative cover. As a result, the banks are actively eroding, subsequently slumping and promoting lateral channel migration and meander creation. The current channel is classified as an "F" type channel (with some sections minimally classifying as an E-type channel) under the Rosgen Stream Classification System. Some sections of channel have limited access to the flood plain during peak flood flows but not bankfull events that occur as a result of the 1.5 to 2 year storm event. The current channel is in an incised state, therefore flood flows are concentrated within the channel and an active flood plain does not exist at the bankfull elevation. The channel is in a progressive state of transition. As a result of the stream bank instability, meanders and a new floodplain located at the bankfull elevation are beginning to take form within the existing confined channel.

The current obviously degraded state of the channel, limited flood plain functionality due to channel incision, existing and future erosion potential, limited native vegetation along the banks and riparian buffer zone, and an amenable landowner to work with, presents this site as a viable restoration project.

The restoration plan proposes to construct a stream channel that is stable and self-maintaining that will not aggrade or degrade over time by utilizing Rosgen-based natural channel design procedures and techniques. This will be accomplished by fulfilling the following objectives:

1) Develop a channel with the appropriate cross-sectional dimension, pattern, and longitudinal profile utilizing the existing channel condition survey, and collected reference reach data as a guide.
2) Improve and create bed form diversity (riffles, runs, pools, and glides).
3) Construct a flood plain (bankfull bench) that is accessible at the proposed bankfull channel elevation (Priority II restoration).
4) Insure channel and stream bank stabilization by integrating grade control structures, root wads, and native vegetation, in conjunction with the eradication or modification of current grounds maintenance practices.

5) Establish a native forested riparian plant community within a minimum of 30 feet, when possible, from the edge of the restored reach.
6) Integrate existing golf course uses with the proposed restoration plan providing aesthetic and education values.

1.1 Project Site Description

The proposed restoration site is currently being utilized as a golf course facility, owned, operated and maintained by the Prestonwood County Club. The project site is specifically located approximately 2,600 feet southwest of the Morrisville-Carpenter Road (SR 3014)/Aviation Parkway (SR 3015) Intersection and 3,000 feet east of Davis Drive (SR 1613), Morrisville, Wake county, North Carolina (Figures 1-3). The project is entirely located within the Prestonwood Country Club property.

Hatchet's Grove Tributary flows from west to east and empties directly into Crabtree Creek, which flows from the south to the north. An unnamed tributary, which intersects Hatchet's Grove 400 feet from the western property boundary flows from west to east also. The project initiates at the western-most property line and terminates at a sanitary sewer line approximately 100 feet upstream of the confluence with Crabtree Creek.

The project site currently exhibits numerous existing uses. The primary land use within the site is as a golf course facility, which includes all of the amenities and structures required to access, maintain, and service the area for this purpose. Structures include 6 golf cart bridges, numerous asphalt paths, five ponds, two sanitary sewer lines, irrigation facilities, multiple stormwater outfalls, fairway under-drain discharge pipes, and tee boxes. Access within the site is provided by six 30-foot long golf cart bridges that cross the project stream starting approximately 450 feet down stream of the project origin and are sporadically located along the channel reach with the sixth bridge located approximately 300 feet upstream of Crabtree Creek. Utilities are also located within the site consisting of two sanitary sewer lines, and a CP&L 100-foot wide power line easement. The main sanitary sewer line is located south and parallel to Hatchet's Grove along the entire length of the project stream. The easement is located along the right bank starting at the western property boundary, crossing the unnamed tributary at a 45 degree angle and continues along Hatchet's Grove until it joins Crabtree Creek were the line crosses Hatchet's Grove at a perpendicular angle and continues parallel to Crabtree Creek. The location of the sewer line along the right bank of Hatchet's Grove has subsequently confined, restricted and limited any potential restoration of the creek along this area. Amenities on site include five ponds, that were used as borrow sources to create tee boxes, elevated greens, and other fairway features.

1.2 Stream Survey Methodology

A field reconnaissance of the channel was performed prior to the commencement of the site survey. The purpose of the reconnaissance is to identify the bankfull elevation utilizing existing indicators. Typical bankfull indicators were obscured and sporadic due to active bank erosion, slumping, grounds maintenance activities, and past channel modifications. Features that were utilized when present included depositional features, vegetation positions, scour lines, and wrack lines. Other feature that were identified during the reconnaissance and subsequently surveyed included existing stormwater outfalls, bridges and utilities.

Soil & Environmental Consultants, PA subcontracted Withers & Ravenel Inc. to survey the existing channel conditions under our field supervision and to develop a 1-foot topographic map of the restoration site. The map was used to evaluate present landscape conditions and

constraints, to determine the final location of the proposed channel alignment, and to calculate required grading volumes.

During the channel survey, 15 cross-sections were completed along Hatchet's Grove Tributary utilizing a total station to collect the field data. The cross-section data is present in Appendix A.

1.2.1 Bankfull Verification

Cross-sectional data that was collected in the field was plotted and subsequently compared to the North Carolina Rural Regional Curve (SRI 2000) for accuracy. All of the cross-sectional areas surveyed plotted within the 95% confidence interval as depicted on Figure 4. The surveyed cross-sections were not utilized to generate the trend line or the 95% confidence intervals.

1.2.2 Stream Classification

The channel was classified utilizing the stream classification system devised by Dave Rosgen (Rosgen 1996). This classification scheme utilizes several parameters based on field collected data and site observation, which collectively determines the stream type. The criteria utilized to determine stream type includes the slope, width/depth ratio, entrenchment ratio, sinuosity, and bed materials. A summary of these channel parameters are available in Appendix A.

2.0 Existing Site Conditions

2.1 Watershed

2.1.1 General Description

The site is located in the Triassic Basin of the Piedmont physiographic region of North Carolina. The surrounding landscape topography is characterized as hilly, with side slopes that are generally steep to moderately sloping. The site topography is relatively flat adjacent to the stream; vertical fall from the project origin to the confluence with Crabtree Creek is approximately 6 feet resulting in a valley slope of 0.0022 based on the 1-foot topographic map provided by Withers & Ravenel. The wide, gently sloping, well-defined flood plain is a Valley Type VIII as defined in Applied River Morphology (Rosgen 1996).

2.1.2 Surface Waters

The channel is located within the Neuse River Basin, USGS Hydrologic Unit 03020201 and DWQ subbasin 030402 (USGS 1974 and DENR 1992). Hatchet's Grove Tributary flows directly into Crabtree Creek (Stream Index Number 27-33-(1)), which also correlates with the terminus of the project. The North Carolina Division of Water Quality (NC DWQ) has not assigned a stream index number to Hatchet's Grove Tributary or the unnamed tributary located within the project site. The current State classification of the stream is Class **C NSW** waters (DENR 1992). Class **C** waters are protected for aquatic life propagation and survival, fishing, wildlife, secondary recreation, and agriculture. The **NSW** designation is a Nutrient Sensitive Waters which require limitations on nutrient inputs. Based on the most recent USGS quadrangle the restoration channel is a 3rd order stream and the drainage area at the terminus of the project is approximately 3.7 mi^2 (Figure 5).

2.1.3 Soils

The project site is located in the Triassic Basin region of the North Carolina Piedmont physiographic province. Soils present in the riparian areas adjacent to Hatchet's Grove Tributary are characteristic of those found in alluvial landforms in the Triassic Basin. However, extensive grading and filling associated with the golf course has likely modified much of the naturally occurring soils onsite.

Chewacla soils (*Aquic Fluventic Dystrochrepts*) are the prevalent map unit along the channel. Formed in fine loamy alluvial material, they are somewhat poorly drained with low natural fertility. Wehadkee soils (*Fluventic Haplaquepts*) are present along the channel to a lesser extent. These soils are also formed in fine loamy alluvial material, and are poorly drained with low fertility. As Hatchet's Grove Branch nears Crabtree Creek, it enters a large, contiguous area of Congaree (*Typic Udifluvents*) mapped immediately adjacent and parallel to Crabtree Creek. These are also alluvial soils with low fertility frequently found on floodplains.

Other soils in the project's vicinity include Augusta (*Aeric Ochraquults*) and Wahee (*Aeric Ochraquults*), which are often mapped on terraces. In the upland areas surrounding the project, Mayodan (*Typic Hapludults*) and Creedmoor (*Aquic Hapludults*) are the predominate soil series, which are both closely associated with the Triassic Basin landscape.

2.1.4 Land Use

Currently, the project site is being utilized as a golf course facility and the majority of the surrounding area located immediately adjacent to the site has been converted to housing (apartments and single family homes), and infrastructure uses (roads, parking lots). Areas of forest and agricultural land exist sporadically throughout the watershed, yet numerous parcels have recently had development plans approved by the local municipalities or are under construction (Figure 6). As a result of the land use conversion, impervious area has been drastically increased to an estimated 15-20%, and is expected to nearly double in the next decade based on current development trends in the vicinity.

2.2 Restoration Site

2.2.1 Site Description

The restoration site consists of a historically modified (re-aligned, channelized, and dredged) stream channel as interpreted from aerial photography supplied by the Wake County Natural Resources Conservation Service. Photographs observed during the file search included years 1949, 1954, 1965, 1971, 1988, and 1993. Based on photographic interpretation, the site has been historically utilized for agricultural production (row crops) from 1949 to the early 1990's. More than likely, the site has probably been farmed since the Civil War. As a result of this past use, the natural plant communities, topography, and hydrologic conditions have been altered or in some cases obliterated. Since the early 1990's, land use in the vicinity has been progressively converted to residential and commercial land uses.

Although the site use has been converted and subsequently stabilized due to the termination of tillage, grounds maintenance adjacent to the channel has continued and is likely more aggressive than it was in the past. Vegetation along the channel is continuously cut down to the edge of the water in order to provide fairway visibility and clearance required for play over. Fairways cross Hatchet's Grove Tributary five individual times within the project site. The maintenance practices combined with increased stormwater discharge resulting from the increase of impervious area within the watershed has resulted in continuous bank failure and channel degradation (scour, down cutting, etc.). Previous historic alteration such has straightening and dredging the channel has increased slope, stream power, and confined flood flows which has perpetuated the channel degradation process.

2.2.2 Existing Stream Conditions

The project stream originates at the Prestonwood County Club's western property line and continues until approximately 100 feet upstream of the confluence with Crabtree Creek. The current channel length of Hatchet's Grove Tributary is approximately 3,200 linear feet. An additional 300 linear feet of an unnamed tributary is located perpendicular to the western property line and parallel to Hatchet's Grove. This tributary joins Hatchet's Grove approximately 250 feet east of the project origin. The total project length is approximately 3,500 linear feet. The channel and site surveys were conducted from July 23 to the 26, 2002. Additional data including the pebble count and BEHIs were collected on the 13 of August 2002. Photographs taken of the project site are provided in Appendix B.

Based on the completed channel survey and observations made during the site reconnaissance, Hatchet's Grove Tributary was historically channelized and subsequently re-aligned during the process. Stream channelization in this case was probably completed to maximize productive

cropland acreage, promote site drainage, and to reduce the historic groundwater table elevation. As a direct result of the channelization procedure, the dredged and lowered channel no longer has full access to the historic flood plain at the bankfull elevation. As a result of this modification the channel is considered to be incised or confined, concentrating flood flows that would have originally been dispersed onto the flood plain. As a result of the incision, boundary shear stress along the banks has increased beyond historical levels and bank erosion and bed scour is fairly prominent.

Bank erosion is present throughout the length of the project reach. Perpetuated by incision, the channel is the preliminary stages of transition from an "F" to a "C" type channel. As depicted on the photograph of cross-section K, a flood plain is beginning to develop at a lower elevation. In this same photograph, evidence of the high banks and lateral channel migration and meander formation is evident.

Computing current bank height ratios, which is the maximum bank height divided by the maximum bankfull depth, can numerically express the extent of channel incision. Utilizing the survey data gathered in the field, bank height ratios averaged 1.96 with a range of 1.5 to 2.1. Typically, bank height ratios on a reference reach streams are 1.0 and rarely greater than 1.1, therefore based on this comparison Hatchet's Grove is extremely incised. Channel adjustments due to these conditions include lateral channel extension, slumping, bed instability, and bank erosion.

Fourteen riffle cross-sections were surveyed along Hatchet's Grove Tributary. Bankfull cross-sectional area ranges from 23.7 to 55.9 square feet. Bankfull width ranges from 14.9 to 27.6 feet with mean depths between 1.6 to 3.0 feet. The stream type varies along the restoration reach from an F to an E, with the majority of the reach emulating an F channel type. The average dimensions are below and the individual cross-sections are summarized in Appendix A.

Bankfull Width:	21.73 feet
Cross-sectional Area:	45.06 square feet
Bankfull Mean Depth:	2.10 feet
Maximum Depth:	3.53 feet
Width/Depth Ratio:	10.75
Entrenchment Ratio:	7.11
Bank Height Ratio:	1.9

Past impacts as explained in the previous paragraphs culminated with current site influences such as increased stormwater flows and intensity, golf cart bridges, and aggressive grounds maintenance are perpetuating and accelerating the degradation process of Hatchet's Grove Tributary. Stormwater sources piped directly into the main stem of the creek have steadily increased following the construction of the golf course and adjacent apartment complexes. The cart bridges installed across the channel, which provide access to the golf course, have constrained the channel and resulted in bed scour and bank erosion immediately below and above each span. The channel is currently crossed by six 30-foot long bridges. The majority of the riparian zone is aggressively maintained because of the numerous fairways that cross the channel. As a result native plants along the riparian buffer are sparse and this area is dominated by Bermuda grass resulting in shallow rooting depths compared to the existing bank heights, essentially providing limited bank stability and very high erodibility indexes. Bank Erodibility Hazard Index sheets were completed in the field and are provided in Appendix C.

2.2.3 Plant Communities

Throughout most of its extent on the property, Hatchet's Grove Tributary flows through a maintained golf course. Thus, the riparian community is severely restricted to the stream banks, and primarily consists of Bermuda grass (*Cynodon dactylon*) as well as a variety of ornamental species (e.g. crepe myrtle, wax myrtle, annual flowers, etc.). Small stands of loblolly pine (*Pinus taeda*) have been left in some areas, partitioning various holes along the course. In patchy spots along and within the banks, smaller individuals of black willow (*Salix nigra*), alder (*Alnus serrulata*), green ash (*Fraxinus pennsylvanica*), and sweet gum (*Liquidambar styraciflua*) occur sporadically, often within the active channel and on top of features such as depositional bars. Periodically, these species are mowed back or removed altogether. To a lesser extent common wetland herbs such as Carex spp. and Juncus spp. were observed within the active channel and banks.

Upstream of the confluence of Hatchet's Grove Tributary and the unnamed tributary, the riparian area along Hatchet's Grove is wooded and intact with the exception of a mowed and maintained sewer easement that is located along the right (south) bank and between the two channels. The unnamed tributary is sporadically forested from the property boundary to the confluence with Hatchet's Grove. The majority of the riparian area along this unnamed tributary is located within utility rights-of-way or adjacent to manicured putting greens. The existing riparian community, consists primarily of bottomland hardwood forest species, including sycamore, sweetgum, red maple (*Acer rubrum*), and river birch (*Betula nigra*). In higher areas along the channels there are small stands of loblolly pine. The shrub stratum generally consists of smaller individuals of canopy species, as well as sourwood (*Oxydenrum arboretum*), various *Viburnum* species, blackberry (*Rubus spp.*), and privet (*Ligustrum sinense*). Japanese honeysuckle (*Lonicera japonica*) and greenbrier (*Smilax rotundifolia*) are particularly vigorous and widespread in the forested riparian area, often blanketing the open forest floor. Virginia creeper (*Parthenocissus quinquefolia*), poison ivy (Toxicodendron radicans) and trumpet creeper (*Campsis radicans*) are present as well.

2.2.4 Wildlife

In order to assess any potential impacts to threatened and/or endangered species that may potentially occur within the project site, a 2-mile radius encompassed of the project vicinity was searched at the North Carolina Natural Heritage Program (NHP) office for known elements of occurrence of federal listed threaten or endangered species and state species of concern. No elements of occurrence of either federally or state-listed species were identified during the NHP file search within the 2-mile search radius. The species that are listed as federally threatened or endangered by the U.S. Fish and Wildlife Service for Wake County are listed below:

Common Name	Scientific Name	Status
Bald Eagle	*Haliaeetus leucocephalus*	Threaten *
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Dwarf wedge mussel	*Alasmidonta heterodon*	Endangered
Michaux's sumac	*Rhus michauxii*	Endangered

* proposed for delisting

Due to the fact that the land use in the project's immediate vicinity (golf course) requires extensive grounds maintenance associated with the landscaping and the degraded state of the

stream channel, no suitable habitat for the above listed federal species was observed within the proposed restoration site.

Elements of occurrence for the following State rare plants, located outside of the 2-mile radius around the project site, include Indian psychic (*Gillenia stipulata*), Carolina thistle (*Cirsium carolinanum*), American bluehearts (*Buchnera Americana*), and Lewis's heartleaf (*Hexastylis lewisii*). Rare animal elements of occurrence outside the evaluated two mile radius include Bachman's sparrow (*Aimophila aestivalis*), four-toed salamander (*Hemidactylium scutatum*), black vulture (*Coragyps atratus*), and *Ceraclea tarsipunctata*, a rare caddisfly species. Each of these occurrences was recorded by NHP to be located within Umstead State Park. The stream restoration is not expected to have any adverse effect on the habitat of any of these listed species; rather, habitat quality will likely be enhanced as a result of the project.

During the field reconnaissance, characteristic piedmont fauna were observed onsite. Tracks of or physical sighting of the following species were observed: whitetail deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), American crow (*Carduelis tristis*), killdeer (*Charadrius vociferus*), mallards (*Anas platyrhynchos*), Great blue heron (*Ardea herodias*), eastern cottontail (*Sylvilagus floridanus*), and red tail hawk (*Buteo jamaicencis*).

3.0 Reference Reaches

The reference reaches described below were utilized as aids in the design process of the proposed Hatchet's Grove Tributary restoration plan not as a template. These channels were chosen because of the similarities that are evident when compared to the project stream. For instance, all of the reference reaches and Hatchet' Grove are located in a wide flat alluvial valley (Valley Type VIII), classify as E type channels, possess fine grained channel substrate, and have low gradient channel slopes (<1%).

3.1 Sal's Branch

Sal's Branch is located approximately 1.5 miles south east of the Highway 70/540 interchange in Umstead State Park, Raleigh, Wake County, North Carolina. Based on the Southeast Durham 7.5-minute topographic quadrangle Sal's Branch is a 1st order stream and the reference survey was collected at a point at which the drainage area was calculated to be approximately 0.35 mi^2. The headwaters of the stream originate at Highway 70, which is predominately characterized as commercial. As the creek flows onto Park property the watershed becomes forested with the exception of an access road and buildings utilized to service the needs of the park and its patrons.

Stream data was collected in July of 2001. Information gathered included pattern and longitudinal profile, cross-sectional area, slope, and pebble count data. Based on the data collected, Sal's Branch was determined to be an E4 channel type when utilizing the Rosgen Stream Classification System. The channel was determined to have a bankfull cross-sectional area of 13.8 square feet, a width of 10.2 feet, and a mean depth of 1.3 feet.

The channel is located in a Valley Type VIII, which is characterized as a wide alluvial valley with a low slope gradient.

3.2 Mill Creek

Mill Creek is located approximately four miles west of the I-77 and SR 1001 interchange, 2,000 feet north of Charity Hill Church at the end of SR 1321, and 7 miles west of Dobson, Surry County, North Carolina. Based on the Bottom and Roaring Gap 7.5-minute topographic quadrangles, Mill Creek is a 3rd order stream with a total drainage area of approximately 4.5 mi^2 at the point that the survey was conducted. The stream is located in an open field utilized for hay production, immediately upstream the land use adjacent to the creek is active pasture. As the valley gradient increases from the point of the survey to the headwaters, the watershed becomes increasingly forested, with farm uses diminishing. The headwaters are predominately forested with single family homes located sporadically along the State maintained roads. Lake Laurel also exists within the upper drainage area with a watershed of approximately 2.0 mi^2.

Stream data was collected in March of 2002. Over 800 linear feet of channel was longitudinally surveyed, five cross-sections were measured, and pebble count data was collected. The channel had an average bankfull cross-sectional area of 27.5 square feet, width of 18.4 feet, and a mean depth of 1.5. Based on the data collected, Mill Creek was classified as an E4 channel.

After the gathered field data was plotted for Mill Creek it was compared to the North Carolina Regional Curve. As a result of the comparison, Mill Creek plotted at or just below the 95% confidence interval. Re-evaluating the data and the watershed conditions we have determined that several key watershed factors may be affecting the dimension of the stream channel. One of

the most predominate features located within the watershed was Lake Laurel which impounds and controls drainage from approximately 2.0 mi^2. It is believed that the dam and outlet structure may have a significant effect on the volume, discharge rate, and timing of flows equivalent to a bankfull event, thereby reducing the discharge rate or altering the timing of the peak flow through the reference reach during the bankfull event (channel forming flow). As a result of the delay, reduction, or elimination of the bankfull storm flow from the portion of the watershed controlled by Lake Laurel, Mill Creek has apparently adjusted its cross-sectional dimension. The active drainage area of Mill Creek after eliminating the Lake Laurel drainage area is approximately 2.7 mi^2. When the collected field data is compared to the presumed active drainage area, the measured cross-sectional area plotted just below the regression line on the regional curve.

Other factors that may be influencing the dimension of Mill Creek include infiltration of flows into the surrounding landscape, other recently constructed ponds within the watershed, and drainage diversion potentially associated with road projects or farming activities.

Mill Creek is also located in a Valley Type VIII.

4.0 Stream Channel Design

4.1 Natural Channel Design

The restoration design for the Hatchet's Grove Tributary is based on natural channel design principles and techniques utilizing reference reach data sets and the existing channel conditions survey data. Reference data that has been utilized to develop the restoration design for the stream channel included the North Carolina Rural Piedmont Regional Curve (SRI 2000), Sal's Branch reference reach data (Doll and Jelenevsky June 2001), Mill Creek reference reach data (Jelenevsky et. al. March 2002), and the Hatchet's Grove Tributary channel survey.

The proposed stream design will restore a naturally meandering E/C type stream channel to a more appropriate location based on the current site constraints as depicted on the Plan View (Sheets 1-5). A bankfull bench or nested flood plain will also be constructed adjacent to channel alignment. The resulting restored stream channel will be approximately 3,700+ linear feet, increasing the overall channel length by approximately 400 linear feet. This restoration is considered to be a Priority II restoration and is being utilized in this case because the flood plain at its current elevation is not accessible at bankfull flows. This design is distinguished as a Priority II stream restoration since a bankfull bench (nested flood plain) will be constructed adjacent to the proposed channel alignment and will be located at a lower elevation relative to the historic flood plain. The existing and proposed morphological characteristics are depicted on Table 1.

The restoration design will result in a riffle-pool channel profile that will be reinforced utilizing in-stream structures such as boulder cross-vanes, J-hook vanes and root wads. The new channel will subsequently be vegetated with transplants, bare-root seedlings and live stakes. Cross-vanes will be installed at the head of every glide/riffle interface and root wads will be installed at every outside meander bend as determined by the designer during the construction phase to ensure stabilization of the stream channel grade and banks. Erosion control matting, temporary seeding, and live stakes will be utilized to reduce bank erosion immediately following completion of each section of channel and provide bank stabilization.

The proposed channel alignment shifts the stream to the north of its current location through three ponds, between two existing fairways and eventually ties into the original alignment upstream of Bridge #6. This alignment is being proposed because of the numerous site constraints present along the current channel corridor. Constraints include the sanitary sewer line that parallels the south stream bank, six (6) golf cart bridges, five (5) fairways, numerous golf cart paths, and multiple stormwater pipes that discharge directly into the creek. If the channel remained in the current location, a Priority II restoration would not be physically feasible because of the present utilities, infrastructure and course layout. In addition, the proposed buffer restoration would be limited because termination of current site uses is not an option.

The proposed alignment will route the restored channel through three existing ponds and between existing fairways as depicted on the plan view sheets. This alignment will provide several advantages to the restoration project. Shifting the creek to the north will minimize existing site constraints and increase the width available for the restoration corridor. The area within the ponds, based on the land survey, will accommodate the proposed channel and bankfull bench. Placing the channel between fairways, as shown on Sheet 4, will provide a suitable belt width in which to meander the channel and permanently establish a forested riparian zone. This alignment

will also eliminate at least three (3) of the current bridge crossings. Only one bridge crossing will need to be installed along the proposed channel alignment as depicted on Sheet 3.

Table 1. Hatchet's Grove Tributary Morphology

Variables	Sal's Branch	Mill Creek	Hatchet's Grove Tributary	Hatchet's Grove Tributary
Survey Crew	Doll/Jelenevsky	Jelenevsky et. al.	S&EC, Withers & Ravenel	Jelenevsky
Survey Date	Jun-01	Mar-02	Jul-02	Oct-02
Parameter	Reference	Reference	Existing Conditions	Proposed Design
Stream Type	E	E4	E5/F5	E5
Drainage Area (mi^2)	0.35	2.6*	3.7	3.7
Bankfull Width (Wbkf)	10.2	18.4	21.73	20
Bankfull Mean Depth (Dbkf)	1.3	1.5	2.1	2.5
Width/Depth Ratio	7.6	12	10.75	8
Max Riffle Depth (Dmax)	1.9	2.9	3.53	3.5-3.6
Max Riffle Depth Ratio (Dmax/Dbkf)	1.5	1.9	1.68	1.4-1.44
Bankfull Cross-Sectional Area (Abkf)	13.8	27.5	45.06	50-60
Bankfull mean velocity (Vbkf)	3.8	4.9	2.94	3.33
Bankfull Discharge (Qbkf)	51.6	134	132.47	166.5
Width of Flood Prone Area (Wfpa)	100	200	170	200
Entrenchment Ratio (Wfpa/Wbkf)	9.8	10.9	7.66	10
Min Meander Length (Lm)	35.0	40	N/A-Straight Channel	80
Max Meander Length (Lm)	43.0	76	N/A-Straight Channel	150
Min Meander Length Ratio (Lm/Wbkf)	2.0	2.2	N/A-Straight Channel	4
Max Meander Length Ratio (Lm/Wbkf)	4.2	4.1	N/A-Straight Channel	7.5
Min Radius of Curvature (Rc)	11	30	N/A-Straight Channel	30
Max Radius of Curvature (Rc)	21	44	N/A-Straight Channel	60
Min Radius of Curvature Ratio (Rc/Wbkf)	1	1.6	N/A-Straight Channel	1.5
Max Radius of Curvature Ratio (Rc/Wbkf)	2	2.4	N/A-Straight Channel	3
Min Belt Width (Wblt)	20	40	N/A-Straight Channel	40
Max Belt Width (Wblt)	62	76	N/A-Straight Channel	110
Min Meander Width Ratio (Wblt/Wbkf)	2.0	2.2	N/A-Straight Channel	2
Max Meander Width Ratio (Wblt/Wbkf)	6.1	4.1	N/A-Straight Channel	5.5
Sinuosity (stream length/valley length)	2	1.8	1.06	1.22
Valley Slope	0.006	0.14	0.0022	0.0026**
Avg. Stream Slope (bkf)	0.005	0.008	0.002	0.0022
Min Riffle Slope (Srif)	0.016	0.007	0.0028	0.005
Max Riffle Slope (Srif)	0.036	0.0367	0.0301	0.01
Min Riffle Slope/Ave Slope (Sriff/Save)	3.0	1	1.4	2.3
Max Riffle Slope/Ave Slope (Sriff/Save)	6.9	5.2	15.05	4.5
Min Riffle Length Lriffle	3.0	12	27.3	15
Max Riffle Length Lriffle	28	60	67.7	50
Min Riffle Length/Bankfull Width (Lrif/Wbkf)	0.3	0.65	1.26	0.75
Max Riffle Length/Bankfull Width (Lrif/Wbkf)	2.7	3.2	3.12	2.5
Pool Slope (Spool)	0	0	0	0
Pool Slope Ratio (Spool/Savg)	0	0	0	0
Pool Depth (Dpool)	2.8-3.26	4.3-4.4	4.2	5.5-6.0
Pool Depth Ratio (Dpool/Dbkf)	2.2-2.5	2.9	2	2.2-2.4
Pool Area (Apool)	24.0	50.5	80.5	70-80
Pool Area Ratio (Apool/Abkf)	1.7	1.8	1.79	1.2-1.6
Pool Length (Lpool)	21-35	21-53	60-182	20-70
Pool Length Ratio (Lpool/Wbkf)	2.1-3.4	1.14-2.8	2.8-8.4	1-3.5
Pool Width (Wpool)	10.2	19-30	33	20
Pool Width Ratio (Wpool/Wbkf)	1	1.0-1.6	1.52	1
Pool/Pool Spacing (p-p)	51-66	30-84	68-202	50-140
Pool Spacing Ratio (p-p/Wbkf)	5.0-6.5	1.6-4.6	3.1-9.3	2.5-7

* Effective Drainage Area

** Valley slope calculated utilizing proposed bankfull bench elevations versus valley length

Shifting the creek to the north will also provide an area to disperse existing stormwater sources that have been connected directly to the creek. The original channel will be fitted with a stormwater pipe that will conduct the majority of the existing stormwater inputs to the large irrigation pond located southeast of the project corridor and adjacent to Crabtree Creek. This pond will then in affect provide treatment to the stormwater originally straight piped into Hatchet's Grove and will also subsidize the golf course's irrigation requirements. This measure should also reduce previous scour, and bank erosion associated with the stormwater outfall structures. Section **4.1.5 Stormwater** explains this issue in further detail.

4.1.1 Dimension

Based on the channel survey, the bankfull cross-sectional area ranged from 23.7 to 55.9 square feet. The average bankfull cross-sectional area is 45.06 square feet. Bankfull width ranged from 14.9 feet to 28.8 feet wide and the average bankfull width is 21.73 feet. Bankfull mean depth ranged from 1.6 to 3 feet deep with an average value of 2.1 feet.

The proposed design width for Hatchet's Grove is 20 feet and an average depth of 2.5 feet. The width and depth was determined utilizing the average measured width of the existing stream, the North Carolina regional curve, reference reach data, existing site constraints and on the required shear stress to move the D_{84} of the reach-wide pebble count. The proposed dimensions result in an E channel type. The depiction of the proposed cross-section is depicted on Figure 7.

4.1.2 Pattern

The current pattern of the existing project reach is essentially straight, with a measured sinuosity of 1.06. Meanders are beginning to form and are evident by the presence of eroding banks flanked by depositional features located on the opposite bank.

As a result of the proposed channel re-alignment through three existing ponds, channel pattern and subsequently sinuosity will be substantially increased. The proposed sinuosity as a result of the proposed alignment will be 1.2. Meanders have been integrated throughout the length of the project reach to the maximum extent possible based on existing site constraints and the reference reach data. The integration of meanders into the proposed restoration design reduces overall channel slope by increasing channel length decreasing shear stress while providing aquatic habitat diversity.

4.1.3 Bed Form

Bed form along Hatchet's Grove Tributary is in extremely poor condition, due to various channel conditions and off-site influences. The majority of the longitudinal profile resembles a riffle/run bed with large scour pools located immediately below each golf cart bridges. Bed form is in a degraded condition because of several culminating factors. Flood flows are concentrated within the incised and constrained channel and this water is typically laden with excess sediment as a result of bank erosion and upstream sediment sources (i.e. construction). This condition is further exasperated by incremental increases in storm water due to development (imperviousness) in the watershed. Increased stormwater runoff, excess sediment, and current site constraints have resulted in a channel that is in constant transition in an attempt to reach equilibrium. Therefore it is unlikely that the bed form remains consistent but fluctuates after each storm event depending on storm intensity.

The restoration design incorporates riffles, runs, pools, and glides into the longitudinal profile providing bed form characteristics exemplified within the reference reaches. Riffles will be located along straight segments of the channel, runs connect the riffles to the pools which are located along the outside meander bends and glides connect the pool to the riffle. Riffles will have a maximum depth of 3.6 feet and the pools will be substantially deeper at a maximum depth of 6.0 feet. The proposed longitudinal profile is depicted on Sheet 6 and is plotted along with the existing channel longitudinal profile. The as built profile may differ slightly because of unforeseen site constraints or limitations that may be discovered during construction (i.e. bedrock).

4.1.4 Riparian Buffer Zone

A riparian buffer area will be established immediately adjacent to the restored stream channel. The riparian zone will include the entire bankfull bench (nested flood plain) and toe slope, which will tie the surround existing grade with the proposed bankfull bench elevation. Typical width will be approximately 25 to 30 feet on either side of the stream channel. These areas will be planted with the appropriate native riparian vegetation and will provide channel stability and stormwater treatment. Species will consist primarily of trees and small shrubs with some specific areas dominated by shrubs only were required by current site constraints (i.e. fairways). The detailed planting plant is addressed in Section 5.0 Planting Plan.

4.1.5 Stormwater

As mentioned in previous sections, there is a large volume of stormwater directly discharged (straight-piped) into Hatchet's Grove from off-site sources. This storm water run off is primarily attributed to impervious area associated with existing roads, parking lots and rooftops within the Legends at Preston Apartments complex. Discharges associated with this facility and its stormwater network are sizeable. During larger storm events (and resultant higher discharges) the capacity of portions of the existing stormwater system are exceeded and flow to Hatchet's Grove Creek is transported overland.

The feasibility of piping the runoff associated with the first inch of rainfall (or some portion thereof) through a pipe network is being evaluated. Such a network could be installed along the general alignment of the existing stream channel. This pipe network would discharge into the existing irrigation pond (located south of Hatchets Grove and adjacent to the west of Crabtree Creek – Sheet 5). The general idea of the network is to pass frequent event discharges through the pipe network while allowing larger events to flow overland, here again along the alignment of the existing stream channel. This swale could then be graded to outfall into the irrigation pond, into the floodplain of the restored channel, or both.

In addition to allowing for the collection, use (and potential reuse) of stormwater for irrigation purposes, passing some portion of the off-site stormwater through the pond will provide a level of treatment (Total Suspended Solids and Total Nitrogen removal) which not currently provided. And, regardless of its outfall location, the passage of the larger portion of the off-site stormwater though the grass-lined swale would still allow for a level of treatment which is currently not provided. In this fashion previously untreated stormwater will be treated is some fashion prior to its discharge into Hatchet's Grove Tributary or Crabtree Creek.

4.2 Stream Structures

In order to provide grade control following construction of the channel, boulder cross-vane and J-hook structures have been integrated with the design and will be utilized to reinforce and stabilize the proposed channel. All structures will be constructed out of natural materials typically consisting of locally quarried boulders. Existing natural grade control and stable channel sections will be incorporated into the channel profile. Although, cross-vanes are depicted at each riffle/glide interface, some of the structures may be omitted during the construction procedures due to naturally occurring site attributes (i.e. bedrock, etc.). Typical structure layouts, which are based on Rosgen designs, are provided on Figure 8 (Rosgen 2001).

4.2.1 Boulder Cross-Vane

The boulder cross-vane structure plan and cross-section view are illustrated on Figure 8. The cross-vane is an in-stream grade control structure that concentrates stream energy toward the center of the channel and away from the near-bank areas reducing shear stress along the banks and preventing bank erosion. This structure serves as grade control within the bed of the channel and reduces the potential of headcutting, creates a stable width/depth ratio, while promoting sediment transport capacity. Since the structure will be constructed in a sandy loam material the upstream side of the structure will be lined with a non-woven fabric and backfilled with excavated channel material and in some cases imported stone aggregate. This is a modification required because of the potential for the structures to "pipe" following installation due to the voids created during the installation of the structure in fine-grained substrate. Piping may eventually lead to structure failure and potentially catastrophic stream bed and bank erosion.

4.2.2 J-hook Vane

The J-hook vane structure plan and cross-section views are also illustrated on Figure 8. This structure is typically used along outside meander bends where the near-bank shear stresses are the highest. This structure will be utilized to reduce potential bank erosion by redirect velocity gradients toward the center of the channel and away from the near-bank area. This structure occupies 2/3 of the bankfull channel cross-sectional area and is constructed similarly to the cross-vane with footer boulders and non-woven fabric.

4.2.3 Root Wads

Root wads will be utilized along the outer-most sections of the meander bends as determined during the construction process. These structures are composed of available native trees with an appropriately sized root fan and an 8 to 12-foot long trunk section. These structures are installed perpendicular to the side of the stream bank with the root fan exposed to the channel while the trunk section anchors the structure in place. If required, logs can be installed immediately below the channel invert to serve as a footer on which the root wad is positioned. The root wad structure serves multiple purposes such as providing protection of the outer bank from potential erosion, diverse aquatic habitat, shade, and a source of detritus.

4.3 Sediment Transport

A naturally stable channel has the ability to transport its sediment load without aggrading or degrading the channel bed. Sediment load is comprised of suspended load, bed load and wash load. Suspended load is comprised of sediment that is being transported in suspension by upward momentum present in the channel. Bed load is comprised of bed material that is transported by

rolling, sliding, or skipping along the channel bed. Wash load is comprised of fine particles that may remain in suspension indefinitely and have very low rates of settling. At high discharge rates, a significant portion of the bed load and potentially the sub pavement may become suspended, especially if the bed material is composed primarily of fine grained material and the substrate is uniform throughout such as sand-dominated channel.

Hatchet's Grove is a sand-dominated stream therefore typically utilized entrainment computations cannot be applied to accurately determine streams competency to move a particular particle size. Entrainment computations are applicable to gravel bed stream where the median diameter of the riffle (d_{50}) is 2 millimeters or larger.

In order to determine if the proposed channel can transport its current sediment load, shear stress was calculated utilizing the dimensions of the proposed riffle cross-section and the designed bankfull slope. The calculated value was then compared to Shield's Curve to confirm that the designed channel could move the D_{84} particle of the reach wide pebble count, which is 13 mm. The formulas utilized and resulting calculations are provided below:

$$\tau = \gamma RS$$

τ = Shear stress (lbs/ft^2)
γ = Specific gravity of water (62.4lbs/ft^3)
R = Hydraulic radius (ft)
S = Bankfull channel slope (ft/ft)

The hydraulic radius is calculated by:

$$R = A/W_p$$

A = Cross-sectional Area (ft^2)
R = Hydraulic radius (ft)
W_p = Wetted perimeter (ft)

Where W_p = (2 * channel depth) + width = (2 * 2.5) + 20 = 25 ft

R = 50 ft^2 (**A**)/25ft (W_p) = 2.0 ft

Therefore, shear stress was calculated to be:

τ = 62.4lb/ft^2 (γ) * 2.0 ft (**R**) * 0.0022 ft/ft (**S**)

τ = 0.275 lbs./ft^2

Shear stress was calculated to be 0.27 lb/ft^2, and Shield's Curve predicts that the proposed stream could move the 17 mm particle. Based on Rosgen's Revised Shields Diagram (Wildland Hydrology 2001) the channel should be able to move a particle larger than 40 mm in size. Because the channel is characterized as a sand-dominated bed, the proposed channel should have the capacity to transport its current sediment load based on the completed shear stress calculations and Shield's Curve.

5.0 Riparian Planting Plan

The majority of the restored riparian zone, which will be located primarily within the created bankfull bench and toe slope areas, will be planted with bare root seedlings consisting of bottomland hardwood species. Native trees and shrubs that are currently located within the channel clearing and excavation limits will be removed with as much of the root ball intact and transplanted adjacent to the restored creek channel or bankfull bench. Trees as large as 4-inches DBH and approximate 20 feet tall will be transplanted and integrated into the buffer restoration when available. Immediately following the completion of the stream channel, the bare root seedlings will be planted during the fall or early spring seasons. During the following fall, supplemental shrub and tree species will be planted if survival rates of previously planted seedlings are below target densities as determined in late summer (August-September). Plant species that will be utilized within the restoration site are listed in the table below.

The restored stream channel will be planted with the appropriate channel bank species in the form of live stakes, bare-root seedlings, and transplants consisting primarily of black willow (*Salix nigra*), silky dogwood (*Cornus amomum*), and elderberry (*Sambucus canadensis*). If quantities from on site sources are not plentiful the live stakes will be supplemented by locally identified plant sources (i.e. existing power line ROWs, adjacent properties, etc.) or purchased from locally reputable nurseries. Black willow will not consist of more than 40 percent of the stream bank plantings.

The planting plan consists of individual hardwood tree species as listed below. The goal is to plant approximately 600 bare-root seedlings per acre, with an approximate 8-foot by 8-foot spacing.

Plant List

Scientific Name	Common Name
Trees	
Fraxinus pennsylvanica	Green ash
Platanus occidentalis	American sycamore
Quercus pagoda	Cherrybark oak
Betula nigra	River birch
Quercus phellos	Willow oak
Acer negundo	Box elder
Quercus nigra	Water oak
Liriodendron tulipifera	Tulip tree
Small Trees and Shrubs	
Cornus amomum	Silky dogwood
Cephalanthus occidentalis	Buttonbush
Alnus serrulata	Tag alder
Salix nigra	Black willow
Sambucus canadensis	Elderberry

* Species composition may be adjusted based on local availability.

6.0 Monitoring Plan

The restoration site will be monitored for five consecutive years or until the required success criteria has been met as determined by NC DWQ and the U.S. Army Corps of Engineers (USACE). Monitoring activities will initiate immediately following the completion of the stream construction in order to alleviate any potential problems as they occur. The riparian buffer restoration will be monitored the following growing season projected to be summer of 2003.

Parameters that will be included in the annual stream monitoring to ensure the success of the restoration activities will include stream channel surveys (longitudinal and cross-sectional profiles), pebble counts, photographs, plant density, diversity and survival inventories, and benthos sampling.

Following the submittal of the monitoring reports to the appropriate agency representatives, the recipients of the report will be contacted for the purpose of discussing the monitoring data, required success criteria and whether or not the site is functioning as expected. If the site is not functioning as expected a site visit will be scheduled with the review agencies so that a remediation plan can be created and implemented. The remediation plans, if required, will directly reflect the requested alterations suggested by the regulatory agencies.

6.1 Stream Channel

Stream channel stability will be monitored by establishing permanent cross-sections located approximately every 500 to 600 feet that will comprise of a nested riffle and pool segment. Each cross-section will be monumented for future identity and survey. All of these cross-sectional surveys will also be utilized as photographic points. Cross-section locations to be monitored will be established immediately following construction during the completion of the "as built" survey. The "as built" report will include the constructed stream channel dimension, pattern, and longitudinal profile. This data will be utilized as a baseline to compare future monitoring surveys and subsequently to determine channel stability and transition. Other stream channel measurements that will be completed during the annual monitoring exercised will include pebble counts, stream pattern data, and stream side plant conditions. Annual inspection of in-stream rock vane structures will also occur to insure channel stability. Stream channel monitoring surveys will be completed annually for five consecutive years, starting 1 year after the completion of the project.

6.2 Riparian Buffer

Vegetation within the restored riparian buffer will be monitored for five consecutive years. Linear transects will be permanently established following completion of the planting phase and start and end points will be permanently monumented and surveyed. The plant species, density, survival rates, and the cause of mortality if identifiable will be recorded along each transect. Vegetation plots will be sampled annually and reported on every other year along with the channel survey. The primary focus of the vegetative monitoring will be solely on the tree and shrub stratum, although herbaceous species encountered may also be recorded. The target density for the riparian buffer is to establish a minimum of 320 native trees species per acre at the end of the 5-year monitoring period. Vegetation monitoring will occur between August and October.

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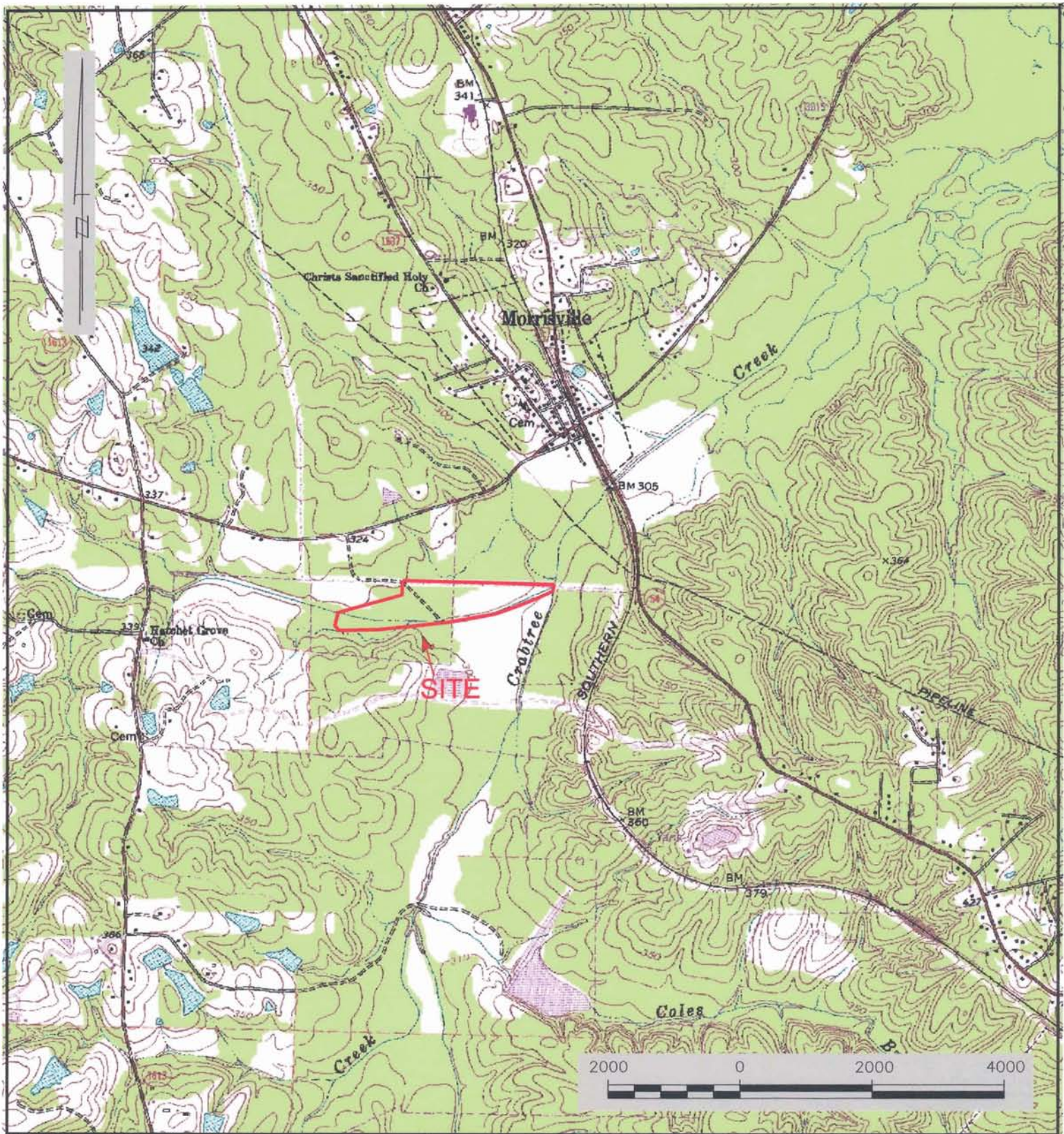

PROJECT NO. 6761	SCALE 1" = 2000'	SHEET TITLE: VICINITY MAP	U.S. GEOLOGICAL SURVEY MAP 1987 — FIGURE 1
PROJECT MGR. PJ	FIELD WORK PJ	PROJECT NAME: NC WETLAND RESTORATION PROGRAM HATCHET'S GROVE STREAM RESTORATION WAKE COUNTY, NORTH CAROLINA OCTOBER 2002	
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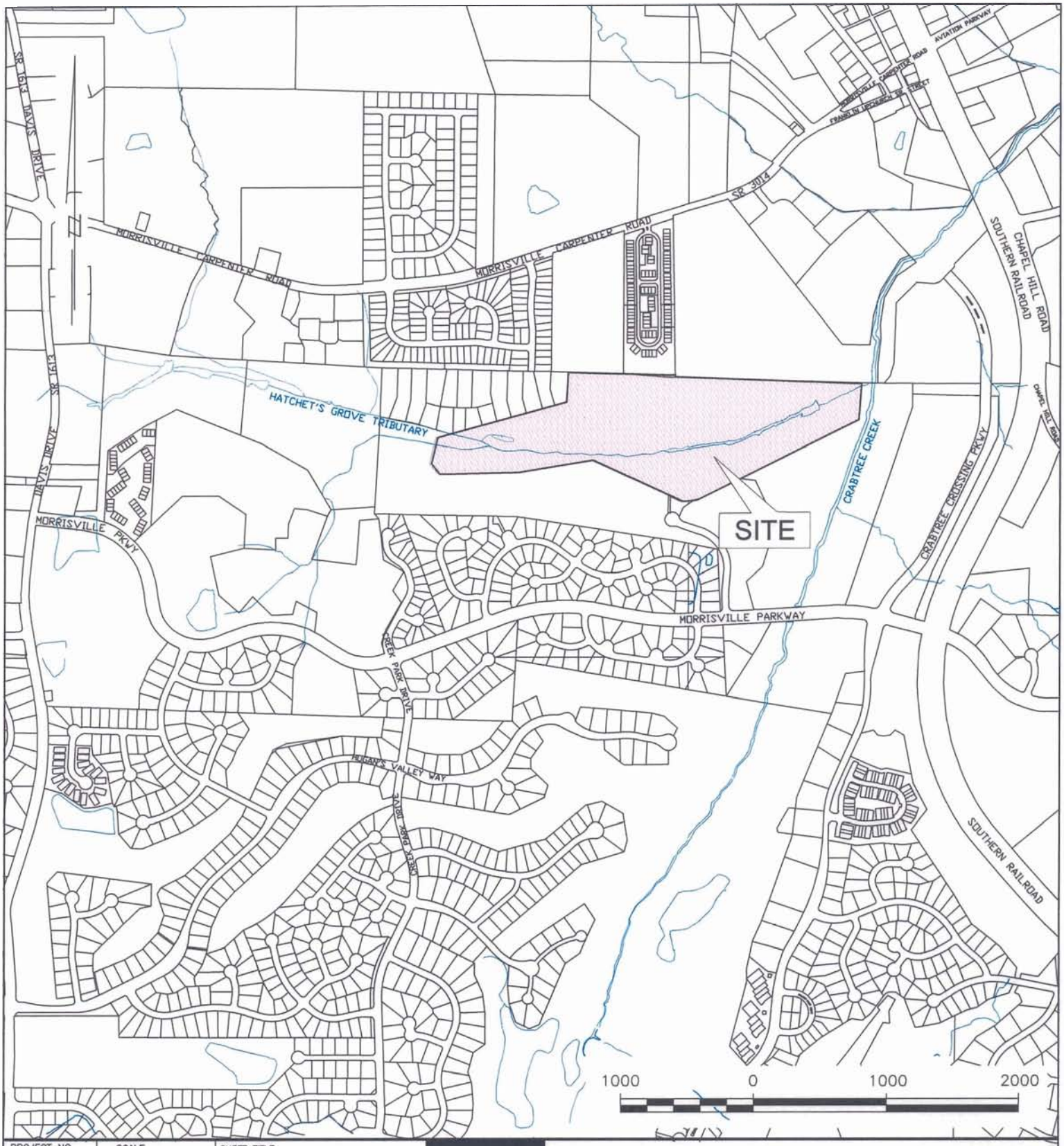

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PROJECT MGR. PJ	FIELD WORK PJ	PROJECT NAME: NC WETLAND RESTORATION PROGRAM HATCHET'S GROVE STREAM RESTORATION WAKE COUNTY, NORTH CAROLINA OCTOBER 2002	FIGURE 2
DRAWN BY MM	FILE SECFILES\6761\ NEWEST10_9\CADASTRAL\OVERALL2.DWG		

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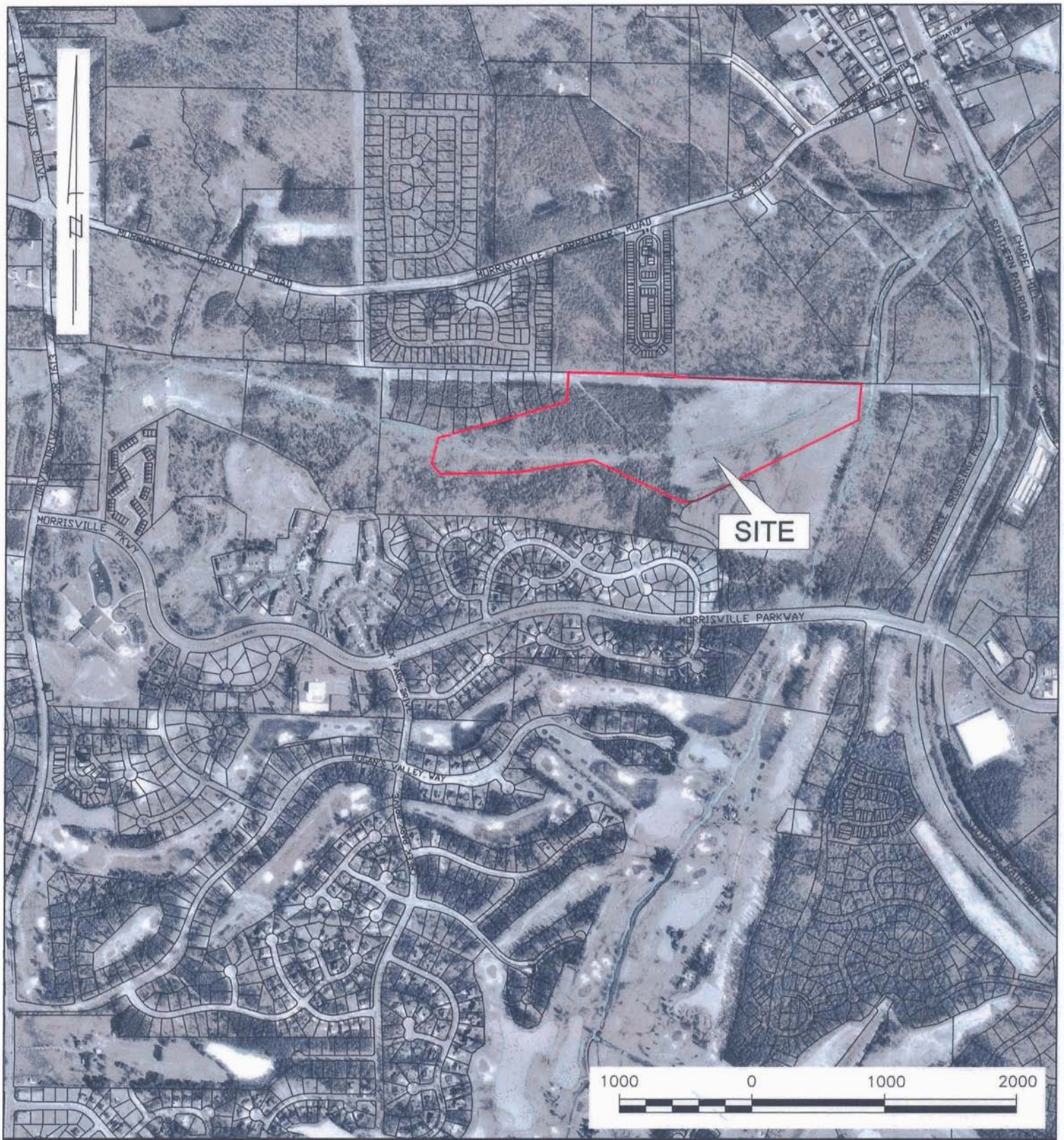

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SHEET TITLE: ORTHOGRAPHIC LOCATION MAP

PROJECT NAME: NC WETLAND RESTORATION PROGRAM HATCHET'S GROVE STREAM RESTORATION WAKE COUNTY, NORTH CAROLINA OCTOBER 2002

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ORTHOGRAPHIC PHOTOGRAPH FROM WAKE COUNTY GIS 1993

FIGURE 3

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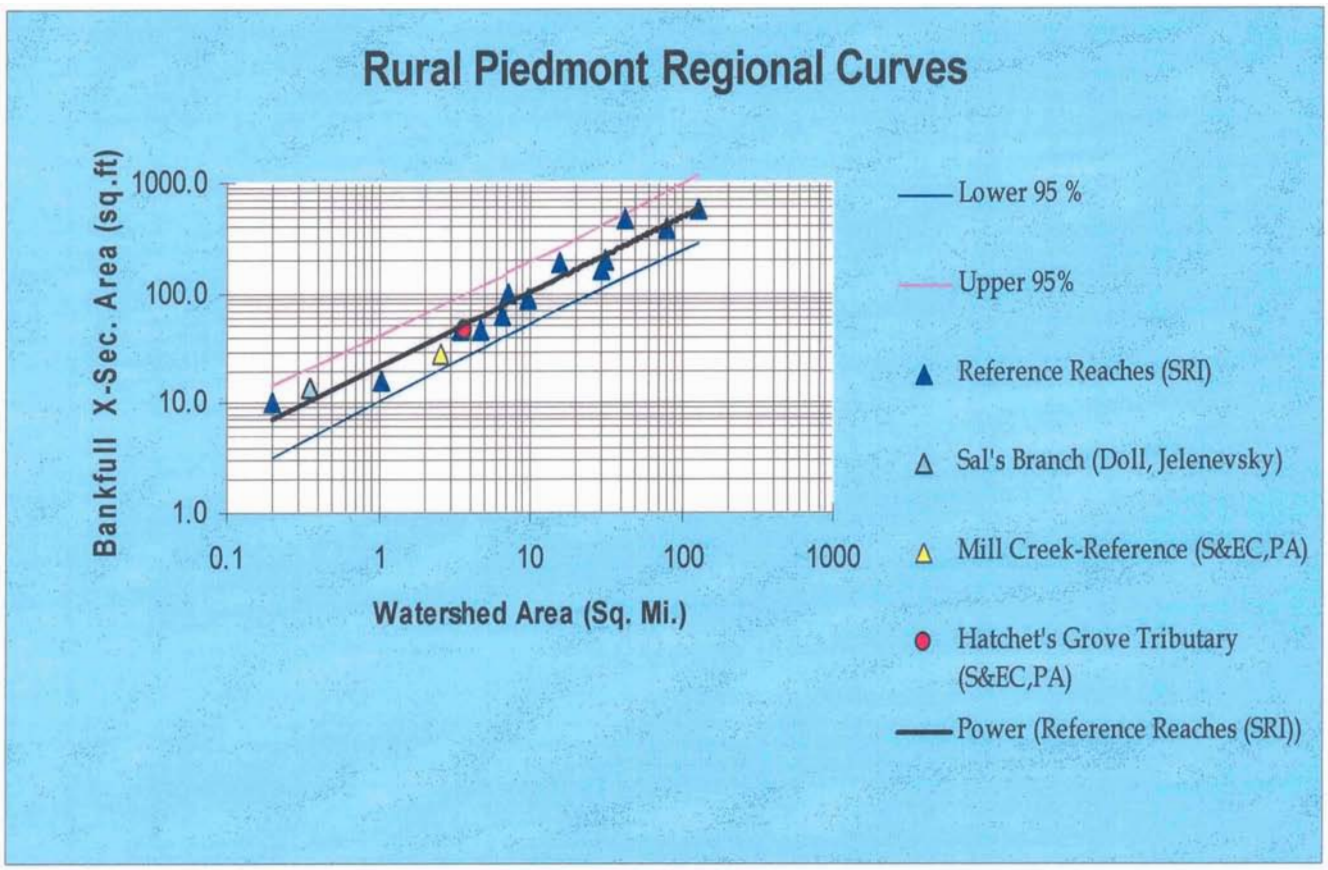
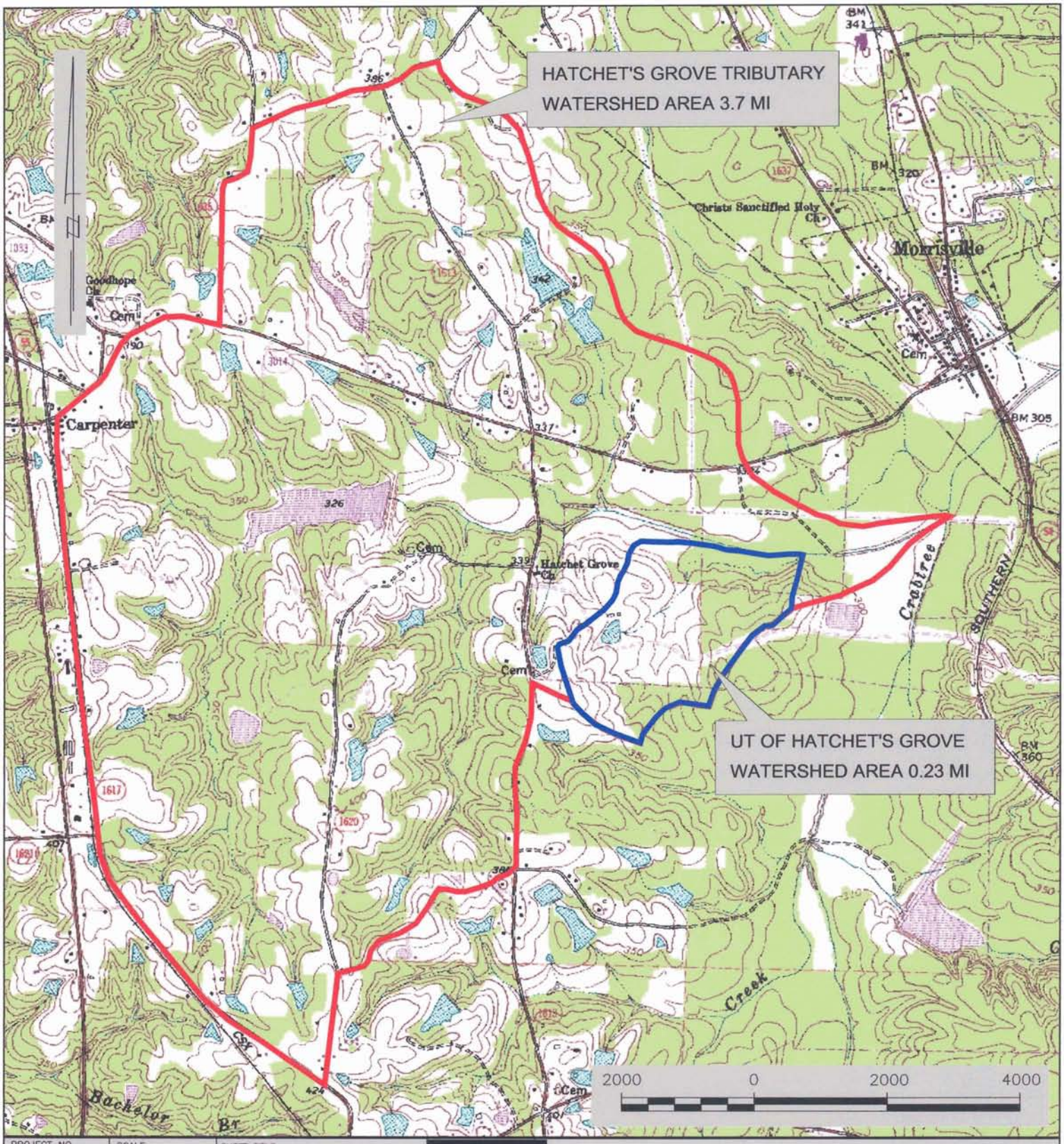


Figure 4
North Carolina Regional Curve



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PROJECT MGR. PJ	FIELD WORK PJ	PROJECT NAME: HATCHET'S GROVE TRIBUTARY NC WETLAND RESTORATION PROGRAM	FIGURE 5
DRAWN BY MM	FILE SECFILES\6761\	WAKE COUNTY, NORTH CAROLINA OCTOBER 2002	
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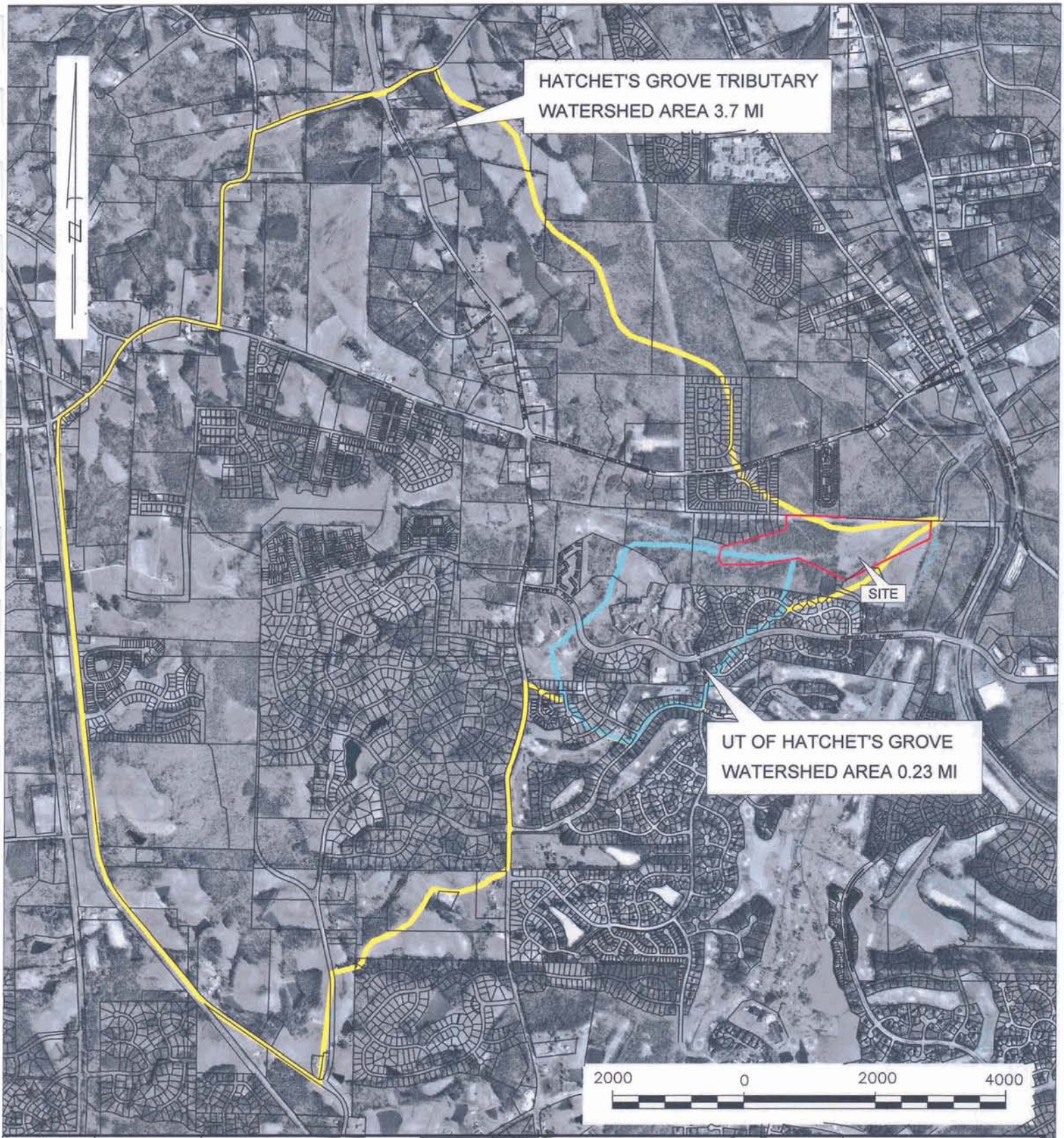

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SHEET TITLE:
WATERSHED AREA – ORTHOPHOTO

PROJECT NAME:
HATCHET'S GROVE TRIBUTARY
NC WETLAND RESTORATION PROGRAM
WAKE COUNTY, NORTH CAROLINA
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SOURCE: 1993 WAKE COUNTY ORTHOPHOTO– CARY, NWC & SWC

FIGURE 6

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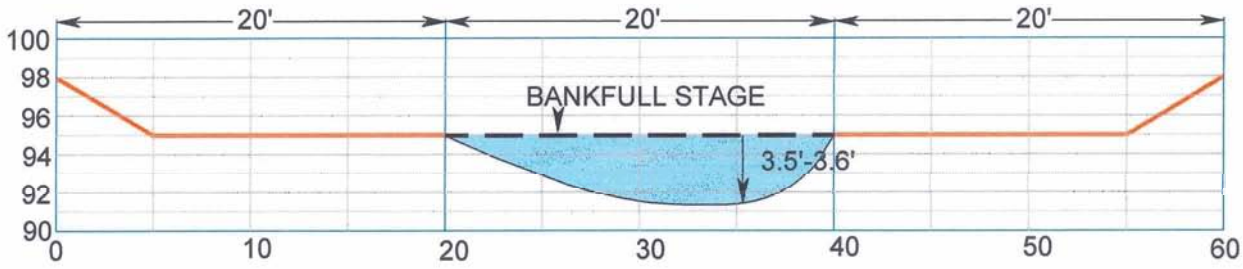
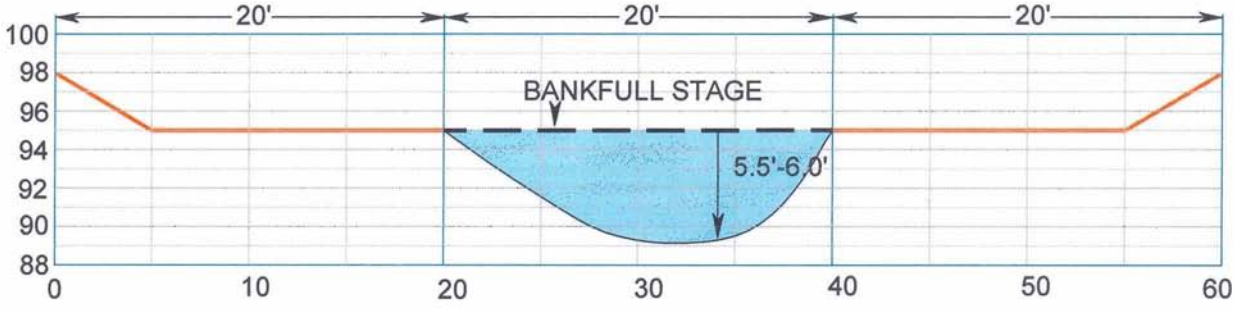
TYPICAL RIFFLE CROSS-SECTION



- BANKFULL BENCH WIDTH 15-20 FEET MINIMUM
- RIFFLE CROSS-SECTION AREA 50-60 FEET^2
- RIFFLE MAX DEPTH 3.5-3.6 FEET
- RIFFLE AVERAGE DEPTH 2.5 FEET
- BANKFULL CHANNEL WIDTH 20 FEET

TYPICAL POOL CROSS-SECTION



- BANKFULL CHANNEL WIDTH 20 FEET
- POOL CROSS-SECTION AREA 70-80 FEET^2
- POOL MAX DEPTH 5.5-6.0 FEET
- POOL AVERAGE DEPTH 4.0 FEET
- BANKFULL BENCH WIDTH 15-20 FEET MINIMUM

FILE NUMBER 6761	NOT TO SCALE	TYPICAL CROSS-SECTIONAL DIMENSIONS	FIGURE 7
PROJECT MGR. PJ	FIELD WORK PJ	PROJECT NAME: HATCHET'S GROVE TRIBUTARY	
DRAWN BY MM	FILE SECFILES\6761\	WAKE COUNTY, NORTH CAROLINA OCTOBER 2002	
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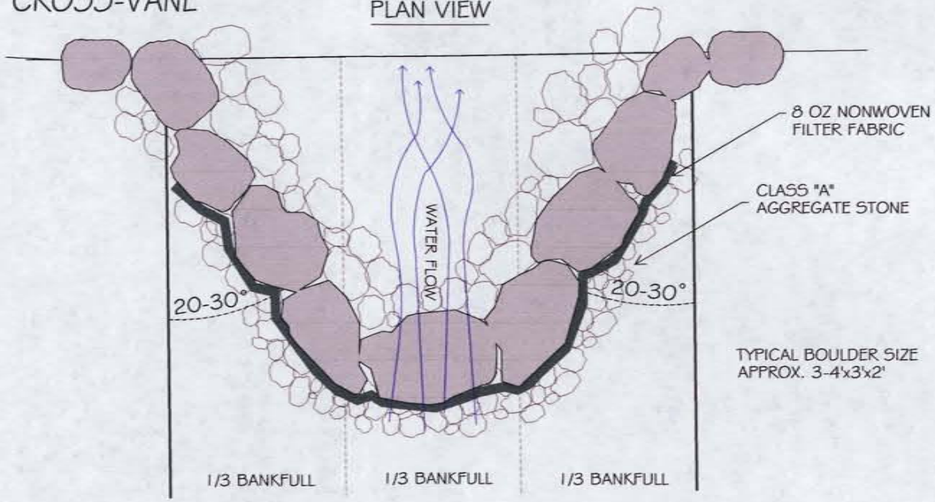
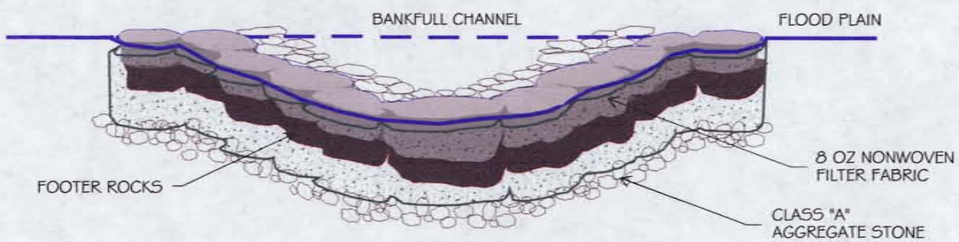
BOULDER CROSS-VANE

PLAN VIEW

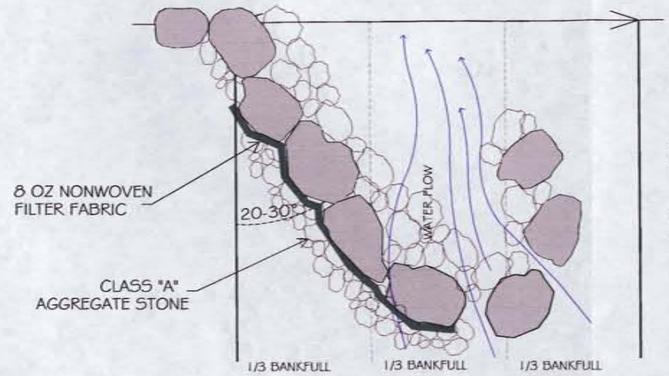


CROSS-SECTION VIEW



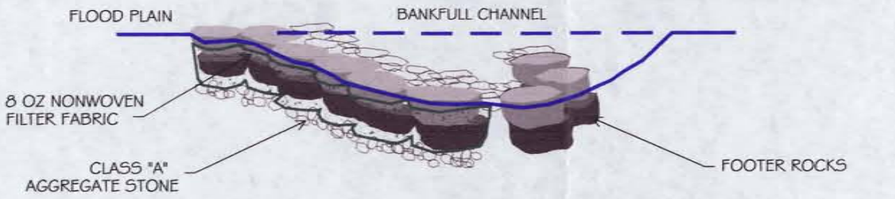
"J" HOOK ROCK VANE

PLAN VIEW

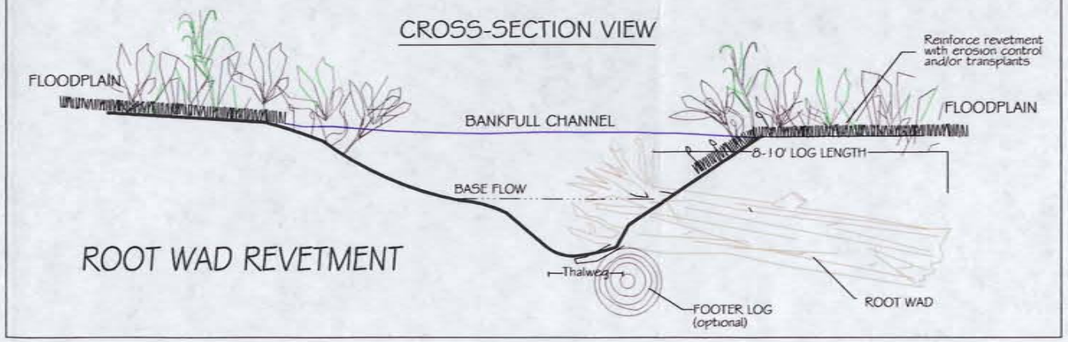


TYPICAL BOULDER SIZE APPROX. 3-4'x3'x2'

CROSS-SECTION VIEW



ROOT WAD REVETMENT



Designer PAJ	Scale	NC WETLANDS RESTORATION PROGRAM	HATCHET'S GROVE TRIBUTARY STREAM RESTORATION	STRUCTURES	Sheet No. 8
Drawn By MM	Date OCTOBER 2002				
Checked By MO	Job No. 6761/NEWEST10_9/ STRUCTURES				

JOB NO.	6761
PROJECT MGR.	PAJ
DRAWN	MM
FIELD WORK	PAJ
SCALE	1" = 250'
FILE	6761/newest10_9 11x17/INDEX

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PROJECT NAME:
NC WETLAND RESTORATION PROGRAM
HATCHET'S GROVE STREAM RESTORATION
WAKE COUNTY, NORTH CAROLINA
OCTOBER 2002

SHEET TITLE:
SHEET INDEX

FIGURE

SHEET 1

GRAPHIC SCALE
1" = 50'
50 0 50 100

MATCH TO SHEET 2

0+00
0+41
0+62
0+81
1+16
1+46
1+66
1+88
1+98
2+16
2+48
2+58
2+87
3+07

40' WATER & WASTEWATER EASEMENT DB 4756 PG 494

PROPOSED CHANNEL ALIGNMENT
EXISTING THALWEG
BOULDER CROSS-VANES
ROOT WADS
J-HOOK VANE
PROPERTY BOUNDARY

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SHEET 2

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GRAPHIC SCALE
1" = 50'
50 0 50 100

- PROPOSED CHANNEL ALIGNMENT
- EXISTING THALWEG
- BOULDER CROSS-VANES
- ROOT WADS
- J-HOOK VANE
- PROPERTY BOUNDARY

MATCH TO SHEET 1

MATCH TO SHEET 3

BRIDGE #1

BRIDGE #2

W.S. 290.88

W.S. 289.98

SHEET 3

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PROPOSED BRIDGE CROSSING

BRIDGE #3

BRIDGE #4

W.S. 289.91

W.S. 289.98

MATCH TO SHEET 2

MATCH TO SHEET 4

PROPOSED CHANNEL ALIGNMENT
EXISTING THALWEG
BOULDER CROSS-VANES
ROOT WADS
J-HOOK VANE
PROPERTY BOUNDARY

GRAPHIC SCALE
1" = 50'
50 0 50 100

SHEET 4

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PROPOSED CHANNEL ALIGNMENT
EXISTING THALWEG
BOULDER CROSS-VANES
ROOT WADS
J-HOOK VANE
PROPERTY BOUNDARY

MATCH TO SHEET 5

MATCH TO SHEET 3

BRIDGE #5

22+02
22+46
22+79
23+09
23+69
23+50
24+03
24+42
24+72
25+05
25+49
25+78
26+09
26+44
26+66
27+91
28+19
28+32
27+57
27+42
27+14
28+63
28+97
29+13
29+42
29+70
29+85
30+19
30+40
30+70
30+98
31+20

GRAPHIC SCALE
1" = 50'
50 0 50 100

SHEET 5

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MATCH TO SHEET 4

BRIDGE #6

31+20 31+34 31+59 31+87 32+02 32+33 32+60 32+76 33+09 33+39 33+58 33+90 34+19 34+33 34+56 34+86 35+04 35+32 35+66 35+85 36+20 36+43 36+90 37+44 37+79

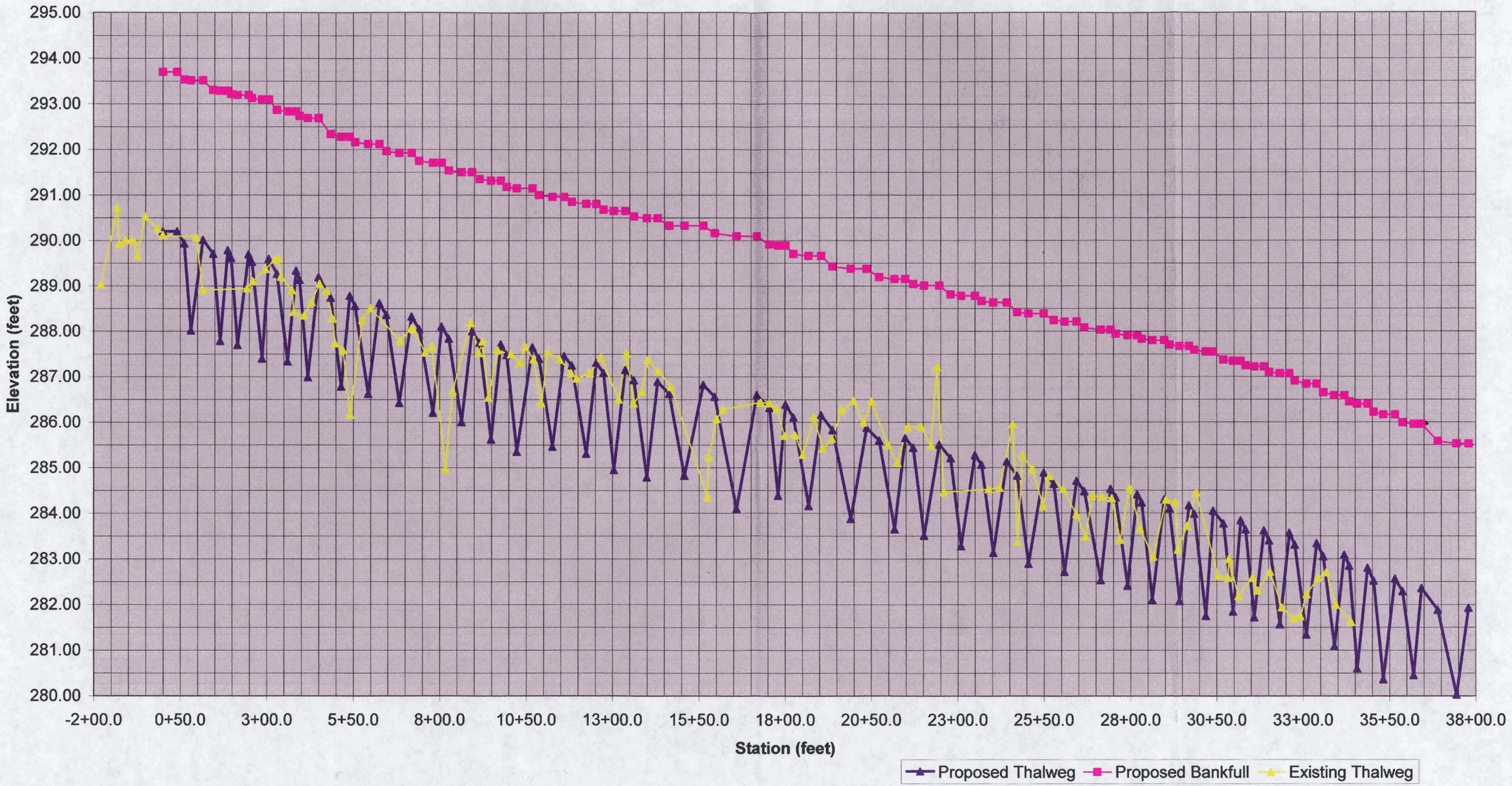
IRRIGATION POND

GRAPHIC SCALE
1" = 50'
50 0 50 100

- PROPOSED CHANNEL ALIGNMENT
- EXISTING THALWEG
- BOULDER CROSS-VANES
- ROOT WADS
- J-HOOK VANE
- PROPERTY BOUNDARY

NOTE: ACTUAL PLACEMENT OF STRUCTURES WILL BE DETERMINED IN THE FIELD BY THE PROJECT DESIGNER.

SHEET 6 - Hatchet's Grove Proposed Longitudinal Profile



Hatchet's Grove Tributary Stream Restoration Project

Summary of Cross-section Data

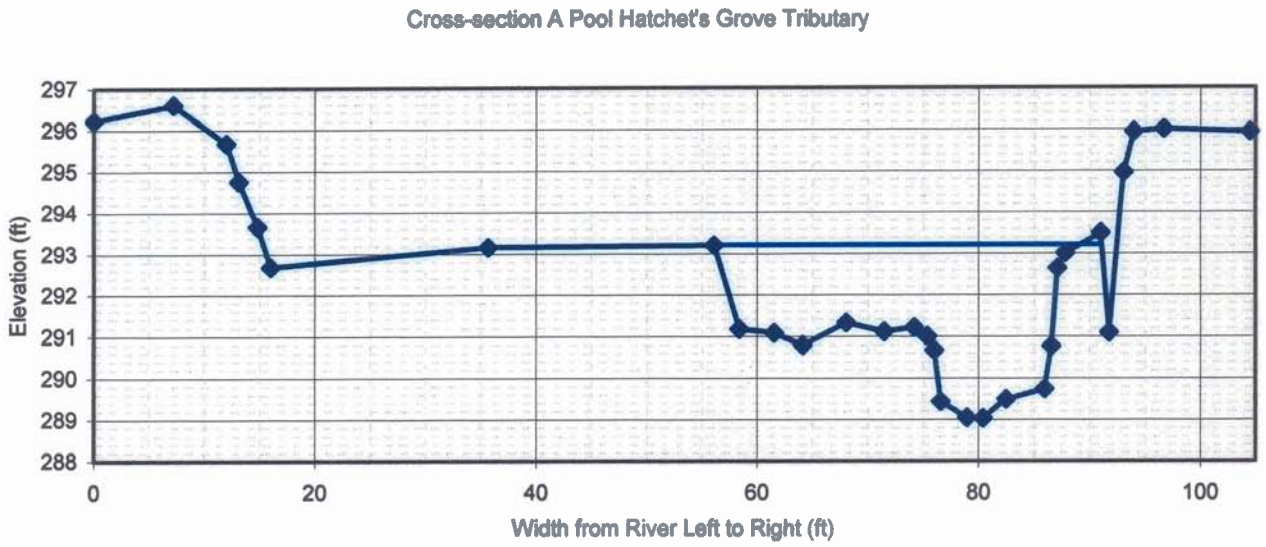
Prepared By: Peter Jelenevsky
River Basin: Neuse River
Watershed: Hatchet's Grove Tributary
Drainage Area (square miles): 3.7

Parameter	Cross-Section								
Station	A	B	E	F	I	J	K	L	M
Feature	Pool	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle/Run	Riffle
Channel Type	F5	F5	E5	F5/E5	E5	E5	F5	F5/E5	E5
Bankfull Cross-sectional Area (square feet)	80.5	23.7	38.9	54.5	47.4	52.3	47.3	50.5	46.9
Bankfull Width (feet)	33	14.9	18.8	27.6	22.7	23.4	26.6	28.8	21.1
Bankfull Mean Depth (feet)	2.4	1.6	2.1	2	2.1	2.2	1.8	1.8	2.2
Bankfull Maximum Depth (feet)	4.2	2	2.8	3.4	3.9	4.4	3.4	4	3.7
Width/Depth Ratio	13.75	9.3	9.1	14	10.8	10.4	14.9	16.4	9.5
Entrenchment Ratio	1.8	1	5.3	3.6	8.8	10.7	1.9	6.9	11.9
Bank Height Ratio (high bank height/max depth)	1.64	3.1	2	1.8	1.85	2.1	2.1	2.1	1.7
Bank Height Ratio (low bank height/max depth)	1	2.38	1.9	1.8	1.8	1	1.65	1.8	1.5

Parameter	Cross-Section						Average Values *
Station	N	O	P	Q	R	S	
Feature	Riffle	Riffle	Riffle/Run	Riffle	Riffle	Riffle	
Channel Type	E5	F5	E5	E5	F5	E5	F5/E5
Bankfull Cross-sectional Area (square feet)	42.7	47.9	46.3	34.1	42.4	55.9	45.06
Bankfull Width (feet)	20	17.8	22.5	21	20.4	18.6	21.73
Bankfull Mean Depth (feet)	2.1	2.7	2.1	1.6	2.1	3	2.10
Bankfull Maximum Depth (feet)	3.7	3.6	3.4	3	3.3	4.8	3.53
Width/Depth Ratio	9.4	6.6	11	13	9.9	6.2	10.75
Entrenchment Ratio	12.5	3.4	8.9	11.9	2	10.7	7.11
Bank Height Ratio (high bank height/max depth)	1.7	2	1.8	1.9	2	1.5	1.98
Bank Height Ratio (low bank height/max depth)	1.7	1.9	1.3	1.2	1.1	1.4	1.60

* Includes Riffle Cross Sections Only

Cross Section



section:	Cross-section A
	Pool
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 0+00
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0	3.78	296.22
NG	☑	7.22	3.4	296.6
L TOB	☑	12.02	4.33	295.67
	☑	13.14	5.25	294.75
	☑	14.83	6.34	293.66
	☑	16.01	7.32	292.68
	☑	35.68	6.84	293.16
BKF	☐	56.09	6.79	293.21
	☐	58.38	8.83	291.17
	☐	61.51	8.92	291.08
	☐	64.13	9.21	290.79
	☐	68.05	8.67	291.33
	☐	71.49	8.89	291.11
	☐	74.2	8.79	291.21
	☐	75.39	9	291
EOW/WS	☐	76.02	9.33	290.67
	☐	76.59	10.56	289.44
	☐	78.95	10.95	289.05
	☐	80.41	10.97	289.03
	☐	82.49	10.51	289.49
	☐	85.94	10.26	289.74
EOW/WS	☐	86.54	9.23	290.77
	☐	87.11	7.36	292.64
	☐	87.8	6.99	293.01
BKF	☐	91	6.5	293.5
NG	☑	91.76	8.91	291.09
NG	☑	93.06	5.04	294.96
TOB	☑	93.98	4.06	295.94
NG	☑	96.69	4	296
NG	☑	104.47	4.07	295.93

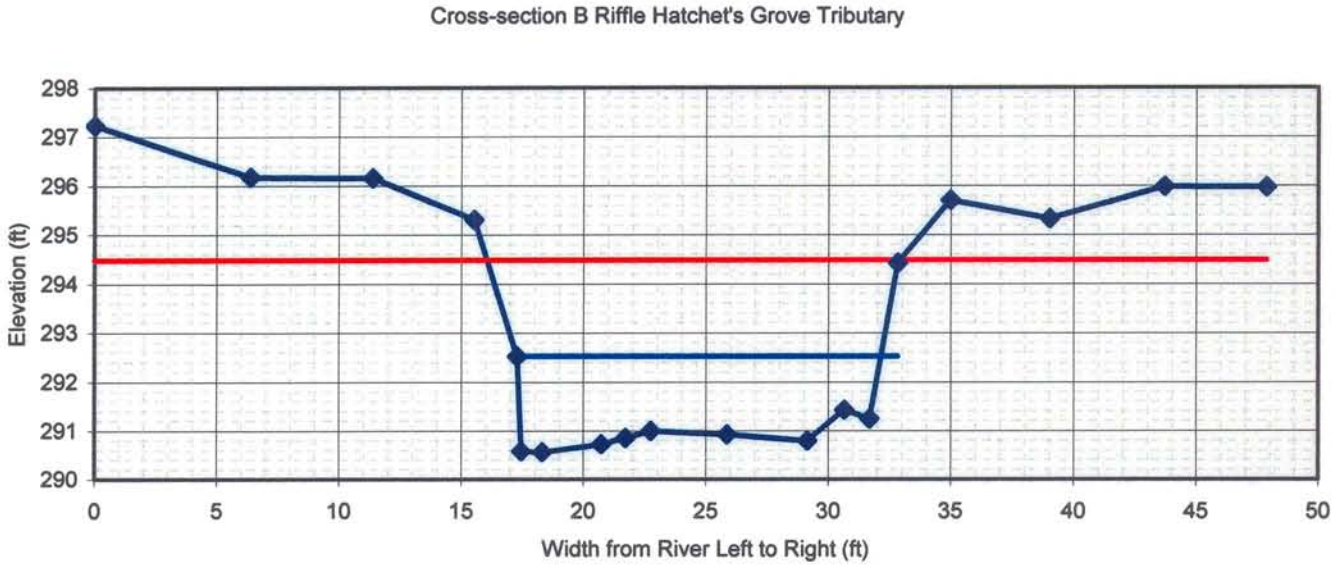
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.79	4.06		0.2	0.033
293.21	295.94			

dimensions			
80.5	x-section area	2.4	d mean
33.0	width	36.9	wet P
4.2	d max	2.2	hyd radi
6.9	bank ht	13.5	w/d ratio
60.0	W flood prone area	1.8	ent ratio

hydraulics	
3.4	velocity (ft/sec)
272.8	discharge rate, Q (cfs)
0.27	shear stress ((lbs/ft sq)
0.37	shear velocity (ft/sec)
1.031	unit stream power (lbs/ft/sec)
0.15	Froude number
9.0	friction factor u/u*
15.0	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
56.5	relative roughness	12.8	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section B
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 0+47.56
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0	2.77	297.23
NG	☑	6.39	3.82	296.18
NG	☑	11.38	3.84	296.16
L TOB	☑	15.52	4.69	295.31
BKF	☐	17.29	7.48	292.52
L EOW	☐	17.45	9.42	290.58
	☐	18.31	9.44	290.56
TW	☐	20.72	9.28	290.72
WS	☐	21.71	9.15	290.85
	☐	22.75	9.01	290.99
	☐	25.86	9.08	290.92
	☐	29.15	9.21	290.79
	☐	30.66	8.58	291.42
	☐	31.69	8.76	291.24
	☐	32.84	5.58	294.42
R TOB	☑	34.99	4.3	295.7
NG	☑	39.02	4.67	295.33
NG	☑	43.71	4.02	295.98
NG	☑	47.87	4.03	295.97
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

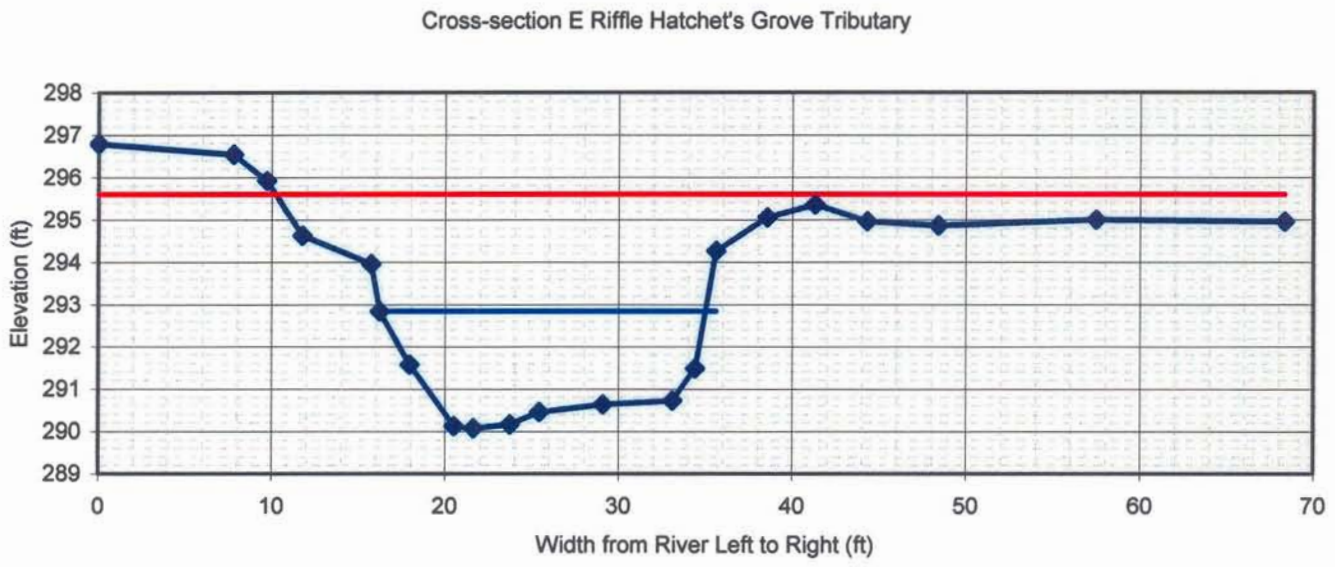
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.48	4.3	15.0	0.2	0.033
292.52	295.7			

dimensions			
23.7	x-section area	1.6	d mean
14.9	width	17.7	wet P
2.0	d max	1.3	hyd radi
5.1	bank ht	9.3	w/d ratio
15.0	W flood prone area	1.0	ent ratio

hydraulics	
2.4	velocity (ft/sec)
58.2	discharge rate, Q (cfs)
0.17	shear stress ((lbs/ft sq)
0.29	shear velocity (ft/sec)
0.488	unit stream power (lbs/ft/sec)
0.12	Froude number
8.3	friction factor u/u*
10.0	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
37.0	relative roughness	11.8	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section E
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 2+75.16
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0	3.21	296.79
	☑	7.8	3.46	296.54
TOB	☑	9.7	4.08	295.92
	☑	11.77	5.38	294.62
	☑	15.73	6.04	293.96
BKF	☐	16.23	7.17	292.83
	☐	17.96	8.43	291.57
	☐	20.52	9.88	290.12
EOW	☐	21.63	9.93	290.07
TW	☐	23.75	9.84	290.16
WS	☐	25.44	9.55	290.45
	☐	29.1	9.37	290.63
	☐	33.1	9.28	290.72
	☐	34.42	8.52	291.48
	☐	35.61	5.74	294.26
	☑	38.55	4.95	295.05
TOB	☑	41.31	4.64	295.36
TOB	☑	44.31	5.04	294.96
NG	☑	48.4	5.14	294.86
NG	☑	57.47	5	295
NG	☑	68.33	5.05	294.95
	☐			
	☐			
	☐			
	☐			
	☐			

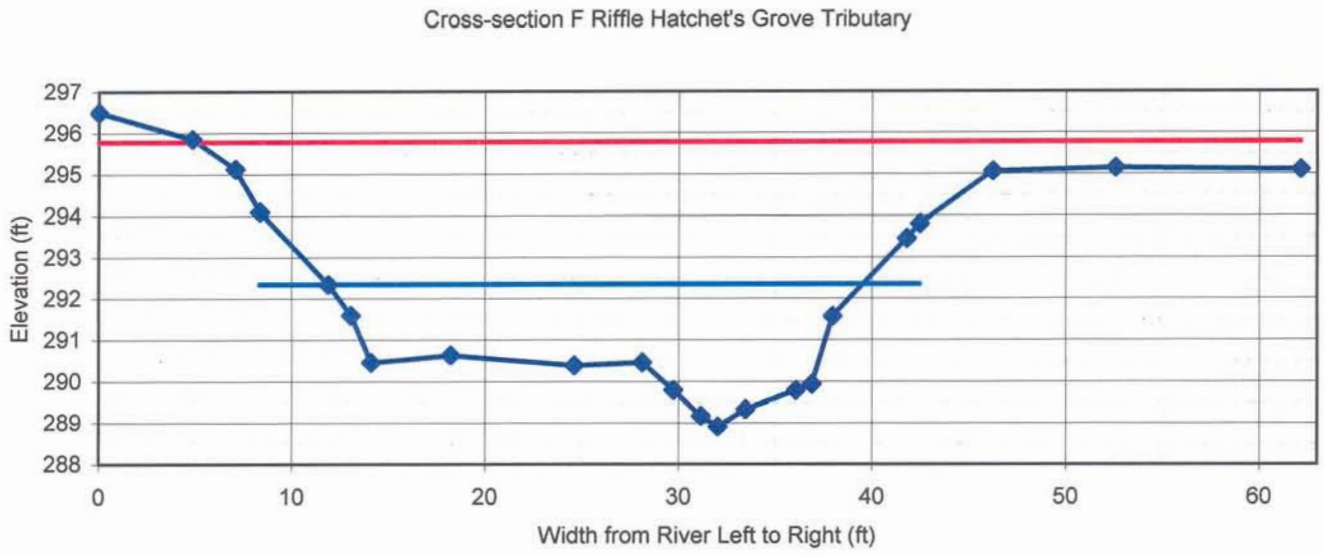
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.17	4.64	100.0	0.2	0.033
292.83	295.36			

dimensions			
38.9	x-section area	2.1	d mean
18.8	width	20.7	wet P
2.8	d max	1.9	hyd radi
5.3	bank ht	9.1	w/d ratio
100.0	W flood prone area	5.3	ent ratio

hydraulics	
3.1	velocity (ft/sec)
119.4	discharge rate, Q (cfs)
0.23	shear stress ((lbs/ft sq)
0.35	shear velocity (ft/sec)
0.794	unit stream power (lbs/ft/sec)
0.14	Froude number
8.8	friction factor u/u*
13.2	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
48.0	relative roughness	12.4	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section F
	Riffle Hatchet's Grove Tributary Neuse River Basin
description:	Station 2+93.62
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0	3.51	296.49
NG	☑	4.85	4.15	295.85
TOB	☑	7.07	4.88	295.12
	☐	8.35	5.91	294.09
BKF	☐	11.9	7.66	292.34
	☐	13.06	8.41	291.59
	☐	14.11	9.55	290.45
	☐	18.21	9.37	290.63
	☐	24.61	9.62	290.38
EDGE BAF	☐	28.12	9.55	290.45
WS/EOW	☐	29.75	10.21	289.79
	☐	31.17	10.83	289.17
TW	☐	32.04	11.09	288.91
	☐	33.47	10.67	289.33
	☐	36.07	10.21	289.79
EOW	☐	36.9	10.07	289.93
	☐	37.97	8.43	291.57
	☐	41.81	6.55	293.45
	☐	42.48	6.2	293.8
TOB	☑	46.24	4.94	295.06
	☑	52.55	4.86	295.14
	☑	62.14	4.9	295.1
	☐			
	☐			

☐

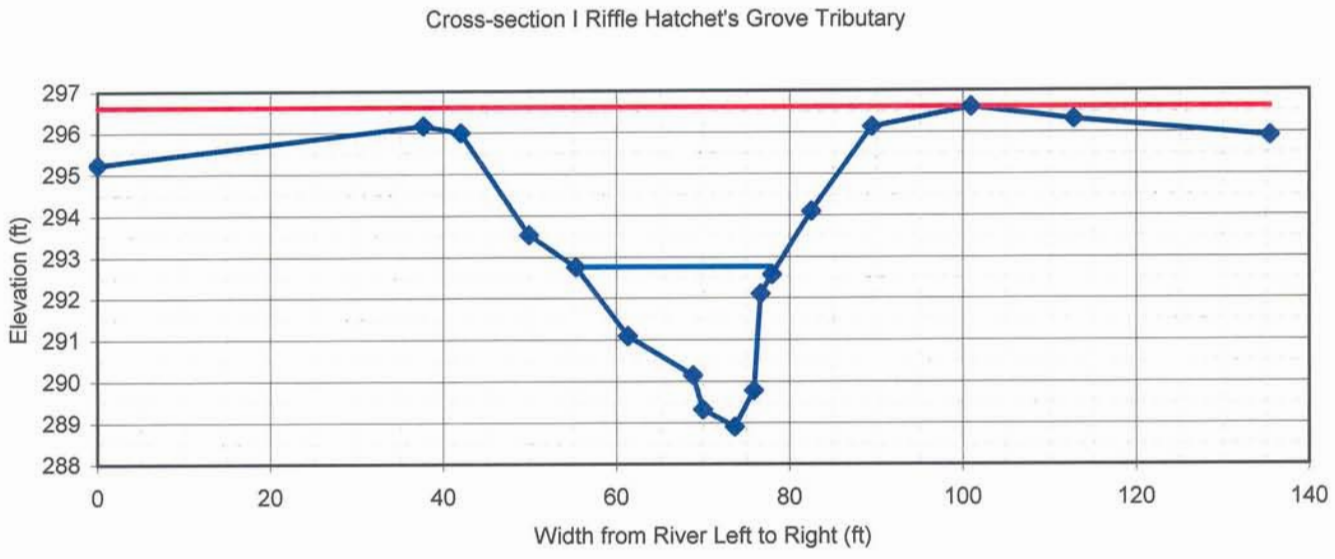
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.66	4.94	100.0	0.2	0.033
292.34	295.06			

dimensions			
54.5	x-section area	2.0	d mean
27.6	width	29.8	wet P
3.4	d max	1.8	hyd radi
6.2	bank ht	14.0	w/d ratio
100.0	W flood prone area	3.6	ent ratio

hydraulics	
3.0	velocity (ft/sec)
163.7	discharge rate, Q (cfs)
0.23	shear stress ((lbs/ft sq)
0.34	shear velocity (ft/sec)
0.739	unit stream power (lbs/ft/sec)
0.14	Froude number
8.8	friction factor u/u*
12.9	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
45.6	relative roughness	12.3	fric. factor
0.024	Manning's n from channel material		

Cross Section



section:	Cross-section I
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 5+52.32, below confluence
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	4.77	295.23
	☑	37.65	3.84	296.16
TOB	☑	41.96	4.01	295.99
	☑	49.88	6.48	293.52
BKF	☐	55.33	7.25	292.75
	☐	61.31	8.91	291.09
	☐	68.85	9.85	290.15
	☐	69.98	10.68	289.32
TW	☐	73.67	11.1	288.9
	☐	75.89	10.22	289.78
	☐	76.67	7.9	292.1
BKF	☐	77.98	7.43	292.57
	☑	82.51	5.91	294.09
	☑	89.51	3.87	296.13
	☑	100.94	3.4	296.6
	☑	112.77	3.69	296.31
TOB	☑	135.43	4.09	295.91
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

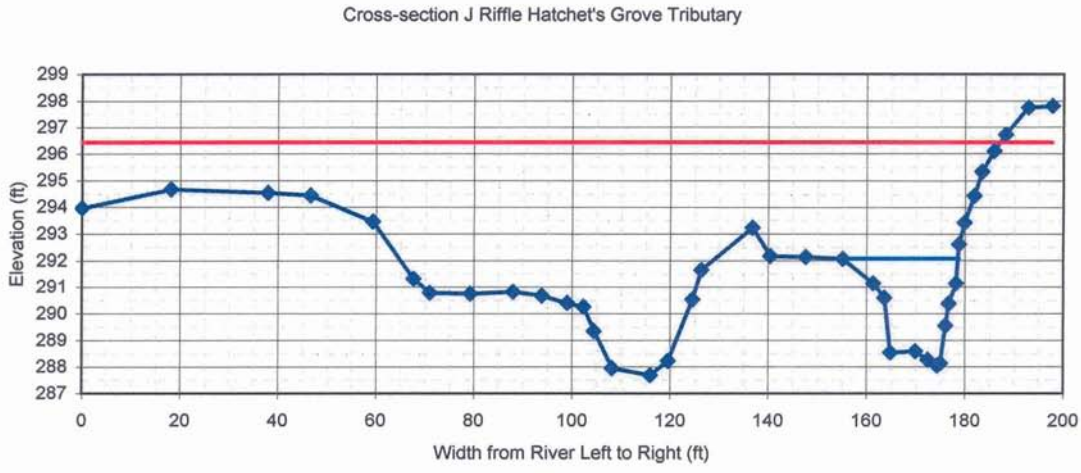
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.25	4.01	200.0	0.2	0.033
292.75	295.99			

dimensions			
47.4	x-section area	2.1	d mean
22.7	width	25.1	wet P
3.9	d max	1.9	hyd radi
7.1	bank ht	10.8	w/d ratio
200.0	W flood prone area	8.8	ent ratio

hydraulics	
3.1	velocity (ft/sec)
145.6	discharge rate, Q (cfs)
0.24	shear stress ((lbs/ft sq)
0.35	shear velocity (ft/sec)
0.802	unit stream power (lbs/ft/sec)
0.14	Froude number
8.8	friction factor u/u*
13.3	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
48.5	relative roughness	12.4	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section J
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 8+97.51
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0	6.04	293.96
NG	☑	18.11	5.34	294.66
E Path	☑	37.88	5.47	294.53
E Path	☑	46.62	5.57	294.43
E Pond	☑	59.39	6.54	293.46
	☑	67.68	8.69	291.31
	☑	70.97	9.22	290.78
	☑	79.29	9.26	290.74
	☑	87.98	9.19	290.81
	☑	93.82	9.33	290.67
	☑	99	9.61	290.39
	☑	102.34	9.75	290.25
	☑	104.51	10.66	289.34
	☑	108.19	12.06	287.94
Mid. Pond	☑	115.97	12.32	287.68
	☑	119.66	11.78	288.22
WS Pond	☑	124.56	9.48	290.52
	☑	126.43	8.36	291.64
T Outfall	☑	136.83	6.77	293.23
	☑	140.42	7.84	292.16
	☑	147.66	7.87	292.13
BKF	☐	155.22	7.95	292.05
	☐	161.39	8.87	291.13
	☐	163.66	9.42	290.58
	☐	164.9	11.47	288.53
	☐	169.97	11.42	288.58
	☐	172.47	11.75	288.25
	☐	174.41	11.96	288.04
	☐	175.04	11.88	288.12
	☐	176.08	10.45	289.55
	☐	176.7	9.63	290.37
	☐	178.25	8.87	291.13
	☐	178.81	7.4	292.6
	☑	179.89	6.58	293.42
	☑	181.89	5.56	294.44
	☑	183.4	4.67	295.33
	☑	185.86	3.91	296.09
TOB	☑	188.25	3.28	296.72
NG	☑	192.87	2.26	297.74
NG	☑	197.75	2.19	297.81

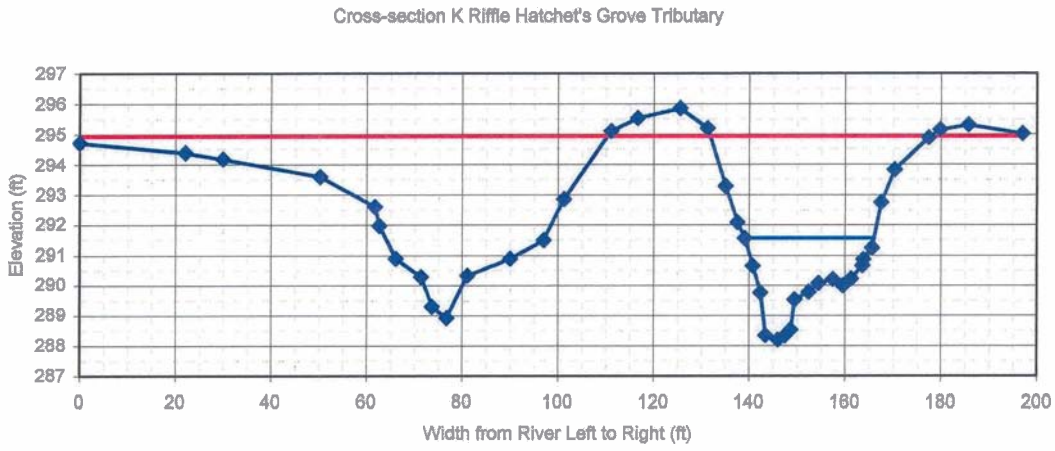
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
7.95	3.28	250.0	0.2	0.033
292.05	296.72			

dimensions			
52.3	x-section area	2.2	d mean
23.4	width	26.7	wet P
4.4	d max	2.0	hyd radi
9.0	bank ht	10.4	w/d ratio
250.0	W flood prone area	10.7	ent ratio

hydraulics	
3.2	velocity (ft/sec)
165.3	discharge rate, Q (cfs)
0.25	shear stress ((lbs/ft sq)
0.36	shear velocity (ft/sec)
0.882	unit stream power (lbs/ft/sec)
0.14	Froude number
8.9	friction factor u/u*
13.7	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
51.9	relative roughness	12.6	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section K
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 10+68.99
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	5.3	294.7
CL Path	☑	22.08	5.62	294.38
	☑	29.99	5.83	294.17
	☑	50.24	6.42	293.58
	☑	61.74	7.41	292.59
E Pond	☑	62.67	8.04	291.96
WS	☑	66.17	9.12	290.88
	☑	71.44	9.73	290.27
	☑	73.67	10.71	289.29
	☑	76.79	11.09	288.91
	☑	81.1	9.68	290.32
WS	☑	90.06	9.12	290.88
	☑	97.05	8.51	291.49
	☑	101.28	7.16	292.84
	☑	111.16	4.91	295.09
CL Path	☑	116.72	4.48	295.52
	☑	125.56	4.15	295.85
TOB	☑	131.29	4.82	295.18
	☑	135.04	6.73	293.27
	☑	137.58	7.92	292.08
BKF	☐	139.15	8.45	291.55
	☐	140.8	9.36	290.64
	☐	142.39	10.25	289.75
	☐	143.43	11.67	288.33
TW	☐	146.08	11.81	288.19
	☐	147.54	11.68	288.32
	☐	148.76	11.48	288.52
	☐	149.53	10.48	289.52
	☐	152.48	10.23	289.77
	☐	154.51	9.94	290.06
	☐	157.56	9.81	290.19
	☐	159.59	10.02	289.98
IB	☐	161.37	9.79	290.21
	☐	163.71	9.35	290.65
	☐	163.89	9.14	290.86
BKF	☐	165.72	8.76	291.24
	☑	167.57	7.26	292.74
TOB	☑	170.39	6.19	293.81
NG	☑	177.44	5.13	294.87
NG	☑	179.86	4.86	295.14
NG	☑	185.7	4.7	295.3
NG	☑	197	4.99	295.01
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
8.45	4.82	50.0	0.2	0.033
291.55	295.18			

dimensions			
47.3	x-section area	1.8	d mean
26.6	width	28.5	wet P
3.4	d max	1.7	hyd radi
7.0	bank ht	14.9	w/d ratio
50.0	W flood prone area	1.9	ent ratio

hydraulics	
2.8	velocity (ft/sec)
133.7	discharge rate, Q (cfs)
0.21	shear stress ((lbs/ft sq)
0.33	shear velocity (ft/sec)
0.628	unit stream power (lbs/ft/sec)
0.14	Froude number
8.6	friction factor u/u*
11.9	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
41.3	relative roughness	12.0	fric. factor
0.024	Manning's n from channel material		

Cross Section

section:	Cross-section L
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 11+02.88
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0.00	5.85	294.15
NG	☑	27.01	4.76	295.24
CL PATH	☑	57.10	5.16	294.84
E POND	☑	69.95	6.54	293.46
	☑	75.88	8.82	291.18
EOW	☑	80.40	9.44	290.56
	☑	91.03	9.90	290.1
	☑	94.70	9.20	290.8
	☑	101.25	10.11	289.89
	☑	109.89	10.75	289.25
	☑	114.73	11.47	288.53
	☑	122.90	9.81	290.19
	☑	127.80	9.91	290.09
	☑	132.72	9.83	290.17
EOW	☑	138.23	9.01	290.99
E POND	☑	141.77	7.89	292.11
	☑	148.10	6.55	293.45
	☑	153.45	5.94	294.06
CL PATH	☑	165.06	5.65	294.35
	☑	193.68	4.90	295.1
TOB	☐	208.62	5.01	294.99
	☐	210.12	9.68	290.32
	☐	212.24	10.67	289.33
	☐	212.90	11.75	288.25
TW	☐	214.95	12.23	287.77
	☐	215.98	12.00	288
		217.56	11.65	288.35
EOW		218.32	11.39	288.61
		219.66	10.30	289.7
		221.91	10.53	289.47
IB		223.63	10.54	289.46
		224.73	10.07	289.93
		226.38	9.48	290.52
		228.72	8.84	291.16
		232.32	8.89	291.11
		235.83	8.94	291.06
BKF		238.48	8.26	291.74
TOB	☑	243.77	6.15	293.85
NG	☑	253.52	4.50	295.5
NG	☑	264.55	3.98	296.02

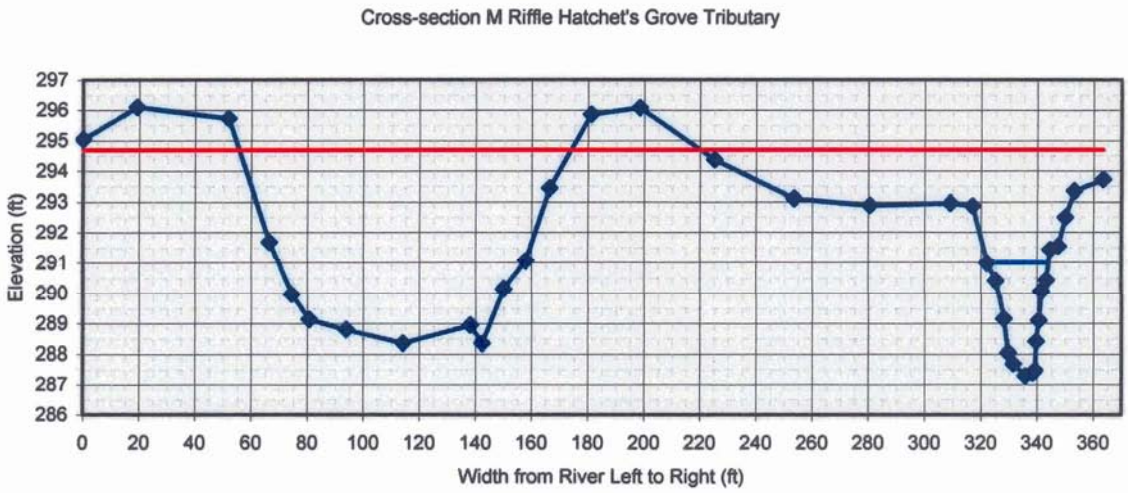
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
8.26	3.98	200.0	0.2	0.033
291.74	296.02			

dimensions			
50.5	x-section area	1.8	d mean
28.8	width	31.6	wet P
4.0	d max	1.6	hyd radi
8.3	bank ht	16.4	w/d ratio
200.0	W flood prone area	6.9	ent ratio

hydraulics	
2.8	velocity (ft/sec)
139.1	discharge rate, Q (cfs)
0.20	shear stress ((lbs/ft sq)
0.32	shear velocity (ft/sec)
0.602	unit stream power (lbs/ft/sec)
0.13	Froude number
8.6	friction factor u/u*
11.6	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
40.6	relative roughness	12.0	fric. factor
0.024	Manning's n from channel material		

Cross Section



section:	Cross-section M
	Riffle Hatchet's Grove Tributary Neuse River Basin
description:	Station 13+26.10
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
CL PATH	☑	0	4.96	295.04
NG	☑	19.28	3.9	296.1
NG	☑	51.75	4.28	295.72
NG	☑	66.46	8.32	291.68
EOW	☑	74.46	10.03	289.97
NG	☑	80.77	10.86	289.14
NG	☑	93.89	11.2	288.8
NG	☑	114.21	11.64	288.36
NG	☑	138.17	11.05	288.95
NG	☑	142.4	11.65	288.35
EOW/WS	☑	150.04	9.86	290.14
NG	☑	157.94	8.94	291.06
NG	☑	166.33	6.56	293.44
NG	☑	181.15	4.14	295.86
CL C PATI	☑	198.44	3.92	296.08
NG	☑	225.24	5.64	294.36
NG	☑	253.52	6.89	293.11
NG	☑	280.54	7.11	292.89
NG	☑	309.14	7.04	292.96
TOB	☑	316.93	7.13	292.87
BKF	☐	322.2	9.02	290.98
	☐	325.22	9.6	290.4
	☐	328.07	10.84	289.16
	☐	329.7	11.95	288.05
	☐	331.57	12.32	287.68
	☐	335.76	12.71	287.29
TW	☐	338.48	12.62	287.38
	☐	339.1	12.53	287.47
	☐	339.64	11.59	288.41
	☐	340.48	10.89	289.11
	☐	341.44	9.93	290.07
BKF	☐	343.29	9.57	290.43
	☑	344.58	8.58	291.42
	☑	347.41	8.46	291.54
	☑	349.94	7.51	292.49
TOB	☑	353.17	6.66	293.34
NG	☑	363.41	6.28	293.72

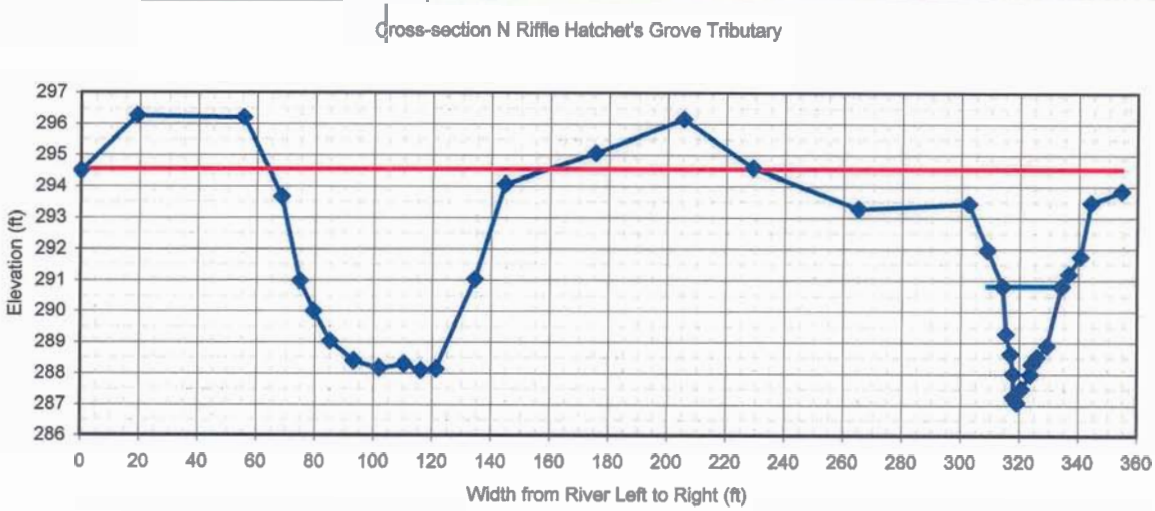
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
9.02	6.66	250.0	0.2	0.033
290.98	293.34			

dimensions			
46.9	x-section area	2.2	d mean
21.1	width	23.0	wet P
3.7	d max	2.0	hyd radi
6.1	bank ht	9.5	w/d ratio
250.0	W flood prone area	11.9	ent ratio

hydraulics	
3.2	velocity (ft/sec)
151.9	discharge rate, Q (cfs)
0.25	shear stress ((lbs/ft sq)
0.36	shear velocity (ft/sec)
0.899	unit stream power (lbs/ft/sec)
0.15	Froude number
8.9	friction factor u/u*
14.2	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
51.6	relative roughness	12.6	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section N
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 13+58.92
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
CL PATH	☑	0	5.52	294.48
NG	☑	19.1	3.73	296.27
NG	☑	55.43	3.8	296.2
NG	☑	68.53	6.34	293.66
NG	☑	74.86	9.04	290.96
EOW	☑	79.55	10.02	289.98
NG	☑	85.2	10.98	289.02
NG	☑	93.25	11.61	288.39
NG	☑	102	11.84	288.16
NG	☑	110.45	11.72	288.28
NG	☑	116.18	11.91	288.09
NG	☑	121.37	11.87	288.13
NG	☑	134.57	8.98	291.02
NG	☑	144.7	5.95	294.05
CL PATH	☑	175.46	4.95	295.05
NG	☑	205.42	3.85	296.15
NG	☑	229.17	5.43	294.57
NG	☑	265.08	6.73	293.27
TOB	☑	302.57	6.57	293.43
	☐	309.04	8.03	291.97
BKF	☐	314.23	9.2	290.8
	☐	315.48	10.73	289.27
	☐	317	11.38	288.62
WS	☐	317.82	12	288
	☐	317.83	12.75	287.25
TW/RIFFL	☐	319.15	12.92	287.08
	☐	320.69	12.49	287.51
	☐	323.72	12.02	287.98
	☐	324.27	11.7	288.3
	☐	325.99	11.48	288.52
	☐	329.4	11.12	288.88
	☐	334.2	9.21	290.79
BKF	☐	336.72	8.81	291.19
	☑	340.65	8.24	291.76
TOB	☑	344.14	6.54	293.46
NG	☑	354.55	6.16	293.84

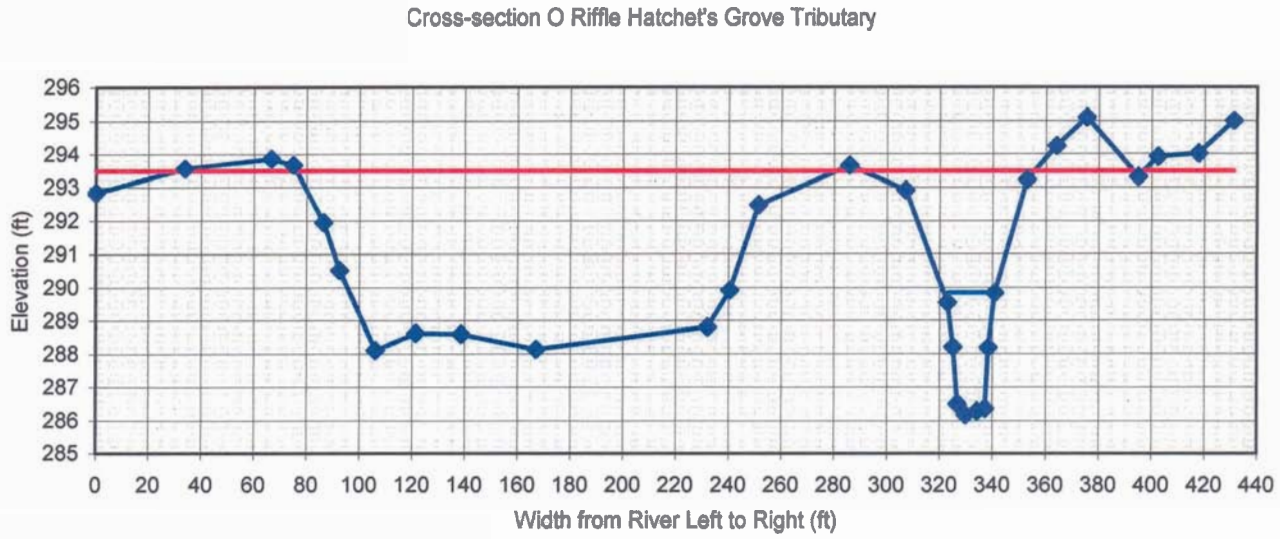
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
9.2	6.54	250.0	0.2	0.033
290.8	293.46			

dimensions			
42.7	x-section area	2.1	d mean
20.0	width	22.4	wet P
3.7	d max	1.9	hyd radi
6.4	bank ht	9.4	w/d ratio
250.0	W flood prone area	12.5	ent ratio

hydraulics	
3.1	velocity (ft/sec)
131.9	discharge rate, Q (cfs)
0.24	shear stress ((lbs/ft sq)
0.35	shear velocity (ft/sec)
0.822	unit stream power (lbs/ft/sec)
0.14	Froude number
8.8	friction factor u/u*
13.4	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
49.4	relative roughness	12.5	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section O
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 17+97.19
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0	7.17	292.83
CL Path	☑	33.75	6.45	293.55
SHRUB	☑	66.55	6.15	293.85
CL PATH	☑	74.92	6.34	293.66
NG	☑	86.38	8.05	291.95
NG	☑	92.55	9.48	290.52
NG	☑	106.04	11.9	288.1
NG	☑	121.44	11.38	288.62
NG	☑	138.59	11.41	288.59
NG	☑	167.08	11.87	288.13
NG	☑	232.02	11.2	288.8
EOW		240.54	10.09	289.91
NG	☑	251.24	7.53	292.47
NG	☑	285.8	6.35	293.65
TOB	☑	306.99	7.09	292.91
BKF	☐	322.97	10.47	289.53
	☐	325.13	11.8	288.2
	☐	326.77	13.51	286.49
	☐	329.75	13.83	286.17
TW		334.18	13.72	286.28
		337.2	13.64	286.36
		338.33	11.82	288.18
BKF		340.75	10.18	289.82
TOB	☑	352.88	6.78	293.22
CL PATH	☑	363.97	5.77	294.23
GN	☑	375.44	4.9	295.1
GN	☑	394.87	6.69	293.31
GN	☑	402.39	6.09	293.91
GN	☑	417.72	6	294
GN	☑	431.17	5.01	294.99

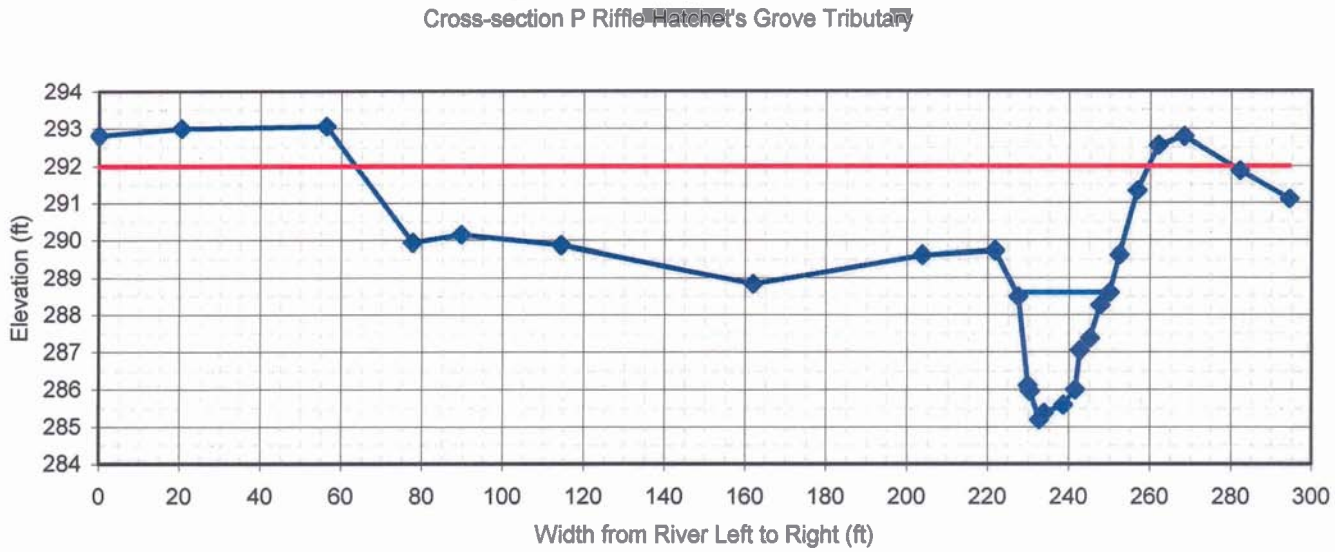
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
10.18	6.78	60.0	0.2	0.033
289.82	293.22			

dimensions			
47.9	x-section area	2.7	d mean
17.8	width	20.4	wet P
3.6	d max	2.3	hyd radi
7.1	bank ht	6.6	w/d ratio
60.0	W flood prone area	3.4	ent ratio

hydraulics	
3.6	velocity (ft/sec)
170.2	discharge rate, Q (cfs)
0.29	shear stress ((lbs/ft sq)
0.39	shear velocity (ft/sec)
1.194	unit stream power (lbs/ft/sec)
0.15	Froude number
9.1	friction factor u/u*
15.9	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
62.4	relative roughness	13.1	fric. factor
0.023	Manning's n from channel material		

Cross Section



section:	Cross-section P
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 24+65.85
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG/PINES	☑	0	7.2	292.8
NG/PINES	☑	20.47	7.01	292.99
NG	☑	56.34	6.95	293.05
Sand Trap	☑	77.67	10.07	289.93
NG	☑	89.67	9.85	290.15
NG	☑	114.46	10.13	289.87
NG	☑	161.99	11.17	288.83
NG	☑	203.79	10.4	289.6
NG	☑	221.72	10.28	289.72
BKF	☐	227.5	11.52	288.48
	☐	229.85	13.89	286.11
	☐	230.42	14.04	285.96
TW	☐	232.75	14.8	285.2
	☐	233.87	14.62	285.38
	☐	238.67	14.4	285.6
	☐	241.57	14	286
EOW	☐	242.63	12.96	287.04
	☐	245.23	12.64	287.36
	☐	247.73	11.75	288.25
BKF	☐	250.03	11.41	288.59
NG	☑	252.45	10.39	289.61
NG	☑	256.77	8.67	291.33
NG	☑	261.93	7.45	292.55
NG	☑	268.34	7.21	292.79
NG	☑	282.18	8.13	291.87
CL PATH	☑	294.48	8.9	291.1
	☐			

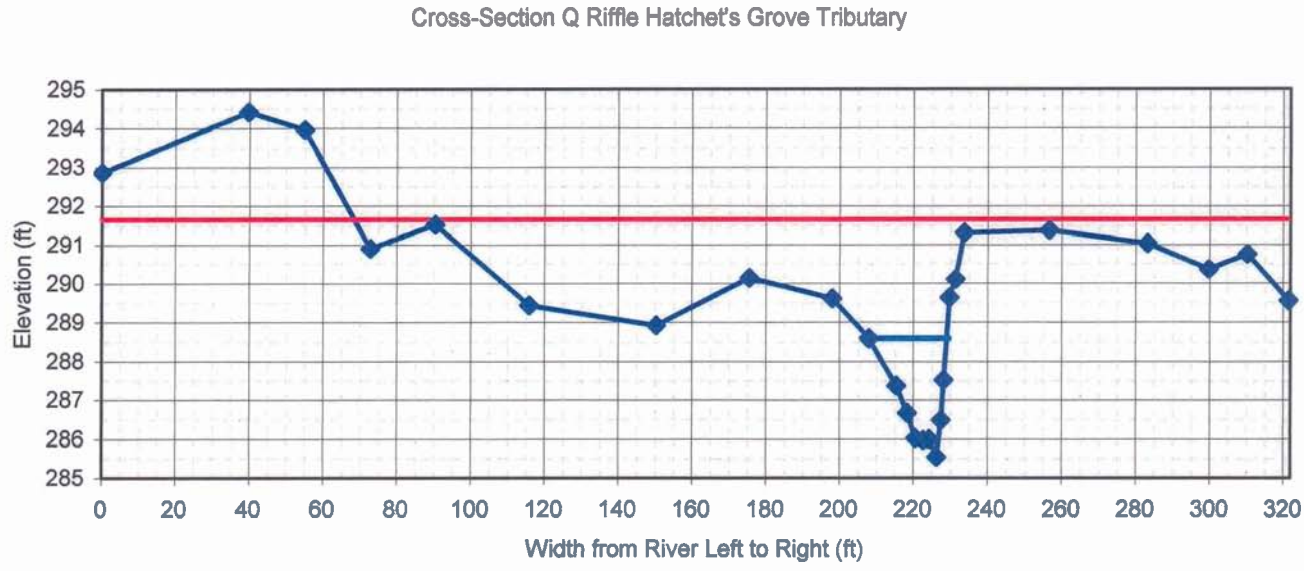
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
11.41	8.67	200.0	0.2	0.033
288.59	291.33			

dimensions			
46.3	x-section area	2.1	d mean
22.5	width	24.3	wet P
3.4	d max	1.9	hyd radi
6.1	bank ht	11.0	w/d ratio
200.0	W flood prone area	8.9	ent ratio

hydraulics	
3.1	velocity (ft/sec)
143.4	discharge rate, Q (cfs)
0.24	shear stress ((lbs/ft sq)
0.35	shear velocity (ft/sec)
0.794	unit stream power (lbs/ft/sec)
0.14	Froude number
8.8	friction factor u/u*
13.4	threshold grain size (mm)

check from channel materia	
	fric. factor
0.024	Manning's n from channel material

Cross Section



section:	Cross-Section Q
	Riffle Hatchet's Grove Tributary Neuse River Basin
description:	Station 24+97.51
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG/PINES	☑	0	7.14	292.86
NG/PINES	☑	39.79	5.58	294.42
NG	☑	54.98	6.04	293.96
NG	☑	72.79	9.1	290.9
NG	☑	90.33	8.48	291.52
NG	☑	115.89	10.56	289.44
NG	☑	150.26	11.08	288.92
NG	☑	175.49	9.86	290.14
	☑	198.05	10.39	289.61
BKF	☐	207.92	11.41	288.59
EOW	☐	215.4	12.63	287.37
	☐	218.29	13.33	286.67
	☐	220.56	13.98	286.02
TW	☐	222.73	14.03	285.97
	☐	224.31	14	286
	☐	226.26	14.46	285.54
	☐	227.45	13.51	286.49
EOW	☐	228.16	12.48	287.52
	☐	229.75	10.37	289.63
NG	☑	231.35	9.89	290.11
TOB	☑	233.69	8.69	291.31
NG	☑	256.63	8.63	291.37
CL C PATI	☑	283.15	8.97	291.03
NG	☑	299.79	9.64	290.36
NG	☑	310.23	9.25	290.75
E POND	☑	321.5	10.45	289.55
	☐			

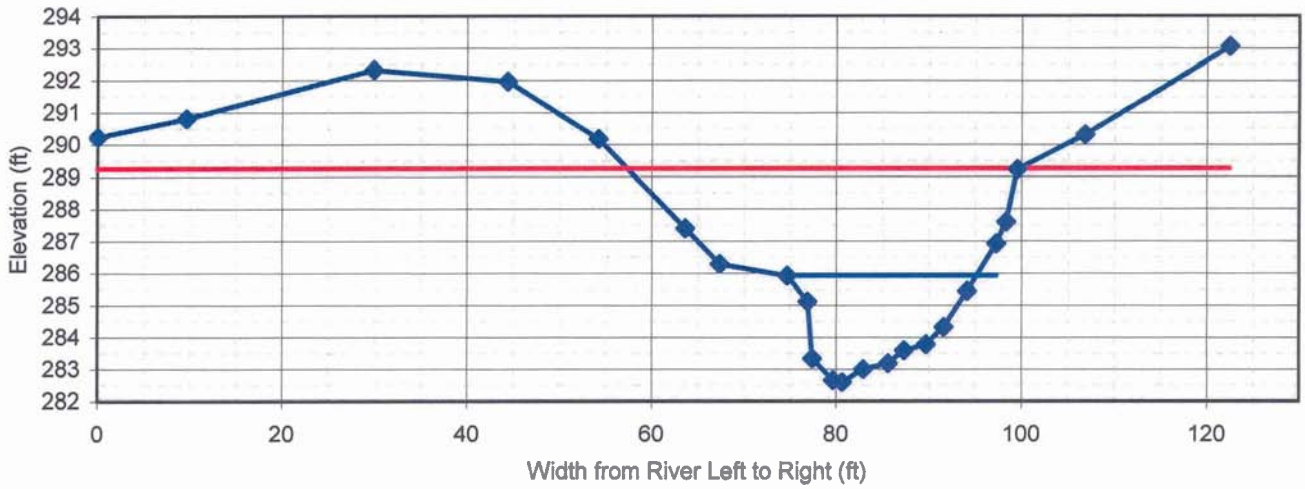
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
11.41	8.69	250.0	0.2	0.033
288.59	291.31			

dimensions			
34.1	x-section area	1.6	d mean
21.0	width	22.8	wet P
3.0	d max	1.5	hyd radi
5.8	bank ht	13.0	w/d ratio
250.0	W flood prone area	11.9	ent ratio

hydraulics	
2.6	velocity (ft/sec)
89.7	discharge rate, Q (cfs)
0.19	shear stress ((lbs/ft sq)
0.31	shear velocity (ft/sec)
0.532	unit stream power (lbs/ft/sec)
0.13	Froude number
8.5	friction factor u/u*
10.9	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
37.5	relative roughness	11.8	fric. factor
0.024	Manning's n from channel material		

Cross Section



section:	Cross-Section R
	Riffle
	Hatchet's Grove Tributary
	Neuse River Basin
description:	Station 32+61.99
height of instrument (ft):	300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
CL PATH	☑	0	9.77	290.23
NG	☑	9.62	9.2	290.8
NG/TEE	☑	29.92	7.68	292.32
NG	☑	44.38	8.04	291.96
NG	☑	54.23	9.83	290.17
NG	☑	63.65	12.61	287.39
NG	☑	67.36	13.72	286.28
BKF	☐	74.68	14.09	285.91
	☐	76.87	14.89	285.11
	☐	77.4	16.67	283.33
	☐	79.64	17.36	282.64
TW	☐	80.63	17.42	282.58
TW/RIFFLE	☐	82.91	17.01	282.99
	☐	85.61	16.82	283.18
	☐	87.35	16.42	283.58
EOW	☐	89.72	16.23	283.77
	☐	91.62	15.68	284.32
	☐	94.12	14.56	285.44
	☐	97.25	13.09	286.91
	☑	98.33	12.42	287.58
TOB	☑	99.55	10.78	289.22
NG	☑	106.83	9.69	290.31
NG	☑	122.44	6.95	293.05
	☑			
	☐			

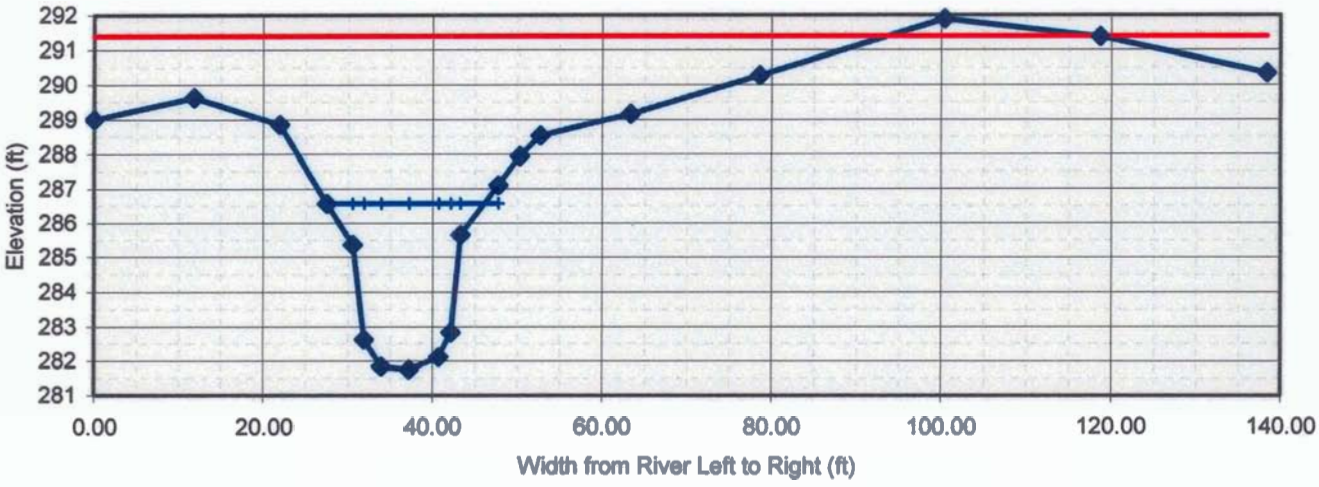
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
14.09	10.78	40.0	0.2	0.033
285.91	289.22			

dimensions			
42.4	x-section area	2.1	d mean
20.4	width	22.5	wet P
3.3	d max	1.9	hyd radi
6.6	bank ht	9.9	w/d ratio
40.0	W flood prone area	2.0	ent ratio

hydraulics	
3.1	velocity (ft/sec)
130.1	discharge rate, Q (cfs)
0.23	shear stress ((lbs/ft sq)
0.35	shear velocity (ft/sec)
0.794	unit stream power (lbs/ft/sec)
0.14	Froude number
8.8	friction factor u/u*
13.2	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
48.1	relative roughness	12.4	fric. factor
0.023	Manning's n from channel material		

Cross Section



section: Cross-Section S
Riffle
Hatchet's Grove Tributary
Neuse River Basin
description: Station 34+70.64
height of instrument (ft): 300.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
NG	☑	0.00	11.00	289
NG	☑	11.81	10.38	289.62
TOB	☑	21.93	11.16	288.84
BKF	☐	27.51	13.44	286.56
	☐	30.58	14.65	285.35
	☐	31.91	17.38	282.62
	☐	33.96	18.17	281.83
TW	☐	37.22	18.26	281.74
	☐	40.72	17.89	282.11
	☐	42.17	17.18	282.82
BKF	☐	43.31	14.36	285.64
	☐	47.76	12.91	287.09
	☑	50.28	12.08	287.92
TOB	☑	52.72	11.48	288.52
NG	☑	63.34	10.85	289.15
NG	☑	78.62	9.74	290.26
NG	☑	100.41	8.12	291.88
NG	☑	118.68	8.63	291.37
CL PATH	☑	138.39	9.67	290.33
	☑			
	☐			
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
13.44	11.16	200.0	0.2	0.033
286.56	288.84			

dimensions			
55.9	x-section area	3.0	d mean
18.6	width	22.9	wet P
4.8	d max	2.4	hyd radi
7.1	bank ht	6.2	w/d ratio
200.0	W flood prone area	10.7	ent ratio

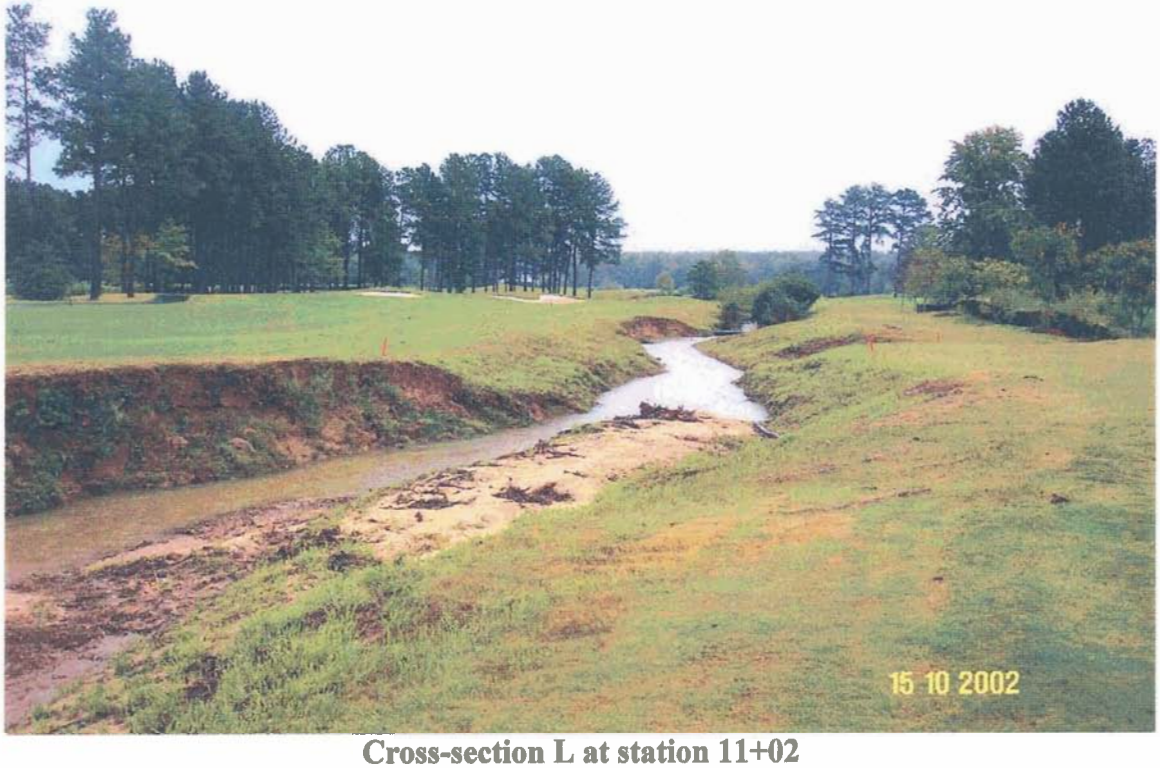
hydraulics	
3.6	velocity (ft/sec)
203.5	discharge rate, Q (cfs)
0.30	shear stress ((lbs/ft sq)
0.40	shear velocity (ft/sec)
1.364	unit stream power (lbs/ft/sec)
0.14	Froude number
9.2	friction factor u/u*
17.6	threshold grain size (mm)

check from channel material			
13	measured D84 (mm)		
69.5	relative roughness	13.3	fric. factor
0.023	Manning's n from channel material		

Cross-section E (near cross-section F) at station 1+78

Cross-section I at station 5+52

Cross-section K at station 10+68



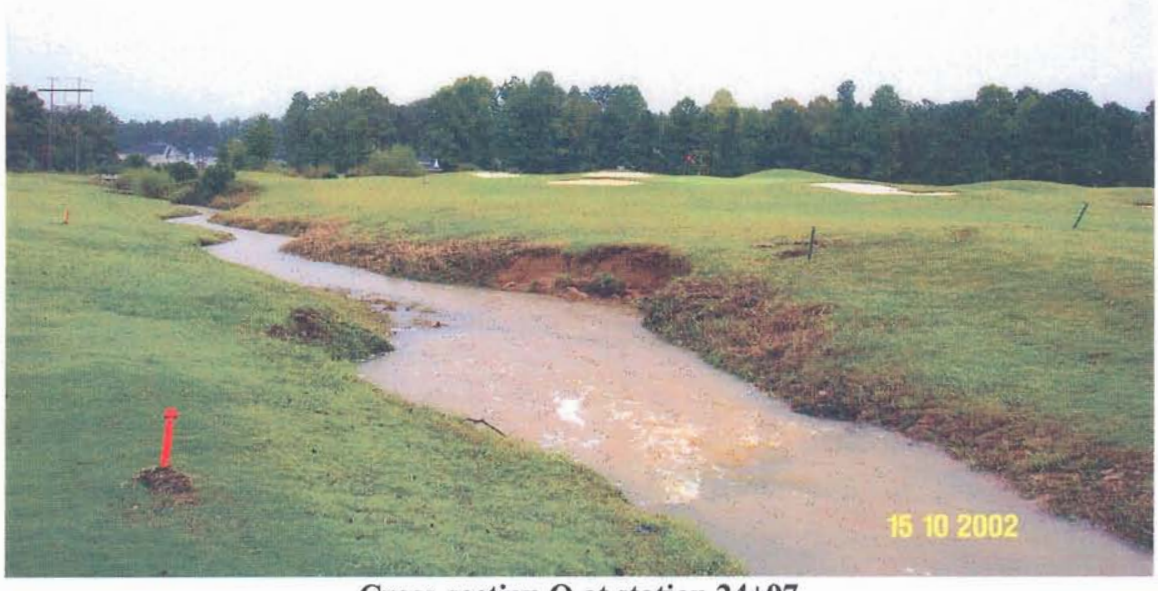
Cross-section L at station 11+02

Cross-section M at station 13+26

Cross-section N at station 13+58

Cross-section O at station 17+97

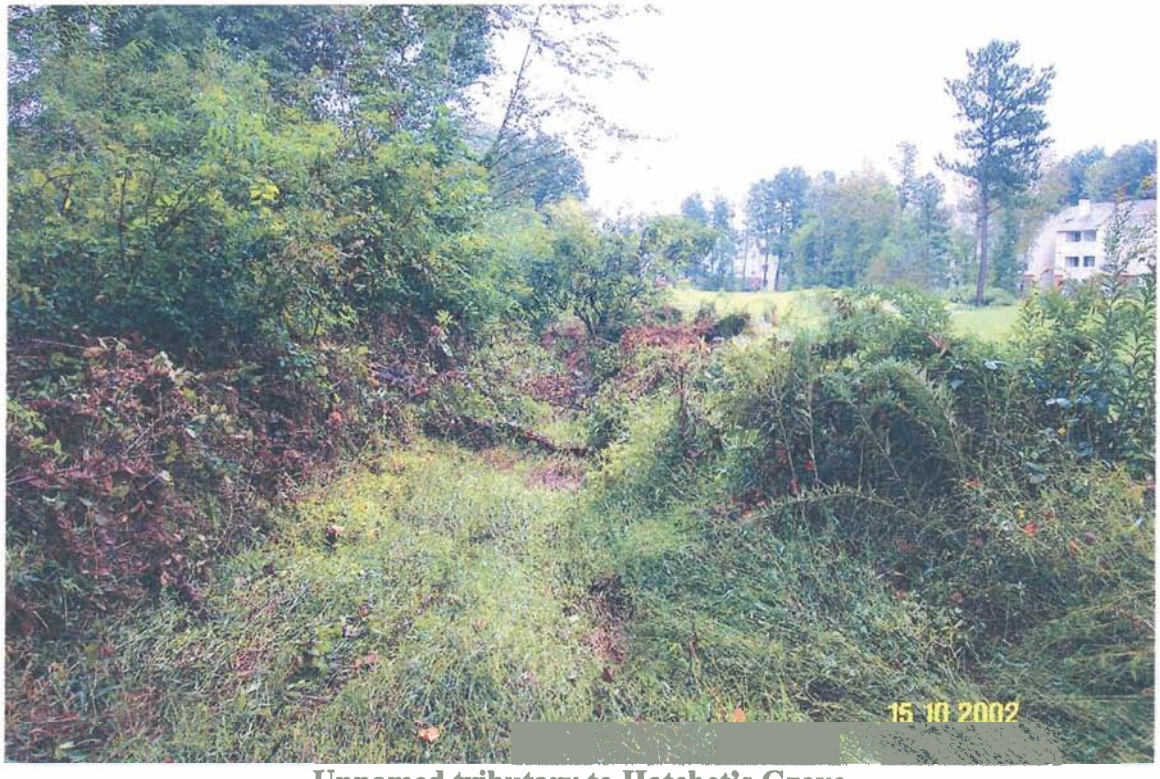
Cross-section P at station 24+65



Cross-section Q at station 24+97

Cross-section R at station 32+61

Cross-section S at station 34+70



Unnamed tributary to Hatchet's Grove

Ongoing bank erosion above bridge #3 after high flow (note collapsed vegetation)

Bare, vertical bank with high erosion potential at high flow

Bank Erosion Potential

Date: 8/13/2002
Stream: Hatchet's Grove Tributary
Feature: Riffle, Cross-Section "K"
Staton: Cross-Section "L" - 11+02
Crew: Jim Cooper, Patrick Smith
Notes: 100' below Bridge #2-BEHI #1

Parameter	Very Low		Low		Moderate		High		Very High		Extreme		Value	Index
	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index		
Bank Height Ratio	1.0-1.1	1.0-1.9	1.11-1.19	2.0-3.9	1.2-1.5	4.0-5.9	1.6-2.0	6.0-7.9	2.1-2.8	8.0-9.0	>2.8	10	2.1	8
Root Depth/Bank Height	1.0-0.9	1.0-1.9	0.89-0.5	2.0-3.9	0.49-0.3	4.0-5.9	0.29-0.15	6.0-7.9	0.14-0.05	8.0-9.0	<0.05	10	0.12	8.3
Root Density (percent)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-5.0	8.0-9.0	<5	10	5	9
Bank Angle (degrees)	0-20	1.0-1.9	21-60	2.0-3.9	61-80	4.0-5.9	81-90	6.0-7.9	91-119	8.0-9.0	>119	10	80	5.9
Surface Protection (percent)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-10	8.0-9.0	<10	10	10	9

	Very Low	Low	Moderate	High	Very High	Extreme
Erosion Potential	5-9.5	10-19.5	20-29.5	30-39.5	40-45	>45

Sub Total **40.2**
Adjustments **0**
Total **40.2**

Adjustments:

Bank Materials

Bank Erosion Potential: **VERY HIGH**

Bedrock- Banks composed of bedrock have a very low bank erosion potential
Boulders- Banks composed of boulder have a very low bank erosion potential
Cobble- Subtract 10 points from total. If sand/gravel matrix is greater than 50% of bank material, then do not adjust.
Gravel- Add 5-10 points depending on percentage of bank material is composed of sand
Sand- Add 10 points
Silt Clay- no adjustment

Stratification- Add 5-10 points depending on position of unstable layers in relation to the bankfull stage

Location of BEHI #1 near cross-section L

Bank Erosion Potential

Date: 8/13/2002
Stream: Hatchet's Grove Tributary
Feature: Riffle/Run
Staton: 21+43, estimated
Crew: Jim Cooper, Patrick Smith
Notes: **150 feet below Bridge #4-BEHI #2**

Parameter	Very Low		Low		Moderate		High		Very High		Extreme		Value	Index
	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index		
Bank Height Ratio	1.0-1.1	1.0-1.9	1.11-1.19	2.0-3.9	1.2-1.5	4.0-5.9	1.6-2.0	6.0-7.9	2.1-2.8	8.0-9.0	>2.8	10	1.4	**5.5**
Root Depth/Bank Height	1.0-0.9	1.0-1.9	0.89-0.5	2.0-3.9	0.49-0.3	4.0-5.9	0.29-0.15	6.0-7.9	0.14-0.05	8.0-9.0	<0.05	10	0.15	**7.9**
Root Density (percent)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-5.0	8.0-9.0	<5	10	<5	**10**
Bank Angle (degrees)	0-20	1.0-1.9	21-60	2.0-3.9	61-80	4.0-5.9	81-90	6.0-7.9	91-119	8.0-9.0	>119	10	100	**8.5**
Surface Protection (percent)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-10	8.0-9.0	<10	10	<10	**10**

	Very Low	Low	Moderate	High	Very High	Extreme
Erosion Potential	5-9.5	10-19.5	20-29.5	30-39.5	40-45	>45

Sub Total **41.9**
Adjustments **0**
Total **41.9**

Adjustments:

Bank Erosion Potential: **VERY HIGH**

Bank Materials

Bedrock- Banks composed of bedrock have a very low bank erosion potential
Boulders- Banks composed of boulder have a very low bank erosion potential
Cobble- Subtract 10 points from total. If sand/gravel matrix is greater than 50% of bank material, then do not adjust.
Gravel- Add 5-10 points depending on percentage of bank material is composed of sand
Sand- Add 10 points
Silt Clay- no adjustment

Stratification- Add 5-10 points depending on position of unstable layers in relation to the bankfull stage

Location of BEHI #2 near cross-section O

Bank Erosion Potential

Date: 8/13/2002
Stream: Hatchet's Grove Tributary
Feature: Riffle
Staton: Cross-Section "Q", 24+97
Crew: Jim Cooper, Patrick Smith
Notes: 200 feet below Bridge #5-BEHI #3

Parameter	Very Low		Low		Moderate		High		Very High		Extreme		Value	Index
	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index		
Bank Height Ratio	1.0-1.1	1.0-1.9	1.11-1.19	2.0-3.9	1.2-1.5	4.0-5.9	1.6-2.0	6.0-7.9	2.1-2.8	8.0-9.0	>2.8	10	2.2	**8.1**
Root Depth/Bank Height	1.0-0.9	1.0-1.9	0.89-0.5	2.0-3.9	0.49-0.3	4.0-5.9	0.29-0.15	6.0-7.9	0.14-0.05	8.0-9.0	<0.05	10	<.05	**10**
Root Density (percent)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-5.0	8.0-9.0	<5	10	10	**8.5**
Bank Angle (degrees)	0-20	1.0-1.9	21-60	2.0-3.9	61-80	4.0-5.9	81-90	6.0-7.9	91-119	8.0-9.0	>119	10	81	**6**
Surface Protection (percent)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-10	8.0-9.0	<10	10	10	**8**

	Very Low	Low	Moderate	High	Very High	Extreme
Erosion Potential	5-9.5	10-19.5	20-29.5	30-39.5	40-45	>45

Sub Total **40.6**
Adjustments **0**
Total **40.6**

Adjustments:

Bank Erosion Potential: VERY HIGH

Bank Materials

Bedrock- Banks composed of bedrock have a very low bank erosion potential
Boulders- Banks composed of boulder have a very low bank erosion potential
Cobble- Subtract 10 points from total. If sand/gravel matrix is greater than 50% of bank material, then do not adjust.
Gravel- Add 5-10 points depending on percentage of bank material is composed of sand
Sand- Add 10 points
Silt Clay- no adjustment

Stratification- Add 5-10 points depending on position of unstable layers in relation to the bankfull stage

Location of BEHI #3 near cross-section Q