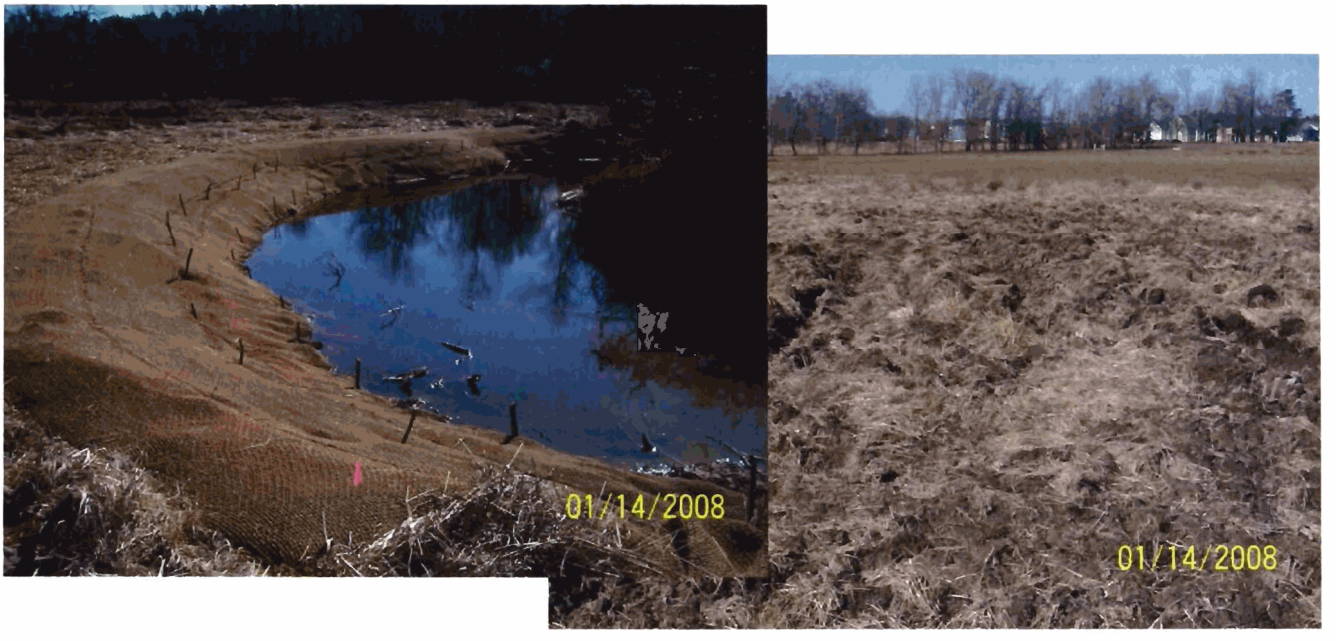
SECTION I. MITIGATION REPORT
TERRIBLE CREEK BUFFER RESTORATION
WAKE COUNTY, NORTH CAROLINA

(SCO Project Number 050667901)
NEUSE RIVER BASIN
CATALOGING UNIT 03020201



Prepared for:

NCDENR

Ecosystem Enhancement PROGRAM

North Carolina Department of Environment and Natural Resources
Ecosystem Enhancement Program
1652 Mail Service Center
Raleigh, North Carolina 27699-1652
EEP Project Manager: Jessica Kemp

June 2008

SECTION I. MITIGATION REPORT
TERRIBLE CREEK BUFFER RESTORATION
WAKE COUNTY, NORTH CAROLINA

(SCO Project Number 050667901)
NEUSE RIVER BASIN
CATALOGING **UNIT** 03020201

Prepared for:

North Carolina Department of Environment and Natural Resources
Ecosystem Enhancement Program
1652 Mail Service Center
Raleigh, North Carolina 27699-1652
EEP Project Manager: Jessica Kemp

Prepared by:

Axiom Environmental, Inc.
2126 **Rowland** Pond Drive
Willow Springs, North Carolina 27592
(919) 215-1693 (phone)
(919) 341-3839 (fax)
Project Manager: Grant Lewis

June 2008

SECTION II. EXECUTIVE SUMMARY

This as-built mitigation plan describes the **Terrible Creek Buffer Restoration Site** (Site) and was designed specifically to assist in fulfilling North Carolina Ecosystem Enhancement Program restoration goals. The Site is located approximately 1 mile northeast of Willow Springs and 4 miles northeast of Fuquay-Varina, in Wake County. This portion of Wake County is located within Neuse River Basin Cataloging Unit 03020201120010. This document details riparian buffer restoration procedures on the 47.84-acre Site, which resulted in a total of 45.6 acres of riparian buffer restoration.

Site drainage features provide water quality function to an approximately 13.0-square mile watershed. The Site is located within a North Carolina Wetlands Restoration Program targeted local watershed; however, Site streams and the receiving stream (Middle Creek) have not been placed on the state's 303(d) list by the North Carolina Division of Water Quality. Terrible Creek has a Best Usage Classification of C, NSW (Nutrient Sensitive Waters) and supports its designated uses.

Pre-construction Site land use consisted primarily of livestock pasture. Terrible Creek was characterized by eroding stream banks and contained a riparian buffer dominated by fescue as well as other herbaceous vegetation. Residential development is currently under construction north of the Site and will continue to expand exacerbating runoff into the Site.

Restoration activities at the Site included

1) one herbicide treatment to control herbaceous species, primarily fescue,
2) bushhogging of the Site and allowing herbaceous vegetation to green up preparing the Site for second herbicide treatment,
3) second herbicide treatment to ensure treatment of herbaceous vegetation that would have otherwise been overtopped,
4) soil discing to prepare the soil bed prior to planting,
5) soil amendments based on NCDA&CS Agronomy Division recommendations from preconstruction soil samples,
6) plant community restoration consisting of Piedmont/Mountain Levee Forest and Piedmont/Mountain Bottomland Forest communities, and
7) outer bend treatments within Terrible Creek.

This Site will serve as a pilot project for outer bend treatments. The erosion status of each outer bend on Terrible Creek within the Site was evaluated and ranked on a qualitative scale. Three outer bend treatments consisting of 1) erosion control matting and live stakes, 2) brush mattresses, and 3) a do nothing alternative were incorporated on bends throughout the Site in order to monitor the progression of each outer bend and compare treatments throughout the monitoring period. As-built the restoration plan restored 45.6 acres of Neuse River Riparian Buffers within the Site boundaries for a total of 45.6 Buffer Mitigation Units.

The primary goals of this buffer restoration project focused on reforestation of the floodplain with native species to

1) improve water quality;
2) enhance flood attenuation;
3) reduce sedimentation/siltation;
4) increase channel bank stability;

5) filter and reduce pollutants prior to entering Terrible Creek;
6) serve as a wildlife corridor by providing connectivity to forested areas adjacent to the Site;
7) provide increased habitat for aquatic and terrestrial wildlife;
8) increase organic matter, carbon export, and woody debris in the stream corridor;
9) restore shade to Site open waters; and
10) enhance characteristic macroinvertebrate species populations in the channel.

Monitoring of restoration efforts will be performed until success criteria are fulfilled; the detailed monitoring plan, success criteria, and contingency plan are outlined in Section 2.0 of this document. Monitoring and success criteria for vegetation are based on the *CVS-EEP Protocol for Recording Vegetation Level 1-2 Plot Sampling Only* (Version 4.0) (Lee et al. 2006). In addition, the outer bend treatments will be evaluated, photographed, and located with GPS as part of the monitoring effort.

Prior to Site construction, a beaver dam was located near the downstream end of the Site and resulted in the mortality of mature hardwood trees in this area. During planting, beaver activity was extremely high and was evidenced by beaver chewed stems and newly built dams. Proactive measures to remove beaver from the Site have been initiated by EEP entering into a contract with APHIS in March 2008 to remove existing beaver and remove any beaver throughout the monitoring period, as necessary.

SECTION III. Table of Contents

Appendices

List of Figures

List of Tables

TERRIBLE CREEK
AS-BUILT MITIGATION PLAN

SECTION IV. INTRODUCTION

The North Carolina Ecosystem Enhancement Program (EEP) completed riparian buffer restoration at Terrible Creek Buffer Restoration Site (Site) located approximately 1 mile northeast of Willow Spring and 4 miles northeast of Fuquay-Varina, in Wake County (Figure 1, Appendix A). The Site is located in United States Geological Survey (USGS) Hydrologic Unit (HU) 03020201120010 (North Carolina Division of Water Quality [NCDWQ] Subbasin 03-04-03) of the Neuse River Basin and will service the USGS 8-digit HU 03020201 (Figure 1, Appendix A) (USGS 1974).

The Site encompasses the left bank of Terrible Creek, several unnamed tributaries to Terrible Creek, floodplains, and jurisdictional wetlands. The Site drains an approximately 13.0-square mile watershed at the Site outfall. Terrible Creek is a fourth-order or greater, bank-to-bank stream system, which had been impacted by vegetative clearing, hoof shear from cattle and horses, and erosive flows. The upstream drainage basin is characterized mainly by agricultural and forest land with interspersed low-density residential development; impervious surfaces appear to account for less than 10 percent of the drainage basin area. Residential development becomes more concentrated southwest of the watershed in the City of Fuquay-Varina and northeast of the watershed in the City of Raleigh. The Site was historically characterized by hardwood forest several decades ago; however, under preconstruction conditions forest vegetation had been cleared and the property was characterized by livestock pasture. The Site contained an abundance of complex microtopography ranging to one foot in vertical symmetry across the landscape most likely remnant from logging operations. A beaver dam is located near the downstream end of the Site and has resulted in the mortality of mature hardwood trees in this area. Several residential developments are currently being constructed immediately north/upslope of the Site.

SECTION IV.1 Restoration Summary

The primary goals of this buffer restoration project focused on reforestation of the Site with native species to 1) improve water quality; 2) enhance flood attenuation; 3) reduce sedimentation/siltation; 4) increase channel bank stability; 5) filter and reduce pollutants prior to entering Terrible Creek; 6) serve as a wildlife corridor by providing connectivity to forested areas adjacent to the Site; 7) provide increased habitat for aquatic and terrestrial wildlife; 8) increase organic matter, carbon export, and woody debris in the stream corridor; 9) restore shade to Site open waters; and 10) enhance characteristic macroinvertebrate species populations in the channel.

The objectives of this project included the following.

- Classify on-Site streams as perennial, intermittent, or ephemeral.
- Identify jurisdictional wetlands within Site boundaries.
- Identify a suitable reference forest to model Site restoration attributes.
- Establish a baseline photographic record of each outer bend of Terrible Creek within the Site.
- Develop a detailed plan of buffer restoration activities within the approximately 47.84-acre conservation easement boundary.
- Establish success criteria and a method of monitoring the Site upon completion of restoration construction.

Restoration activities at the Site included (Figure 2, Appendix A)

1) one herbicide treatment to control herbaceous species, primarily fescue,
2) bushhogging of the Site and allowing herbaceous vegetation to green up preparing the Site for second herbicide treatment,
3) second herbicide treatment to ensure treatment of herbaceous vegetation that would have otherwise been overtopped,
4) soil discing to prepare the soil bed prior to planting,
5) soil amendments based on NCDA&CS Agronomy Division recommendations from preconstruction soil samples,
6) plant community restoration consisting of Piedmont/Mountain Levee Forest and Piedmont/Mountain Bottomland Forest communities, and
7) outer bend treatments within Terrible Creek.

Site restoration efforts resulted in the following.

- Restoration of 45.6 acres of riparian buffer within the Site; therefore, providing 45.6 Buffer Mitigation Units.
- Reforestation within 45.6 acres of the Site with native forest vegetation.
- Installation of outer bend treatments on Terrible Creek.

The primary goals of this buffer restoration project focused on improving water quality, enhancing flood attenuation, and restoring aquatic and riparian habitat and were accomplished by

- Removing nonpoint sources of pollution by providing a vegetative buffer adjacent to streams and wetlands to treat surface runoff.
- Reducing sedimentation within onsite and downstream receiving waters by a) reducing bank erosion associated with vegetation maintenance and agricultural activities to Site streams, b) filtering surface runoff from adjacent developments and reduce particulate matter deposition into area waterways, and c) providing a forested vegetative buffer adjacent to Site streams and wetlands.
- Promoting floodwater attenuation and improving stream stability by a) enhancing depressional floodplain wetlands and the storage capacity for floodwaters within the Site and b) revegetating Site floodplains to reduce floodwater velocities and increase frictional resistance on floodwaters crossing Site floodplains.
- Providing wildlife habitat including a forested riparian corridor within a region of the state increasingly dissected by residential land use.

An additional goal of this riparian buffer restoration project is to study the effects of three different outer bend treatments installed on outer meander bends throughout the Site. The treatments being studied consist of 1) erosion control matting and livestakes, 2) brush mattresses, and 3) do nothing.

SECTION IV.2 Directions to Site

Directions to the Site from Raleigh, North Carolina:

- Take Highway 401 South for approximately 10 miles
- Make a left on Air Park Road
- Travel approximately 0.5 mile to a right into the Stonewall Subdivision
- Take the first right onto Laura Ashley Court and follow to the end of the road
- The Site is at the bottom of the slope

SECTION VI MONITORING PLAN

Monitoring of Site restoration efforts will be performed for vegetation components of the Site until success criteria are fulfilled. In addition, the outer bends will be evaluated, photographed, and located with GPS as part of the monitoring effort. Vegetation monitoring and success criteria are discussed in more detail below. The establishment, collection, and summarization of monitoring data shall be conducted in accordance with the most current version of the EEP document entitled *Content, Format, and Data Requirements for EEP Monitoring Reports.*

SECTION VI.1 Vegetation Monitoring

Restoration monitoring procedures for vegetation are designed in accordance with *CVS-EEP Protocol for Recording Vegetation Level 1-2 Plot Sampling Only* (Version 4.0) (Lee et al. 2006). In February 2008 sixteen vegetation plots (10 meters by 10 meters) were installed within the Site after planting was completed (Figure 4, Appendix A). Baseline vegetation measurements were conducted within each of the sixteen vegetation plots in accordance with the CVS-EEP Protocols; baseline vegetation data can be found in Appendix E.

Quantitative sampling of vegetation will be performed each fall, until vegetation success criteria are achieved. A photographic record of plant growth should be included in each annual monitoring report.

SECTION VI.1.1 Vegetation Success Criteria

Success criteria have been established to verify that the vegetation component supports community elements necessary for forest development. Success criteria are dependent upon the density and growth of characteristic forest species. Additional success criteria are dependent upon density and growth of "Character Tree Species." Character Tree Species include planted species, species identified through visual inventory of an approved reference (relatively undisturbed) forest community used to orient the Site design, and appropriate community descriptions from *Classification of the Natural Communities of North Carolina* (Schafale and Weakley 1990) including Piedmont/Mountain Bottomland Forest and Piedmont/Mountain Levee Forest. All canopy tree species planted and identified in the reference forest will be utilized to define "Character Tree Species" as termed in the success criteria. Tables 1 and 2 below outline planted species and numbers of each species planted within the Site and Table 3 lists reference forest species.

Table 1. Planted Species (Bare Root Seedlings)

Vegetation Association	Piedmont/Mountain Bottomland Forest		Piedmont/Mountain Levee Forest		Stream-side Assemblage		TOTAL
Area (acres)	**35.5**		**8.1**		**2.0**		**45.6**
Species	**Number planted***	**% of total**	**Number planted***	**% of total**	**Number planted****	**% of total**	**Number planted**
Swamp chestnut oak (*Quercus michauxii*)	6000	24.9	--	--	--	--	6000
Cherrybark oak (*Quercus pagoda*)	5900	24.5	1300	23.2	--	--	7200
Green ash (*Fraxinus pennsylvanica*)	2500	10.4	600	10.7	--	--	3100
Shagbark hickory (*Carya ovata*)	2400	10.0	--	--	--	--	2400
Hackberry (*Celtis laevigata*)	2500	10.4	600	10.7	--	--	3100
Painted buckeye (*Asimina triloba*)	4800	19.9	1200	21.4	--	--	6000
Sycamore (*Platanus occidentalis*)	--	--	1300	23.2	--	--	1300
River birch (*Betula nigra*)	--	--	300	5.4	--	--	300
Black walnut (*Juglans nigra*)	--	--	300	5.4	--	--	300
Buttonbush (Cephalanthus occidentalis)	--	--	--	--	4400	80.0	4400
Elderberry (*Sambucus canadensis*)	--	--	--	--	1100	20.0	1100
TOTAL	**24,100**	**100**	**5600**	**100**	**5500**	**100**	**35,200**

* Planted at a density of 680 stems/acre.

** Planted at a density of 2720 stems/acre.

Table 2. Planted Species (1 Gallon Containerized Seedlings)

Species	Number planted
Swamp chestnut oak (*Quercus michauxii*)	25
Cherrybark oak (*Quercus pagoda*)	70
Green ash (*Fraxinus pennsylvanica*)	55
TOTAL	**150**

Table 3. Reference Forest Ecosystem

Reference Forest Ecosystem/Character Tree Species
Red maple (*Acer rubrum*)
River birch (*Betula nigra*)
Ironwood (*Carpinus caroliniana*)
Green ash (*Fraxinus pennsylvanica*)
Sweetgum (*Liquidambar styraciflua*)
Cherrybark oak (*Quercus pagoda*)
Winged elm (*Ulmus alata*)
American elm (*Ulmus americana*)

An average density of 320 stems per acre of Character Tree Species must be surviving after five monitoring years in accordance with North Carolina Division of Water Quality Administrative Code 15A NCAC 02B.0242 (Neuse River Basin, Mitigation Program for Protection and Maintenance of Existing Riparian Buffers) (NCDWQ 2007).

SECTION VI.2 Outer Bend Treatment Monitoring

A baseline photographic record of each Site outer bend of Terrible Creek was compiled and included within the May 2007 *Terrible Creek Detailed Buffer Restoration Plan*. In addition, the apex of each outer bend was located using GPS technology with reported submeter accuracy (Figures 2 and 4, Appendix A). In some cases up to three locations on the same outer bend were located with the GPS due to the length/overall size of the meander. The GPS points will serve as a baseline to monitor if erosion continues post outer bend treatment installation throughout the monitoring period.

Preconstruction the erosion status of each outer bend on Terrible Creek within the Site was evaluated and ranked on a qualitative scale with four erosion categories starting with the lowest extent of erosion consisting of 1) low erosion, 2) moderate erosion, 3) severe erosion, and 4) extreme erosion. Three outer bend treatments consisting of 1) erosion control matting and livestakes, 2) brush mattresses, and 3) do nothing were installed on bends throughout the Site. Outer bend treatments were assigned at random within each of the four erosion categories. The outer bend treatments are depicted in Figures 2 and 4 (Appendix A), and detailed in Figure 3 (Appendix A), and outlined in the following table. Please note that Outer Bends 1 through 3 are not located within the conservation easement and therefore, no treatments were implemented.

Table 4. Outer Bend Treatments

Outer Bend	Extent of Erosion Preconstruction	Treatment to be Installed
1	Low	Outside of easement, no treatment recommended
2	Low	Outside of easement, no treatment recommended
3	Low	Outside of easement, no treatment recommended
4	Moderate	Leave as is
5	Low	Leave as is
6	Moderate	Live stake with erosion control matting
7	Moderate	Brush mattress
8	Severe	Live stake with erosion control matting
9	Moderate	Brush mattress
10	Moderate	Leave as is
11	Severe	Brush mattress
12	Severe	Live stake with erosion control matting
13	Severe	Brush mattress
14	Severe	Leave as is
15	Moderate	Live stake with erosion control matting
16	Moderate	Brush mattress
17	Severe	Brush mattress
18	Extreme	Live stake with erosion control matting
19	Severe	Leave as is
20	Extreme	Brush mattress

Table 4 (continued)

Outer Bend	Extent of Erosion Preconstruction	Treatment to be Installed
21	Extreme	Leave as is
22	Severe	Live stake with erosion control matting
23	Severe	Brush mattress
24	Severe	Leave as is
25	Extreme	Brush mattress
26	Extreme	Leave as is
27	Severe	Brush mattress
28	Severe	Live stake with erosion control matting
29	Severe	Leave as is
30	Extreme	Live stake with erosion control matting

SECTION VI.3 Beaver Management

Prior to Site construction, a beaver dam was located near the downstream end of the Site and resulted in the mortality of mature hardwood trees in this area. During planting, beaver activity was extremely high and was evidenced by beaver chewed stems and newly built dams. Proactive measures to remove beaver from the Site have been initiated by EEP entering into a contract with APHIS in March 2008 to remove existing beaver and remove any beaver throughout the monitoring period, as necessary.

SECTION VII VEGETATION CONTINGENCY

If vegetation success criteria are not achieved based on average density calculations from combined plots over the entire restoration area, supplemental planting may be performed with tree species in the approved Restoration Plan. Supplemental planting will be performed as needed until achievement of vegetation success criteria.

SECTION VIII REFERENCES

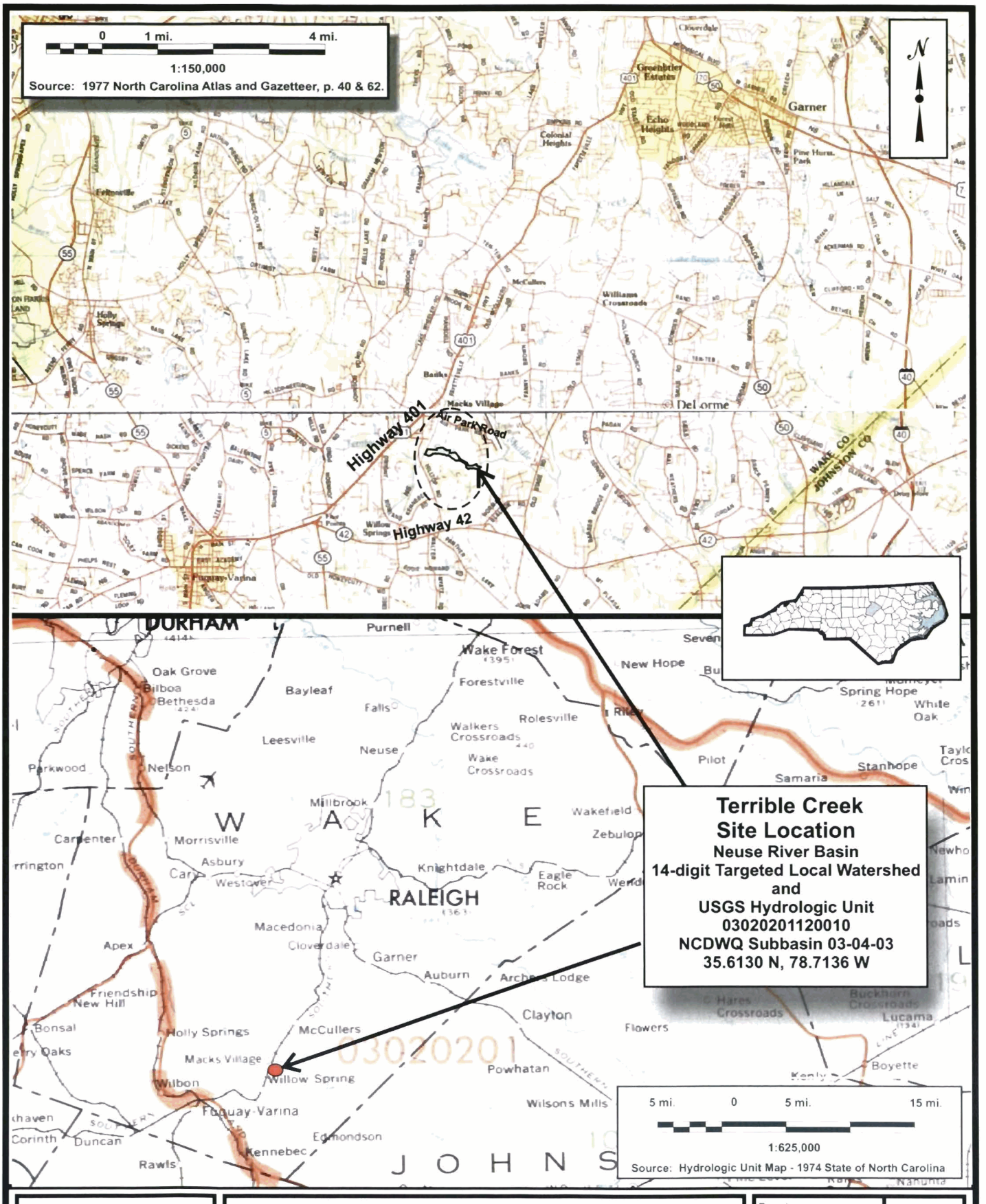
Lee, M.T., R.K. Peet, S.D. Roberts, and T.R. Wentworth. 2006. CVS-EEP Protocol for Recording Vegetation. Version 4.0. North Carolina Department of Environment and Natural Resources, Ecosystem Enhancement Program. Raleigh, North Carolina.

North Carolina Division of Water Quality (NCDWQ). 2007. Redbook, Surface Waters and Wetlands Standards. North Carolina Department of Environment and Natural Resources, Division of Water Quality. Raleigh, North Carolina.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communities of North Carolina: Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, North Ccarolina Department of Environment, Health, and Natural Resources. Raleigh, North Carolina.

United States Geological Survey (USGS). 1974. Hydrologic Unit Map - 1974. State of North Carolina.

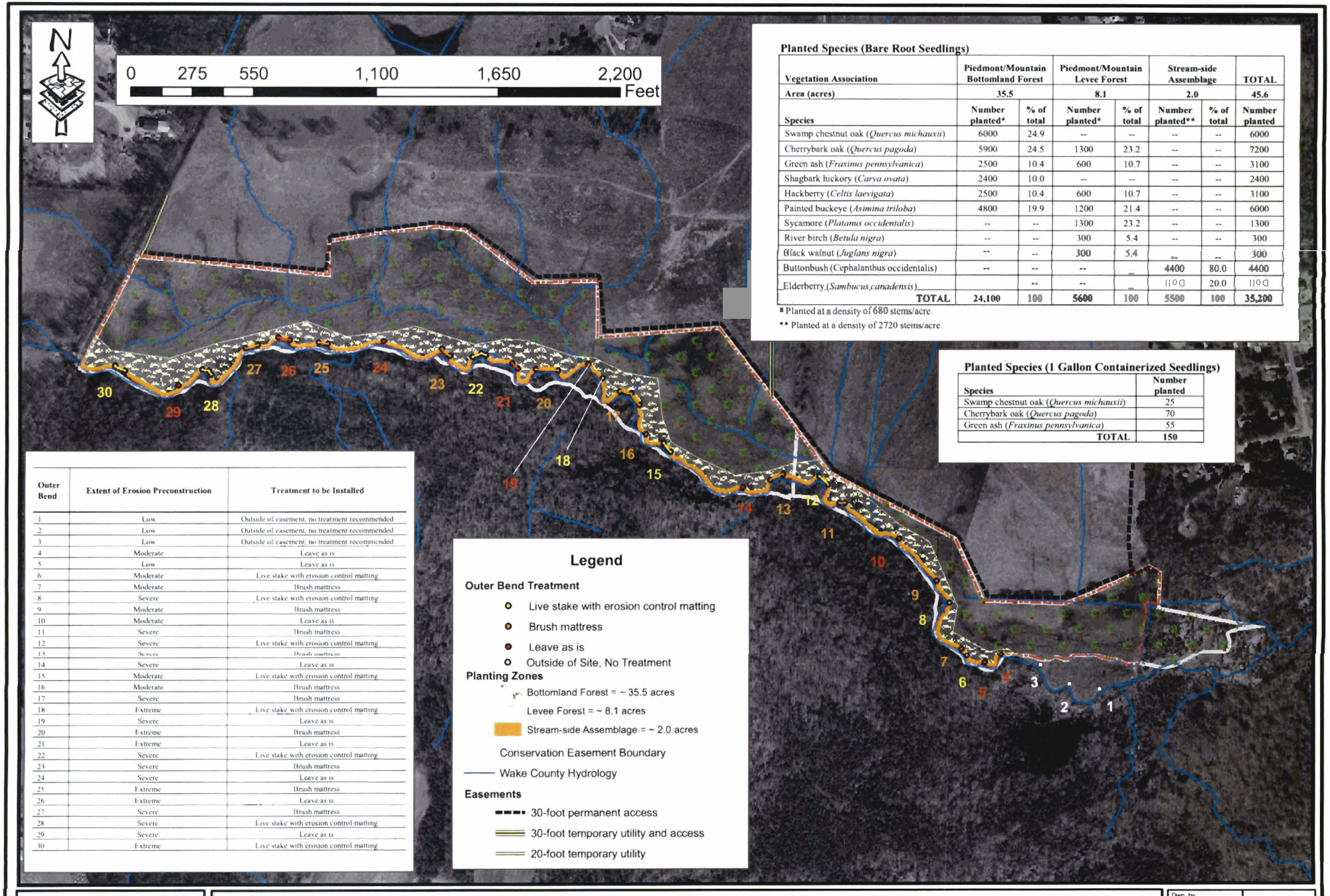
Appendix A.
Section V Figures



Axiom Environmental, Inc.
2126 Rowland Pond Drive
Willow Spring, NC 27592
(919) 215-1693
(919) 341-3839 fax

SITE LOCATION
TERRIBLE CREEK
AS-BUILT MITIGATION PLAN
Wake County, North Carolina

Dwn. by: CLF	FIGURE
Date: Feb 2008	1
Project: 06-013	



Planted Species (Bare Root Seedlings)

Vegetation Association	Piedmont/Mountain Bottomland Forest		Piedmont/Mountain Levee Forest		Stream-side Assemblage		TOTAL
Area (acres)	35.5		8.1		2.0		45.6
Species	Number planted*	% of total	Number planted*	% of total	Number planted**	% of total	Number planted
Swamp chestnut oak (*Quercus michauxii*)	6000	24.9	--	--	--	--	6000
Cherrybark oak (*Quercus pagoda*)	5900	24.5	1300	23.2	--	--	7200
Green ash (*Fraxinus pennsylvanica*)	2500	10.4	600	10.7	--	--	3100
Shagbark hickory (*Carya ovata*)	2400	10.0	--	--	--	--	2400
Hackberry (*Celtis laevigata*)	2500	10.4	600	10.7	--	--	3100
Painted buckeye (*Asimina triloba*)	4800	19.9	1200	21.4	--	--	6000
Sycamore (*Platanus occidentalis*)	--	--	1300	23.2	--	--	1300
River birch (*Betula nigra*)	--	--	300	5.4	--	--	300
Black walnut (*Juglans nigra*)	--	--	300	5.4	--	--	300
Buttonbush (Cephalanthus occidentalis)	--	--	--	--	4400	80.0	4400
Elderberry (*Sambucus canadensis*)	--	--	--	--	1100	20.0	1100
TOTAL	24,100	100	5600	100	5500	100	35,200

* Planted at a density of 680 stems/acre.

** Planted at a density of 2720 stems/acre.

Planted Species (1 Gallon Containerized Seedlings)

Species	Number planted
Swamp chestnut oak (*Quercus michauxii*)	25
Cherrybark oak (*Quercus pagoda*)	70
Green ash (*Fraxinus pennsylvanica*)	55
TOTAL	150

Outer Bend	Extent of Erosion Preconstruction	Treatment to be Installed
1	Low	Outside of easement, no treatment recommended
2	Low	Outside of easement, no treatment recommended
3	Low	Outside of easement, no treatment recommended
4	Moderate	Leave as is
5	Low	Leave as is
6	Moderate	Live stake with erosion control matting
7	Moderate	Brush mattress
8	Severe	Live stake with erosion control matting
9	Moderate	Brush mattress
10	Moderate	Leave as is
11	Severe	Brush mattress
12	Severe	Live stake with erosion control matting
13	Severe	Brush mattress
14	Severe	Leave as is
15	Moderate	Live stake with erosion control matting
16	Moderate	Brush mattress
17	Severe	Brush mattress
18	Extreme	Live stake with erosion control matting
19	Severe	Leave as is
20	Extreme	Brush mattress
21	Extreme	Leave as is
22	Severe	Live stake with erosion control matting
23	Severe	Brush mattress
24	Severe	Leave as is
25	Extreme	Brush mattress
26	Extreme	Leave as is
27	Severe	Brush mattress
28	Severe	Live stake with erosion control matting
29	Severe	Leave as is
30	Extreme	Live stake with erosion control matting

Legend

Outer Bend Treatment

- Live stake with erosion control matting
- Brush mattress
- Leave as is
- Outside of Site, No Treatment

Planting Zones

- Bottomland Forest = ~ 35.5 acres
- Levee Forest = ~ 8.1 acres
- Stream-side Assemblage = ~ 2.0 acres
- Conservation Easement Boundary
- Wake County Hydrology

Easements

- 30-foot permanent access
- 30-foot temporary utility and access
- 20-foot temporary utility

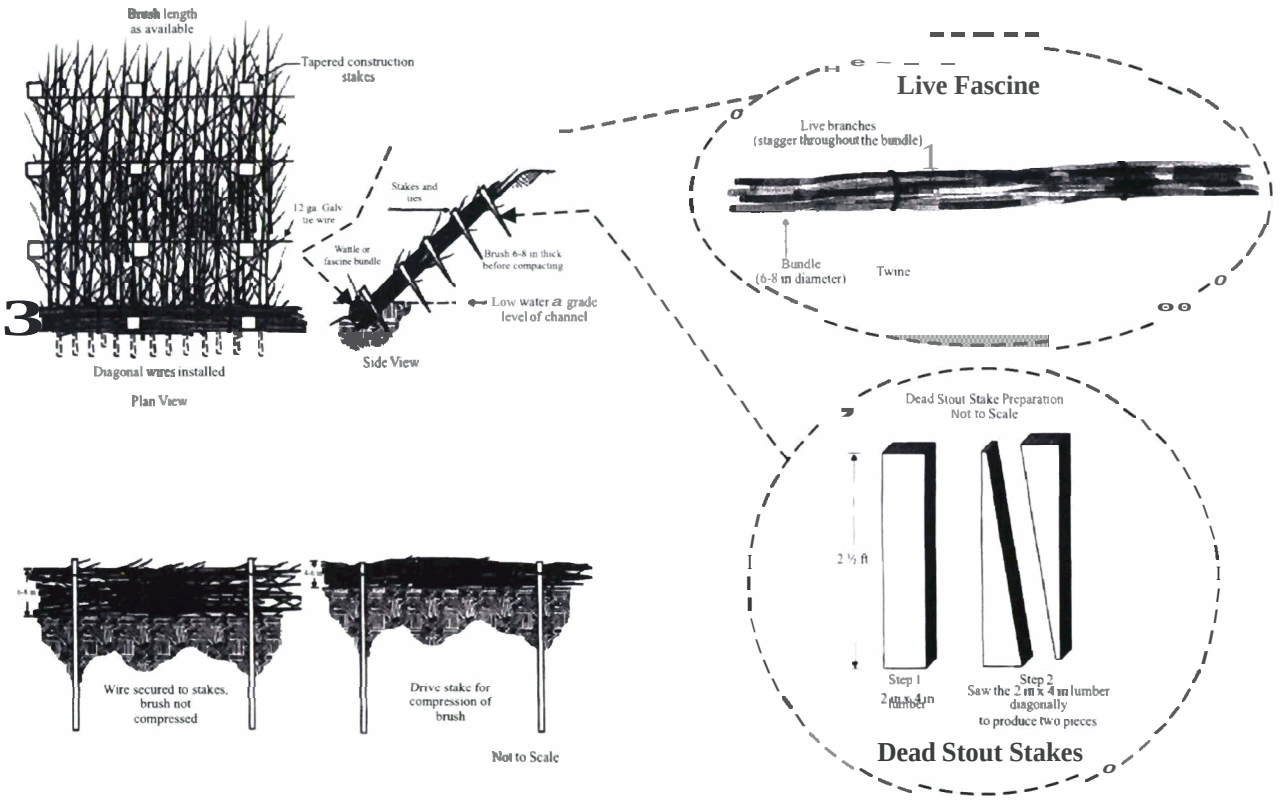
Axiom Environmental, Inc.
2126 Rowland Pond Drive
Willow Spring, NC 27592
(919) 215-1693
(919) 341-3839 fax

PROJECT MAP & RESTORATION ACTIVITIES
TERRIBLE CREEK MITIGATION REPORT
Wake County, North Carolina

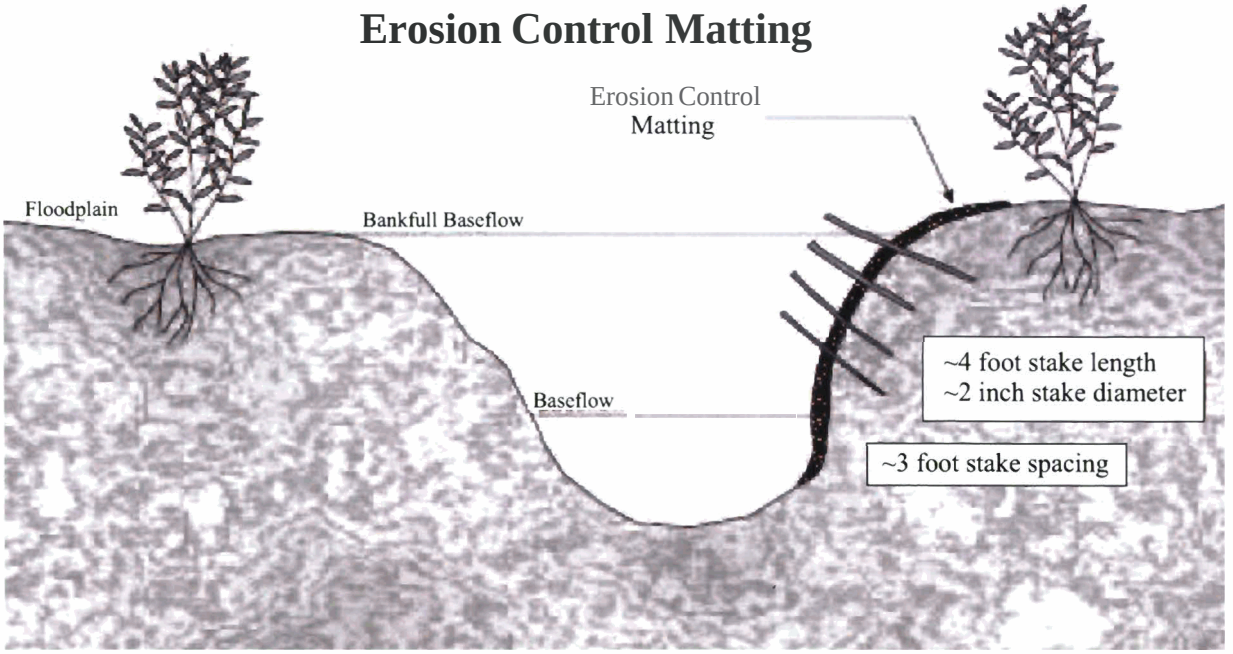
Dwn. by: CLF
Date: February 2008
Project: 06-013

FIGURE 2

Brush Mattress



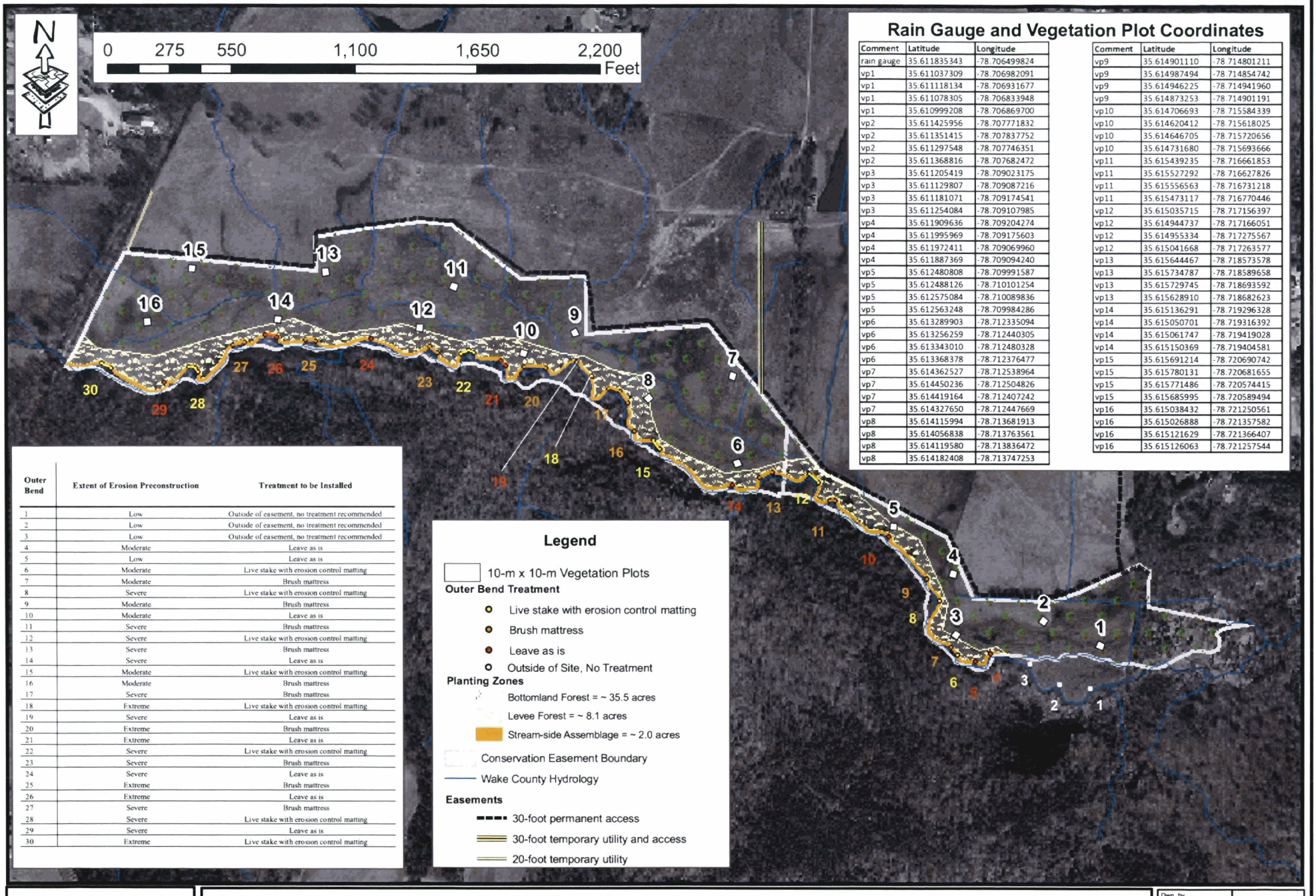
Live Stake Embankment with Erosion Control Matting



2126 Rowland Pond Drive
Willow Spring, NC 27592
(919) 2151693
(919) 341-3839 fax
Axiom Environmental, Inc.

OUTER BEND TREATMENT DETAILS
TERRIBLE CREEK MITIGATION REPORT
Wake County, North Carolina

Dwn. by: CLF	FIGURE
Date: February 2008	3
JT : 06-013	



Rain Gauge and Vegetation Plot Coordinates

Comment	Latitude	Longitude
rain gauge	35.611835343	-78.706499824
vp1	35.611037309	-78.706982091
vp1	35.611118134	-78.706931677
vp1	35.611078305	-78.706833948
vp1	35.610999208	-78.706869700
vp2	35.611425956	-78.707771832
vp2	35.611351415	-78.707837752
vp2	35.611297548	-78.707746351
vp2	35.611368816	-78.707682472
vp3	35.611205419	-78.709023175
vp3	35.611129807	-78.709087216
vp3	35.611181071	-78.709174541
vp3	35.611254084	-78.709107985
vp4	35.611909636	-78.709204274
vp4	35.611995969	-78.709175603
vp4	35.611972411	-78.709069960
vp4	35.611887369	-78.709094240
vp5	35.612480808	-78.709991587
vp5	35.612488126	-78.710101254
vp5	35.612575084	-78.710089836
vp5	35.612563248	-78.709984286
vp6	35.613289903	-78.712335094
vp6	35.613256259	-78.712440305
vp6	35.613343010	-78.712480328
vp6	35.613368378	-78.712376477
vp7	35.614362527	-78.712538964
vp7	35.614450236	-78.712504826
vp7	35.614419164	-78.712407242
vp7	35.614327650	-78.712447669
vp8	35.614115994	-78.713681913
vp8	35.614056838	-78.713763561
vp8	35.614119580	-78.713836472
vp8	35.614182408	-78.713747253

Comment	Latitude	Longitude
vp9	35.614901110	-78.714801211
vp9	35.614987494	-78.714854742
vp9	35.614946225	-78.714941960
vp9	35.614873253	-78.714901191
vp10	35.614706693	-78.715584339
vp10	35.614620412	-78.715618025
vp10	35.614646705	-78.715720656
vp10	35.614731680	-78.715693666
vp11	35.615439235	-78.716661853
vp11	35.615527292	-78.716627826
vp11	35.615556563	-78.716731218
vp11	35.615473117	-78.716770446
vp12	35.615035715	-78.717156397
vp12	35.614944737	-78.717166051
vp12	35.614955334	-78.717275567
vp12	35.615041668	-78.717263577
vp13	35.615644467	-78.718573578
vp13	35.615734787	-78.718589658
vp13	35.615729745	-78.718693592
vp13	35.615628910	-78.718682623
vp14	35.615136291	-78.719296328
vp14	35.615050701	-78.719316392
vp14	35.615061747	-78.719419028
vp14	35.615150369	-78.719404581
vp15	35.615691214	-78.720690742
vp15	35.615780131	-78.720681655
vp15	35.615771486	-78.720574415
vp15	35.615685995	-78.720589494
vp16	35.615038432	-78.721250561
vp16	35.615026888	-78.721357582
vp16	35.615121629	-78.721366407
vp16	35.615126063	-78.721257544

Outer Bend	Extent of Erosion Preconstruction	Treatment to be Installed
1	Low	Outside of easement, no treatment recommended
2	Low	Outside of easement, no treatment recommended
3	Low	Outside of easement, no treatment recommended
4	Moderate	Leave as is
5	Low	Leave as is
6	Moderate	Live stake with erosion control matting
7	Moderate	Brush mattress
8	Severe	Live stake with erosion control matting
9	Moderate	Brush mattress
10	Moderate	Leave as is
11	Severe	Brush mattress
12	Severe	Live stake with erosion control matting
13	Severe	Brush mattress
14	Severe	Leave as is
15	Moderate	Live stake with erosion control matting
16	Moderate	Brush mattress
17	Severe	Brush mattress
18	Extreme	Live stake with erosion control matting
19	Severe	Leave as is
20	Extreme	Brush mattress
21	Extreme	Leave as is
22	Severe	Live stake with erosion control matting
23	Severe	Brush mattress
24	Severe	Leave as is
25	Extreme	Brush mattress
26	Extreme	Leave as is
27	Severe	Brush mattress
28	Severe	Live stake with erosion control matting
29	Severe	Leave as is
30	Extreme	Live stake with erosion control matting

Legend

10-m x 10-m Vegetation Plots

Outer Bend Treatment

- Live stake with erosion control matting
- Brush mattress
- Leave as is
- Outside of Site, No Treatment

Planting Zones

- Bottomland Forest = ~ 35.5 acres
- Levee Forest = ~ 8.1 acres
- Stream-side Assemblage = ~ 2.0 acres

Conservation Easement Boundary

Wake County Hydrology

Easements

- 30-foot permanent access
- 30-foot temporary utility and access
- 20-foot temporary utility

Axiom Environmental, Inc.
2126 Rowland Pond Drive
Willow Spring, NC 27592
(919) 215-1693
(919) 341-3839 fax

Axiom Environmental, Inc.

MONITORING PLAN
TERRIBLE CREEK MITIGATION REPORT
Wake County, North Carolina

Dwn. by: CLF

Date: February 2008

Project: 06-013

FIGURE 4

Appendix B.
Preconstruction Photographs

Preconstruction Photographs
July 2006
looking across the floodplain
at the fallow pasture

Appendix C.
Preconstruction Outer Bend Erosion Photographs

Outer Bend #1 - Looking Upstream
at beaver dam.
(Low Erosion)

Outer Bend #2 - looking upstream
approximately **150** feet upstream from beaver dam.
(Low Erosion)

Outer Bend #3 - Looking Upstream
approximately **400** ft upstream from beaver dam,
still in impounded reach.
(Low Erosion)

Outer Bend #4 - Looking Upstream
approximately **500** ft upstream from beaver dam,
still in impounded reach.
(Moderate Erosion)

Outer Bend #5 - Looking Upstream
a bend with a larger radius.
(Low Erosion)

Outer Bend #6 - Looking Upstream
in a double outer bend.
(Moderate Erosion)

Outer Bend #7 - Looking Upstream
Privet on opposite bank may causing erosion on Site bank.
(Moderate Erosion)

Outer Bend #8 - Looking Upstream
(Severe Erosion)

Outer Bend #9 - Looking Upstream
at outer bend in a straight, immediately upstream from a tight radius.
(Moderate Erosion)

Outer Bend #10 - Looking Upstream
at tight radius below a large river birch.
Moderate Erosion)

Outer Bend **#11** - Looking Upstream
at tight radius. **A** fallen tree has cause
a hole in the bank.
(Severe Erosion)

Outer Bend **#11** - Looking Downstream
at fallen tree causing a hole in the bank.
(Severe Erosion)

Outer Bend **#12** - Looking Upstream
(Severe Erosion)

Outer Bend **#12** - Looking Upstream
(Severe Erosion)

Outer Bend **#13** - Looking Upstream
A fallen tree may be causing erosion
on Site stream banks.
(Severe Erosion)

Outer Bend **#13** - Looking Upstream
A fallen tree may be causing erosion
on Site stream banks.
(Severe Erosion)

Outer Bend #**14** - Looking Upstream
at tight radius caused by point bar and
transverse bar.
(Severe Erosion)

Outer Bend #15 - Looking Upstream
at a long bend with two stumps extending
into the stream.
(Moderate Erosion)

Outer Bend #**16** - Looking Upstream
at tight bends. This is not a good reach for
bank stabilization comparisons.
(Moderate Erosion)

Outer Bend #**16** - Looking Upstream
at tight bends. This is not a good reach for
bank stabilization comparisons.
(Moderate Erosion)

Outer Bend **#17** - Looking Upstream
(Severe Erosion)

Outer Bend **#17** - Looking Downstream
(Severe Erosion)

Outer Bend **#18** - Looking Upstream
(Extreme Erosion)

Outer Bend **#19** - Looking Upstream
(Severe Erosion)

Outer Bend **#20** - Looking Upstream
at a long bend with a tight radius in the
middle of the bend.
(Extreme Erosion)

Outer Bend **#20** - Looking Downstream
at a long bend with a tight radius in the
middle of the bend.
(Extreme Erosion)

Outer Bend #21 - Looking Upstream
at bank sloughing
(Extreme Erosion)

Outer Bend #**22** - Looking Upstream
at lateral migration of outer bend with
point bar extension into the stream bed.
(Severe Erosion)

Outer Bend #**23** - Looking Upstream
at root balls in channel and bank sloughing
(Severe Erosion)

Outer Bend #**24** - Looking Upstream
at a short reach of erosion.
(Severe Erosion)

Outer Bend #25 - Looking Upstream
at transverse bar and tight radius at upper
reach of the bend.
(Extreme Erosion)

Outer Bend #26 - Looking Upstream
at migrating outer bend and extension of
point barltransverse bar at lower
reach of bend.
(Extreme Erosion)

Outer Bend #27 - Looking Upstream
at erosion on low slope reach.
(Severe Erosion)

Outer Bend **#28** - Looking Upstream
at potential shoot cutoff development.
(Severe Erosion)

Outer Bend **#28** - Looking Downstream
at potential shoot cutoff development.
(Severe Erosion)

Outer Bend #29 - Looking Upstream
at shoot cutoff. Not a good bank erosion
treatment comparison area.
(Severe Erosion)

Outer Bend #30 - Looking Upstream
at lateral migration of out bend with extension
of point bar into the stream bed.
(Extreme Erosion)

Appendix D.
During Construction Photographs

During Construction

After Discing

Outer Bends 6 (Live stake with erosion control matting) and 7 (Brush Mattress)

Outer Bend 8
(Live stake with erosion control matting)

Outer Bend 9 (Brush Mattress)

Outer Bend 11 (Brush Mattress)

Outer Bend 12
(Live stake with erosion control matting)

During Construction
(continued)

Outer Bend 13 (Brush Mattress)

Outer Bend 15
(Live stake with erosion control matting)

Outer Bend 16 (Brush Mattress)

Outer Bend 17 (Brush Mattress)

Outer Bend 18
(Live stake with erosion control matting)

Outer Bend 19 (No Treatment)

During Construction
(continued)

Outer Bend 20 (Brush Mattress)

Outer Bend 22
(Live stake with erosion control matting)

Outer Bend 23 (Brush Mattress)

Outer Bend 25 (Brush Mattress)

Outer Bend 27
(Brush Mattress)

Outer Bend 28
(Live stake with erosion control matting)

During Construction
(continued)

Outer Bend 30
(Live stake with erosion control matting)

Evidence of Bankfull Event in January 2008

Appendix E.
Baseline As-built Vegetation Data

Report Prepared By	Corri Faquin
Date Prepared	3/30/2008 19:10

database name	Axiom_2008-CVS_EEP_EntryTool_v220.mdb
database location	C:\Business\Projects\06\06-013 Terrible Creek\as-built mitigation plan\CVS
computer name	AXIOM-0A9116A70

DESCRIPTION OF WORKSHEETS IN THIS DOCUMENT--------

Metadata	This worksheet, which is a summary of the project and the project data.
Proj, planted	Each project is listed with its PLANTED stems, for each year. This excludes live stakes and lists stems per acre.
Proj, total stems	Each project is listed with its TOTAL stems, for each year. This includes live stakes, all planted stems, and all natural/volunteer stems. Listed in stems per acre.
Plots	List of plots surveyed.
Vigor	Frequency distribution of vigor classes.
Vigor by Spp	Frequency distribution of vigor classes listed by species.
Damage	List of most frequent damage classes with number of occurrences and percent of total stems impacted by each.
Damage by Spp	Damage values tallied by type for each species.
Damage by Plot	Damage values tallied by type for each plot.
ALL Stems by Plot and spp	Count of total living stems of each species (planted and natural volunteers combined) for each plot; dead and missing stems are excluded.

PROJECT SUMMARY----------

Project Code	50667901
project Name	Terrible Creek
Description	Buffer Restoration Site
River Basin	
length(ft)	
stream-to-edge width (ft)	
area (sq m)	
Required Plots (calculated)	
Sampled Plots	16

Table 1. Living planted stems, excluding live stakes, per acre.

Project Code	Project Name	Year 0 (baseline)
050667901	Terrible Creek	670

Table 2. Total stems, including planted stems of all kinds (including live stakes) and natural/volunteer stems per acre.

Project Code	Project Name	Year 0 (baseline)
050667901	Terrible Creek	680

Table 3 Plots (Plot Level 2, Year 0)

Latitude/ Northing	Longitude/ Easting	Datum	Date Sampled	Planted Living Stems	Planted Living Stems EXCLUDING Live Stakes	Dead/ Missing Stems	Natural (Volunteer) Stems	Total Living Stems	Total Living Stems EXCLUDING Live Stakes	Planted Living Stems per ACRE	Planted Living Stems EXCLUDING Live Stakes PER ACRE	Natural (Volunteer) Stems PER ACRE	Total Living Stems PER ACRE	Total Living Stems EXCLUDING Live Stakes PER ACRE	# species
35.611037309	-78.706982091	NAD83/WGS84	3/18/2008	21	21	0	4	25	25	850	850	162	1012	1012	3
35.614646705	-78.715720656	NAD83/WGS84	3/25/2008	13	13	1	0	13	13	526	526	0	526	526	4
35.615473117	-78.716770446	NAD83/WGS84	3/25/2008	20	20	0	0	20	20	809	809	0	809	809	3
35.614955334	-78.717275567	NAD83/WGS84	3/25/2008	21	21	0	0	21	21	850	850	0	850	850	2
35.615628910	-78.718682623	NAD83/WGS84	3/25/2008	17	17	0	0	17	17	688	688	0	688	688	2
35.615061747	-78.719419028	NAD83/WGS84	3/25/2008	10	10	0	0	10	10	405	405	0	405	405	4
35.615691214	-78.720690742	NAD83/WGS84	3/25/2008	16	16	0	0	16	16	647	647	0	647	647	3
35.615026888	-78.721357582	NAD83/WGS84	3/25/2008	19	19	0	0	19	19	769	769	0	769	769	2
35.611351415	-78.707837752	NAD83/WGS84	3/18/2008	17	17	0	0	17	17	688	688	0	688	688	1
35.611181070	-78.709174541	NAD83/WGS84	3/18/2008	13	13	0	0	13	13	526	526	0	526	526	4
35.611909636	-78.709204274	NAD83/WGS84	3/18/2008	15	15	0	0	15	15	607	607	0	607	607	3
35.612488126	-78.710101254	NAD83/WGS84	3/18/2008	18	18	0	0	18	18	728	728	0	728	728	5
35.613256259	-78.712440305	NAD83/WGS84	3/18/2008	13	13	0	0	13	13	526	526	0	526	526	6
35.61436252	-78.712538964	NAD83/WGS84	3/18/2008	15	15	0	0	15	15	607	607	0	607	607	2
35.614119580	-78.713836472	NAD83/WGS84	3/18/2008	21	21	0	0	21	21	850	850	0	850	850	4
35.614873253	-78.714901191	NAD83/WGS84	3/18/2008	16	16	0	0	16	16	647	647	0	647	647	3

Table 4. Vigor

Vigor	Count	Percent
0	1	0.4
1	8	3
2	45	16.9
3	206	77.4
4	6	2.3

Table 5. Vigor by Species

	Species	4	3	2	1	0	Missing
	Asimina triloba		37	9		1	
	Betula nigra	1	1				
	Carya ovata		5	2			
	Celtis laevigata		8	8	2		
	Fraxinus pennsylvanica	2	38	6	1		
	Juglans nigra		4	1			
	Quercus	2	112	16	4		
	Unknown	1	1	3	1		
Total	**8**	**6**	**206**	**45**	**8**	**1**	

Table 6. Damage

Damage	Count	Percent Of Stems
(no damage)	254	95.5
Drought	9	3.4
(other damage)	3	1.1

Table 7. Damage by Species

	Species	All Damage Categories	(no damage)	Drought	(other damage)
	Asimina triloba	47	46	1	
	Betula nigra	2	2		
	Carya ovata	7	7		
	Celtis laevigata	18	16	2	
	Fraxinus pennsylvanica	47	46	1	
	Juglans nigra	5	5		
	Quercus	134	130	4	
	Unknown	6	2	1	3
Total	**8**	**266**	**254**	**9**	**3**

Table 8. Damage by Plot

	Plot	All Damage Categories	(no damage)	Drought	(other damage)
	050667901-01-0001	21	21		
	050667901-01-0002	17	13	4	
	050667901-01-0003	13	13		
	050667901-01-0004	15	13	1	1
	050667901-01-0005	18	16	1	1
	050667901-01-0006	13	13		
	050667901-01-0007	15	15		
	050667901-01-0008	21	21		
	050667901-01-0009	16	16		
	050667901-01-0010	14	13	1	
	050667901-01-0011	20	17	2	1
	050667901-01-0012	21	21		
	050667901-01-0013	17	17		
	050667901-01-0014	10	10		
	050667901-01-0015	16	16		
	050667901-01-0016	19	19		
Total	**16**	**266**	**254**	**9**	**3**

Table 9. Planted Stems by Plot and Species

	Species	Total Planted Stems	# plots	Avg # stems	plot 1	plot 2	plot 3	plot 4	plot 5	plot 6	plot 7	plot 8	plot 9	plot 10	plot 11	plot 12	plot 13	plot 14	plot 15	plot 16
	Asimina triloba	46	9	5.11			1		6	2	9	6	6	5		5	6			
	Betula nigra	2	2	1						1				1						
	Carya ovata	7	3	2.33			4					2							1	
	Celtis laevigata	18	5	3.6					4	2				2	8			2		
	Fraxinus pennsylvanica	47	10	4.7	6		4	5	4	1		10	5					1	5	6
	Juglans nigra	5	3	1.67					2	1								2		
	Quercus	134	15	8.93	13	17	4	9		6	6	3	5	5	11	16	11	5	10	13
	Unknown	6	4	1.5	2			1	2						1					
Total	**8**	**265**	**8**		**21**	**17**	**13**	**15**	**18**	**13**	**15**	**21**	**16**	**13**	**20**	**21**	**17**	**10**	**16**	**19**

Table 10. All Stems by Plot and Species

	Species	Total Planted Stems	# plots	Avg # stems	plot 1	plot 2	plot 3	plot 4	plot 5	plot 6	plot 7	plot 8	plot 9	plot 10	plot 11	plot 12	plot 13	plot 14	plot 15	plot 16
	Betula nigra	2	2	1						1				1						
	Carya ovata	7	3	2.33			4					2							1	
	Celtis laevigata	18	5	3.6					4	2				2	8			2		
	Cephalanthus occidentalis	4	1	4	4															
	Fraxinus pennsylvanica	47	10	4.7	6		4	5	4	1		10	5					1	5	6
	Juglans nigra	5	3	1.67					2	1								2		
	Quercus	134	15	8.93	13	17	4	9		6	6	3	5	5	11	16	11	5	10	13
	Unknown	6	4	1.5	2			1	2						1					
Total	**9**	**270**	**9**		**25**	**17**	**13**	**15**	**18**	**13**	**15**	**21**	**16**	**14**	**20**	**21**	**17**	**10**	**16**	**19**