

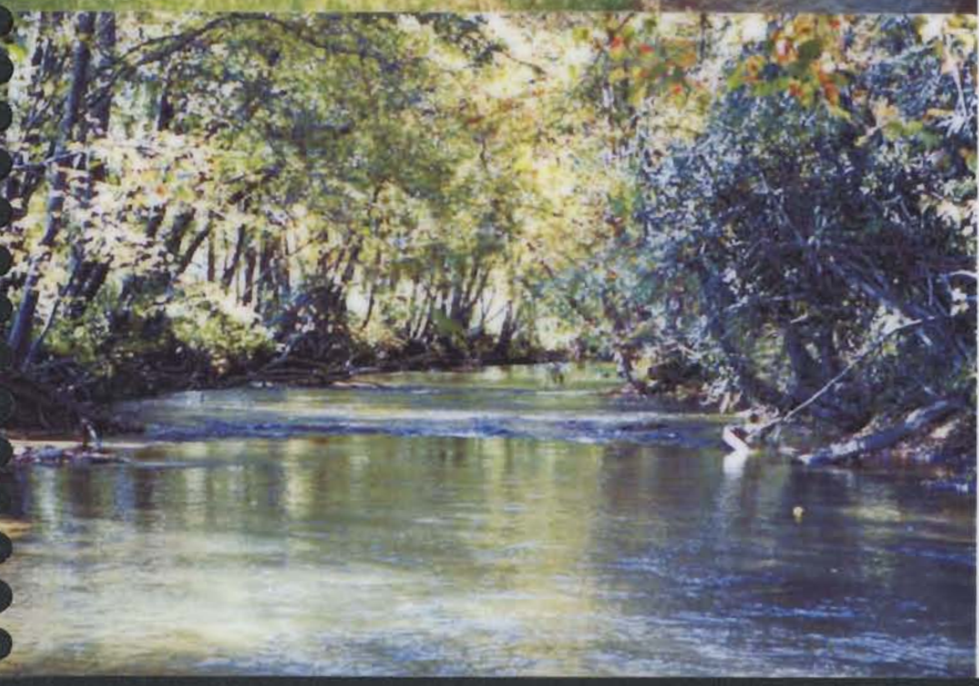

Site Characterization and Conceptual Plans

BRUSH CREEK PROJECT

Alleghany County, North Carolina

Prepared for:

N.C. Wetlands Restoration Program

N.C. Wetland Restoration Program

October 2000

Prepared by:

HDR

HDR Engineering, Inc. of the Carolinas

Habitat Assessment and Restoration Program

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Executive Summary

The North Carolina Wetlands Restoration Program (NCWRP), in conjunction with the Natural Resources Conservation Service (NRCS), HDR Engineering, Inc. of the Carolinas (HDR), the Habitat Assessment and Restoration Program (HARP), and local landowners is seeking to perform stream restoration efforts on 950 feet of Little Pine Creek and 2,640 feet of Brush Creek, in eastern Alleghany County (the County), North Carolina. Both streams have been impacted by past land use and should benefit from the proposed restoration efforts.

At the proposed project site, Little Pine Creek flows into Brush Creek, a larger stream that eventually enters the Little River before contributing flow to the New River. In recent years, approximately 340 feet of Brush Creek streambank downstream of the Little Pine Creek confluence has experienced significant bank collapse. This collapse may be linked to a variety of factors, including the steep angle of the Little Pine Creek confluence, deflection of Brush Creek streamflow by point bar formation downstream of the confluence, the unconsolidated alluvial composition of the collapsing Brush Creek streambank, and limited riparian vegetation.

The proposed project detailed in this document seeks to address both the issue of Little Pine Creek restoration and the concerns regarding Brush Creek streambank collapse. This project has the following goals and objectives:

1. To replace 600 feet of altered Little Pine Creek stream channel with a new, 950-foot meandering channel reconnected to the floodplain and designed to maintain stable dimension, pattern, and profile while effectively transporting anticipated streamflow and sediment load.
2. To restore a vegetated riparian corridor 30-50 feet wide along the new, proposed reach of Little Pine Creek, in order to improve water quality and increase available aquatic and terrestrial habitat resources.
3. To restore stable channel dimensions and stable streambank conditions to 340 feet of Brush Creek currently experiencing severe bank collapse, thereby improving downstream water quality through sedimentation reduction and enhancing aquatic habitat.
4. To restore/enhance 2,300 feet of degraded Brush Creek riparian corridor, with bioengineering stabilization of unstable streambanks, instream aquatic habitat improvements, and increased riparian buffer vegetation.
5. To improve overall terrestrial habitat connectivity through the restoration of riparian corridors along both streams, and improve overall aquatic habitat through the creation of increased habitat complexity.

1.0 Introduction

The NCWRP is planning stream restoration activities on two tributaries of the Little River in the New River Basin in the County, North Carolina. This report has been prepared to characterize conditions at the confluence of these two streams and recommend conceptual restoration plans. At the project site, Little Pine Creek, a third-order perennial stream draining a watershed of 4.3 square miles enters Brush Creek, a fourth-order perennial stream draining a watershed area of 26.3 square miles (refer to Figures 1-4). In 1969, Little Pine Creek was channelized upstream of its confluence with Brush Creek. Ownership of the property adjacent to the stream has since changed hands and the present landowner desires to see Little Pine Creek restored to a condition of natural stability, for the purposes of good environmental stewardship and a potential reduction in downstream streambank collapse along Brush Creek. In recent years, various reaches of Brush Creek upstream and downstream of the Little Pine Creek confluence have experienced significant streambank collapse. While this streambank collapse may only be partly related to the earlier channelization of Little Pine Creek, restoration of both will be addressed in this NCWRP project. Approximately 600 linear feet of the existing Little Pine Creek channel will be involved in this effort, along with 2,640 linear feet of Brush Creek (refer to Figure 4).

The New River Basin is located in the northwestern corner of North Carolina, in the Blue Ridge Province of the Appalachian Mountains. Within North Carolina, three principal divisions of the New River exist: the North Fork New River, the South Fork New River, and the Little River. Flow from Brush Creek and Little Pine Creek enters the Little River prior to joining the New River in Virginia. According to the North Carolina Department of Environment and Natural Resources (NCDENR), the New River is part of the oldest river system in North America. The 825 miles of streams within this ancient river basin generally exhibit high water quality and support diverse aquatic life. Approximately 70 percent of the basin's streams are designated as trout waters. Additionally, a 26.5-mile portion of the river near the North Carolina/Virginia border has also been classified as both a National Scenic River and a State Natural and Scenic River. Commensurate with this has been the assignment of Outstanding Resource Waters (ORW) status to this portion of the river (NCDENR New River Basinwide Water Quality Management Plan, 1995).

2.0 Site Characterization

This Site Characterization Report details existing conditions at and adjacent to the proposed stream restoration project site, based on field investigations and data collection. Particular attention has been paid to the physical, or morphological, condition of Brush Creek and Little Pine Creek. Morphological characteristics of each stream have been assessed to specifically address channel plan, dimension, and profile. Additional data have been collected to assess soils, water quality, aquatic habitat, and watershed land use. In the following report, detailed descriptions of the two stream channels have been provided to support the proposed stream restoration, relocation, and enhancement plan.

FIGURE1: MAJOR NORTH CAROLINA RIVER BASINS

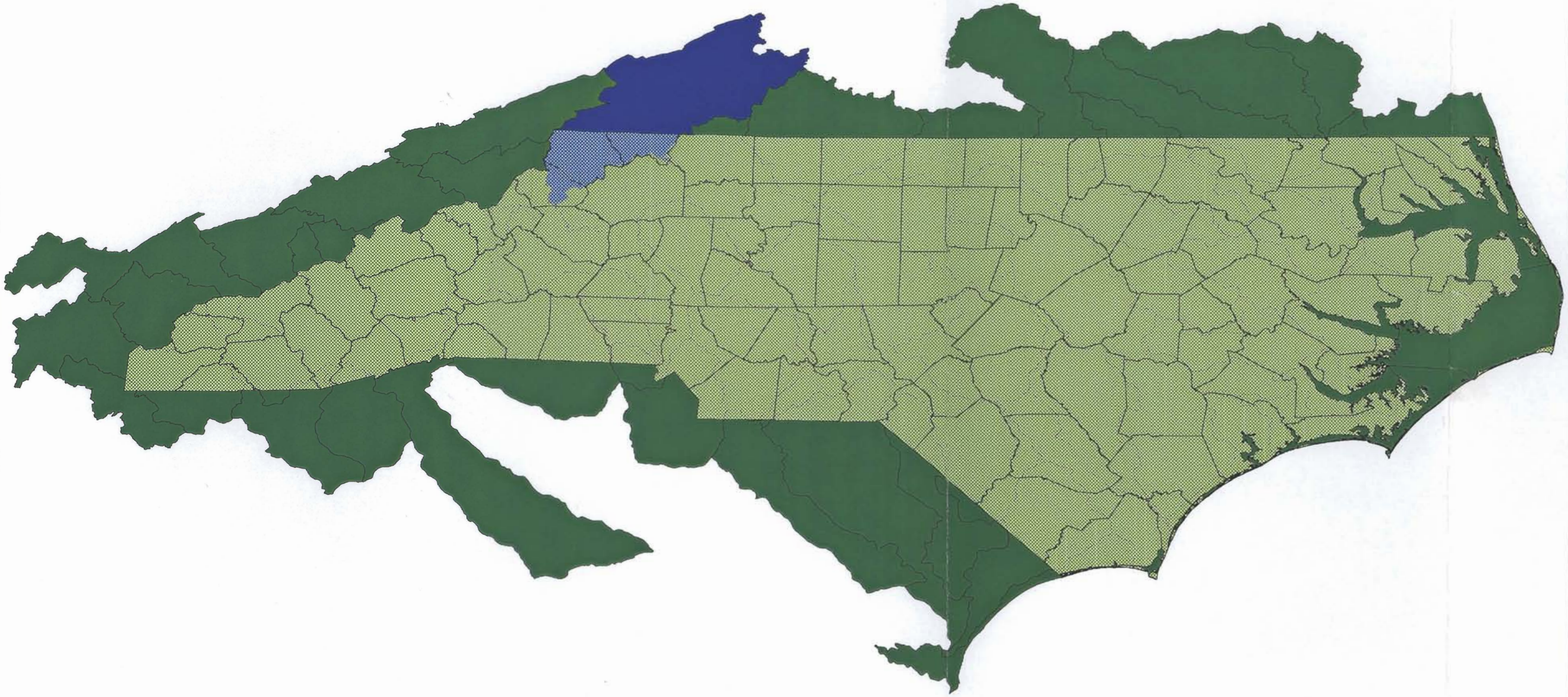

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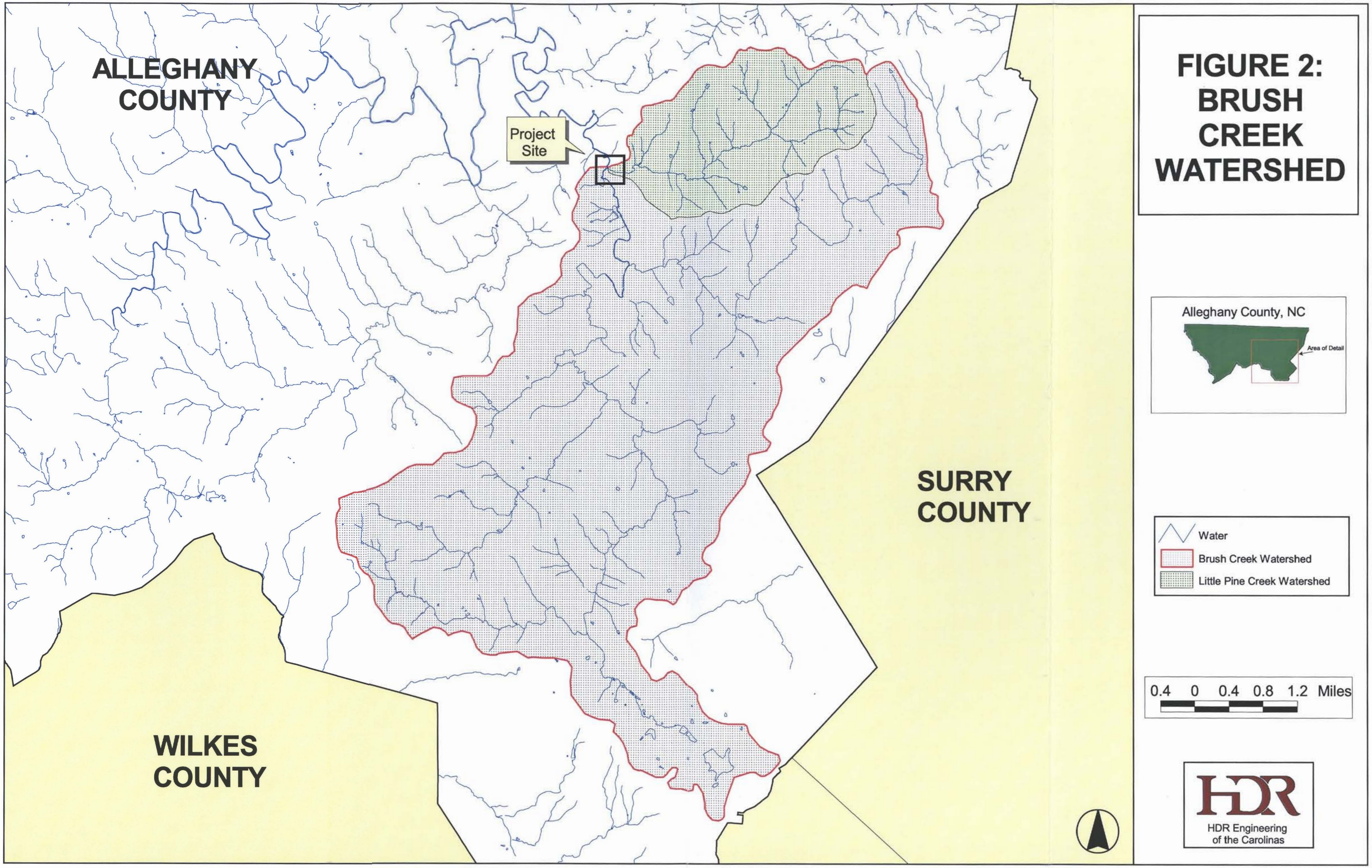
FIGURE 2: BRUSH CREEK WATERSHED



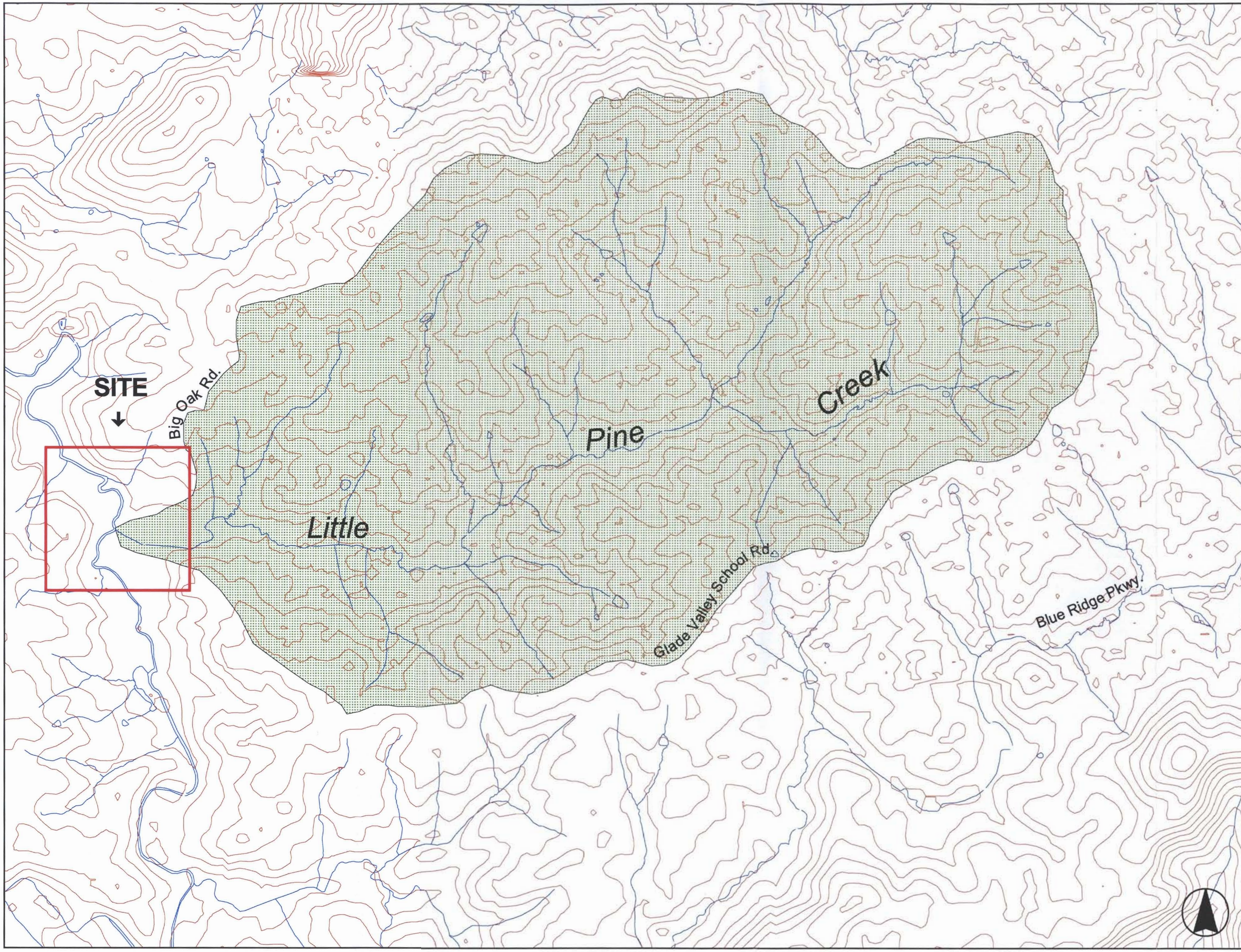


FIGURE 3: LITTLE PINE CREEK WATERSHED

Roads
Water
40 Ft. Elevation Contours
Little Pine Creek Watershed

0.1 0 0.1 0.2 0.3 0.4 Miles

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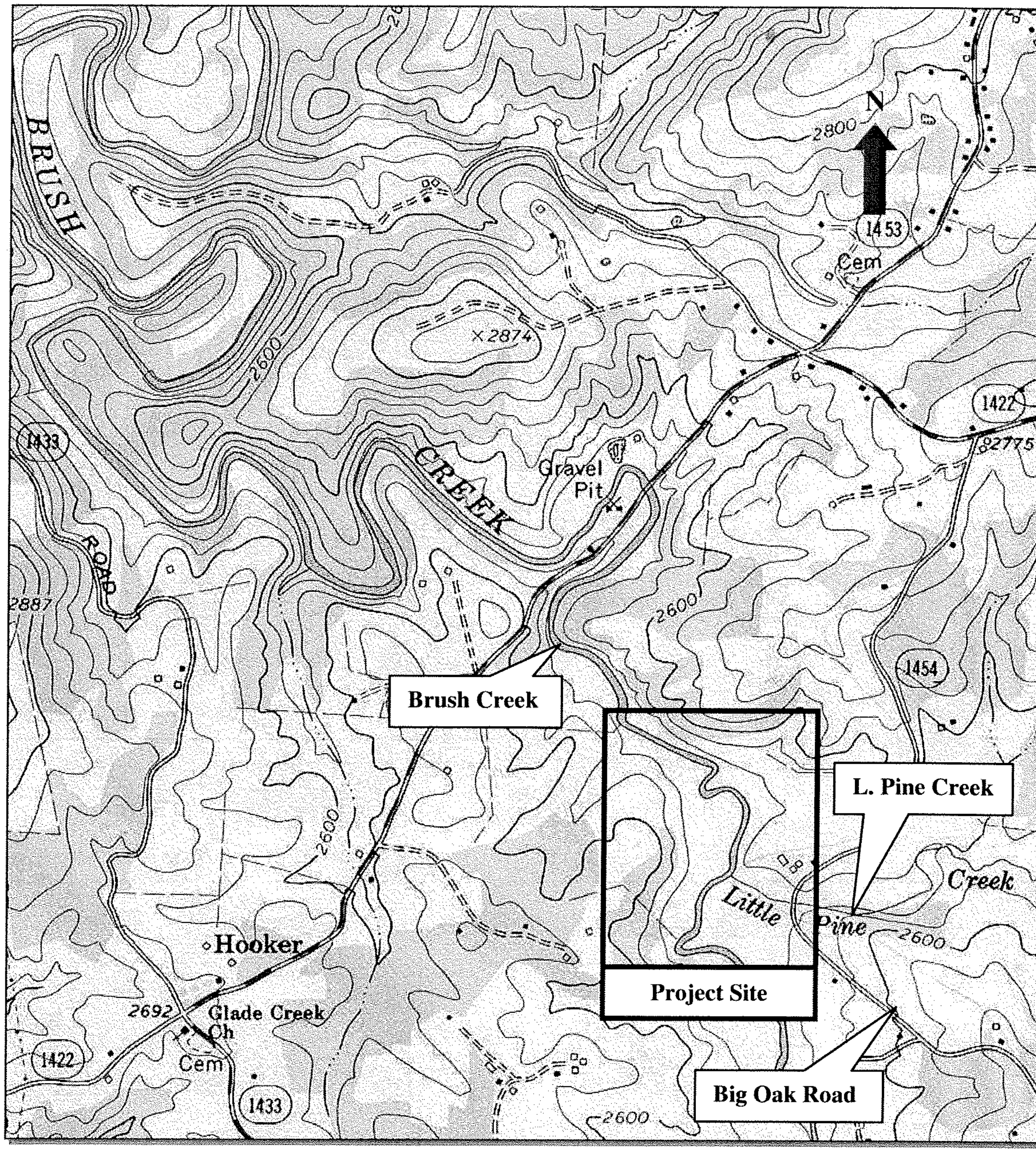

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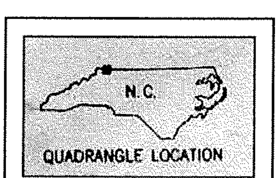

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FIGURE 4
Brush Creek/Little Pine Creek Project Site
Alleghany County, North Carolina

2.1 Basin Relief/Landforms

The project site itself is located in eastern Alleghany County, North Carolina (refer to Figure 1). The County is situated in the Blue Ridge chain of the Southern Appalachian Mountains. This location places the project site within the Mountain physiographic region of the State, an area characterized by moderately rolling to steeply mountainous terrain, rural land use, and significant aesthetic beauty.

Elevations within the county range from 2,000 feet to 4,200 feet, and include numerous small valleys and occasional granitic outcroppings. Average elevation at the project site itself has been estimated at 2,520 feet. This is typical for the intermountain valleys found throughout the county. Little Pine Creek and Brush Creek, like most of the County, are contained within the New River Basin.

The Little Pine Creek watershed drains an area of 4.33 square miles in the eastern part of the County as it carries flow to the southwest (refer to Figures 2 and 3). Elevations within this watershed range from 2,980 feet (near the headwaters) to 2,520 feet (at the confluence with Brush Creek). The headwaters of this third-order perennial stream originate near the intersection of State Road 1422 and State Road 1444, east of the Barrett community and approximately 3,500 feet (0.66 miles) west of the Blue Ridge Parkway. Little Pine Creek eventually flows into Brush Creek at the proposed project site east of Big Oak Road (State Road 1457). Though relatively small, Little Pine Creek is designated as a N.C. Trout Water (Tr) by the NCDENR Division of Water Quality.

In contrast, the Brush Creek watershed drains approximately 26.3 square miles of the southeastern part of the County as it flows northwesterly into the Little River (refer to Figure 2). Brush Creek's headwaters originate near the town of Roaring Gap, to the south, and the stream carries flow contributed by Laurel Branch, Little Glade Creek, Big Pine Creek, and Little Pine Creek. Surface water flow through this stream enters the Little River, south of N.C. Highway 18 near Blevins Crossroads, before continuing to the New River. Like Little Pine Creek, this fourth-order perennial stream has also been designated as a Tr.

2.2 Stream Channel Geometry

Hydrologists often study variations in morphological stream characteristics in order to differentiate among stream types, evaluate existing conditions, and assess processes at work in the stream channel and adjacent riparian area. The three primary characteristics of channels most often studied include profile, pattern, and dimension. For the proposed project, each component was evaluated using the Rosgen approach (Rosgen, 1996).

2.2.1 Profile

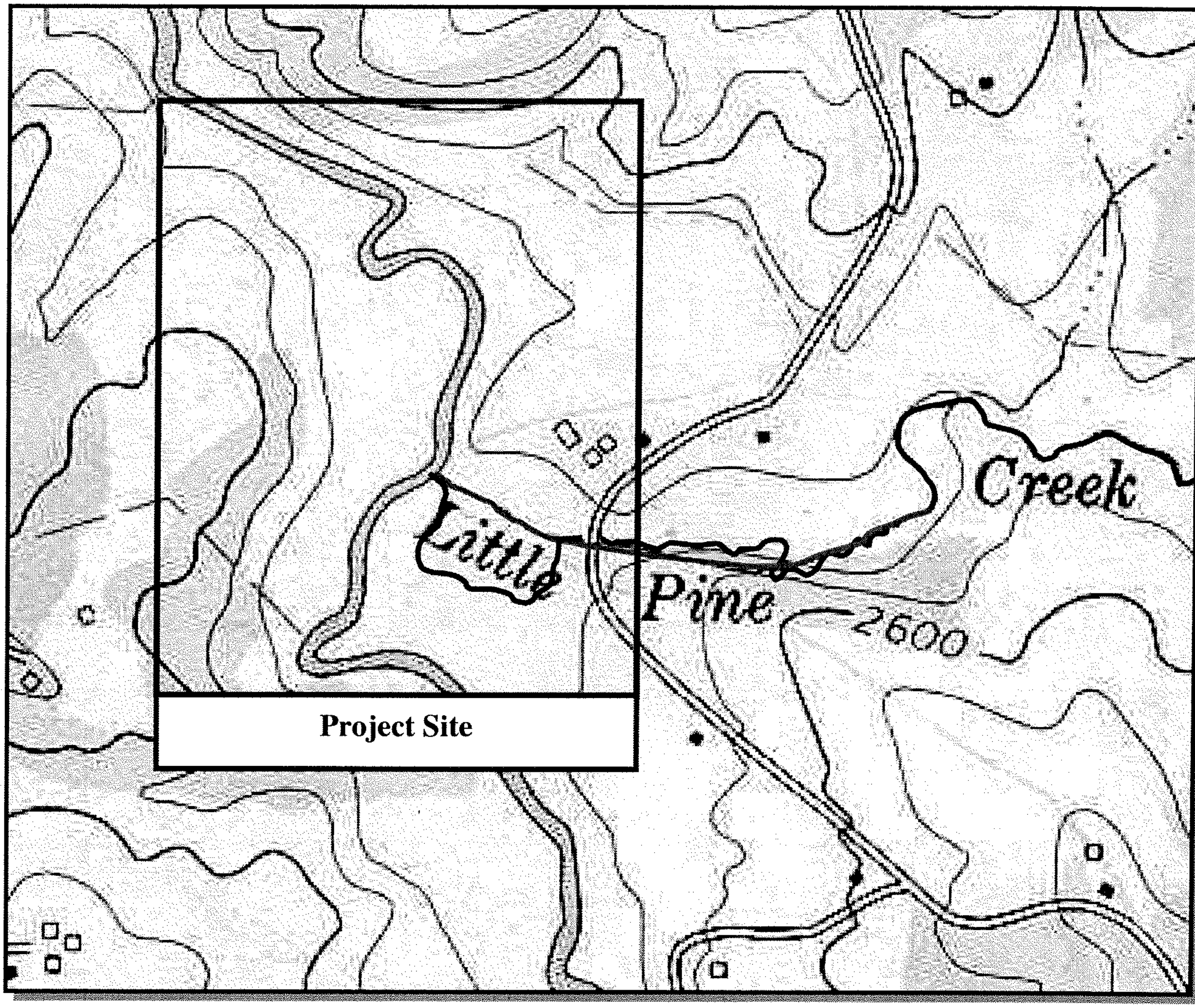
The profiles of Little Pine Creek and Brush Creek were considered carefully during preliminary site characterization in order to plan restoration efforts. The profile, or gradient, of both water surface and streambed were used to evaluate sediment transport relationships, to plan appropriate riffle-pool sequencing, and to select and position habitat improvements. In general, mountainous areas like the County contain a combination of high-gradient streams flowing through steep valleys, and low-gradient streams flowing through alluvial floodplain valleys. Both Brush Creek and Little Pine Creek fall into the latter of these two categories as they carry flow through floodplain areas built up from weathered materials historically transported from the upstream slopes of their respective watersheds.

For the proposed restoration effort, the stream profiles (slopes) of both Little Pine Creek and Brush Creek were evaluated. Appropriate reaches were selected and surveyed in conjunction with cross-section mapping. A total of thirteen cross-sections were surveyed along with longitudinal measurements to determine an average streambed slope for Little Pine Creek of 0.7 percent and an average streambed slope for Brush Creek of 0.3 percent. Water surface slopes for both streams varied only slightly from streambed gradient, with a slope of 0.6 percent in Little Pine Creek and 0.3 percent in Brush Creek.

2.2.2 Pattern

A second important morphological channel characteristic is pattern, or planform, essentially an overhead view. Analysis of a stream pattern allows evaluation of elements such as stream length, valley length, channel width, meander length, belt width, radius of curvature, meander arc length, meander width ratio, sinuosity, and landscape position. An understanding of stream pattern relationships is important for any restoration effort.

For the proposed project, four sources of planform data were used: 1) site survey mapping, 2) U.S. Geological Survey (USGS) 7.5-minute series topographic maps, 3) Alleghany County's 40-foot and 100-foot Geographic Information System (GIS) contour data layers, and 4) NRCS aerial photographs from 1964 and 1988. Data from these sources allowed planform calculations to be made and provided representations of existing and historic stream channel characteristics. Evidence provided by aerial photography indicates that approximately 2,200 feet of Little Pine Creek was artificially straightened and deepened by a local landowner in 1969. Of this total distance, approximately 1,000 feet of channel west of Big Oak Road was straightened and replaced by a 610-foot channel. The proposed restoration effort will restore 1,100 feet of Little Pine Creek channel through the floodplain area that accommodated the stream prior to 1969. The 1,200-foot reach of Little Pine Creek upstream of Big Oak Road appears to be gradually re-establishing a natural meander pattern since the channel alteration activities.



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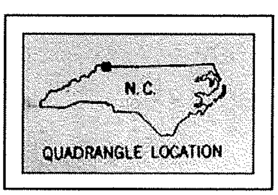

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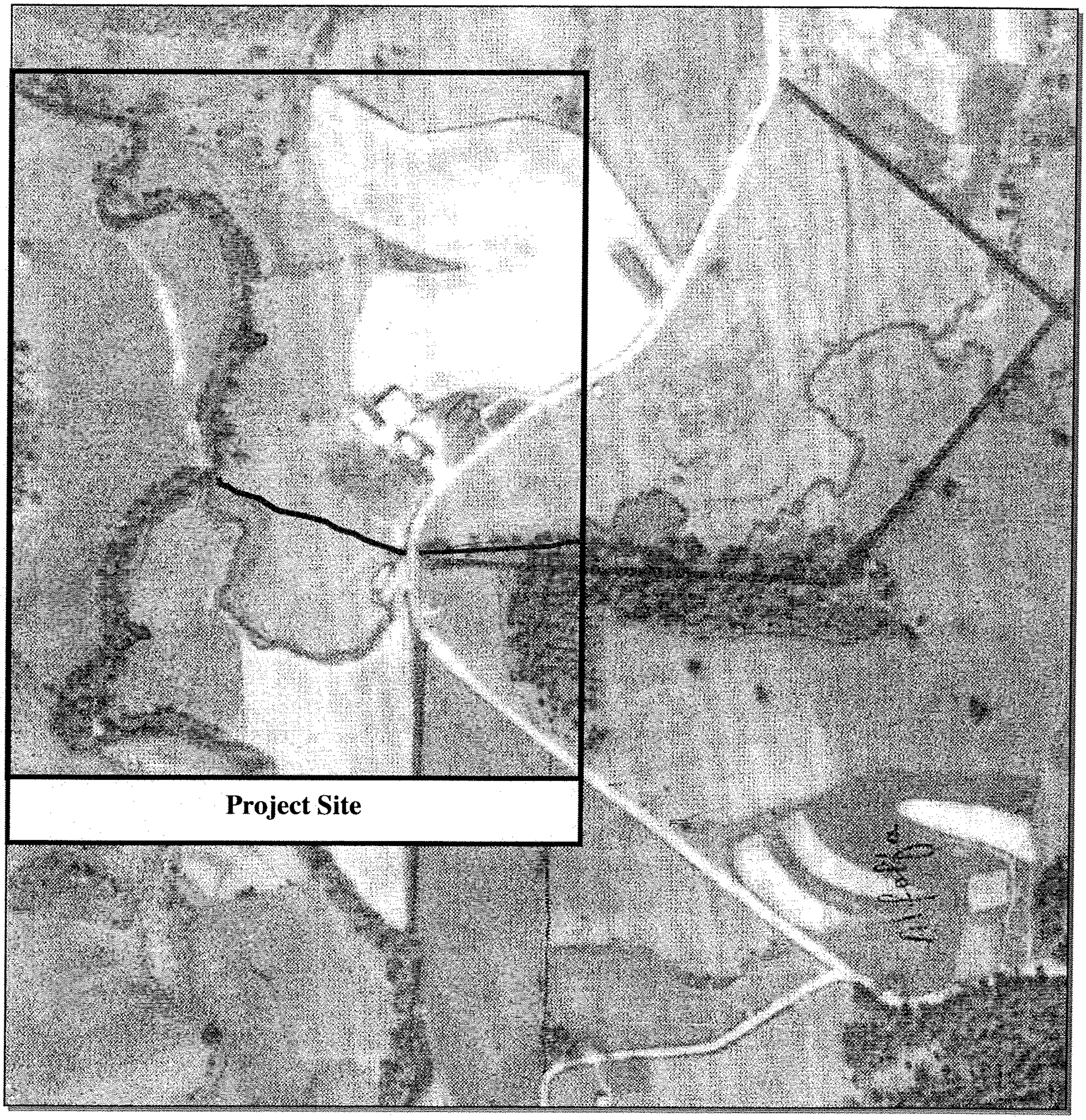
FIGURE 5
Existing Little Pine Creek Alignment

Existing Little Pine Creek Channel (2000)

Approximate Pre-1969 Little Pine Creek Channel



Map Source:
- Alleghany County NRCS
- USDA 1964 SCS aerial photo
- Sheet 1FF-56

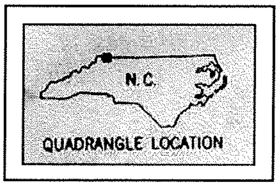


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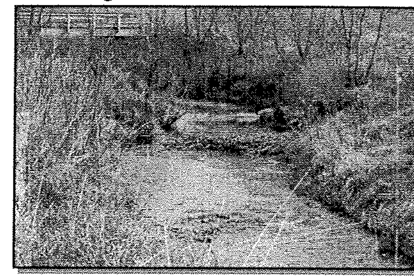
FIGURE 6
1964 Aerial Photograph of Project Site

— Existing Location of Little Pine Creek Channel (2000)

In recent years, beaver (*Castor canadensis*) have migrated into the watershed and have periodically dammed the stream at various locations. These dams have been responsible for some alteration of discharge, but are not primarily responsible for the present stream condition. At present, approximately 60 percent of one relic beaver dam remains in the stream channel. Following breach of this dam by a stormflow event in Spring 2000, an upstream pool once again became a run feature. The absence of either dam repairs or a burrow since that time suggests that beaver may not presently be active in this stream reach. To minimize potential future beaver impacts to bioengineering vegetation, however, "tree tubes" or other similar structures may be used to protect planted riparian vegetation.



2.2.3 Dimension

Channel dimension refers to the cross-section aspect of a stream channel within the landscape. A variety of measurements and calculations are used to evaluate channel dimension, including cross-sectional areas, mean depths, maximum depths, and widths. These measurements are particularly significant when they relate to bankfull discharge, or effective discharge, an important consideration in restoration efforts. Under most natural, undisturbed conditions, a stream's bankfull cross-sectional area should accommodate stormflow discharges from the 1 to 1.5-year recurrence storm. In consideration of this, most stream restoration efforts use bankfull cross-sectional area as a basis for comparison to other design parameters.

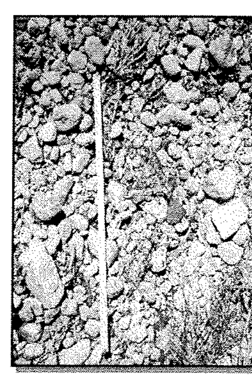
To collect dimension data for the proposed project, a total of thirteen stream cross-sections were surveyed during field investigations. Ten cross-sections were located along Brush Creek, while three cross-sections were surveyed along the existing Little Pine Creek channel. The results of this surveying effort indicated a bankfull cross-sectional area of 27.7 square feet in Little Pine Creek and a bankfull cross-sectional area of 188.8 square feet for Brush Creek (refer to Appendix B). The bankfull cross-sectional area for Little Pine Creek is significantly lower than that predicted in some N.C. regional curve models, though Brush Creek's bankfull area is similar to expected conditions.

To compare Little Pine Creek bankfull estimates to known reference reaches, results were evaluated against a reference stream reach along Mill Creek and the N.C. Rural Mountain Regional Curve, developed and published by the N.C. Cooperative Extension Service, N.C. State University, and N.C. A&T University (Harman, 1999). Based on cross-sections taken from riffle and run sections of the stream, bankfull cross-sectional area in the Mill Creek reference site was calculated at approximately 34.15 square feet. In contrast, the Rural Mountain Regional Curve predicts a Mill Creek cross-sectional area of 50-80 square feet. This same regional curve predicts a cross-sectional area for Little Pine Creek of 40-80 square feet. The results of these comparisons indicate that the cross-sectional characteristics of the Mill Creek reference reach may be slightly atypical of expected conditions. This may be due to aggradation in the surveyed reach and subsequent, frequent overbank discharge volume lower than the expected "bankfull." Abundant riparian vegetation along Mill Creek may also have influenced the noted variation. The presence of riparian vegetation and root mass plays an important role in the stabilization of streambanks, and may be significantly enhancing the stability of this smaller-than-expected channel.

Results from the ten cross-sections taken along Brush Creek indicate that the calculated bankfull cross-sectional area of Brush Creek is within the expected range of 100-250 square feet (N.C. Rural Mountain Regional Curve).

Based on the collected cross-sectional data, two additional characteristics of channel dimension were determined, entrenchment ratio and width/depth ratio. Entrenchment has been defined by Rosgen as "the vertical containment of a river and the degree to which it is incised in the valley floor (Kellerhalls, 1972)." The entrenchment ratio is the ratio of the width of the flood-prone area to the surface width of the bankfull channel (Rosgen, 1996). In order to calculate entrenchment ratio, the average bankfull channel width is first determined. The flood-prone elevation is then calculated as equivalent to twice the maximum depth of the bankfull channel and the flood prone area width is measured. Finally, bankfull channel widths are compared to flood-prone area widths to determine entrenchment ratios. For the existing Little Pine Creek channel, an entrenchment ratio of 1.2 was calculated, while Brush Creek entrenchment was found to be approximately 2.3. These estimates agree with the morphological characterization of the existing Little Pine Creek and Brush Creek channels as Rosgen Type F4 and Type F4/C4 streams, respectively.

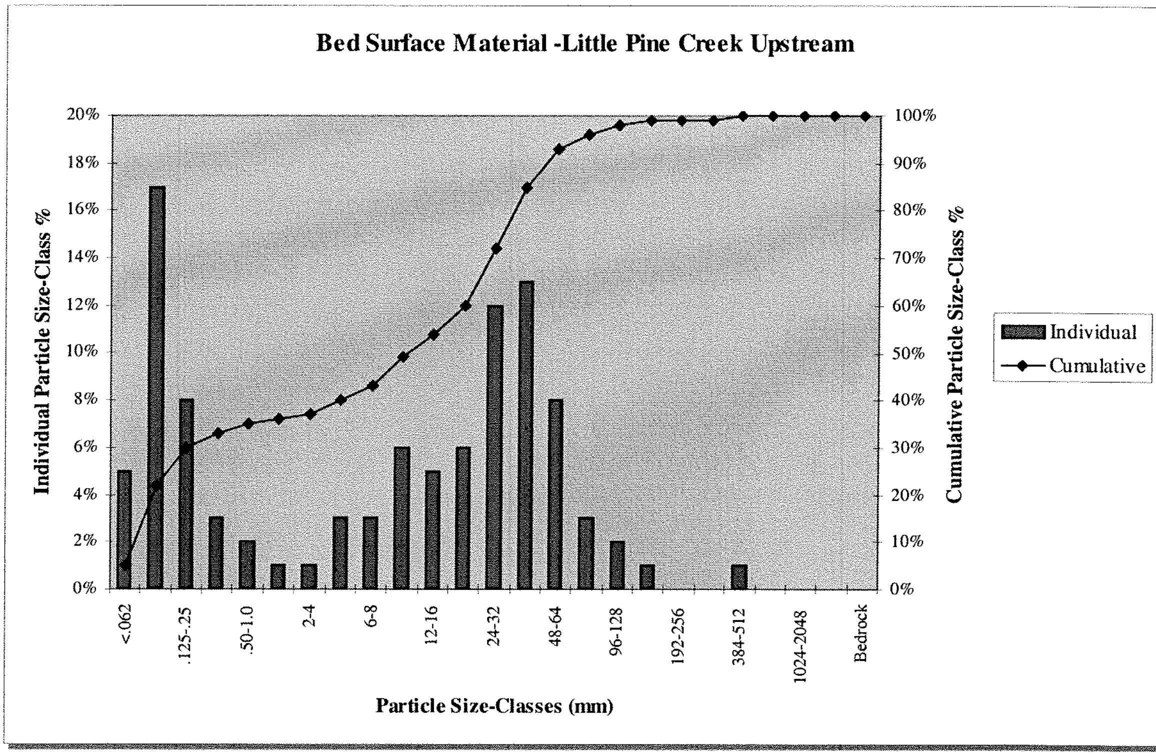
2.4 Stream Channel Substrate



Brush Creek Point Bar Material

Streambed substrate composition varied somewhat between Little Pine Creek and Brush Creek, though the majority of substrate appears to be composed of materials derived from upstream quartz and micaceous schist. Some variation in composition between streams is to be expected due to slight variations in upstream watershed geology. In terms of size, Little Pine Creek substrates typically included significant quantities of gravel, sand, and silt (refer to Figures 7 and 8). For the surveyed reach, the existing Little Pine Creek substrate had an average D_{16}=0.1 mm, D_{50} =11 mm, and D_{84}=60 mm. Brush Creek contained similar materials but with a smaller average D_{84} particle size than Little Pine

Figure 7 – Little Pine Creek Pebble Count Near Big Oak Road Bridge



Creek (Figures 9 and 10).

Figure 8 – Little Pine Creek Pebble Count Near Confluence With Brush Creek

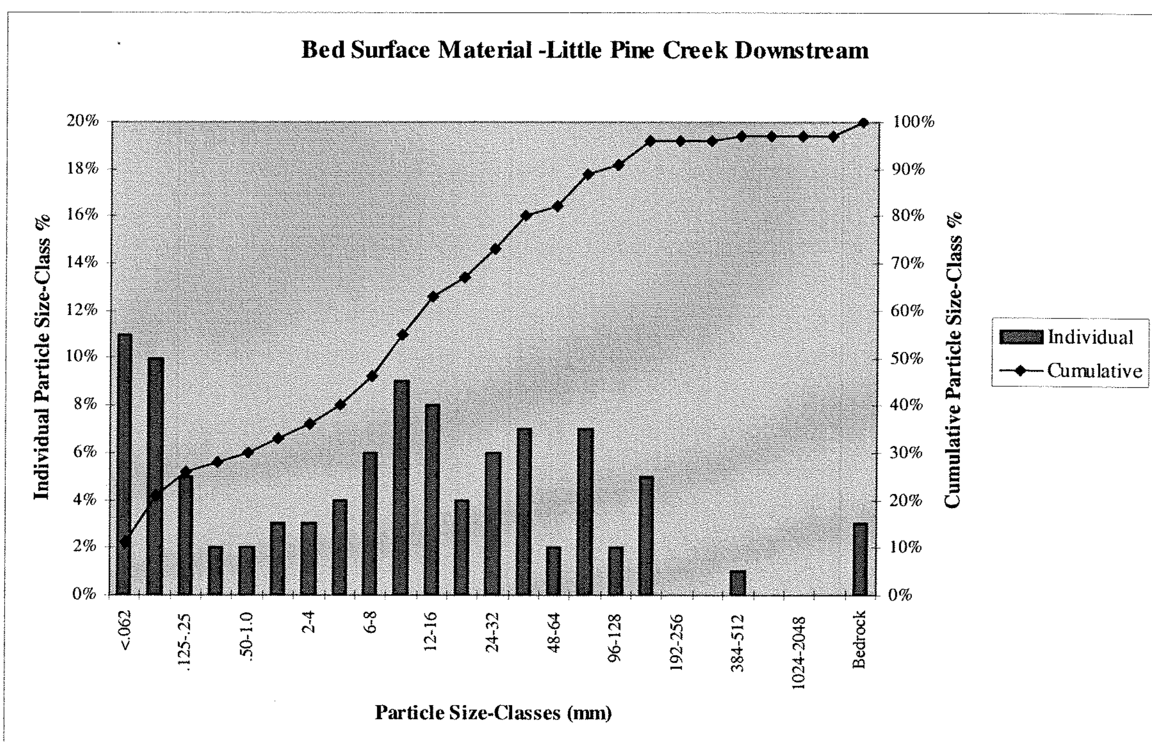


Figure 9 – Brush Creek Pebble Count Upstream of Confluence

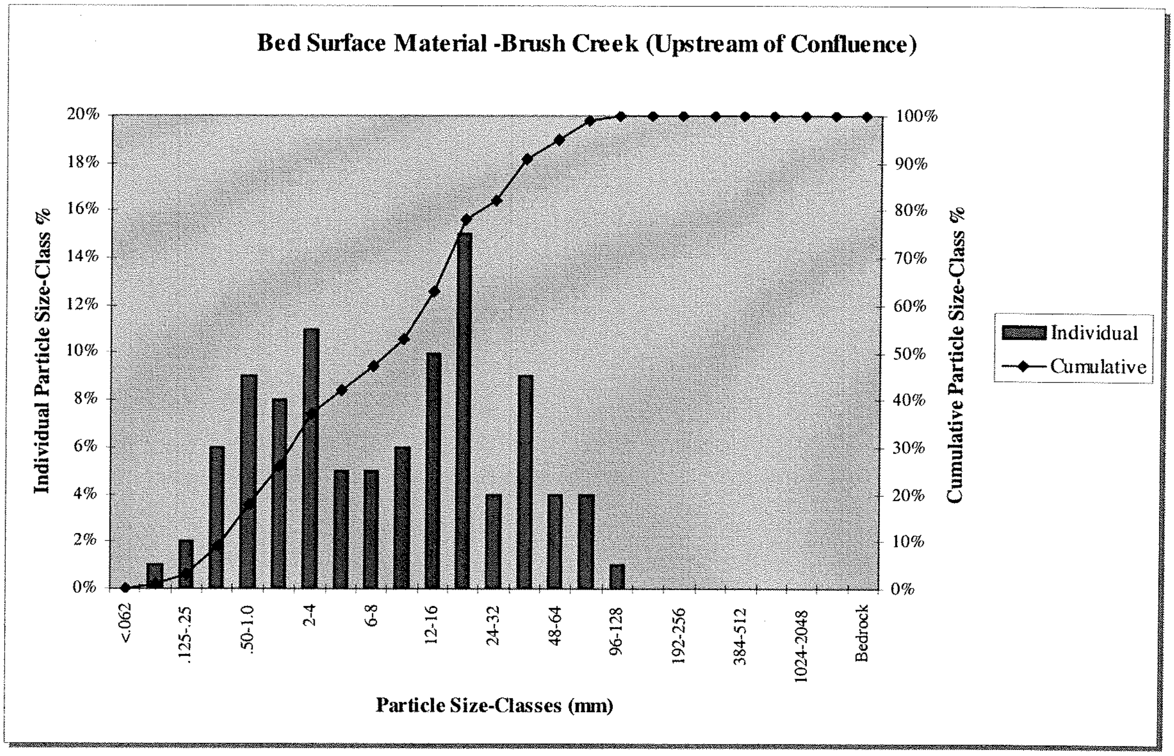
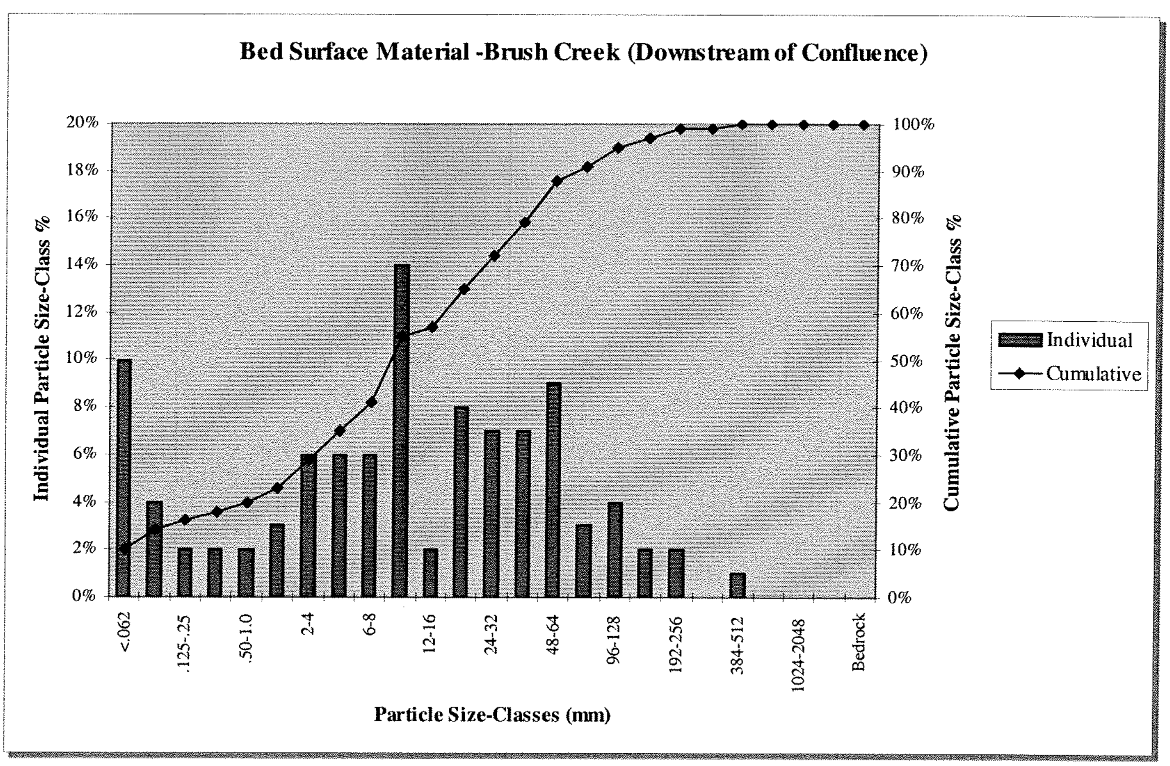


Figure 10 – Brush Creek Pebble Count Downstream of Confluence



Brush Creek substrate materials were characterized by an average D_{16} diameter of 0.5 mm, D_{50} diameter of 11 mm, and D_{84} diameter of 45 mm. Bedrock exposures within both the Little Pine Creek channel and the Brush Creek channel were also observed during field investigations (refer to Figure 11). These bedrock exposures are presently acting as natural grade control features within each channel. This is particularly evident in Reach 4 of Brush Creek, with bedrock at both the upstream and downstream limits of this reach. These substrate features will be considered in the restoration plan for both streams.

2.5 Manning's "n"

It is known that the size, weight, composition, and abundance of substrate materials significantly influence natural channel morphology. For Little Pine Creek and Brush Creek, these substrate characteristics were evaluated to determine a relative measure of channel roughness, or resistance to flow. Calculations of Manning's "n", a roughness coefficient used in the Manning equation, were used to compare the conditions within the different stream reaches. This roughness coefficient is not a product of substrate alone, however. According to Chaudhry (1993), Manning's "n" is largely dependent upon "the surface roughness, amount of vegetation, and channel irregularity, and – to a lesser degree – upon stage, scour and deposition, and channel alignment." As observed, a variety of channel characteristics affect overall roughness by either accelerating or impeding discharge.

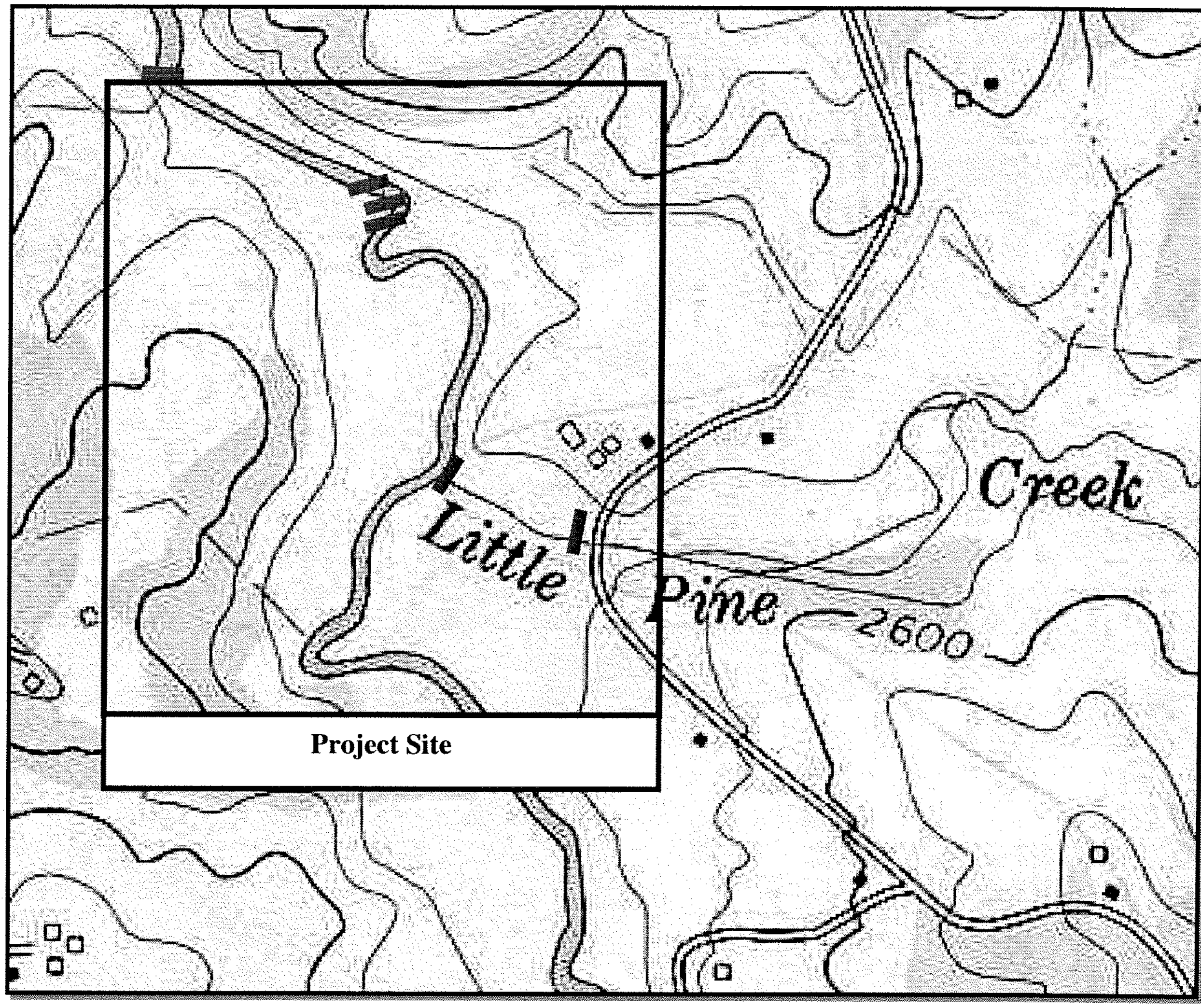
During field investigations for the proposed project, specific channel features were evaluated to determine their subsequent effect on channel roughness and streamflow. Typical "n" values for natural mountain streams often range from 0.030 to 0.070, with normal values of approximately 0.040-0.050. Since utilization of Manning's "n" values in highly variable natural streams may at times be difficult, additional calculations were made to further determine actual roughness coefficients. As explained by Debo (1995), Cowan's formula for identifying specific components of Manning's "n" value may be used to accomplish this with:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4) * m_5$$

where:

- n = Manning roughness coefficient for natural channel
- n_0 = coefficient associated with lining material type
- n_1 = coefficient associated with degree of irregularity
- n_2 = coefficient associated with variations of the channel cross-section
- n_3 = coefficient associated with channel obstructions
- n_4 = coefficient associated with channel vegetation
- m_5 = coefficient associated with channel meandering

Applying this formula to roughness calculations for the existing Little Pine Creek and Brush Creek channels yielded similar results for the two streams. This is not surprising, since a number of channel similarities exist. Evaluation of the existing Little Pine Creek channel resulted in a Manning "n" value of 0.045, while roughness through Brush Creek



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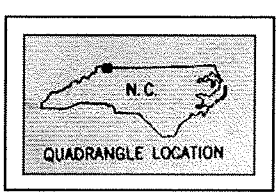

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FIGURE 11
Bedrock Presence in Stream Substrate

Exposed Bedrock and Orientation in Stream

Table 1 – Manning's "n" Calculation

	LITTLE PINE CREEK		BRUSH CREEK	
n_0 – Bank Material	0.020	(earth)	0.020	(earth)
n_1 – Degree of Irregularity	0.005	(minor)	0.005	(minor)
n_2 – Cross Section Variations	0.000	(gradual)	0.005	(alternating some)
n_3 – Obstructions	0.013	(minor)	0.013	(minor)
n_4 – Vegetation	0.008	(low)	0.008	(low)
m_5 – Meandering	1.000	(minor)	1.150	(minor)
Manning's "n"	**0.045**		**0.050**	

Creek was 0.050 (refer to Table 1). The most significant differences between these streams in this calculation were variation in cross-section and meandering pattern. These roughness coefficients were considered in the proposed stream restoration project to better anticipate storm flow discharge and sediment transport relationships. The calculated "n" values suggest that the Brush Creek channel is slightly 'rougher' than the existing Little Pine Creek channel and exerts a greater resistance to flow.

2.6 Width/Depth Ratios

In stream classification efforts, calculation of width/depth (W/D) ratio provides valuable insight into channel stability relationships. Rosgen defines the Width/Depth Ratio as "the ratio of the bankfull surface width to the mean depth of the bankfull channel." Observation of changes in W/D ratios over time allows study of both increasing or decreasing stream channel stability patterns, and sediment transport relationships. As the width of a channel increases relative to its depth, streamflow velocity decreases. This lower velocity translates to less energy available for sediment transport and subsequent aggradation occurs within the stream.

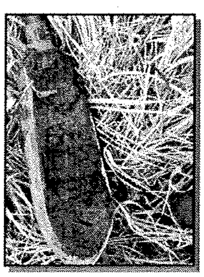
W/D ratios should be calculated prior to the initiation of a stream restoration effort and may additionally be used later to monitor the completed restoration project. For the proposed project, W/D calculations were made for each of the eight stream cross-sections. The results indicate a ratio for Brush Creek of 15.7 and an average ratio for Little Pine Creek of 19.0. Even considering the impacts of excavation along Little Pine Creek, these estimations are consistent with classification of these two streams as F4 channels progressing toward C4 condition. For a natural Type E stream channel, the goal of this project along Little Pine Creek, a W/D ratio <12 is typically expected. In contrast, the Type C channel gradually developing along Brush Creek would be expected to have a W/D ratio >12. Mill Creek, the reference reach used to plan restoration of Little Pine Creek, was found to have a W/D ratio of 7.8. The existing Little Pine Creek and Brush Creek channels are slightly deeper and narrower than would be expected under normal, undisturbed conditions. Monitoring of changes in the W/D ratios for these two streams during project implementation and following project completion should provide a greater understanding of on-going stability relationships.

2.7 Sediment Supply and Transport

Stream substrate and upstream sediment supply are also important considerations for restoration projects. The effective discharge, or bankfull discharge, through a stream channel naturally mobilizes bedload particles and transports these sediments downstream. Should an imbalance develop between effective discharge and sediment supply, stream channels will begin a process of adjustment to restore a naturally stable balance. As anthropogenic modifications of the landscape often lead to imbalances in these parameters, human land use practices may contribute to stream channel instability.

Sediment transport in both Little Pine Creek and Brush Creek is also a concern. The channelization of Little Pine Creek in 1969 produced a stream channel that was steeper than the original channel and subsequently contained bankfull events within its banks. As a result of this containment, shear stress likely increased within the straightened Little Pine Creek channel. The increased shear stresses and available erosive energy in the channel could then effectively transport sediment particles much larger in diameter than previously possible. Over time, these large-diameter particles may have been transported into the Brush Creek channel. The lower gradient and lower tractive forces in Brush Creek may have been unable to effectively transport some of the largest-diameter material received from Little Pine Creek. This may have contributed to the formation of a large gravel bar that diverted streamflow to subsequently erode the western Brush Creek streambank at the confluence.

2.8 Soils



Soil Sample

As noted earlier, soil associations near the project are largely alluvial in nature. In the stream valleys of Little Pine Creek and Brush Creek, 10 soil borings confirmed this, and provided evidence of unconsolidated gravels and sands. This is consistent with previous NRCS observations of soils located in the river valleys of the County.

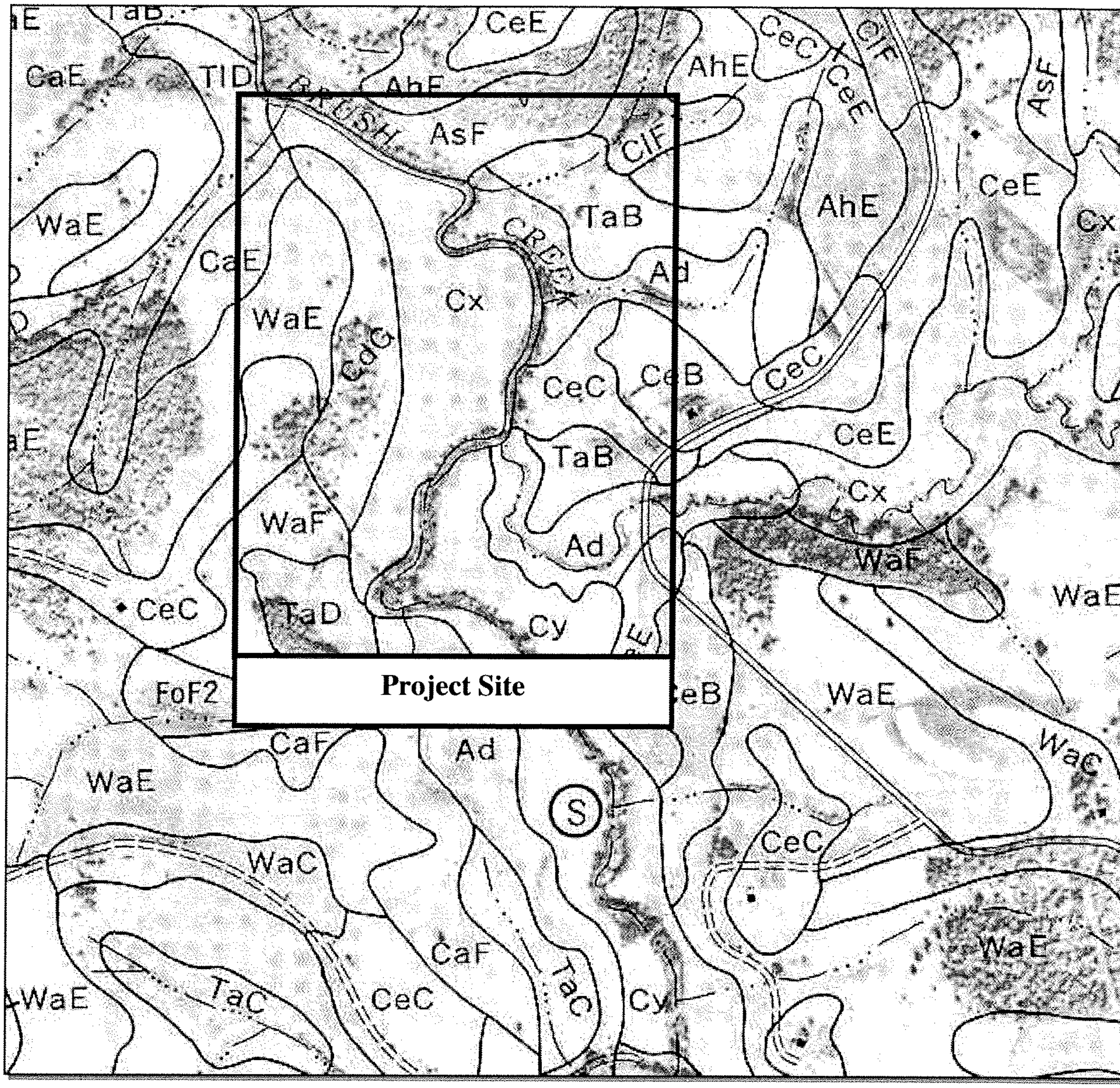
According to the NRCS, the soils immediately adjacent to the Little Pine Creek and Brush Creek stream channels have been classified as predominantly Alluvial Land (Ad), Comus fine sandy loam (Cy), and Codorus complex (Cx) associations (refer to Figure 12). All three soil types possess shallow seasonal high water tables (0-2.5 feet below surface), are subject to frequent, brief flooding, have pH values of 5.1 – 6.0, and have low shrink-swell potential. All three of these soil types are typically found in relatively level valley areas throughout the County and are often used for pasture or hay production. These soils are commonly characterized as alluvial loams, sandy loams, or fine sandy loams, with dark grayish- brown to brown surface layers 8-15 inches deep.

The noted soil characteristics were considered during planning of the proposed stream relocation and restoration efforts. The relative instability of some alluvial soils on-site will be offset through the use of erosion control blankets, rapid seeding of temporary vegetative cover species, and eventual establishment of woody vegetation and dense root mass. It is also important that all three noted soil types typically have low fertility, an issue that will be addressed through the use of limited soil amendments during bioengineering installation efforts along the proposed Little Pine Creek channel.

2.9 Stream Types

Rosgen stream type determinations for Little Pine Creek and Brush Creek were based on observations of streambed and bank characteristics, entrenchment, W/D ratios, sinuosity, slopes, and substrate material. Little Pine Creek may be best characterized currently as a Type F4 stream. This stream is entrenched (<1.4), a moderate/high W/D ratio (>12), moderate sinuosity (>1.2), relatively low gradient (<0.02), and a predominantly gravel substrate. Under natural, undisturbed conditions, this stream may have likely been a Type E4 stream with a stable, sinuous channel and good riffle-pool sequences. Through channelization, human modification has straightened the stream's meander pattern (plan), increased the stream's slope (profile), and increased the channel's cross-sectional area (dimension). The purpose of the proposed stream restoration effort along Little Pine Creek will be to help restore a meandering E4 channel. One potential limitation of any design for the proposed project site, however, will be the presence of the Brush Creek floodplain through which Little Pine Creek flows. Big Oak Road is presently located at the margin of the Brush Creek floodplain and serves as a convenient demarcation between the adjacent hillslope and the floodplain itself. The consequence of this situation is that under natural, undisturbed conditions, the slope of the Little Pine Creek channel would have decreased at approximately the location of the road, as the small stream entered the floodplain of Brush Creek, the master stream. This could have produced a channel that was naturally aggradational and periodically migrated across the Brush Creek floodplain as it "choked" on its own accumulated sediment. Greater discussion of this issue is provided later in this document.

The proposed channel has been designed to approximate the dimensions of an E4 channel. According to Rosgen, E4 streams are generally stable and typically transport sediment efficiently. Rosgen notes that the relatively narrow and deep channels are also not generally susceptible to significant lateral adjustment. The potential for lateral



Map Source:
- USDA Soil Survey for Alleghany County, North Carolina
- Soil Conservation Service
- Issued February, 1973
- Sheet 20

North Carolina Wetlands Restoration Program

FIGURE 12
Soil Survey Data for Alleghany County

adjustment of the new Little Pine Creek channel is addressed later in this document. An additional concern relates to the fact that E4 streambanks are typically composed of unconsolidated alluvial material that may be prone to collapse when significantly disturbed. Effectively addressing this concern will require particular attention during stabilization of the new, relocated channel during and after construction.

In contrast, most indications suggest that Brush Creek is a C4 stream that has gradually become incised within its floodplain and now exhibits a combination of both C4 and F4 channel characteristics. The F4 channel characteristics of entrenchment, moderate/high W/D ratio, and moderate sinuosity are particularly evident in portions of Reach 1 and Reach 4. The stream has largely abandoned its original floodplain and left behind a terrace, though not in all reaches. Anecdotal evidence suggests that Brush Creek discharge may still exit the defined channel and move across its floodplain approximately every 5 years. Overall, this stream is slightly entrenched, has a moderate W/D ratio, high sinuosity, moderate slope, and a predominantly gravel substrate. Existing conditions suggest that Brush Creek may be attempting to recreate a stable C4 channel.

The proposed restoration efforts for this stream should restore streambank stability along some reaches, while restoring the riparian corridor and enhancing stability in other reaches. By restoring streambanks in place, Brush Creek efforts may be categorized as Priority 4 restoration. Specific efforts will target streambank restoration, toe protection, increased aquatic habitat diversity, terrestrial habitat improvement, increased channel shading, and riparian corridor restoration. In the proposed project, the establishment of vegetative cover along the re-contoured streambanks will be a priority, while toe protection will be provided to enhance stability until root systems become fully established.

2.10 Construction Area Habitat

2.10.1 Vegetation

A variety of vegetation is present at the project site, including grasses and herbaceous species in pasture areas, sparse shrubs along existing streambanks, and mature hardwood trees along Brush Creek itself. On-site vegetation is currently playing an important role in stabilizing many streambank areas. Most streambanks devoid of woody vegetation are now experiencing bank collapse and gradual sloughing.

The vegetation present at the project site may be easily classified into four general categories: the Little Pine Creek riparian area, the Brush Creek riparian area, the pasture area east of Brush Creek, and the pasture area west of Brush Creek. These four areas contain vegetative species typical of rural mountain valleys.

The streambank riparian areas along both creeks are largely populated by woody tree species, with an understory of herbaceous materials. These riparian areas are narrow, however, and often only a single large tree is present between the adjacent pasture area and the stream itself. Along the Little Pine Creek stream channel are a variety of shrubs and small trees, along with abundant herbaceous species. Species present include red maple (*Acer rubrum*), hazel alder (*Alnus serrulata*), river birch (*Betula nigra*), wild rose (*Rosa multiflora*), blackberry (*Rubus* spp.), and greenbrier (*Smilax rotundifolia*). Along Brush Creek are a significant number of mature trees, including 8-12 inch diameter river birch and yellow poplar (*Liriodendron tulipifera*), as well as red maple, silky dogwood (*Cornus amomum*), and black willow (*Salix nigra*) (Radford, 1968, and Little, 1997).

Little Pine Creek- View Downstream

The vegetation present in the pasture areas east and west of Brush Creek varies largely according to land use. East of Brush Creek and south of Little Pine Creek, the majority of the floodplain area is used for hay production, with little livestock grazing. As a result, various low-lying areas include moisture tolerant species of rushes (*Juncus* spp.) and sedges (*Carex* spp.), in addition to tall, abundant fescue (*Festuca* spp.) grasses. In contrast, the pasture area west of Brush Creek is in continual use for livestock grazing. This floodplain area contains relatively short fescue along with other herbaceous species. Fences along the present streambanks have served to limit livestock access to much of the riparian vegetation nearest the stream itself, but have in some areas collapsed into the creek as a result of continued streambank erosion. The floodplain east of Brush Creek and north of Little Pine Creek is significantly narrower than the western floodplain, with pasture areas in its southeastern extents, and mature riparian forest in its northeastern extents.

2.10.2 Aquatic Environment

Aquatic surveying results suggest that Little Pine Creek is somewhat more impaired than Brush Creek. This may be due, in part, to the surrounding land use (livestock operations) and relatively small size of Little Pine Creek. Based upon fish collection data, Brush Creek has less impairment and a larger diversity of fish habitat than Little Pine Creek. Both streams have an adequate population of aquatic macroinvertebrates, though Brush Creek has a greater abundance and a larger diversity. Emphemeroptera (mayflies) were especially abundant in both streams. While Little Pine Creek contained a greater numerical abundance of Trichoptera (caddisflies), greater species diversity was found in Brush Creek. The majority of Plecoptera (stoneflies) were found in Brush Creek. The abundance of Emphemeroptera, Plecoptera, and Trichoptera (EPT) was generally equivalent for both streams. No Unionoid mussels were found in either stream. *It is recommended that a NCDENR-DWQ bioassessment team sample the project site prior to implementation of the proposed stream restoration project, in order to establish a baseline for comparison to future monitoring results.*

2.10.3 Terrestrial Environment

The terrestrial environment surrounding the project site is typical of many rural, agricultural areas in the North Carolina mountains. Like many small tributaries, the streambanks of Little Pine Creek are vegetated with a variety of small trees, shrubs, and herbaceous species of vegetation. Similar species are present along the majority of Brush Creek streambanks. In contrast, however, the banks of this larger stream also contain a variety of mature, deciduous trees.

Beyond the immediate Brush Creek streambanks, pasture areas are extensive. To the west, the majority of the floodplain is currently in use for cattle grazing. Beyond this floodplain, steep hillslopes are vegetated with a combination of forest (40 percent) and pasture areas (60 percent). To the east of Brush Creek is additional pastureland, though less extensive than that found on the western floodplain. The eastern Brush Creek floodplain is also generally narrower than the western floodplain, and eventually rises into hill slopes of mixed forest (70 percent) and pasture (30 percent).

Conditions north and south of Little Pine Creek are generally similar. The tall grass pasture area to the south is presently in use for hay production, while the pasture to the north is fenced for livestock grazing. Both pasture areas likely provide foraging habitat for bird species, insects, and small rodents. The pasture area south of Little Pine Creek presently contains 4-6 groundhog (*Marmota monax*) burrows. With only limited cover and shelter in these areas, the overall faunal population may be limited.

2.10.4 Protected Species

During initial site investigations, no Federal or State-listed threatened or endangered species were observed. Two fish species historically present but rare in the river basin were encountered. The Kanawha minnow (*Phenacobius teretulus*) and the Kanawha darter (*Etheostoma kanawhae*) were both observed in Brush Creek. No freshwater mussels were observed in either Little Pine Creek or Brush Creek. In general, Brush Creek provides greater habitat diversity for aquatic species than Little Pine Creek.

No rare or protected fishes were found in Little Pine Creek. Brush Creek yielded one game fish and two species that appear on the North Carolina Natural Heritage List. Four (4) small brown trout (*Salmo trutta*) were collected in Brush Creek. More importantly, 15 Kanawha darters were sampled from the swiftest riffles in Brush Creek. The Kanawha darter has a Natural Heritage Program (NHP) designation of Significantly Rare (SR). This fish is restricted to the New River drainage and is somewhat common in the County. The other species of fish found during the survey was the Kanawha minnow, which has an NHP designation of Special Concern (SC) and is listed as a "Historic" record for the County, meaning it has not been observed in over 20 years. This fish also has a Federal designation of Federal Species of Concern (FSC). The Kanawha minnow is also restricted to the New River Drainage and is generally uncommon. This fish's Historic designation may be due to limited surveying in Allegheny County, no recent sampling of Brush Creek, or infrequent collection due to the small size of the Kanawha minnow. Regardless, the presence of these fish species in the project area is a good sign that the habitat and water quality are good in Brush Creek and that the proposed restoration efforts should include habitat enhancement for these populations

While neither the Kanawha darter nor the Kanawha minnow have protected status, special efforts may need to be taken to protect these populations during the construction phase of the project. Fish removal and the use of block nets may be required upstream of the construction area before equipment is placed in the stream. Fish could be relocated to an upstream location and allowed to re-colonize the construction area following completion of stream restoration efforts.

2.10.5 Wildlife Issues

In addition to the aquatic and terrestrial habitats noted earlier, some wildlife could be affected by the stream restoration project and could themselves affect the success of the proposed project. Evidence of numerous bird and mammal species was observed during field investigations. The valleys containing Little Pine Creek and Brush Creek provide habitat for a variety of mammals, including whitetail deer (*Odocoileus virginianus*), beaver (*Castor canadensis*), raccoon (*Procyon lotor*), groundhog (*Marmota monax*), muskrat (*Ondatra zibethica*), Virginia opossum (*Didelphis marsupialis*), gray squirrel (*Sciurus carolinensis*), and a variety of small rodents. Bird species observed included wild turkey (*Meleagris gallopavo*), common crow (*Corvus brachyrhynchos*), eastern bluebird (*Sialia sialis*), belted kingfisher (*Megaceryle alcyon*), and red-tailed hawk (*Buteo jamaicensis*). Stream restoration efforts at the project site should result in few negative impacts to the noted wildlife species. Whitetail deer, beaver, muskrat, and other rodents may, however, over-browse planted vegetation and impact survivorship. Beaver may also alter streamflow in Little Pine Creek through dam construction efforts.

2.11 Water Quality

Water Quality Testing

Water quality sampling was also conducted during site assessments for this project. On-site samples were taken from three (3) locations: Brush Creek at the southern project limit, Brush Creek at the northern project limit, and Little Pine Creek at Big Oak Road. This sampling was conducted during estimated normal baseflow conditions. Water sampling included: Temperature, Dissolved Oxygen, Nitrates, Phosphates, Ammonia, CO_2, Chloride, Sulfide, pH, Total Dissolved Solids, and Conductivity (refer to Table 2). Sampling results indicate generally good water quality in the two streams, with only slight variation. The most significant variances were higher conductivity and total dissolved solids in Little Pine Creek. These elevated levels may result from upstream livestock operations and higher sedimentation levels in the smaller of these two streams. Additional samples were taken from Brush Creek and Little Pine creek upstream of the confluence and analyzed for chemical composition (refer to Table 3). The elevated presence of some minerals was noted, though only Beryllium concentrations were above the U.S. EPA's Maximum Contaminant Level for drinking water. While this stream is not a known human drinking water source, Beryllium is a likely human carcinogen and may impacting the aquatic biology of the stream at elevated levels. On-site water quality measurements were made using a Sentry III DO/temperature meter, an Oyster Model 29588 pH/TDS/conductivity meter, and a LaMotte AM-22 Water Pollution Detection Kit (direct titration and comparators).

Table 2 – On-site Water Quality Assessment

WATER QUALITY	Brush Creek Upstream	Brush Creek Downstream	Little Pine Creek Big Oak Road
Channel Width	6 m	6 m	4 m
Channel Depth	22 cm	40 cm	20 cm
Velocity	0.33 m/sec	0.46 m/sec	0.33 m/sec
Temperature	6°C / 42°F	8°C / 43°F	6°C / 42°F
Dissolved Oxygen	130 ppm	120 ppm	125 ppm
pH	6.21	6.41	6.41
Turbidity	Clear	Clear	Clear
Total Dissolved Solids	200 ppm	200 ppm	300 ppm
Conductivity	300 µs/cm	300 µs/cm	400 µs/cm
Ammonia	< 1.0 ppm	< 1.0 ppm	< 1.0 ppm
Sulfide	< 0.2 ppm	< 0.2 ppm	< 0.2 ppm
Chloride	8.0 ppm	8.0 ppm	8.0 ppm
CO2	3.0 ppm	3.0 ppm	3.0 ppm

Table 3: Water Chemistry Analysis

INTERCOUPLED PLASMA (ICP) WATER QUALITY ANALYSIS Values higher than normal N.C. values are in bold (ppm) Elements at Maximum Contaminant Level (USEPA standards) are shaded (ppm)				
Symbol	**Element**	**Normal Piedmont Value**	**Brush Creek**	**Little Pine Creek**
Ag	**Silver**	0.000	0.000	**0.064**
Al	**Aluminum**	0.101	0.000	0.000
As	**Arsenic**	0.006	0.000	0.000
B	**Boron**	0.024	0.000	0.000
Ba	**Barium**	0.024	0.000	0.000
Be	**Beryllium**	0.000	**0.015**	**0.007**
Ca	**Calcium**	11.000	0.963	2.126
Cd	**Cadmium**	0.001	0.000	0.000
Co	**Cobalt**	0.000	0.000	0.003
Cr	**Chromium**	0.007	0.000	0.000
Cu	**Copper**	0.006	0.000	0.000
Fe	**Iron**	0.290	**0.323**	**0.445**
K	**Potassium**	2.900	1.577	2.617
Mg	**Magnesium**	3.700	0.733	1.004
Mn	**Manganese**	0.077	0.000	0.000
Mo	**Molybednum**	0.001	0.000	0.000
Na	**Sodium**	11.000	0.000	1.774
Ni	**Nickel**	0.002	0.000	0.000
P	**Phosphorus**	0.055	0.000	0.000
Pb	**Lead**	0.002	0.000	0.000
Sb	**Antimony**	0.003	0.000	0.000
Se	**Selenium**	0.009	0.000	0.000
Si	**Silcon**	2.200	**2.372**	**3.234**
Sn	**Tin**	0.017	0.000	0.000
Sr	**Strontium**	0.114	0.000	0.000
Ti	**Titanium**	0.002	0.000	0.000
U	**Uranium**	0.060	**0.249**	**0.377**
W	**Tungsten**	0.007	0.000	0.000
Zn	**Zinc**	0.008	0.000	0.000
bold	indicates measurements that exceed normal N.C. values			
shading	indicates measurements that exceed USEPA Maximum Contaminant Level (MCL)			

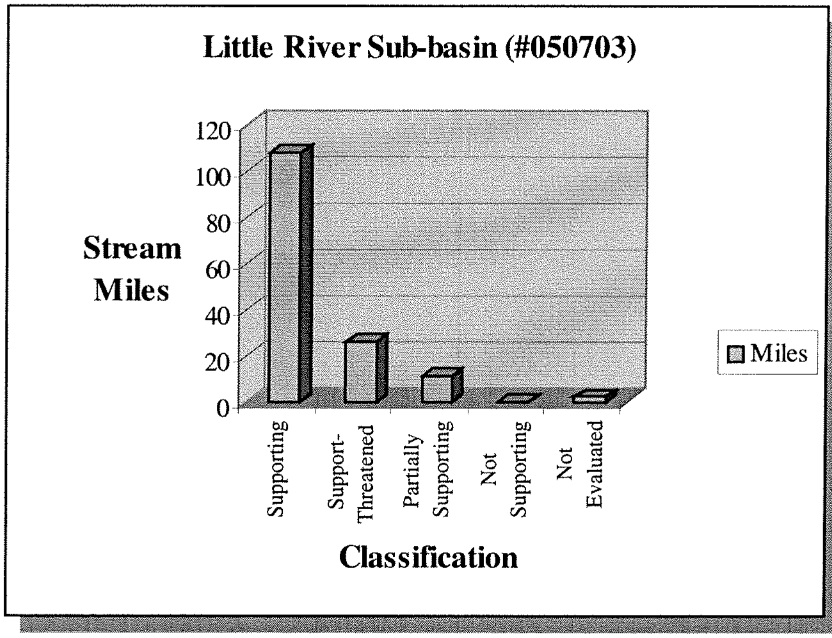
The NCDENR Division of Water Quality published the first New River Basinwide Water Quality Management Plan in September 1995. This plan detailed the results of previous water quality sampling efforts, identified impairment issues, noted existing regulated dischargers, and described potential water quality improvement efforts within the river basin. This basin plan is to be updated every five years, with water sampling in 1998-99. A draft, revised plan was published in February 2000, with the final version to be completed this year, as well.

The North Carolina portion of the New River basin itself has been divided into three sub-basin areas. Both Little Pine Creek and Brush Creek are located within the easternmost of these basins, and flow into the Little River (Sub-basin No. 050703). This sub-basin currently contains 5 small dischargers that are regulated under the National Pollutant Discharge Elimination System (NPDES). The largest of these is the Sparta Wastewater Treatment Plant (WWTP), which is currently permitted to discharge up to 0.375 million gallons per day (MGD). However, no NPDES dischargers are currently located upstream of the project site on either Little Pine Creek or Brush Creek.

During 1993 NCDENR sampling, overall water quality within most of this sub-basin's streams was classified as good or excellent (refer to Figure 13). According to the Division of Water Quality, the greatest water quality concern in this sub-basin is nonpoint source pollution. Agricultural land use, residential construction, and golf course development appear to be the primary activities responsible for this pollution. Water quality remains good, however, and the Little River itself has subsequently been recommended for evaluation for potential High Quality Water (HQW) classification. A total of 147.7 miles of streams are present within the Little River sub-basin.

Particularly relevant to the proposed stream restoration project were discussions of Little Pine Creek and Brush Creek water quality in the 1995 basinwide management plan. Both streams have been classified by the State as Class C surface waters and N. C. Trout Waters. In 1995, use-support evaluations indicated Little Pine Creek as "Partially Supporting" and Brush Creek as "Fully Supporting." These classifications are used to describe a stream's ability to support the uses intended for its category of surface water. Brush Creek was therefore supporting the water uses associated with Class C surface waters and N.C. Trout Waters. However, Little Pine Creek was affected by non-point source pollution and was only partially able to support these same intended uses. In the revised draft NCDENR New River Basinwide Water Quality Plan for 2000, conditions in Little Pine Creek were noted to have improved somewhat, and the stream was once again classified as "Fully Supporting" its intended uses.

Figure 13 – Little River Sub-basin Support Ratings



2.12 Archaeological and Cultural Resources

During the course of initial site investigations, no evidence of archaeologically significant structures was noted. *However, the broad floodplains and low hills adjacent to both Little Pine Creek and Brush Creek may have provided a potential location for a Native American encampment, and could be investigated for archaeological evidence. This issue will be investigated during the permitting phase of the proposed project.* The North Carolina Department of Cultural Resources (NCDCR) should be contacted and provided with an accurate site map for the project. This state historic preservation office (SHPO) may then review records of local, known archaeological sites and provide a recommendation to the N.C. Wetlands Restoration Program.

In consideration of cultural resources, the project is not likely to affect any known historic properties or structures. Structures observed nearest the proposed project site include a farm northeast of the confluence of Little Pine Creek and Brush Creek and a collapsed barn on the western Brush Creek floodplain. Neither of these should be impacted by this restoration project.

2.13 Watershed Reconnaissance

The site investigation for this project included a vehicular survey of the Little Pine Creek and Brush Creek watersheds. The greatest emphasis during this effort was placed on the evaluation of potential stormflow and water quality concerns within the Little Pine Creek drainage area. Information from upstream investigations was used to develop recommendations for effectively addressing the specific land use issues in this watershed. These include stormwater conveyance, upstream residential and commercial development, livestock watering, other land disturbances, and aesthetic concerns.

2.13.1 Land Use

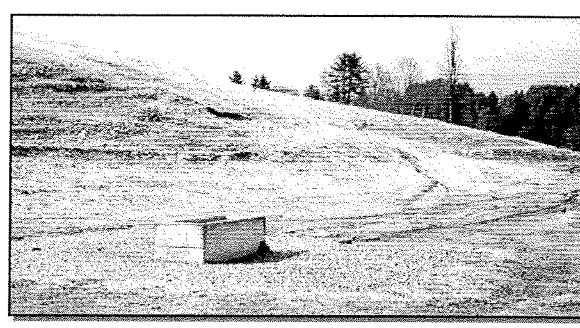
Land use within both the Little Pine Creek watershed and the Brush Creek watershed is primarily agricultural in nature. Many of the ridges and hills are forested by deciduous and coniferous tree species, while most valley areas are in use as cropland or pasture. Christmas tree farms are also abundant throughout the County and both of the noted watersheds.

The absence of easy highway access and local mountainous terrain have largely limited commercial development within both watersheds, though residential land use is common along most roadways. Some limited commercial development has occurred along N.C. Highway 21, to the west, and in the town of Sparta, N.C., 5 miles west of the project site. No countywide zoning presently exists and "built-out" conditions are not anticipated within the foreseeable future.

Livestock presence along tributaries (note impacted streams)

Within the Little Pine Creek watershed, the greatest issues potentially affecting the proposed project are associated with local land-disturbing activities. Two issues, in particular, may exert an influence on the relocation and restoration of Little Pine Creek, livestock access to the stream, and erosion-control practices.

Traditionally, livestock have been allowed access to streams flowing through pasture areas. This has often led to streambank collapse from livestock traffic ("hoof shear"), elevated sediment and nutrient levels in streams themselves, and destruction of aquatic habitat. Alternative watering programs being implemented by local landowners, the NRCS, and cooperative extension services often require the exclusion of livestock from streams in conjunction with such efforts. This approach has been pursued by the landowner immediately west of Brush Creek, though streambank collapse has already claimed multiple fence lines along the creek. The successful stabilization of



Livestock Watering Trough West of Brush Creek

Brush Creek streambanks should further protect not only water quality, but also livestock in this pasture, as well. Further application of alternative watering programs upstream should be encouraged. Doing so will reduce downstream sediment transport, reduce aggradation of the stream channel, and improve aquatic habitat.

Erosion control practices are the second concern upstream of the project site in the Little Pine Creek watershed. On-going State, Federal, and local programs encourage the implementation of erosion-control practices during any land-disturbing activity. These practices are varied and include measures to limit sediment soil loss from agricultural croplands, construction sites, and silvicultural operations. Consistent and widespread implementation of these measures can provide numerous water quality benefits downstream and improve the potential success of stream restoration projects. As noted in the 1995 NCDENR New River Basinwide Water Quality Management Plan, some evidence suggests that the average overall erosion rate for North Carolina is already showing general improvement, as it decreased from 1.4 tons/acre/year in 1982 to 1.1 tons/acre/year in 1992 (USDA, NRCS, 1992).

2.13.2 Tributary Conditions

Tributaries within the Little Pine Creek and Brush Creek watersheds exhibit many characteristics similar to the streams at the proposed project site. Small first and second order tributaries (2-4 feet wide, 3-5 inches deep) evidence the greatest similarities to Little Pine Creek, however. Meander patterns, substrate composition, and streambanks all closely resemble conditions in this F4 stream. As noted earlier, livestock and other non-point source pollutants also impact many of these small streams. This non-point source pollution may be the primary causative factor for Little Pine Creek's "Partially Supporting" classification in 1995. On a positive note, 1999 water quality monitoring by NCDENR has resulted in a present classification of Little Pine Creek as once again "Supporting" its intended uses (NCDENR, 2000). It should be expected that upstream watershed conditions may persist in the future, however, and will likely continue to contribute non-point source pollutants and sediment to both streams.

2.14 Hydraulics / Hydrology (H&H) Modeling and Analysis

To understand existing hydraulic and hydrologic relationships in Little Pine Creek and Brush Creek, evaluations of discharge, climate, precipitation, stormflow velocity, channel roughness, and flood frequency were made. Data for these calculations were collected from field surveying visits, the USGS Buffalo Creek gaging station near Warrensville, NC (No. 03162110), and USGS 7.5-minute topographic mapping. Field surveying provided insights into channel dimension, plan, and profile, along with substrate composition and streamflow. The USGS gaging station on Buffalo Creek (Ashe County, N.C.) provided a complete 17-year data record for a 21.7 square mile watershed. Buffalo Creek gage data was used for H&H calculations because of its proximity and the similar Brush Creek watershed area (26.3 square miles). Finally, USGS topographic mapping was used to produce estimates of surface terrain. Data from each of these sources was evaluated in the preparation of conceptual plans for the stream restoration, relocation, and stabilization efforts. Hydraulic and hydrologic study of the project site addressed a variety of issues relevant to the proposed stream restoration efforts, including anticipated bankfull discharge (refer to Tables 4 - 6).

Table 4 – Discharge Calculations for Little Pine Creek

Regression			Little Pine Creek			Buffalo Creek at Warrensville				
Frequency	a	b	Area	Qn		Area	Qn		Qg	
			4.33	cfs	cfs/sq.mi.	21.7	cfs	cfs/sq.mi.		cfs/sq.mi.
Q1.25				256	59.10				675	31.11
Q1.5				326	75.30				860	39.63
Q2	144	0.691		396	84.35		1207	15.32	1110	51.15
Q5	248	0.670		662	140.86		1949	24.74	1870	86.18
Q10	334	0.665		885	188.33		2585	32.81	2570	118.43
Q25	467	0.655		1220	259.49		3505	44.48	3710	170.97
Q50	581	0.650		1506	320.48		4294	54.49	4800	221.20
Q100	719	0.643		1845	392.55		5201	66.00	6120	282.03

Table 5 – Discharge Calculations for Mill Creek

Regression			Mill Creek			Mitchell River				
Frequency	a	b	Area	Qn		Area	Qn		Qg	
			4.7	cfs	cfs/sq.mi.	78.8	cfs	cfs/sq.mi.		cfs/sq.mi.
Q1.25				254	54.00				2300	29.19
Q1.5				323	68.79				2930	37.18
Q2	144	0.691		420	89.27		2943.49	37.35	3800	48.22
Q5	248	0.670		699	148.82		4625.13	58.69	5425	68.85
Q10	334	0.665		935	198.88		6094.48	77.34	6510	82.61
Q25	467	0.655		1287	273.81		8157.21	103.52	8290	105.20
Q50	581	0.650		1589	338.02		9929.29	126.01	9485	120.37
Q100	719	0.643		1945	413.80		11917.78	151.24	10140	128.68

Table 6 – Discharge Calculations for Brush Creek

Frequency	Regression		Brush Creek				Buffalo Creek at Warrensville					
Annual			Area, Au	Qn	Qu	Qu(w)	Area, Ag	Qn	N	Qg	EY	Qg(w)
	a	b	(sq. mi.)	(cfs)	(cfs)	(cfs)	(sq. mi.)	(cfs)	(yrs)	(cfs)	(yrs)	(cfs)
			26.34	67*								
Q2	144	0.691	26.34	1380	1280	**1323**	21.7	1207	17	1110	2	1120
Q5	248	0.670	26.34	2220	2139	**2173**	21.7	1949	17	1870	2	1878
Q10	334	0.665	26.34	2941	2927	**2933**	21.7	2585	17	2570	4	2573
Q25	467	0.655	26.34	3979	4158	**4082**	21.7	3505	17	3710	5	3662
Q50	581	0.650	26.34	4871	5270	**5099**	21.7	4294	17	4800	7	4647
Q100	719	0.643	26.34	5891	6552	**6270**	21.7	5201	17	6120	9	5785

Formulas
Qn=a*A^b
Qu=((Au/Ag)^b)*Qg(w)
Qg(w)=10^((N*logQg+EY*logQn)/(N+EY))
Qu(w)=(2*(Au-Ag)/Ag)*Qn)+((1-(2*(Au-Ag)/Ag))*Qu)

Factors	
Q2	2-year recurrence interval stormflow (etc.)
a	Regression coefficient
b	Regression coefficient
Area	Watershed area
Qn	Volume
Area, Au	Area, ungaged watershed
Qu	Volume, ungaged
Qu (w)	Volume, ungaged, weighted
Are, Ag	Area, gaged watershed
N	Years of gage data
Qg	Volume, gaged
EY	Equivalent Years of Record
Qg(w)	Volume, gaged, weighted

Notes
* Based on 2.56 cfs/sm as measured at USGS gage 0316100 near Jefferson
Used Procedures from *Magnitude and Frequency of Floods in Rural and Urban Basins of North Carolina,* USGS Water-Resources Investigation Report 87-4096
Used Little Pine Creek values based on unadjusted regression equation.
Adjusted Brush Creek Values based on comparison to USGS gage 03162110 at Buffalo Creek at Warrensville, North Carolina

Units	
(sq. mi.)	square miles
(cfs)	cubic feet per second
(yrs)	years

2.14.1 Little Pine Creek

Along Little Pine Creek, H&H efforts focused on channel design parameters and stormflow hydraulics. The existing F4 channel's total cross-sectional area (84.0 square feet) is sufficient to transport stormflow, but is deeper and narrower than would be a natural, unmodified C4 or E4 channel in the same setting. The proposed channel's bankfull cross-sectional area must be capable of transporting expected stormflow discharge up to the bankfull stage, but should allow flows higher than bankfull to flow across adjacent floodplain areas. Based on reference reach data and the predicted bankfull discharge, the proposed Little Pine Creek channel's bankfull cross-sectional area was designed to be approximately 41.1 square feet. This cross-sectional area should also be comparable to other rural mountain reference streams used to develop the N.C. Rural Mountain Regional Curve (Harman, 1999). The proposed channel should handle discharges less than bankfull within the new streambanks, and should closely replicate expected E4 stream channel characteristics of plan, dimension, and profile. The new, adjacent floodplain should be graded and planted within the conservation easement limits and will contain the new vegetated riparian corridor. Though longer and having a slightly higher roughness coefficient than the existing channel, the proposed 950-foot Little Pine Creek channel should possess sufficient slope for effective sediment transport.

Two issues inherent in the proposed restoration effort are the potential for channel aggradation and potential for streambank instability. As the new Little Pine Creek transitions from its own, higher-gradient floodplain upstream of the Big Oak Road bridge to the lower-gradient floodplain of Brush Creek downstream of the bridge, it will likely experience a reduction in discharge velocity. As indicated in the Lane model, this decrease in slope will produce a corresponding decrease in available energy for sediment transport and a tendency toward aggradation in the new channel. Under undisturbed conditions, the downstream reach of Little Pine Creek may have been aggradational, periodically "choking" on the accumulated sediment, until a large discharge event scoured the channel clean or the stream channel migrated laterally across the floodplain. Either condition could eventually result from the proposed restoration effort, simply as a consequence of slope and discharge. The proposed channel design should minimize the likelihood of either condition, but has not been designed to structurally prevent the development of this natural process. As noted by Leopold (1997), "Thus it is usual for a river channel gradually to migrate laterally across the valley floor."

The second concern, streambank instability, is an issue for most stream restoration projects both during construction and after completion. Most undisturbed, stable stream channels have abundant riparian vegetation along their streambanks and the associated below-ground root mass of that vegetation. This root mass effectively holds the soil particles and imparts to the streambank greater structural strength and resistance to shear stress. With the majority of land-disturbing activities, most surface vegetation is impacted or completely removed. The greatest risk of erosion and soil instability then occurs immediately following land-disturbing activities. To offset the increased exposure of soil particles to direct precipitation impact, a variety of protective measures have historically been developed. In the proposed restoration effort, temporary stabilization of exposed soils will be accomplished through the use of erosion control matting and rapid seeding of a grass cover crop, while long-term stabilization will be achieved through the planting of woody vegetation, whose eventual root mass should impart significant stability to the new streambanks. Long-term vegetative stabilization will likely require a minimum of 3-5 years to become effective. To further minimize the risk of streambank instability, the mean bankfull cross-sectional area of the new channel should maintain discharge velocities that do not significantly exceed 5-6 feet per second (fps), a generally accepted threshold for ensuring bed and bank material stability.

To minimize the potential for aggradation, other specific design characteristics have been selected. The new channel will have toe protection measures placed at the mean daily flow elevation, in order to encourage the stream channel to maintain a width of approximately 7 feet under normal baseflow conditions. This narrow streambed should encourage near-bankfull discharges to transport small-diameter bed materials effectively.

2.14.2 Brush Creek

Hydraulic and hydrologic evaluations of Brush Creek also provided valuable information for streambank stabilization efforts. During field investigations, large, accumulated woody debris was observed along floodplain fences. Further assessment of flow regimes revealed that overbank flooding of the existing Brush Creek channel likely occurs between the 2 and 5-year recurrence interval storm events, at a Qt of between 2,166 and 2,905 cfs (refer to Tables 6 and 7). The anticipated bankfull discharge through this stream is generally contained within the existing streambanks, at an elevation 2-4 feet below "top-of-bank". Additional evaluation of predicted discharge indicated that mean flow velocity downstream of the Little Pine Creek confluence would exceed 5 fps between the 5 and 10-year recurrence interval stormflow events (Qt of 2905-3804 cfs). While this indicates rather infrequent high velocity events, this estimate represents only the 'mean' streamflow velocity. Natural variation in velocity across the channel could likely result in velocities over 5 fps in the near-bank region of meander bends and along the concave bank. With this knowledge, it was determined that reducing flow velocity against the western bank of Brush Creek downstream of the confluence should be a priority of the proposed restoration efforts. Other less-severe streambank erosion areas upstream of the Little Pine Creek confluence should be effectively restored through the use of toe protection, vegetative planting and temporary stabilization measures.

2.15 Reference Stream Reach

Reference stream reaches are sections of stable stream channels whose position in the landscape and underlying lithology are generally similar to those of a stream being studied for restoration efforts. As suggested by Rosgen (1996), "interpretations developed on the basis of data and analysis related to the reference reach can then be extrapolated to other similar reaches, where such detailed data is not readily available." This is significant since evaluation of a reference reach provides a means to evaluate a targeted stream's departure from naturally stable conditions.

To estimate undisturbed conditions for the proposed restoration of Little Pine Creek, nearby streams were evaluated for stable channel plan, profile, and cross-section. Initial investigations revealed a number of potential reference reach streams nearby, including Mill Creek, Beaver Creek, Big Pine Creek, Brush Creek (upstream of the project site), Glade Creek, Little Glade Creek, Meadow Creek, Moccasin Creek, Vile Creek, and Wolf Branch. Mill Creek, in western Surry County, was eventually selected and an appropriate reach was surveyed to provide quantitative data for comparison. This stream reach is approximately 11 miles southeast of the project site and drains a watershed area of 4.7 square miles.

Data collected during surveying of Mill Creek have been applied to the proposed Little Pine Creek conceptual restoration design. Of particular importance were the

Table 7 - Brush Creek Hydraulic Calculations

			Main Channel, Downstream of Confluence						
Depth (ft)	Qt (cfs)	Stage (MSL)	Qm (cfs)	n	A (sf)	P (ft)	R (ft)	S (ft/ft)	V (fps)
1	9	2502.08	9	0.05	16	36	0.44	0.00103	0.6
2	66	2503.08	66	0.05	60	49	1.22	0.00103	1.1
3	180	2504.08	180	0.05	114	54	2.11	0.00103	1.6
4	331	2505.08	331	0.05	169	58	2.91	0.00103	2.0
5	524	2506.08	524	0.05	227	61	3.72	0.00103	2.3
6	712	2507.08	712	0.05	280	65	4.31	0.00103	2.5
7	975	2508.08	975	0.05	350	71	4.93	0.00103	2.8
8	1249	2509.08	1249	0.05	428	81	5.28	0.00103	2.9
9	1516	2510.08	1516	0.05	506	92	5.50	0.00103	3.0
10	2053	2511.08	1988	0.05	595	92	6.47	0.00103	3.3
11	2734	2512.08	2509	0.05	684	92	7.43	0.00103	3.7
12	3592	2513.08	3077	0.05	773	92	8.40	0.00103	4.0
13	4658	2514.08	3691	0.05	862	92	9.37	0.00103	4.3
14	5952	2515.08	4350	0.05	951	92	10.34	0.00103	4.6
15	7495	2516.08	5051	0.05	1040	92	11.30	0.00103	4.9
16	9321	2517.08	5793	0.05	1129	92	12.27	0.00103	5.1
17	11377	2518.08	6575	0.05	1218	92	13.24	0.00103	5.4
18	13805	2519.08	7397	0.05	1307	92	14.21	0.00103	5.7
19	16564	2520.08	8258	0.05	1396	92	15.17	0.00103	5.9

		Left Overbank							Right Overbank						
Depth (ft)	Qt (cfs)	Ql (cfs)	n	A (sf)	P (ft)	R (ft)	S (ft/ft)	V (fps)	Qr (cfs)	n	A (sf)	P (ft)	R (ft)	S (ft/ft)	V (fps)
1	9														
2	66														
3	180														
4	331														
5	524														
6	712														
7	975														
8	1249														
9	1516														
10	2053	21	0.06	38	65	0.58	0.00103	0.6	44	0.06	50	43	1.16	0.00103	0.9
11	2734	110	0.06	125	108	1.16	0.00103	0.9	116	0.06	99	56	1.77	0.00103	1.2
12	3592	289	0.06	255	151	1.69	0.00103	1.1	226	0.06	161	69	2.33	0.00103	1.4
13	4658	580	0.06	428	194	2.21	0.00103	1.4	387	0.06	238	82	2.90	0.00103	1.6
14	5952	1003	0.06	644	237	2.72	0.00103	1.6	600	0.06	328	95	3.45	0.00103	1.8
15	7495	1580	0.06	904	280	3.23	0.00103	1.7	865	0.06	430	108	3.98	0.00103	2.0
16	9321	2330	0.06	1208	323	3.74	0.00103	1.9	1198	0.06	547	121	4.52	0.00103	2.2
17	11377	3263	0.06	1554	366	4.25	0.00103	2.1	1539	0.06	662	134	4.94	0.00103	2.3
18	13805	4403	0.06	1944	409	4.75	0.00103	2.3	2005	0.06	805	147	5.48	0.00103	2.5
19	16564	5761	0.06	2377	452	5.26	0.00103	2.4	2546	0.06	961	160	6.01	0.00103	2.6

Units	
(cfs)	cubic feet per second
(ft)	feet
(MSL)	Mean Sea Level (elevation in feet)
(sf)	square feet
(fps)	feet per second
(ft/ft)	feet per feet

Factors	
Depth	Water depth, in feet
Qt	Total volume, in cubic feet per second
Stage	Flood stage, in feet above Mean Sea Level
Qm	Mean volume, in cubic feet per second
n	Roughness coefficient
A	Area, in square feet
P	Wetted perimeter, in feet
R	Hydraulic radius (A/P)
S	Slope (vertical distance/horizontal distance)
V	Velocity, in feet per second
Ql	Volume, left
Qr	Volume, right

evaluation of bankfull cross-sectional area, W/D ratios, entrenchment ratios, riffle-pool relationships, sinuosity, substrate composition, and vegetative stabilization of the streambanks. Each consideration was subsequently incorporated into recommendations for Little Pine Creek, with considerations made for the differences in drainage area between the streams.

3.0 Recommendations and Conceptual Designs

A variety of factors may have accelerated the rate of bar formation and subsequent bank erosion visible along Brush Creek at the Little Pine Creek confluence. These may have included increased shear stresses and sediment transport through the straightened Little Pine Creek channel, as a result of higher-velocity peak discharge, confluence angle, and increased stream gradient. Of importance also is the smaller watershed area of the Little Pine Creek drainage basin. Smaller watersheds are may be more susceptible to discharge variability than larger watersheds, and these smaller streams may reach peak discharge more quickly than larger streams. As a result, Little Pine Creek's discharge may have, over time, periodically reached bankfull stage more frequently and more rapidly than Brush Creek. Such discharges could have increased discharge velocity into the Brush Creek channel and may have influenced flow through the larger stream. The increased shear stresses in the modified Little Pine Creek channel may have transported a greater volume and size of sediment into Brush Creek. The combined result of these changes may have been to accelerate bar formation in Brush Creek and "trigger" accelerated Brush Creek channel migration. As increased sediment load may have been transported into Brush Creek, the largest-diameter materials may have proved difficult for Brush Creek discharge to transport through the system and may have gradually accumulated into the bar that is presently visible downstream of the confluence. The presence of exposed bedrock along Brush Creek's right streambank downstream of the confluence may have effectively "armored" this bank and may have accelerated channel migration westward around the developing bar, into the alluvial, unconsolidated materials of the left streambank. In terms of confluence angle, 1964 aerial photography and soil survey mapping indicate that the pattern of Little Pine creek prior to 1969 conveyed flow into Brush Creek at an angle of approximately 55 degrees. The straightened existing channel now enters Brush Creek at an angle of approximately 90 degrees. Little Pine Creek channelization efforts may have therefore played some role in accelerating the natural process of Brush Creek bar formation at the confluence by increasing channel gradient, reducing sinuosity, and increasing the confluence angle.

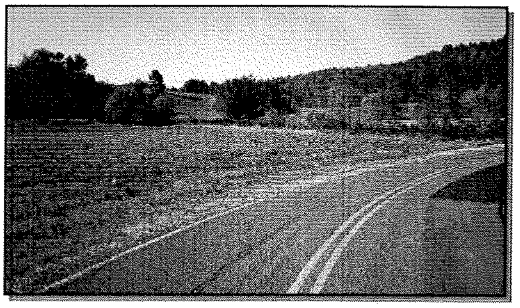
The overall Brush Creek Project will involve three phases of work. The first phase will focus on changing the plan, dimension, and profile of Little Pine Creek by creating a new stream channel approximately 950 feet in length. This will be a Rosgen Priority 1 restoration, incorporating F4 - E4 conversion, with modification of stream plan, dimension, and profile, and re-connection with the floodplain. This new channel will meander through the pasture area south of the existing straightened channel. The second phase of work will involve 340 feet of Brush Creek channel restoration downstream of the Little Pine Creek confluence. The final phase of work will involve 2,300 feet of enhancement and riparian corridor restoration along Brush Creek.

3.1 Little Pine Creek

The proposed project site offers a great opportunity for restoration of Little Pine Creek. The large floodplain pasture area provides a desirable project site and the presence of a previously straightened channel offers the potential for Priority 1 "restoration." Cooperative local landowners and an easily accessible site also contribute to the potential benefits of restoration at the proposed site. As discussed previously, the existing stream channel downstream of Big Oak Road was artificially straightened and deepened in 1969. The proposed project will seek to restore this channel to a more natural plan, dimension, and profile. It is anticipated that this effort may result in sediment transport relationships in the new channel similar to those expected in the original channel prior to channelization. Since the artificial straightening of Little Pine Creek disconnected the stream from the historic Brush Creek floodplain, the existing channel now completely contains the anticipated bankfull discharge. The proposed design should allow periodic overbank flow, should reduce channel gradient, and should reduce discharge velocity and shear stresses. This combination of effects may then produce a channel with slight aggradational tendencies, the likely historic tendency of Little Pine Creek.

The proposed Little Pine Creek relocation and restoration effort will proceed in four distinct phases. Implementation should proceed sequentially through each phase. This approach should minimize downstream sedimentation impacts and on-site land disturbance. The proposed construction sequence will proceed through 1) new channel construction, 2) new channel stabilization, 3) streamflow diversion, and 4) existing channel elimination.

3.1.1 New Channel Creation



Pasture south of Little Pine Creek

The initial undertaking for this effort will be the creation of a new Little Pine Creek stream channel. Excavation and grading of this new channel will take place within the existing pasture area south of the present Little Pine Creek stream channel (refer to Figures 4-6). The proposed channel will be constructed independently of the present channel and will not be connected until later in the project schedule. The upstream connection to the present stream channel will be made only after the proposed channel's streambanks have been stabilized and appropriate substrate has been installed. By avoiding any upstream and downstream connections to streamflow during construction, the new channel should essentially function as a sediment basin during any storm events, and should produce no downstream water quality impacts. This should allow any sediment that may be mobilized from the new streambanks to be retained on-site.

During new channel excavation, additional steps will also be taken to minimize potential environmental impacts. Construction of the new Little Pine Creek channel will be divided into three 325-foot reaches, from the beginning of Reach 1 at Big Oak Road to the end of Reach 3, at the Brush Creek confluence. These sections will be graded in sequence, with temporary stabilization of each section through the use of sod placement and/or erosion control matting and cover crop seeding. Second, topsoil excavated from the new channel excavation will be stockpiled north of the new channel for later use in establishing vegetative cover over the existing channel, once it is filled. Mineral soil removed during excavation will be stockpiled separately, also to the north of the new Little Pine

Creek channel, in order to better facilitate later filling of the existing stream channel. This stockpiled soil material will then be seeded for temporary stabilization while long-term stabilization of the new Little Pine Creek channel begins.

The new channel will possess different characteristics than the existing Little Pine Creek channel. Selection of the proposed morphological characteristics was based on both a reference reach comparison and anticipated bankfull discharge estimates derived from USGS gage station data. These characteristics have also been compared to data collected by the N.C. Stream Restoration Institute (NCSRI) and published in the N.C. Rural Mountain Regional Curve. As noted earlier, Little Pine Creek was straightened in 1969, altering what may have originally been a C4 or E4 stream and initiating a series of adjustments that have since produced an F4 channel.

The proposed stream channel should replicate many of the E4 channel characteristics evidenced by the selected reference for this project, Mill Creek, in western Surry County. Mill Creek is located approximately 11.2 miles southeast of the proposed project site, and drains a watershed area of approximately 4.7 square miles. This stream flows through a small alluvial floodplain valley that has been constructed by the gradual movement of Mill Creek over geologic time. Land use within the Mill Creek watershed and Little Pine Creek watershed is similar and consists of approximately 70 percent agriculture, 25 percent silviculture, and 5 percent residential. While many of the impaired characteristics of Little Pine Creek should disappear in the course of this project, some differences between the two streams will likely remain. These include Mill Creek's presence in its own floodplain (not that of a larger, master stream like Brush Creek), Mill Creek's slightly steeper gradient, and Mill Creek's less-disturbed upstream character.

Some previous NCSRI studies of stream reaches throughout the mountains of western North Carolina have indicated that bankfull cross-sectional area for a stream draining a watershed area of 4.3 square miles may normally range from 40 square feet to 100 square feet (Harman, 1999). The regressions used for this calculation indicate a similar expected cross-sectional area for Mill Creek's 4.7 square mile drainage area. However, the surveyed bankfull cross-sectional area of the Mill Creek reference reach was calculated at 34.6 square feet, (refer to Table 8). While this estimate is somewhat inconsistent with the expected regional curve bankfull cross-sectional area, it matches closely with predicted Q1.25 discharges (bankfull discharge being Q1-Q1.5). The variance may indicate that Mill Creek's smaller cross-sectional area is being maintained by the root mass of abundant riparian vegetation or that the stream overtops its banks with greater frequency than expected.

Table 8: NCDENR Morphological Measurement Table

Variables	Existing Channel	Proposed Reach	USGS Station	Reference Reach
1. Stream type:	F4	E4	-	E4
2. Drainage area (sq. miles):	4.33	4.33	78.8	4.65
3. Bankfull width (ft.):	19.0	20.0	-	18.0
4. Bankfull mean depth (ft.):	1.2	2.3	-	2.5
5. Width/depth ratio:	16.34	8.81	-	7.17
6. Bankfull cross-sectional area (sq. ft.):	27.7	41.1	-	34.6
7. Bankfull mean velocity (f/s):	-	5.67	-	7.62
8. Bankfull discharge (cfs)	-	233.1	1500	263.8
9. Bankfull max. depth (ft.):	2.0	4.0	-	4.1
10. Width of floodprone area (ft.):	22.7	82.0	-	334.0
11. Entrenchment ratio:	1.2	4.1	-	18.6
12. Meander length (ft.):	125.0	110.0	-	101.5
13. Ratio of meander length to bankfull width:	6.6	5.5	-	5.6
14. Radius of curvature (ft.):	-	25.0	-	23.0
15. Ratio of radius of curvature to bankfull width:	-	1.3	-	1.3
16. Belt width (ft.):	41.7	50.0	-	39.0
17. Meander width ratio:	2.20	2.50	-	2.17
18. Sinuosity	1.0	1.6	-	1.7
19. Valley slope:	0.5%	0.6%	-	0.9%
20. Average slope:	0.7%	0.6%	-	0.9%
21. Pool slope:	-	0.2%	-	0.3%
22. Ratio of pool slope to average slope:	-	0.3	-	0.4
23. Maximum pool depth (ft.):	2.0	1.3	-	1.3
24. Ratio of pool depth to average bankfull depth:	1.7	0.6	-	0.5
25. Pool width (ft.):	55.7	25.0	-	25.2
26. Ratio of pool width to bankfull width:	2.9	1.3	-	1.4
27. Pool to pool spacing (ft.):	150.5	62.5	-	66.8
28. Ratio of pool to pool spacing to bankfull width:	7.9	3.1	-	3.7
29. D_{16} particle size (mm):	0.1	1.0	-	1.0
30. D_{50} particle size (mm):	11.0	50.0	-	40.0
31. D_{84} particle size (mm):	60.0	100.0	-	110.0

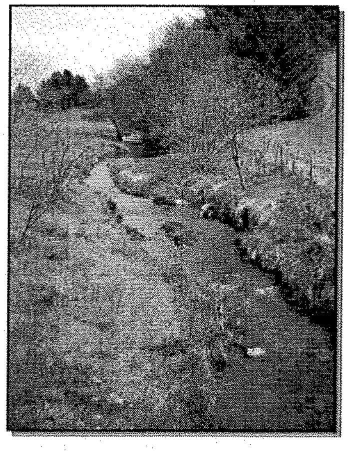
After considering the noted comparisons, site conditions, expected discharges, and upstream land use, design characteristics of the proposed Little Pine Creek channel were developed (refer to Table 8). In order to accommodate the anticipated discharge from the Little Pine Creek watershed and replicate the dimension characteristics of Mill Creek, it was determined that the new channel should provide approximately 41.1 square feet of cross-sectional area at bankfull stage. The bankfull cross-sectional area of the existing Little Pine Creek channel has been estimated at approximately 27.7 square feet. Most indicators suggest that the existing Little Pine Creek channel presently conveys bankfull discharge entirely within its banks. The anticipated design sinuosity of the new channel will be approximately 1.6, in order to restore a natural meander pattern while maintaining sufficient slope for effective sediment transport. A new confluence with Brush Creek will be created approximately 25 feet south of the existing confluence. This location should take advantage of a natural drainage channel into Brush Creek that may in fact be the result of previous fill material settling over time in the original Little Pine Creek channel at this location. Plans to relocate the Little Pine Creek mouth have resulted in slightly greater valley slope calculation (0.6 percent for the new channel pattern versus 0.5 percent for the existing channel pattern).

The proposed Little Pine Creek channel should more closely replicate E4 channel morphology and resemble the Mill Creek channel in many ways. The new stream channel will be narrower at its base than the existing channel and should allow more-frequent overbank flow across the adjacent floodplain. The calculated design parameters should also be comparable to those anticipated by N.C. Rural Mountain Regional Curve estimates. Since Big Oak Road (SR 1454) is currently located approximately four feet above the Brush Creek floodplain through which the new channel will flow, upstream flooding hazards should be minimal. It is estimated that the new flood-prone area of Little Pine Creek will effectively accommodate the majority of anticipated discharges without flooding the existing roadway or bridge. The new floodplain of Little Pine creek will be restored within the existing Brush Creek floodplain by grading the inside of meander bends to 10:1 slopes and the outside of meander bends to 3:1 slopes. Transitional slopes will exist along riffle/run portions of the new channel. This channel should produce conditions similar to those found at the Mill Creek reference site and provide sufficient area for periodic overbank events, while the vegetated riparian corridor develops over time.

3.1.2 New Channel Stabilization

Stabilization of the proposed Little Pine Creek stream channel will involve a variety of bioengineering and stream restoration techniques, each selected on the basis of effectiveness and flexibility. Streambanks immediately adjacent to the creek will initially be graded to produce the bank dimensions indicated in the conceptual plans. These streambanks will then be prepared for vegetative stabilization.

Vegetative stabilization will be particularly important in the unconsolidated, alluvial soils present within the floodplain. Bioengineering of the slopes will include coir fiber log (or equivalent) toe protection, followed by topsoil application, soil surface roughening, cover crop seeding (refer to Table 9), erosion-control matting placement, and live staking (refer to Table 10). Containerized and bare-root materials will then be installed on the reshaped floodplain (refer to Table 10). While this vegetation is becoming initially established, grading and excavation efforts on Brush Creek will begin. This schedule should allow equipment to be utilized efficiently and should minimize equipment transport costs. A portion of the material removed from Brush Creek bar downstream of the confluence may be used as Little Pine Creek substrate if it matches the design diameter criteria. The D_{50} diameter of new channel substrate was selected to approximate reference reach material and to provide a measure of stream channel stability while riparian vegetation becomes established. The majority of material will likely be acquired off-site. Riffle areas in the new channel will be approximately two feet deep in order to maintain stream gradient and provide some degree of initial protection from channel degradation. Substrate for the new riffle areas should have a D_{50} diameter of approximately 50mm. Should project construction proceed during the growing season, secondary live staking along the new stream channel will be performed during the first dormant season following construction completion. Live staking during winter months will take advantage of natural plant dormancy. Live stakes will generally be installed 18-inches apart, to a minimum depth of 12 inches, and left with 2 leaf scars or nodes above ground.



Little Pine Creek – upstream

Little Pine Creek - downstream

Table 9 – Cover Crop Seed Mixture

Cover Crop	Species	Rate
Annual Rye Grass	*Lolium multiflorum*	2 lbs. / 1000 sq. ft.
Creeping Red Fescue	*Festuca rubra*	1 lb. / 1000 sq. ft.
Redtop	*Agrostis stolonifera*	1 lb. / 1000 sq. ft.

Table 10 – Live-staking, Bare-root, and Containerized Species

		Common Name	Scientific Name
RIPARIAN ZONE 1	Live Stakes	Silky Dogwood	*Cornus amomum*
		Black Willow	*Salix nigra*
		Silky Willow	*Salix sericea*
		American Elder	*Sambucus canadensis*
		Coralberry	*Symphoricarpos orbiculatus*
		Hobblebush	*Viburnum alnifolium*
		Yellow-Root	*Xanthorhiza simplicissima*
RIPARIAN ZONE 2	Bare-Root & Containerized	Red Maple	*Acer rubrum*
		Sugar Maple	*Acer saccharum*
		Hazel Alder	*Alnus serrulata*
		River Birch	*Betula nigra*
		Green Ash	*Fraxinus pennsylvanica*
		Possumhaw	*Ilex decidua*
		Mountain Winterberry	*Ilex montana*
		Black Walnut	*Juglans nigra*
		Yellow Poplar	*Liriodendron tulipifera*
		Black Gum	*Nyssa sylvatica*
		White Oak	*Quercus alba*

3.1.3 Streamflow Diversion

Once live stakes and the temporary grass cover crop have been installed, streamflow diversion efforts should take place. The downstream connection to Brush Creek will be made first, with excavated material stockpiled for later use. Following subsequent substrate placement at the downstream end of the new channel and live staking of the streambank and floodplain there, streamflow diversion will proceed. Prior to making the actual upstream connection, seines will be placed at each end of the existing Little Pine Creek channel and fish will be collected and relocated to Brush Creek. The upstream connection to the new Little Pine Creek channel will then be made and streamflow will be transferred. To accomplish this, sandbags will initially divert streamflow into the new channel, while root wads with footer logs will be overlain by compacted clay to produce a channel plug. Rock protection may be installed along the toe of this plug to the elevation of daily mean flow. Streambanks at this upstream crossover will also receive erosion control matting and live staking to enhance temporary and long-term stabilization.

3.1.4 Existing Channel Elimination

Once streamflow diversion efforts are completed, the previous Little Pine Creek channel will be filled to restore surface contours at the site. Initially, sandbags may be used to impound some water in the remaining pools of the previous Little Pine Creek channel. Macroinvertebrates and other aquatic organisms may then be taken from these pools and transferred to the new channel in water-filled buckets.

Along with microorganism transport via future streamflow through the new channel, this action may help encourage the establishment of aquatic macroinvertebrate communities in the restored channel. The straightened Little Pine Creek channel will be filled to near-final grade with mineral soil previously stockpiled from the new channel excavation; then the old channel will be overlain with the excavated topsoil stockpiled. While the creation of a new, longer channel should provide sufficient excavated soil material for filling the previous channel, compaction of this soil may reduce the available material volume. Should this occur, a small wetland area may be constructed in the riparian area north of the new channel. The seed bank present in the stockpiled topsoil should encourage the vegetative stabilization of this area and encourage its eventual return to pasture conditions. Temporary stabilization of the previous channel fill be accomplished through cover crop seeding and temporary silt fence placement.

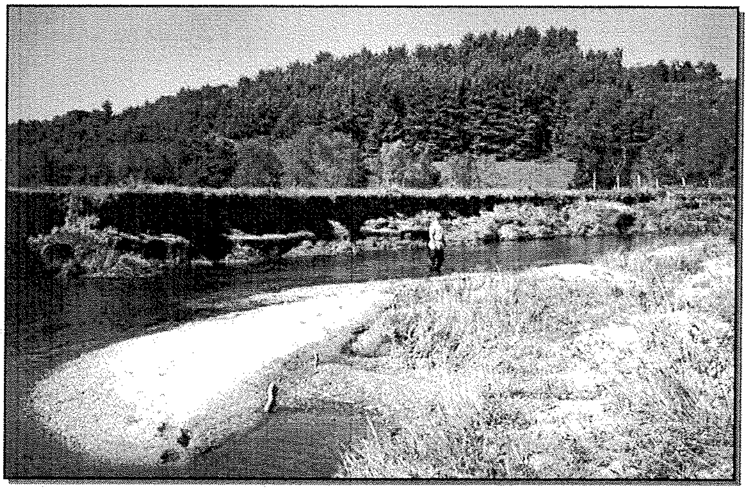
3.1.5 Project Schedule

A variety of issues were considered when developing the proposed project schedule for the Little Pine Creek relocation effort. These included coordination with Brush Creek efforts, erosion control, vegetation establishment, wildlife impacts, overall cost, and desired project completion date. These issues were then prioritized, to help minimize inevitable conflicts. Due to trout spawning season and NCWRC guidelines, instream construction activities will have to be conducted between April 15 and November 15. During project implementation, the steps in the proposed schedule should be followed sequentially to avoid subsequent confusion, to minimize materials costs, and to use equipment efficiently. The following schedule is proposed to coordinate with Brush Creek restoration efforts:

November 2000 – NCWRP Review of Conceptual Relocation Plan and Revisions
December 2000 – Preparation of Final Design / Contractor Bid Package
January 2001 – Advertisement of Project for Bids
February 2001 – Award of Contract
March 2001 – Pre-construction Bioassessment Monitoring
March 2001 – Grading, Excavation, and Initial Vegetative Stabilization
May 2001 – Streamflow Diversion
June 2001 – Maintenance Efforts
December 2001 – Secondary Vegetative Stabilization Planting
June 2002 – Initial Bioassessment Monitoring Event

3.2 Brush Creek

Brush Creek is presently experiencing streambank instability both upstream and downstream of the Little Pine Creek confluence. However, the most severe bank erosion is taking place immediately downstream of the confluence. This area will receive the greatest attention during channel restoration efforts. Specific grading and planting efforts in this and other eroding areas are proposed to address both the severity and extent of streambank collapse throughout the Brush Creek. While the term "stream reach" typically refers to a channel distance of at least two wavelengths, in the proposed project, Brush Creek has been divided into four distinct reaches to better communicate restoration plan details. Reach 1 is located upstream of the Little Pine creek confluence and exhibits many characteristics of a C4 stream reconstructing a new floodplain within an incised F4 channel. Reach 2 includes the section of stream channel immediately downstream from the confluence and is currently experiencing significant bank collapse through rotational slumping and soil fall (Leopold, 1992). Reach 3 includes one meander wavelength and currently exhibits generally stable characteristics, but possesses only limited riparian vegetation and the corresponding stability provided by the root mass of such vegetation. Reach 4 is the downstream-most section of Brush Creek considered in this project. While this reach currently exhibits many characteristics of an F4 channel and presently has only limited aquatic habitat, low banks along some portions of this reach may currently provide a degree of connectivity to the historic floodplain.



Brush Creek western streambank – downstream of confluence

As previously discussed, much of the severe streambank collapse along Reach 2 of Brush Creek may be partially attributable to increased discharge and sediment transport from Little Pine Creek since 1969. Little Pine Creek may have transported greater sediment loads into Brush Creek that exceeded the larger stream's ability to move as suspended load or bedload, potentially contributing to bar formation and channel migration. Once such a process begins, a negative feedback loop may develop. As the Brush Creek channel becomes over-wide, subsequent discharges through this section of channel decrease velocity and drop additional sediment loads, increasing bar development and further channel migration. The unconsolidated alluvial sediment that composes the western Brush Creek floodplain currently has little vegetative stabilization and may be eroding at an accelerated rate. Since confluence bar formation and channel migration are natural processes, the long-term effectiveness of structural controls may be limited under most circumstances. The proposed project will therefore seek to reduce the accelerated rate of these processes without structurally controlling the confluence. It is anticipated that the proposed combination of stream restoration efforts should increase Brush Creek streambank stability and restore appropriate plan, dimension and profile to the Little Pine Creek channel.

3.2.1 Restoration Issues

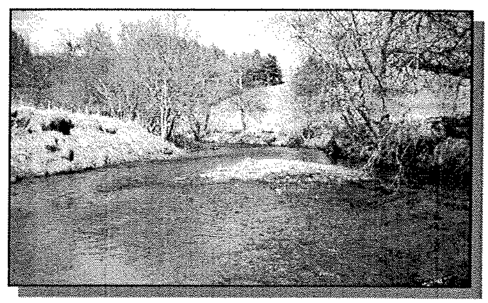
A variety of issues were considered when planning restoration of Brush Creek, including streambank stability, sediment transport, riparian vegetation, and Little Pine Creek relocation/restoration. Both streams currently flow through a floodplain created by Brush Creek itself. As a result, interaction between the two streams may be responsible for the conditions presently evident at the project site. As Brush Creek has historically migrated laterally across the valley through which it flows, it has produced a broad, alluvial floodplain. The present stream channel appears to be somewhat incised into this floodplain, transforming the original floodplain into a terrace feature along much of the channel. Due to the depth of incision, a Priority 4 restoration effort is proposed for Brush Creek. This will involve efforts to reduce the streambank instability in-place while maintaining energy through the channel.

The proposed Brush Creek restoration will involve a variety of efforts targeting channel stability improvements and riparian corridor restoration. Initial activities will be to transfer a portion of the accumulated Brush Creek bar material at the Little Pine Creek confluence to the opposite streambank, reconfigure the existing channel, and install root wads and toe protection along the western streambank. Cross-sectional dimensions and shear stresses through this section of channel will be based on stable upstream Brush Creek conditions. Concurrent with this effort will be the installation of cross-vanes upstream and downstream of the new confluence to reduce near-bank shear stress. The second phase of work will be the installation of two additional cross-vanes in Reach 4 of Brush Creek to create scour pools and improve aquatic habitat. The final phase of work will include 2:1 grading of other unstable Brush Creek streambanks, toe protection installation, cover crop seeding, installation of Curlex III (or equivalent) erosion control fabric, and bioengineering (live-staking) of the restored streambanks.

The initial phase of streambank reconstruction and restoration effort will be along the section of Brush Creek immediately downstream of the Little Pine Creek confluence. This 340-foot section of channel presently evidences a significant degree of instability, has high bank erosion potential, and little riparian vegetation, with the exception of pasture grasses. During construction, a portion of the bar material presently accumulated along the eastern Brush Creek streambank will be excavated and placed along this collapsing western streambank. The new western streambank will then be receive toe protection and 2:1 grading, followed by topsoil placement, cover crop seeding, NAG Curlex III (or equivalent) erosion control matting placement, and live-staking with Riparian Zone 1 species. Channel cross-section dimensions will be based on stable, upstream channel conditions.

Cross-vanes installed during the first and second phase of work will be used to reduce shear stress in the near-bank region of the reconfigured channel. These cross-vanes will be installed in order to increase scour along the channel centerline while reducing discharge velocities along the toe of the streambanks. In order to accomplish this, each cross-vane will be angled vertically from the streambank toward the center of the channel at an angle of 3-7 degrees. Each cross-vane structure will also be oriented upstream at 20-30 degrees. Footer rocks (3'x 4'x 5') will be used to reinforce these structures. Rock for these cross-vanes will likely be acquired from the Cardinal Quarry and transported to the site.

The ability of cross-vanes to create scour pools downstream of the structures will be utilized in Reach 4 of Brush Creek to increase aquatic habitat diversity. In this section of stream channel, the placement of cross-vanes should produce deep scour holes in the center of the channel while reducing shear stress along the stream banks. Earlier electrofishing efforts during site investigations revealed the presence of the Kanawha darter in the fastest riffles and runs of Brush Creek. The proposed cross-vanes should increase the availability of well-aerated, higher-velocity streamflow through Reach 4 and should provide increased habitat resources for this and other fish species.

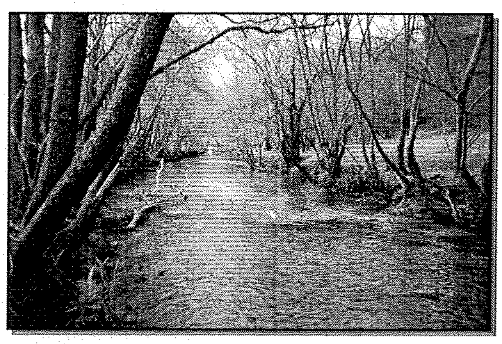


Scattered trees along Reach 2

The third phase of Brush Creek efforts will involve the installation of riparian vegetative to enhance long-term streambank stability. The areas that are presently experiencing the greatest instability and subsequent collapse are, in most cases, vegetated with only grasses and/or herbaceous species. In contrast, those streambank areas with mature trees and associated root mass exhibit much greater stability. As the root systems of such woody species help stabilize the alluvial soils in the streambank, the larger exposed roots may also currently provide some degree of physical streambank toe protection. These conditions are most apparent along stream reaches that have been fenced from livestock grazing and traffic. The most-stable bank areas, then, are those that have large woody species growing within streambank riparian areas that are free from livestock impacts. One of the primary goals of the proposed effort will be the restoration of this riparian corridor and replication of these stable streambank conditions along the entire length of Brush Creek through the project area.

An important issue that should be addressed in the implementation of this project is that of streambank toe protection. Effective toe protection will be an important component of the proposed stabilization and restoration efforts, as it should strengthen the restored streambanks, increase available aquatic habitat resources, and improve the performance of associated bioengineering efforts. In straight sections of stream channel, these efforts will utilize log toe protection with footer logs. These logs will be placed so that 60 percent of each log is below the surface of mean baseflow elevation. Each toe log and footer log will be anchored via steel cable and duckbill anchors placed 3-4 feet deep.

Through sinuous stream sections, a combination of coir fiber logs, flexible fascines, or equivalents will be used. Coir fiber logs composed of coconut fiber should be 12-24 inches in diameter. This toe protection will extend from the streambed to 1 foot above the mean baseflow elevation. Rock toe may be used only in the areas of greatest streambank instability. Flexible, inert bamboo fascines may be utilized in combination with coir fiber logs in most meanders currently evidencing good bank stability. Fascines may be constructed with inert bamboo and silky willow, silky dogwood, and black willow cuttings. The purpose of the proposed toe protection will be to provide temporary stability enhancement while live stakes, bare-root seedlings, and containerized materials develop sufficient root mass to provide long-term streambank stabilization.



Riparian Vegetation in Reach 4

Woody Debris in Reach 1

In the Brush Creek project, the presence of streambank toe protection should allow vegetation to become established on the re-graded slopes and should provide on-going protection during baseflow conditions. Natural accumulations of large, woody debris along some sections of streambanks have already provided important toe protection and reduced bank collapse in many areas. The planted riparian vegetation should provide a source of large woody debris by the time log toe protection measures decompose over the course of 10-20 years.

3.2.2 Streambank Restoration Areas

In addition to the unstable streambank located in Reach 2 of Brush Creek, additional streambank sections will receive re-contouring and bioengineering during the course of restoration efforts. Targeted restoration areas will include all streambanks currently experiencing active collapse, along with areas that exhibit high, very high, or extreme bank erosion potential (Rosgen, 1996). Since variable conditions (woody debris accumulation, hoof shear, etc.) and infrequent discharge events may alter streambank erosion rates, specific restoration areas will be designated in the field prior to initiation of construction activities on-site. By using this approach, changes in streambank condition that occur during the period between restoration design efforts and actual plan implementation may be addressed most effectively. During final restoration design, detailed specifications and plans will be prepared to accommodate micro-topographic variation and provide adaptive flexibility.

3.2.3 Streambank Restoration Techniques

A variety of streambank restoration techniques will be implemented to address conditions that exist along Brush Creek. These include Live Staking, Log-Toe Protection, Coir Log Toe Protection, Fascine Toe Protection, Boulder Toe Protection, and Cross-Vanes. These measures will be applied in various combinations to meet site-specific needs and restore individual streambank slopes.

The first proposed technique, live staking, will involve the planting of "live stakes" in graded streambank slopes. These "live stakes" are 12-36 inch cuttings taken from native tree and shrub species that are appropriate for riparian growing conditions. Many of these cuttings will be harvested from trees upstream and downstream of the project site, and collection will be coordinated with local landowners. Planting these materials will help establish riparian vegetation along previously eroded streambanks and will aid long-term stabilization through the establishment of extensive, soil-retaining root systems. Live staking efforts for this project will involve the use of both tree and shrub species to encourage diversity (refer to Table 10). Initial live staking will occur immediately following grading efforts and will be augmented by the installation of containerized materials. Live stakes will be installed following topsoil spreading, soil surface roughening, cover crop seeding (refer to Table 9), leaf-stripping, and erosion-control matting placement. To minimize the risk of nutrient enrichment within Brush Creek, no fertilizer will be used during initial vegetative stabilization efforts. Secondary vegetative stabilization will involve installation of additional live stakes during the first dormant season following construction. Live stakes will be planted 18 inches apart, to a minimum depth of 12 inches, and left with 2 leaf scars or nodes above ground. If soil amendments become necessary, fertilizer and lime may be applied during secondary planting efforts, but only in Riparian Zone 2 (20-30 feet from top of bank). Initial and secondary live staking efforts will be coordinated with similar actions along Little Pine Creek. This approach will be used in all restoration areas along Brush Creek.

The second set of streambank stabilization techniques planned for Brush Creek will include Log Toe Protection, Coir Log Toe Protection, and Fascine Toe Protection. Log Toe Protection will involve the placement and anchoring of 12-24 inch hardwood logs along the toe of the streambank slope at the water's edge. These logs will serve the dual functions of toe protection and habitat improvement. Log toe protection will be implemented primarily in straight sections of channel. Within meander areas, coir logs 12-24 inches in diameter will also be used, along with flexible bamboo fascines. In eroded areas void of woody vegetation, these supplemental toe protection measures should enable bioengineering plantings on the streambank above to become well-established. Hardwood logs and coir logs should also provide additional habitat for aquatic macroinvertebrates, and shade along the edges of the stream channel. These areas should eventually stabilize with woody vegetation and should not require permanent toe protection. Coir Logs and fascines should gradually decompose over a period of 5-10 years, while hardwood logs may remain present for 10-20 years, with each technique allowing time for riparian vegetation to become established.

For eroded streambank areas that require a greater degree of permanent armoring, Boulder Toe Protection may be used. This streambank restoration technique will involve the placement of 12-24 inch boulders along the toe of the streambank slope, in a similar manner to Log Toe Protection. The difference between these two techniques is that the use of boulders represents a longer-term approach to toe protection. To minimize the visual impact of this technique, live stake materials will be joint-planted among the boulders and should eventually disguise the presence of the stone. Additionally, these boulders will be acquired from local source areas and will be color-matched as close as possible to the existing substrate material. The use of boulders will only occur along streambank areas exhibiting extreme bank instability.

The rock cross-vanes proposed for Brush Creek will be sized to perform most efficiently at near-bankfull discharge. This should produce the desired downstream pool scour and streambank protection during discharge events that exert the most significant channel-forming influence. By nature, the performance of rock vanes and other flow control structures will vary according to discharge. The cross-vanes themselves will be keyed into the streambank approximately 6 feet, angled 20-30 degrees upstream, sloped 3-7% into the channel from bankfull stage elevation, and underlain with footer rocks to a depth of 3-4 feet.

The proposed combination of Brush Creek restoration efforts should improve the variety and quality of aquatic habitat in the stream. Earlier, it was noted that the Kanawha minnow and Kanawha darter were both collected during field investigations of biotic communities. The Brush Creek Project should provide a unique opportunity to enhance the available habitat resources for these and other native fish species. During project implementation, special attention will be paid to protecting and enhancing riffles and runs. Both the Kanawha minnow and Kanawha darter favor these habitat features. To provide additional in-stream cover, two boulder clusters will be installed in Reach 1 with two additional clusters in Reach 3. Each boulder cluster will be composed of 3-4 boulders approximately 3'x 4'x 5' (90cm x 120cm x 140cm) arranged in a triangular relationship and orientation upstream. These should provide increased cover and water depth for fish within the downstream scour areas, while providing increased surface area and habitat diversity for macroinvertebrates. The boulders used elsewhere for toe protection should provide similar benefits along the channel margins. Specific spacing and location details for the proposed boulder clusters will be determined according to field conditions as they exist prior to construction.

3.2.4 Project Schedule

The project schedule for Brush Creek restoration efforts is envisioned to efficiently utilize equipment and minimize potential environmental impacts. These efforts should be coordinated with the relocation and restoration of Little Pine Creek, and a single grading contractor should be able to effectively handle the entire scope of work.

Brush Creek stream restoration efforts will proceed from grading to toe protection placement to live staking. Initial efforts will focus on re-contouring collapsing streambanks to produce 2:1 slopes. The presence of sloped conditions will reduce overhead streambank obstructions during toe protection installation efforts and will allow initial live staking efforts to proceed concurrently. Additional bioengineering efforts will incorporate live staking along all streambank areas that evidence insufficient riparian vegetation. During toe protection installation, graded slopes will be covered with NAG Curlex III (or equivalent) erosion control matting and seeded with the specified temporary cover crop (refer to Table 9). Once the placement of toe protection is accomplished in each area, initial live staking will begin. Upon completion of all restoration efforts along Brush Creek, an "as-built" report may be prepared to establish baseline conditions for subsequent monitoring efforts. The condition of restoration efforts will then be assessed every 30 days for the following six months to evaluate and implement any necessary maintenance measures. Due to trout spawning season, construction activities along Brush Creek should be conducted between April 15 and November 15.

November 2000 – NCWRP Review of Conceptual Relocation Plan and Revisions
December 2000 – Preparation of Final Design / Contractor Bid Package
January 2001 – Advertisement of Project for Bids
February 2001 – Award of Contract
April 2001 – Grading and Toe Protection Installation
May 2001 – Completion of Restoration Efforts
December 2001 – Secondary Vegetative Stabilization and Maintenance
June 2002 – Initial Bioassessment Monitoring Event

3.3 Monitoring

Due to the dynamic nature of hydraulic systems and the inherent uncertainties in stream modification projects, frequent monitoring and assessment will be conducted before, during, and after completion of stabilization efforts. Monitoring should be conducted to assess aquatic ecosystem health, water quality, and stream channel stability. Monitoring of the proposed project will be the responsibility of the NCDENR DWQ, as set forth in the interagency agreement between the Division of Water Quality and the NCWRP.

Initial biological monitoring of Little Pine Creek and Brush Creek should be conducted to establish baseline conditions prior to implementation of the proposed stream restoration project. The initial monitoring event should be performed one year prior to implementation of restoration efforts (or for one year at a reference stream), as per guidance noted in the Draft Technical Guide for Stream Work in North Carolina (DWQ, August 2000). Benthic macroinvertebrate monitoring should follow accepted procedures as described in the Internal Technical Guide: Benthic Macroinvertebrate Monitoring Protocols for Stream Restoration Projects (DWQ, February 2000). Physical and chemical water quality characteristics should also be evaluated during bioassessment efforts, including: pH, water temperature, water clarity, dissolved oxygen, total dissolved solids, conductivity, nitrate concentration, and phosphate concentration. This monitoring should be continued for a period of at least three years, beginning with the first post-construction event one year after completion of restoration efforts.

During the proposed monitoring period, physical evaluation of the restored stream channel should also be conducted. Physical assessment should utilize permanent, established cross-sections along each restored reach of stream channel to monitor stream plan, dimension, and profile. The Rosgen stream classification system or other similar approach should be used to evaluate any morphological changes. Data collected during monitoring events should be compared over time to evaluate any changes in channel characteristics and should be supplemented by photographic documentation from photo-stations established during the first year of monitoring. Evaluation of stream dimension should incorporate the use of bank pins, scour chains, and permanent cross-sections.

Monitoring of vegetative survival should be assessed for both the planted streambank areas and the restored riparian corridor. This should be accomplished through the use of random radial plots and established monitoring quadrats. In order to compensate for potential dieback, initial vegetation installation is proposed at densities greater than the recommended 400 trees/acre density suggested in the Draft Technical Guide for Stream Work in North Carolina (DWQ, August 2000). Vegetative success criteria should include a target density of 320 trees/acre at the end of five years. Installed woody vegetation success should be assessed on the basis of density per acre, tree height (cm), and diameter at breast height (cm) during the proposed monitoring period. Additional evaluations of natural recruitment, long-term species composition (at five years), vegetation predation, nuisance vegetation presence, and overall habitat diversity should also be made. Photographic documentation should be made at established photo-stations to provide a visual record of vegetative development.

The combined results of the proposed monitoring efforts should be summarized and presented to all the involved state and federal regulatory agencies (NCDENR DWQ, USACE, USFWS, and NCWRC) in an annual report format. Additional copies of these monitoring reports should be sent to the local landowners and Alleghany County Natural Resources Conservation Service personnel.

During the proposed monitoring period, it is recommended that NCWRP set aside funding for potential maintenance needs. The dynamic hydraulic relationships that exist, particularly at the confluence of Little Pine Creek and Brush Creek, may produce unexpected changes in stream plan and dimension. While the proposed stabilization activities have been designed to incorporate adaptive flexibility, some maintenance efforts should be anticipated during the monitoring period. Secondary vegetative planting efforts should be performed in the first dormant season following project completion.

4.0 Critical Project Goals and Concerns

The dynamic characteristics of streams and hydraulic relationships within stream channels invariably introduce uncertainties into proposed restoration efforts. To offset some of the unforeseen changes that may result, restoration planners and the restorative measures they propose should be adaptively flexible. Streambank stabilization methods should be adaptable, as they may have to be modified to accommodate specific site conditions. Additionally, reserved financial resources should be available for maintenance activities or design modifications following construction completion.

Understanding the inherent limitations of restoration planning, the proposed project has excellent potential to return appropriate plan, dimension, and profile to Little Pine Creek and enhance streambank stability along Brush Creek. The combination of the proposed efforts should restore the altered Little Pine Creek channel, should improve the morphological stability of Brush Creek, should enhance the riparian corridor along both streams, and should increase instream habitat. In order to evaluate the attainment of these goals, previously-noted success criteria should be incorporated into the final monitoring program. Of primary importance should be the encouragement of natural stream stabilization processes. Working *with* the natural environment, rather than *against* it should be the goal, in order to avoid environmental impacts greater than those a project is intended to remedy.

5.0 Conclusions

The NCWRP is engaged in vital efforts across the state to alleviate the impacts of human activity on the natural environment and restore previously degraded systems. This work is important to the state of North Carolina and its citizens and may prove essential to the survival of natural resources of this region. The Brush Creek project provides an ideal opportunity to pursue these efforts and produce positive, measurable results. With effective planning and implementation, the proposed effort may serve as a model for similar efforts throughout the county and surrounding region.

6.0 Materials Disposal Plan

The proposed stream relocation, restoration, and stabilization efforts should result in minimal waste materials if the project schedule is followed. Soil excavated from the new Little Pine Creek channel will be temporarily stored on-site, north of the new channel. This material will be vegetatively stabilized and managed with Best Management Practices (BMP's) until it is used to fill the existing Little Pine Creek channel, after streamflow diversion efforts are completed. Some substrate material may be removed from this existing channel after streamflow diversion efforts and used in the proposed Little Pine creek channel. The majority of substrate material for the new channel will be sized according to the design parameters noted earlier. Material removed from the existing Brush Creek point bar will be used to backfill the opposite Brush Creek streambank during the course of channel restoration efforts. It has been estimated that approximately 198,170 cubic feet of alluvial soil material will be excavated during the course of work along Little Pine Creek, while 43,750 cubic feet of material will be handled during Brush Creek efforts. Approximately 113,496 cubic feet of this material will be required to fill the existing Little Pine Creek channel. According to these calculations, approximately 84,674 cubic feet of excess soil material would remain. However, in many projects similar to the one proposed here, soil compaction and disturbance typically results in a soil deficit. Final design plans and soil testing prior to construction should provide a more accurate estimate of cut and fill quantities. If necessary, a soil deficit may be accommodated through the construction of a small wetland area in the Brush Creek floodplain. During construction, fueling and maintenance of all construction equipment will be conducted a minimum of 100 feet away from any streams.

Table 11– Cut and Fill Estimates

New Little Pine Creek Channel	198,170	*950 feet of new channel* *41.1 sq. ft. BKF cross-sectional area* *283.1 sq. ft. FPA cross-sectional area*
Brush Creek Restoration	43,750	*340 feet* *50 feet wide, 5 feet deep*
Total	241,920	cubic feet
	TOTAL FILL:	
Location	**Quantity (ft^3)**	**Description**
Existing Little Pine Creek	113,496	*189.2 sq. ft. cross-sectional area X 600 ft.*
Brush Creek	43,750	*cubic feet*
Total	157,246	cubic feet
Total Excess Material	**84,674**	**cubic feet**

7.0 Construction Material Requirements

The majority of construction materials will be acquired locally. This will reduce transport cost and should provide materials characteristically similar to those already on-site. Local quarries will be contacted for stone and boulders. Live staking materials and logs will be harvested after consultation with local property owners and NRCS representatives. Local building/construction suppliers will be contacted for installation materials and erosion control matting. U.S. Forest Service and local nurseries/seed suppliers will be the source of bare-root seedlings, containerized trees, and cover crop seed. If no readily available supply is found for a particular need, suppliers within the surrounding multi-county region will then be contacted, followed by other North Carolina suppliers. It is recommended that potential construction contractors be considered on the basis of previous similar experience and proximity to the project site.

Construction materials may be divided into two basic categories: vegetative materials and structural materials. Vegetative materials will likely include appropriate species of live stakes, bare-root seedlings, containerized tree materials, cover crop grass seed, erosion control matting, and staples. Structural materials will likely include large-diameter logs, large-diameter (3'x 4'x 5') boulders, medium-diameter boulders (1'x 2'x 3'), steel rebar, steel cable, gravel, and duckbill soil anchors.

These materials will largely be consumed or installed during the course of work efforts, and minimal excess should remain. All loose, unused construction materials present on-site at the completion of relocation, restoration, and stabilization efforts will be removed and disposed of in an approved manner. The following is a general initial estimate of materials likely required for the proposed project:

Anticipated Vegetative Materials –

10,000 live stakes, 12-36 inches in length, of appropriate species
5,000 bare-root seedlings, of appropriate species
400 1 to 3-gallon containerized trees, of appropriate species
50,000 square feet of biodegradable erosion control matting (North American Green Curlex III or equivalent)
10,000 10 to 12-inch staples
100 pounds annual rye seed (certified live and pure)
50 pounds creeping red fescue seed (certified live and pure)
50 pounds redtop seed (certified live and pure)

Anticipated Structural Materials –

15 large logs, 12-24 inch diameter, 8-15 feet in length, hardwood species
15 large coir fiber logs, 12-24 inches in diameter, 6-8 feet in length
25 bamboo fascines, 8-10 inches in diameter, 6-8 feet in length
10 large boulders, 24-36 inch diameter, quarried locally
60 medium boulders, 12-24 inch diameter, quarried locally
25 feet of steel rebar, 3/4-inch diameter
210 feet steel cable, 3/16-inch diameter
45 duckbill soil anchors
7 cubic yards gravel, of appropriate diameter (preferably washed river stone)

Anticipated Construction Equipment –

1-2 trackhoe(s), w/hydraulic thumb
1 dump truck
1 back hoe
1 bulldozer / rubber-tire loader
2 12 foot x 12 foot oak construction mats
1 chainsaw
1 portable gas auger, 8-inch bit
1 hand winch (“come-along”)
1 lightweight hand-drill for logs and rock (Hilti or similar)
Miscellaneous hand tools (pick, hammer, pry bar, sledgehammer, hacksaw, pliers, etc.)

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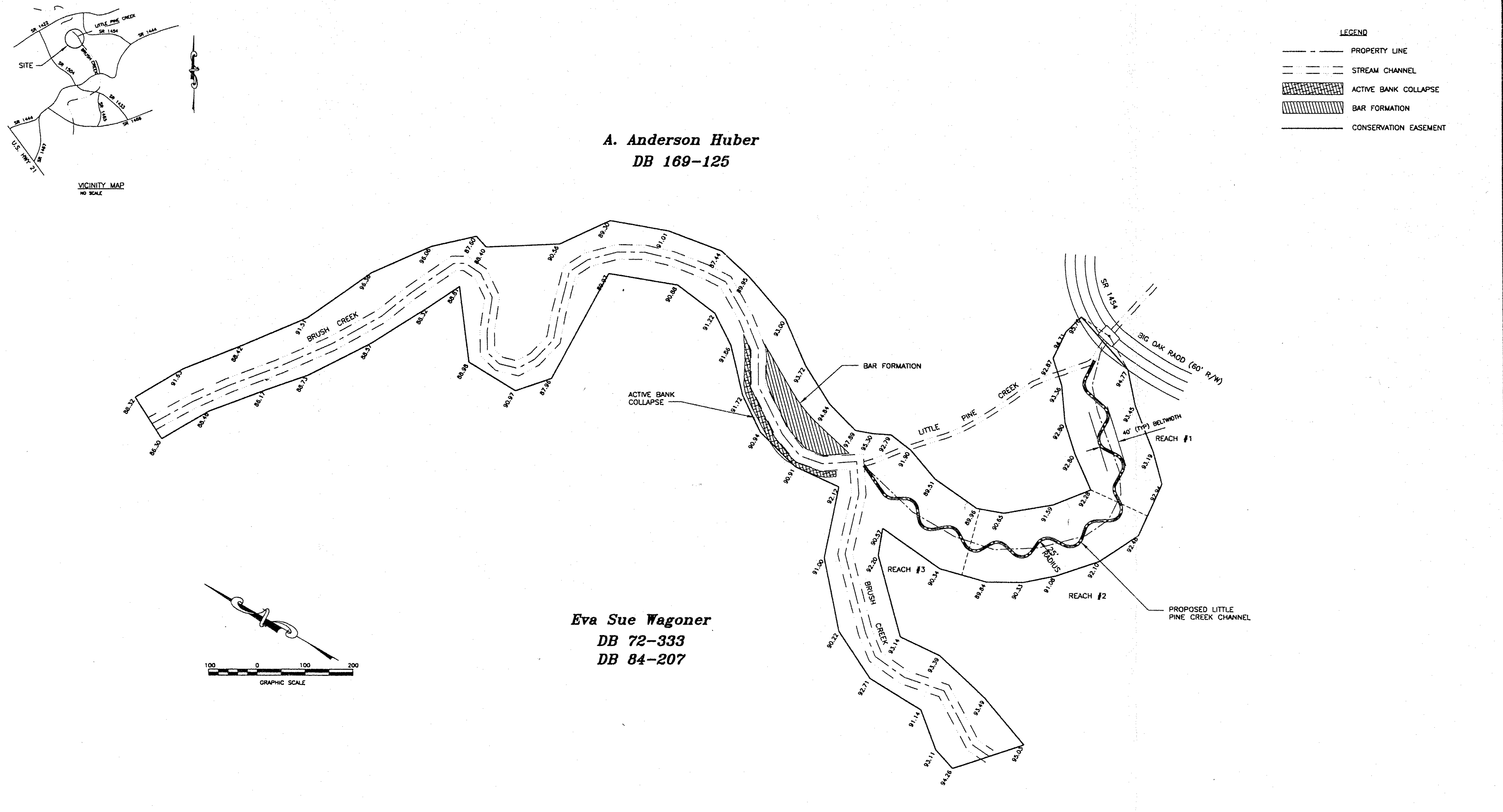
Appendix A

Conceptual Plans



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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

Project Manager: Ben Leatherland	
Architect: –	I&C/Process: –
Civil: –	Mechanical: –
Electrical: –	Structural: –
Geology: –	Drawn By: GRH

NCWRP - BRUSH CREEK

LITTLE PINE CREEK RESTORATION

ALLEGHANY COUNTY — NORTH CAROLINA

OVERALL SITE PLAN

–

Date	Project No.	Drawing No.	Issue
SEPT. 2000	09177-004-018-03	1	A

Scale: 1" = 100'

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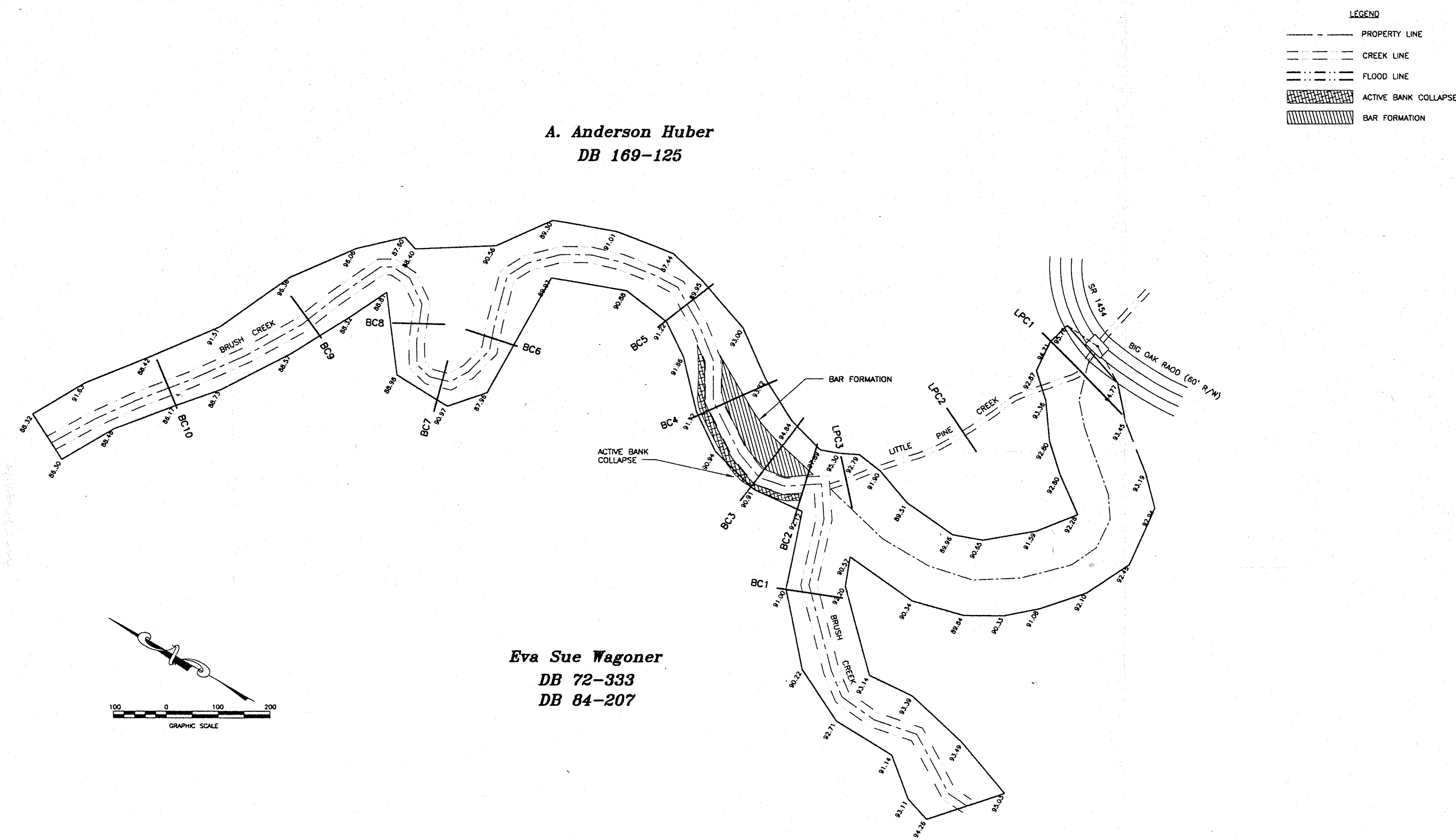

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

Project Manager: Ben Leatherland	
Architect: -	I&C/Process: -
Civil: -	Mechanical: -
Electrical: -	Structural: -
Geology: -	Drawn By: GRH

NCWRP - BRUSH CREEK

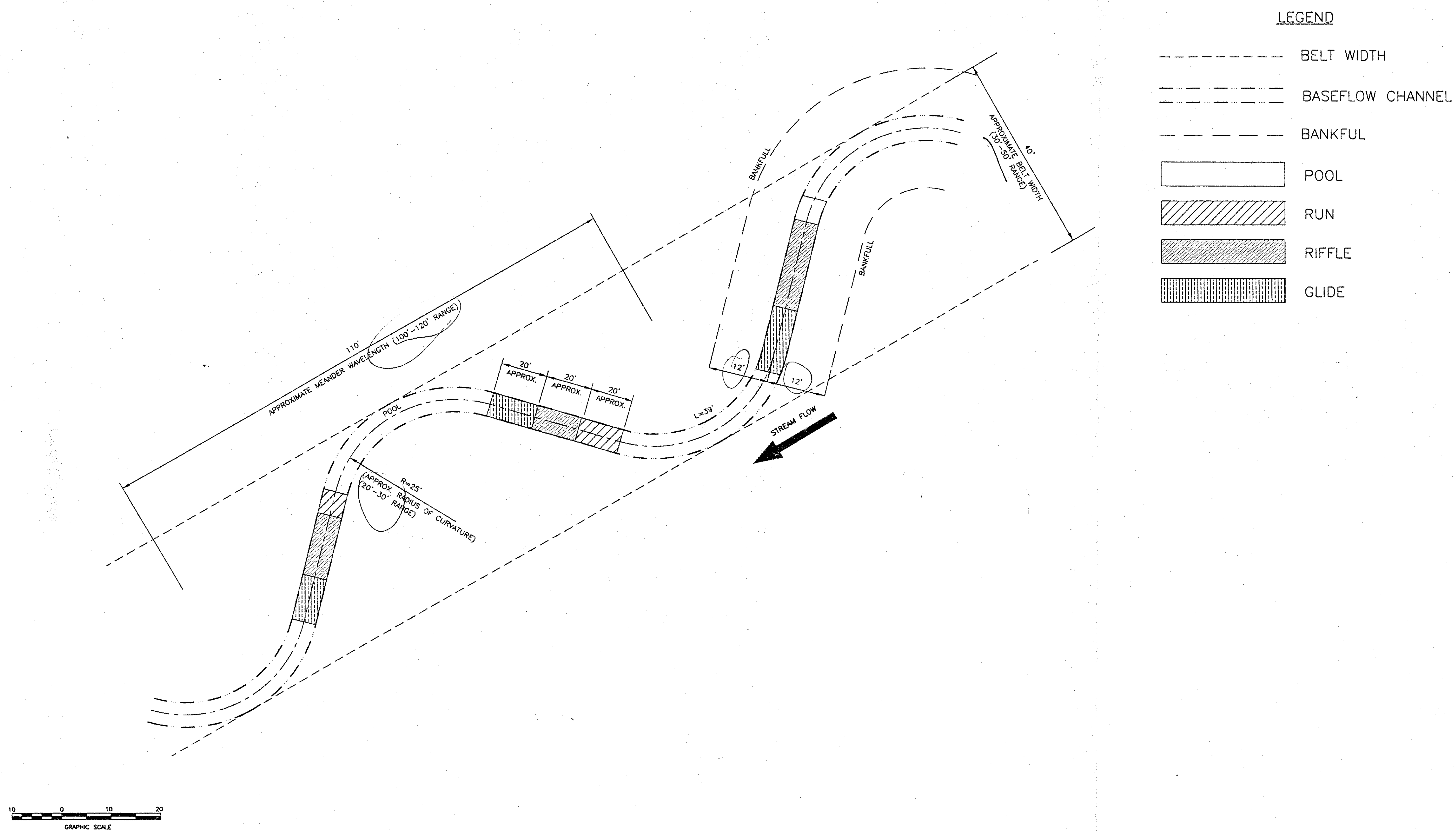
LITTLE PINE CREEK RESTORATION

ALLEGHANY COUNTY NORTH CAROLINA

CROSS SECTION LOCATION

Date	Project No.	Drawing No.	Issue
SEPT. 2000	09177-004-018-03	2	A

Scale: 1" = 100'



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HDR
HDR Engineering, Inc. of the Carolinas
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128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

Project Manager: Ben Leatherland	
Architect: -	I&C/Process: -
Civil: -	Mechanical: -
Electrical: -	Structural: -
Geology: -	Drawn By: GRH

NCWRP - BRUSH CREEK

LITTLE PINE CREEK RESTORATION

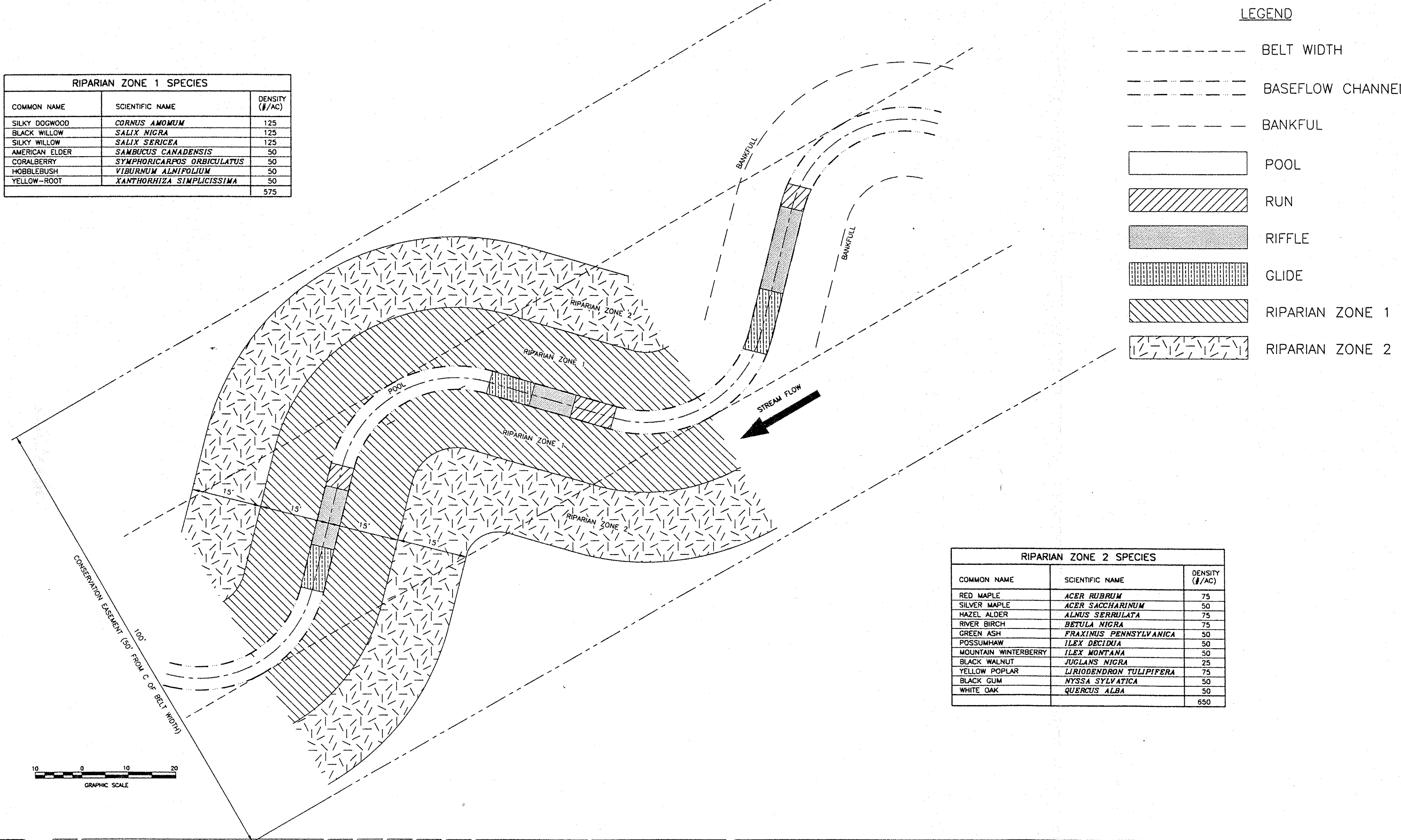
ALLEGHANY COUNTY NORTH CAROLINA

LITTLE PINE CREEK CHANNEL DIMENSIONS

Date	Project No.	Drawing No.	Issue
SEPT. 2000	09177-004-018-03	3	A

Scale: 1" = 10'

RIPARIAN ZONE 1 SPECIES		
COMMON NAME	SCIENTIFIC NAME	DENSITY (#/AC)
SILKY DOGWOOD	*CORNUS AMOMUM*	125
BLACK WILLOW	*SALIX NIGRA*	125
SILKY WILLOW	*SALIX SERICEA*	125
AMERICAN ELDER	*SAMBUCUS CANADENSIS*	50
CORALBERRY	*SYMPHORICARPOS ORBICULATUS*	50
HOBBLEBUSH	*VIBURNUM ALNIFOLIUM*	50
YELLOW-ROOT	*XANTHORHIZA SIMPLICISSIMA*	50
		575



RIPARIAN ZONE 2 SPECIES		
COMMON NAME	SCIENTIFIC NAME	DENSITY (#/AC)
RED MAPLE	*ACER RUBRUM*	75
SILVER MAPLE	*ACER SACCHARINUM*	50
HAZEL ALDER	*ALNUS SERRULATA*	75
RIVER BIRCH	*BETULA NIGRA*	75
GREEN ASH	*FRAXINUS PENNSYLVANICA*	50
POSSUMHAW	*ILEX DECIDUA*	50
MOUNTAIN WINTERBERRY	*ILEX MONTANA*	50
BLACK WALNUT	*JUGLANS NIGRA*	25
YELLOW POPLAR	*LIRIODENDRON TULIPIFERA*	75
BLACK GUM	*NYSSA SYLVATICA*	50
WHITE OAK	*QUERCUS ALBA*	50
		650

HDR

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Issue No. | Description | Date | Drwn. | Chkd. | Resp. Engr. | Proj. Mgr.

Project Manager: Ben Leatherland
Architect: -
I&C/Process: -
Civil: -
Mechanical: -
Electrical: -
Structural: -
Geology: -
Drawn By: CRH

NCWRP - BRUSH CREEK

LITTLE PINE CREEK RESTORATION

ALLEGHANY COUNTY — NORTH CAROLINA

RIPARIAN VEGETATION

Date: SEPT. 2000
Scale: 1" = 10'
Project No.: 09177-004-018-03
Drawing No.: 4
Issue: A

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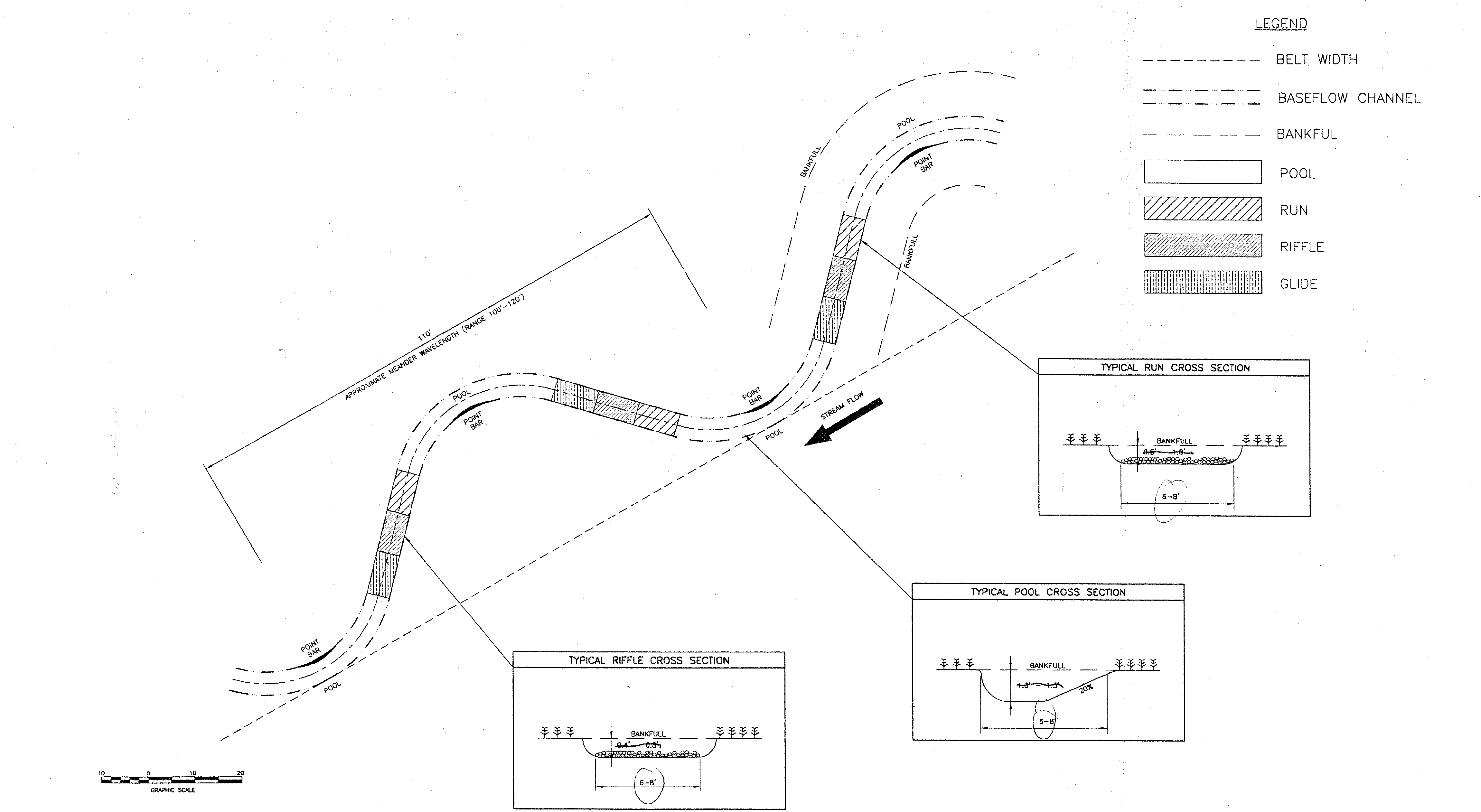

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

Project Manager: Ben Leatherland
Architect: -
AC/Process: -
Civil: -
Mechanical: -
Electrical: -
Structural: -
Geology: -
Drawn By: GRH

NCWRP - BRUSH CREEK

LITTLE PINE CREEK RESTORATION

ALLEGHANY COUNTY NORTH CAROLINA

CHANNEL DETAILS

Date: SEPT. 2000
Scale: 1" = 10'
Project No.: 09177-004-018-03
Drawing No.: 5
Issue: A

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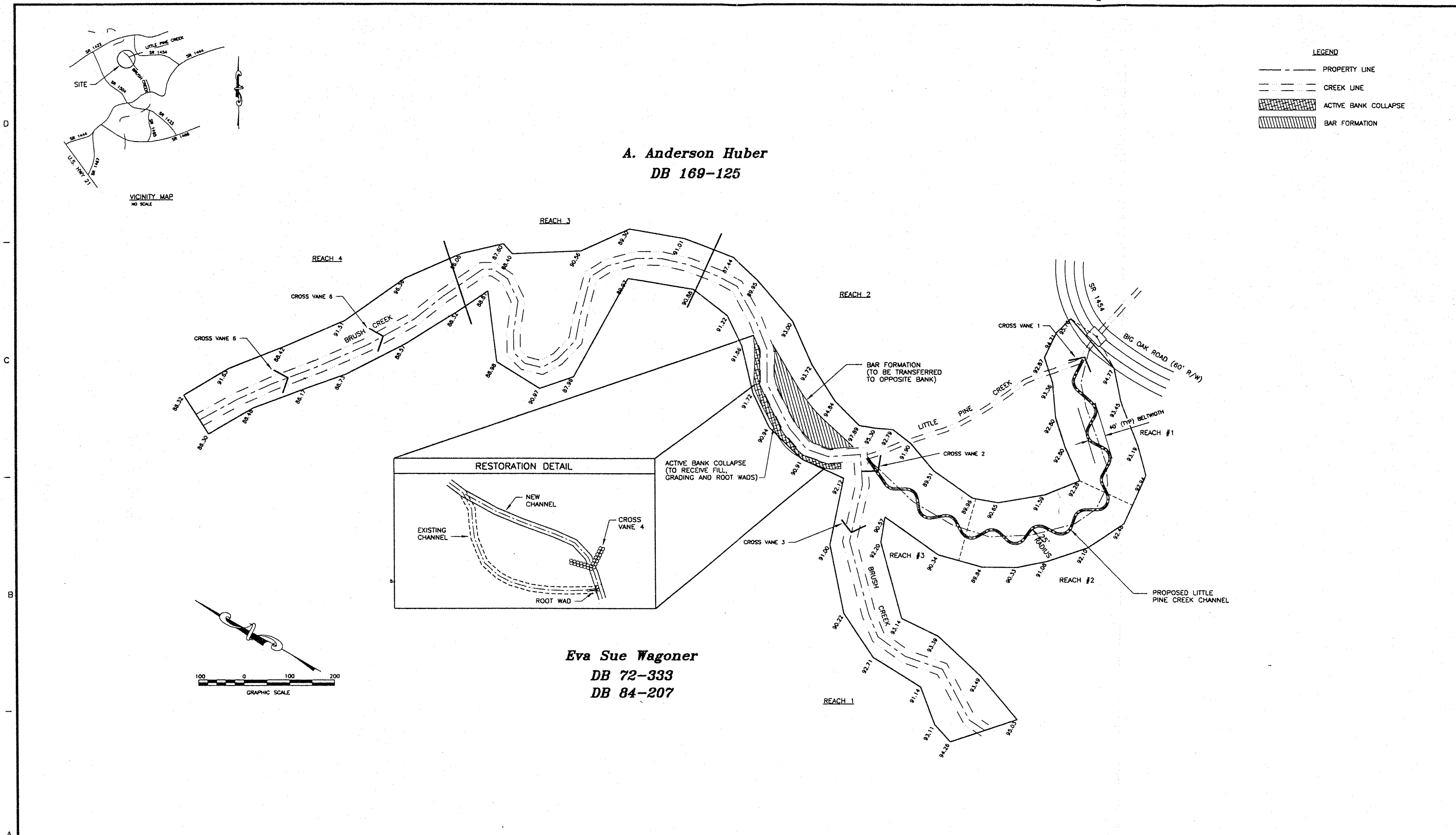

HDR
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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

Project Manager: Ben Leatherland
Architect: -
IAC/Process: -
Civil: -
Mechanical: -
Electrical: -
Structural: -
Geology: -
Drawn By: GRH

NCWRP - BRUSH CREEK

BRUSH CREEK RESTORATION

ALLEGHANY COUNTY — NORTH CAROLINA

BRUSH CREEK PLAN

Date	Project No.	Drawing No.	Issue
SEPT. 2000	09177-004-018-03	6	A

Scale: 1" = 100'

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Appendix B

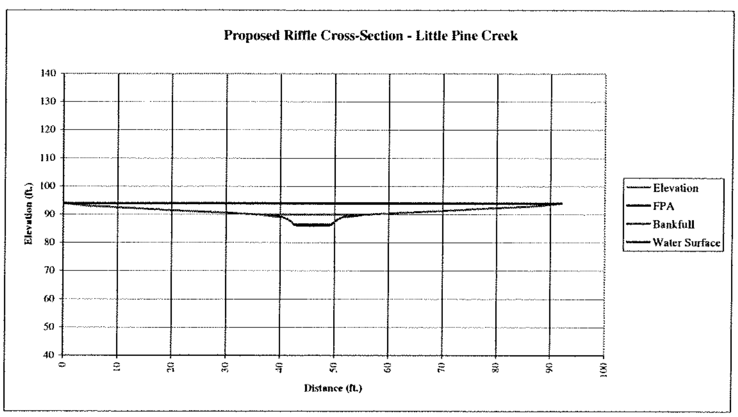
Stream Restoration Calculations

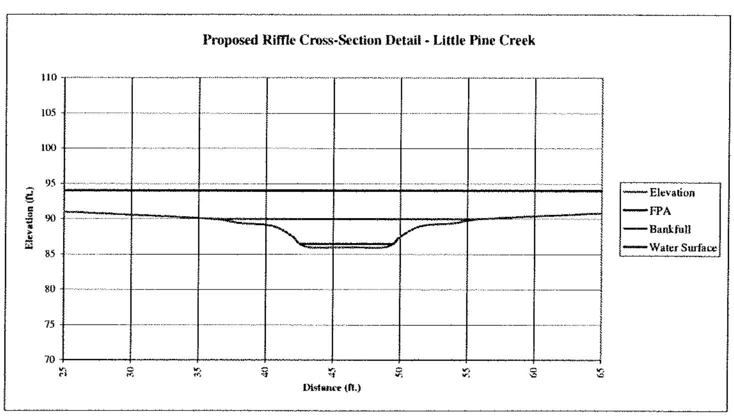
NCDENR Morphological Measurement Table

Variables	Existing Channel	Proposed Reach	USGS Station	Reference Reach
1. Stream type:	F4	E4	-	E4
2. Drainage area (sq. miles):	4.33	4.33	78.8	4.65
3. Bankfull width (ft.):	19.0	20.0	-	18.0
4. Bankfull mean depth (ft.):	1.2	2.3	-	2.5
5. Width/depth ratio:	16.34	8.81	-	7.17
6. Bankfull cross-sectional area (sq. ft.):	27.7	41.1	-	34.6
7. Bankfull mean velocity (f/s):	-	5.67	-	7.62
8. Bankfull discharge (cfs)	-	233.1	1500	263.8
9. Bankfull max. depth (ft.):	2.0	4.0	-	4.1
10. Width of floodprone area (ft.):	22.7	82.0	-	334.0
11. Entrenchment ratio:	1.2	4.1	-	18.6
12. Meander length (ft.):	125.0	110.0	-	101.5
13. Ratio of meander length to bankfull width:	6.6	5.5	-	5.6
14. Radius of curvature (ft.):	-	25.0	-	23.0
15. Ratio of radius of curvature to bankfull width:	-	1.3	-	1.3
16. Belt width (ft.):	41.7	50.0	-	39.0
17. Meander width ratio:	2.20	2.50	-	2.17
18. Sinuosity	1.0	1.6	-	1.7
19. Valley slope:	0.5%	0.6%	-	0.9%
20. Average slope:	0.7%	0.6%	-	0.9%
21. Pool slope:	-	0.2%	-	0.3%
22. Ratio of pool slope to average slope:	-	0.3	-	0.4
23. Maximum pool depth (ft.):	2.0	1.3	-	1.3
24. Ratio of pool depth to average bankfull depth:	1.7	0.6	-	0.5
25. Pool width (ft.):	55.7	25.0	-	25.2
26. Ratio of pool width to bankfull width:	2.9	1.3	-	1.4
27. Pool to pool spacing (ft.):	150.5	62.5	-	66.8
28. Ratio of pool to pool spacing to bankfull width:	7.9	3.1	-	3.7
29. D_{16} particle size (mm):	0.1	1.0	-	1.0
30. D_{50} particle size (mm):	11.0	50.0	-	40.0
31. D_{84} particle size (mm):	60.0	100.0	-	110.0
31. Valley length (ft.):	595	595	-	-
32. Channel length (ft.):	610	950	-	-
33. Mean riffle length (ft.):	18.0	22.5	-	26.0
34. Mean riffle depth (ft.):	0.3	0.7	-	0.7
35. Mean riffle slope (%):	-	1.4%	-	2.2%
36. Riffle to riffle spacing (ft.):	-	120.0	-	123.0
37. Mean run length (ft.):	100.3	30.0	-	24.0
38. Mean run depth (ft.):	-	0.8	-	0.8
39. Mean run slope (%):	-	0.7%	-	0.7%
40. Manning's "n"	0.040	0.052	-	0.045
41. Bottom width of channel (ft.):	-	7.0	-	5.7
42. Side slope ratio (ft. horizontal / ft. vertical):	-	2.43	-	2.07
43. Wetted perimeter (ft.)	-	18.92	-	17.24
44. Hydraulic radius (ft.):	-	2.17	-	1.98
45. Shear stress (lb./ft.^{2}):	-	1.9	-	2.72
46. Approximate grain diameter movement (mm):	-	200	-	250
47. Critical dimensionless shear stress:	-	0.08	-	0.08
48. Flood-prone area cross-sectional area (sq. ft.):	-	266.3	-	-
49. Estimated flood-prone area discharge (cfs):	-	1386.7	-	-

PROPOSED LITTLE PINE CREEK CHANNEL											
		Proposed	Water	Bankfull	FPA	Bankfull Cross-Sectional Area			FPA Cross-Sectional Area		
Feature	Distance	Elevation	Surface	Elevation	Elevation	Width	Depth	Area	Width	Depth	Area
LFPA	0.0	94.0			94.0				0.0	0.0	0.00
	5.0	93.0			94.0				5.0	1.0	2.50
	10.0	92.5			94.0				10.0	1.5	6.25
	15.0	92.0			94.0				15.0	2.0	8.75
	20.0	91.5			94.0				20.0	2.5	11.25
LTOB	25.0	91.0			94.0				25.0	3.0	13.75
LBKF	36.0	90.0		90.0	94.0	0.0	0.00	0.00	36.0	4.0	38.50
	38.0	89.4		90.0	94.0	2.0	0.60	0.60	38.0	4.6	8.60
	40.5	89.0		90.0	94.0	4.5	1.00	2.00	40.5	5.0	12.00
	42.0	87.5		90.0	94.0	6.0	2.50	2.63	42.0	6.5	8.63
LWS	42.5	86.5	86.5	90.0	94.0	6.5	3.50	1.50	42.5	7.5	3.50
	43.2	86.0	86.5	90.0	94.0	7.2	4.00	2.63	43.2	8.0	5.43
THAW	46.0	86.0	86.5	90.0	94.0	10.0	4.00	11.20	46.0	8.0	22.40
	48.8	86.0	86.5	90.0	94.0	12.8	4.00	11.20	48.8	8.0	22.40
RWS	49.5	86.5	86.5	90.0	94.0	13.5	3.50	2.63	49.5	7.5	5.43
	50.0	87.5		90.0	94.0	14.0	2.50	1.50	50.0	6.5	3.50
	51.5	89.0		90.0	94.0	15.5	1.00	2.63	51.5	5.0	8.63
	54.0	89.4		90.0	94.0	18.0	0.60	2.00	54.0	4.6	12.00
RBKF	56.0	90.0		90.0	94.0	20.0	0.00	0.60	56.0	4.0	8.60
RTOB	67.0	91.0			94.0				67.0	3.0	38.50
	72.0	91.5			94.0				72.0	2.5	13.75
	77.0	92.0			94.0				77.0	2.0	11.25
	82.0	92.5			94.0				82.0	1.5	8.75
	87.0	93.0			94.0				87.0	1.0	6.25
RFPA	92.0	94.0			94.0				92.0	0.0	2.50

Calculations		
Calculated Bankfull Cross-sectional Area:	**41.1**	sq. ft.
Mean Bankfull Depth:	2.27	ft.
Bankfull Width:	20.0	ft.
Max. Bankfull Depth:	4.0	ft.
FPA Elevation:	94.0	ft.
FPA Width:	92.0	ft.
Width/Depth Ratio:	8.8	
Entrenchment Ratio:	4.6	
Bank Height Ratio:	1.01	
Average Water Depth:	0.5	ft.
FPA Cross-sectional Area:	283.1	sq. ft.
Bottom Width:	7.0	ft.
Mean Baseflow Water Depth:	0.5	ft.





Proposed Little Pine Creek Channel

Channel Characteristics	Measurements
$d_i = d_{50}$ of riffle bed surface (mm)	50.0
d_{50} = subsurface d_{50} (mm)	50.0
t^*_{ci} = critical dimensionless shear stress	0.08
$d_{84} = d_{84}$ of pavement sample (or bar sample) (mm)	100.0
P_{sand} = density of sand (2.65 g/c^3)	2.65
P_{water} = density of water (1.0 g/c^3)	1.00
D_i = largest particle found in the point bar sample (ft.)	0.33
S = average riffle slope	0.014
BKF = mean bankfull depth (ft.)	2.27
R = hydraulic radius (ft.)	2.17
s = average riffle slope (ft./ft.)	0.014
n = Manning roughness coefficient (dimensionless)	0.052
A = cross-sectional area (sq. ft.)	41.10
s = longitudinal water surface slope (ft./ft.)	0.014

Critical Dimensionless Shear Stress

To predict critical shear stress:	**$t^*_{ci} = 0.0834\ (di/d_{50})^{-0.872}$**
- where:	t^*_{ci} = critical dimensionless shear stress
	$d_i = d_{50}$ of riffle bed surface (mm)
	d_{50} = subsurface d_{50} (mm)
	note: equation applies only to gravel bed streams
Formula	**Calculations**
$t^*_{ci} = 0.0834\ (50/50)^{-0.872}$	
$t^*_{ci} = 0.0834\ (1.00)^{-0.872}$	1.00
$t^*_{ci} = 0.0834\ (1.00)$	1.00
$t^*_{ci} = 0.08$	0.08
Critical dimensionless shear stress:	**0.08**

Required Water Depth

To predict required water depth at riffle:	**$d = (t^*_{ci}\ ((P_{sand} - P_{water}) / P_{water})\ D_i) / S$**
- where:	d = water depth (ft.)
	t^*_{ci} = critical dimensionless shear stress
	P_{sand} = density of sand (2.65 g/c^3)
	P_{water} = density of water (1.0 g/c^3)
	D_i = largest particle found in the point bar sample (ft.)
	S = average riffle slope (ft./ft.)
	note: equation applies only to gravel bed streams
Formula	**Calculations**
$d = (t^*_{ci}\ ((P_{sand} - P_{water}) / P_{water})\ D_i) / S$	
d = (0.08 * ((2.65 - 1.0) / 1.0) * 0.33) / 0.014	
d = (0.08 * ((1.65) / 1.0) * 0.33) / 0.014	1.65
d = (0.08 * (1.65 * 0.33)) / 0.014	1.65
d = (0.08 * 0.54) / 0.014	0.54
d = 0.05 / 0.014	0.05
d = 3.24 ft.	3.24
Required water depth (ft.):	**3.24**
- assuming D_i = 100 mm (0.33 feet)	
- assuming t^*_{ci} = 0.08 (*see above*)	
- assuming S = 1.4 % riffle slope (0.014 ft. / ft.)	

Proposed Little Pine Creek Channel	
Shield's Curve	
To predict shear stress on particles:	**t = *yRs***
- where:	t = shear stress (lb./ft.^{2})
	y = specific gravity of water (62.4 lb./ft.^{3})
	R = hydraulic radius (ft.)
	s = average riffle slope (ft./ft.)
Formula	**Calculations**
t = *yRs*	
t = 62.4 * 2.17 * 0.014	
t = 62.4 * 0.030	0.030
t = 1.90 lb./ft.^{2}	1.90
Shear stress (lb./ft.^{2}):	**1.90**
Approximate grain diameter movement:	**200 mm**
- assuming average riffle slope of 1.4 % (0.014 ft. / ft.)	
- assuming wetted perimeter of 18.92 ft.	
- assuming bankfull cross-sectional area of 41.1 ft.^{2}	

Hydraulic Radius	
To calculate hydraulic radius:	***R* = A / P**
- where:	A = cross-sectional area (sq. ft.)
	P = wetted perimeter (ft.)
	P = B + 2y * (SQRT(1+M^2))
	B = bottom width of channel (ft.)
	M = side slope ratio (ft / ft.)
	y = depth of flow (ft.)

B = 49.5 - 42.5	
Bottom Width of Channel (ft.):	**7.00**

M = ft. horizontal / ft. vertical	
M = (42.5-34.0) / (90.0-86.5)	
M = 8.5 / 3.5	
Side Slope Ratio (ft. horizontal / ft. vertical):	**2.43**

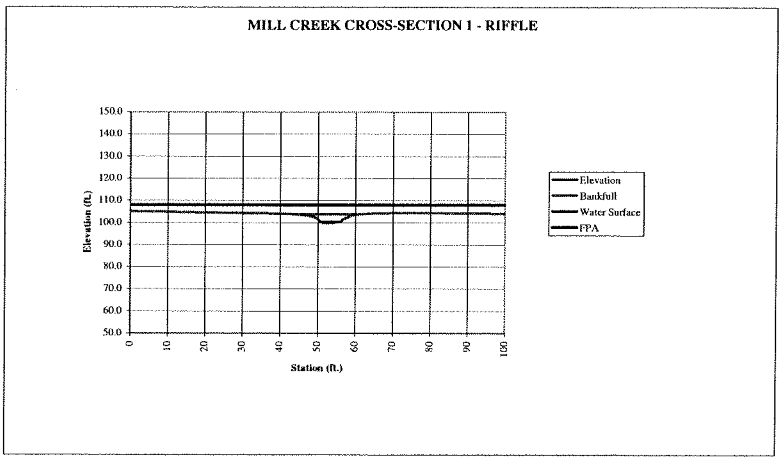
P = B + 2y * (SQRT(1+ M^2))	
P = 7.0 + 2 (2.27) * (SQRT(1 + (2.43)^2))	4.54
P = 7.0 + 4.54 * (SQRT(1 + (5.90))	5.90
P = 7.0 + 4.54 * (SQRT(6.90))	2.63
P = 7.0 + 4.54 * (2.63)	11.92
P = 7.0 + 11.92	18.92
Wetted Perimeter (ft.):	**18.92**

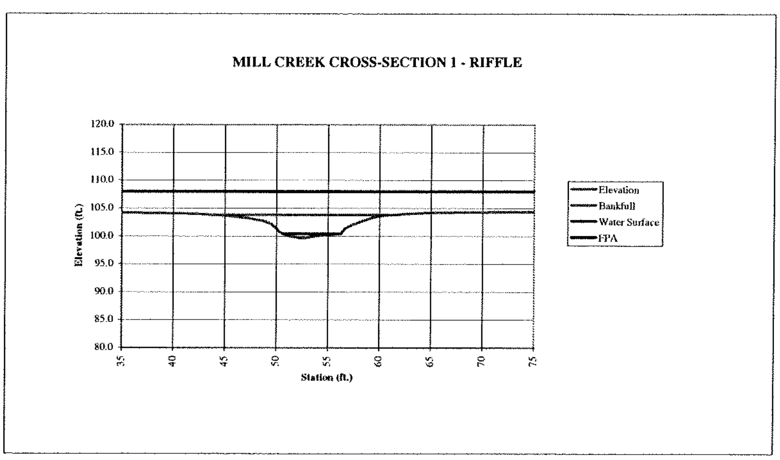
R = A / P	
R = 41.10 / 18.92	
Hydraulic Radius (ft.):	**2.17**

Discharge	
To calculate discharge (Q):	**Q = (1.486 / n) * A * R$^{2/3}$ * S$^{1/2}$**
- where:	Q = discharge (cfs)
	n = Manning roughness coefficient
	A = cross-sectional area (sq. ft.)
	R = hydraulic radius (ft.)
	s = longitudinal slope of water surface (ft./ft.)
Q = (1.486 / n) * A * R$^{2/3}$ * S$^{1/2}$	
Q = (1.486 / 0.052) * (42.3) * (2.17)$^{2/3}$ * (0.014)$^{1/2}$	28.58
Q = (28.58) * (41.1) * (2.17)$^{2/3}$ * (0.014)$^{1/2}$	1.68
Q = (28.58) * (41.1) * (1.68) * (0.118)	0.118
Discharge (cfs):	**233.1**

MILL CREEK REFERENCE CROSS-SECTION 1 - RIFFLE														
						Bankfull	Water		Bankfull Cross-Sectional Area			FPA Cross-Sectional Area		
Station	Backsight	Height of Inst.	Foresight	Elevation	Notes	Elevation	Surface	FPA	Width	Depth	Area	Width	Depth	Area
		109.73												
0.0			4.64	105.09				107.99				0.00	0.00	0.00
20.0			5.25	104.48				107.99				20.00	0.61	6.10
33.0			5.48	104.25				107.99				33.00	0.84	9.43
40.0			5.64	104.09				107.99				40.00	1.00	6.44
42.0			5.71	104.02		103.86		107.99				42.00	1.07	2.07
43.5			5.87	103.86	L-BKF	103.86		107.99	0.0	0.00	0.00	43.50	1.23	1.73
46.2			6.30	103.43		103.86		107.99	2.7	0.43	0.58	46.20	1.66	3.90
47.8			6.71	103.02	L-SCOUR	103.86		107.99	4.3	0.84	1.02	47.80	2.07	2.98
49.4			7.53	102.20		103.86		107.99	5.9	1.66	2.00	49.40	2.89	3.97
50.6			9.79	100.43	LEW	103.86	100.43	107.99	7.1	3.43	3.05	50.60	4.66	4.53
52.0			10.00	99.73	THAW	103.86	100.43	107.99	8.5	4.13	5.29	52.00	5.36	7.01
53.0			9.97	99.76		103.86	100.43	107.99	9.5	4.10	4.11	53.00	5.33	5.35
54.7			9.53	100.20		103.86	100.43	107.99	11.2	3.66	6.60	54.70	4.89	8.69
56.3			9.30	100.43	REW	103.86	100.43	107.99	12.8	3.43	5.67	56.30	4.66	7.64
56.3			9.12	100.61	RWS	103.86		107.99	12.8	3.25	0.00	56.30	4.48	0.00
57.0			8.05	101.68		103.86		107.99	13.5	2.18	1.90	57.00	3.41	2.76
59.5			6.38	103.35		103.86		107.99	16.0	0.51	3.36	59.50	1.74	6.44
61.7			5.87	103.86	R-BKF			107.99	18.2	0.00	0.56	61.70	1.23	3.27
64.0			5.63	104.10	R-TOB			107.99				64.00	0.99	2.55
66.0			5.47	104.26				107.99				66.00	0.83	1.82
76.0			5.38	104.35				107.99				76.00	0.74	7.85
100.0			5.55	104.18				107.99				100.00	0.91	19.80

Calculations		
Calculated Bankfull Cross-sectional Area:	**34.15**	sq. ft.
Average Bankfull Depth:	2.51	ft.
Bankfull Width:	18.20	ft.
Max. Depth:	4.13	ft.
FPA Elevation:	107.99	ft.
FPA Width:	318.0	ft.
Width/Depth Ratio:	7.2	
Entrenchment Ratio:	17.5	
Bank Height Ratio:	1.00	
Flood-prone Area Cross-sectional Area	114.3	sq. ft.

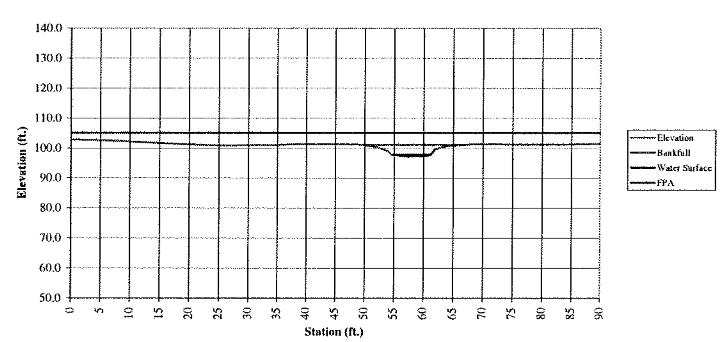




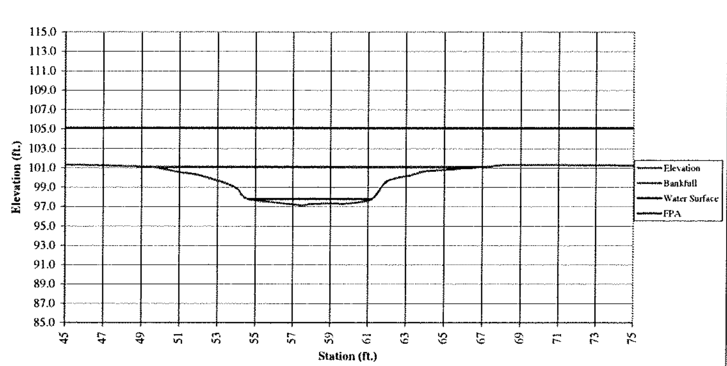
MILL CREEK REFERENCE CROSS-SECTION 2 - RUN											
						Bankfull	Water		Cross-Sectional Area		
Station	Backsight	Height of Inst.	Foresight	Elevation	Notes	Elevation	Surface	FPA	Width	Depth	Area
		105.91									
0.0			3.10	102.81	L-Pin			105.15			
5.0			3.28	102.63				105.15			
10.0			3.73	102.18				105.15			
15.0			4.25	101.66				105.15			
20.0			4.72	101.19				105.15			
25.0			4.96	100.95				105.15			
30.0			4.94	100.97				105.15			
35.0			4.85	101.06				105.15			
40.0			4.58	101.33				105.15			
45.0			4.58	101.33				105.15			
49.4			4.77	101.14	L-BKF	101.14		105.15	0.0	0.00	0.00
50.0			4.95	100.96		101.14		105.15	0.6	0.18	0.05
51.0			5.33	100.58		101.14		105.15	1.6	0.56	0.37
52.0			5.65	100.26	Slope Break	101.14		105.15	2.6	0.88	0.72
53.0			6.22	99.69		101.14		105.15	3.6	1.45	1.17
54.0			6.99	98.92		101.14		105.15	4.6	2.22	1.84
54.6			8.10	97.81	LWS	101.14	97.81	105.15	5.2	3.33	1.67
57.0			8.66	97.25		101.14	97.81	105.15	7.6	3.89	8.66
57.5			8.78	97.13	THAW	101.14	97.81	105.15	8.1	4.01	1.98
58.0			8.63	97.28		101.14	97.81	105.15	8.6	3.86	1.97
59.0			8.55	97.36		101.14	97.81	105.15	9.6	3.78	3.82
60.0			8.57	97.34		101.14	97.81	105.15	10.6	3.80	3.79
61.2			8.18	97.81	RWS	101.14	97.81	105.15	11.8	3.33	4.28
62.0			6.27	99.64		101.14		105.15	12.6	1.50	1.93
63.3			5.64	100.27	R-Inner Berm	101.14		105.15	13.9	0.87	1.54
64.0			5.26	100.65		101.14		105.15	14.6	0.49	0.48
65.0			5.13	100.78		101.14		105.15	15.6	0.36	0.43
67.2			4.77	101.14	R-BKF	101.14		105.15	17.8	0.00	0.40
68.0			4.63	101.28				105.15			
69.0			4.58	101.33				105.15			
70.0			4.57	101.34				105.15			
75.0			4.65	101.26				105.15			
80.0			4.72	101.19				105.15			
85.0			4.65	101.26				105.15			
90.0			4.48	101.43	R-Pin			105.15			

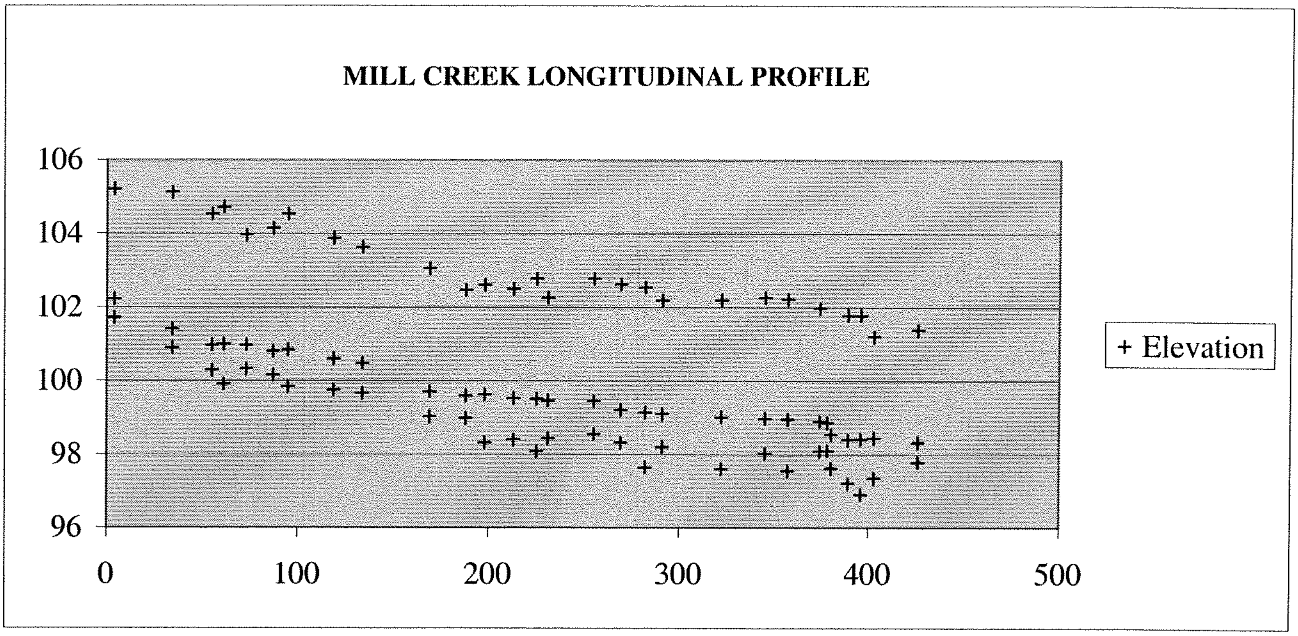
Calculations		
Calculated Bankfull Cross-sectional Area:	**35.07**	sq. ft.
Average Bankfull Depth:	2.16	ft.
Bankfull Width:	17.80	ft.
Max. Depth:	4.01	ft.
FPA Elevation:	105.15	ft.
FPA Width:	350.00	ft.
Width/Depth Ratio:	8.3	
Entrenchment Ratio:	19.7	
Bank Height Ratio:	1.0	

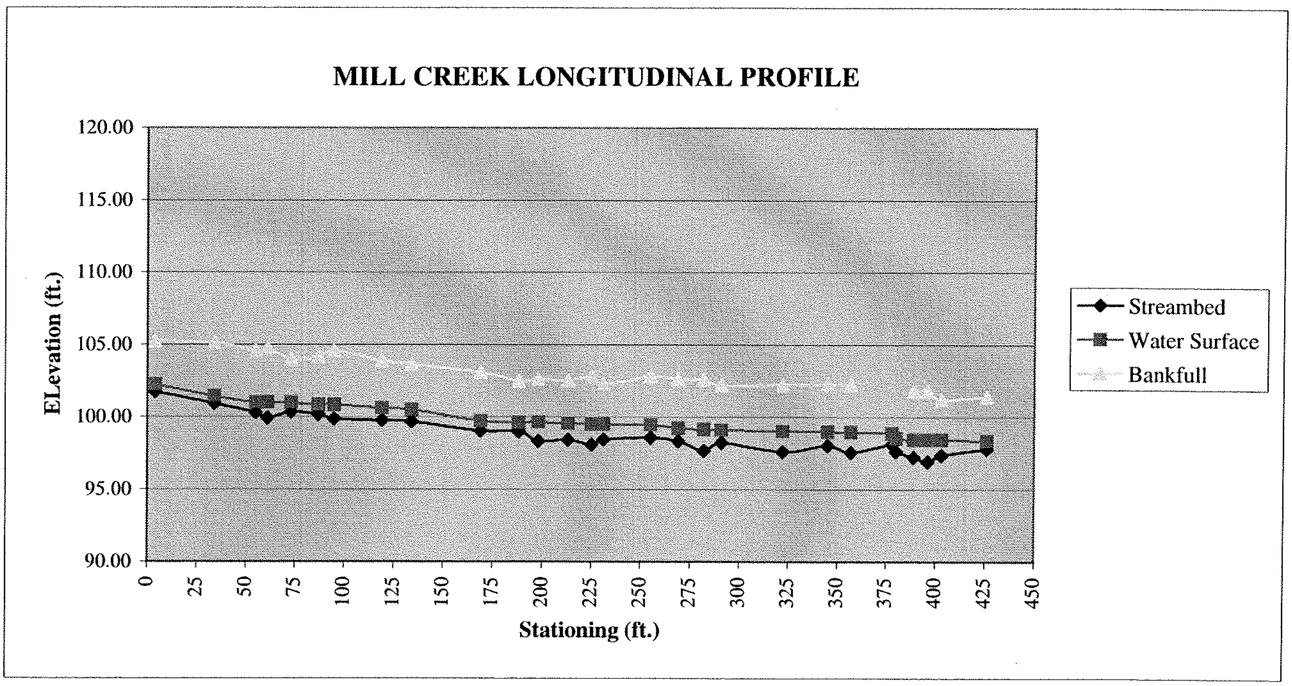
MILL CREEK CROSS-SECTION 2 - RUN



MILL CREEK CROSS-SECTION 2 DETAIL - RUN




MILL CREEK LONGITUDINAL PROFILE
106
104
102
100
98
96
0
100
200
300
400
500
+ Elevation


MILL CREEK LONGITUDINAL PROFILE
120.00
115.00
110.00
105.00
100.00
95.00
90.00
ELevation (ft.)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
Stationing (ft.)
Streambed
Water Surface
Bankfull

Mill Creek Reference Reach Channel	
Channel Characteristics	**Measurements**
d_i = d_{50} of riffle bed surface (mm)	40.0
d_{50} = subsurface d_{50} (mm)	40.0
t^*_{ci} = critical dimensionless shear stress	0.08
d_{84} = d_{84} of pavement sample (or bar sample) (mm)	110.0
P_{sand} = density of sand (2.65 g/c^3)	2.65
P_{water} = density of water (1.0 g/c^3)	1.00
D_i = largest particle found in the point bar sample (ft.)	0.36
S = average riffle slope	0.022
BKF = mean bankfull depth (ft.)	2.51
R = hydraulic radius (ft.)	1.98
s = average riffle slope (ft./ft.)	0.022
n = Manning roughness coefficient (dimensionless)	0.045
A = cross-sectional area (sq. ft.)	34.15
s = longitudinal water surface slope (ft./ft.)	0.022

Critical Dimensionless Shear Stress	
To predict critical shear stress:	**$t^*_{ci} = 0.0834\ (di/d_{50})^{-0.872}$**
- where:	t^*_{ci} = critical dimensionless shear stress
	d_i = d_{50} of riffle bed surface (mm)
	d_{50} = subsurface d_{50} (mm)
	note: equation applies only to gravel bed streams
Formula	**Calculations**
$t^*_{ci} = 0.0834\ (40/40)^{-0.872}$	
$t^*_{ci} = 0.0834\ (1.00)^{-0.872}$	1.00
$t^*_{ci} = 0.0834\ (1.00)$	1.00
$t^*_{ci} = 0.08$	0.08
Critical dimensionless shear stress:	**0.08**

Required Water Depth	
To predict required water depth at riffle:	**$d = (t^*_{ci}\ ((P_{sand} - P_{water}) / P_{water})\ D_i) / S$**
- where:	d = water depth (ft.)
	t^*_{ci} = critical dimensionless shear stress
	P_{sand} = density of sand (2.65 g/c^3)
	P_{water} = density of water (1.0 g/c^3)
	D_i = largest particle found in the point bar sample (ft.)
	S = average riffle slope (ft./ft.)
	note: equation applies only to gravel bed streams
Formula	**Calculations**
$d = (t^*_{ci}\ ((P_{sand} - P_{water}) / P_{water})\ D_i) / S$	
d = (0.08 * ((2.65 - 1.0) / 1.0) * 0.19) / 0.022	
d = (0.08 * ((1.65) / 1.0) * 0.19) / 0.022	1.65
d = (0.08 * (1.65 * 0.19)) / 0.022	1.65
d = (0.08 * 0.31) / 0.022	0.59
d = 0.03 / 0.022	0.05
d = 1.19 ft.	2.25
Required water depth (ft.):	**2.25**
- assuming D_i = 110 mm (0.36 feet)	
- assuming t^*_{ci} = 0.08 (*see above*)	
- assuming S = 2.2 % riffle slope (0.022 ft. / ft.)	

Mill Creek Reference Reach Channel	
Shield's Curve	
To predict shear stress on particles: - where:	**t = *yRs*** t = shear stress (lb./ft.^{2}) *y* = specific gravity of water (62.4 lb./ft.^{3}) *R* = hydraulic radius (ft.) *s* = average riffle slope (ft./ft.)
Formula	**Calculations**
t = *yRs*	
t = 62.4 * 1.98 * 0.022	
t = 62.4 * 0.044	0.044
t = 2.72 lb./ft.^{2}	2.72
Shear stress (lb./ft.^{2}):	**2.72**
Approximate grain diameter movement:	**250 mm**
- assuming average riffle slope of 2.2 % (0.022 ft. / ft.) - assuming wetted perimeter of 17.24 ft. - assuming bankfull cross-sectional area of 34.15 ft.^{2}	

Hydraulic Radius	
To calculate hydraulic radius: - where:	***R* = A / P** A = cross-sectional area (sq. ft.) P = wetted perimeter (ft.) P = B + 2y * (SQRT(1+M^2)) B = bottom width of channel (ft.) M = side slope ratio (ft / ft.) y = depth of flow (ft.)

B = 56.3 - 50.6	
Bottom Width of Channel (ft.):	**5.70**

M = ft. horizontal / ft. vertical	
M = (50.6 - 43.5) / (103.86 - 100.43)	
M = 7.10 / 3.43	
Side Slope Ratio (ft. horizontal / ft. vertical):	**2.07**

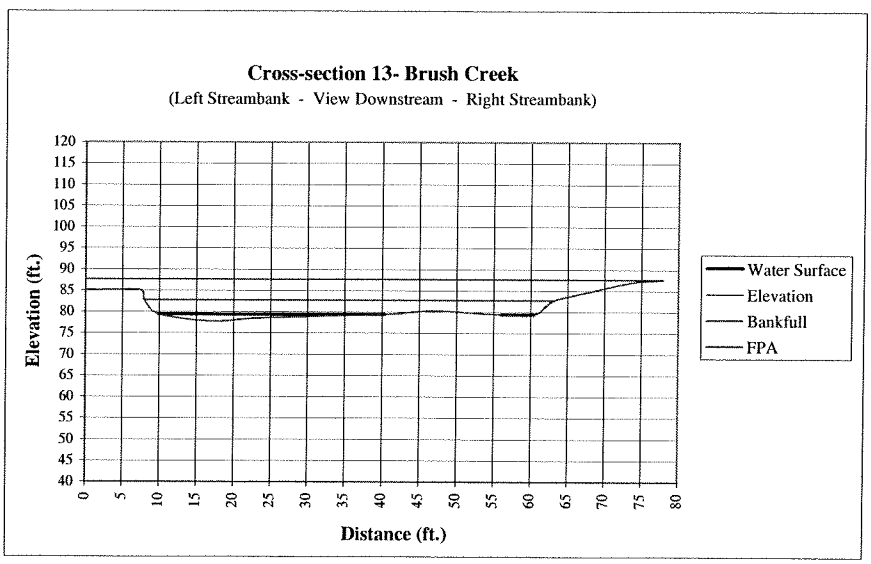
P = B + 2y * (SQRT(1+ M^2))	
P = 5.7 + 2 (2.51) * (SQRT(1 + (2.07)^2))	5.02
P = 5.7 + 5.02 * (SQRT(1 + (4.28))	4.28
P = 5.7 + 5.02 * (SQRT(5.28))	2.30
P = 5.7 + 5.02 * (2.30)	11.54
P = 5.7 + 11.54	17.24
Wetted Perimeter (ft.):	**17.24**

R = A / P	
R = 34.15 / 17.24	
Hydraulic Radius (ft.):	**1.98**

Discharge	
To calculate discharge (Q): - where:	**Q = (1.486 / n) * A * R$^{2/3}$ * S$^{1/2}$** Q = discharge (cfs) n = Manning roughness coefficient A = cross-sectional area (sq. ft.) R = hydraulic radius (ft.) s = longitudinal slope of water surface (ft./ft.)
Q = (1.486 / n) * A * R$^{2/3}$ * S$^{1/2}$	
Q = (1.486 / 0.045) * (34.15) * (1.98)$^{2/3}$ * (0.022)$^{1/2}$	33.02
Q = (33.02) * (34.15) * (1.98)$^{2/3}$ * (0.022)$^{1/2}$	1.58
Q = (33.02) * (34.15) * (1.58) * (0.148)	0.148
Discharge (cfs):	**263.8**

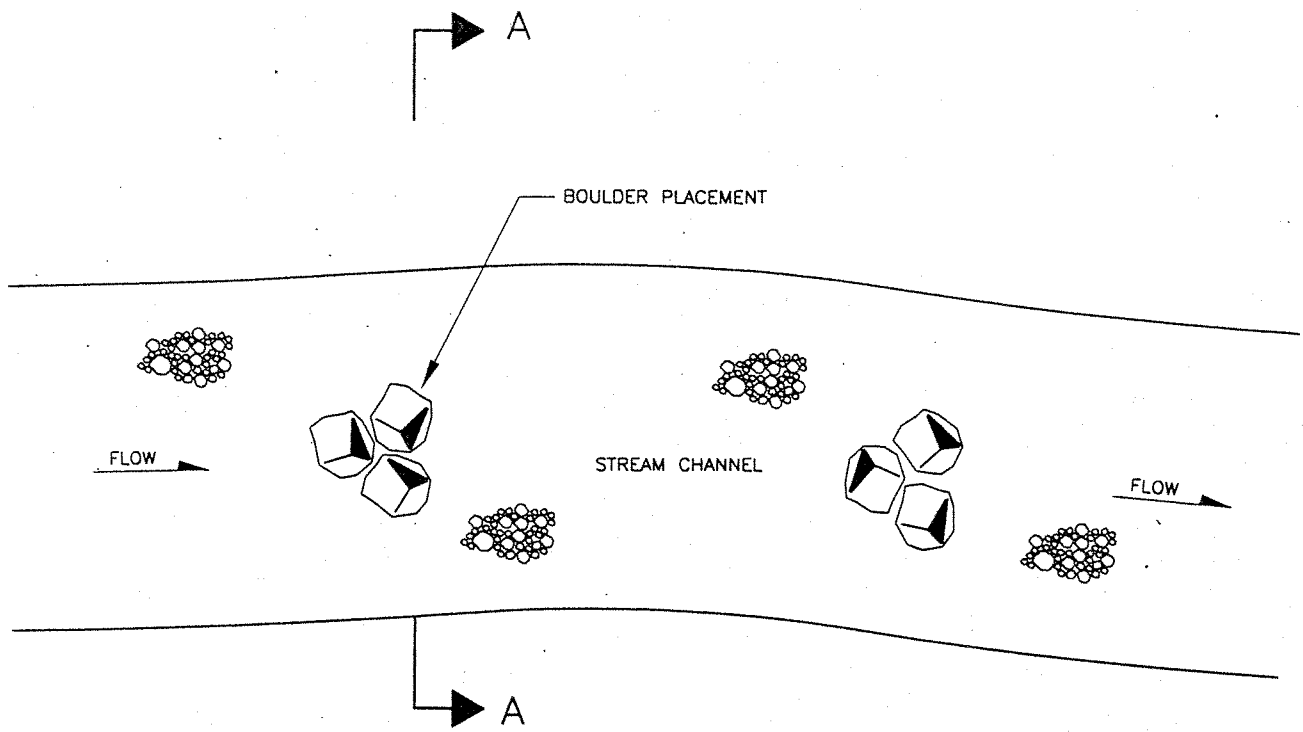
CROSS-SECTION BC6 (#13) - BRUSH CREEK											
		Existing	Water	Bankfull		Bankfull Cross-Sectional Area			FPA Cross-Sectional Area		
Feature	Distance	Elevation	Surface	Elevation	FPA	Width	Depth	Area	Width	Depth	Area
LFPA (extrapolated)	-49.2	87.7			87.66				0.0	0.0	0.00
50' offset-L	-42.6	84.8			87.66				6.6	2.8	9.40
fence-L	0.0	85.1			87.66				49.2	2.6	115.83
TOB-L	7.4	85.1			87.66				56.6	2.5	19.06
LBKF	7.9	82.7		82.7	87.66	0.0	0.00	0.00	57.1	5.0	1.88
LWS	9.9	79.4	79.4	82.7	87.66	2.0	3.26	3.26	59.1	8.2	13.20
THAW	17.0	77.7	79.4	82.7	87.66	9.1	4.97	29.15	66.2	9.9	64.35
stream bed-R	24.4	78.6	79.4	82.7	87.66	16.5	4.10	33.63	73.6	9.1	70.50
RWS	40.3	79.4	79.4	82.7	87.66	32.4	3.27	58.65	89.5	8.2	137.76
top of bar-R	46.8	80.3		82.7	87.66	38.9	2.44	18.56	96.0	7.4	50.86
slough-R	56.0	79.4	79.4	82.7	87.66	48.1	3.30	26.31	105.2	8.3	71.87
RWS	60.5	79.4	79.4	82.7	87.66	52.6	3.30	14.85	109.7	8.3	37.22
RBKF	63.2	82.7		82.7	87.66	55.3	-0.01	4.39	112.4	5.0	17.64
midbank-R	68.0	84.7			87.66				117.2	2.9	19.09
TOB-R	73.5	87.0			87.66				122.7	0.7	9.98
RFPA (extrapolated)	77.9	87.7			87.66				127.1	0.0	1.52

Calculations		
Calculated Bankfull Cross-sectional Area:	**188.8**	sq. ft.
Mean Bankfull Depth:	3.5	ft.
Bankfull Width:	55.3	ft.
Max. Bankfull Depth:	5.0	ft.
FPA Elevation:	87.7	ft.
FPA Width:	127.1	ft.
FPA Cross-sectional Area:	640.1	sq. ft.
Width/Depth Ratio:	15.7	
Entrenchment Ratio:	2.3	
Bank Height Ratio:	1.03	



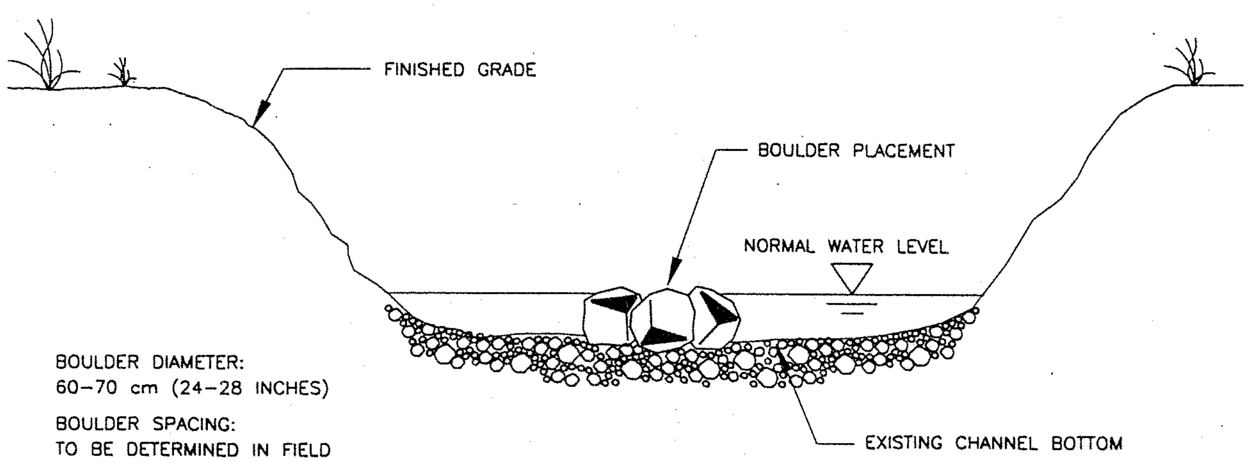
Appendix C

Stream Restoration Details



PLAN VIEW

NOT TO SCALE



BOULDER DIAMETER:
60–70 cm (24–28 INCHES)

BOULDER SPACING:
TO BE DETERMINED IN FIELD

BOULDER ORIENTATION:
1 UPSTREAM
2 DOWNSTREAM

SECTION A–A

HDR HDR Engineering, Inc. of the Carolinas Suite 1400 128 S. Tryon Street Charlotte, NC 28202-5001 (704) 338-6700	NC WETLANDS RESTORATION PROGRAM BRUSH CREEK PROJECT BOULDER PLACEMENT	APPROVAL DATE APRIL, 2000 STD. NO. —— / REV.

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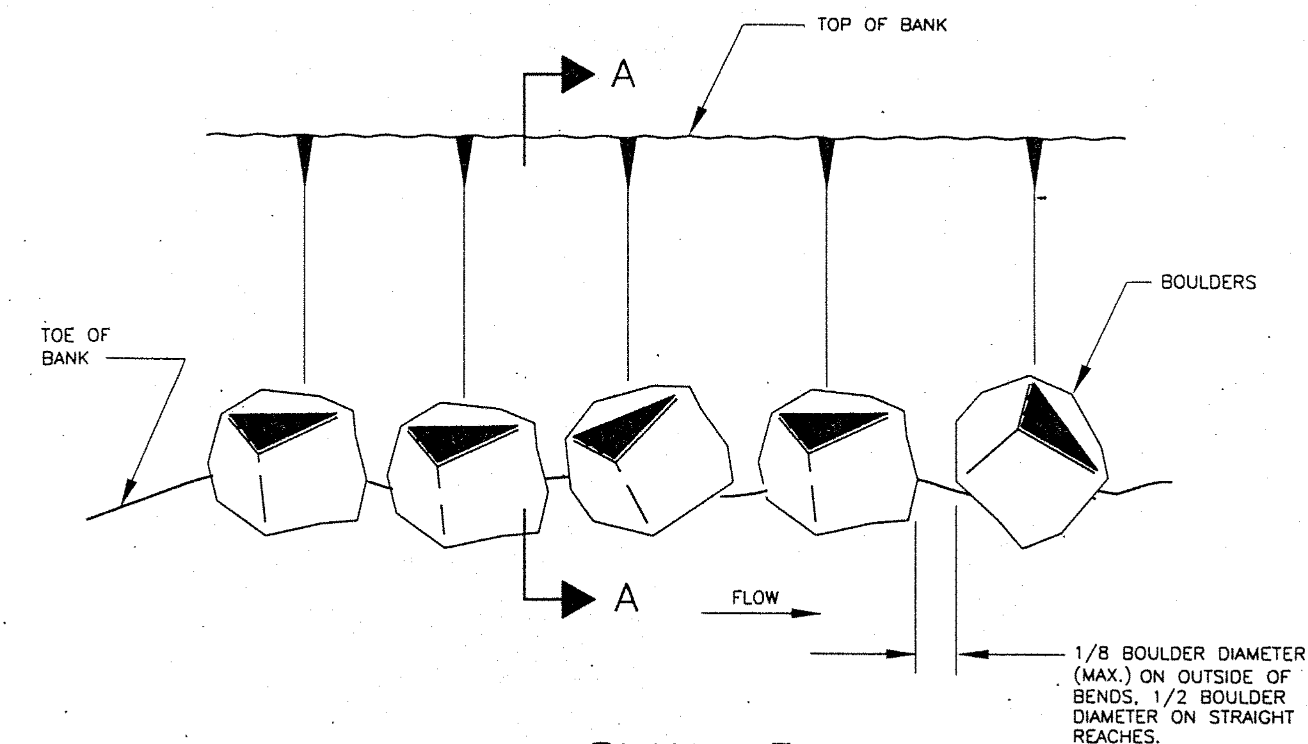

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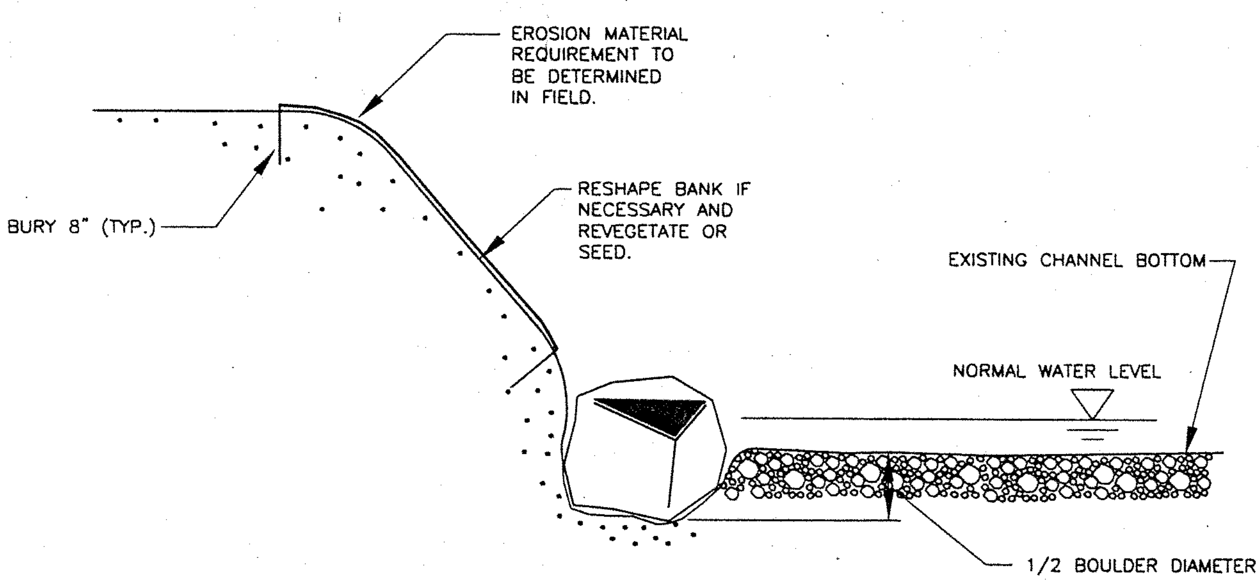

SECTION A–A

HDR

HDR Engineering, Inc. of the Carolinas
Suite 1400
128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-6700

NC WETLANDS RESTORATION PROGRAM
BRUSH CREEK PROJECT

BOULDER TOE PROTECTION

APPROVAL DATE	
APRIL, 2000	
STD. NO.	REV.
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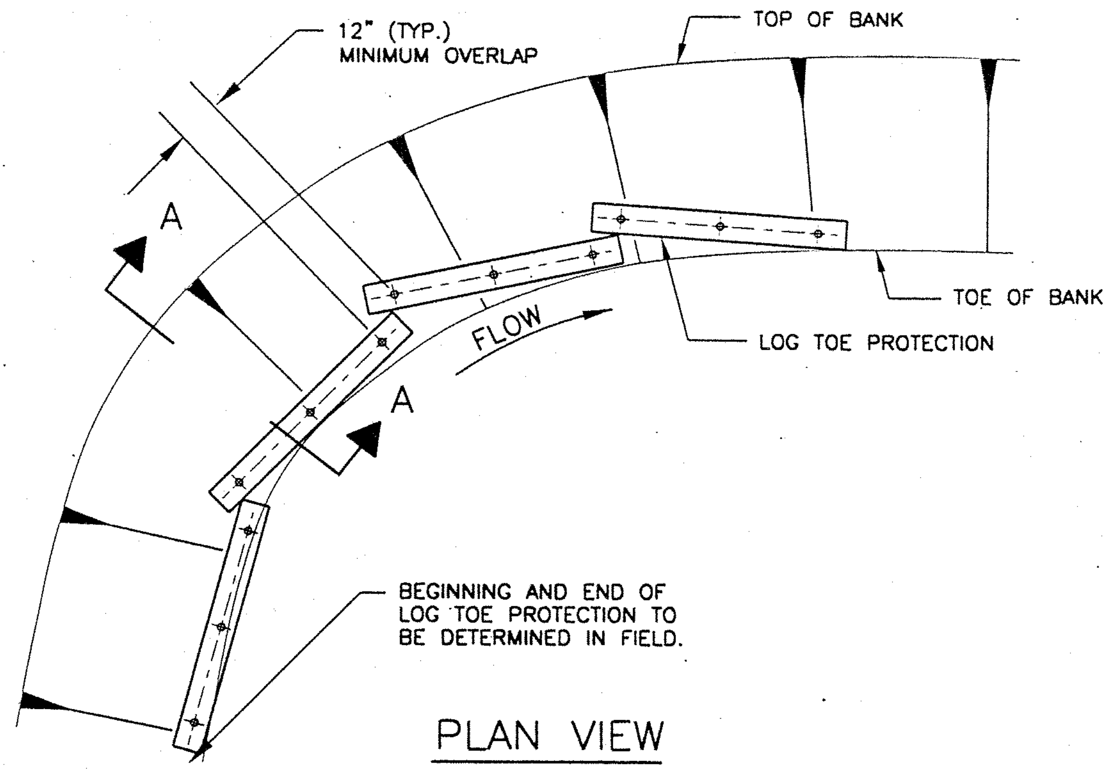

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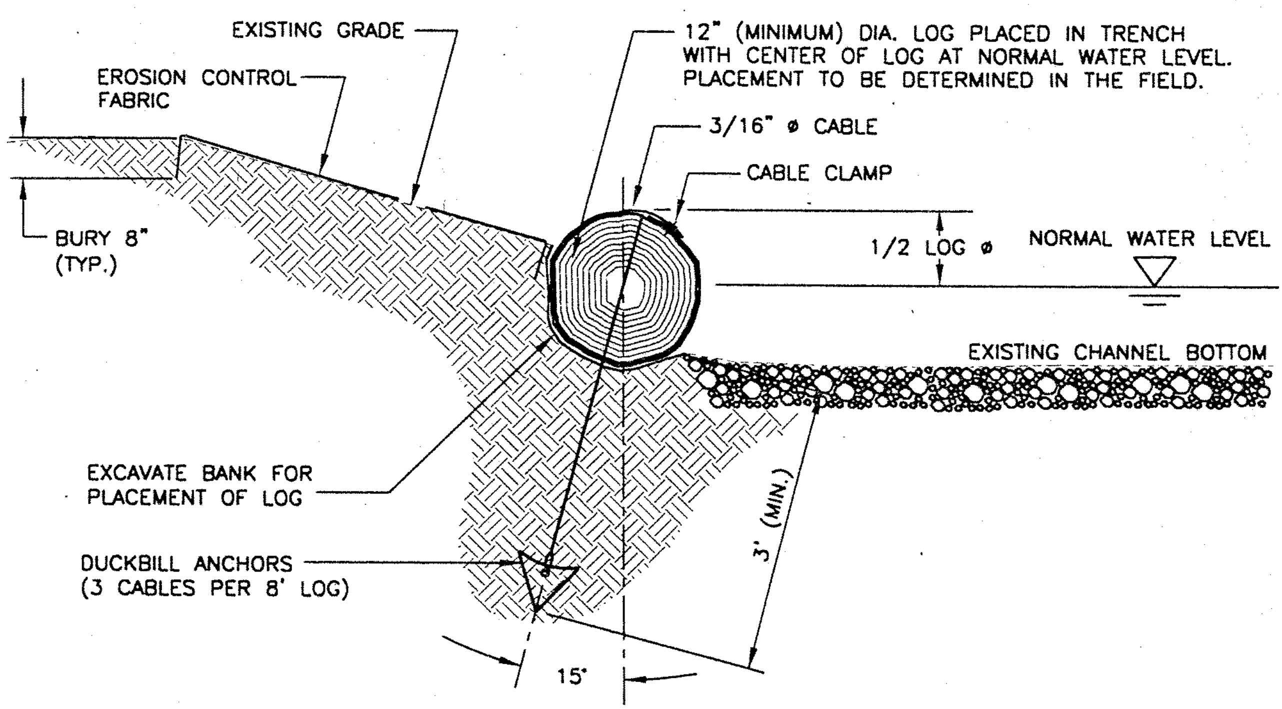

SECTION A–A

HDR
HDR Engineering, Inc.
of the Carolinas
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128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-6700

NC WETLANDS RESTORATION PROGRAM
BRUSH CREEK PROJECT

LOG TOE PROTECTION

APPROVAL DATE	
APRIL, 2000	
STD. NO.	REV.
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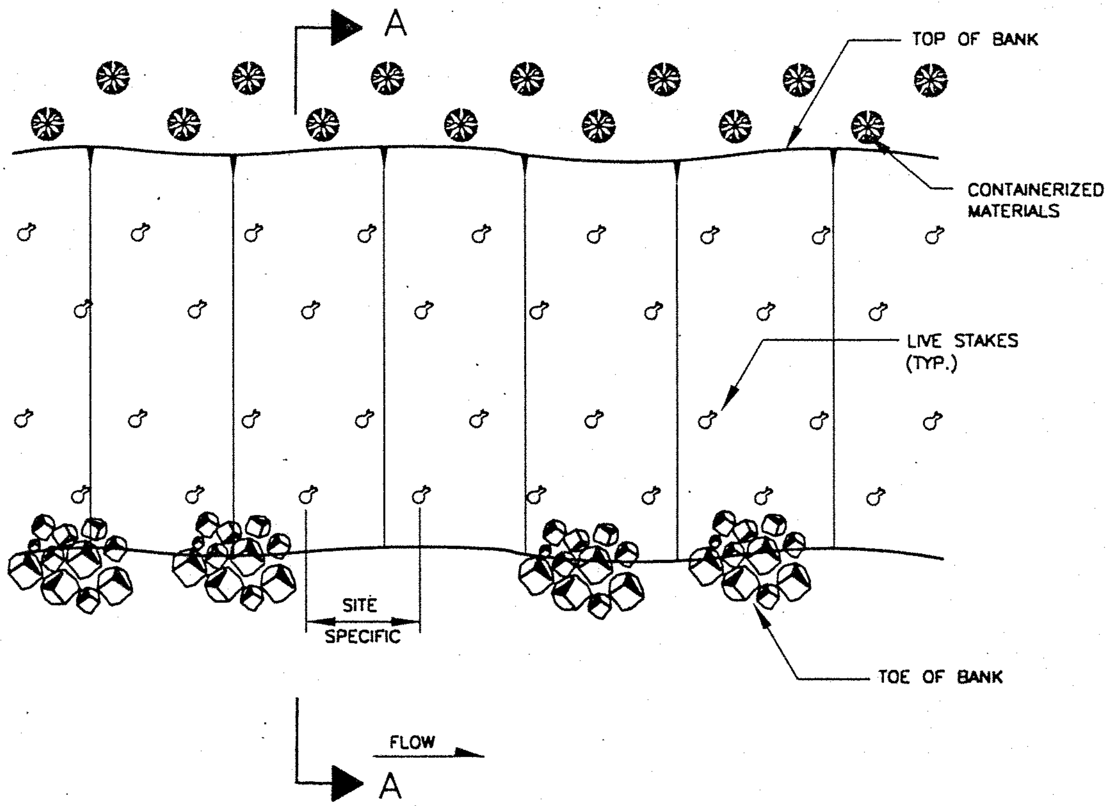

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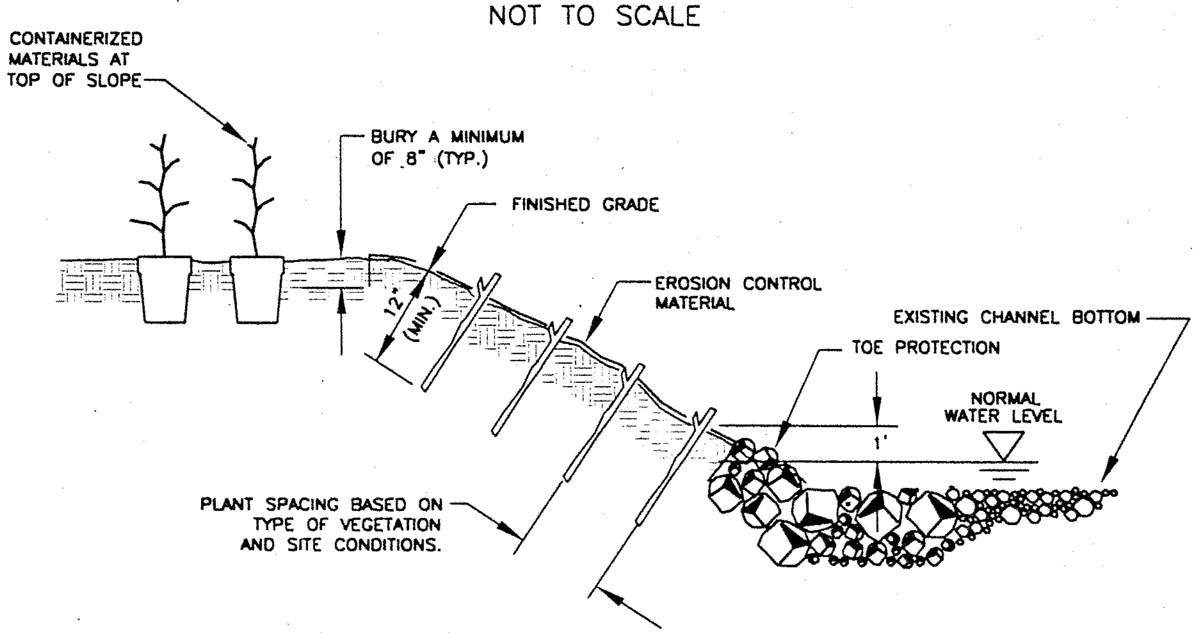

SECTION A–A

HDR Engineering, Inc. of the Carolinas Suite 1400 128 S. Tryon Street Charlotte, NC 28202-5001 (704) 338-6700	NC WETLANDS RESTORATION PROGRAM BRUSH CREEK PROJECT LIVE STAKING	APPROVAL DATE APRIL, 2000	
		STD. NO.	REV.
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