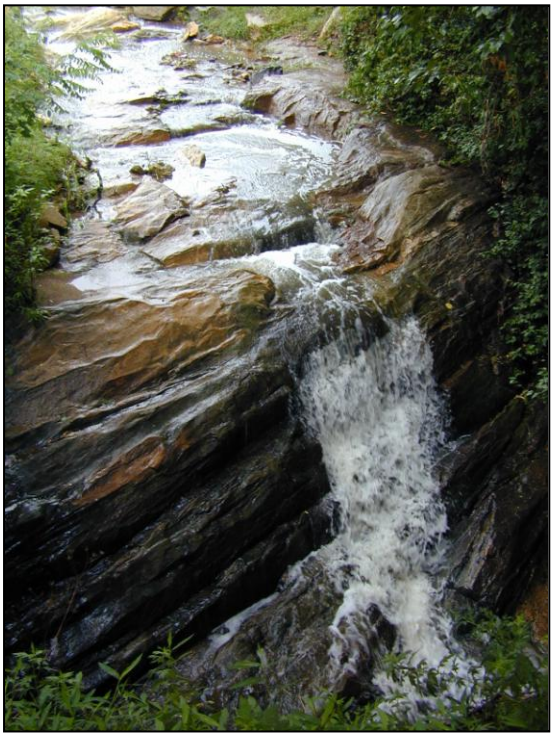
ROCKY BRANCH - PHASE 1 STREAM RESTORATION
2007 FINAL MONITORING REPORT

FOR NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION



NC STATE UNIVERSITY

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

Sea Grant
North Carolina

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UNC-SG-10-12

Project Designed by: AECOM (formerly EarthTech)

Submitted to NC DOT: August, 2010

TABLE OF CONTENTS

TABLES

APPENDIX

I. Executive Summary/Project Abstract

Rocky Branch Phase I construction was complete in early 2001. Despite a lengthy period of vegetation establishment due to infertile clay soils combined with severe drought conditions during and immediately following construction, the creek has achieved good morphologic stability and function. The channel suffered some areas of incision and associated bank erosion in the first two years following construction. These areas of instability represented less than 2% of the restoration reach. Volunteers made hand repairs to isolated areas of bank erosion in April, 2004. Top soil, erosion control matting and livestakes were installed in the small isolated areas of bank erosion. The channel has remained stable since these repairs were made. No other repair or intervention to the stream has Morphological monitoring (cross-sections and longitudinal profile) indicate some areas of down cutting in the channel bed and channel cross-section modification during the first two years following construction. However, there has been very little change in bed profile, channel pattern or cross sectional area since 2003. The streambanks have lush vegetative cover and planted trees and shrubs are thriving throughout the buffer. Extrapolation from the four random survey plots resulted in an overall average of 1416 planted woody stems per acre for this restoration site. Overall, vegetation has grown in size and density steadily over the past five years. The site continues to be in an early successional state, with volunteer pine seedlings as the dominant species. Invasive exotic weeds continue to be problematic in certain areas of the riparian buffer, though treatment by NCSU's Grounds Management Department is helping to alleviate some of the problem.

Currently, there are no problem areas identified in the restoration reach.

II. Project Background

Table I and II list project structure and objectives. Figure 1 shows a map with detailed directions to the project site. Activities and reporting history for the project are listed in Table III. Table IV lists project contacts and Table V list background information for the project.

Table I. Project Structure
Project Name: (Rocky Branch)

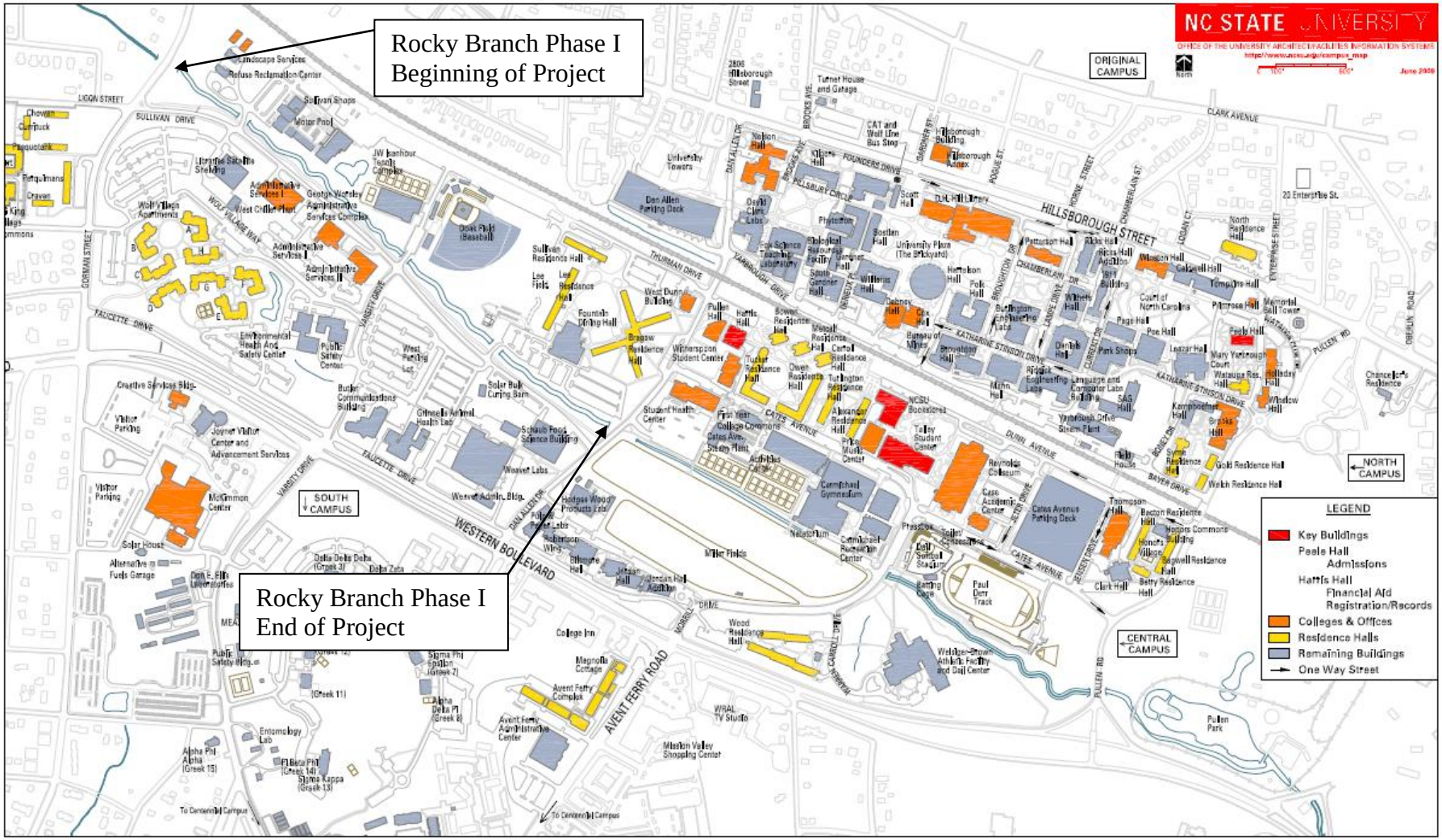
Segment/Reach ID	Linear Feet or Acreage
Rocky Branch - Phase 1	3300 linear feet

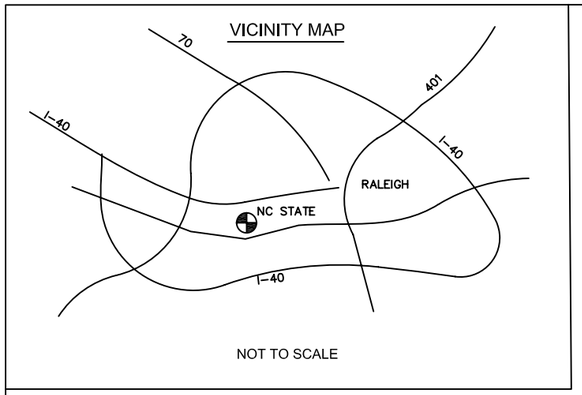
Table II. Project Objectives Table
Project Number and Name: 294 (Purlear Creek - Phase 1)

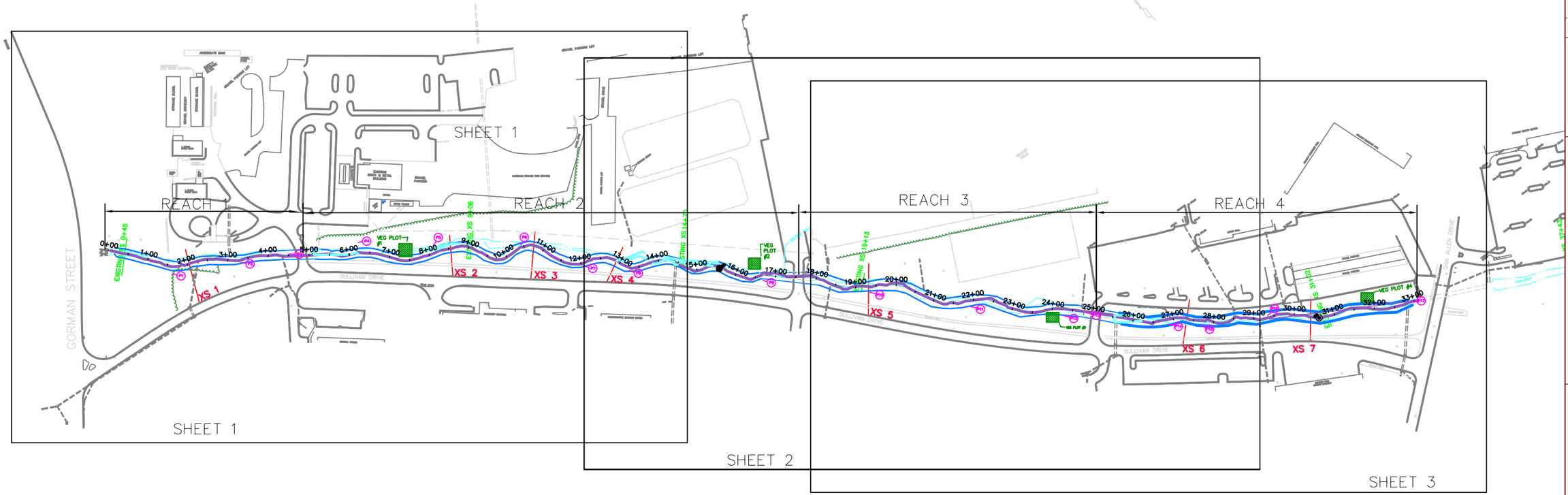
Segment/Reach ID	Objectives	Linear Feet* or Acreage	Comment
R1 - Main Reach (Gorman St.)	Full Restoration	450 linear feet	Priority 2 and 3 approach, dimension, pattern & profile modifications; riparian enhancement
R2 – Main Reach (Motor Pool)	Full Restoration	1320 linear feet	
R3 - Main Reach (Varsity Dr.)	Full Restoration	724 linear feet	
R4 – Main Reach (Bragaw Lot)	Full Restoration	810 linear feet	

* Linear footage listed is approximate as it is based on construction documents

Figure 1. Project Location







SCALE 1" = 100'

NO	REVISIONS	DRN	CHK	DATE
1	MONITORING PLAN SHEET	BAD	BAD	8/7/08

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ROCKY BRANCH PHASE I
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WAKE COUNTY, NC

MONITORING PLAN SHEET
FIGURE 2b

DATE	8/7/2008
PROJECT NO.	
FILENAME	RBASBLT.DWG
SHEET NO.	Monitoring Sheet 3 of 3
DRAWING NO.	

AGGREGATE BINS
CONC. PAD
EMERGENCY EYE WASH STATION
SAFETY STORAGE BLDG.
STORAGE BLDGS.
GRAVEL DRIVEWAY
STORAGE BLDGS.
RETAINING WALL
GRAVEL PARKING LOT
GRAVEL PARKING LOT
GRAVEL PA
GRAVEL DRIVE
1 STORY BRICK BLDG
ASPHALT PARKING LOT
CONC. PAD
CONC. PAD
1 STORY BRICK BLDG
GRAVEL PARKING LOT
CONCRETE
EXISTING BRICK & METAL BUILDING
GRAVEL PARKING
GRAVEL
WASH BAY
OFFICE TRAILER
MATERIALS STORAGE YARD (GRAVEL)
GRAVEL DRIVE
GRAVEL PARKING LOT
STORAGE SHEDS
GORMAN STREET
EXISTING XS 0+45
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
11+00
12+00
13+00
14+00
EXISTING XS 9+06
EXISTING XS 14+70
ROCKY BRANCH
P1
P2
P3
P4
P5
P6
P7
P8
VEG PLOT #1
XS 1
XS 2
XS 3
XS 4
SULLIVAN DRIVE
6"PVC
6"PVC
UNIVERSITY GRAPHICS
ADMINISTRATIVE SERVICES CENTER
CENTRAL STORES

SCALE 1" = 100'

50 0 50 100

NO	REVISIONS	DRN	CHK	DATE
1	MONITORING PLAN SHEET	BAD	BAD	8/7/2008

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ROCKY BRANCH PHASE I
NC STATE UNIVERSITY
WAKE COUNTY, NC

MONITORING PLAN SHEET
FIGURE 2a

DATE 8/7/2008
PROJECT NO.
FILENAME RBASBLT.DWG
SHEET NO. Monitoring Sheet 1 of 3
DRAWING NO.

GRAVEL PARKING LOT

GRAVEL DRIVE

GRAVEL PARKING LOT

STORAGE SHEDS

EXISTING XS 14+70

VEG PLOT #2

WATER FALL

EXISTING XS 19+13

SOCCER FIELD

13+00 14+00 15+00 16+00 17+00 18+00 19+00 20+00 21+00 22+00 23+00 24+00 25+00 26+00 27+00 28+

P7 P8 P9 P10 P11 P12 P13 P14 P15

XS 4

XS 5

XS 6

VEG PLOT #3

ADMINISTRATIVE SERVICES CENTER

SULLIVAN DRIVE

ASPHALT WALK

ROCKY BRANCH

SULLIVAN DRIVE

SCALE 1" = 100'

50 0 50 100

NO	REVISIONS	DRN	CHK	DATE
1	MONITORING PLAN SHEET	BAD	BAD	8/7/08

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ROCKY BRANCH PHASE I
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MONITORING PLAN SHEET
FIGURE 2b

DATE 7/8/2008

PROJECT NO.

FILENAME RBASBLT.DWG

SHEET NO. Monitoring Sheet 2 of 3

DRAWING NO.

SOCCER FIELD

BRAGAW RESIDENCE HALL

DINING HALL

GRAVEL PARKING

GRAVEL PARKING

SCHAUB FOOD SCIENCE BUILDING

DAN ALLEN DRIVE

ASPHALT DRIVE

ASPHALT WALK

SULLIVAN DRIVE

ROCKY BRANCH

XS 5

XS 6

XS 7

VEG PLOT #3

VEG PLOT #4

20+00 21+00 22+00 23+00 24+00 25+00 26+00 27+00 28+00 29+00 30+00 31+00 32+00 33+00

P10 P11 P12 P13 P14 P15 P16 P17

SCALE 1" = 100'

50 0 50 100

NO	REVISIONS	DRN	CHK	DATE
1	MONITORING PLAN SHEET	BAD	BAD	8/7/08

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ROCKY BRANCH PHASE I
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WAKE COUNTY, NC

MONITORING PLAN SHEET
FIGURE 2b

DATE 8/7/2008

PROJECT NO.

FILENAME RBASBLT.DWG

SHEET NO. Monitoring Sheet 3 of 3

DRAWING NO.

Table III. Project Activity and Reporting History		
Project Number and Name: Rocky Branch		
Activity or Report	**Calendar Year of Completion or Planned Completion**	**Actual Completion Date**
Restoration Plan	Oct-00	Jan-01
Mitigation Plan	N/A*	N/A*
Construction	Oct-01	May-02
Temporary S&E mix applied to entire project area	Fall-01	Spring-02
As-Built report	Fall-01	Spring-02
Permanent seed mix applied to reach	Fall-01	Spring-02
Structural Maintenance (Repair/Enhancement)	N/A	N/A
Initial – Year 1 monitoring	Summer-02	Aug-02
Year 2 Monitoring	Summer-03	July-03
Year 3 Monitoring	Summer-04	July-04
Year 4 Monitoring	Summer-05	May-05
Year 5 Monitoring	Summer-06	May-06

* Historical project documents necessary to provide these data were unavailable at the time of report submission

Table IV. Project Contact Table Project Number and Name: 294 (Purlear Creek)	
Designer Primary project design POC	EarthTech Corporation 701 Corporate Center Dr., Ste 475 Raleigh, NC 27607 (919)854-6200 Bill Jenkins, PE
Construction Contractor	Tri-State Consultants
Planting Contractor Planting contractor POC	Valley Crest Jay Lalley 17701 New Hampshire Ave Ashton MD 20861 (301)924-7828
Seeding Contractor Seeding contractor point of contact	Southern Seeding Service, Inc. N/A
Nursery Stock Suppliers	N/A
Monitoring Performers	NC Sea Grant (Box 8605) & Biological & Agricultural Engineering Dept. (Box 7625) North Carolina State University Raleigh, NC 27695
Stream Monitoring POC	Barbara Doll (919) 515-5287
Vegetation Monitoring	Karen Hall (919) 515-8242

Table V. Project Background Table Project Name: Rocky Branch	
Project County	Wake
Drainage Area	0.3 – 0.7 mi² (Main Reach)
Drainage impervious cover estimate (%)	Estimated at 70%
Stream Order	1st Order
Physiographic Region	Piedmont
Ecoregion	Northern Inner Piedmont (45e)
Rosgen Classification of As-built	B, E and C-stream types
Cowardin Classification	N/A*
Dominant soil types	N/A*
Reference site ID	
USGS HUC for Project and Reference	03020201090010
NCDWQ Sub-basin for Project and Reference	27-34-6
NCDWQ classification for Project and Reference	C NSW
Any portion of any project segment 303d listed?	No
Any portion of any project segment upstream of a 303d listed segment?	Yes, Walnut Creek downstream is 303d listed
Reasons for 303d listing or stressor	Impaired biological integrity due to urban runoff
% of project easement fenced	0%

III. Project Condition and Monitoring Results

A. Vegetation Assessment 2004-2007

Using the protocols specified in the Content, Format and Data Requirements for EEP Monitoring Reports, 4 vegetation monitoring plots were established and surveyed in 2004, 2005, 2006 and 2007. Each plot has a size of 100 square meters in the riparian buffer of the Rocky Branch Phase I project. Results from each year's survey are provided below.

Vegetation Assessment 2004

Overall, vegetation is in an early successional state. Volunteer pine seedlings are dominant throughout. Herbaceous cover is composed of *Solidago spp*. and various grasses. All areas of the riparian corridor are covered in vegetation.

Planted trees and shrubs are growing well. Mortality was low at survey time. A variety of oak species (*Quercus spp.*) and tulip poplars (*Liriodendron tulipefera*) are exceptionally healthy. The willow stakes (*Salix nigra*) are thriving along the stream banks. Individual stakes have produced multiple stems. Silky dogwood stakes (*Cornus amomum*) are also growing well, though not as prolific as the willows.

Volunteer or naturally regenerating vegetation from neighboring seed sources is prolific. Loblolly pine (*Pinus taeda*) is the dominant tree species. Volunteer woody species outnumber planted species by nearly half.

A few issues to monitor are the invasive species and the proliferation of the willows. Kudzu (*Pueraria lobata*) was spotted in a couple of locations at the end of the project. Japanese stilt-grass (*Microstegium vimineum*) was also found throughout the project. These exotic invasive species can out-compete the more favorable native species. The willows, though stabilizing the stream banks, can create a monoculture and potential crowd out other native vegetation.

Stem tallies are broken out into 3 components. The first is total woody stems per acre, which are volunteer and planted species, including stakes. On average across the plots there are 2236 stems per acre. The second calculation is just volunteers and on average resulted in 1325 stems per acre. The third calculation was performed with just planted stems and stakes. There are 911 stems per acre on average across the plots.

Vegetation Assessment 2005

Overall, vegetation continues to be in an early successional state. Volunteer pine seedlings continue to be dominant throughout. Herbaceous cover includes a variety of different species at different locations throughout the buffer. Warm season grasses planted 2 years ago are now appearing and seem to be healthy. Invasive exotic weeds are more predominate this year.

Planted trees and shrubs are continuing to grow well. Mortality was low at survey time. A variety of oak species (*Quercus spp.*), tulip poplars (*Liriodendron tulipefera*), and sycamores (*Platanus occidentalis*) have grown considerably since last year. The willow stakes (Salix nigra) continue to thrive along the stream banks and in several sections of the stream banks have formed a dense monoculture. Silky dogwood stakes (*Cornus amomum*) are also growing well, though not as prolific as the willows. Some shrubs had bloomed during this growing season.

Volunteer or naturally regenerating vegetation from neighboring seed sources continues to be prolific. Loblolly pine (*Pinus taeda*) continues to be the dominant tree species. *Baccharis halimifolia* is the dominant shrub volunteer along the stream banks. Blackberry and dewberry (*Rubus spp*.) are pervasive throughout the riparian buffer.

Invasive species populations have increased in all areas with Kudzu (*Pueraria lobata*) and Japanese honeysuckle (*Lonicera japonica*) being the most problematic. Japanese stilt-grass (Microstegium vimineum) was also found throughout the project. These exotic invasive species can out-compete the more favorable native species.

Stem tallies are broken out into 3 components. The first is total woody stems per acre, which are volunteer and planted species, including stakes. On average across the plots there are 2742 stems per acre. The second calculation is just volunteers and on average resulted in 1386 stems per acre. The third calculation was performed with just planted stems and stakes. There are 1356 stems per acre on average across the plots.

Vegetation Assessment 2006

Overall, vegetation grew in size and density from the previous year. The site continues to be in an early successional state. Volunteer pine seedlings continue to be dominant throughout. Herbaceous cover includes a variety of different species at different locations throughout the buffer. Warm season grasses are more prolific in select areas. Invasive exotic weeds are more predominate this year and are problematic in certain segments of the riparian buffer.

Planted trees and shrubs are continuing to grow well. Mortality was low at survey time. A variety of oak species (*Quercus spp.*), tulip poplars (*Liriodendron tulipefera*), and sycamores (*Platanus occidentalis*) continue to grow well. The willow stakes (*Salix nigra*) continue to thrive along the stream banks and in several sections of the stream banks have formed a dense monoculture. Some shrubs had expanded their population through rhizomal growth. *Sassafras albidum* and sweetshrub (*Calycanthus floridus*) have produced new stems via this growth.

Volunteer or naturally regenerating vegetation from neighboring seed sources continues to be prolific. Loblolly pine (*Pinus taeda*) continues to be the dominant tree species. *Baccharis halimifolia* is the dominant shrub volunteer along the stream banks. Blackberry and dewberry (*Rubus spp*.) are pervasive throughout the riparian buffer.

Invasive species populations have increased in all areas with Kudzu (*Pueraria lobata*) and Japanese honeysuckle (*Lonicera japonica*) being the most problematic. Kudzu threatens native vegetation growth at the lower end of the project. Japanese honeysuckle covers the ground in large sections of the buffer. Japanese stilt-grass (*Microstegium vimineum*) is also found throughout the project and covers the ground in areas where dewberry and honeysuckle are not present.

Stem tallies are broken out into 3 components. The first is total woody stems per acre, which are volunteer and planted species, including stakes. On average across the plots there are 2914 stems per acre. The second calculation is just volunteers and on average resulted in 1487 stems per acre. The third calculation was performed with just planted stems and stakes. There are 1427 stems per acre on average across the plots.

Vegetation Assessment 2007

Overall, vegetation grew in size and density from the previous year. The site continues to be in an early successional state. Volunteer pine seedlings continue to be dominant throughout. Herbaceous cover includes a variety of different species at different locations throughout the buffer. In general, the site is dense with different species of vegetation. Invasive exotic weeds continue to be problematic in certain segments of the riparian buffer, though treatment was performed this year helping to alleviate some of the problem.

Planted trees and shrubs are continuing to grow well. Mortality was low at survey time. A variety of oak species (*Quercus spp*.), tulip poplars (*Liriodendron tulipefera*), and sycamores (Platanus occidentalis) continue to grow well s do select shrubs. The willow stakes (*Salix nigra*) continue to thrive along the stream banks and in several sections of the stream banks have formed a dense monoculture. Some shrubs have continued to expand their population through rhizomal growth. *Sassafras albidum* and sweetshrub (*Calycanthus floridus*) have produced new stems via this growth.

Volunteer or naturally regenerating vegetation from neighboring seed sources continues to be prolific. Loblolly pine (*Pinus taeda*) continues to be the dominant tree species. *Baccharis halimifolia* continues to be the dominant shrub volunteer along the stream banks. Blackberry and dewberry (*Rubus spp*.) are still pervasive throughout the riparian buffer.

Invasive species populations have increased in all areas with Kudzu (*Pueraria lobata*) and Japanese honeysuckle (*Lonicera japonica*) being the most problematic. Kudzu was treated this season throughout the buffer. Japanese honeysuckle covers the ground in large sections of the buffer. Japanese stilt-grass (*Microstegium vimineum*) is also found throughout the project and covers the ground in areas where dewberry and honeysuckle are not present.

Stem tallies are broken out into 3 components. The first is total woody stems per acre, which are volunteer and planted species, including stakes. On average across the plots there are 2894 stems per acre. The second calculation is just volunteers and on average resulted in 1447 stems per acre. The third calculation was performed with just planted stems and stakes. There are 1416 stems per acre on average across the plots.

Table VI below provides a summary of the vegetation results for the 2004, 2005, 2006 and 2007 monitoring efforts. In addition, raw vegetation survey data can be found in the Appendices.

Table VI: Vegetation Survey Summary Data 2004-2007								
Species	**2004**		**2005**		**2006**		**2007**	
	Total	**Average**	**Total**	**Average**	**Total**	**Average**	**Total**	**Average**
Alnus serrulata (p)	2	0.5	1	0.25	1	0.25	1	0.25
Acer rubrum (v)	0	0	0	0	0	0	3	0.75
Asimina triloba (p)	0	0	1	0.25	1	0.25	1	0.25
Baccharis halimifolia (v)	0	0	4	1	8	2	11	2.75
Betula nigra (p)	14	3.5	4	1	4	1	4	1
Calycanthus floridus (p)	1	0.25	2	0.5	4	1	4	1
Carya sp. (v)	2	0.5	0	0	0	0	0	0
Cercis canadensis (p)	2	0.5	3	0.75	3	0.75	3	0.75
Cornus amomum (stake)	20	5	7	1.75	7	1.75	7	1.75
Cornus florida (p)	0	0	1	0.25	1	0.25	1	0.25
Fraxinus pensylvanica (p)	2	0.5	2	0.5	2	0.5	2	0.5
Hamamelis virginiana (p)	0	0	2	0.5	2	0.5	2	0.5
Ilex decidua (p)	4	1	0	0	0	0	0	0
Juniperus virginiana (v)	0	0	1	0.25	1	0.25	1	0.25
Ligustrum japonica (v)	0	0	1	0.25	1	0.25	1	0.25
Ligustrum sinense (v)	0	0	1	0.25	9	2.25	12	3
Liquidambar styraciflua (v)	0	0	4	1	9	2.25	13	3.25
Liriodendron tulipefera (p)	5	1.25	3	0.75	3	0.75	3	0.75
Myrica cerifera (p)	22	5.5	8	2	8	2	8	2
Oxydenrum arboreum (v)	1	0.25	0	0	0	0	0	0
Pinus taeda (v)	92	23	106	26.5	101	25.25	86	21.5
Platanus occidentalis (p)	5	1.25	3	0.75	3	0.75	3	0.75
Prunus serotina (v)	1	0.25	0	0	0	0	0	0
Pyrus sp. (v)	0	0	1	0.25	1	0.25	3	0.75
Quercus sp. (p)	10	2.5	9	2.25	9	2.25	9	2.25
Robinia pseudoacacia (v)	4	1	19	4.75	17	4.25	19	4.75
Salix nigra (stake)	33	8.25	78	19.5	82	20.5	81	20.25
Sassafras albidum (p)	0	0	6	1.5	8	2	8	2
Ulmus sp. (v)	1	0.25	0	0	0	0	0	0
Viburnum sp.(p)	0	0	4	1	3	0.75	3	0.75
Total	**221**	**55**	**271**	**68**	**288**	**72**	**289**	**72**
Stems per acre (volunteer and planted)		**2236**		**2742**		**2914**		**2924**
Stems per acre (volunteer)		**1325**		**1386**		**1487**		**1477**
Stems per acre (planted and staked)		**911**		**1356**		**1427**		**1416**

B. Stream Assessment

The stream channel is in a stable condition, with no local problem areas identified in this survey.

Reach 1 –Gorman Street to Motor Pool Entrance

Reach 1 is 450 feet in length and runs from Gorman St. to the Motor Pool entrance. This reach was constructed as a Bc channel that followed the path of the existing channel. As a result the stream is nearly straight. The streambed was raised by two feet at the end of this reach in association with the replacement and increase in elevation and capacity of the motor pool entrance culvert. The longitudinal surveys indicate several areas of scour (approximately 1 foot) just downstream of the cross vane structures in this reach that occurred between the as-built (2001) and (MY-2) 2003. For all post surveys, there is very little change in the channel profile and bedform features maintained their locations and depths. This reach includes 4 cross vane grade controls with downstream elevation drops of 0.5 ft or less. In addition, one single arm cross-vane and numerous rootwads were installed. By year five, the single arm vane and most of the rootwads are not visible and are no longer providing key functions to the morphology, stability or habitat in the channel.

There is only one permanent cross section located in this reach (XS 1). The cross-section shows some narrowing and deepening following the establishment of vegetation during the first two years. Very little change has been witnessed in the cross-section configuration since 2004 (MY-3).

The typical bed material particle size decreased from 2002 (MY-1) to 2003 (MY-2). Then, in 2004 (MY-4), the cross section again coarsened to the 2002 level. The 2006(MY-5) survey showed significant coarsening, but this is mostly due to a switch to wetted perimeter sampling of the entire riffle versus a bankfull to bankfull survey across the cross-section axis of the riffle only.

Little change was made to channel pattern in this reach. The stream is very straight due to confinement by utilities and the motor pool facility. As such, little change has occurred in the channel pattern over the five years of monitoring. Dense vegetation is establishing along the channel banks. This vegetation is providing an excellent root mass to stabilize the banks.

Reach 2 – Motor Pool Entrance to Dunn Avenue

Reach 2 is 1320 feet in length and extends from the Motor Pool entrance culvert to the Dunn Avenue culvert that serves as the entrance to Doak Baseball Field. The restoration of reach 2 involved creating meandering C stream type. The reach was raised by approximately 2 vertical feet in elevation. The culvert at the Motor Pool entrance was replaced in order to raise the streambed elevation. In addition, two floodplain pipes were added at the Motor Pool, one on each side of the new cast-in-place concrete double box structure that replaced an existing single circular concrete pipe. Eight cross-vanes, one log vane and nine single-arm vanes were installed in this reach. The eight cross vane grade controls have downstream elevation drops of greater than 0.5 ft. The longitudinal profile monitoring results indicate that the channel profile is similar to the as-built survey condition. Some riffle features have

migrated slightly downstream of their original location and some no longer present. However, there is still a reasonable alternation between riffles and pools in the stream. Pools have maintained their locations and depths. By year five, most of the rootwads are no longer visible and are no longer providing key functions to the morphology, stability or habitat in the channel.

Three permanent cross-sections are located in Reach 2 including XS 2, XS 3 & XS 4. All three cross-sections indicate narrowing by several feet and deepening by less than one foot during the time between the as-built survey and year 2, indicating some reduction in overall cross-sectional area. The cross-sections have remained fairly unchanged for all post surveys. The channel banks are well vegetated and the chancel cross-sections appear stable.

The typical bed material particle size decreased between 2002 (MY-1) and 2003&2004 (MY-2&3) for both riffle and the one pool cross-section. This was likely the result of upstream construction at Wolf Village apartments which resulted in substantial sedimentation of the stream. However, in 2006 (MY-5) the pebble counts indicated substantial coarsening of the two riffles. Some of this is likely the result of the switch from bankfull counts to wetted perimeter pebble counts. No aggradation or degradation has occurred in the channel, indicating the channel appears to be transporting the sediment load delivered to it by its watershed.

Channel pattern is similar to as-built conditions. Dense vegetation is establishing along the channel banks. This vegetation is providing an excellent root mass to stabilize the banks. A 100 feet long stretch of streambank was experiencing erosion, however, this erosion has subsided as the result of hand-repair work in 2004 that included adding topsoil, matting and livestakes to this area.

Reach 3 – Dunn Ave to Bragaw Dormitory Parking Lot Entrance

Reach 3 is 724 feet in length and runs from Dunn Ave to the entrance for Bragaw Dorm. The restoration approach included some meandering in the upper half of the reach and creation of both C and Bc stream types. The bottom half of the reach was raised by two vertical feet in association with the replacement of the Bragaw parking entrance culvert. This reach includes 7 cross-vanes, 4 single-arm vanes and several rootwads. The cross-vanes serve as grade controls with downstream elevation drops of greater than 0.5 ft. The channel profile is similar to the as-built survey condition, with bedform features maintaining their locations and depths. There has been some migration of the riffles in the upstream portion of the reach. The end of the reach has experienced substantial scour for approximately 100 feet (station 23+40 to 24+45) between 2002 (MY-1) and 2003 (MY-2). This scour has resulted in the loss of riffle habitat. The two cross-vanes located in the area of scour have some failure of the vane arms due to very steep arm angles and high spots in the floodplain combined with the downcutting of the bed of the stream channel. Little change has occurred in the bed since 2003.

One permanent cross-section is located in this reach (XS 5). The cross-section has narrowed substantially due to establishment of vegetation and deposition on the banks. The cross-section is very stable. The measured cross sectional area has decreased over time by approximately 30%, however there has been little to no change in the maximum depth. Channel banks are well vegetated and appear stable.

The typical bed material particle size decreased between 2003 (MY-2) and 2004 (MY-3) for the riffle cross-section. This was likely the result of upstream construction at Wolf Village apartments which resulted in substantial sedimentation of the stream. However, in 2006 the pebble count indicates substantial coarsening. Some of this is likely the result of the switch from bankfull counts to wetted perimeter counts. There is degradation that occurred during the first two years at the downstream end of the channel, however, subsequent surveys indicate the channel is stable and appears to be transporting the sediment load delivered to it by its watershed.

Channel pattern is similar to as-built conditions. Dense vegetation is establishing along the channel banks. This vegetation is providing an excellent root mass to stabilize the banks. There is one area of erosion along the reach which occurs on the right bank near the downstream end where the degradation of the channel bed has occurred. The erosion appears to be localized around the vane arm (station 24+40) and at minimal risk of expanding.

Reach 4 – Bragaw Dormitory Parking Lot Entrance to Dan Allen Drive

Reach 4 is approximately 800 feet in length and extends from the Bragaw Dorm entrance to Dan Allen Drive. The restoration involved raising the streambed by nearly four vertical feet to maximize the floodplain bench width to create a Bc channel. The vertical lift of the streambed was done in conjunction with the replacement and hydraulic upgrade of the Bragaw entrance culvert. In addition, two floodplain pipes were added to the culvert, one on each side of the new cast-in-place concrete double box structure that replaced an existing single circular concrete pipe. This reach includes 8 cross-vane grade controls with downstream elevation drops of greater than 0.5 ft, 3 single-arm vanes and several rootwads. By year five, most of the rootwads are no longer visible and are no longer providing key functions to the morphology, stability or habitat in the channel. The cross-vanes at the lower half of the channel are located close together and form a step-pool channel that transitions the streambed back down to the existing elevation of Dan Allen Dr., which is the end of the project. Streambed erosion of around one foot has occurred along approximately half of this reach between 2002 (MY-1) and 2003 (MY-2). The first section runs from approximately stations 26+00 and 28+00 and the second section runs from 28+70 to 30+83. This downcut resulted in a loss of riffle habitat and under-mining of the cross-vanes structures in these two segments. As a result, some piping continues around the structures. The streambed has changed little in these reaches since 2003 (MY-2). The remainder of the channel profile is similar to the as-built survey condition, with bedform features maintaining their locations and depths.

Two permanent cross-sections are located within this reach, including a pool at XS 6 and a riffle at XS 7. Both cross-sections occur within the two areas of the stream that have experienced significant streambed downcut, with XS 7 eroding by more than 1 foot between 2002 and 2004. This erosion resulted in a loss of the riffle habitat. The 2007 survey indicates that XS7 downcut by another 1.4 feet since the MY-5 survey of 2006. As a result there has been a 20 to 25 percent increase in the bankfull cross-sectional area for the channel, which is not desirable. As a result, two areas of bank erosion remain pervasive. With the exception of these two short eroded areas, the channel banks are well vegetated and appear stable.

The typical bed material particle size remained fairly consistent until 2006 (MY-5), where some increase in material size was witnessed. However, this is mostly due to the switch to wetted perimeter pebble count sampling methods. As mentioned previously, degradation has occurred in about half the reach. The degradation occurred within the first two years following construction. Little change has been witnessed in the channel bed or its stability since 2003. In its current condition, the channel appears to be transporting the sediment load delivered to it by its watershed.

No change in channel pattern since construction. Dense vegetation is establishing along the channel banks. This vegetation is providing an excellent root mass to stabilize the banks. Despite the two areas of erosion and some piping of the cross-vanes in these segments, conditions have not worsened since 2003 thus indicating only a minimal risk of the condition expanding.

Exhibit Table VII. Baseline Morphology and Hydraulic Summary
Project Name: Rocky Branch, NCSU
Segment/Reach: Phase I

Parameter	Regional Curve Interval			Pre-Existing Condition			Project Reference Streams "C"			Project Reference Streams "Bc"			Design			As-built		
Dimension	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med
BF Width (ft)				13.5	34.9	23.1							21	26	23.5	21.5	26	24
Floodprone Width (ft)				20.5	50.9	34.0							40	139	50	41	117	51
BF Cross Sectional Area (ft^2)				26.5	57.5	37.3							31	48	40	31.6	54.6	43
BF Mean Depth (ft)				1.0	2.6	1.7							1.5	1.8	1.65	1.5	2.1	1.8
BF Max Depth (ft)				2.2	3.9	2.7							2.25	2.8	2.5	2	3.7	2.9
Width/Depth Ratio				6.9	33.2	12.1	14	20.8	17.2	13.7	30.7	15.6	14	14.4	14.2	12.4	14.6	13.5
Entrenchment Ratio				1.1	2.3	1.4							1.7	6.6	2.5	2	4	2
Wetted Perimeter(ft)				15.8	35.9	23.3							24	30	27	22.6	27.8	25.2
Hydraulic radius (ft)				0.9	2.4	1.5							1.3	1.6	1.45	1.4	2	1.7
Pattern																		
Channel Beltwidth (ft)				n/a	n/a	n/a							26	58	40			
Radius of Curvature (ft)				n/a	n/a	n/a							53	118	96	57	103	69
Meander Wavelength (ft)				n/a	n/a	n/a							115	253	167			
Meander Width ratio				n/a	n/a	n/a	0.9	11.4	8.7			3.7	4.4	12	7			
Profile																		
Riffle length (ft)				*	*	*							4	88	16	9.4	58	20
Riffle slope (ft/ft)				.012	.024	.018	.009	.059	.034	.015	.039	.027	.008	.023	.014	.01	.11	.02
Pool length (ft)				*	*	*							4	87	11	19.3	94	42.7
Pool spacing (ft)				*	*	*	4.4	8.3	6.3	0.5	8.9	3.9	38	156	85.5	17	111	58
Substrate																		
d50 (mm)				0.06	23	0.87	3	45	3.1			40	n/a	n/a	n/a			
d84 (mm)				10.2	128	26	77	125	83.5			210	n/a	n/a	n/a			
Additional Reach Parameters																		
Valley Length (ft)				2767									2767			2767		
Channel Length (ft)				3033									3306			3310		
Sinuosity				1.1				1.2			1.1		1.1			1.2		
Water Surface Slope (ft/ft)				.0063 to .0126									.008 to .023			.003 to .015		
BF slope (ft/ft)				.0068 to .0095									.008 to .023			.004 to .015		
Rosgen Classification				G and F									Bc and C			Bc and C		
Number of Bankfull Events																		
Extent of BF floodplain (acres)																		
*BEHI				16.2-38 (low to high)														
*Habitat Index																		
*Macrobenthos																		

* Inclusion will be project specific and determined primarily by As-built monitoring plan/success criteria

Exhibit Table VIII. Morphology and Hydraulic Monitoring Summary
Project Name Rocky Branch, NCSU
Segment/Reach: Phase I (Gorman St. to Dan Allen Dr.)

Parameter	Cross Section 1 (2+05) Riffle							Cross Section 2 (Station 8+55) Riffle							Cross Section 3 (Station 10+75) Pool							Cross Section 4 (Station 12+90) Riffle					
Dimension	AB*	MY1	MY2	MY3	MY4	MY5	MY6	MY1	MY2	MY3	MY4	MY5	MY6	MY+	MY1	MY2	MY3	MY4	MY5	MY6	MY+	MY1	MY2	MY3	MY4	MY5	MY6
BF Width (ft)	21.5	20.5	19.4	19.7	19.7	18.4	26.3	25.4	21.8	26.4	26.4	21.7	23.5		28.7	22.1	25.0	25.4	27.4	21.4		32.8	36.1	22.9	29.4	25.3	21.4
Floodprone Width (ft)	42.1	51.2	53.3	52.6	48.3	43.6	18.2	101	100	101	101	101	101		>117	>117	>117	>117	>117	117		>91	>93	>93	>93	>93	93
BF Cross Sectional Area (ft^2)	31.6	37.8	29.8	32.6	31.2	33.3	31.3	35.1	30.6	30.1	30.1	28.5	23.9		43.5	34.0	36.1	36.3	38.3	34.5		40.9	34.6	33.5	29.7	33.2	32.3
BF Mean Depth (ft)	1.5	1.8	1.5	1.7	1.6	1.8	26.3	1.4	1.4	1.1	1.1	1.3	1.0		1.5	1.5	1.4	1.4	1.4	1.6		1.2	1.0	1.5	1.0	1.3	1.5
BF Max Depth (ft)	2	2.8	3.3	3.2	3.1	3.1	1.4	2.3	2.9	2.9	2.9	2.9	2.4		3.1	3.1	3.6	3.4	3.1	3.3		2.6	2.9	2.7	3.1	3.3	4.3
Width/Depth Ratio	14.6	11.2	12.6	11.9	12.4	10.2	2.72	18.4	15.5	23.2	23.2	16.5	23.1		19.0	14.4	17.3	17.7	19.6	13.3		26.4	37.6	15.7	29.2	19.3	14.2
Entrenchment Ratio	2	2.5	2.7	2.7	2.5	2.4	12.5	4.0	4.6	3.8	3.8	4.6	4.3		4.1	5.2	4.7	4.6	4.3	5.4		2.8	2.6	4.0	3.1	3.7	4.3
Wetted Perimeter(ft)	22.6	21.9	22.8	19.2	23.3	20.4	1.7	26.3	23.4	27.6	27.6	22.9	24.7		29.8	23.2	26.6	27.1	28.4	23.3		34.3	38.2	24.6	31.3	27.5	25.8
Hydraulic radius (ft)	1.4	1.7	1.3	1.7	1.3	1.6	20.9	1.3	1.3	1.1	1.1	1.2	1.0		1.5	1.5	1.4	1.3	1.3	1.5		1.2	0.9	1.4	0.9	1.2	1.3
Substrate																											
d50 (mm)		0.09	.08	1.13		15.1		.09	.08	1.44		21.08			.12	1.2	.29					.18	.12	.16		9.06	
d84 (mm)		16.5	.2	3.9		34.5		24.5	.8	5.1		35.9			22.7	14.2	2.6					28.1	8	9.9		19	

Parameter	Cross Section 5 (Station 19+31) Riffle							Cross Section 6 (Station 27+34) Pool							Cross Section 7 (Station 30+41) Riffle												
Dimension	AB*	MY1	MY2	MY3	MY4	MY5	MY+	AB	MY1	MY2	MY3	MY4	MY5	MY6	AB*	MY1	MY2	MY3	MY4	MY5	MY6	MY1	MY2	MY3	MY4	MY5	MY+
BF Width (ft)	26.2	24.9	25.3	23.5	27.9	27.6	18.5	22.5	25.2	25.2	24.5	21.6	23.7	22.3	26	25.5	25.2	25.5	26.7	28.2	25.4						
Floodprone Width (ft)	48	47	46	45	44	46	45	51	41	53	53	56	52	51	50	49	52	53	54	54	59						
BF Cross Sectional Area (ft^2)	50.5	48.3	34.7	28.8	40.5	33.3	31.7	40.2	47.2	55.6	55.6	49.3	48.7	47.6	54.6	57.1	62.7	67.3	66.8	67.8	73.2						
BF Mean Depth (ft)	1.9	1.9	1.4	1.2	1.4	1.2	1.7	1.8	1.9	2.2	2.3	2.3	2.1	2.1	2.1	2.2	2.5	2.6	2.5	2.4	2.9						
BF Max Depth (ft)	2.9	2.8	2.8	2.8	2.9	3.2	2.8	3.8	3.4	4.1	4.1	5	4.3	3.9	3.7	3.6	4.5	4.7	5.1	5	6.4						
Width/Depth Ratio	13.6	12.9	18.4	19.1	19.3	22.9	10.8	12.6	13.5	11.5	10.8	9.5	11.5	10.4	12.4	11.4	10.1	9.7	10.7	11.7	8.8						
Entrenchment Ratio	1.8	1.9	1.8	1.9	1.6	1.7	2.4	2.3	1.6	2.1	2.1	2.6	2.2	2.3	1.9	1.9	2.1	2.1	2	1.9	2.3						
Wetted Perimeter(ft)	27.4	26.1	26.5	24.7	29.2	29.0	22.3	24.3	27.1	28.5	27.9	25.9	27.3	26.7	27.8	27.5	27.8	28.8	31.9	32.3	31.7						
Hydraulic radius (ft)	1.8	1.8	1.3	1.2	1.4	1.1	1.4	1.7	1.7	1.9	2	1.9	1.8	1.8	2	2.1	2.3	2.3	2.1	2.1	2.3						
Substrate																											
d50 (mm)		.06	.16	.14		6			.08	.1	.36					.06	.08	.3		0.89							
d84 (mm)		6.9	6.9	2.6		11.8			11.9	8.7	9.6					26.6	10.5	2.3		7.7							

*As-Built survey data provided by EarthTech from construction inspection surveys taken in 2001. All subsequent surveys were conducted by NC State University

Parameter	MY-01 (2001)			MY-02 (2002)			MY-03 (2003)			MY-04 (2004)			MY-05 (2005)			MY+ (2006)		
Pattern	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med
Channel Beltwidth (ft)																		
Radius of Curvature (ft)				57	103	69												
Meander Wavelength (ft)																		
Meander Width ratio																		
Profile																		
Riffle length (ft)										2.3	17.8	9.1	5.6	45	16.3			
Riffle slope (ft/ft)										.005	.109	.053	.007	.189	.040			
Pool length (ft)										5	54.6	17.5	12.4	89.8	36			
Pool spacing (ft)										10	120	46	25.4	137.3	60.3			
Additional Reach Parameters																		
Valley Length (ft)	2767																	
Channel Length (ft)	3310			3310			3310			3310			3310			3310		
Sinuosity	1.2			1.2			1.2			1.2			1.2			1.2		
Water Surface Slope (ft/ft)	.004 to .015			.004 to .015			.004 to .015			.004 to .015			.004 to .015			.004 to .015		
BF slope (ft/ft)	.01			.01			.01			.01			.01			.01		
Rosgen Classification	C, Bc			E,C, Bc			E,C, Bc			E,C, Bc			E,C, Bc			E,C, Bc		
Number of Bankfull Events	0			1			2			1			1			2		
Extent of BF floodplain (area)																		
BEHI*																		
Habitat Index*																		
Macrobenthos*																		

IV. Methodology Section

Monitoring methods used are based on US Army Corps of Engineering and NC Division of Water Quality Guides as referenced below.

References:

USACOE (2003) *Stream Mitigation Guidelines*. USACOE, USEPA, NCWRC, NCDENR-DWQ

Rosgen, D L. (1996) *Applied River Morphology*. Wildland Hydrology Books, Pagosa Springs, CO.