Reedy Branch
Restoration Design Report

Alamance County, North Carolina

Produced for

North Carolina Wetland Restoration Program

By

EcoLogic Associates, PC

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1. Introduction

The North Carolina Wetland Restoration Program seeks to restore 3100 linear feet of Reedy Branch, located in the Cane Creek Watershed in Alamance County, North Carolina. Reedy Branch is located in the Upper Cape Fear River Basin. This document summarizes the project's purpose, existing site conditions, assessment methodologies, and proposed restoration design. Supporting information is included in the attached appendices.

a. Project Justification

Reedy Branch is located in an agricultural valley where cattle have full access to the creek, have trampled the banks, and have virtually eliminated the herb, shrub and juvenile tree populations along its banks. The lack of woody riparian vegetation has resulted in accelerated erosion in the form of vertical and undercut banks. The width/depth ratio has increased as a result of bank failures. The problem is exacerbated because the channel has cut down to bedrock in many places, forcing excess stream power into unprotected banks.

In addition to bank instabilities, the channel bed lacks proper distribution and development of riffles and pools. Riffles occur in curves and pools in straight reaches. Pools are often long, wide and shallow. Furthermore, the channel substrate alternates between scoured armor and heavy deposition of fines.

2. Goals and Objectives

The design goals of the Reedy Branch restoration project are as follows:

1. Improve water quality by reducing the sediment load generated by eroding banks and by restoring a riparian buffer;
2. Reestablish stable channel dimension, pattern, and profile;
3. Restore a functioning floodplain;
4. Enhance aquatic and terrestrial habitat in the stream corridor; and
5. Provide at least one stable cattle crossing across the main channel.

3. Location Information

a. River Basin

Reedy Branch drains to Cane Creek, which drains to the Haw River in the Cape Fear River Basin.

b. USGS Catalog Number

The USGS 8-digit Catalog number of the watershed that includes the restoration reach is 03030002- Haw River, NC.

c. County

The site is in south central Alamance County.

d. Site Map (See Appendix 1, Vicinity Map)

e. Location

The site can be accessed from Quackenbush Road (SR 2354), which crosses Reedy Branch at the northern end of the project. The landowners for this project are Deborah and Sam Kiser (1957 Quackenbush Road, Snow Camp, NC, 27349). The project starts at the property line southeast of the landowners' house, at the point where the creek enters their property, and ends where the creek passes under Quackenbush Road.

4. General Watershed Information

a. Drainage Area

The Reedy Branch watershed above the restoration reach drains about 1.6 square miles. The creek starts about one-half mile south of the Alamance and Chatham County line and flows generally north to its confluence with Cane Creek, about 1.6 miles east of Snow Camp, NC.

b. Dominant Land Use

The watershed consists primarily of woodland and famland. The agricultural land use is a combination of row crops and animal grazing. The row crops include silage corn, winter wheat, soybeans and a few others. The primary animal grazing is cattle. Historically, this region has been a dairy farming area however; most of the dairy farms converted to beef cattle in recent years.

c. Distribution of Land Use

Cultivated land makes up a significant portion of the watershed, although it has been declining in the last two decades. The peak occurred in the late 1940's, with as much as 45 percent of the watershed under cultivation (mostly dairy farms). Currently, the degree of agricultural landuse has dropped to about 25 percent with just over half of that being cultivated land and the rest pasture and hay fields. About 20 large poultry farms occur in the area, including the Kiser farm. Poultry is a growing segment of the agricultural sector throughout the region.

The remainder of the watershed is woodlands, which often are extensively and routinely logged. There are scattered residential lots throughout the watershed.

The amount of residential development is higher in the southern portion of the watershed, along the Chatham County line. There are no other urban, commercial or industrial land uses in the project watershed.

d. Estimation of Future Land Use Change

Over the last several years residential development has increased. Increased residential development will likely lead to increases in the volume of stormwater discharging into Reedy Branch. Residential and small commercial development is expected to continue in the watershed in the future.

5. Description of Existing Conditions

The entire project is on the property of one landowner. The landowners are willing to donate a conservation easement over the entire floodplain following the restoration work. They have been very helpful and understanding and should good stewards of this conservation site. The current owners have been on the property for about 15 years. Current land use in the valley includes pasture and hayfields and a large poultry house on the hill above the main channel. The restoration reach runs through a forested but heavily browsed floodplain.

a. Existing Hydrological Features

The Reedy Branch restoration site is located in a relatively low-slope Piedmont valley in the Carolina Slate Belt. It is a second order tributary to Cane Creek in the Haw River Basin.

Reedy Branch is listed by the NC DWQ as Class C waters, protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, and agriculture. There are no restrictions on watershed development activities.

b. Soils (See Appendix 2, Soils Map)

The soils of Alamance County are currently being remapped. The current soils map was published in 1960 and is known to have significant errors and discrepancies. Soils classification and re-mapping is currently underway; published results are expected in about ten years. The soils around Reedy Branch are currently identified as Herndon silt loam on the upland terraces and other well-drained, moderately permeable "mixed alluvial" soils on floodplains.

The Herndon series consists of light brownish-gray, very acid, well-drained soils on uplands. These soils occur in the southern and eastern parts of Alamance County in the volcanic slate region. The soils of the Kiser farm are found on 2 to15 percent slopes and include several mapped types of Herndon silt loams of various depths over rocky subsoils. The soils have a moderately permeable texture and a medium capacity to hold water. They have been shown to be agriculturally workable and respond well to fertilizer and lime application. Depending on the slope they are moderately to highly susceptible to erosion, and the management recommendations of the sloping soil locations include close-grown pasture and forage crops and forestry uses that minimize soil disturbance. In the middle of the restoration reach, the soils have eroded away leaving many areas of exposed bedrock within and along both sides of the stream.

Several areas along the restoration reach are mapped as "stony soils", another classification that is being updated. The current classification describes stony soils as having a high proportion of gravel, cobbles and boulders. These soils are thin and droughty, providing little habitat for deep-rooted species. In many areas of the thin, stony soils, the trees have suffered dramatically during the current drought.

The alluvial soils that are mapped along the channel are not specifically named. The description is of general alluvial deposition, with moderate to high permeability and high levels of organic matter and sandy inclusions. Both the Herndon and mixed alluvial soils are noted to be droughty when they are thin and associated with bedrock outcrops. Our observations of this restoration reach throughout the dry summer of 2002 confirm this fact. Premature leaf-drop and senescence of the riparian deciduous trees was evident in early August. By the end of the month, many mature trees in the floodplain were showing signs of drought stress and dieback.

Because the stream is incised, long sections of bare, vertical banks are exposed. Materials eroded from these areas are transported downstream since the stream has limited access to its floodplain.

c. Existing Plant Communities

Historically, the natural vegetation in the floodplain of Reedy Branch was likely mixed hardwoods with thick undergrowth of riparian shrubs and herbs. There are several natural plant communities listed in the Third Approximation of Natural Communities of North Carolina, which could be found in this area depending on the local conditions and amount of disturbance.

The current existing vegetation is a mixture of the remnant natural alluvial community and introduced agricultural weedy and pasture species, and a few invasive exotics. The riparian vegetation corridor varies in width from zero to several hundred feet of successional forest. On average, the buffer width is probably over 150 feet.

The banks of the creek and the floodplain are vegetated with a medium-aged, mixed hardwood forest typical of this area. The canopy includes Red Maple, Sycamores, several Hickory and Oak species, Boxelders, Green Ash, Tulip

Trees, Sweet Gum and Virginia and Shortleaf Pines. The understory species include, Ironwood Dogwood, Sourwood, Red Cedar, Slippery Elm, American Holly, Hackberry and juveniles of the canopy tree species. The shrubs include Spicebush, Buckthorn, Multiflora Rose and Strawberry Bush. There are also several areas with thick growths of Japanese Honeysuckle, Greenbrier, Poison Ivy and Blackberry Brambles. There are herbs in areas having few trees including mixtures of native and introduced grasses such as Blue Grass, Orchard Grass, Timothy, Fescue, bromes, vetches, clover, Wingstem, Japanese Grass, several sedges, Soft rush, Christmas Fern, Grape Ferns, False Nettle, Asters, native Sunflower species and Goldenrods.

Cattle pasture makes up most of the land use on adjacent uplands above the floodplain containing the restoration reach. The cattle currently have access to the entire floodplain and cross the creek at many locations. They have browsed most of the trees and shrubs below 5 feet and have also eliminated almost all herbaceous species that are edible. Because the channel was dry this summer, the cattle walk along the bed in search of the few remaining pools of water, damaging or eating much of the in-stream and bank vegetation.

d. Stream Geometry and Substrate

1. Level II Classification

An existing condition survey of Reedy Branch was conducted in July 2002. The pre-restoration stream length is 3100 linear feet. Based on the Rosgen stream classification system, the stream is an unstable C4/1 stream type. (*Applied River Morphology,* D. Rosgen, 1996, p. 6-5)

The survey of this stream was complicated by the local drought, which resulted in the stream having very little flow early in the season, and then drying up completely. As a result, it was very difficult to survey and inspect subtle features like runs and glides, and it was impossible to get water surface measurements at all but a few pools.

The cross-section dimensions are typical of this impacted stream type, location and drainage area (see Appendix 3, Morphology Summary). Due to the loss of much of the riparian vegetation, the direct impacts from the cattle, and agricultural alteration of the watershed and the channel, the bankfull width has increased. In most areas throughout the restoration reach the creek grade is controlled by exposed bedrock, which deflects the energy of the stream into the soft, unprotected banks. The lateral movement of the creek through these soft banks has undermined many of the well-rooted mature trees, resulting in debris jams that further destabilize the creek. The incised sections of the creek exaggerates the stress on the banks since there is less ability to dissipate flood energy across the floodplain. The majority of the banks are therefore undercut and failing.

Overall sinuosity, at 1.4, is acceptable for a C4 stream type. Generally, a C stream channel has a sinuosity of 1.2 or greater. However, there are several areas that are overly straight and other areas that have bends with low and unstable radii of curvature. The planform geometry is irregular and, combined with the bedrock outcrops, results in unstable bedform features (riffles, runs, glides and pools). Almost all of the riffles throughout the reach have been used as crossing points by cattle, which has resulted in further destabilization of the banks and bed, acceleration of bank erosion, and the introduction of manure into the channel.

The Pfankuch rating for this stream is 109, which indicates a Fair to Poor quality channel for a C4 stream type. A BEHI bank erosion prediction was calculated for the eroding bank in the middle of the restoration reach. The BEHI analysis indicates very high erosion potential. We do not have an erosion estimate since the channel was dry and we have no facet slope data for bank erosion calculations. The measurement of facet slopes requires flowing waters and cannot be accurately estimated in dry conditions. Given the soft and sandy unconsolidated and unprotected nature of the banks, we would expect the sediment contribution to the watershed from this reach would be very high.

The North Carolina Rural Piedmont Regional Curve and a gage analysis of the Cane Creek Gage near Orange Grove, NC were used to verify the bankfull stage identified in the field. By continuity, bankfull discharge is calculated to be 133 cubic feet per second. The velocity comparison calculation gives a calculated velocity of 3.5 feet per second.

2. Pavement / Subpavement Analysis

The geology of the Slate Belt region strongly influences the morphology of the stream and the distribution of the bed material. There are several outcrops of bedrock that cross the channel and, in some cases, confine the channel in a bedrock chute. As mentioned above, one of the soils classifications for this area is "stony areas", which seem to occur mostly in the middle of the restoration reach.

The bedrock distribution controls the bed elevation of most of the creek. The creek is, therefore, a "threshold channel" that is not free to adjust all its boundaries and has increased in width since the depth is largely fixed. This means that the channel will naturally have a higher width-to-depth ratio than would be expected under less confining conditions.

The pavement and subpavement of the most diagnostic portions of the stream were sampled at four different locations throughout the restoration reach. The typical pavement D50 was about 11.6 mm, with the D84 being 26.1 mm. The subpavement D50 was 9 mm, with a D84 of 62 mm.

Given these samples, a D50 of a bar of 14mm, and a largest particle on the bar being 35mm, the entrainment calculation results in a depth of 1.22 feet required to move the largest particle in the bar sample. The calculated slope is 0.0032, which combined with the depth gives a Bankfull Shear Stress of 0.28 pounds per square foot. The entrainment calculation indicates the channel is stable and competent to move its sediment load. The vertical stability of the stream is stable largely due to the extensive bedrock found throughout the restoration reach. Refer to Appendix 4, Existing Entrainment and Velocity Forms.

6. Stream Reference Reach Studies

a. Classification of Reference Stream(s)

An unnamed tributary to Varnals Creek was used as a reference reach for design (see Appendix 5, Reference Vicinity Map). We obtained the location information from colleagues working in the same area. They surveyed an upstream section of the creek that had a more confined valley type and steeper slope than would be appropriate for our restoration. Fortunately, the section just downstream changed to a wider valley and a shallower slope. The data from both reference reach sections is shown on the morphological data table. The data from the C4 reach was used as the primary reference.

The gage on Cane Creek near Orange Grove, NC is on a stream reach that also shows indications of stability and other features of valley type and stream type that would qualify it as a potential reference reach. We have not officially requested approval from DWQ to consider this reach as a reference; however, the data collected from this reach supports our design choices.

The section of Varnals Creek that we chose for our reference reach has a width-to-depth ratio of 19.3, an entrenchment ratio of 7.2 and a sinuosity of 1.4. Together these indicate a C type stream. The D50 of the channel material is 8.7, mm making it a gravel bed stream. There are also significant bedrock outcrops that appear to control the grade of the stream. The resulting Rosgen Stream Type is C4/1 (see Appendix 3, Morphology Table).

b. Reference Dimension, Pattern and Profile

The reference reach has a watershed drainage area of about 0.4 square mile. The measured bankfull width was 11.8 feet, with a mean depth of 0.6 feet. The calculated cross-sectional area is 7.2 square feet. At the point of our survey, the stream had access to 85 feet of floodplain at twice the bankfull depth.

The pattern of the reference reach indicated a meander length of 79 feet and a belt width of 23 feet. The average radius of curvature was 17.7 feet. This produced a radius of curvature to bankfull width ratio range of 2.5 to 4.4 and a meander length to bankfull width ratio of 6.7.

The valley type is similar in the reach surveyed to the valley type of the restoration reach. The valley slope is 2.5 percent, which is steeper than the restoration reach valley slope of 0.4 percent. This is typical, since most reference reaches we have observed are in headwater forested areas, while most restoration projects occur further down the valley in agriculturally-impacted, larger floodplains.

The reference reach was a dry channel at the time of our survey. This is apparently a common feature of Slate Belt streams. The average water surface slope was estimated using the slope from the top of a riffle with good bankfull indicators to the top of the lowest riffle with good bankfull indicators. The estimated water surface slope of the reference reach was calculated to be 1.8 percent.

The Stream Morphology Table (Appendix 3) contains the numerical details of the reference reach survey. In addition, to the basic morphological data, the Band Erosion Hazard Index analysis indicated low bank erosion potential. The Pfankuch channel stability evaluation indicated good channel stability for this reach based on stream type C4.

c. Reference Stream Vegetative Community

The reference reach lies in a forested valley northeast of Cane Creek Mountain. There is some new residential development on the edge of the watershed along Bass Mountain Road. Like most forests of the Piedmont, this site has been logged several times. The growth of the current forest indicates the most recent logging to have been 30 to 40 years ago.

The vegetation along the creek is a diverse mixture that includes a canopy of Oaks, Red Maple, Tulip Trees, Hickories, and Green Ash. The sub canopy includes juveniles of these species plus some Sourwoods, Dogwoods, Redbud, and Cucumber Magnolia. The shrub layer includes several Vaccinium species and Clethera along the channel edge. The most significant feature of the streamside vegetation is thick colonies of Lady Fern, New York Fern and Royal Fern. These ferns were conspicuous in spite of the drought that had dramatically affected the other herbaceous plants along the valley floor. Additional plants along the riparian edge include Greenbrier, Evergreen Gingers, Blackberry, Foamflower, Falsenettle, Lamp Rush and Sedges.

7. Stream Restoration Plan

a. Stream Classification of Restored Site

The natural channel design procedure relies on the interpretation of all available information about the site and its watershed. Aerial photographs from 1988 and 1993 are available for this site; however, they are of little use since they don't show enough detail to provide a good source of historical information on channel stability, modifications, and adjustment. Based on the current condition, valley type and slope, as well as the existing dimension, pattern and profile of the channel, the restored channel will be designed to be a stable C4/1.

b. Morphological Table (see Appendix 3)

1. Existing Conditions

2. Proposed Conditions

3. Reference Conditions

c. Scaled Plan View of Current and Proposed Channels

(see Appendix 6)

d. Plan View with Proposed Structures

(see Appendix 7)

Cross vanes, weirs and existing bedrock will be used to control grade at the tops of riffles. Root wads will be used to protect the outside of meander bends. In the interest of reducing the bank height ratio, vertical banks will be laid back to create a bankfull bench and to establish a more stable growing surface. The planform geometry of the creek will also require adjustment to a more stable meander pattern that eliminates some over-sharp, eroding curves in the existing channel. The narrow confines of the valley require that the new channel cross the existing channel at several locations. These crossing points will require clay channel plugs to prevent the water flow from seeping into the old channel. These crossings have been kept to an absolute minimum. Structural details and specifications will be provided in the final design package.

The tie-in to natural grade will be done at the upper end using a cross vane located slightly downstream of a bedrock outcrop on the upstream property. The downstream tie-in will be at a bedrock outcrop just upstream of the bridge on Quackenbush Road. The natural substrate of the stream will not be altered.

e. Proposed Longitudinal Profile

(see Appendix 8)

f. Sediment Transport Analysis

(see Appendix 9, Proposed Entrainment and Velocity Forms)

The critical shear stress calculated for the proposed channel must be able to move the largest particle on the point bar. Entrainment calculations based on the riffle pebble count and a sieved bar sample are included in Appendix 9. Based on these calculations, the critical dimensionless shear stress calculated for Reedy Branch is 0.024. This value corresponds to a required mean bankfull depth of 1.2 feet to move the design particle size. Measured mean depth is 1.4 feet. The bankfull water surface slope required is 0.0032 ft/ft, which is roughly equal to the current bankfull slope of 0.0039 ft/ft. Mean depth calculations indicate a stable stream, with vertical stability controlled by bedrock throughout the channel.

The calculated bankfull shear stress is 0.28 lb/ft^2. Based on the Shields diagram, bankfull flow can move a particle 17 mm in diameter. However, using a revised curve generated by Dave Rosgen based on competence of natural rivers to move particles, a shear stress of 0.28 lb/ft^2 corresponds to moving a particle closer to 60 mm in diameter. This is consistent with a 35 mm particle found in our bar sample.

Estimated channel velocities, based on four calculation methods for existing and proposed conditions, range from 2.0 to 5.5 feet per second (fps). The estimated velocities selected are 3.5 and 5.4 fps for existing and proposed conditions respectively. These velocities were then compared with velocities predicted by Figure 8.31 on page 8-49 of *Stream Corridor Restoration Principals, Processes, and Practices* (1998, The Federal Interagency Stream Restoration Working Group). The chart predicted basic velocities ranging from 4.25 to 6.75 fps depending on sediment load. This range supports the selected velocity estimate for the proposed bankfull flow event.

The stability inventory for the Level 3 assessment indicates that Reedy Branch is a laterally unstable, bedrock controlled, C4 stream type, which can be restored to a stable C4/1. Problems arise due to high bank height ratio and high sediment supply from the cattle crossings, overly sharp bends and failing banks. This is evident in the amount of fines found in the pools. Therefore, the restoration design will focus on restoring stable meander geometry and establishing a bank height ratio of one (1) by creating bankfull benches and laying back banks so that woody vegetation can be established. These measures will restore stability and diminish sediment loads delivered into the creek.

The restoration will provide habitat improvement, stabilized bed features, and a reduced sediment supply. The revegetated riparian zone will improve habitat for aquatic and terrestrial species, which is of importance to the landowner and NC WRP.

8. Stream Performance Criteria and Monitoring Plan

The purpose of post-construction monitoring is to assess 1) the stability of the restored channel (physical monitoring of stream geomorphology) and 2) the survival rate of the vegetation planted during the restoration. EcoLogic will provide as-built plans following construction and prior to the first annual monitoring. The restoration of Reedy Branch involves changes to dimension, pattern and profile. Benchmarks for permanent monitoring cross-sections, reference photo points, and at other locations along the restoration reach profile will be installed during construction. These benchmarks will be referenced during all subsequent monitoring visits to allow all monitoring data to be comparable.

The monitoring period will be five (5) years from the end of construction. The monitoring shall be done annually during the fall and winter following the completion of construction and preferably following a bankfull event. EcoLogic staff will conduct the first year of monitoring. NC WRP staff or their designated contractor will conduct subsequent monitoring. Reports from each monitoring year will be sent to the NC WRP and EcoLogic.

The minimum requirement for dimension monitoring of one cross-section per 20 bankfull widths can be met with eight (6) cross-sections. The cross-sections will be located in such a way as to capture the range of cross-sectional geometry installed at the site. One cross-section will be located in a riffle section in the middle of the project that will also be the site of monitoring pebble counts and channel geometry diagnostics like width/depth ratio, entrenchment ratio, low bank height ratio and bankfull depth. The other cross-sections will be spread throughout the remainder of the channel to monitor other geomorphic features and locations.

The pattern of the restored stream will be documented with measurements of sinuosity, meander width ratio, and radius of curvature on the newly constructed meanders (first year only).

The longitudinal profile will be monitored throughout the length of the restoration reach. The profile will measure the bed, water surface, and bankfull indicator elevations, with careful documentation of bed features. The resultant data will provide facet slopes of the riffles and pools, average slope, and the spacing and length of the features documented (e.g., pool-to-pool spacing).

The bed materials will be documented by conducting a pebble count at each reference location. The D50 and D84 of the riffles and pools will be calculated and reported. A classification pebble count based on the percentage of riffles and pools will also be conducted and reported.

Photographs showing the banks and the channel, with a scale included will document each permanent (reference) cross-section. Photographs will also be taken of in-stream structures, the riparian vegetation, and one or more longitudinal views of the restoration reach.

Transects or sample blocks will be established for monitoring riparian vegetation. Seeded areas, transplants, and/or new seedlings will be assessed for establishment, survival rate and durability. Woody transplants and/or planted woody stems will be counted and assessed for species survival. Monitoring of woody vegetation will document attainment of the success criteria of 320 stems per acre after five years (5) and species diversity.

The monitoring plan may include benthic macroinvertebrate sampling. This will be contingent on NC DWQ acceptance of this site for study.

9. Sediment and Erosion Control Plan

(To be completed as part of the final design)

a. Narrative

b. Supporting Calculations

c. Schematics of Structures

List of Appendices

1. Site Maps and Photographs

2. Soils Map

3. Geomorphology Table and Typical Cross Sections

4. Existing Channel Velocity and Entrainment

5. Reference Reach Vicinity Map

6. Planview of Existing Conditions

7. Planview of Proposed Channel with Structures

8. Proposed Longitudinal Profile

9. Proposed Channel Velocity and Entrainment

10. Preliminary Planting Plan

Appendix 1

Vicinity Map of Reedy Branch

Watershed of Restoration Reach

Kiser Farm from Alamance County GIS

Site Photographs

Reedy Branch
Kiser Farm, Snow Camp, Alamance County


Local bank failure where channel is shifting laterally.


Long, straight pool with unstable banks. Note cattle tracks in mud.

Reedy Branch
Kiser Farm, Snow Camp, Alamance County


Bedrock constraining bed and bank


Bedrock and boulders on floodplain. Riparian vegetation cleared.

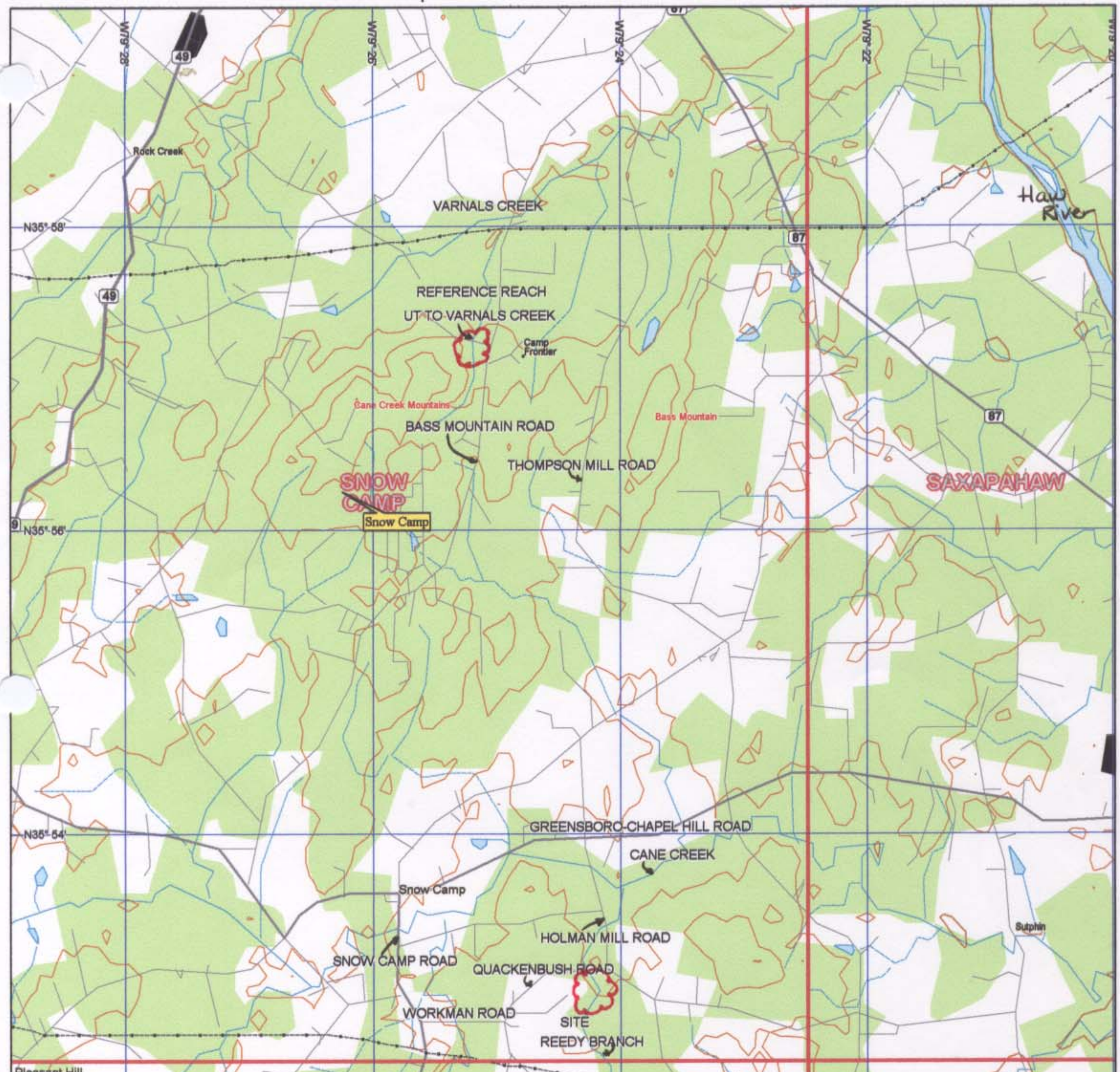
Reedy Branch

Kiser Farm, Snow Camp, Alamance County

Substrate alternates between boulders, fines, and bedrock. Note absence of shrubs and herbaceous species, channel pattern, and 36” to 42” vertical banks.

One of many cattle crossings

VICINITY MAP



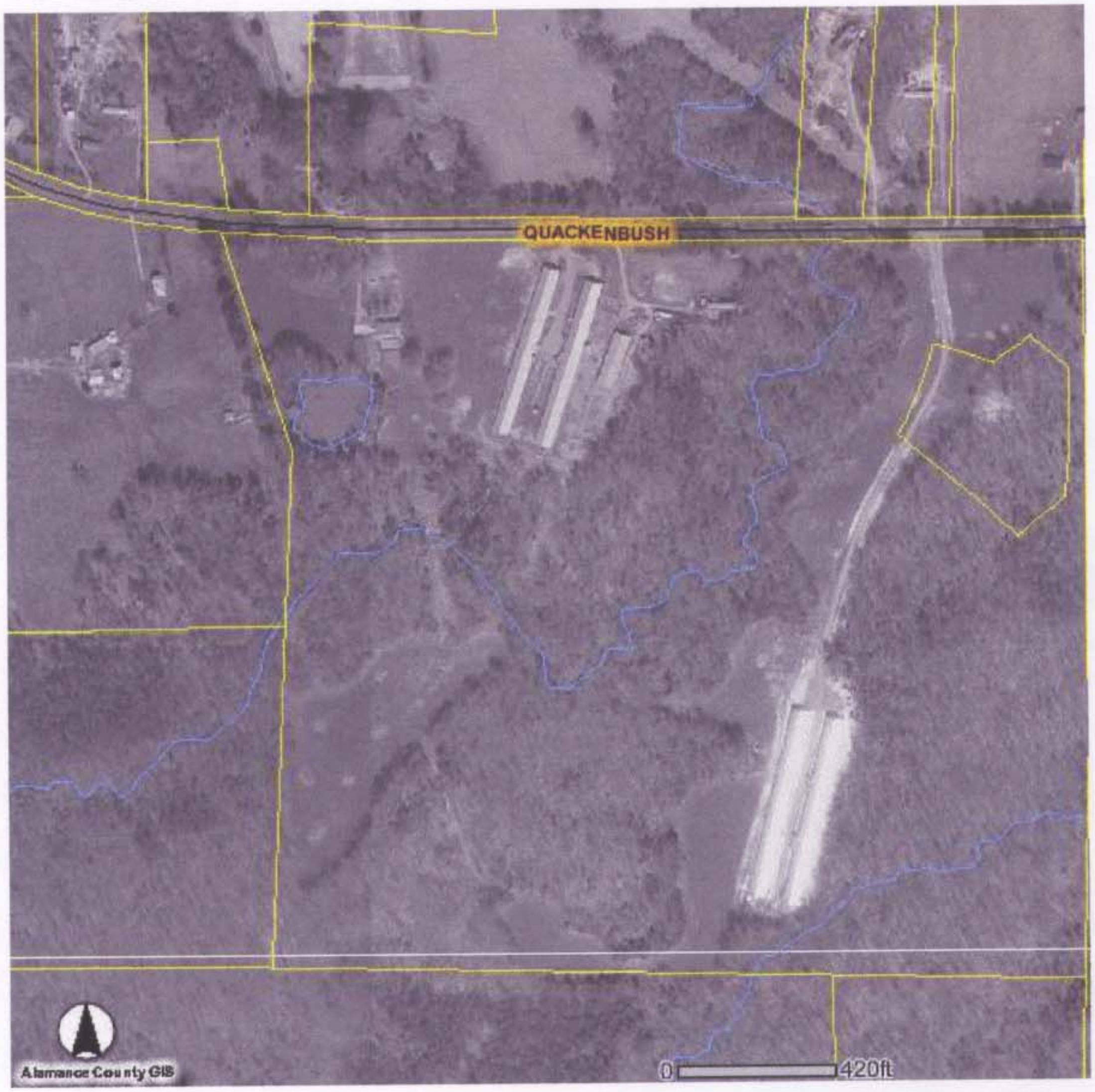
3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 2500 ft Scale: 1 : 68,750 Detail: 11-5 Datum: WGS84

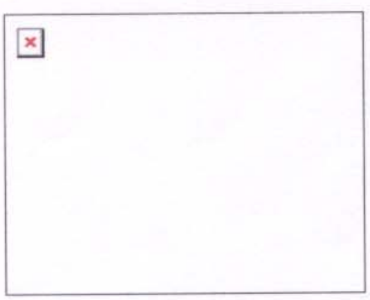
Name: CRUTCHFIELD CROSSROADS
Date: 5/1/2002
Scale: 1 inch equals 1428 feet

Location: 035° 51' 07.8" N 079° 24' 37.0" W
Caption: Reedy Creek WRP Project
1.6 square miles, 1065 acres

Reedy Branch Watershed

Reedy Creek, Kiser





Legend


200' Aerial Photos
400' Aerial Photos

Print Close Window

Appendix 2

Alamance County NRCS Soils Maps

Alamance County Soils Map

00 0 5000 Feet

(Sheet 35)

This is one of a set of maps prepared by the Soil Conservation Service, U. S. Department of Agriculture, for a soil survey report of this area. For information regarding the complete soil survey report, write the Soil Conservation Service, U. S. Department of Agriculture, Washington 25, D. C. This map compiled from aerial photographs flown in 1955

Appendix 3

Geomorphology Table

Typical Cross Sections

Morphological Data, Reedy Branch NCWRP Project

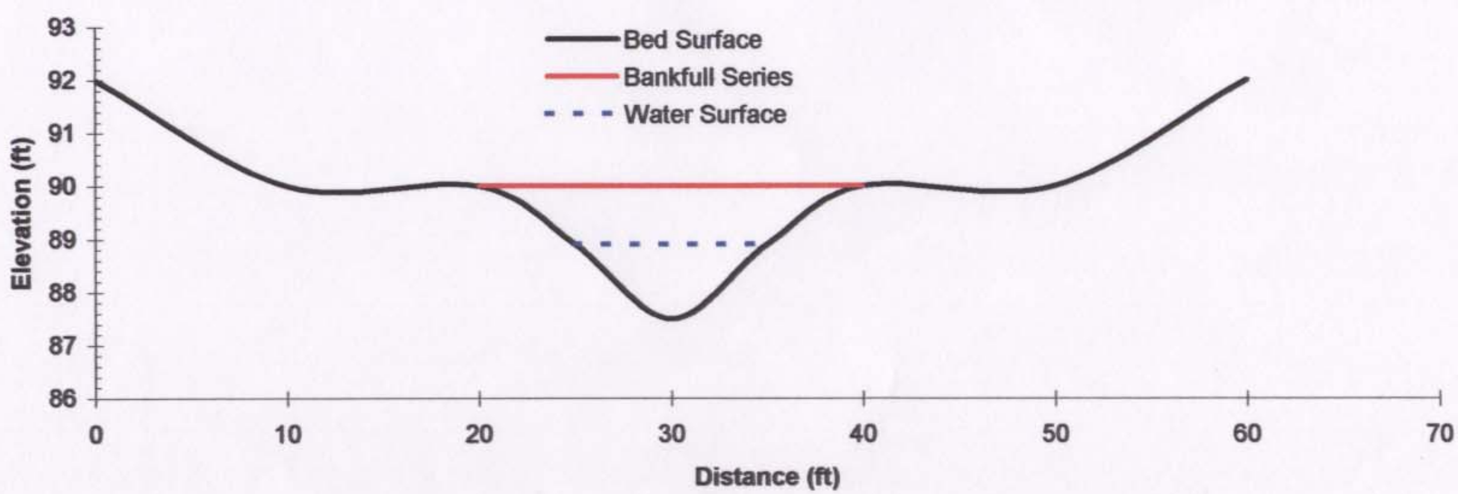
CLASSIFICATION DATA	Existing Channel	Reference UT to Varnals	Reference UT to Varnals	Gage Cane Creek	Proposed Channel
Rosgen Stream Type	C4/1	C4/1		C4/1	C4/1
Drainage Area (sq mi)	1.6	0.4	0.24	7.5	1.6
Bankfull Width (W_{bkf}) (ft)	27.1	11.8	9.75	27.8	18
Bankfull Mean Depth (d_{bkf}) (ft)	1.4	0.6	0.8	2.8	1.2
Bankfull Cross Sectional Area (A_{bkf}) (sf)	37.9	7.2	7.8	78.7	21.6
Width/Depth ratio (W_{bkf}/d_{bkf})	19.4	19.3	7.9	9.8	15.0
Maximum depth (d_{mbkf}) (ft)	2.5	2.5	1.09	3.7	2.5
Width of flood prone area (W_{fpa}) (ft)	142	85	26	92	142
Entrenchment ratio (ER)	5.2	7.2	2.7	3.3	7.9
Water surface slope (S) (ft/ft)			0.04	0.007	.0022-.012
Sinuosity (stream length/valley length) (K)	1.3	1.4	1.15	1.1	1.2
DIMENSION DATA					
Pool Depth (ft)	2.5	1.6	1	3.3	1.5
Riffle Depth (ft)	1.4	0.6	0.8	2.8	1.2
Pool Width (ft)	16.5	17.7	12	26.5	20
Riffle Width (ft)	27.1	11.8	9.75	27.8	18
Pool XS Area (sf)	41.3	15.5	12	88.2	30.0
Riffle XS area (sf)	37.9	7.2	7.8	78.7	21.6
Pool depth/mean riffle depth	1.8	2.6	1.3	1.2	1.3
Pool width/riffle width	0.6	1.5	1.2	1.0	1.1
Pool area/riffle area	1.1	2.2	1.5	1.1	1.4
Max pool depth/d_{bkf}	3.0	5.1	2.0	1.4	3.0
Low bankheight/max bankfull depth	1.1	1	1.15	1	1
Mean bankfull velocity (V) (fps)	3.5	4.9	4.1	5.4	5.8
Bankfull discharge (Q) (cfs)	125	35	32	424	125
PATTERN DATA					
Meander length (L_m) (ft)	128	79	59	390	120.6
Radius of curvature (Rc) (ft)	17.1	17.1	13.4	75	43.2
Belt width (W_{blt}) (ft)	80.8	23	15	150	34.2
Meander width ratio (W_{blt}/W_{bkf})	2.98	1.9	1.2-1.9	5.4	1.9
Radius of curvature/bankfull width	1.44	2.5-4.4	0.8-2.3	2.7	2.4
Meander length/bankfull width	3.7	6.7	4.8-6.9	14.0	6.7
PROFILE DATA					
Valley slope	0.004	0.025	0.046	0.010	0.004
Average water surface slope	0.0037	0.018	0.040	0.007	0.0037
Riffle slope			0.039	0.014	0.0052
Pool slope			0.005	0.0002	0.0001
Pool to pool spacing	84	24	35	94	63
Pool length	26	11	6.3	55	36
Riffle slope/avg water surface slope	0.0	0.00	1.0-1.4	2.07	1.4
Pool slope/avg water surface slope	0.0	0.00	0.12	0.02	0.02
Run slope/avg water surface slope			0.5-3.25	2.72	1.7
Run depth/d_{bkf}	1.1	1	1.3-1.8	1.40	1.1
Pool length/bankfull width	2.2	0.9	0.7	2.0	2.0
Pool to pool spacing/bankfull width	5.9	2.0	3.5	3.4	3.5
CHANNEL MATERIALS					
D16	0.5	0.5	0.2	6	0.5
D35	3.4	1.3	2.5	37	3.4
D50	21	8.7	8	73	21
D84	175	97	92	249	175
D95	434	162	1536	876	434
PAVEMENT MATERIALS			Bar sample		
D16	2.7		0.675	32	2.7
D35	7.6		3.6	50	7.6
D50	11.6		6	55	11.6
D84	26.1		15	90	26.1
D95	33.8		21	100	33.8
SUBPAVEMENT MATERIALS			30		
D16		1.5		1.5	
D35		5		3.5	
D50	<1	18		8	9
D84	7.1	75		40	62
D95	17.9	85		70	

NOTE: No water was flowing at the time of our survey of Reedy Branch or the UT to Varnals Creek therefore, facet slopes are unknown

STREAM: Reedy Branch
ID NUMBER: proposed riffle
DATE 8/30/2002

Width (ft)	Cross-Sectional Area (Sq.ft)	Mean Depth (ft)	Maximum Depth (ft)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Width/Depth Ratio	
20.00	23.50	1.18	2.50	20.62	1.14	17.02	Bankfull
10.00	0.00	0.00	0.00	10.38	0.00		Water Surface

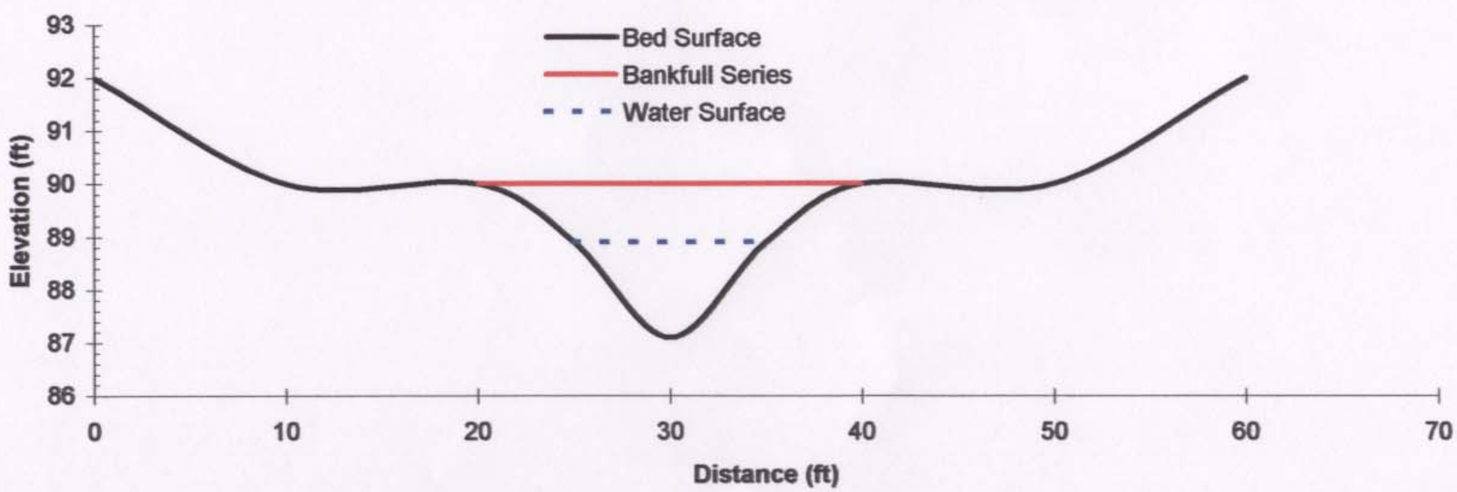
Identifier	Distance (ft)	Elevation (ft)	Identifier	Distance (ft)	Elevation (ft)
	0.0	92.00			
	10.0	90.00			
lbf	20.0	90.00			
lew	25.0	88.90			
	30.0	87.50			
rew	35.0	88.90			
rbf	40.0	90.00			
	50.0	90.00			
	60.0	92.00			



STREAM:	Reedy Branch
ID NUMBER:	proposed run
DATE	8/30/2002

Width (ft)	Cross-Sectional Area (Sq.ft)	Mean Depth (ft)	Maximum Depth (ft)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Width/Depth Ratio	
20.00	25.50	1.28	2.90	20.87	1.22	15.69	Bankfull
10.00	0.00	0.00	0.00	10.63	0.00		Water Surface

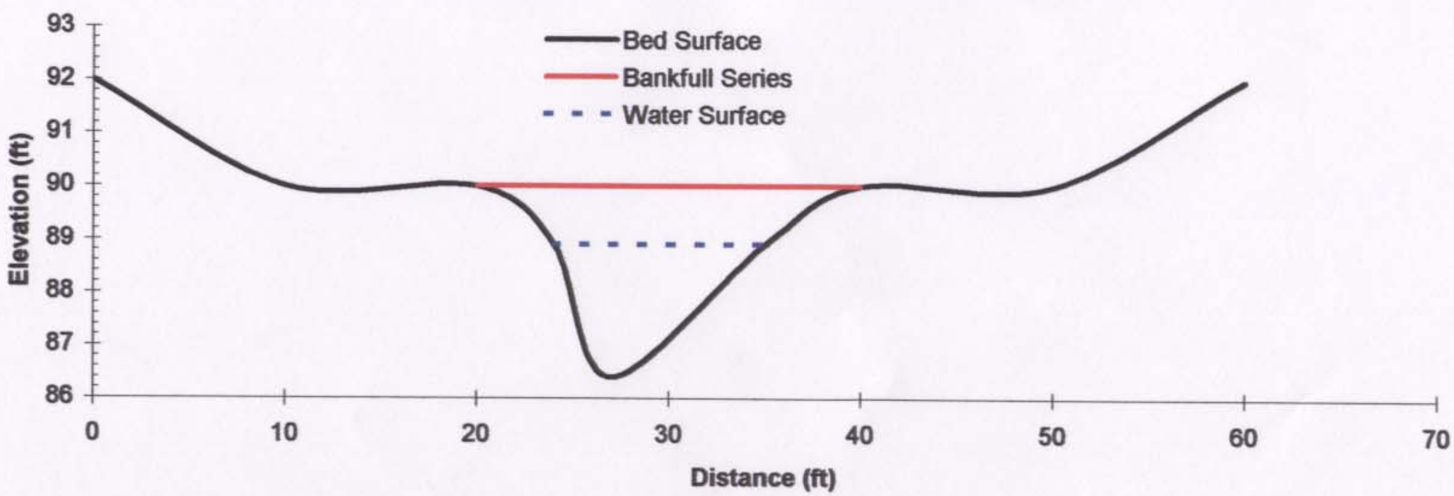
Identifier	Distance (ft)	Elevation (ft)	Identifier	Distance (ft)	Elevation (ft)
	0.0	92.00			
	10.0	90.00			
lbf	20.0	90.00			
lew	25.0	88.90			
	30.0	87.10			
rew	35.0	88.90			
rbf	40.0	90.00			
	50.0	90.00			
	60.0	92.00			



STREAM:	Reedy Branch
ID NUMBER:	proposed pool
DATE	8/30/2002

Width (ft)	Cross-Sectional Area (Sq.ft)	Mean Depth (ft)	Maximum Depth (ft)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Width/Depth Ratio	
20.00	30.80	1.54	3.60	21.55	1.43	12.99	Bankfull
11.00	0.00	0.00	0.00	12.29	0.00		Water Surface

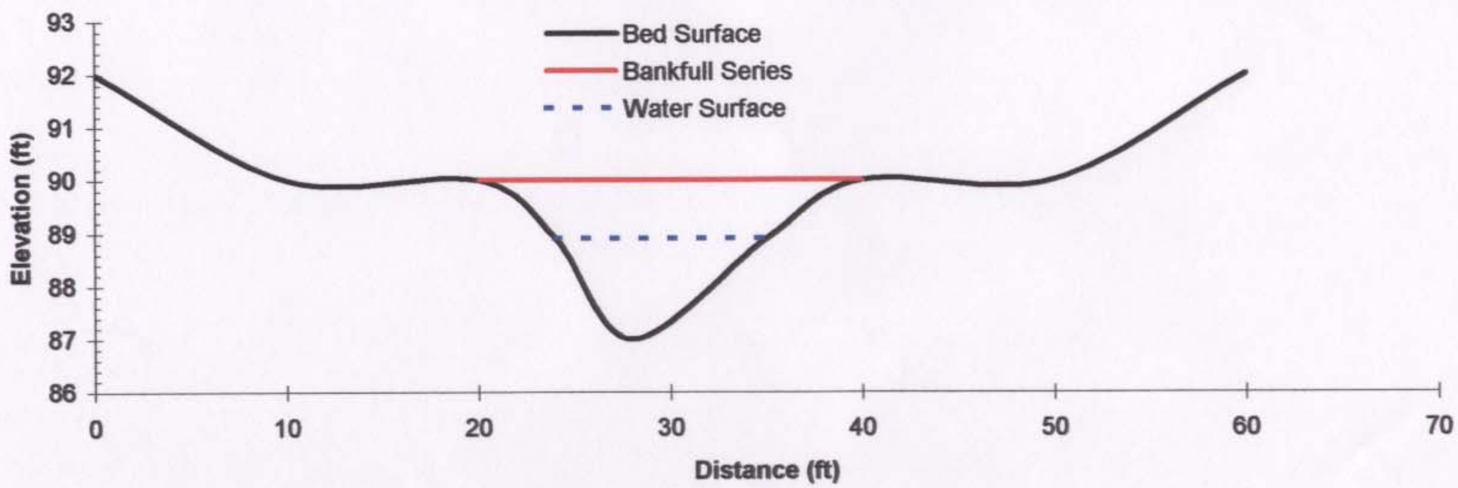
Identifier	Distance (ft)	Elevation (ft)	Identifier	Distance (ft)	Elevation (ft)
	0.0	92.00			
	10.0	90.00			
lbf	20.0	90.00			
lew	24.0	88.90			
	27.0	86.40			
rew	35.0	88.90			
rbf	40.0	90.00			
	50.0	90.00			
	60.0	92.00			



Width (ft)	Cross-Sectional Area (Sq.ft)	Mean Depth (ft)	Maximum Depth (ft)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Width/Depth Ratio	
20.00	27.50	1.38	3.00	20.95	1.31	14.55	Bankfull
11.00	0.00	0.00	0.00	11.68	0.00		Water Surface

STREAM: Reedy Branch
ID NUMBER: proposed glide
DATE 8/30/2002

Identifier	Distance (ft)	Elevation (ft)	Identifier	Distance (ft)	Elevation (ft)
	0.0	92.00			
	10.0	90.00			
lbf	20.0	90.00			
lew	24.0	88.90			
	28.0	87.00			
rew	35.0	88.90			
rbf	40.0	90.00			
	50.0	90.00			
	60.0	92.00			



Reference Reach

Hints

Stream:	Reedy Branch
Watershed:	Cape Fear
Location:	Quackenbush Road, Snow Camp NC
Latitude:	
Longitude:	
County:	Alamance
Date:	August 02-2002
Observers:	Louise, Ken, Kyle
Channel Type:	C4
Drainage Area (sq mi):	1.6
Notes:	data entered and compiled by Ken Bridle

Dimension

		typical	min	max
Size:	x-area bankfull	37.3	29.0	45.0
	width bankfull	27.1	20.3	33.9
	mean depth	1.4	1.3	1.4
Ratios:	Width/Depth Ratio	19.7	9.6	13.2
	Entrenchment Ratio	5.2	6.6	7.0
	Riffle Max Depth Ratio	1.8	1.4	2.2
	Pool Area Ratio	1.2	1.0	1.4
	Pool Width Ratio	0.6	0.5	0.7
	Pool Max Depth Ratio	2.4	2.4	2.4
	Bank Height Ratio	1.1		
	Run Area Ratio	---	---	---
	Run Width Ratio	---	---	---
	Run Max Depth Ratio	---	---	---
	Glide Area Ratio	0.8	---	---
	Glide Width Ratio	0.4	---	---
	Glide Max Depth Ratio	2.0	---	---

Hydraulics:	riffle	pool	run
discharge rate, Q (cfs)	130.0	130.0	130.0
velocity (ft/sec)	3.5	3.0	---
shear stress @ max depth (lbs/ft sq)	0.06	0.08	---
shear stress (lbs/ft sq)	0.03	0.05	---
shear velocity (ft/sec)	0.12	0.15	---
unit stream power (lbs/ft/sec)	0.111	0.111	0.11
relative roughness	2.4	4.6	---
friction factor u/u*	28.6	19.2	---
threshold grain size @ max depth (mm)	4.1	5.2	---
threshold grain size (mm)	2	3	---

Pattern

	typical	min	max
Sinuosity	1.4		
Meander Width Ratio	3.0	1.4	6.3
Amplitude Ratio	1.3	0.6	2.2
Meander Length Ratio	4.7	2.2	10.3
Straight Length Ratio	3.3	1.1	5.5
Radius Ratio	0.6	0.4	0.9
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	0.004	---	---
measured valley slope (%)	0.004	---	---
valley slope (%)	0.006		
Riffle Slope Ratio	---	---	---
Pool Slope Ratio	---	---	---
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	3.1	1.5	3.0

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	0.493	0.973	0.250	0.0	0.0	1.6
D35	3.36	8.13	0.73	0	0	7
D50	21.0	58.6	16.0	0	0	13
D84	175.2	210	158	0	0	69
D95	433.5	398	575	0	0	109
Largest Bar						0
% Silt/Clay	12%	8%	16%	---	---	---
% Sand	19%	10%	28%	---	---	23%
% Gravel	23%	33%	14%	---	---	59%
% Cobble	37%	39%	36%	---	---	17%
% Boulder	8%	10%	6%	---	---	---
% Bedrock	0%	0%	0%	---	---	

Appendix 4

Existing Channel Velocity and Entrainment

Velocity Comparison Form			
Existing Condition			
Date	Aug 28,2002	Team	Louise, Ken, Kyle
Stream	Reedy Branch	Location	Alamance County, NC
Input Variables		Output Variables	
Bankfull Cross Sectional Area (A_{BKF})	36.8	Bankfull Mean Depth D_{BKF} = (A_{BKF}/W_{BKF})	1.3
Bankfull Width (W_{BKF})	27.4	Wetted Perimeter (WP) (~(2*D_{BKF})+W_{BKF})	30.1
D84 (Riffle) (mm)	108	(mm/304.8)	0.35
Bankfull Slope (S) (ft/ft)	0.0039	Hydraulic Radius (A_{BKF}/WP)	1.2
Gravitational Acceleration (g)	32.2	R/D84 (use D84 in FEET)	3.45

R/D84, u/u*, Mannings n	
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book: p233)	5.90
Mannings n: (Reference Reach Field Book: p189, River Field Book: p236)	0.04
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	2.7

u/u*=2.83+5.7logR/D84	
u*: $u^*=(gRS)^{0.5}$	0.39
Velocity: u=u*(2.83+5.7logR/D84)	2.3

Mannings n by Stream Type	
Stream Type	C4
Mannings n: (Reference Reach Field Book: p187, River Field Book: p237)	0.018
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	5.9

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	130
Velocity: (u=Q/A or from stream gage hydraulic geometry)	3.5

After Wildland Hydrology 2001

ENTRAINMENT CALCULATION FORM

Stream:	Reedy Branch, existing	Reach:	Kiser Farm
Team:	Ken, Louise, Kyle	Date:	8/28/2002

Information Input Area

59	D_{50}	Riffle bed material D50 (mm)			
14	$\hat{D}_{50}$	Bar sample D50 (mm)			
35.0	D_i	Largest particle from bar sample (mm)	0.11	(feet)	304.8 mm/foot
0.004	S_e	Existing bankfull water surface slope (ft/ft)			
1.4	d_e	Existing bankfull mean depth (ft)			
1.2	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	g_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

4.21	$D_{50}/\hat{D}_{50}$	If value is between 3-7	**Equation 1** will be used: $t^*_{ci} = 0.0834(D_{50}/\hat{D}_{50})^{-0.872}$
0.59	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used: $t^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0238	t^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:** 1

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

1.22	d_r	Required bankfull mean depth (ft)	$d_r = \frac{t^*_{ci} g_s D_i}{S_e}$		
1.15	d_e/d_r	$\frac{\text{Existing mean bankfull depth}}{\text{Required mean bankfull depth}}$	Stable ($d_e/d_r = 1$)	Aggrading ($d_e/d_r<1$)	Degrading ($d_e/d_r>1$)
Degrading	Vertical Stability of Stream				

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0032	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{t^*_{ci} g_s D_i}{d_e}$		
1.15	S_e/S_r	$\frac{\text{Existing water surface slope}}{\text{Required water surface slope}}$	Stable ($S_e/S_r = 1$)	Aggrading ($S_e/S_r < 1$)	Degrading ($S_e/S_r > 1$)
Degrading	Vertical Stability of Stream				

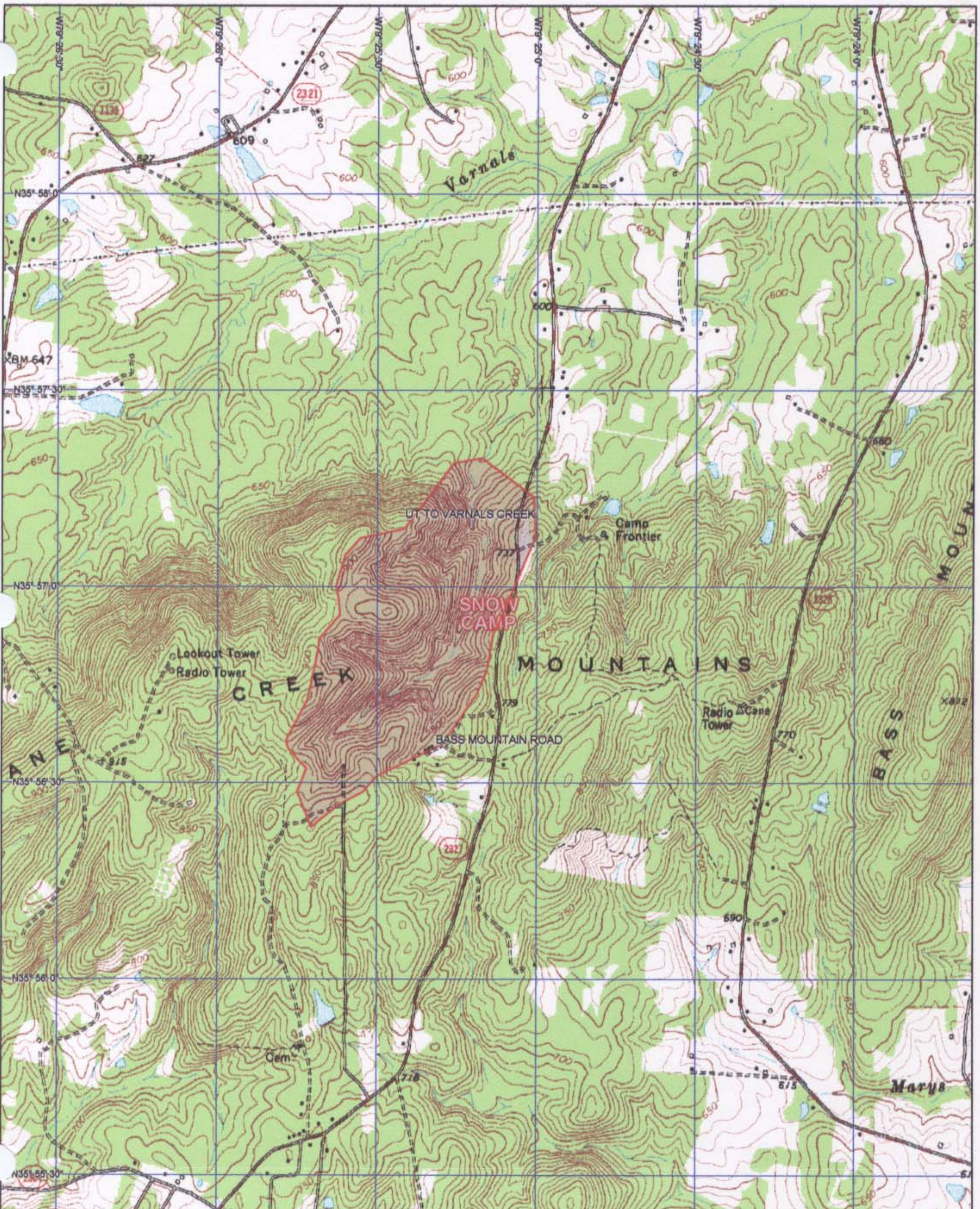
Sediment Transport Validation

0.28	Bankfull Shear Stress t_c =gRS (lb/ft2) g = Density of water = 62.4 lbs/ft^3
17 to 50	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book:p190)
0.19 to 0.55	Predicted shear stress required to initate movement of D_i (mm) (see Shields Diagram: Blue field book:p238, Red field book:p190)

Appendix 5

Reference Reach Vicinity Map

REFERENCE REACH VICINITY MAP



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 950 ft Scale: 1 : 24,000 Detail: 13-1 Datum: WGS84

Reference Reach

Hints

Stream:	UT to Varnals Creek
Watershed:	Cape Fear
Location:	Bass Mountain Rd (across from Camp Frontier)
Latitude:	N 35 57'15"
Longitude:	W 79 25'15"
County:	Alamance
Date:	August 6, 2002
Observers:	Ken Bridle, Louise Slate, Kyle Hoover
Channel Type:	C4
Drainage Area (sq mi):	0.4
Notes:	Creek was dry, typical of slate belt streams in drought. Water level approx 4 to 6 inches below bed. Surface of bed was moist in places due to capillary action.

Dimension

		typical	min	max
Size:	x-area bankfull	7.2	---	---
	width bankfull	11.8	---	---
	mean depth	0.6	---	---
Ratios:	Width/Depth Ratio	19.3	---	---
	Entrenchment Ratio	2.3	---	---
	Riffle Max Depth Ratio	1.6	---	---
	Pool Area Ratio	2.2	1.5	---
	Pool Width Ratio	1.5	1.0	---
	Pool Max Depth Ratio	3.3	3.4	---
	Bank Height Ratio	1.6		
	Run Area Ratio	1.5	---	---
	Run Width Ratio	0.9	---	---
	Run Max Depth Ratio	3.0	---	---
	Glide Area Ratio	1.5	---	---
	Glide Width Ratio	1.1	---	---
	Glide Max Depth Ratio	2.8	---	---

Hydraulics:

	riffle	pool	run
discharge rate, Q (cfs)	35.0	35.0	35.0
velocity (ft/sec)	4.9	2.3	3.2
shear stress @ max depth (lbs/ft sq)	0.01	0.02	0.02
shear stress (lbs/ft sq)	0.01	0.01	0.01
shear velocity (ft/sec)	0.06	0.07	0.07
unit stream power (lbs/ft/sec)	0.033	0.033	0.03
relative roughness	1.9	2.8	3.071117
friction factor u/u*	82.4	33.2	44.5
threshold grain size @ max depth (mm)	1.0	1.9	1.7
threshold grain size (mm)	1	1	1

Pattern

	typical	min	max
Sinuosity	1.4		
Meander Width Ratio	1.9	1.3	2.5
Amplitude Ratio	---	---	---
Meander Length Ratio	6.7	3.4	---
Straight Length Ratio	---	---	---
Radius Ratio	1.4	0.7	1.4
arc angle (degrees)	---	---	---

Profile

	typical	min	max
channel slope (%)	1.800	---	---
measured valley slope (%)	---	---	---
valley slope (%)	2.529		
Riffle Slope Ratio	---	---	---
Pool Slope Ratio	---	---	---
Run Slope Ratio	---	---	---
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	2.0	1.7	4.2

Channel Materials

	total	riffle	pool	run	glide	bar sample
D16	0.518	1.584	0.112	0.0	0.0	1.5
D35	1.34	16.40	0.65	0	0	5
D50	8.7	47.3	0.9	0	0	18
D84	96.6	124	12	0	0	75
D95	161.7	170	141	0	0	85
Largest Bar						0
% Silt/Clay	9%	5%	14%	---	---	---
% Sand	28%	13%	44%	---	---	27%
% Gravel	35%	38%	32%	---	---	44%
% Cobble	25%	44%	6%	---	---	29%
% Boulder	1%	0%	2%	---	---	---
% Bedrock	1%	0%	2%	---	---	

Appendix 6

Planview of Existing Conditions

SHEET 2 OF 18
DRAWING
2

SCALE: 1" = 40'
DATE: 9/03/02
DRN. BY: KDH
CHECKED BY:
PROJECT NO:

PLAN VIEW

REVISIONS

NO.	DESCRIPTION	DATE

PREPARED FOR:

NORTH CAROLINA
WETLANDS RESTORATION PROGRAM

PROJECT:

REEDY BRANCH
STREAM
RESTORATION

ECOLOGIC

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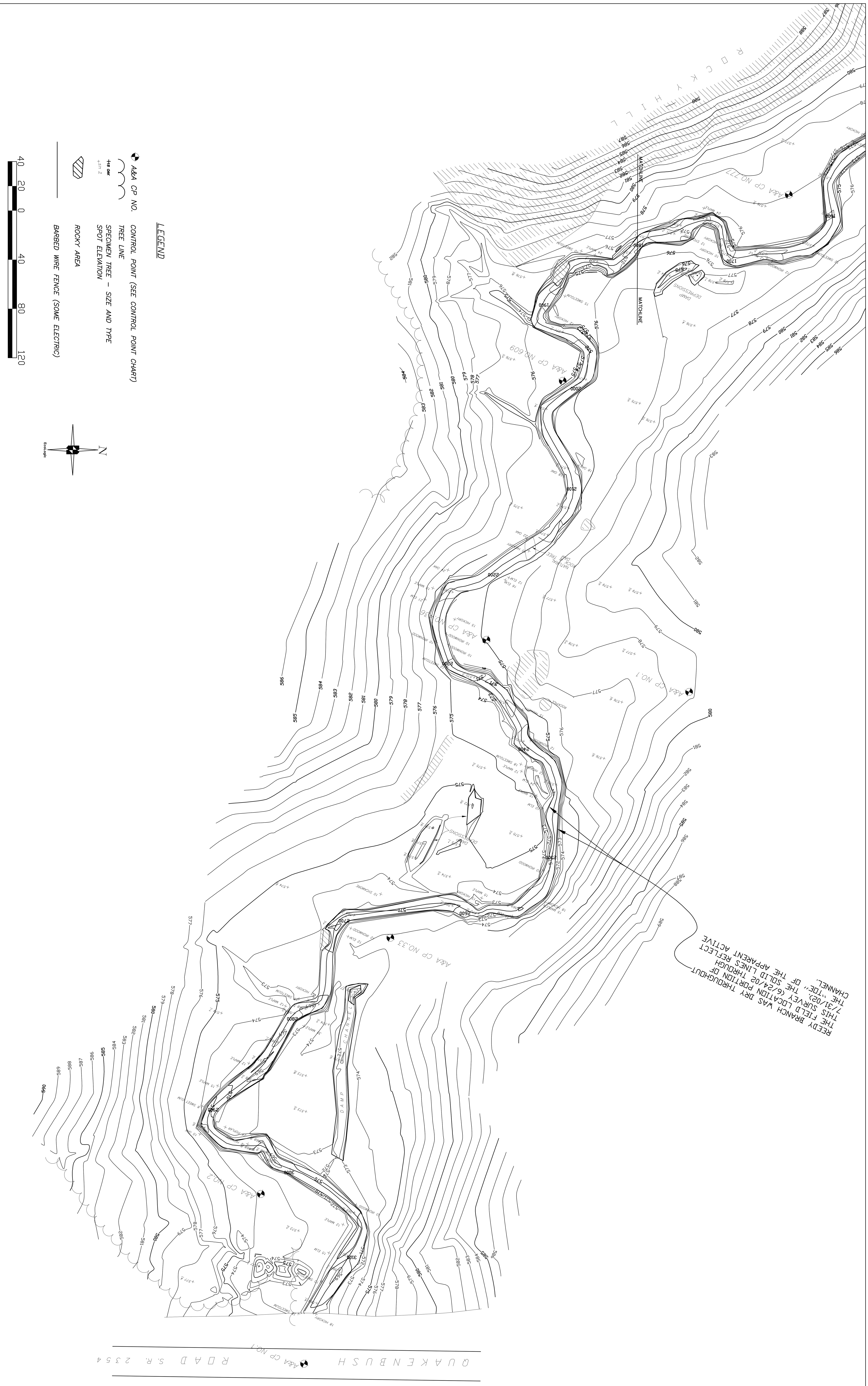

SHEET 3 OF 18 DRAWING 3	PROJECT NO: -	SCALE: 1" = 40' DATE: 9/03/02 DRN. BY: KDH CHECKED BY:	PLAN VIEW	REVISIONS (NO. / DESCRIPTION / DATE)

PREPARED FOR:

NORTH CAROLINA WETLANDS RESTORATION PROGRAM

PROJECT:

REEDY BRANCH STREAM RESTORATION

ECOLOGIC

ECOLOGIC ASSOCIATES, P.C.
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GREENSBORO, NC 27409

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FAX: 336/855-7688
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www.ecologic-nc.com

Appendix 7

Planview of Proposed Channel with Structures

PLAN VIEW

SCALE: 1" = 40'
DATE: 9/03/02
DRN. BY: KDH
CHECKED BY:

PROJECT NO.: –

SHEET 4 OF 18
DRAWING 4

NO.	DESCRIPTION	DATE

REVISIONS

PREPARED FOR:

NORTH CAROLINA
WETLANDS RESTORATION PROGRAM

PROJECT:

REEDY BRANCH
STREAM
RESTORATION

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PLAN VIEW	SCALE: 1" = 40' DATE: 9/03/02 DRN. BY: KDH CHECKED BY: PROJECT NO:	SHEET 5 OF 18 DRAWING 5

REVISIONS

NO.	DESCRIPTION	DATE

PREPARED FOR:

NORTH CAROLINA
WETLANDS RESTORATION PROGRAM

PROJECT:

REEDY BRANCH
STREAM
RESTORATION

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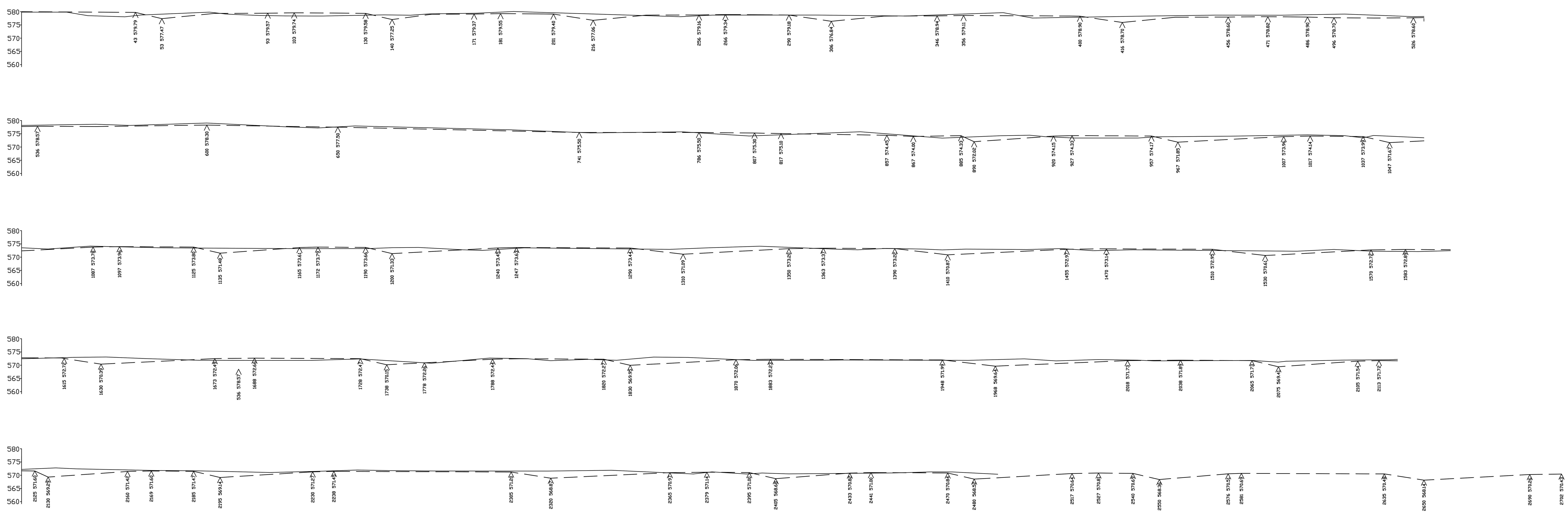
Appendix 8

Proposed Longitudinal Profile



FLOW ⟹

EXISTING THALWEG ————

PROPOSED THALWEG — — — —

Station	BKF EL	TW Elev	Top Bank	Structure
0	581.20	580	583	CROSS VANE
33	581.12	579.87		
43	581.09	579.79		
53	581.07	577.47		
73	581.02	579.47		
93	580.97	579.57		
103	580.94	579.74	582	CROSS VANE
120	580.90	579.65		
130	580.88	579.58		
140	580.85	577.25		
155	580.81	579.26		
171	580.77	579.37		
181	580.75	579.55	583	CROSS VANE
195	580.71	579.46		
201	580.70	579.40		
216	580.66	577.06		
236	580.61	579.06		
256	580.56	579.16		
266	580.54	579.34	582	CROSS VANE
280	580.50	579.25		
290	580.48	579.18		
306	580.44	576.84		
326	580.39	578.84		
346	580.34	578.94		
356	580.31	579.11	581	CROSS VANE
396	580.21	579.00		
400	580.20	578.90		
416	580.16	578.70		
436	580.11	578.80		
456	580.06	578.60		
471	580.02	578.82	581	CROSS VANE
480	580.00	579.00		
486	579.99	578.90		
496	579.96	578.70		
511	579.92	578.80		
526	579.89	578.60		
536	579.77	578.57	581	CROSS VANE
580	579.24	577.90		boulder field
600	579.00	578.30		boulder field
650	578.40	577.50		boulder field
695	577.86	577.00		boulder field
741	577.31	575.50		boulder field
786	576.77	575.50	579	CROSS VANE
797	576.63	575.40		
807	576.51	575.30		
817	576.39	575.10		
837	576.15	574.90		bedrock outcrop
857	575.91	574.45		
867	575.79	574.00	578	CROSS VANE
880	575.64	574.39		
885	575.63	574.33		
890	575.62	572.02		
905	575.58	574.03		
920	575.55	574.15		
927	575.53	574.33	578	CROSS VANE
947	575.49	574.24		
957	575.47	574.17		
967	575.45	571.85		
987	575.40	573.85		
1007	575.36	573.96		
1017	575.34	574.14	578	CROSS VANE
1027	575.31	574.06		
1037	575.29	573.99		
1047	575.27	571.67		
1067	575.23	573.68		
1087	575.18	573.78		
1097	575.16	573.96	578	CROSS VANE
1115	575.12	573.87		
1125	575.10	573.80		
1135	575.08	571.48		
1150	575.04	573.49		
1165	575.01	573.61		
1172	574.99	573.79	578	CROSS VANE
1180	574.98	573.73		
1190	574.96	573.66		
1200	574.93	571.33		
1220	574.89	573.34		
1240	574.85	573.45		
1247	574.83	573.63	578	CROSS VANE
1270	574.78	573.53		
1290	574.74	573.44		
1310	574.69	571.09		
1330	574.65	573.10		
1350	574.60	573.20		
1363	574.57	573.37	576.5	CROSS VANE
1375	574.55	573.30		
1390	574.52	573.22		
1410	574.47	570.87		
1430	574.43	572.88		
1455	574.37	572.97		
1470	574.34	573.14	576	CROSS VANE
1490	574.30	573.05		
1510	574.25	572.95		
1530	574.21	570.61		
1550	574.16	572.61		
1570	574.12	572.72		
1583	574.09	572.89	576	CROSS VANE
1603	574.05	572.80		
1615	574.02	572.72		
1630	573.99	570.39		
1650	573.94	572.39		
1673	573.89	572.49		
1688	573.86	572.66	576.5	CROSS VANE
1708	573.82	572.57		
1728	573.77	572.47		
1738	573.75	570.15		
1758	573.71	572.16		
1778	573.66	572.26		
1788	573.64	572.44	575	CROSS VANE
1815	573.58	572.33		
1820	573.57	572.27		
1830	573.55	569.95		
1850	573.50	571.95		
1870	573.46	572.06		
1883	573.43	572.23	574	CROSS VANE
1928	573.33	572.08		
1948	573.29	571.99		
1968	573.24	569.64		
1998	573.18	571.63		
2018	573.13	571.73		
2038	573.09	571.89	574	CROSS VANE
2055	573.05	571.80		
2065	573.03	571.73		
2075	573.01	569.41		
2090	572.98	571.43		
2105	572.94	571.54		
2113	572.92	571.72	574	CROSS VANE
2120	572.91	571.66		
2125	572.90	571.60		
2130	572.89	569.29		
2145	572.85	571.30		
2160	572.82	571.42		
2169	572.80	571.60	575	CROSS VANE
2180	572.78	571.53		
2185	572.77	571.47		
2195	572.74	569.14		
2210	572.71	571.16		
2230	572.67	571.27		
2238	572.65	571.45	574	CROSS VANE
2280	572.56	571.31		
2305	572.50	571.20		
2320	572.47	568.87		
2345	572.41	570.86		
2365	572.37	570.97		
2379	572.34	571.14	573	CROSS VANE
2390	572.32	571.07		
2395	572.30	571.00		
2405	572.28	568.68		
2420	572.25	570.70		
2433	572.22	570.82		
2441	572.20	571.00	573	CROSS VANE
2460	572.16	570.91		
2470	572.14	570.84		
2480	572.12	568.52		
2500	572.07	570.52		
2517	572.04	570.64		
2527	572.01	570.81	573.5	CROSS VANE
2535	572.00	570.75		
2540	571.99	570.69		
2550	571.96	568.36		
2560	571.94	570.39		
2576	571.91	570.51		
2581	571.89	570.69	573	CROSS VANE
2615	571.82	570.57		
2635	571.78	570.48		
2650	571.74	568.14		
2670	571.70	570.15		
2690	571.66	570.26		
2702	571.63	570.43	572	CROSS VANE
2750	571.52			End project

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PROJECT:
REEDY BRANCH
STREAM
RESTORATION

PREPARED FOR:
NORTH CAROLINA
WETLANDS RESTORATION PROGRAM

NO.	DESCRIPTION	DATE

REVISIONS

LOGITUDINAL PROFILE

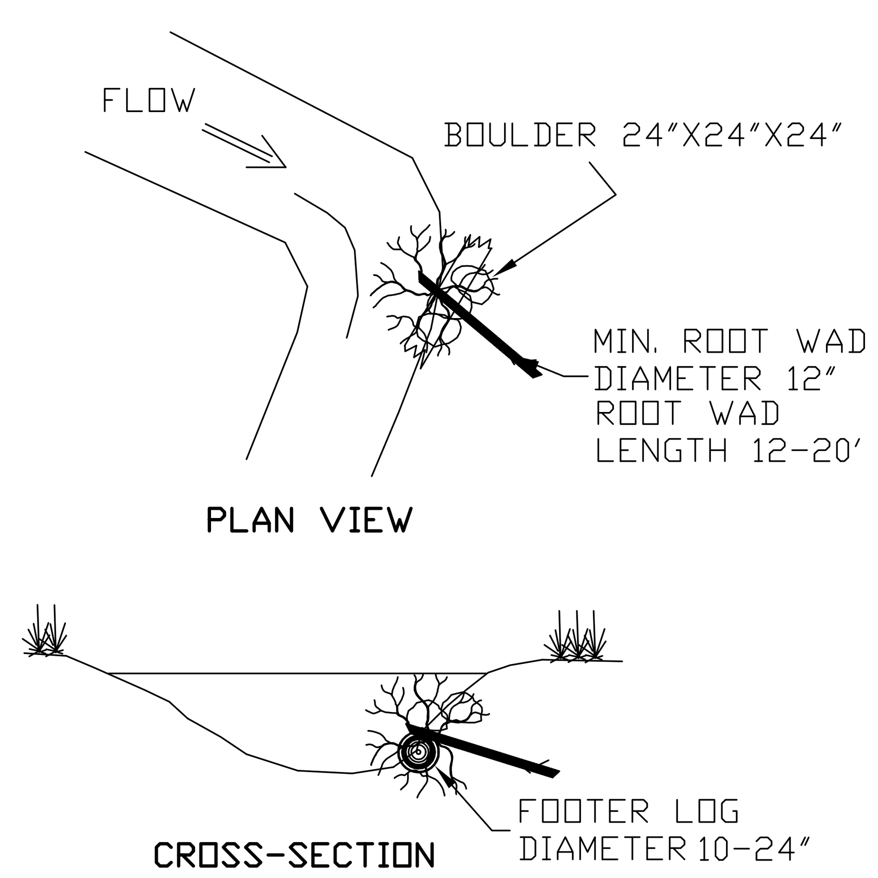
SCALE: 1" = 20'
DATE: 9/03/02
DRN. BY: KDH
CHECKED BY:

PROJECT NO:
–

SHEET 8 OF 18

DRAWING
8

ROOT WAD DETAIL 1



INSTALLATION

A TRENCH SHALL BE DUG ALONG THE TOE OF THE BANK TO A DEPTH OF THE DIAMETER OF THE FOOTER LOG. A PRUNED FOOTER LOG (DIA 10-24") SHALL BE PLACED AT THE TOE OF THE CHANNEL AND THE ROOT WAD (MIN. BASAL DIAMETER 12",LENGTH 12-20') SHALL BE PLACED DIRECTLY ABOVE IT. THE ROOT MASS SHALL BE ORIENTED IN SUCH A WAY THAT THE VELOCITY VECTORS OF THE WATER ARE ALIGNED WITH THE TRUNKS LOGITUDINAL AXIS AND WILL INTERSECT THE ROOT MASS AT A 90 DEGREE ANGLE. THERE SHALL BE NO VOID BEWEEN THE ROOT MASS AND THE BANK ON THE UPSTREAM SIDE OF THE CHANNEL. A BOULDER MAY BE PLACED ON THE DOWNSTREAM SIDE, ON TOP OF, AND ON THE UPSTREAM SIDE BETWEEN THE ROOT MASS AND THE BANK TO PROVIDE EROSION CONTROL AS DIRECTED BY THE ENGINEER. BOULDERS FOR THE ROOT WAD STRUCTURES SHALL BE LARGER THAN 0.66 TON (OR APPROX. 24"X24"X24") AS APPROVED BY THE ENGINEER.

THE PREFFERED METHOD FOR INSTALLATION OF A ROOT WAD IS TO DRIVE THE SHARPENED TRUNK OF THE ROOT WAD INTO THE STREAMBANK USING AN EXCAVATOR CONTAINING A HYDRAULIC THUMB. IF IT IS DEEMED NOT POSSIBLE TO DRIVE THE TRUNK INTO THE BANK, A TRENCH SHALL BE DUG IN THE BANK AND THE TRUNK SHALL BE PLACED IN THE TRENCH. THE TRENCH SHALL BE BACKFILLED AND COMPACTED.

ALL DISTURBED OR FILL MATERIAL SHALL BE COMPACTED TO A DENSITY COMPARABLE TO THE ADJACENT UNDISTURBED MATERIAL UNLESS OTHERWISE APPROVED BY THE ENGINEER.

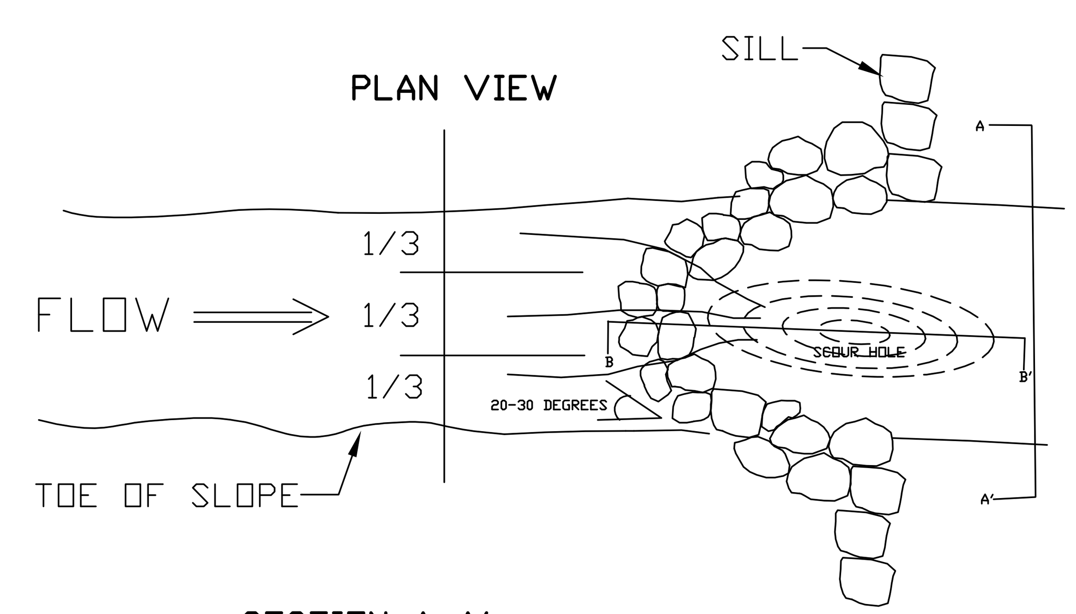
ALL MATERIALS FOR THIS STRUCTURE SHALL BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

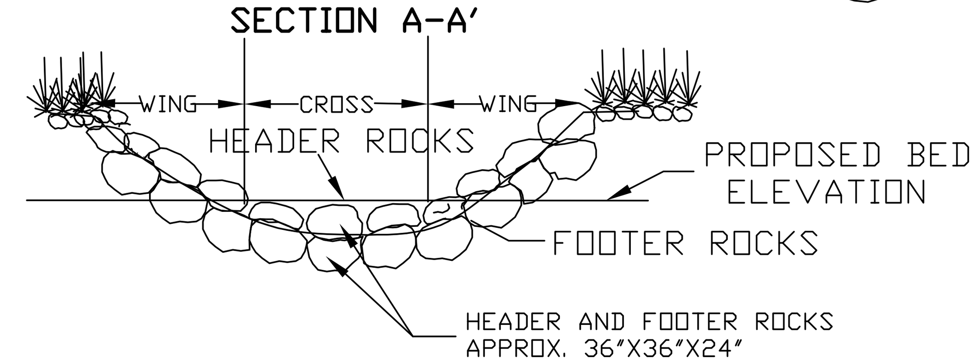
STATIONING OF ROOT WADS SHALL BE AS SHOWN ON THE PLANS OR AS DIRECTED BY THE ENGINEER. THE ACTUAL NUMBER OF ROOT WADS NECESSARY WILL DEPEND ON THE SIZE OF THE ROOT FAN AND THE ACTUAL CONDITION OF THE SITE AT THE TIME OF CONSTRUCTION.

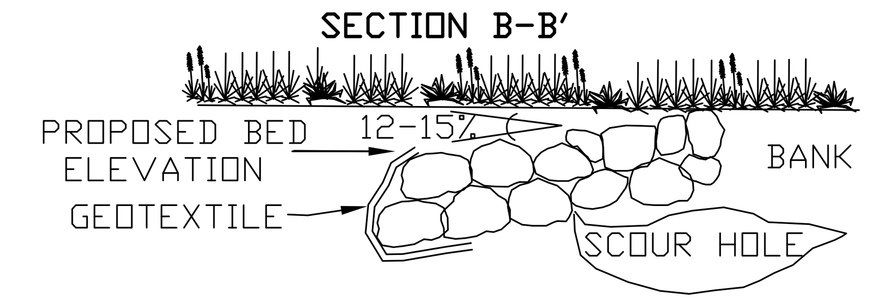
CROSS-VANE DETAIL 2

INSTALLATION

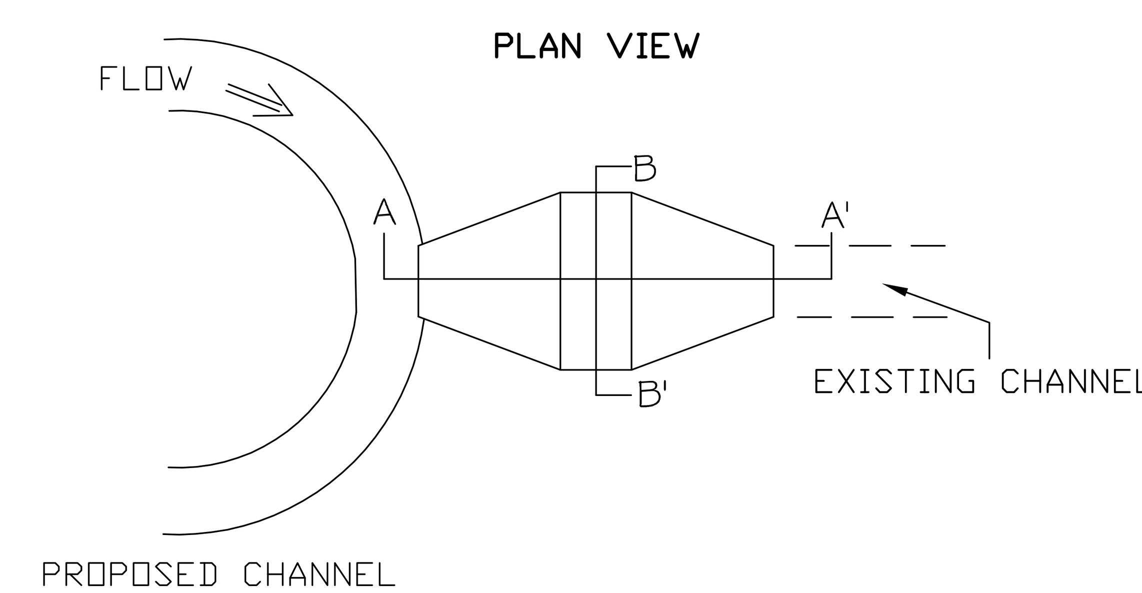
A TRENCH SHALL BE DUG IN SUCH A MANNER THAT THE FOOTER ROCKS, CROSS HEADER ROCKS AND A MINIMUM OF 1/3 OF THE WING HEADER ROCKS ARE BURIED BENEATH THE BED SURFACE ELEVATION. AN EXCAVATOR, WITH A BUCKET THAT CONTAINS A HYDRAULIC THUMB, SHALL BE USED TO PLACE ROCKS WITH THE SUPERVISION OF THE ENGINEER. HEADER AND FOOTER ROCKS SHALL BE APPROX. 36"X36"X24" WITH THE MINIMUM DIMENSIONS BEING 24" ALONG ANY AXIS. THE UPPER LIMIT OF BOULDERS SHALL BE APPORVED BY THE ENGINEER PRIOR TO INSTALLATION OF THE STRUCTURE. FOOTER ROCKS SHALL BE PLACED FIRST WITH HEADER ROCKS PLACED ON TOP PRIOR TO BACK FILLING OF THE TRENCH. IN THE CENTER OR CROSS PORTION OF THE CHANNEL THE HEADER ROCKS SHALL BE PLACED IN SUCH A MANNER THAT THE TOP OF THE HEADER ROCK IS AT AN ELEVATION EQUAL TO THE PROPOSED BED ELEVATION. A NON-WOVEN GEOTEXTILE SHALL BE PLACED IN THE TRENCH AND WRAPPED OVER THE TOP OF THE HEADER ROCKS WITH APPROX. 2' OF OVERLAP. ROCK FILL MATERIAL SHALL BE BACK FILLED AROUND THE FABRIC AND TAMPED DOWN. THE HEADER ROCKS ON THE SIDE OR WING PORTION SHALL BE PLACED IN SUCH A MANNER AS THEY SLOPE UP FROM THE BED ELEVATION AT THE CROSS PORTION, TO THE BANK AT APPROX. 15% SLOPE AND MEET THE BANK AT A 20 DEGREE ANGLE. HEADER AND FOOTER ROCKS AT BOTH BANKS SHALL BE TIED IN SECURELY TO THE BANK IN SUCH A WAY THAT ELIMINATES THE POSSIBILITY OF WATER DIVERTING AROUND THEM. A ROCK SILL SHALL BE CONSTRUCTED PERPENDICULAR FROM THE STREAMBANK. A TRENCH SHALL BE DUG SUCH THAT THE TOP OF THE ROCKS ARE JUST BELOW THE BANKFULL ELEVATION. THE TRENCH WILL THEN BE BACKFILLED WITH SOIL. ROCKS LESS THAN 24" ALONG ANY DIMENSION OR ROCKS NOT ACCEPTABLE FOR USE IN OTHER STRUCTURES MAY BE UTILIZED IN CONSTRUCTION OF THE SILL AND TO FILL IN GAPS BETWEEN HEADER AND FOOTER ROCKS AS APPROVED BY THE ENGINEER.



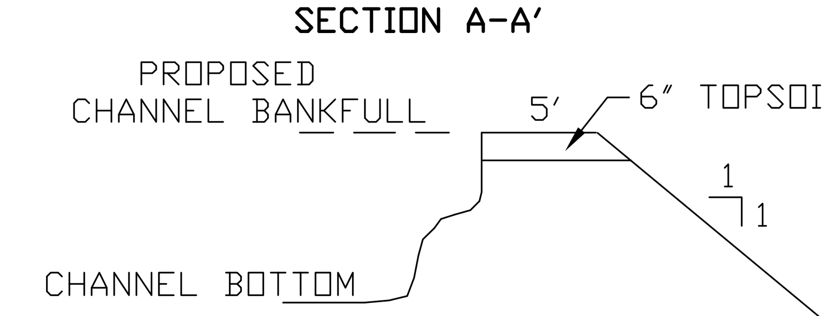


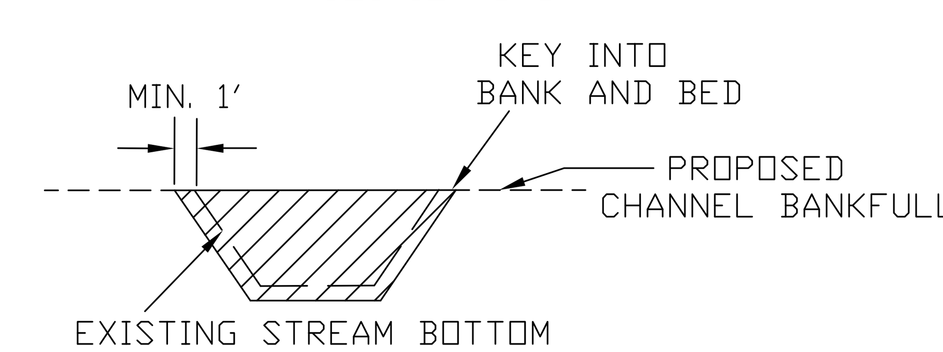


CHANNEL PLUG DETAIL 3



1. CHANNEL PLUGS TO BE LOCATED AS SHOWN ON THE PLANS AND AT OTHER LOCATIONS AS DIRECTED BY THE ENGINEER.
2. SIDE SLOPE THAT IS ADJACENT TO PROPOSED STREAM NEEDS TO MATCH PROPOSED CROSS SECTION IN THAT REGION.
3. THIS STRUCTURE SHALL BE PLACED AS DIRECTED BY THE ENGINEER.
4. KEY THE CHANNEL PLUG INTO THE BED AND BANK A MINIMUM OF 1 FOOT.





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PROJECT: REEDY BRANCH STREAM RESTORATION

PREPARED FOR: NORTH CAROLINA WETLANDS RESTORATION PROGRAM

NO.	DESCRIPTION	DATE

REVISIONS

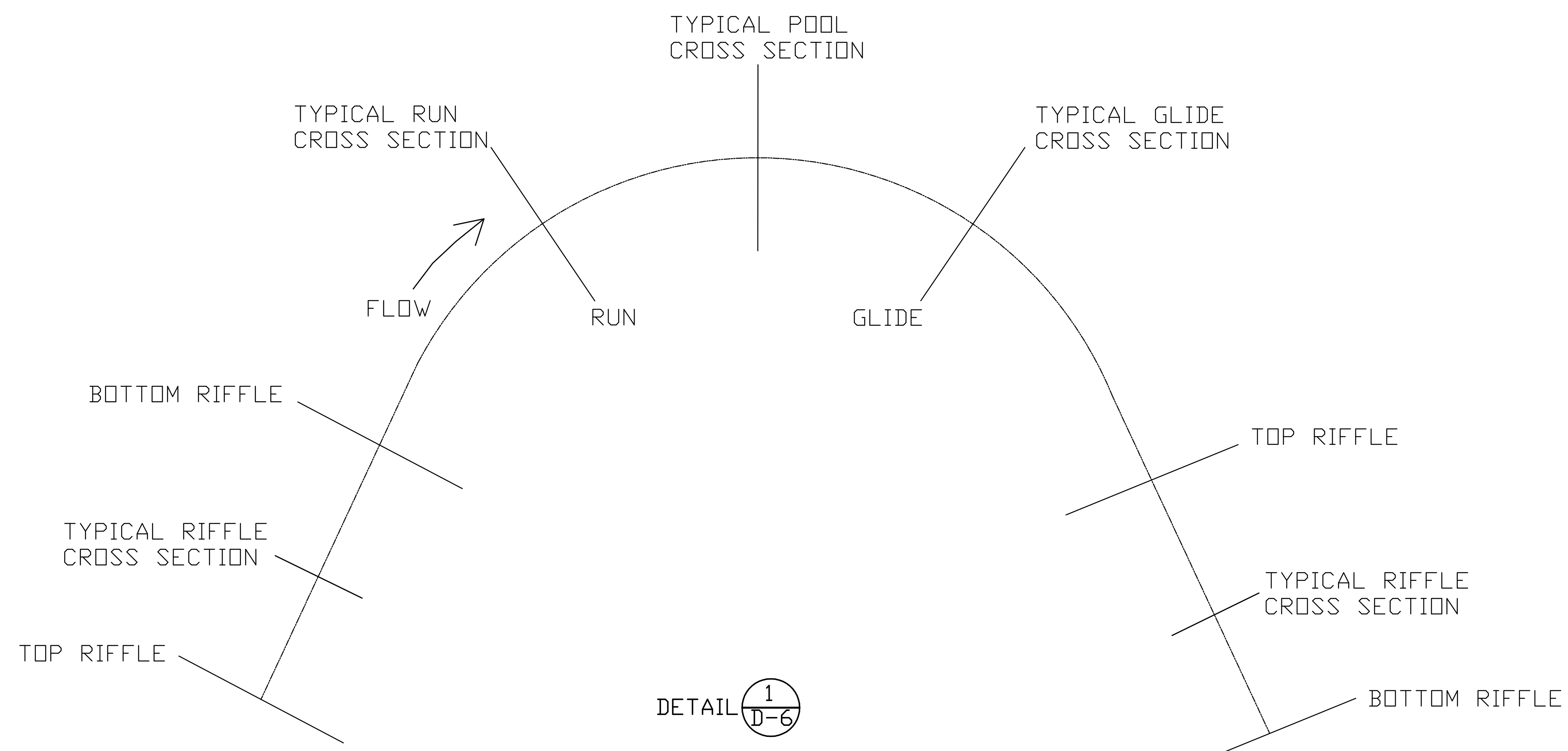
DETAILS

SCALE: NO SCALE
DATE: 9/03/02
DRN. BY: KDH
CHECKED BY:

PROJECT NO: –

SHEET 9 OF 18

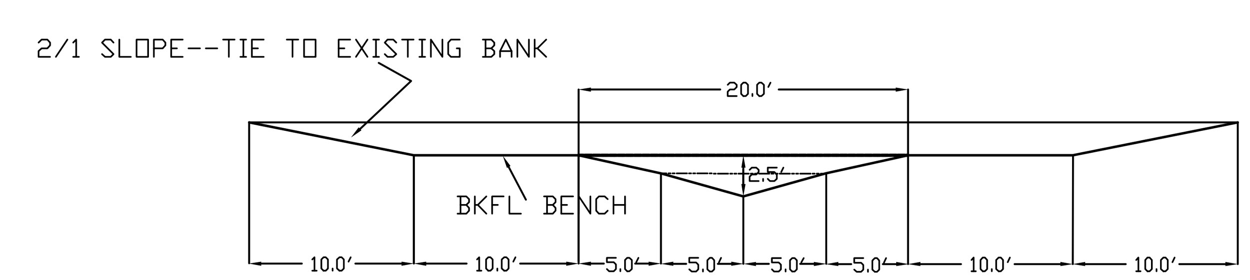
DRAWING 9



DETAIL 1/D-6

Cross Section Transition Locations

SEE TYPICAL CROSS SECTIONS AND STATIONING FOR MORE DETAILS.

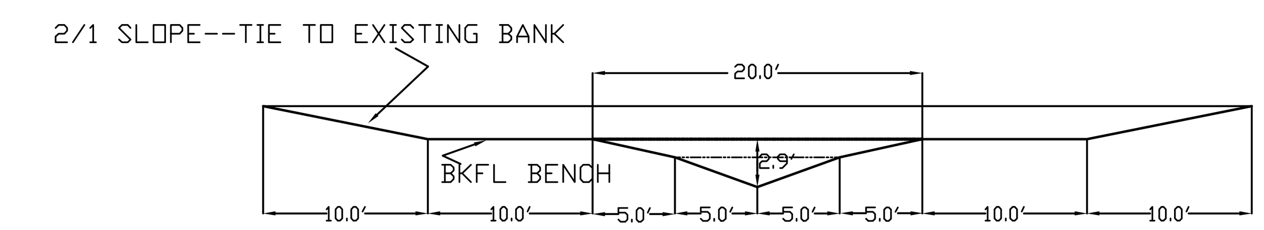


TYPICAL SECTION-RIFFLE

DETAIL 2/D-7

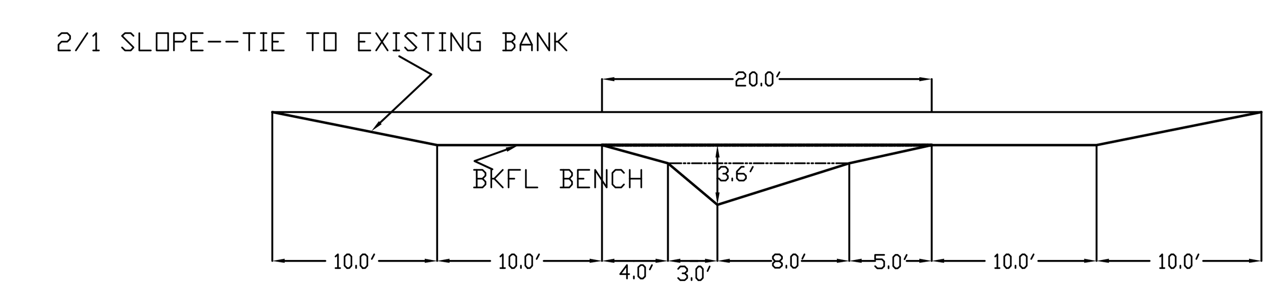
LEGEND

- BED SURFACE
- WATER SURFACE
- BANKFUL SURFACE



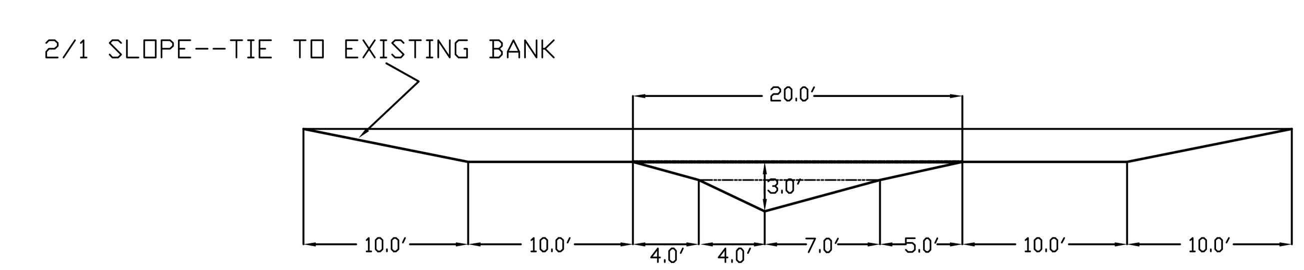
TYPICAL SECTION-RUN

DETAIL 3/D-7



TYPICAL SECTION-POOL

DETAIL 4/D-7



TYPICAL SECTION-GLIDE

DETAIL 5/D-7

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PROJECT: REEDY BRANCH STREAM RESTORATION

PREPARED FOR: NORTH CAROLINA WETLANDS RESTORATION PROGRAM

NO.	DESCRIPTION	DATE

REVISIONS

TYPICAL CROSS-SECTIONS

SCALE: 1" = 10'
DATE: 9/03/02
DRN. BY: KDH
CHECKED BY:

PROJECT NO: –

SHEET 13 OF 18

DRAWING

13

Appendix 9

Proposed Channel Velocity and Entrainment

Velocity Comparison Form			
Proposed Conditions			
Date	Aug 23,2002	Team	Louise, Ken, Kyle
Stream	Reedy Branch	Location	Alamance County, NC
Input Variables		Output Variables	
Bankfull Cross Sectional Area (A_{BKF})	24	Bankfull Mean Depth $D_{BKF} = (A_{BKF}/W_{BKF})$	1.2
Bankfull Width (W_{BKF})	20	Wetted Perimeter (WP)	22.4
D84 (Riffle) (mm)	108	(mm/304.8)	0.35
Bankfull Slope (S) (ft/ft)	0.0039	Hydraulic Radius (A_{BKF}/WP)	1.1
Gravitational Acceleration (g)	32.2	R/D84 (use D84 in FEET)	3.02

R/D84, u/u*, Mannings n	
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book: p233)	5.57
Mannings n: (Reference Reach Field Book: p189, River Field Book: p236)	0.042
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	2.3

u/u*=2.83+5.7logR/D84	
u*: $u^*=(gRS)^{0.5}$	0.37
Velocity: u=u*(2.83+5.7logR/D84)	2.0

Mannings n by Stream Type	
Stream Type	C4
Mannings n: (Reference Reach Field Book: p187, River Field Book: p237)	0.018
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	5.4

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	130
Velocity: (u=Q/A or from stream gage hydraulic geometry)	5.4

After Wildland Hydrology 2001

ENTRAINMENT CALCULATION FORM

Stream:	Reedy Branch, proposed	Reach:	Kiser Farm
Team:	Ken, Louise, Kyle	Date:	8/28/2002

Information Input Area

59	D_{50}	Riffle bed material D50 (mm)			
14	$\hat{D}_{50}$	Bar sample D50 (mm)			
35.0	D_i	Largest particle from bar sample (mm)	0.11	(feet)	304.8 mm/foot
0.004	S_e	Existing bankfull water surface slope (ft/ft)			
1.2	d_e	Existing bankfull mean depth (ft)			
1.14	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

4.21	$D_{50}/\hat{D}_{50}$	If value is between 3-7	**Equation 1** will be used:	$\tau^*_{ci} = 0.0834(D_{50}/\hat{D}_{50})^{-0.872}$
0.59	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used:	$\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0238	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:**	1

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

1.16	d_r	Required bankfull mean depth (ft)	$d_r = \frac{\tau^*_{ci}\gamma_s D_i}{S_e}$		
1.04	d_e/d_r	$\frac{\text{Existing mean bankfull depth}}{\text{Required mean bankfull depth}}$	Stable ($d_e/d_r = 1$)	Aggrading ($d_e/d_r<1$)	Degrading ($d_e/d_r>1$)
Stable	Vertical Stability of Stream				

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0038	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{\tau^*_{ci}\gamma_s D_i}{d_e}$		
1.04	S_e/S_r	$\frac{\text{Existing water surface slope}}{\text{Required water surface slope}}$	Stable ($S_e/S_r = 1$)	Aggrading ($S_e/S_r < 1$)	Degrading ($S_e/S_r > 1$)
Stable	Vertical Stability of Stream				

Sediment Transport Validation

0.28	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) γ = Density of water = 62.4 lbs/ft^3
17 to 50	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book:p190)
0.19 to 0.55	Predicted shear stress required to initate movement of D_i (mm) (see Shields Diagram: Blue field book:p238, Red field book:p190)

Appendix 10

Preliminary Planting Plan

Streamside Vegetation & Planting Plan

Reedy Branch, Alamance County
North Carolina Wetland Restoration Program

Introduction & Site Preparation

The stream restoration vegetation plan will consist of the preservation of suitable existing vegetation, the reuse (transplanting) of existing woody and herbaceous plants that require relocation, and the addition of new, native plant material. The work will consist of preparing the planting areas including the addition of fertilizer and soil amendments, identifying, extracting, preserving and planting transplants and installing herbaceous seed mix, live stakes, bareroot seedling trees, mulch, and anchored ground cover materials. Seed and plant materials will be placed on/in the stream banks, the floodplain (bankfull bench), access areas and any other areas disturbed by construction.

A serious effort should be made to retain and protect existing native vegetation that is well-rooted, healthy and appropriately sited alongside the impacted channel. In those areas, plants suitable for reuse should be flagged by someone familiar with native riparian flora, then carefully extracted for subsequent transplanting.

Those areas of the site that become or have previously been compacted by construction equipment, trucks, etc. should be ripped with a subsoiler, raked and left in a rough, loose condition. Subsoil ripping should also occur on exposed banks and other denuded areas where trees are to be planted. The surface should be left rough for tree planting, with the orientation of any furrows being parallel to the stream and perpendicular to the slope. Following this step, the surface can then be prepared for seeding using rubber tired equipment or by hand to avoid re-compaction.

Seeding

Seedbed Preparation

On areas where equipment can be operated safely, the seedbed shall be adequately loosened and smoothed. Foreign material and obstructions should be removed at this time. Disking and/or cultipacking may be necessary. On sites where equipment cannot operate, the seedbed should be prepared by hand. All surfaces should be scarified to produce a surface where seed can stay in place until successful germination. If seeding is done immediately after construction, seedbed preparation may not be required except on compacted or freshly cut areas.

Fertilizing

Note that fertilizing areas where native grasses are to be established is not recommended until the second or third year of growth. In areas outside of the riparian easement where pasture grasses are to be restored fertilizer and lime are recommended. Evenly distribute lime and fertilizer over the area to be seeded. Uniformly mix the lime and fertilizer into the top 3 inches of soil. Apply lime and fertilizer according to soil test results or at the following rates:

Lime	50-100 lbs./1000 sq. ft.	(1-2 tons/acre)
Fertilizer (10-10-10)	9-12 lbs./1000 sq. ft.	(400-500 lbs./acre)

<u>Permanent Seeding</u>
Use in combination with woody plantings and transplants on the bankfull bench, on side slopes and upslope of the channel in the riparian buffer. A mixture of native grasses and herbs should be used. Competing, sod-forming grasses like fescue and bluegrass should be removed by either mechanical or chemical methods before planting native mixes. Seeding should occur before coir fiber mats are placed on the subgrade.

Late summer through early fall is the ideal planting time for many native, perennial grasses and herbs. Omit the fertilizer when planting native herbaceous species to reduce weed production. The native grasses and herbs should be used when enhancing wildlife habitat is a goal of the riparian planting. For Reedy Branch, winter seeding is anticipated.

<u>Cool Season Seeding</u>
A grass and herb mix similar to the following is recommended and commercially available from several sources. Otherwise, a custom blend can be obtained and mixed locally. Soil temperature must be above 32^{o}F for proper germination. Seed should be spread on a suitably prepared surface free of obstructions and competing weedy species. Seed germination can be further enhanced by pressing the seed into the seedbed using a roller.

Seed mixture for the riparian corridor:

Annual Rye	20%
Virginia Wild Ryegrass	20%
Fowl Bluegrass	20%
Nodding Smartweed	20%
Showy Tickseed	10%
Switchgrass	5%
Hop Sedge	2.5%
Fringed Sedge	2.5%

The recommended rate is 20 lbs./acre.

A mixture similar to this can be purchased from Ernst Conservation Seeds (Seasonally Flooded Area Annual and Perennial Wildlife Food Mix ERNMX #128)

Additional seed mixes suitable for the floodplain portion of the restoration. Examples of seed mixes include: the Wildlife Food and Shelter Shrub Mix, (ERNMX #138) which includes a nice mixture of herb and shrub species that would compliment the hardwood trees of the floodplain, or the Flood Plain Wildlife Mix (ERNMX #154) which contains one of the widest ranges of plant diversity in a commercially available mixture, or the Shaded Roadside Mix, (ERNMX #140) which can be planted around and under the existing trees and will help establish an herb layer appropriate to the developing hardwood forest.

The designers preference would be to plant a mixture suitable for occasional flooding (#128) within the channel and along any additional low spots in the floodplain. A different shade adapted plant mix (#140) should be planted in disturbed areas under existing mature trees and along the forest edge where full sunlight might be problematical. The remaining open floodplain should be planted with a combination of a wildlife herb and grass mixture (#154) with inclusions of small patches of a wildlife shelter shrub mixture (#138). This combination of seed mixes will provide the most chance of establishment of a successful, diversified and ecologically functional riparian restoration.

<u>Mulching</u>
Mulching shall be performed at the time of seed sowing or within 48 hours of that time. Weed-free grain straw shall be applied on seeded areas at a rate of 3 bales per 1000 square feet or 1.5 tons per acre. Mulch shall be applied uniformly, preferably with a straw blower. Mulch shall then be anchored with a mulch crimper, asphalt tackifier, organic tackifier, or held in place with appropriate mulch netting.

<u>Sod Mats</u>
Strip and stockpile mats of existing desirable herbaceous vegetation. Ensure that several inches of soil remains attached to the vegetation. The root system should be kept moist and protected from direct sunlight and drying winds while the vegetation is stockpiled. These mats can be placed on the bankfull benches and lower slopes of the stream banks and anchored in place with stakes. *Native sedges, rushes, grasses and riparian herbs are preferred for use as sod mats*. Fescue and other sod-forming grass species may be acceptable only if they can be transplanted in areas where they will not compete with the establishment of native grasses or native perennial trees and shrubs.

<u>**Woody Plant Installation (Trees and Shrubs)**</u>

<u>Care and Handling</u>
All planting stock shall be handled in such a manner as to promote the health and vigor of the plant material and reduce the stress of transplanting and reestablishment. This means that all woody planting shall occur in the plant's dormant season, normally from about November 15 to March 31. Planting stock shall be stored in a cool and moist environment and protected from direct sun and drying winds. Roots of bare root stock shall be kept moist before and during planting operations. Stock shall be kept moist at all times. Live stakes shall be prevented from drying and kept in a dormant condition, which may require daily moisture addition and refrigeration if the weather is warm. Damaged roots or shoots should be pruned appropriately before or during installation.

Salvage of Existing Vegetation

There are elderberry, silky dogwood, river birch and tag alders that occur along the channel that will transplant well during construction. These plants should be dug in such a way as to maximize the rootball and set immediately in the new location. The top of the plant should be pruned to remove at least one half of the plants stem mass.

Planting

New woody plant material shall be installed in the restoration corridor as shown on the plans to enhance biodiversity, which improves both ecological function and aesthetics. This also allows the introduction of species that would not reestablish on their own and provides for site selection to enhance plant performance and restoration success. Planting stock may include containerized, bare root or balled and burlaped trees and shrubs. Bare root seedlings should be planted using a spade or dibble. Rooted plants should be planted in holes sized to match the existing container or root ball.

Plant bare root and rooted stock in a vertical position with the root collar even with the soil surface. The planting trench or hole must be deep enough and wide enough to permit the roots to spread out and down without bending the primary root structures. Care should be taken to prevent breaking or damaging the roots or "J" planting of taproot structures. Make sure that the roots are in contact with soil and no air pockets remain after the soil has been packed and firmed around the plant. Dormant plantings should be inserted to a depth that allows them to reach adequate soil moisture.

Species Selection

It is important to plant as much diversity as is available to enhance the wildlife value, aesthetics and resilience of the riparian corridor restoration. A minimum of 4 to 8 tree and shrub species should be selected to enhance the species diversity that occurs naturally at the site. The density, effectiveness and ecological function of the woody plantings will be enhanced by combining canopy trees, understory trees and shrubs in a mixture that approximates a natural riparian forest that would occur at an undisturbed site.

Bare root and containerized woody species should be planted on the upper portion of the bank and within the upslope riparian corridor. Live stakes and transplanted material should be planted on the bankfull benches and just above the toe of the banks.

Planting Density

Tree Species	Plant Spacing = 8 feet	680 plants/acre initial stock density
Shrub Species	Plant Spacing = 5 feet	1740 plants/acre initial stock density
Target density of plantings at maturity:		320 trees/acre and 1200 shrubs/acre.

Tree Species Suitable for Reedy Branch Restoration

Black Willow, Green Ash, Sugar Maple, Sycamore, American Chestnut, Hackberry, River Birch, Bitternut or Pignut Hickory, Persimmon, Black Walnut, Black Gum, Sourwood, Black Cherry, Red Oak, Water Oak, Black Locust, American Elm, Pawpaw, Dogwood, Redbud, American Holly and Fringetree.

Shrub Species Suitable for Reedy Branch Restoration
Buttonbush, Hazelnut, Elderberry, Red Chokeberry, Silky Dogwood, Spicebush, Serviceberry, Hawthorne, Highbush Blueberry, Tag Alder, Witch Hazel, Sweet Shrub, Sweet Pepperbush, Winterberry, Blackhaw and Yellowroot.

Recommended Species for Reedy Branch Restoration
Based on observations of the natural riparian communities in the Alamance County region, there are several plant species that are recommended. It can be assumed that Red Maple and Tulip Tree will establish themselves voluntarily in the restoration reach as they are well represented in the adjacent forests.

The added woody plants may include Sycamore, Southern Red Oak, Schmard Oak, Pignut Hickory, Green Ash and Black Willow as eventual canopy species. Subcanopy species may include Dogwood, Redbud, American Holly, Fringetree and Sourwood. Shrub species may include Elderberry, Tag Alder, Highbush Blueberry, Silky Dogwood, Red Chokeberry and Hawthorne.

This mixture will maximize the vertical diversity for wildlife, produce a wide range of fruit and seed types, and provide the human neighborhood with seasonal displays of flower, fruit and leaf color.

Live stakes
Some of the species recommended above can best be propagated as live stem cuttings called live stakes. Live stakes and other cuttings should be dormant at the time of installation. They are typically ½ to 1 inch in diameter and 2 to 3 feet long. They should have a pointed end at the bottom to facilitate driving into the bank. The live stakes can be purchased, harvested off site, or occasionally harvested on site from dormant trees and shrubs.

The stakes shall be planted on a 3-foot center-to-center spacing in staggered rows as shown on the plans. The number and location of live stake rows will be determined in the field by the size and shape of the bank and the location of transplants, sod mats and existing woody vegetation.

Stakes shall be driven into the ground perpendicular to the slope with a dead-blow hammer. Two-thirds of the stake’s length should be driven into the ground unless the stake “refuses” in dense soil or on a rock or root or other buried obstacle. If less than 12 inches of penetration is achieved, the stake should be removed, discarded if damaged, and a replacement stake should be driven nearby. Damage from hammering should be cut off promptly with sharp loppers, leaving a clean, angled cut less than 6 inches above the ground surface.

Live Stake Species Recommended for Reedy Branch Restoration
The live staking should include a mixture of at least three of the following species, with no more than 40% and no less than 15% of any one species.

Black Willow, Silky Dogwood, Redosier Dogwood

Woody Plant Protection
The use of tree shelters, bark wrap, fencing or chemical deterrents may be necessary at Reedy Branch to prevent damage by deer. The shelters can be used on the more valuable material and the most slow-growing and hard to establish species. These shelters will also accelerate the growth of the woody plants so that they can withstand herbivore attack. Anti-browsing chemical deterrents may also be needed to train the animals to avoid the plantings until they become established.