MITIGATION PLAN

UNNAMED TRIBUTARY TO BEAR SWAMP CREEK

April 2003

Mitigation Plan

Unnamed Tributary to Bear Swamp Creek

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North Carolina Department of Transportation

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1. Introduction

1.1 Project Description

ARCADIS was retained by the North Carolina Department of Environment and Natural Resources, Wetlands Restoration Program (NCWRP) to conduct stream restoration using natural channel design methodologies on an unnamed tributary to Bear Swamp Creek in central Franklin County (Figure 1). The site is located on an unnamed tributary to Bear Swamp Creek at the Murphy Hay Farm immediately south of Dyking Road near the town of Louisburg, Franklin County, North Carolina. Mr. Glenn Murphy owns the property.

1.2 Goals and Objectives

The goal of the stream restoration is to improve water quality in the Tar-Pamlico River Basin. An estimated 34 tons of sediment were generated from the project area. This estimate is conservative given that less than 600 linear feet of the 1,500 linear feet of stream bank were studied. The restoration will ultimately improve water quality by reducing the overall amount of sediment contributed by the watershed via stabilization of the streambed and stream banks. Nutrient input should decrease through the establishment of a permanent riparian buffer. The buffer will provide shading to the stream, in turn reducing water temperatures and providing additional wildlife habitat to the site. Stabilization and vegetation development will be monitored.

2. Summary

2.1 Site Description and Land Use

The unnamed tributary originates at a small pond approximately 500 feet east of Dyking Road and 1,000 feet east of the project. Land use in the watershed consists of agricultural, pastureland, forested, and single-family residential. Within the project limits the unnamed tributary flows from the northeast to the southwest through pastureland. Cattle previously had access to the tributary, thus limiting the type and amount of vegetation throughout the riparian zone. Grasses dominate the area with only a few mature sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*) and sycamore (*Platanus occidentalis*) trees located along the stream. This first order stream was incised with near vertical banks along most of the reach. The stream was approximately 10 feet wide at the top of bank and approximately 4 feet deep. In some areas the banks were nearly 6 feet tall with no bank protection present.

Stream restoration onsite was a Priority II and Priority III restoration for the site. The degraded "F5" and "G5c" stream types were restored to a stable "B5c" (step-pool) stream type (Rosgen 1994). This scenario fit both the stream evolution for the site (C5 or B5c→G5→F5→B5c) and the valley type (Type II) (Rosgen and Silvey 1998; Rosgen 1997; Rosgen 1996). Approximately 780 feet of new channel were created, and 680 linear feet of stream were stabilized in place. The width-to-depth ratio was increased to reduce shear stress. Stresses in the near bank region were reduced by the installation of boulder cross vanes. The boulder cross vanes also stabilized the streambed and improved in-stream habitat by creating plunge pools. Root wads were used to help protect the stream banks, mainly where the existing channel was abandoned, and to provide additional aquatic habitat diversity. The establishment of vegetation will also stabilize the stream banks. Locations of the root wads and boulder cross vanes are shown in Sheets 1 through 3.

The existing 16-inch pipe under the driveway was replaced with a 73-inch by 55-inch corrugated metal pipe arch culvert and two 24-inch reinforced concrete pipes at higher elevations to drain the flood plain. Hydraulic analysis showed the proposed culvert design will lower the water surface of the 10-year storm event approximately 0.6 foot. Two crossings were constructed, one upstream and one downstream of the new culverts. The crossings provide access to the pastures on both sides of the stream while keeping cattle and farm machinery out of the stream.

A 50-foot buffer from the bankfull was created. The buffer is comprised of 30 feet of trees and 20 feet of grass. Cattle are excluded from the 30-foot buffer. Piedmont alluvial forest species (Schafale and Weakley 1990) were planted in the buffer in March 2003 and include silky dogwood (*Cornus amomum*), red mulberry (*Morus rubra*), black walnut (*Juglans nigra*), black willow (*Salix nigra*), tag alder (*Alnus serrulata*), cherry bark oak (*Quercus pagoda*), swamp chestnut oak (*Q. michauxii*), river birch (*Betula nigra*), elderberry (*Sambucus canadensis*), green ash (*Fraxinus pennsylvanica*), iron wood (*Carpinus caroliniana*), winterberry holly (*Ilex verticillata*) and eastern hop-hornbeam (*Ostrya virginlana*). Red maple, box elder (*A. negundo*), and sycamore currently exist onsite and are expected to reestablish on their own. The property owner requested that the view of the barn from his house not be obstructed. Therefore, the area between Station 16+50 and Station 19+00 was planted with shrubbier species. The larger trees were planted on 8-foot to 15-foot centers and the smaller trees planted on 6-foot to 8-foot centers. This will give densities of 4 to 15 and 15 to 25 per 1,000 square feet. Black willow and silky dogwood were planted along the stream banks as live stakes.

2.2 Methodology

Location surveys of the constructed features were conducted to monitor the performance of the stream restoration. These surveys were conducted on August 29 and 30, 2002, using total station survey equipment. A longitudinal profile, five permanent cross sections, and a topographical survey were conducted to establish baseline conditions after completion of construction. Subsequent surveys will be taken at 12-month intervals and compared to the baseline surveys to determine if the restoration met the designed goal and objectives. Periodic pebble counts, photographs, and vegetation assessments will also provide information to determine the success of the restoration. Baseline, proposed, and reference reach data are presented in Table 1.

2.2.1 Longitudinal Profile

The longitudinal profile of the restored stream was surveyed for its entire length. The heads of riffles, pools and steps, and maximum pool features were surveyed in the longitudinal profile. Surveying these features will allow the calculation of water surface slope at each feature, average water surface slope, pool length, and pool-to-pool spacing. At each feature, locations were determined for the thalweg, left and right edges of water, left and right bankfull elevations, and left and right tops of bank. These locations enabled the creation of a plan view of the restored stream. Stream pattern

(i.e., meander length, radius of curvature, belt width, and sinuosity) were also measured from the baseline plan view.

2.2.2 Permanent Cross Sections

Five permanent cross sections were surveyed. Two riffles and one pool upstream of the driveway culvert complex and one riffle and one pool downstream of the driveway culvert complex were selected. The cross sections are located where pre-restoration cross sections were taken. The beginning and end of each permanent cross section were marked using wooden stakes labeled with the cross section number. Cross sections extend from fence to fence and are perpendicular to the stream flow. The cross section survey noted all grade breaks, tops of banks, left and right bankfull, edges of water, and thalweg. The cross sections were plotted and the bankfull cross sectional area calculated. The area will be compared to the *Regional Curves for Rural Piedmont North Carolina* (Harmen, et al 1999) (Appendix A). The bankfull mean depth was calculated by dividing the bankfull cross sectional area by the bankfull width. The width-to-depth ratio was calculated by dividing the bankfull width by the bankfull mean depth. The stream will be classified using the Rosgen system of stream classification (Rosgen 1994).

2.2.3 Topographical Survey

A topographical survey was conducted to show that the prerestoration stream channel was filled, the extent of the new driveway and culverts, and the new fences. Permanent photo points and benchmarks will also be shown on the topographical survey.

2.2.4 Pebble Count

The stream substrate will also be monitored. A modified Wolman pebble count (Rosgen 1993) was taken at each permanent cross section. Fifty samples were taken below bankfull. The cumulative percent was graphed and the D16, D35, D50, D84, and D95 calculated. During subsequent surveys, pebble counts will be conducted at each location and compared to the baseline pebble count.

2.2.5 Photo Documentation

Permanent photo points have been established. Periodic photographs of the site will provide valuable visual information as a complement to the figures and narrative material included in the monitoring reports. The photo points were selected to show

reaches of the stream as well as the buffer. Photographs will be taken to record any events that may have a significant effect on the success of the restoration, such as flood, fire, drought, or vandalism. The locations of the photo points are shown on the plan view.

2.2.6 Vegetation

A survey of vegetation during the growing season (August to October) will be conducted annually over the 5-year monitoring period to verify survivability of the installed plantings. Stem survival of woody vegetation will be monitored at five permanent 20-foot by 45-foot plots. Plots are shown on Sheets 1 through 3. The corners of the plots are permanently marked so they can be located in future surveys. Baseline data for woody vegetation was collected on March 10, 2003, and is presented in Table 2. The sample areas and sizes might be slightly increased or decreased after initial data are collected and analyzed. Surviving stems within the plots will be tallied. The stem survival rate per acre will be computed from the plots.

3. Success Criteria

Success criteria need to be established to determine if the restoration project is meeting the designed goals and objectives. These will include changes in the dimension, pattern, profile, bed material, and vegetation over the 5-year monitoring period. The monitoring schedule is discussed later in this report.

3.1 Dimension

The stream cross section should not significantly change from the baseline cross section. Minor adjustment in the cross section is expected. The adjustment is due to the lack of precision of large heavy machinery on a small stream. The lack of permanent vegetation can also contribute to adjustments in the channel dimension. A change in the width-to-depth ratio of ±5 percent beyond the as-built width-to-depth ratio is tolerable.

3.2 Pattern

The stability of stream pattern will be measured using stream sinuosity (the ratio of stream length divided by valley length or approximated by the ratio of valley slope divided by stream slope). A change of ±5 percent or more from baseline in sinuosity will be considered significant. If there is a significant change in sinuosity, belt width, radius of curvature, and meander, the length will be evaluated to determine where the adjustment that affected the sinuosity occurred.

3.3 Profile

The channel profile is not expected to significantly change over the monitoring period. The baseline average water surface slope will be used as a measure of profile stability. The average water surface slope will be determined by taking water surface elevation readings at the beginning and end of the project at the same feature (head of riffle, head of pool, etc.), determining the elevation difference between the two, and dividing the difference by the stream length between the two features. A change of ±5 percent or more in average water slope will be considered significant.

Another measure of channel profile stability is pool-to-pool spacing. This is the stream distance between the same features on sequential pools. The measurements are usually taken between heads of pools. Baseline pool-to-pool spacing will be measured and

recorded. Pool-to-pool spacing deviating ±5 percent or more from the designed ranges will be considered significant.

3.4 Material

Usually there is a shift in particle size distribution of the bed material as a result of stream restoration. This is a result of adjusting the shear stress and stabilizing the existing banks. The change in the substrate material will be measured over the 5-year monitoring period.

3.5 Photo Points

Permanent photo points were established on the site and are shown in Sheets 1 through 3. The photographs should show the succession of vegetation growth and no significant changes in the stream configuration.

3.6 Vegetation

Woody vegetation success will be measured by stem survivability over a 5-year monitoring period. Survivability will be based on 320 stems per acre after 5 years. This survey will track the total mortality on an annual basis and will be used to calculate survivability at the end of 3 years and 5 years. Survivability of less than 320 stems per acre at the end of 5 years will require the installation of replacement plantings. Volunteer woody vegetation will also be included in the survivability calculations.

3.7 Discussions

It is possible that some of the above parameters might fail to meet the success criteria. If the dimension, pattern, or profile parameters are not met, further analysis will be required. The goal of the restoration project is to improve water quality by reducing sedimentation. During year three of monitoring, bank erosion rates will be estimated along the stream using bank erosion hazard index (BEHI) methodology (Rosgen 1996), and a modified Pfankuch channel stability evaluation will be conducted. Estimating erosion rates and channel stability during year three will allow the vegetation time to develop.

4. Monitoring Schedule

4.1 Stream Surveys

Stream surveys will be conducted during August or September of each year. This is the month that the baseline survey was conducted and will give a time period of 1 year between surveys. Surveys will be conducted each of the 5 years of monitoring. The same methods that are discussed above will be followed.

4.2 Vegetation Monitoring

Vegetation monitoring will be conducted concurrently with the stream survey (August or September). Monitoring during these periods will ensure that woody species will not be dormant. Monitoring will be conducted each of the 5 years. Monitoring methods described above will be followed.

4.3 Reports

Monitoring reports will be prepared within 2 months of data collection. Six copies of the report will be provided to the NCWRP. The reports will include the following:

- Introduction
- Summary
- Materials/Methods
- Results
- Discussion
- Recommendations
- References
- Appendices

4.4 Monitoring Procedure Adjustments

The protocol and results of the monitoring will be reviewed annually by the monitoring firm. Adjustment to monitoring procedures or schedule may be required as the site changes over time, or if logistical problems render a procedure unduly difficult to conduct. Such adjustments would be developed by the monitoring firm and reported to

the NCWRP for approval prior to application. After reviewing the annual reports, the NCWRP or regulatory agencies may also have suggestions for adjustment to the monitoring. Suggestions will be reviewed and, if appropriate, will be incorporated into the following year's monitoring. The key is to anticipate that the monitoring program may need occasional adjustments to remain accurate, complete, and feasible.

5. Mitigation

See Sheets

6. Maintenance and Contingency Plans

The need for maintenance of the site will be determined during monitoring visits. Maintenance might include litter removal, filling of holes or gullies, removal of large dead trees, etc. Minor maintenance that can be performed by hand will be performed by ARCADIS either at the time the need is identified or rescheduled for a later time. Maintenance that requires the use of specialized equipment will be coordinated with the NCWRP.

7. References

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Unnamed Tributary to Bear Swamp Creek Mitigation Plan

Tables

MORPHOLOGICAL CHATACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION AND REFERENCE REACH DATA

(Adapted from Rosgen 1996)

Restoration Site: Unnamed Tributary to Bear Swamp Creek, Baseline Survey, Louisburg, Franklin County, NC
USGS Gage Station: No. 02082950 Little Fishing Creek near White Oak, Halifax County, NC
Reference Reach: Unnamed Tributary to Crooked Creek near Rolesville, Wake County, NC

Variables	Existing Constructed Channel	Proposed Reach	Reference Reach	USGS Gage Station
1. Stream Type	B5c	B5c	B5c	E
2. Drainage Area	0.26 sq mi	0.26 sq mi	0.49 sq mi	177.0 sq mi
3. Bankfull Width (Wbkf)	Mean: 9.6 ft Range: 8.1 ft - 10.7 ft	Mean: 10.0 ft Range:	Mean: 11.4 ft Range: 11.0 ft - 11.8 ft	Mean: 63.5 ft Range:
4. Bankfull Mean Depth (dbkf)	Mean: 1.0 ft Range: 0.9 ft - 1.0 ft	Mean: 0.8 ft Range:	Mean: 1.1 ft Range: 0.9 ft - 1.2 ft	Mean: 7.6 ft Range:
5. Width/Depth Ratio (Wbkf/dbkf)	Mean: 10.0 Range: 8.2 - 11.4	Mean: 12 Range:	Mean: 10.7 Range: 11.0 - 11.8	Mean: 8.0 Range:
6. Bankfull Cross-Sectional Area (Abkf)	Mean: 9.3 ft2 Range: 8.1 ft2 - 10.7 ft2	Mean: 8.6 ft2 Range:	Mean: 12.1 ft2 Range: 10.3 ft2 - 14.0 ft2	Mean: 485.4 ft2 Range:
7. Bankfull Mean Velocity (Vbkf)	Mean: 5.5 fps Range: 3.2 fps - 7.3fps	Mean: 4.2 fps Range:	Mean: 3.6 fps Range: 3.1 fps - 4.2 fps	Mean: Range:
8. Bankfull Discharge, cfs (Qbkf)	Mean: 51.2 cfs Range: 29.8 cfs - 67.9 cfs	Mean: 33.1 cfs Range: 20.8 cfs - 45.4 cfs	Mean: 43.8 cfs Range: 37.1 cfs - 50.4 cfs	Mean: Range:
9. Maximum Bankfull Depth (dmax)	Mean: 1.6 ft Range: 1.5 ft - 1.7 ft	Mean: 1.6 ft Range: 1.4 ft - 1.8 ft	Mean: 2.1 ft Range: 1.9 ft - 2.4 ft	Mean: 8.5 ft Range:
10. Ratio of Low Bank Height to Max. Bankfull Depth (Bhlow/dmax)	Mean: Range: N/A for B type streams	Mean: Range: N/A for B type streams	Mean: Range: N/A for B type streams	Mean: 1.1 Range:
11. Width of Flood Prone Area (Wfpa)	Mean: 11.4 ft Range: 13.5 ft - 19.0 ft	Mean: 18.0 ft Range: 14.0 ft - 22.0 ft	Mean: 40.6 ft Range: 25.5 ft - 80.0 ft	Mean: >150 ft Range:
12. Entrenchment Ratio (Wfpa/Wbkf)	Mean: 1.7 Range: 1.7 - 1.8	Mean: 1.8 Range: 1.4 - 2.2	Mean: 2.3 Range: 2.2 - 2.4	Mean: >2.4 Range:
13. Meander Length (Lm)	Mean: 121.3 ft Range: 42.4 ft - 236.9 ft	Mean: 40.0 ft Range: 18.0 ft - 77.0 ft	Mean: 46.0 ft Range: 21.0 ft - 88.0 ft	Mean: Range:
14. Ratio of Meander Length to Bankfull Width (Lm/Wbkf)	Mean: 12.6 Range: 4.4 - 24.7	Mean: 4.0 Range: 1.8 - 7.7	Mean: 4.0 Range: 1.8 - 7.7	Mean: Range:
15. Radius of Curvature (Rc)	Mean: 77.8 ft Range: 11.0 ft - 221.0 ft	Mean: 199.0 ft Range: 55.0 ft - 342.0 ft	Mean: 240 ft Range: 63 ft - 390 ft	Mean: Range:
16. Ratio of Radius of Curvature to Bankfull Width (Rc/Wbkf)	Mean: 8.1 Range: 1.1 - 23.0	Mean: 19.9 Range: 5.5 - 34.2	Mean: 19.9 Range: 5.5 - 34.2	Mean: Range:
17. Belt Width (Wblt)	Mean: 31.3 ft Range: 5.5 ft - 82.5 ft	Mean: 37.0 ft Range: 20.0 ft - 80.0 ft	Mean: 7.0 ft Range: 6.0 ft - 8.0 ft	Mean: Range:
18. Meander Width Ratio (Wblt/Wbkf)	Mean: 3.3 Range: 0.6 - 8.6	Mean: 3.7 Range: 2.0 - 8.0	Mean: 0.6 Range: 0.5 - 0.7	Mean: Range:
19. Sinuosity (Stream length/valley distance) (k)	Mean: 1.11 Range:	Mean: 1.1 Range:	Mean: 1.1 Range:	Mean: Range:
20. Valley Slope (ft/ft)	Mean: 0.0168 ft/ft Range:	Mean: 0.017 ft/ft Range:	Mean: 0.017 ft/ft Range:	Mean: Range:
21. Average Water Surface Slope or Bankful Slope for Reach (Sbkf or Savg)=(Svalley/k)	Mean: 0.0154 ft/ft Range: 0.0152 - 0.0156 ft/ft	Mean: 0.0157 ft/ft Range:	Mean: 0.016 ft/ft Range:	Mean: Range:

MORPHOLOGICAL CHATACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION AND REFERENCE REACH DATA

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Reference Reach: Unnamed Tributary to Crooked Creek near Rolesville, Wake County, NC

Variables	Existing Constructed Channel	Proposed Reach	Reference Reach	USGS Gage Station
22. Pool Slope (Spool)	Mean: 0.0042 ft/ft Range: 0.0 - 0.0084 ft/ft	Mean: 0.033ft/ft Range: 0.0 ft/ft - 0.066 ft/ft	Mean: 0.029 ft/ft Range: 0.0 ft/ft - 0.07 ft/ft	Mean: Range:
23. Ratio of Pool Slope to Average Slope (Spool/Sbkf)	Mean: 0.3 Range: 0.0 - 0.5	Mean: 1.8 Range: 0.0 - 4.4	Mean: 1.8 Range: 0.0 - 4.4	Mean: Range:
24. Maximum Pool Depth (dpool)	Mean: 3.3 ft Range: 2.6 - 4.1 ft	Mean: 2.4 ft Range: 2.3 ft - 2.6 ft	Mean: 3.2 ft Range: 3.1 ft - 3.4 ft	Mean: Range:
25. Ratio of Maximum Pool Depth to Bankfull Mean Depth (dpool/dbkf)	Mean: 3.3 Range: 2.6 - 4.1	Mean: 3.0 Range: 2.9 - 3.3	Mean: 3.0 Range: 2.9 - 3.2	Mean: Range:
26. Pool Width (Wpool)	Mean: 10.5 ft Range: 10.7 - 11.3 ft	Mean: 8.0 ft Range: 7.0 ft - 8.0 ft	Mean: 8.8 ft Range: 8.0 ft - 9.5 ft	Mean: Range:
27. Ratio of Pool Width to Bankfull Width (Wpool/Wbkf)	Mean: 1.1 Range: 1.1 - 1.2	Mean: 0.8 Range: 0.7 - 0.8	Mean: 0.8 Range: 0.7 - 0.8	Mean: Range:
28. Bankfull Cross-sectional Area at Pool (Apool)	Mean: 17.8 ft2 Range: 17.0 - 18.6 ft2	Mean: 11.2 ft2 Range: 9.5 ft2 - 12.9 ft2	Mean: 15.4 ft2 Range: 15.2 ft2 - 15.6 ft2	Mean: Range:
29. Ratio of Pool Area to Bankfull Area (Apool/Abkf)	Mean: 1.9 Range: 1.8 - 2.0	Mean: 1.3 Range: 1.1 - 1.5	Mean: 1.3 Range: 1.1 - 1.5	Mean: Range:
30. Pool to Pool Spacing (p-p)	Mean: 53.5 ft Range: 31.7 ft - 115.5 ft	Mean: 37.0 ft Range: 19.0 ft - 61.0 ft	Mean: 42.0 ft Range: 22.0 ft - 69.0 ft	Mean: Range:
31. Ratio of Pool-to-Pool Spacing to Bankfull Width (p-p/Wbkf)	Mean: 5.6 Range: 3.3 - 12.0	Mean: 3.7 Range: 1.9 - 6.1	Mean: 3.7 Range: 1.9 -6.1	Mean: Range:
32. Pool Length (Lp)	Mean: 11.1 ft Range: 3.9 ft - 30.6 ft	Mean: 8.0 ft Range: 6.0 ft - 11.0 ft	Mean: 9.3 ft Range: 7.0 ft - 13.0 ft	Mean: Range:
33. Pool Length to Bankfull Width Ratio (Lp/Wbkf)	Mean: 1.1 Range: 0.4 - 3.2	Mean: 0.8 Range: 0.6 - 1.1	Mean: 0.8 Range: 0.6 - 1.1	Mean: Range:
34. Riffle Slope (Sriff)	Mean: 0.0108 ft/ft Range: 0.0026 ft/ft - 0.0238 ft/ft	Mean: 0.067 ft/ft Range: 0.0015 ft/ft - 0.132 ft/ft	Mean: 0.04 ft/ft Range: 0.001 ft/ft - 0.14 ft/ft	Mean: Range:
35. Ratio of Riffle Slope to Average Slope (Sriff/Sbkf)	Mean: 0.7 Range: 0.2 - 1.5	Mean: 2.5 Range: 0.1 - 8.8	Mean: 2.5 D32Range: 0.1 - 8.8	Mean: Range:
36. Maximum Riffle Depth (driff)	Mean: 1.6 ft Range: 1.5 ft - 1.7 ft	Mean: 1.6 ft Range: 1.4 ft - 1.8 ft	Mean: 2.1 ft Range: 1.9 ft - 2.4 ft	Mean: Range:
37. Ratio of Riffle Depth to Bankfull Mean Depth (driff/dbkf)	Mean: 1.6 Range: 1.5 - 1.7	Mean: 2.0 Range: 1.8 - 2.2	Mean: 2.0 D34Range: 1.8 - 2.2	Mean: Range:
38. Run Slope (Srun)	Mean: 0.0093 ft/ft Range: 0.0088 ft/ft - 0.0097 ft/ft	Mean: 0.027 ft/ft Range: 0.003 ft/ft - 0.051 ft/ft	Mean: 0.042 ft/ft Range: 0.034 ft/ft - 0.057 ft/ft	Mean: Range:
39. Ratio of Run Slope to Average Slope (Srun/Sbkf)	Mean: 0.6 Range: 0.6 - 0.6	Mean: 1.8 Range: 0.2 - 3.4	Mean: 1.8 Range: 0.2 - 3.4	Mean: Range:
40. Maximum Run Depth (drun)	Mean: 1.7 ft Range: 1.6 ft - 2.0 ft	Mean: 1.5 ft Range: 1.2 ft - 1.7 ft	Mean: 2.1 ft Range: 1.7 ft - 2.4 ft	Mean: Range:
41. Ratio of Run Depth to Bankfull Mean Depth (drun/dbkf)	Mean: 1.7 B38Range: 1.6 - 2.0	Mean: 1.9 Range: 1.5 - 2.2	Mean: 1.9 Range: 1.5 - 2.2	Mean: Range:

MORPHOLOGICAL CHATACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION AND REFERENCE REACH DATA

(Adapted from Rosgen 1996)

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USGS Gage Station: No. 02082950 Little Fishing Creek near White Oak, Halifax County, NC
Reference Reach: Unnamed Tributary to Crooked Creek near Rolesville, Wake County, NC

Variables	Existing Constructed Channel	Proposed Reach	Reference Reach	USGS Gage Station
42. Slope of Glide (Sgl)	Mean: 0.0189 ft/ft Range: 0.0 ft/ft - 0.0382 ft/ft	Mean: 0.017 Range:0.0015 ft/ft - 0.032 ft/ft	Mean: 0.019 ft/ft Range: 0.002 ft/ft - 0.034 ft/ft	Mean: Range:
43. Ratio of Glide Slope to Average Water Surface Slope (Sgl/Sws)	Mean: 1.2 Range: 0.0 - 2.4	Mean: 1.1 Range: 0.1 - 2.1	Mean: 1.1 Range: 0.1 - 2.1	Mean: Range:
44. Maximum Glide Depth (dgl)	Mean: 2.9 ft Range: 2.2 ft - 3.6 ft	Mean: 1.8 ft Range: 1.7 ft - 1.9 ft	Mean: 2.4 ft Range: 2.3 ft - 2.6 ft	Mean: Range:
45. Ratio of Glide Depth to Bankfull Mean Depth (dgl/dbkf)	Mean: 2.9 Range: 2.2 - 3.6	Mean: 2.3 Range: 2.1 - 2.4	Mean: 2.3 Range: 2.1 - 2.4	Mean: Range:
46. Slope of Step (Sstep)	Mean: 0.3418 ft/ft Range: 0.0120 - 1.3511 ft/ft	Mean: 0.4098 ft/ft Range: 0.3799 ft/ft - 0.4396 ft/ft	Mean: 0.4100 ft/ft Range: 0.3800 ft/ft - 0.4400 ft/ft	Mean: Range:
47. Ratio of Step Slope to Average Water Surface Slope (Sst/Sws)	Mean: 21.9 Range: 0.8 - 86.6	Mean: 26.1 Range: 24.2 - 28.0	Mean: 26.1 Range: 24.2 - 28.0	Mean: Range:
48. Maximum Step Depth (dst)	Mean: 1.5 ft Range: 1.1 ft - 2.0 ft	Mean: 1.3 ft Range: 1.1 ft - 1.5 ft	Mean: 1.6 ft Range: 1.4 ft - 1.9 ft	Mean: Range:
49. Ratio of Step Depth to Bankfull Mean Depth (dst/dbkf)	Mean: 1.5 Range: 1.1 - 2.0	Mean: 1.6 Range: 1.4 - 1.9	Mean: 1.6 Range: 1.4 - 1.9	Mean: Range:

Materials:

Particle Size Distribution of Channel Material	Existing Channel	Proposed Reach	Reference Reach	USGS Gage Station
D16	0.07 mm	N/A	0.1 mm	
D35	0.2 mm	0.1 mm	0.2 mm	
D50	0.4 mm	0.2 mm	3.0 mm	
D84	16 mm	2.9 mm	49.7 mm	
D95	2,363 mm	10.3 mm	252.1 mm	
Particle Size Distribution of Bar Material				
D16	Not Sampled	N/A	15.3 mm	
D35	Not Sampled	N/A	55.5 mm	
D50	Not Sampled	N/A	65.9 mm	
D84	Not Sampled	2.4 mm	99.1 mm	
D95	Not Sampled	7.3 mm	156.6 mm	
Largest Size Particle on Bar	Not Sampled	2.0 mm	150.0 mm	

MORPHOLOGICAL CHATACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION AND REFERENCE REACH DATA

(Adapted from Rosgen 1996)

Restoration Site: Unnamed Tributary to Bear Swamp Creek, Baseline Survey, Louisburg, Franklin County, NC
USGS Gage Station: No. 02082950 Little Fishing Creek near White Oak, Halifax County, NC
Reference Reach: Unnamed Tributary to Crooked Creek near Rolesville, Wake County, NC

Sediment Transport:

Sediment Transport Validation (Based on Bankfull Shear Stress)	Existing	Proposed
Calculated value (mm) from curve	50	10
Value from Sheilds Curve (lb/ft2)	0.5	0.11
Critical dimensionless shear stress	Not Calculated. No Bar sample collected	0.03
Minimal mean dbkf (ft) calculated using critical dimensionless shear stress equations	Not Calculated. No Bar sample collected	0.4

Unnamed Tributary to Bear Swamp Creek Mitigation Plan

Sheets

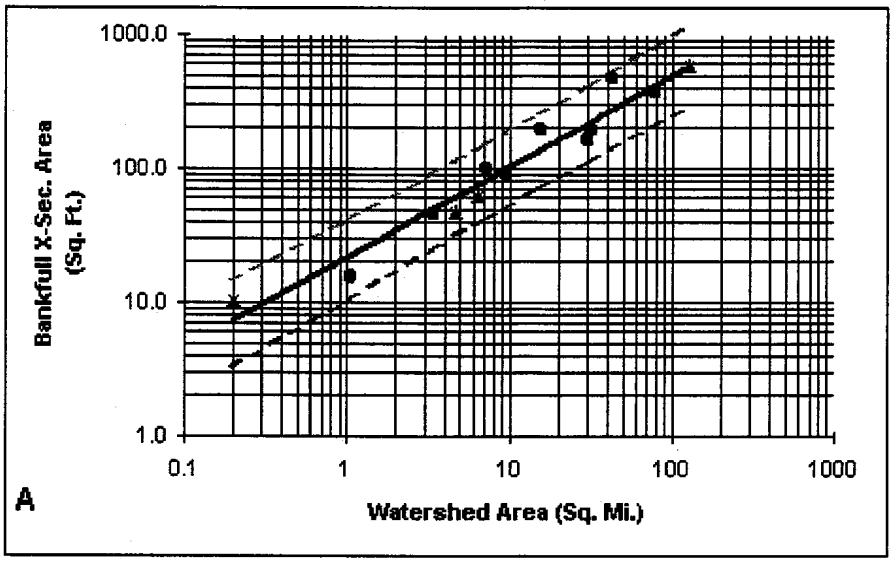
Unnamed Tributary to Bear Swamp Creek Mitigation Plan

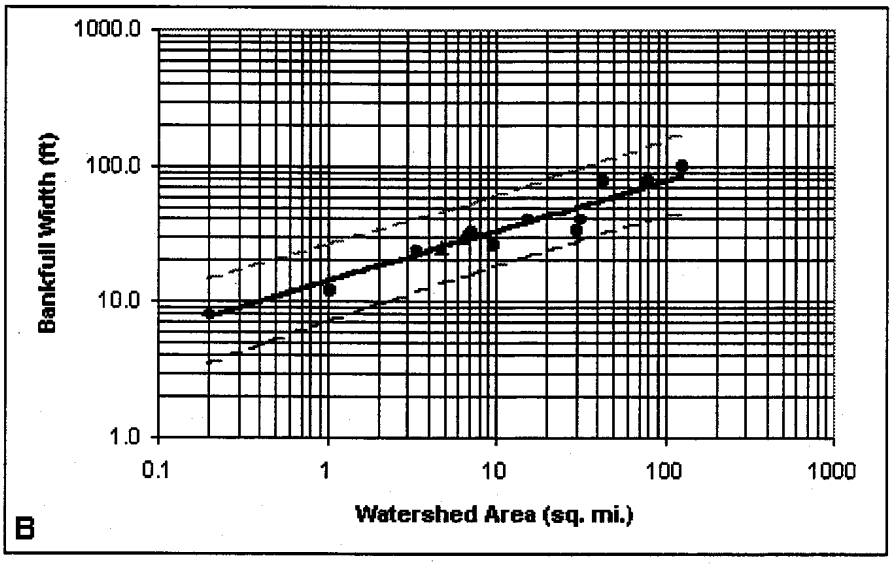
Figures

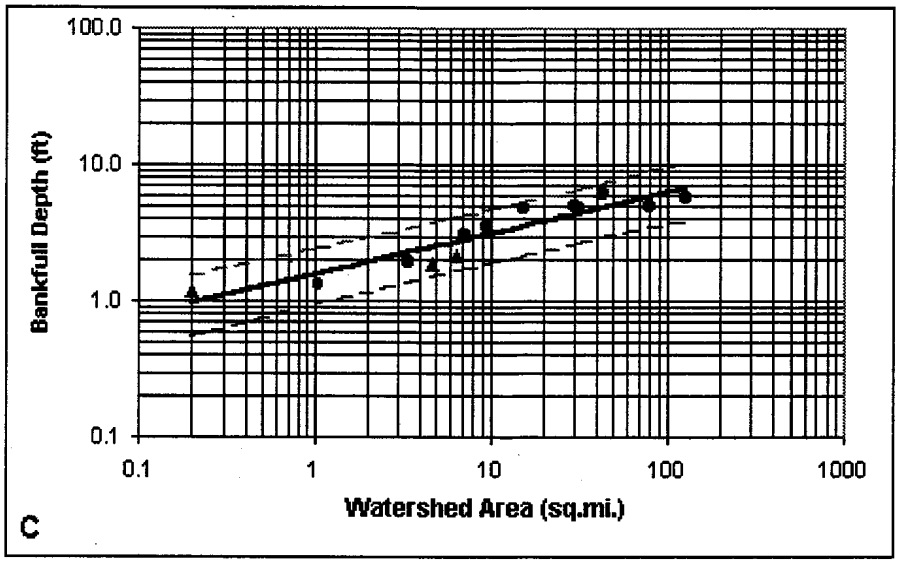
Appendix A

Regional Curves

Bankfull hydraulic geometry relationships for rural Piedmont North Carolina Streams. The four graphs represent:
a) cross sectional area, b) width, c) depth, and d) discharge. The circles represent gage stations and the triangles
represent ungaged streams. The outside dashed lines are the 95% confidence intervals for all the data points.






100.0
10.0
1.0
0.1
Bankfull Depth (ft)
0.1
1
10
100
1000
Watershed Area (sq.mi.)
C

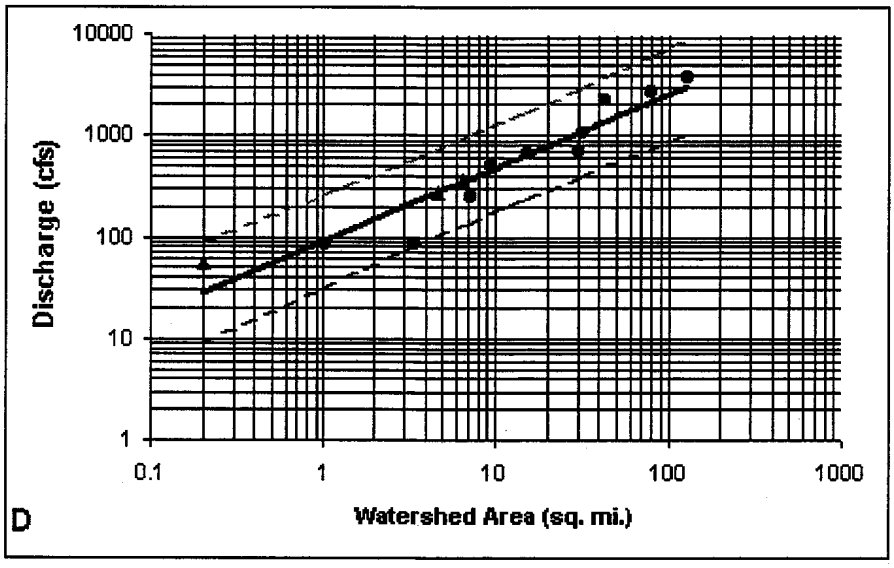

10000
1000
100
10
1
Discharge (cfs)
0.1
1
10
100
1000
Watershed Area (sq. mi.)
D

Table 1: Hydraulic geometry, survey summary, and flood frequency analyses for gaged and ungaged stream reaches.

Stream Name	Gage Station ID	Drainage Area (mi^2)	Stream Type (Rosgen)	Bankfull Discharge (cfs)	Bankfull Xsec Area (ft^2)	Bankfull Width (ft)	Bankfull Mean Depth (ft)	Water Surface Slope (ft/ft)	Return Interval (Years)	Exceedence Probability (%)
Sal's Branch	Reference Reach	0.2	E4	55.4	10.4	8.7	1.2	0.0109	n/a	n/a
Humpy Creek	02117030	1.05	E5	83.0	15.8	12.0	1.3	0.0060	1.7	59
Dutchmans	02123567	3.44	C5	85.1	45.6	23.5	1.9	0.0170	1	100
Mill Creek	Reference Reach	4.7	E4	277	46.7	24.5	1.9	0.0080	n/a	n/a
Upper Mitchell River	Reference Reach	6.5	B4c	356	62.5	29.2	2.1	0.0095	n/a	n/a
Norwood Creek	0214253830	7.18	E5	253.7	98.8	32.0	3.1	0.0008	1.1	91
North Pott's Creek	02121180	9.6	E5	507.2	89.6	25.4	3.5	0.0012	1.7	59
Tick Creek	02101800	15.5	E	655.3	194	40.5	4.8	0.0005	1.3	77
Moon Creek	02075160	29.9	E5	708.8	162	33.0	4.9	0.0015	1.8	56
Long Creek	02144000	31.8	E5	1041	195	40.0	4.9	0.0010	1.4	71
Little Yadkin River	02114450	42.8	G5	2236	469	77.5	6.1	0.0018	1.4	71
Mitchell River	02112360	78.8	C	2681	377	77.0	4.9	0.0030	1.6	63
Fisher River	02113000	128	C3	3687	578	101	5.7	0.0023	1.4	71

Equations

Bankfull Cross-Sectional Area vs. Drainage Area: $y = 21.43x^{0.68}$

Bankfull Discharge vs. Drainage Area: $y = 89.04x^{0.72}$

Bankfull Width vs. Drainage Area: $y = 11.89x^{0.43}$

Appendix B

Project Contacts

Project Contacts
Unnamed Tributary to Bear Swamp Creek
Baseline Monitoring

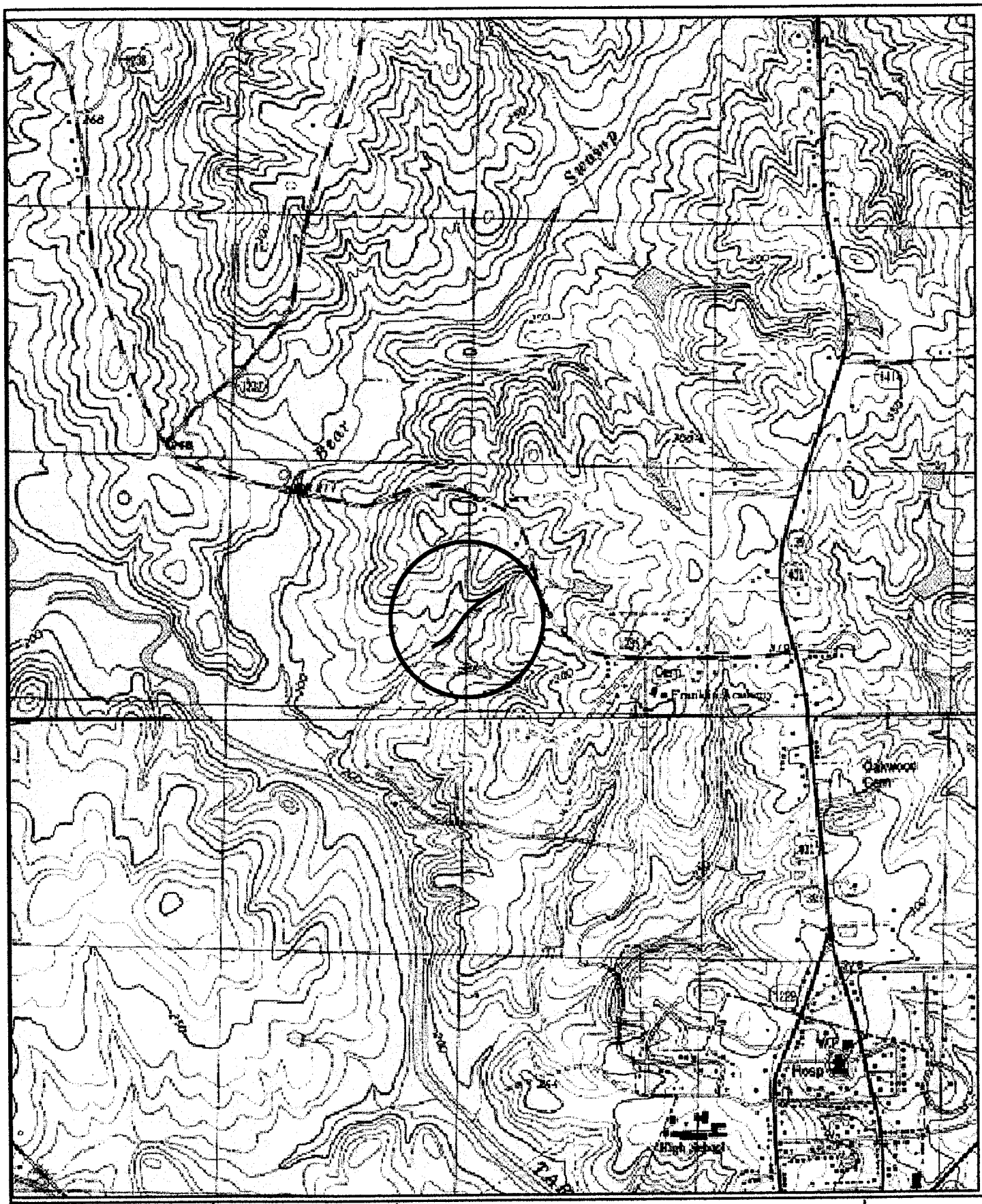
ARCADIS G&M of North Carolina, Inc. designed the restoration project. Contact Mr. Robert Lepsic, 801 Corporate Center Drive, Suite 300, Raleigh, NC 27607-5073. Phone (919) 854-51282.

SEI Environmental, Inc. constructed the restoration project. Contact Mr. Thad Valentine, 130 Penmarc Drive, Suite 108, Raleigh, NC 27603-2434. Phone (919) 832-2535.

Wetlands Restoration Program manager is Ms. Cherri Smith, 1619 Mail Center, Raleigh, NC 27699-1619. Phone (919) 715-3466.

Appendix C

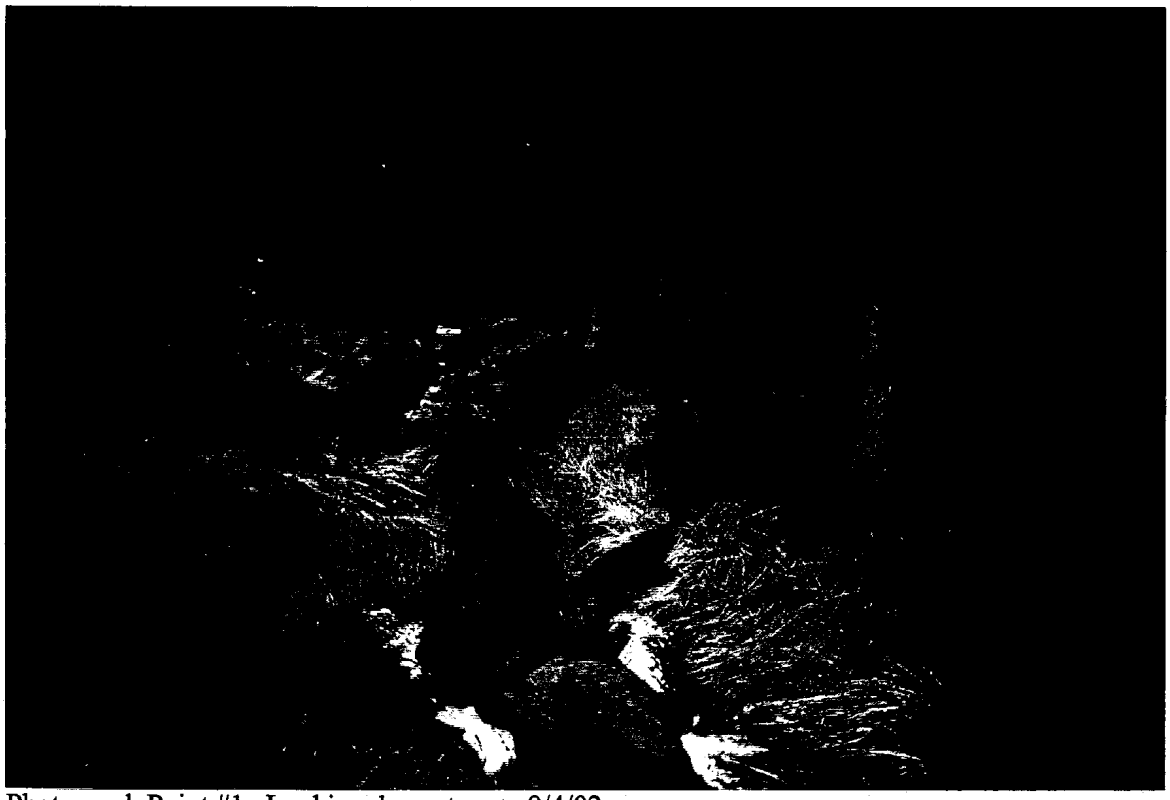
Photographs



Prepared For:
North Carolina Wetlands Restoration Program

PROJECT VICINITY
UT to Bear Swamp Creek at Murphy Farm
Franklin County, North Carolina
USGS 7.5 Minute Topographic Quad:
Ingleside, NC Louisburg, NC
Map Not to Scale

Figure No.
1

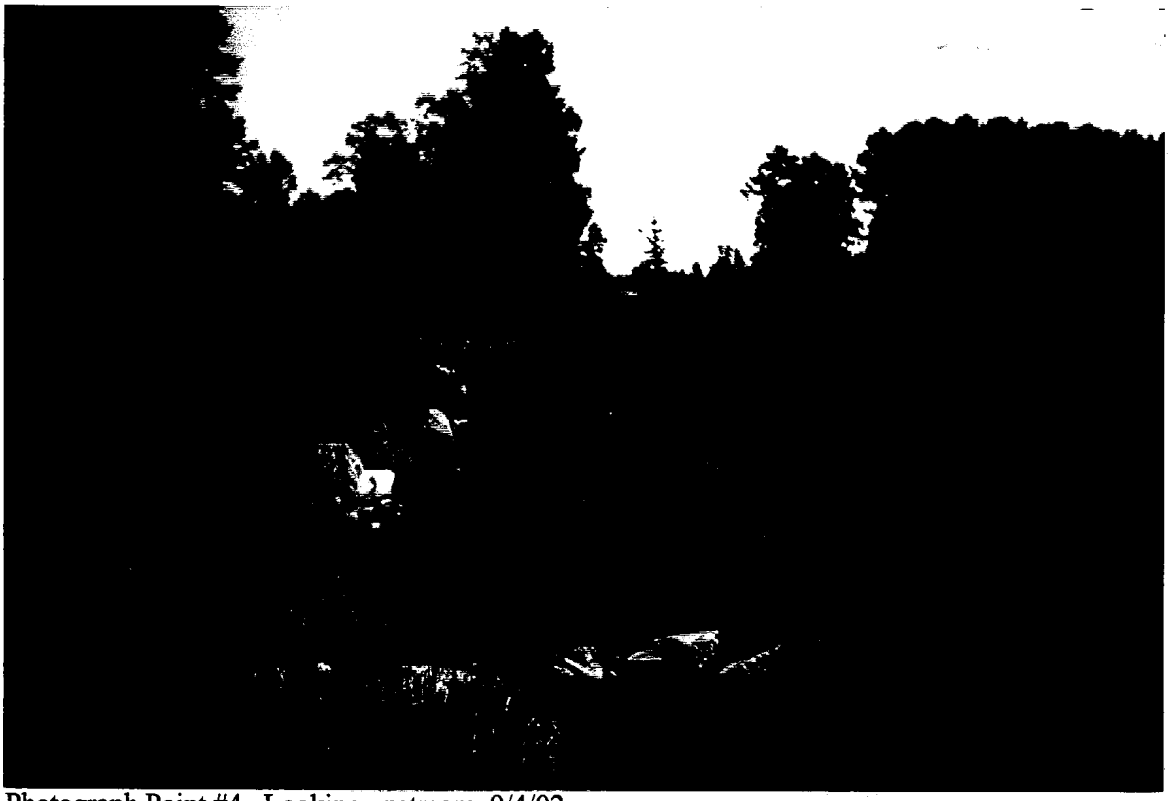


Photograph Point #1. Looking downstream. 9/4/02

Photograph Point #2. Looking upstream. 9/4/02

Photograph Point #3. Looking upstream. 9/4/02

Photograph Point #3. Looking downstream. 9/4/02



Photograph Point #4. Looking upstream. 9/4/02

Photograph Point #4. Looking downstream. 9/4/02

Photograph Point #5. Looking upstream. 9/4/02

Photograph Point #5. Looking downstream. 9/4/02

Photograph Point #6. Looking upstream. 9/4/02

Photograph Point #6. Looking downstream. 9/4/02

Photograph Point #7. Looking upstream. 9/4/02

Photograph Point #7. Looking downstream. 9/4/02