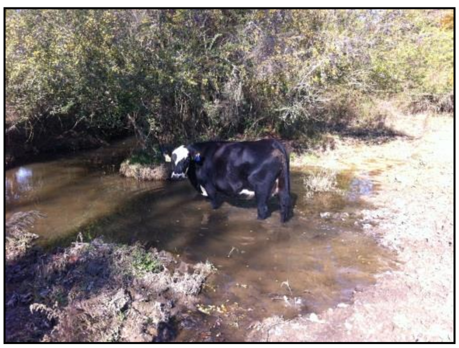
MITIGATION PLAN

Hopewell Stream Mitigation Site
Randolph County, North Carolina
DENR Contract No. 004642
EEP ID #95352

Yadkin River Basin
HUC 03040104



Prepared for:

NC Department of Environment and Natural Resources
Ecosystem Enhancement Program
1652 Mail Service Center
Raleigh, NC 27699-1652

October 2013

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Ocotber 2013

EXECUTIVE SUMMARY

Wildlands Engineering, Inc. (Wildlands) is developing a full delivery project for the North Carolina Ecosystem Enhancement Program (EEP) to restore, enhance, and preserve a total of 12,519 existing linear feet (LF) of perennial and intermittent stream in Randolph County, NC. The streams proposed for restoration include UT2 (a tributary to Little River) UT2A, a portion of UT2B, and a portion of UT2C (all tributaries to UT2). Enhancement activities are proposed for a portion of Little River, a portion of UT1A, UT1B, a portion of UT2B, and a portion of UT2C. Preservation is proposed on short reaches of Little River and UT1A. This site is located in the Yadkin-Pee Dee River Basin within hydrologic unit (HU) 03040104 (Yadkin 04). The project is intended to provide 7,463 stream mitigation units.

The Hopewell Stream Mitigation Site (project site) is located in the Little River watershed (HU 03040104030010). The 2009 Lower Yadkin Pee-Dee River Basin Restoration Priorities (RBRP) plan identified the Little River watershed as a Targeted Local Watershed (TLW). The RBRP plan does not specifically identify stressors or project goals in this TLW but states that continuing watershed improvements will increase ecological uplift.

The proposed project will help meet the goals for the watershed outlined in the RBRP and provide numerous ecological benefits within the Yadkin-Pee Dee River Basin. While many of these benefits are limited to the Hopewell project area, others, such as pollutant removal, reduced sediment loading, and improved aquatic and terrestrial habitat, have farther-reaching effects.

This mitigation plan has been written in conformance with the requirements of the following:

- Federal rule for compensatory mitigation project sites as described in the Federal Register Title 33 Navigation and Navigable Waters Volume 3 Chapter 2 Section § 332.8 paragraphs (c)(2) through (c)(14).
- NCDENR Ecosystem Enhancement Program In-Lieu Fee Instrument signed and dated July 28, 2010.

These documents govern EEP operations and procedures for the delivery of compensatory mitigation.

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1.0 Restoration Project Goals and Objectives

The Hopewell Stream Mitigation Site is located in the Lower Yadkin-Pee Dee River Basin within hydrologic unit (HU) 03040104030010, the Little River watershed. The 2009 Lower Yadkin Pee-Dee River Basin Restoration Priorities (RBRP) identified the Little River watershed as a Targeted Local Watershed (TLW) http://portal.ncdenr.org/c/document_library/get_file?uuid=081b34ec-8b4c-434f-9e25-57c713cb136c&groupId=60329. Land cover within the Little River watershed is 13% agricultural including 56 animal operations. The watershed is adjacent to the City of Asheboro and is 1.9% impervious. A total of 18.3% of the streams within the watershed are without riparian buffers. There are 38 documented Natural Heritage Element Occurrences (NHEO) and 3.65% of the watershed is classified as Significant Natural Heritage Area (SNHA). The watershed also includes a NC Wildlife Resources Commission priority area and land protected by the Nature Conservancy. There are 17 miles of Outstanding Resource Waters in the watershed. There is a SNHA (Upper Little River Aquatic Habitat) that provides habitat for an NHEO approximately 2.8 miles downstream of the project site.

The 2009 Lower Yadkin Pee-Dee River Basin RBRP does not specifically identify stressors or project goals in this TLW but states that continuing watershed improvements will increase ecological uplift. For the 8-digit HU that includes this TLW, 03040104, there are multiple streams listed for impairment of aquatic life including the Pee Dee River downstream of the project site. Point and non-point source pollution, such wastewater discharges and stormwater runoff, are listed as causes of the impairments. The Yadkin Pee-Dee River Basinwide Plan prepared by the North Carolina Division of Water Quality (DWQ) cites runoff from agricultural operations and the inability of small streams to assimilate waste loads as contributing factors to stream impairment in this 8-digit HU. The RBRP describes the goals for the 8-digit HU as the following:

- Continuation of watershed improvement efforts already on-going;
- Protection of valuable natural resources; and
- Development of local partnerships that will work together to implement management strategies for stormwater impacts.

The Hopewell Stream Mitigation Project will contribute to meeting management goals as described above for the Yadkin-Pee Dee Catalog Unit 03040104 and the Little River TLW by:

- Restoring a degraded stream impacted by cattle to create and improve aquatic habitat, reduce sediment inputs from streambank erosion, and reduce agricultural runoff pollution; and
- Restoring a riparian buffer along stream corridors for additional terrestrial and aquatic habitat, nutrient input reduction, and water quality benefits.

The project goals will be addressed through the following project objectives:

- On-site nutrient inputs will be decreased by removing cattle from streams and filtering on-site runoff through buffer zones. Off-site nutrient input will be absorbed on-site by filtering flood flows through restored floodplain areas, where flood flows will spread through native vegetation.
- Restored buffers and exclusion of livestock to streams will significantly reduce inputs of livestock wastes to streams. This will eliminate a major source of fecal coliform pollution.

- Stream bank erosion which contributes sediment load to the creek will be greatly reduced, if not eliminated, in the project area. Eroding stream banks will be stabilized using bioengineering, natural channel design techniques, and grading to reduce bank angles and bank height. Storm flow containing fine sediment will be filtered through restored floodplain areas, where flow will spread through native vegetation. Spreading flood flows will also reduce velocity and allow sediment to settle out. Sediment transport capacity of restored reaches will be improved so that capacity balances more closely to load.
- Restored riffle/pool sequences will promote aeration of water and create deep water zones, helping to lower water temperature. Establishment and maintenance of riparian buffers will create long-term shading of the channel flow to minimize thermal heating. Lower water temperatures will help maintain dissolved oxygen concentrations.
- In-stream structures will be constructed to improve habitat diversity and trap detritus. Wood habitat structures will be included in the stream as part of the restoration design. Such structures may include log drops and riffle structures that incorporate woody debris.
- Adjacent buffer and riparian habitats will be restored with native vegetation as part of the project. Native vegetation will provide cover and food for terrestrial wildlife. Native plant species will be planted and invasive species will be treated. Eroding and unstable areas will also be stabilized with vegetation as part of this project.
- The restored land will be protected in perpetuity through a conservation easement.

2.0 Project Site Location and Selection

2.1 Directions to Project Site

The site is located in central Randolph County, southwest of Asheboro (Figure 1). From Route 64 in Asheboro, take Route 220 south 4.6 miles. Take Exit 68 for Dawson Miller Road. Turn right onto Dawson Miller Road and travel 1.2 miles. Turn left onto Pisgah Covered Bridge Road and travel 0.2 miles. The main entrance to the site is on the right. A second entrance offering easy access to the western side of the site also exists. To reach this entrance continue on Pisgah Covered Bridge Road for an additional 90 feet past the main entrance and turn right onto Hopewell Friends Road. Travel 0.9 miles and turn right onto Mack Road. Travel 0.5 miles and entrance will be on the right.

2.2 Site Selection and Project Components

The project site has been selected to provide stream mitigation units (SMUs) in the Yadkin-Pee Dee River Basin. The site was selected due to the on-site opportunities for restoration, enhancement, and preservation of ecological functions as described in Section 1.0. Credit determinations are presented in Section 7.0.

The streams proposed for restoration and enhancement include UT1A, UT1B, UT2, UT2A, UT2B, and UT2C (Figure 2). A section of Little River and a short section of UT1A are proposed for preservation. The site is comprised of two clusters of stream reaches, referred to in the remainder of this document as Hopewell East and Hopewell West. On the eastern side of the site, UT1A and UT1B flow northwestward into Little River which flows generally north to south but has a large meander shifting its flow eastward and then back to the west approximately half way through the length of the reach. UT1B has a large farm pond near the middle of the reach. The remaining project streams are located on the western side of the site. UT2 flows generally southward form the northern edge of the property. It is joined by UT2A approximately three fourths of the way to the southern property boundary and UT2C just before it flows onto the neighboring property to the south. Both of these streams join UT2 from the west. UT2B flows west to east into UT2B near the northern edge of the property. UT2 flows into Little River just before the downstream end of the preservation reach of the river. Little River eventually flows into the Pee Dee River near the town of Ingram in Richmond County. Photographs of the project site are included in Appendix 1.

3.0 Site Protection Instrument

The land required for construction, management, and stewardship of the mitigation project includes portions of the parcel listed in Table 1. A conservation easement will be recorded following finalization of the mitigation plan. While the conservation easement will not include the pond on UT1B, a restrictive covenant will be established that will require that cattle not be permitted access to the pond.

Table 1. Site Protection Instrument

Landowner	PIN	County	Site Protection Instrument	Deed Book and Page Number	Acreage Protected
Double T Farms of Randolph, LLC	7648735056	Randolph	Conservation Easement	TBD	35.4

All site protection instruments require 60-day advance notification to the U.S. Army Corps of Engineers and the State prior to any action to void, amend, or modify the document. No such action shall take place unless approved by the State.

4.0 Baseline Information –Project Site and Watershed Summary

Table 2 presents the project information and baseline watershed information.

Table 2. Project and Watershed Information

Project County	Randolph County						
Project Area (acres)	35.4						
Project Coordinates	35°37'37.32" N, 79° 51'13.27" W						
Physiographic Region	Carolina Slate Belt of the Piedmont Physiographic Province						
Ecoregion	Piedmont						
River Basin	Yadkin-Pee Dee						
USGS HUC (8 digit, 14 digit)	03040104, 03040104030010						
NCDWQ Sub-basin	03-07-15						
CGIA Land Use Classification	2.01.03 – Hay and Pasture Land; 2.99.05 - Farm Ponds; 4 – Forest Land						
Reaches	**Little River**	**UT1A**	**UT1B**	**UT2**	**UT2A**	**UT2B**	**UT2C**
Drainage Area (acres)	4,083	38	45	434	102	22	51
Drainage Area (sq. mi.)	6.38	0.06	0.07	0.59	0.16	0.03	0.08
Watershed Land Use							
Developed	2%	0%	0%	<1%	0%	0%	0%

Forested/Scrubland	76%	44%	14%	62%	51%	38%	33%
Agriculture/Managed Herb.	20%	55%	85%	37%	48%	61%	66%
Open Water	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Watershed Impervious Cover	<1%	<1%	<1%	1%	<1%	<1%	<1%

4.1 *Watershed Historical Land Use and Development Trends*

The watershed area for the project streams (Figure 3) was delineated using a combination of USGS 7.5-minute topographic quadrangles and available GIS LIDAR data. From review of aerial photos, the watershed for Little River appears to be mostly agricultural and wooded but the northern extent of the watershed includes portions of the City of Asheboro. There are areas of high impervious cover in the more developed portion of the watershed, especially around the northern and northeastern edges.

The reaches proposed completely or partially for restoration (UT2, UT2A, UT2B, UT2C) as well as UT1A and UT1B are in completely rural watersheds. There is a small amount of low density residential development in the very northern portion of the UT2 watershed but the vast majority is forest or agricultural land. The little development that exists in the northern portion of this watershed appears to have been constructed during the period from the early 1970s to early 1980s but resolution on the older photos makes it difficult to determine when the few streets and structures appeared. This development in the northern third of the watershed along Spring Drive, Spring Village Drive, Forest Oaks Drive, Oakdale and Mack Road and is low-density, single-family. Mack Road, Forest Oaks Drive, and Oakdale Drive existed prior to 1957 but the other roads were built as the development occurred. Very little land was cleared specifically for this development as most of it was farm land previously. No significant changes likely to affect the project streams appear to have occurred in any of these watersheds since the 1950s or earlier. The extent and patterns of forested and agricultural lands remain remarkably similar today throughout these watersheds as they were in 1957 (the date of the earliest available aerial photo). Percentages of land use type for each of the project reach watersheds are shown in Table 2. More detail on existing land cover and watershed conditions is included below in Section 4.2.

Review of historic aerial photos (Appendix 2) indicates that much of the Hopewell project site was cleared for agricultural use at some point prior to the 1957, although no information exists to verify exactly when the clearing was completed. The site remains very similar today in terms of the extent of pasture and vegetation to its condition in 1957. The 1957 aerial photo shows that, at that time, very narrow streamside zones were left vegetated on portions of the site. However, for some of the project reaches (e.g. the lower end of UT2), all vegetation had been removed from the riparian zones. Forested areas remained in the northwestern portion of the eastern side, along UT2A, to the north and east of the pond on UT2B, and from UT2C to the southern and western property lines. The site became slightly more vegetated over time, but the vegetation was allowed to grow primarily in narrow swaths along the streams. Much of this vegetation, at least at the present time, is Chinese privet (*Lingustrum sinense*).

Two farm ponds remain on the eastern portion of the site that were also present in the 1957 aerial photo. Several structures including a small house, a garage/shop, and multiple barns sit near the middle of the eastern side of the site. These structures can be seen on the 1957 aerial photo. Two newer structures were built during the 1990's, one in the vicinity of the small house on the eastern side and one on the western side, to the east of UT2. One additional barn was built on the eastern side after 2010. Very little else has changed on the property since the late 1950s.

4.2 *Watershed Assessment*

Wildlands conducted a watershed reconnaissance for the restoration and enhancement I reaches to verify current land uses observed from the aerial photography described above in Section 4.1 and to identify potential stressors. Windshield and on-foot reconnaissance of the UT2 watershed confirmed that there has been little or no change in the overall location and extents of forested and agricultural land use since at least as far back as the 1957 aerial photo. There has been no additional clearing upstream of the site in the UT2 watershed; in fact some land previously cleared has become forested. Otherwise, there has been no land use change in the watershed since the early 1980s. The agricultural land use in the watershed is primarily used for livestock grazing. A field walk of the UT2 channel upstream of the site revealed that the stream is stable although some sections appear as if they have been channelized in the past. The bed material is primarily gravel with significant amounts of cobble and sand. No areas of significant erosion or deposition were observed.

The UT2A watershed extends off of the property to the north but is much smaller than that of UT2. This watershed does not include the development described above that occurred in the late 1970s or early 1980s and is all forest or farm land. The patterns of forest cover and cleared lands have not changed significantly since the 1957 aerial photo. There is a pond near the headwaters of this stream that has been there at least since the 1960s. The stream channel continues upstream from the project site for about 600 feet to the pond. It appears to be stable and unincised.

The watersheds for UT1, UT2B, and UT2C are all very small but each does include land that is off the property. The upstream portion of the watershed for UT1A is part of a parcel to the east of Pisgah Church Road from the project site. This site was largely cleared sometime after 1983. The channel for UT1 on this property extends to the remaining woodline and consists of a small ephemeral to intermittent swale feature that is lined with pastures grasses and is stable. There has been no development in this watershed and there are no existing sources of excessive sediment. There has been very little land clearing in the UT2B watershed since 1957 and the only construction that has taken place has been a few small houses and barns during the 1980s. The watershed for UT2C extends into very small portions of the property to the south and west of the project site. The land cover patterns are the same in this watershed as they were in 1957. There has been no significant construction in the watershed since the 1957 aerial photo.

The watershed assessment supports the conclusion that the overall watershed hydrology and sediment regime have remained essentially the same for the last several decades and no recent watershed stressors are affecting the stability of the project reaches. While fine sediments are present in the project channels, it seems very likely that this material is the result of livestock trampling of the stream banks and bed. In most cases, this fine material appears to have come from the directly adjacent banks from recent trampling. The major stressors to the streams on the project site are livestock access, poor buffer condition, and possibly past channelization of downstream reaches. There is also no reason to believe the trajectories of these watersheds will be changing in the near future. The stability of the watersheds indicates that restoration and enhancement of these reaches will not be affected by changes in upstream conditions. It also provides some insight into the sediment regimes of the restoration and enhancement reaches. Given the watershed conditions, sediment supplies should be relatively low for restoration and enhancement reaches as is typical of small piedmont streams. In this case, a threshold channel design approach is appropriate.

4.3 *Physiography, Geology, and Soils*

The project site is located in the Carolina Slate Belt region of the Piedmont Physiographic Province between the Triassic Basins to the east and Inner Piedmont to the west. The Piedmont Province is characterized by gently rolling, well-rounded hills with long low ridges, with elevations ranging anywhere from 300 to 1,500 feet above sea level. The Carolina Slate Belt consists of heated and deformed volcanic and sedimentary rocks. The area is called "Slate Belt" because of the slatey cleavage of many of the surficial rocks. The region's geology also includes coarse-grained intrusive granites. Specifically, the proposed restoration site is located in the CZfv1 sub region of the CZfv region within the Carolina Slate Belt. The CZfv1 sub region is classified as the metavolcanic, Uwharrie formation of meta-argillite and metamudstone rock. These rock types are described as metamorphosed dacitic to rhyolitic flows and tuffs interbedded with mafic and intermediate metavolcanic rock, meta-argillite and metamudstone (NCGS b, n.d.).

The floodplain areas of the proposed project are mapped by the Randolph County Soil Survey. Soils in the project area floodplain are primarily mapped as Badin-Tarrus complex, Chewacla loam, Georgeville silt loam, Georgeville silty clay loam, Mecklenburg clay loam, and Riverview sandy loam. These soils are described below in Table 3. A soils map is provided in Figure 4.

Table 3. Floodplain Soil Types and Descriptions

Soil Name	Description
Badin-Tarrus complex, 8-15% slopes	Badin and Tarrus soils are found on hillslopes on ridges and uplands. They are moderately deep, well-drained soils that are typically not flooded or ponded.
Badin-Tarrus complex, 15-25% slopes	Badin and Tarrus soils are found on hillslopes on ridges and uplands. They are moderately deep, well-drained soils that are typically not flooded or ponded.
Chewacla loam, 0-2% slopes	Chewacla soils are found on floodplains and valleys. They are somewhat poorly-drained and exhibit moderately high permeability. This soil unit is frequently flooded.
Georgeville silt loam, 8-15% slopes	Georgeville soils are found on hillslopes on ridges and uplands. They are well-drained with low shrink-swell potential and moderately high permeability. This soil unit is not typically flooded or ponded.
Georgeville silty clay loam, 2-8% slopes	Georgeville soils are found on interfluves and uplands. They are well-drained with low shrink-swell potential and moderately high permeability. This soil unit is not typically flooded or ponded.
Georgeville silty clay loam, 8-15% slopes	Georgeville soils are found on interfluves and uplands. They are well-drained with low shrink-swell potential and moderately high permeability. This soil unit is not typically flooded or ponded.
Mecklenburg clay loam, 2-8% slopes	Mecklenburg soils are typically found on interfluves and uplands. They are a deep, well-drained soil with moderately low permeability. This soil is not typically flooded or ponded.
Riverview sandy loam, 0-2% slopes	Riverview soils are a well-drained soil type, exhibiting moderately high permeability, found on floodplains and valleys. These soils are frequently flooded.

Soil Name	Description
Source: Randolph County Soil Survey, USDA-NRCS, http://efotg.nrcs.usda.gov	

4.4 *Valley Classification*

The majority of the Hopewell project streams are bound by relatively narrow valleys with moderately steep side slopes ranging from 7% – 20%. Overall longitudinal valley slopes on the site range from 0.8% – 5.8%. It should be noted that the surrounding fluvial and morphological landforms do not fit neatly into any of the Rosgen (1996) valley type classification descriptions which are mostly based on landforms of the Western and Central United States. However, valleys on the Hopewell site most closely resemble Valley Type II, which are characterized by moderate relief, moderate side slope and longitudinal gradients, and often have colluvial slopes. The valleys of the larger streams on the site – Little River, UT2, and UT2A – generally run north to south. The valleys of the smaller tributaries generally run east to west or west to east.

4.5 *Surface Water Classification and Water Quality*

On November 10, 2011, October 3 and November 19, 2012, Wildlands investigated and assessed on-site jurisdictional Waters of the United States using the U.S. Army Corps of Engineers (USACE) Routine On-Site Determination Method. This method is defined in the 1987 Corps of Engineers Wetlands Delineation Manual and subsequent Eastern Mountain and Piedmont Regional Supplement. Potential jurisdictional wetland areas as well as typical upland areas were classified using the USACE Routine Wetland Determination Data Form. Determination methods also included stream classification utilizing the NC Division of Water Quality (NCDWQ) Stream Identification Form and the USACE Stream Quality Assessment Worksheet. On-site jurisdictional wetland areas were also assessed using the North Carolina Wetland Assessment Method (NCWAM). All USACE and NCWAM wetland forms are included in Appendix 3.

The results of the on-site field investigation indicate that there are seven (7) jurisdictional stream channels within the project area including Little River and six unnamed tributaries herein referred to as UT1A, UT1B, UT2, UT2A, UT2B, and UT2C.

Of these jurisdictional stream channels five (5) were classified as perennial relatively permanent waters (RPW) and include Little River, UT2, UT2C, and the lower portions of UT1B and UT2A (Figure 5). On-site perennial channels exhibited moderate to strong baseflow conditions, minor channel incision with access to the adjacent floodplain, defined riffle-pool sequences, and substrate consisting of gravel to large cobbles and bedrock outcrops. Biological sampling within these reaches resulted in a weak to moderate presence of fish and a weak presence of benthic macroinvertebrates. Scores on the USACE Stream Quality Assessment Form for these channels, ranged from 44 to 72 out of a possible 100 points. The scores on the NCDWQ Stream Classification Form ranged from 30 to 43.5 out of 61.5 possible points, indicating perennial status (SCP1, SCP4, SCP5, SCP7, and SCP9).

There are four (4) intermittent RPW channels located within the project area including UT1A, UT2B, and the upper portions of UT1B and UT2A. These reaches are typically small headwater systems stemming from small groundwater seeps and off-site ephemeral drainages. These channels exhibited weak baseflow conditions, poorly-defined riffle-pool sequences, weak to moderate head-cutting, moderate debris lines, and substrate consisting of sand to medium gravel. Scores on the USACE Stream Quality Assessment Form, for these channels, ranged from 20 to 45 out of a possible 100 points and ranged from 22.5 to 27 out of 61.5 possible points on the NCDWQ Stream Classification Form, indicating intermittent status (SCP2, SCP3, SCP6, and SCP8).

Little River and its unnamed tributaries are located within the NC Division of Water Quality (NCDWQ) subbasin 03-07-15. Little River (NCDWQ Index No. 13-25-(1)) is classified as C waters. Class C waters are protected for uses such as secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, and agriculture. Little River eventually drains to the Pee Dee River below Lake Tillery. This section of the Pee Dee River is classified as WS-V; B. This section of the Pee Dee River has a use support rating of "not rated" at this time. All NCDWQ Stream Classification Forms and USACE Stream Quality Assessment Forms are included in Appendix 4.

There are eleven (11) jurisdictional wetlands located within the project easement. A large portion of these wetland features were classified as Riverine lower and upper perennial emergent systems (R2EM2 and R3EM2). Eight jurisdictional features fall under this classification and include Wetlands A – E and Wetlands G – I (Figure 5). These wetlands occur in the floodplains of on-site perennial streams and within and adjacent to riparian corridors. These features exhibited oxidized rhizospheres, sediment deposits, water-stained leaves, drainage patterns, pockets of shallow inundation, a low chroma matrix, and saturation within the upper 12 inches of the soil profile. Common hydrophytic vegetation includes tag alder (*Alnus serrulata*), jewelweed (*Impatiens capensis*), smartweed (*Polygonum pensylvanicum*), green arrow arum (*Peltandra virginica*), false nettle (*Boehmeria cylindrica*), soft stem rush (*Juncus effusus*), beggartick (*Bidens aristosa*), red maple (*Acer rubrum*), ironwood (*Carpinus caroliniana*), green ash (*Fraxinus pennsylvanica*), black willow (*Salix nigra*), sweetgum (*Liquidambar styraciflua*), and strawcolored flatsedge (*Cyperus strigosus*). A large portion of these areas experience impacts from regular cattle grazing, trampling, and pasture maintenance. Wetland Determination Data Forms representative of Wetlands A – E and Wetlands G – I are enclosed in Appendix 3 (DP1 – DP5 and DP7 – DP9, respectively).

Several jurisdictional wetlands were classified as Riverine intermittent streambed systems (R4SB5). These features occur adjacent to and at the headwaters of on-site intermittent channels and include Wetlands F, J, and K. These areas exhibited water marks, water-stained leaves, oxidized rhizospheres, a low chroma matrix, and saturation in the upper 12 inches of the soil profile. Common hydrophytic vegetation includes stilt grass (*Microstegium vimineum*), cinnamon fern (*Osmunda cinnamomea*), false nettle, smartweed, tag alder, ironwood, and soft stem rush. Similar to the perennial emergent wetlands, these areas experience significant surface impacts from cattle grazing and pasture maintenance. Wetland Determination Data Forms representative of Wetlands F, J, and K are enclosed in Appendix 3 (DP6, DP10, and DP11, respectively). Wetland Determination Data Forms representative of on-site non-jurisdictional upland areas have also been enclosed (DP12 and DP13).

On-site jurisdictional wetlands are primarily found within the Badin, Chewacla , and Georgeville soil series. Badin soils are moderately deep, well-drained soils, found mainly on gently sloping to steep uplands in the Piedmont, exhibit moderate permeability, and are typically not ponded or flooded. Chewacla soils are typically found on floodplains and in valleys, are somewhat poorly-drained, exhibit moderately high permeability, and are frequently flooded. The Georgeville soil unit is typically found on hillslopes, ridges, and interfluves. This soil type is well-drained, exhibits moderately high permeability, and is not typically flooded or ponded.

5.0 Baseline Information – Reach Summary

On-site existing conditions assessments were conducted by Wildlands between August 2012 and February 2013. The locations of the project reaches and surveyed cross sections are shown in Figure 5. Existing geomorphic survey data is included in Appendix 5. Tables 4a and 4b presents the reach summary information.

Table 4a. Reach Summary Information for Hopewell East

	Little River	UT1A	UT1B Reach 1	UT1B Reach 2
Restored Length (LF)	3,078	1,728	475	580
Valley Type	II	II	II	II
Valley Slope (feet/ foot)	0.0051	0.0389	0.03	0.0583
Drainage Area (acres)	4,083	38	19	45
Drainage Area (sq. mi.)	6.38	0.06	0.03	0.07
NCDWQ stream ID score	43.5	22.5	24.5	30.0
Perennial or Intermittent	P	I	I	P
NCDWQ Classification	C	C	C	C
Existing Rosgen Classification	C4	B5[2]	Eb/B4	B4
Simon Evolutionary Stage	I/II	I	III	I
FEMA classification	AE	None	None	None

Notes:
1. Length for UT2C includes only stream length within easement not stream length on adjacent property.
2. Bed material composition impacted by cattle access. Streams would most likely have D50 values in the gravel range under normal conditions.

Table 4b. Reach Summary Information for Hopewell West

	UT2 Reach 1	UT2 Reach 2	UT2A Reach 1	UT2A Reach 2	UT2B	UT2C
Restored Length (LF)	1,715	732	386	1,311	1,046	1,497[1]
Valley Type	II	II	II	II	II	II
Valley Slope (feet/ foot)	0.0093	0.0075	0.0102	0.0110	0.0259	0.0154
Drainage Area (acres)	246	378	64	102	22	51
Drainage Area (sq. mi.)	0.38	0.59	0.1	0.16	0.03	0.08

	UT2 Reach 1	UT2 Reach 2	UT2A Reach 1	UT2A Reach 2	UT2B	UT2C
NCDWQ stream ID score	35.5	35.5	27	35	23.7	31
Perennial or Intermittent	P	P	I	P	I	P
NCDWQ Classification	C	C	C	C	C	C
Existing Rosgen Classification	E4/5[2]	G4	E/G4/5[2]	E/G4/5[2]	E/G4	E/G4
Simon Evolutionary Stage	III/IV	IV	III	III/IV	III	III
FEMA classification	None	None	None	None	None	None

Notes:

1. Length for UT2C includes only stream length within easement not stream length on adjacent property.
2. Bed material composition impacted by cattle access. Streams would most likely have D50 values in the gravel range under normal conditions.

5.1 *Existing Stream and Vegetation Condition*

The project site exhibits the same land use patterns and active cattle pastures as the property did in the 1957 aerial photo. The majority of the stream riparian areas have been maintained to narrow corridors to maximize pasture land. The site is currently used to maintain 250 head of cattle, all of which have access to nearly all on-site stream channels except for a small portion of Little River. From the property boundary to just below the confluence with UT1A, Little River is fenced off from cattle access and exhibits low banks and a relatively mature forested riparian area. Below this area, the riparian corridor narrows and is completely dominated by invasive mature Chinese privet (*Ligustrum sinense*). Through this lower reach, cattle have had access to the channel resulting in trampled banks; however, bedrock outcrops have prevented channel incision. Mature privet remains the dominant vegetation through the remainder of the reach with sporadic hardwood species of red maple, sweetgum, American beech (*Fagus grandifolia*), southern red oak (*Quercus falcata*), and American sycamore (*Platanus occidentalis*).

UT1A and UT1B are small intermittent and intermittent/perennial tributaries that originate in the eastern portion of the site. These channels flow through thinly forested riparian areas before their confluence with Little River. Cattle have access to the majority of both channels, resulting in trampled, un-vegetated banks. UT1B transitions to a perennial channel in the vicinity of the woodline upstream of the pond. Cattle remain fenced out from this pond, but continue to have access to the lower portion of this reach resulting in a sparse understory vegetation layer. Dominant vegetation includes a small amount of invasive privet, red maple, ironwood (*Carpinus caroliniana*), southern red oak, and American holly (*Ilex opaca*).

The western portion of the project is drained by several small intermittent and perennial tributaries including UT2, UT2A, UT2B, and UT2C. Similar to the eastern side of the property, these channels are largely affected by cattle access. UT2 is a perennial channel that exhibits sheer and eroded banks throughout the majority of its length along with a narrow riparian corridor dominated by invasive Chinese privet, multiflora rose (*Rosa multiflora*) and Japanese honeysuckle (*Lonicera japonica*). The upstream portion of this reach displays less incision and the riparian area is comprised of sporadic hardwoods including American sycamore, sweetgum, red maple, and southern red oak.

UT2A, like UT2, has been heavily impacted by cattle access resulting in trampled stream bed and banks. The majority of the riparian corridor along UT2A is heavily choked with privet, multiflora rose, and invasive vine species making stream access difficult. UT2A's condition improves near the upstream boundary, above its confluence with UT2B. At this confluence point, UT2A and UT2B are both intermittent streams. These channels are moderately impacted by cattle in the form of trampling, with sparse, hardwood riparian zones and a moderate amount of invasive privet and honeysuckle. Roots from large woody vegetation provide grade control throughout these upper reaches.

UT2C is a perennial stream that flows along the wooded southern property boundary and joins UT2 near the downstream boundary. Overall, UT2C currently exhibits good bedform diversity and channel pattern, however effects from cattle trampling along portions of the banks are evident throughout the reach. Dominant vegetation throughout this area includes large mature hardwood species of sweetgum, sycamore, red maple, southern red oak, and tulip poplar (*Liriodendron tulipifera*). Understory vegetation shows some degradation from cattle access and includes numerous, young privet shrubs, American holly, and ironwood.

5.2 Stream Geomorphology

The project site is located in the central Piedmont physiographic province, specifically in the Carolina Slate Belt. The site is on the Uwharrie formation which consists of felsic volcanic rocks with mafic and sedimentary members (Hibbard, 2002). This region is hilly and lies just east of the Uwharrie Mountains. Valleys in the region are somewhat narrow and confined and streams tend to be relatively straight and organized in dendritic or trellis drainage patterns. According to the USGS and others the slate belt contain some of the lowest water-yielding rocks in the state and base flows in streams tend to be low (Griffith and Omernik, 2008; Guise and Mason, 1993).

On the project site, the valley of Little River is somewhat confined on the upstream end but becomes wider downstream. The valleys of the tributaries are also somewhat confined but wide enough in certain locations to allow the streams to meander. However, some reaches have very tight valleys and the streams are therefore quite straight through these areas. The valley walls tend to be fairly steep (up to 20% slopes) and colluvial deposits in the streams are common. Bedrock outcrops are fairly common adjacent to the streams and in the channels.

The streams may or may not have been channelized at some point in the past but have followed the same alignments since at least as far back as 1957 (the date of the earliest aerial photo obtained). However, given that streams on most farm sites in the Piedmont have been altered, it is not unreasonable to expect that some alterations were performed at some point on the channels. Regardless, all of the channels on the project site, with the possible exception of the upstream portion of Little River and the downstream reach of UT1A have been trampled by cattle. The cattle trampling has destabilized streambanks and altered the channel beds significantly. In many reaches, the bed morphology has been obliterated and bed material size distributions have been greatly altered (skewing finer) as a result of the cattle access. In addition, UT1B, UT2, UT2A, portions of UT2B, and portions of UT2C are all incised and disconnected from their floodplains.

Due to incision and trampling of the streambanks by cattle, identifiable bankfull features were extremely limited. Wildlands staff performed existing conditions stream assessments on all of the project streams and attempted to classify the channels based on the Rosgen (1994) classification system, but in many cases field determination of bankfull stage was impossible. Where possible, estimates of bankfull stage were made in the field. Potential bankfull features identified in the field included the top of bank (for unincised reaches) or breaks in slope along incised, trampled reaches. If no bankfull features were field identified, a stage that corresponded to a bankfull channel cross-sectional area similar to that predicted by the Piedmont regional curve for the appropriate drainage area (or a similar stage at a slope break) was selected in the office. There were not enough bankfull features present in the incised, trampled stream reaches to produce bankfull profiles. The main purpose of estimating bankfull stage in these heavily impacted channels was to roughly quantify the departure from a stable, functioning state (e.g. develop bank height ratios (BHR) for the existing reaches). Existing geomorphic conditions for each reach included in the project are summarized below in Tables 5a through 5c. The reaches and surveyed cross sections are mapped on Figure 5. Geomorphic survey data and pebble count data are included in Appendix 5.

Little River (Photos 1 and 2) is much larger than the other streams on the project site and is located on the eastern side of the property. The project reach flows in a southwesterly direction and is straight except for a large meander midway through the project reach. The floodplain is fairly broad and unconfined (entrenchment ratio is greater than 2.5) in the area around this meander and two directly connected side channels are located near the apex of the meander bend (Photo 3). The river has a low gradient through this section (0.46%) and is impounded by several beaver dams on the site. Due to the impoundments, there is little change in bed morphology along the reach, which appears to be a plane bed channel rather than a sequence of riffles and pools. The reach is a gravel bed stream with significant amounts of sand and silt (D50 is 27.3). The reach is not significantly incised (BHR is close to 1) and the width to depth ratio is 12.4. According to the Rosgen classification system, the river classifies as a C4 stream. The stream has a healthy buffer along both sides of the upstream reach (Reach 1) but much of the channel on the property (all of Reach 2) has a buffer comprised primarily of large privet plants. The privet and trees have helped to keep the banks largely stable, though cattle still access the stream in some locations.

Table 5a. Existing Stream Conditions for Hopewell East

			Little River		UT1A		UT1B Reach 1		UT1B Reach 2	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
stream type			C4		B5		Eb/B4		B4	
drainage area	DA	sq mi	6.38		0.06		0.03		0.07	
bankfull discharge	Q_{bkf}	cfs	338.1		12.0		6.0		13.0	
bankfull cross-sectional area	A_{bkf}	SF	54.4		6.9		8.0	12.0	6.1	
average velocity during bankfull event	v_{bkf}	fps	6.2		1.74		0.75		2.13	
width at bankfull	w_{bkf}	feet	26.0		11.2		7.1	13.2	15.8	
maximum depth at bankfull	d_{max}	feet	2.5		0.9		1.2	1.9	0.9	
mean depth at bankfull	d_{bkf}	feet	2.1		0.6		0.7	1.1	0.4	
bankfull width to depth ratio	w_{bkf}/d_{bkf}		12.4		18.2		10.1	12.0	40.0	
max depth ratio	d_{max}/d_{bkf}		1.2		1.5		1.7		2.3	

			Little River		UT1A		UT1B Reach 1		UT1B Reach 2	
Parameter	Notation	Units	min	max	min	max	min	max	min	max
bank height ratio	BHR		1.0		1.1		2.5		1.0	
floodprone area width	w_{fpa}	feet	>50		24.0		8	28	22.5	
entrenchment ratio	ER		>2.5		2.1		2.2		1.4	
valley slope	S_{valley}	ft/ft	0.0051		0.0389		0.03		0.0583	
channel slope[1]	$S_{channel}$	ft/ft	0.0046		0.0327		0.0369		0.1	
sinuosity	K		1.5		1.2		1.1		1.4	
riffle slope	S_{riffle}	ft/ft	---		---		---		---	
riffle slope ratio	$S_{riffle}/S_{channel}$		---		---		---		---	
pool slope	S_{pool}	ft/ft	---		---		---		---	
pool slope ratio	$S_{pool}/S_{channel}$		---		---		---		---	
pool-to-pool spacing	L_{p-p}	feet	---		---		---		---	
pool spacing ratio	L_{p-p}/w_{bkf}		---		---		---		---	
maximum pool depth at bankfull	d_{pool}	feet	3.8		0.8		1.4	2.6	1.3	
pool depth ratio	d_{pool}/d_{bkf}		1.8		1.3		2.0	2.4	3.3	
pool width at bankfull	w_{pool}	feet	20.8		8.5		3.9	7.5	13.3	
pool width ratio	w_{pool}/w_{bkf}		0.8		0.8		0.6		0.8	
pool cross-sectional area at bankfull	A_{pool}	SF	59.5		4.3		6.8	7.4	9.7	
pool area ratio	A_{pool}/A_{bkf}		1.1		0.6		0.6	0.9	1.6	
belt width	w_{blt}	feet	661		20	47	15		10	26
meander width ratio	w_{blt}/w_{bkf}		25.4		1.8	4.2	1.5		0.6	1.7
meander length	L_m	feet	1011		68	294	149		41	65

			Little River		UT1A		UT1B Reach 1		UT1B Reach 2	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
meander length ratio	L_m/w_{bkf}		38.9		6.1	26.3	14.7		2.6	4.1
radius of curvature	R_c	feet	68	288	10	84	39	66	8	28
radius of curvature ratio	R_c/ w_{bkf}		2.6	11.1	0.9	7.5	3.8	6.5	0.5	1.8
Sediment										
Particle size distribution of reach-wide material D_{50} for Rosgen Classification			Coarse Gravel		Very Fine Sand[2]		Very Fine Gravel[2]		Very Fine Gravel[2]	
D_{16}	D_{16}	mm	8.0		N/A		N/A		N/A	
D_{35}	D_{35}	mm	17.6		0.07		15.41		11.5	
D_{50}	D_{50}	mm	27.3		0.1		52.3		29.1	
D_{84}	D_{84}	mm	121		49		136		151.0	
D_{95}	D_{95}	mm	215		136		172		296.1	

Notes:
1. Channel slope may be greater than valley slope due to increasing incision in the downstream direction.
2. Bed material composition altered due to cattle access. Streams would likely have D50 values in the gravel range under normal conditions.

Table 5b. Existing Stream Conditions for Hopewell West – UT2

			UT2 Reach 1		UT2 Reach 2	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**
stream type			G5/4		G4	
drainage area	DA	sq mi	0.38		0.59	
bankfull discharge	Q_{bkf}	cfs	45		58	
bankfull cross-sectional area	A_{bkf}	SF	11.1	11.4	14.9	
average velocity during bankfull event	v_{bkf}	fps	3.7	4.0	3.9	
width at bankfull	w_{bkf}	feet	7.9	10.9	10.7	
maximum depth at bankfull	d_{max}	feet	1.4	1.8	2.0	
mean depth at bankfull	d_{bkf}	feet	1.0	1.4	1.4	
bankfull width to depth ratio	w_{bkf}/d_{bkf}		5.7	10.4	7.7	

			UT2 Reach 1		UT2 Reach 2	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**
max depth ratio	d_{max}/d_{bkf}		1.3	1.4	1.4	
bank height ratio	BHR		1.4	1.9	2.1	
floodprone area width	w_{fpa}	feet	12.0	18.0	14.0	
entrenchment ratio	ER		1.5	1.7	1.3	
valley slope	S_{valley}	ft/ft	0.0093		0.0075	
channel slope[1]	$S_{channel}$	ft/ft	0.0083		0.0082	
sinuosity	K		1.3		1.1	
riffle slope	S_{riffle}	ft/ft	---	---	---	---
riffle slope ratio	$S_{riffle}/S_{channel}$		---	---	---	---
pool slope	S_{pool}	ft/ft	---	---	---	---
pool slope ratio	$S_{pool}/S_{channel}$		---	---	---	---
pool-to-pool spacing	$L_{p\text{-}p}$	feet	---	---	---	---
pool spacing ratio	$L_{p\text{-}p}/w_{bkf}$		---	---	---	---
maximum pool depth at bankfull	d_{pool}	feet	2.0	2.2	2.2	
pool depth ratio	d_{pool}/d_{bkf}		2.0	1.6	1.6	
pool width at bankfull	w_{pool}	feet	7.1	9.7	13.7	
pool width ratio	w_{pool}/w_{bkf}		0.9	0.9	1.3	
pool cross-sectional area at bankfull	A_{pool}	SF	12.2	15.8	22.2	
pool area ratio	A_{pool}/A_{bkf}		1.1	1.4	1.5	
belt width	w_{blt}	feet	45	79	67	69
meander width ratio	w_{blt}/w_{bkf}		5.7	7.2	6.3	6.4

			UT2 Reach 1		UT2 Reach 2	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**
meander length	L_m	feet	102	245	125	132
meander length ratio	L_m/w_{bkf}		12.9	22.5	11.7	12.3
radius of curvature	R_c	feet	12	28	22	25
radius of curvature ratio	R_c/ w_{bkf}		1.5	2.6	2.1	2.3
Sediment						
Particle size distribution of reach-wide material D_{50} for Rosgen Classification			Very Fine Sand[2]		Medium Gravel	
D_{16}	D_{16}	mm	N/A		N/A	
D_{35}	D_{35}	mm	N/A		4.6	
D_{50}	D_{50}	mm	0.1		12.5	
D_{84}	D_{84}	mm	45		70	
D_{95}	D_{95}	mm	180		128	

Notes:
1. Channel slope may be greater than valley slope due to increasing incision in the downstream direction.
2. Bed material composition altered due to cattle access. Streams would likely have D50 values in the gravel range under normal conditions.

Table 5c. Existing Stream Conditions for Hopewell West – UT2A, UT2B, and UT2C

			UT2A Reach 1		UT2A Reach 2		UT2B		UT2C	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
stream type			E/G5/4[2]		E/G5/4[2]		G4		E/G4	
drainage area	DA	sq mi	0.1		0.16		0.03		0.08	
bankfull discharge	Q_{bkf}	cfs	19		19		7		14	
bankfull cross-sectional area	A_{bkf}	SF	6.2		6.1	6.2	2.2	2.3	3.8	4.2
average velocity during bankfull event	v_{bkf}	fps	3.0		2.7	3.1	3.2	3.0	3.3	3.7
width at bankfull	w_{bkf}	feet	6.2		6.0	7.9	3.4	5.1	4.2	6.4
maximum depth at bankfull	d_{max}	feet	2.0		1.1	1.5	0.7	1.0	0.9	1.4

			UT2A Reach 1		UT2A Reach 2		UT2B		UT2C	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
mean depth at bankfull	d_{bkf}	feet	1.0		0.8	1.0	0.4	0.6	0.6	0.9
bankfull width to depth ratio	w_{bkf}/d_{bkf}		6.2		5.9	10.0	5.5	11.3	4.6	9.6
max depth ratio	d_{max}/d_{bkf}		2.0		1.4	1.5	1.7	1.8	1.3	1.8
bank height ratio	BHR		1.4		2.3	2.9	1.7	4.0	1.0	3.4
floodprone area width	w_{fpa}	feet	40.0		6.0	10.0	4.0	8.0	7.0	53.0
entrenchment ratio	ER		6.5		0.8	1.7	1.2	1.6	1.2	2.6
valley slope	S_{valley}	ft/ft	0.0102		0.011		0.0259		0.0154	
channel slope	$S_{channel}$	ft/ft	0.0082		0.0086		0.0250		0.0120	
sinuosity	K		1.3		1.2		1.2		1.1	
riffle slope	S_{riffle}	ft/ft	---		---	---	---	---	---	---
riffle slope ratio	$S_{riffle}/S_{channel}$		---		---	---	---	---	---	---
pool slope	S_{pool}	ft/ft	---		---	---	---	---	---	---
pool slope ratio	$S_{pool}/S_{channel}$		---		---	---	---	---	---	---
pool-to-pool spacing	$L_{p\text{-}p}$	feet	---		---	---	---	---	---	---
pool spacing ratio	$L_{p\text{-}p}/w_{bkf}$		---		---	---	---	---	---	---
maximum pool depth at bankfull	d_{pool}	feet	2.3		1.9	2.7	---		1.1	1.2
pool depth ratio	d_{pool}/d_{bkf}		2.3		2.4	2.7	---		1.8	1.3
pool width at bankfull	w_{pool}	feet	5.9		4.5	7.1	---		4.6	5.6
pool width ratio	w_{pool}/w_{bkf}		1.0		0.8	0.9	---		1.1	0.9
pool cross-sectional area at bankfull	A_{pool}	SF	10.3		6.9	13.1	---		4.5	4.9
pool area ratio	A_{pool}/A_{bkf}		1.7		1.1	2.1	---		1.2	1.2

			UT2A Reach 1		UT2A Reach 2		UT2B		UT2C	
Parameter	Notation	Units	min	max	min	max	min	max	min	max
belt width	w_{blt}	feet	18	22	26	72	25	32	33	46
meander width ratio	w_{blt}/w_{bkf}		2.9	3.6	4.3	9.1	7.4	6.3	7.9	7.2
meander length	L_m	feet	54	61	102	173	79	107	160	165
meander length ratio	L_m/w_{bkf}		8.7	9.8	17.0	21.9	23.2	21.0	38.1	25.8
radius of curvature	R_c	feet	8	31	6	28	10	20	6	20
radius of curvature ratio	R_c/ w_{bkf}		1.3	5.0	1.0	3.5	2.9	3.9	1.4	3.1
Sediment										
Particle size distribution of reach-wide material D_{50} for Rosgen Classification			Very Fine Sand[2]		Very Fine Sand[2]		Very Fine Gravel[2]		Fine Gravel[2]	
D_{16}	D_{16}	mm	N/A		N/A		N/A		N/A	
D_{35}	D_{35}	mm	N/A		N/A		N/A		0.8	
D_{50}	D_{50}	mm	0.1		0.1		2.1		6	
D_{84}	D_{84}	mm	3		3		18		45	
D_{95}	D_{95}	mm	7		7		107		78	

Notes:
1. Channel slope may be greater than valley slope due to increasing incision in the downstream direction.
2. Bed material composition altered due to cattle access. Streams would likely have D50 values in the gravel range under normal conditions.

UT1A (Photo 4) is a small channel that begins near the eastern edge of the property at a small wetland that collects runoff from the surrounding hill slopes and flows to the northwest. The drainage area at the downstream end of the reach is 0.06 sq. mi. The stream is not significantly incised but the channel banks have been severely trampled by cattle. The stream is mostly straight but becomes somewhat more sinuous downstream (sinuosity is 1.2). The width to depth ratio of the stream is 18.2 and the entrenchment ratio is 2.4 (cross section 29). The channel slope is 3.2%. Although there are significant pockets of gravel in the channel, the reach-wide D50 of the stream is 0.1 mm indicating that it is a sand bed channel. Cattle access has likely resulted in fining of the bed material. Based on the data resulting from the assessment, the stream is classified as a B5. There is a wide buffer along much of the northern bank of the stream but a narrow buffer on the south bank.

UT1B (Photo 5) is another small tributary to Little River that flows in a northwesterly direction from the eastern edge of the property to the river. The downstream drainage area is 0.07 sq. mi. There is a pond approximately 2.4 acres in size located near the middle of the reach . For slightly more than 300 feet upstream of the pond the reach flows through a wooded area. This reach is stable despite some past cattle access and has a BHR of approximately 2, a width to depth ratio of 10.1 and an entrenchment ratio of greater than 2.2. Upstream of the woodline, the stream runs through a cattle pasture with no vegetation except for pasture grasses. Through this section, the stream is very incised (cross section 23) with a BHR up to 2.4. The channel through this section has a width to depth ratio of 6.3, an entrenchment ratio of 2.1, and the slope is 2.8%. The reach downstream of the pond to the river is also wooded. This reach is also more stable due to bedrock grade controls and is wide and steep. This section (cross section 28) has a BHR of approximately 1, a width to depth ratio of 41.3, and an entrenchment ratio of 1.4. The overall slope of the project reach below the pond is nearly 10%. The reach-wide pebble count results indicate that the D50 upstream of the pond is 52.3 mm and downstream of the pond is 29.1 mm. However, there are significant bedrock outcrops throughout this reach. Based on these data, the stream is classified as a Eb4 to B4. It is important to note that in the current configuration, the primary outlet of the pond is an overflow spillway that routs flow away from UT1B immediately downstream of the pond and into a separate channel. This channel rejoins UT1B approximately 120 feet downstream of the dam.

The largest stream on the western side of the site is UT2 (drainage area at the downstream end of the project is 0.68 sq. mi.). This project reach of UT2 (Photo 6) begins near the northern edge of the property and flows south. UT2A and UT2C flow into it near the southern edge of the property. It has minimal buffer, which consists of a few hardwoods, occasional cedars, and privet and it has been trampled by cattle. The cattle have caused severe impacts to the channel banks and have created a large "wallow" near the upstream where the channel has been obliterated. For the purposes of the design, the stream has been divided into two reaches – Reach 1 upstream of UT2A and Reach 2 downstream. Reach 1 becomes more incised going downstream. Two riffle cross sections (cross sections 19 and 20) were surveyed along this reach. The increasing incision can be seen by comparing the bank height ratios between cross section 20 (BHR = 1.4) upstream and cross section 19 (BHR = 1.9) downstream. The width to depth ratios of Reach 1 are 5.7 to 10.4, the entrenchment ratios are 1.5 to 1.7, and the channel slope is 0.83%. The D50 is 0.1 mm (indicating a sand bed channel) but there is gravel and colluvial cobble in the bed of the stream and the cattle access has likely led to fining of the substrate material. The sinuosity is 1.3, due to two large meanders in the upstream section where the valley bottom is broader. Reach 1 classifies as an E5 stream. Reach 2 (cross section 13) is a somewhat larger channel due to the increased streamflow from UT2A. It has a width to depth ratio of 7.7, and bank height ratio of 2.1, and entrenchment ratio of 1.3, a channel slope of 0.82%, a D50 of 12.5mm, and a sinuosity of 1.1. Based on these data, the stream classifies as a G4.

UT2A (Photo 7) flows south from the northern edge of the property until it joins UT2 near the southern property boundary. UT2B flows into it approximately 400 feet south of the property boundary. Reach 1 of UT2A is upstream of the confluence and Reach 2 is downstream of this confluence. The stream is mostly in a narrow valley and is quite straight, except for one large meander just downstream of the confluence with UT2B. The buffer is similar to that of UT2 including a considerable amount of privet growth. This stream, also like UT2, has been heavily accessed by cattle and the banks have been severely trampled in many locations. This stream also becomes more incised in the downstream direction. The width to depth ratio of Reach 1 (cross section 4) is 6.2, the entrenchment ratio is 6.5, the slope is 1.09%, and the sinuosity is 1.13. The D50 is 0.1 indicating a sand bed channel, which is related to trampling of the bed and banks by cattle. This reach is classified as an E/G5. Reach 2 of UT2B (cross sections 16 and 17) has a width to depth ratio of 5.9 to 10, an entrenchment ratio of 0.8 to 1.7, a channel slope of 0.86%, a sinuosity of 1.2, and a D50 of 0.1 mm. Based on these data, this reach also classifies as an E/G5.

A short reach of UT2B (Photo 8) is also included in the project from the northwest corner of the site to the confluence with UT2A. This stream has a similar buffer to UT2 and UT2A and at the downstream end has been trampled by cattle. This is a smaller stream with a drainage area of 0.03 sq. mi. Based on field measurements (cross sections 3 and 6), the stream has a width to depth ratio of 5.5 to 11.3, an entrenchment ratio of 1.2 to 1.6, a sinuosity of 1.2, and channel slope of 2.5%, and a D50 of 2.1 mm (indicating a fine gravel bed). This stream classifies as G4.

UT2C (Photos 9 and 10) flows in a southeasterly direction near the southwestern edge of the property. It joins UT2 at the downstream end of that reach. This stream has relatively healthy buffer for much of its length, but privet is an issue for the downstream half of the reach and becomes increasingly pervasive in the downstream direction. The stream flows off of the property for a short section and then reenters the property just upstream of its confluence with UT2. This stream is also accessed by cattle and the related impacts become worse in the downstream portions of the reach. Two riffle cross sections (cross section 1 and cross section 9) were surveyed along with two pool cross sections for this reach. The reach has a width to depth ratio range of 4.6 to 9.6, and entrenchment ratio range of 1.2 to 2.6, a slope of 1.8%, a sinuosity of 1.1, and a D50 of 6mm. This stream classifies as an E/G4.

5.3 Channel Evolution

Channelization usually includes straightening and deepening of streams and is one of the major causes of channel down-cutting or incision (Simon, 1989; Simon and Rinaldi, 2006). Based on Simon's model termed the Channel Evolution Model for Incised Rivers (1989), alluvial streams follow a sequential series of evolutionary stages as they respond and ultimately recover from impacts due to channelization or majors changes to hydrologic and sediment regime. This model is often used to describe the evolutionary state of stream restoration/enhancement projects. In this model, pre-disturbance is considered Stage I - Equilibrium. Stage II – Channelization, occurs when the stream is either directly channelized by man through ditching or channelization occurs as an indirect result of hydrologic or sediment regime changes in the watershed. These actions take the stream out of equilibrium and alluvial channels will then incise and degrade in response to the excess stream energy associated with Stage II. This incision process is Stage III – Degradation. As the bottom of the channel continues to erode and stream banks are undercut, the banks will begin to fail and the channel widens as it degrades. This is Stage IV – Degradation and Widening. Eventually, the stream slope will decrease enough that the stream stops incising but continues to widen through alternate bank erosion and aggradation (Stage V- Aggradation and Widening). At Stage V, new bankfull features begin to establish at a lower position relative to the old valley floor, and the stream continues to widen its new floodplain through alternate bank erosion until it eventually returns to a state of quasi-equlibrium (Stage VI). Lateral adjustment processes (migration) are often associated with Stages IV and V.

The history of alterations and maintenance of the stream channels on the project site is unclear. The channels appear to be the same in planview pattern today as they were at the time of the earliest available aerial photo of the site – 1957. The current landowner does not have knowledge of the site prior to that date. Therefore, descriptions of the evolution of the streams must be based on observations of their current form and condition. Many of the streams on the project site, especially those that are accessed less by cattle, exhibit relative stability. However, other project reaches appear to have incised and have been severely trampled by cattle so that the banks have become unstable and the bed morphologies are often destroyed. A theory of the evolution of each of the project reaches is described below, although they do not necessarily fit the model developed by Simon.

Most of the length of the Little River on the project site appears relatively stable (Photo 1). It is a fairly large stream, which may indicate a lower likelihood of past channelization. However, review of the 1957 aerial shows that the vegetation had previously been removed from the stream banks and floodplain along the river. The reach immediately downstream of the project area is very straight and past channelization seems possible. Also, there is a bridge 1,200 feet downstream of the project site on Hopewell Friends Road that was present on the aerial. Some manipulation of the channel was likely performed during construction of the bridge. The side channel features are also apparent in the 1957 photo indicating that the channel has adjusted its pattern through the valley or was moved. What is clear at this time is that the vegetation along the channel has reestablished, though much of it is privet, and multiple beaver dams (see example in Photo 2) have altered the bed features of the stream, raised the water level, and slowed the current. The channel does not appear incised and bank erosion is minimal due partly to vegetation on the banks and limited cattle access. The secondary channels remain today (Photo 3) much as they appeared in the 1957 aerial. The best estimate of the evolutionary state of this channel is that it is has remained unchannelized and is in Simon's Stage I or that it has been altered but that, most likely due to lack of base level alteration downstream, it has not moved beyond Stage II.

There is no clear evidence of past channelization of UT1A (Photo 4). The buffer on the southern portion of the stream appears from aerial photos to have been disturbed at the same time the Little River floodplain was cleared, especially at the downstream end. The upstream portion of the reach has been accessed by cattle and in many areas the banks are trampled. The greatest departures from the original stable channel and healthy riparian zone have not come from channelization but from clearing and narrowing of the buffer, proliferation of privet along certain sections, and trampling of the channel banks and bed by cattle. The trampling of the banks causes bank erosion, sloughing, and, in many cases, over-widening of the channel. The stream is still accessible to the herds and has not had a chance to recover from these impacts. The stream bed, however, has not incised. These impacts and causes of instability do not fit Simon's model, so no evolutionary stage described by that model is appropriate to describe the condition or trajectory of this stream. It is likely that, if cattle were prohibited from accessing the stream and the appropriate buffer species were replanted, the stream would regain equilibrium on its own.

A pond was constructed on UT1B prior to 1957. Undoubtedly, other alterations were made to the stream at the same time but there is little direct evidence of specific activities. The valley upstream of the pond is narrow with steep side slopes and past channelization seems unlikely. The area immediately above the pond remained wooded in 1957 much as it is today (Photo 5) and the area downstream of the pond has had some vegetation since that time as well. The upper reach of UT1B has remained cleared since the 1957 photo was taken and cattle have unrestricted access to that reach. The upper reach is incised above the wood line and banks have been trampled. This portion of the stream is most likely now in stage III of Simon's evolutionary model and may eventually reach stage IV and widen if action is not taken to prevent this further instability. The rest of the channel below the wood line and below the pond appears relatively stable and if cattle are prevented from accessing the channel, further action should not be necessary to ensure future stability and recovery.

The pattern of UT2 is the same now as it was in 1957. The stream was and remains fairly sinuous where its valley is broad enough to allow any meandering, so if the stream was ever channelized it appears to have reestablished much of its pattern. However, UT2 is deeply incised and cattle have trampled the banks, severely in some locations (Photo 6). The incision decreases in the upstream direction until, near the northern edge of the property, it ceases and the channel seems to remain vertically stable. The causes of incision are unclear but may be related to channelization and lowering of Little River downstream of the project site and/or at the downstream bridge on Hopewell Friends Road. It is likely that the channel is also becoming overly widened as a result of cattle access and sloughing of the banks. The stream is mostly likely at an evolutionary point similar to Stage III or Stage IV if widening of the channels is occurring. Regardless, the stream is overly incised, the bed morphology has been largely destroyed by cattle, the banks have been eroded due to cattle access, and the narrow riparian buffer is comprised primarily of privet. A greater degree of intervention is required to remediate these problems and prevent further instability from occurring.

UT2A is a very similar stream to UT2 in its present condition. The valley is narrower with equally steep side slopes, so the pattern of this stream is straighter. However, it is equally incised and trampled and the buffer is in equally poor condition (Photo 7). The incision decreases in the upstream direction on this channel. Because it flows into UT2, a lowering of base level on that stream has resulted in incision on UT2A. This channel shows signs of some over widening as well. Most of this stream is at a point similar to Stage III or IV and will also require significant intervention for stabilization and remediation. The upstream end of the reach, however, is more stable and less incised that lower sections.

UT2B is a relatively short reach that becomes more incised as it approaches its confluence with UT2A. This stream may be actively head-cutting as there appears to be a nick point about 120 feet upstream from the confluence. The stream is fairly sinuous and does not appear to have been channelized. Cattle have accessed the stream in the lower section resulting in bank erosion, destruction of bed morphology, and fining of sediments. Due to the active head cutting of the channel, this stream is in a state most similar to Simon's stage III and remedial action will be necessary at the lower end to prevent the incision from extending upstream.

The riparian buffer on the northern side of UT2C was cleared prior to the 1957 aerial photo but a narrow buffer has been allowed to grow back over the years. However, privet is pervasive in the buffer of the lower half of the reach. The stream does not appear to have been channelized. UT2C is similar to UT2B in that it is relatively stable for much of its length until the downstream end where it becomes incised as it approaches its confluence with UT2 (Photos 9 and 10). There is a bedrock nick point near the downstream end. Cattle access the reach and there are localized areas of bank trampling along most of the reach. The evolutionary stage of the downstream end of the reach is best represented as Stage III. Most of the reach upstream is more stable and, given that it has likely never been channelized, does not fit any of the stages of the Simon evolution model well. Localized bank treatment, fencing out cattle, and removal of invasives are all that should be needed to remediate most of this stream. More significant treatment will be required for the downstream end.

5.4 Channel Stability Assessment

Wildlands utilized a modified version of the Rapid Assessment of Channel Stability as described in Hydrologic Engineering Circular (HEC)-20 (Lagasse, 2001). The method is semi-quantitative and incorporates thirteen stability indicators that are evaluated in the field. In a 2006 publication, the Federal Highway Administration (FHWA) updated the method for HEC-20 by modifying the metrics included in the assessment and incorporating a stream type determination. The result is an assessment method that can be rapidly applied on a variety of stream types in different physiographic settings with a range of bed and bank materials.

The Channel Stability Assessment protocol was designed to evaluate 13 parameters: watershed land use, status of flow, channel pattern, entrenchment/channel confinement, bed substrate material, bar development, presence of obstructions and debris jams, bank soil texture and coherence, average bank angle, bank vegetation, bank cutting, mass wasting/bank failure, and upstream distance to bridge. Once all parameters are scored, the stability of the stream is then classified as Excellent, Good, Fair, or Poor. As the protocol was designed to assess stream channel stability near bridges, two minor modifications were made to the methodology to make it more applicable to project specific conditions. The first modification involved adjusting the scoring so that naturally meandering streams score lower (better condition) than straight and/or engineered channels. Because straight, engineered channels are hydraulically efficient and necessary for bridge protection, they score low (excellent to good rating) with the original methodology. Secondly, the last assessment parameter – upstream distance to bridge – was removed from the protocol because it relates directly to the potential effects of instability on a bridge and should not influence stability ratings for the streams assessed for this project. The final scores and corresponding ratings were based on the twelve remaining parameters. The rating adjectives were assigned to the streams based on the FHWA guidelines for pool-riffle stream types.

The HEC-20 manual also describes both lateral and vertical components of overall channel stability which can be separated with this assessment methodology. Some of the 13 parameters described above relate specifically to either vertical or horizontal stability. When all parameter scores for the vertical category or all parameter scores for the horizontal category are summed and normalized by the total possible scores for their respective categories, a vertical or horizontal fraction is produced. These fractions may then be compared to one another determine if the channel is more vertically or horizontally unstable.

The assessment results for the streams on the Hopewell site indicate that all of the streams are rated good except for UT2 and UT2A Reach 2 which were rated fair (the second to lowest category). For every stream assessed, the lateral fraction was greater than the vertical fraction indicating that the streams are more laterally unstable than vertically unstable. This is mostly because of cattle impacts. UT2 and UT2A Reach 2 are very incised resulting in there higher relative vertical instability fractions. Total scores, stability ratings, and vertical and horizontal fractions are provided in Table 6.

Table 6. Existing Conditions Channel Stability Assessment Results

Parameter	Little River	UT1A	UT1B	UT2 R1	UT2 R2	UT2A R1	UT2A R2	UT2B
1. Watershed characteristics	5	4	4	3	3	3	3	4
2. Flow habit	2	4	4	3	3	3	4	3
3. Channel pattern	5	5	7	4	4	4	5	3
4. Entrenchment	3	3	3	10	10	5	10	3
5. Bed material	7	7	7	8	8	7	7	8
6. Bar development	2	5	5	5	5	7	5	5
7. Obstructions	6	4	4	4	4	4	4	4
8. Bank soil texture and coherence	6	6	6	6	6	6	6	6

Parameter	Little River	UT1A	UT1B	UT2 R1	UT2 R2	UT2A R1	UT2A R2	UT2B
9. Average bank slope angle	6	9	9	9	9	5	9	9
10. Bank protection	4	6	7	7	7	6	7	6
11. Bank cutting	4	7	6	9	10	9	10	7
12. Mass wasting or bank failure	2	6	5	9	9	5	9	6
Score	**52**	**66**	**67**	**77**	**78**	**64**	**79**	**64**
Ranking	**Good**	**Good**	**Good**	**Fair**	**Fair**	**Good**	**Fair**	**Good**
Lateral Score	22	34	33	40	41	31	41	34
Vertical Score	12	15	15	23	23	19	22	16
Lateral Fraction	36.7%	56.7%	55.0%	66.7%	68.3%	51.7%	68.3%	56.7%
Vertical Fraction	33.3%	41.7%	41.7%	63.9%	63.9%	52.8%	61.1%	44.4%

5.5 Bankfull Verification

Many of the stream banks along the project reaches have been trampled by cattle and therefore bankfull indicators were difficult to identify. However, during the existing conditions assessment, Wildlands staff identified bankfull indicators when available and noted breaks in bank slope. Cross sections were surveyed for each project reach to characterize the existing conditions of riffles and pools along each reach and to help verify bankfull discharge and dimensions. For cross sections where bankfull indicators were available, the Manning's equation was applied to the surveyed cross-sections with a water surface at the bankfull stage to calculate an estimated bankfull discharge. The computed bankfull discharges and bankfull cross-sectional areas of these reaches were plotted on the North Carolina rural Piedmont regional curves (Figure 6) in order to verify that the bankfull stage estimates were reasonably similar to values predicted by the regional curves. For cross sections where no bankfull indicators were available, bankfull stage was estimated in the office with the regional curve. This was most often done by picking a break in bank slope that most closely corresponded with the bankfull area predicted by the regional curve. The estimates of bankfull stage were used to characterize the existing channel cross sections (e.g. width to depth ratios, bank height ratios, etc.) and have no bearing on the design.

A nearby USGS gauging station (station 02123567 – Dutchman's Creek Near Uwharrie, NC) was used to develop a calibrated estimate of bankfull discharge for use in verifying the existing conditions discharges calculated at the project site. The bankfull discharge of the Dutchman's gauge site was determined to be 220 cfs with a recurrence interval of 1.3 years. Bankfull data for the gauge site are plotted with the North Carolina rural Piedmont regional curve for discharge and drainage area in Figure 6.

Analysis of the bankfull discharges for the project reaches, reference reaches, and gauge survey reveals that the data consistently plot within the 95% confidence intervals of the regional curve in all cases where the points are within the range of drainage areas (independent variable) covered by the regional curves. This information indicates that the bankfull indicators identified during the existing conditions assessment provide reasonable estimates of bankfull discharge and associated hydraulic geometry for the existing conditions. The next section discusses the development of design discharges.

5.6 Design Discharge

Multiple methods were used to develop bankfull discharge estimates of the project reaches. The resulting values were compared and concurrence between the estimates and best professional judgment were used to determine the specific design discharge for each project reach.

The methods to estimate discharge included:

- The published North Carolina rural piedmont regional curve (Harman, et al., 1999) and the calibrated discharge for the Dutchman's Creek gauge;
- Regional flood frequency analysis developed for this project;
- USGS Regional Flood Frequency equations; and
- Drainage area – discharge relations from select reference reaches.

A common practice for stream restoration projects in the North Carolina Piedmont is to use the 1999 regional curves to estimate discharge and/or cross-sectional area. The regional curve for discharge was used to estimate bankfull discharge with the drainage area for each project reach as the input.

To develop the regional flood frequency relations, seven USGS stream gauge sites were identified within reasonable proximity of the project site. Data from these gauges were used to develop three regional flood frequency curves as described by Dalrymple (1960). The gauges used were:

- 02123567 Dutchman's Creek near Uwharrie, NC – Drainage Area is 3.44 square miles
- 02099000 East Fork Deep River near High Point, NC – Drainage Area is 14.8 square miles
- 0210166029 Rocky River near Crutchfield Crossroads, NC – Drainage Area is 7.42 square miles
- 0212467595 Goose Creek at Indian Trail, NC – Drainage Area is 11.0 square miles
- 02125699 Wicker Creek near Trinity, NC – Drainage Area is 5.83 square miles
- 0212466000 Clear Creek near Mint Hill, NC – Drainage Area is 12.6 square miles
- 02124080 Clarke Creek near Harrisburg, NC – Drainage Area is 21.9 square miles

Flood frequency curves were developed for the 1.1-year, 1.25-year, and 1.50-year recurrence interval discharges. These relations can be used to estimate discharge of those recurrence intervals for ungauged streams in the same hydrologic region and were solved for discharge with the drainage area for each project reach as the input.

The USGS National Flood Frequency (NFF) equation for the Piedmont of the rural Southeastern United States (Weaver et al., 2009) was used to develop an estimate of the 2-year peak discharge. The equation was solved for discharge with the drainage area for each project reach as the input.

The drainage area and bankfull discharge values (calculated with Manning's equation) for four ungauged reference reaches selected for use in the project (see Section 7) were compiled for comparison to the discharge estimates described above. These drainage area and bankfull discharge values were used to create a reference reach drainage area – discharge regression curve.

A design discharge was selected for each reach based on comparison of the results of these analyses. The rural Piedmont regional curve predicts bankfull discharges for the project reaches that are very similar to the regional flood frequency 1.2-year discharges. The reference reach drainage area-discharge curve produces discharges that are similar to the regional flood frequency 1.1-year discharges. The USGS NFF equation produces an estimate of the 2-year discharges which are significantly larger magnitude than the other estimates but provide a useful comparison from a separate method. The design discharges were chosen to be on the low end of the predicted range of the bankfull or 1.0- to 1.2-year discharges predicted by the various analyses. The design discharges are significantly lower than the estimates made from the rural Piedmont regional curves but similar to the 1.1-year regional flood frequency and the reference reach drainage area-discharge curve. Out-of-bank flow events are expected to occur on the proposed channels one or more times per year. Table 7 summarizes the results of each of the discharge analyses described in this section and shows the selected design discharges.

Table 7. Design Discharge Analysis Summary

Reach	Drainage Area (ac)	Drainage Area (sq. mi.)	Regional Curve Qbkf (CFS) [1]	Reference Reach Qbkf (CFS) [2]	USGS NFF Q 2- yr (CFS) [3]	RFF Q1.5-yr (CFS) [4]	RFF Q1.2-yr (CFS) [5]	RFF Q1.1-yr (CFS) [6]	Design Qbkf (CFS)
UT1B Reach 1	19	0.03	7	5	15	10	7	6	6
UT2 Reach 1	246	0.38	46	38	85	65	46	39	40
UT2 Reach 2	378	0.59	63	54	112	87	62	54	54
UT2A Reach 1	64	0.01	18	13	35	25	18	15	15
UT2A Reach 2	102	0.16	25	19	48	35	25	21	21
UT2B Reach 2	22	0.03	8	5	18	12	9	7	7
UT2C Reach 2 and 3	51	0.08	15	10	31	21	15	13	13

Notes:
1. Estimate of bankfull discharge based on rural Piedmont regional curve (Harman et al., 1999).
2. Bankfull discharge estimates based on regression relation developed from reference reach data collected for this project.
3. 2-year year discharge estimate calculated from USGS NFF regional regression equations (Weaver et al., 2009).
4. 1.5-year discharge estimate developed through a regional flood frequency analysis of four nearby gauges
5. 1.2-year discharge estimate developed through a regional flood frequency analysis of four nearby gauges.
6. 1.1-year discharge estimate developed through a regional flood frequency analysis of four nearby gauges.

6.0 Baseline Information - Regulatory Considerations

Table 8 presents the project information and baseline wetland information.

Table 8. Regulatory Considerations

	Applicable?	Resolved?	Supporting Documentation
Waters of the US – Section 404	Yes	Yes	NW27 Permit pending
Waters of the US – Section 401	Yes	Yes	401 Certification pending
Endangered Species Act	Yes	Yes	Letter from USFWS (see Appendix 6)
Historic Preservation Act	Yes	Yes	Letter from SHPO (see Appendix 6)
Coastal Zone Management Act/Coastal Area Management Act	No	N/A	N/A
FEMA Floodplain Compliance	Yes	No	In Progress (see Appendix 7)
Essential Fisheries Habitat	No	N/A	N/A

6.1 401/404

As discussed in Section 4.5, the results of the onsite field investigation indicate that seven channels including Little River and its unnamed tributaries are jurisdictional within the project limits (Figure 2). Additionally there are eleven jurisdictional wetland areas (Wetland A – K) located within the proposed project area. Each of the described tributaries and wetland features will be protected under the conservation easement to be placed on the properties. The Jurisdictional Determination, including all necessary and required forms, was submitted to the USACE Wilmington District on December 7, 2012. Following submittal, a verification field walk was conducted with John Thomas of the USACE Raleigh Field Office and Wildlands on February 5, 2013 to review on-site Water of the U.S. A signed Notification of Jurisdictional Determination has been completed by the USACE on February 28, 2013 and is enclosed in Appendix 3. There will be an impact to wetland A of 0.009 acres due to construction of UT2 and an impact to wetland B of 0.006 acres due to construction of UT2A. These impacts will be offset by the creation of several acres of vernal pools throughout the project site. Remaining existing wetland areas will be protected by high visibility safety fence. The contractor will be instructed to avoid disturbing those wetland areas during construction.

6.2 Endangered and Threatened Species

6.2.1 Site Evaluation Methodology

The Endangered Species Act (ESA) of 1973, amended (16 U.S.C. 1531 et seq.), defines protection for species with the Federal Classification of Threatened (T) or Endangered (E). An "Endangered Species" is defined as "any species which is in danger of extinction throughout all or a significant portion of its range" and a "Threatened Species" is defined as "any species which is likely to become an Endangered Species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532).

The US Fish and Wildlife Service (USFWS) and NC Natural Heritage Program (NHP) databases were searched for federally listed threatened and endangered plant and animal species for Randolph

County, NC. Two federally listed species, the Cape Fear shiner (*Notropis mekistocholas*) and Schweinitz's sunflower (*Helianthus schweinitzii*) are currently listed in Randolph County (Table 9).

Table 9. Listed Threatened and Endangered Species in Randolph County, NC
Hopewell Stream Mitigation Project

Species	Federal Status	Habitat	Biological Conclusion
Invertebrate			
Cape Fear Shiner (*Notropis mekistocholas*)	E	Pools, riffles, and runs of rocky, clean freshwater streams	No effect
Vascular Plants			
Schweinitz's sunflower *(Helianthus schweinitzii)*	E	Open, disturbed areas	No effect
E = Endangered; T=Threatened; BGEPA = Bald and Golden Eagle Protection Act			

6.2.2 Threatened and Endangered Species Descriptions

Cape Fear Shiner

The Cape Fear shiner is a small minnow fish species, typically six (6) centimeters in length. This species is pale silvery yellow in color with a black stripe along each side and yellow fins. Water willow beds in flowing areas of creeks and rivers appear to be part of the essential habitat for this species. Individuals can be found in pools, riffles, and slow runs of clean, rocky streams composed of gravel, cobble, and boulder substrates.

Schweinitz's Sunflower

Schweinitz's sunflower is found in open areas where disturbance has occurred such as roadsides, power line clearings, old pastures and woodland openings. This species is generally found growing in shallow, poor, clayey and/or rocky soils.

6.2.3 Biological Conclusion

Based on a pedestrian surveys of the site that were performed on November 10, 2011, October 3 and November 19, 2012, no individual species, critical habitat, or suitable habitat was found to exist on the site. It was determined that the biological conclusion is "no effect."

Review and comment from the United States Fish and Wildlife Service (USFWS) was requested on June 26, 2012 in respect to the Hopewell Stream Mitigation Site and its potential impacts on threatened or endangered species (Appendix 6). The USFWS responded on July 27, 2012 and determined that "based on the information provided and other information available, it appears that the proposed action is not likely to adversely affect any federally-listed endangered or threatened species, their formally designated critical habitat, or species currently proposed for listing under the Act at these sites."

6.3 Cultural Resources

6.3.1 Site Evaluation Methodology

The National Historic Preservation Act (NHPA) of 1966, amended (16 U.S.C. 470), defines the policy of historic preservation to protect, restore, and reuse districts, sites, structures, and objects significant in American history, architecture, and culture. Section 106 of the NHPA mandates that federal agencies take into account the effect of an undertaking on any property, which is included in, or eligible for inclusion in, the National Register of Historic Places. A letter was sent to the North Carolina State Historic Preservation Office (SHPO) on June 26, 2012, requesting review and comment on any cultural resources potentially affected by the Hopewell Stream Mitigation Project.

6.3.2 SHPO/THPO Concurrence

A request for review and comment from the SHPO with respect to any archeological and architectural resources related to the Hopewell Stream Mitigation Project was made on June 26, 2012 (Appendix 6). SHPO responded on July 13, 2012 and determined that the project as proposed will not have an effect on any historic resources.

6.4 FEMA Floodplain Compliance and Hydrologic Trespass

The stream channel on the site is mapped as Little River on Panel 7648 of the Randolph County FIRM floodplain mapping (Appendix 7). Little River is a mapped Zone AE floodplain with defined base flood elevations. A floodway has not been delineated but non-encroachment widths have been defined. The project includes Enhancement II for most of the length of Little River on the project site in the form of riparian species management, spot stabilization, and planting. A short reach of Little River will also be preserved. These actions will not cause adverse floodplain impacts to adjacent properties or local roadways or cause impacts to the 100-year water surface elevations. None of the other project streams are mapped on the Randolph County FIRM panels. Therefore, no flood study will be performed for this project. WEI will coordinate with the local floodplain administrator as needed to ensure any required floodplain development permits are obtained.

6.5 Essential Fisheries Habitat

6.5.1 Habitat Description

The USFWS does not list any Critical Habitat areas for Randolph County. Agency correspondence received for the project contains no mention of essential fisheries or requests for additional information related to essential fisheries.

6.5.2 Biological Conclusion

Given that there are no listed Critical Habitat areas, the project will have no effect on essential fisheries habitat.

6.6 Utilities and Site Access

There are no known utilities or other easements located on the properties that will affect the project. The DOT right-of-ways along Pisgah Covered Bridge Road and Mack Road will be excluded from the project area. There are three ford crossings on the project site including one crossing each on UT1A, UT2, and UT2A. There is a bridge crossing on Little River near the downstream end of the project.

There is also a dam and pond on UT1B and a farm road crosses the top of the dam. The project will include culverted crossings at or very near each existing ford on UT2 and UT2A. The ford crossing on UT1A will remain as a wet crossing. The road over the dam will be left in its current state. There is also a 12-inch culvert at the upstream end of UT2A that will not be affected by the project.

The western side of the site will be accessed from Mack Road through an existing gate. The eastern side of the site will be accessed through an existing gate and the primary driveway off of Pisgah Covered Bridge Road and/or through a second existing gate farther north on Pisgah Covered Bridge Road. Open fields will allow easy movement of construction equipment within the properties.

6.7 Reference Streams

Five reference reaches were identified near the project area and used to support the design of the project reaches (Figure 7). Reference reaches can be used as a basis for design or, more appropriately, as one source of information on which to base a stream restoration design. Most, if not all, reference reaches identified in the North Carolina Piedmont are in heavily wooded areas and the mature vegetation contributes greatly to their stability. Design parameters for this project were also developed based on the design discharge along with dimensionless ratio values associated with successful restoration designs of streams in the North Carolina Piedmont. Reference reach data for similar streams were obtained from existing data sets or were collected for this project specifically and used to verify design parameters (Tables 10a and 10b). The reference streams considered when developing design parameters for this project include Dutchman's Creek (upstream of the USGS gauge site), three reaches of Spencer Creek, and UT to Rocky Creek. These reference streams were chosen because of similarities to the project streams including drainage area, valley slope and morphology, and bed material. The reference reaches are within the Carolina Slate Belt region of the Piedmont.

6.7.1 Reference Streams Channel Morphology and Classification

Dutchmans Creek is located on the western edge of Montgomery County, west of Albemarle, NC. Wildlands collected three cross sections and a longitudinal profile representative of the reference reach. The drainage area is 2.90 square miles and the land use within the drainage area is all forest. The Dutchmans Creek reference site was classified as a B/C4 channel type. The channel has a width to depth ratio ranging from 16.4 to 28.9 and an entrenchment ratio of 2.15 to 2.63. The reach has a channel slope of 0.019 ft/ ft.

The UT to Rocky Creek reference site is located in central Montgomery County within the Uwharrie National Forest. The drainage area is 1.10 square miles and the land use within the drainage area is a semi-mature forest. The UT to Rocky Creek reference site was classified as an E4b stream type with a low sinuosity (1.1). The channel has a width to depth ratio of 9.1 and an entrenchment ratio of 6. The reach has a valley slope of 2.6% while the channel slope is 2.4%. The bed material d_{50} for the reach is 22.6 mm indicating a gravel bed channel. Due to the low sinuosity, no pattern data were collected.

The Spencer Creek reference site consists of three reaches with separate datasets and is located in Central Montgomery County within the Uwharrie National Forest. The Spencer Creek Reach 1 site has a drainage area of 0.50 square miles and the land use within the drainage area is a semi-mature forest. The reach was classified as an E4 stream type with a low sinuosity (1.1). The channel has a width to depth ratio of 7.3 and an entrenchment ratio of 26.3. The reach has a valley slope of 1.4% while the channel slope is 1.3%. The bed material d_{50} for the reach is 8.6 mm indicating a small gravel bed channel. The Spencer Creek Reach 2 site has a drainage area of 0.96 square miles and the land use within the drainage area is a semi-mature forest. The reach was classified as an E4 stream type with a sinuosity of 1.3. The channel has a width to depth ranging from 5.8 to 7.1 and an entrenchment ratio ranging from 5.5 to 10.2. The reach has a valley slope of 0.4% while the channel slope is 0.3%. The bed material d_{50} for the reach is 8.8 mm indicating a small gravel bed channel. The Spencer Creek Reach 3 site is just downstream of Reach 2. Wildlands surveyed this reach specifically for this project. The width to depth ratio ranges from 7.9 to 9.3, the entrenchment ratio ranges from 1.7 to 4.3, the channel slope ranges from 1.9% to 2.2%, and the d_{50} is 11 mm. Pattern data are included for each of the three datasets for Spencer Creek. Given the similarities in drainage area, stream type, stream and valley slope, and bed material size, the Spencer Creek reaches are the most directly applicable reference reaches for UT2, UT2A, UT2B, and UT2C (the reaches proposed for restoration).

Table 10a. Summary of Reference Reach Geomorphic Parameters

			Dutchman's Creek		UT to Rocky Creek	
Parameter	Notation	Units	min	max	min	max
stream type			B/C		E4b	
drainage area	DA	sq mi	2.9		1.1	
bankfull discharge	Q_{bkf}	cfs	203		85.0	
bankfull cross-sectional area	A_{bkf}	SF	32.9	36.1	16.3	
average velocity during bankfull event	v_{bkf}	fps	---	---	5.5	
width at bankfull	w_{bkf}	feet	23	32	12.2	
maximum depth at bankfull	d_{max}	feet	1.88	2.13	1.8	
mean depth at bankfull	d_{bkf}	feet	1.1	1.4	1.3	
bankfull width to depth ratio	w_{bkf}/d_{bkf}		16.4	28.9	9.1	
max depth ratio	d_{max}/d_{bkf}		1.5	1.7	1.3	
bank height ratio	BHR		---	---	1.0	
floodprone area width	w_{fpa}	feet	61.2	69.4	72.0	
entrenchment ratio	ER		2.15	2.63	6.0	

			Dutchman's Creek		UT to Rocky Creek	
Parameter	Notation	Units	min	max	min	max
valley slope	S_{valley}	ft/ft	---		0.0261	
channel slope	$S_{channel}$	ft/ft	0.019		0.0235	
sinuosity	K		---	---	1.1	
riffle slope	S_{riffle}	ft/ft	---	---	0.0606	0.0892
riffle slope ratio	$S_{riffle}/S_{channel}$		---	---	2.6	3.8
pool slope	S_{pool}	ft/ft	---	---	0	0.0037
pool slope ratio	$S_{pool}/S_{channel}$		---	---	0.0	0.2
pool-to-pool spacing	L_{p-p}	feet	---	---	26	81
pool spacing ratio	L_{p-p}/w_{bkf}		---	---	2.2	6.7
maximum pool depth at bankfull	d_{pool}	feet	---	---	2.2	
pool depth ratio	d_{pool}/d_{bkf}		---	---	1.6	
pool width at bankfull	w_{pool}	feet	---	---	10.9	
pool width ratio	w_{pool}/w_{bkf}		---	---	0.9	
pool cross-sectional area at bankfull	A_{pool}	SF	---	---	19.3	
pool area ratio	A_{pool}/A_{bkf}		---	---	1.2	
belt width	w_{blt}	feet	---	---	N/A	
meander width ratio	w_{blt}/w_{bkf}		---	---	N/A	
meander length	L_m	feet	---	---	N/A	
meander length ratio	L_m/w_{bkf}		---	---	N/A	

			Dutchman's Creek		UT to Rocky Creek	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**
radius of curvature	R_c	feet	---	---	N/A	
radius of curvature ratio	R_c/ w_{bkf}		---	---	N/A	
meander stream length	L_{sm}	feet	---	---	---	---
meander stream length ratio	L_{sm}/w_{bkf}		---	---	---	---
Sediment						
Bed material data for stream classification			---	---	**Coarse Gravel**	
D_{16}	D_{16}	mm	---	---	<0.063	
D_{35}	D_{35}	mm	---	---	2.4	
D_{50}	D_{50}	mm	---	---	22.6	
D_{84}	D_{84}	mm	---	---	120	
D_{95}	D_{95}	mm	---	---	256	

Table 10b. Summary of Reference Reach Geomorphic Parameters

			Spencer Creek 1		Spencer Creek 2		Spencer Creek 3	
Parameter	**Notation**	**Units**			**min**	**max**	**min**	**max**
stream type			E4/C4		E4		E4	
drainage area	DA	sq mi	0.5		0.96		0.37	
bankfull discharge	Q_{bkf}	cfs	N/P		97.0		35.0	
bankfull cross-sectional area	A_{bkf}	SF	10.6		17.8	19.7	6.6	8.7
average velocity during bankfull event	v_{bkf}	fps	N/P		4.9	5.4	5.0	5.6
width at bankfull	w_{bkf}	feet	8.7		10.7	11.2	6.3	9.3
maximum depth at bankfull	d_{max}	feet	1.9		2.1	2.6	1.0	1.2

			Spencer Creek 1		Spencer Creek 2		Spencer Creek 3	
Parameter	**Notation**	**Units**			**min**	**max**	**min**	**max**
mean depth at bankfull	d_{bkf}	feet	1.2		1.6	1.8	0.8	1.0
bankfull width to depth ratio	w_{bkf}/d_{bkf}		7.3		5.8	7.1	7.9	9.3
max depth ratio	d_{max}/d_{bkf}		1.6		1.3	1.4	1.3	1.2
bank height ratio	BHR		1		1.0		1.0	1.0
floodprone area width	w_{fpa}	feet	229		60.0	114+	14.0	125.0
entrenchment ratio	ER		26.3		5.5	10.2	1.7	4.3
valley slope	S_{valley}	ft/ft	0.0139		0.0109		0.022	0.031
channel slope	$S_{channel}$	ft/ft	0.0132		0.0047		0.019	0.022
sinuosity	K		1.1		1.3		1.0	1.3
riffle slope	S_{riffle}	ft/ft	0.010	0.067	0.013		0.0184	0.0343
riffle slope ratio	$S_{riffle}/S_{channel}$		0.8	5.1	0.0		1.0	1.6
pool slope	S_{pool}	ft/ft	0		0.0007	0.0009	0.0007	0.0140
pool slope ratio	$S_{pool}/S_{channel}$		0.0		0.2	0.2	0.0	0.6
pool-to-pool spacing	L_{p-p}	feet	13	47	71		9	46
pool spacing ratio	L_{p-p}/w_{bkf}		1.5	5.3	6.3	6.6	1.4	4.9
maximum pool depth at bankfull	d_{pool}	feet	2.5		3.3		1.2	1.8
pool depth ratio	d_{pool}/d_{bkf}		2.1		1.8	2.0	1.5	1.8
pool width at bankfull	w_{pool}	feet	8.4		17.5		6.0	12.0
pool width ratio	w_{pool}/w_{bkf}		1.0		2.7		1.0	1.3

			Spencer Creek 1		Spencer Creek 2		Spencer Creek 3	
Parameter	**Notation**	**Units**			**min**	**max**	**min**	**max**
pool cross-sectional area at bankfull	A_{pool}	SF	12.8		24.5		6.5	9.8
pool area ratio	A_{pool}/A_{bkf}		1.2		1.2	1.4	1.0	1.1
belt width	w_{blt}	feet	24	52	38	41	10	50
meander width ratio	w_{blt}/w_{bkf}		2.8	6.0	3.4	3.6	1.6	5.4
meander length	L_m	feet	54	196	46	48	55	142
meander length ratio	L_m/w_{bkf}		6.2	22.5	4.1	4.4	8.7	15.3
radius of curvature	R_c	feet	5	22	11	15	12	85
radius of curvature ratio	R_c/ w_{bkf}		0.6	2.5	1.3	1.4	1.9	9.1
meander stream length	L_{sm}	feet	---	---	---	---	53	178
meander stream length ratio	L_{sm}/w_{bkf}		---	---	---	---	8.4	19.1
Sediment								
Bed material data for stream classification			**Medium Gravel**		**Medium Gravel**		**Medium Gravel**	
D_{16}	D_{16}	mm	0.1		<0.063		1.866	
D_{35}	D_{35}	mm	3		3		8.85	
D_{50}	D_{50}	mm	8.6		8.8		11	
D_{84}	D_{84}	mm	77		42		64	
D_{95}	D_{95}	mm	180		90		128	

6.7.2 Reference Streams Vegetation Community Types Descriptions

The Spencer Creek and Dutchmans Creek reference sites provide the best reference vegetation information to be used for this project based on their proximity to the site and the condition of the forests surrounding the sites. Both are surrounded by mature hardwood forests within the Uwharrie National Forest. Vegetation at Spencer Creek is composed of typical Piedmont bottomland forest tree species (Shafale and Weakley, 1990). Dominant species include sweet gum (Liquidambar styraciflua), tulip poplar (Liriodendron tulipifera), red maple (Acer rubrum), hackberry (Celtis occidentalis), and American elm (Ulmus Americana). Common understory vegetation includes ironwood (Carpinus caroliniana), American holly (Ilex opaca), paw paw (Asimina triloba), and flowering dogwood (Cornus florida). The Dutchmans Creek site is classified as a Mesic Mixed Hardwood Forest (Schafale and Weakley, 1990). Dominant species include American beech (Fagus grandifolia), Northern Red Oak (Quercus rubra), tulip poplar, and red maple. Understory vegetation includes American holly, red maple, and flowering dogwood. In addition, rhododendron species were present and dense along portions of the reach.

7.0 Determination of Credits

Mitigation credits presented in Table 11 are projections based upon site design. Upon completion of site construction the project components and credits data will be revised to be consistent with the as-built condition.

Table 11. Determination of Credits

Hopewell Mitigation Site, Randolph County, DENR Contract #004642										
Mitigation Credits										
	Stream		**Riparian Wetland**		**Non-riparian Wetland**		**Buffer**	**Nitrogen Nutrient Offset**	**Phosphorus Nutrient Offset**	
Type	R	RE	R	RE	R	RE				
Totals	7,299	164	NA	NA	NA	NA	NA	NA	NA	

Project Components							
Project Component or Reach ID	**Stationing / Location**	**Existing Footage / Acreage**	**Approach (PI, PII, etc.)**	**Restoration or Restoration Equivalent**	**Restoration Footage or Acreage**	**Mitigation Ratio**	**Credits**
Little River	100+00 – 107+04	704	Fencing/ invasives control	P	704	5:1	141
Little River	107+04 – 127+28 and 128+07 – 131+57	2,374	Fencing/ invasives control	EII	2,374	2.5:1	950
UT1A	200+00 – 108+95 and 209+84 – 217+00	1,611	Fencing/ invasives control	EII	1,611	2.5:1	644
UT1A	217+00 – 218+17	117	Fencing/ invasives control	P	117	5:1	23
UT1B	300+87 – 305+62	475	P2	EI	475	1.5:1	317
UT1B	305+62 – 308+25 and 350+00 – 353+17	580	Fencing/ invasives control	EII	580	2.5:1	232

UT2	400+00 – 415+27 and 416+13 – 423+17	2,419	P1	R	2,231	1:1	2,231
UT2A	500+39 – 504+25	368	Fencing/ invasives control – P1	EI	386	1.5:1	257
UT2A	504+25 – 516+20 and 517+00 – 518+68	1,368	P1	R	1,363	1:1	1,363
UT2B	600+00 – 608+48	848	Fencing/ invasives control	EII	848	2.5:1	339
UT2B	608+48 – 610+46	114	P1	R	198	1:1	198
UT2C	700+00 – 712+15	1,215	Fencing/ invasives control	EII	1,215	2.5:1	486
UT2C	712+15 – 713+60 and 800+00 to 801+37	326	P2	R	282	1:1	282

Component Summation

Restoration Level	Stream (linear feet)	Riparian Wetland (acres)		Non-Riparian Wetland (acres)	Buffer (square feet)	Upland (acres)
		Riverine	Non-Riv.			
Restoration	4,074	NA	NA	NA	NA	NA
Enhancement		NA	NA	NA	NA	NA
Enhancement I	861					
Enhancement II	6,628					
Creation		NA	NA	NA		
Preservation	821	NA	NA	NA		NA
High Quality Preservation	NA	NA	NA	NA		NA

8.0 Credit Release Schedule

All credit releases will be based on the total credit generated as reported by the as-built survey of the mitigation site. Under no circumstances shall any mitigation project be debited until the necessary DA authorization has been received for its construction or the District Engineer (DE) has otherwise provided written approval for the project in the case where no DA authorization is required for construction of the mitigation project. The DE, in consultation with the Interagency Review Team (IRT), will determine if performance standards have been satisfied sufficiently to meet the requirements of the release schedules below. In cases where some performance standards have not been met, credits may still be released depending on the specifics of the case. Monitoring may be required to restart or be extended, depending on the extent to which the site fails to meet the specified performance standard. The release of project credits will be subject to the criteria described as follows:

Table 12. Credit Release Schedule – Stream Credits

Monitoring Year	Credit Release Activity	Interim Release	Total Released
0	Initial Allocation – see requirements below	30%	30%
1	First year monitoring report demonstrates performance standards are being met	10%	40%
2	Second year monitoring report demonstrates performance standards are being met	10%	50% (60%*)
3	Third year monitoring report demonstrates performance standards are being met	10%	60% (70%*)
4	Fourth year monitoring report demonstrates performance standards are being met	10%	75% (85%*)
5	Fifth year monitoring report demonstrates performance standards are being met and project has received closeout approval	15%	90% (100%)

8.1 Initial Allocation of Released Credits

The initial allocation of released credits, as specified in the mitigation plan can be released by the NCEEP without prior written approval of the DE upon satisfactory completion of the following activities:

a. Approval of the final Mitigation Plan
b. Recordation of the preservation mechanism, as well as a title opinion acceptable to the USACE covering the property
c. Completion of project construction (the initial physical and biological improvements to the mitigation site) pursuant to the mitigation plan; Per the NCEEP Instrument, construction means that a mitigation site has been constructed in its entirety, to include planting, and an as-built report has been produced. As-built reports must be sealed by an engineer prior to project closeout, if appropriate but not prior to the initial allocation of released credits.
d. Receipt of necessary DA permit authorization or written DA approval for projects where DA permit issuance is not required.

8.2 Subsequent Credit Releases

All subsequent credit releases must be approved by the DE, in consultation with the IRT, based on a determination that required performance standards have been achieved. For stream projects a reserve of 10% of a site's total stream credits shall be released after two bank-full events have occurred, in separate years, provided the channel is stable and all other performance standards are met. In the event that less than two bank-full events occur during the monitoring period, release of these reserve credits shall be at the discretion of the IRT. As projects approach milestones associated with credit release, the NCEEP will submit a request for credit release to the DE along with documentation substantiating achievement of criteria required for release to occur. This documentation will be included with the annual monitoring report.

9.0 Project Site Mitigation Plan

9.1 Channel Design Summary

The design streams will be restored to the appropriate type based on the surrounding landscape, climate, and natural vegetation communities but also with strong consideration for existing watershed conditions and trajectory. The project includes stream restoration, enhancement, and preservation as shown in Figure 8. The specific proposed stream types are described below.

The stream restoration portion of this project includes six reaches on four streams:

UT2: This restoration reach extends from a point 380 feet southwest of the eastern corner on the northern-most property boundary to the existing location at which the stream crosses the southern property boundary on the western side. This reach includes one 75-foot easement break for a culvert farm road crossing and the stream within this break is not included in the restoration credit total. The design includes two reaches – upstream of the confluence with UT2A and one downstream of the confluence.

UT2A: This reach begins immediately downstream of the existing culvert on UT2A and continues to the confluence with UT2. This reach also includes one 75-foot easement break for a culvert farm road crossing that is not included in the restoration credit total. The design includes Reach 1 above the confluence with UT2B and Reach 2 from this confluence to the confluence with UT2.

UT2B: Restoration is planned for the lower 114 feet of the existing stream from the end of the enhancement II section to the confluence with UT2A.

UT2C: Restoration is planned for the lower 326 feet of the existing stream from the end of the enhancement II section to the confluence with UT2.

The project also includes stream enhancement on six reaches classified as either enhancement I (EI) or enhancement II (EII):

UT1B, EI: The enhancement I reach on UT1B extends from the upstream end of the project reach just 100 feet downstream of the DOT right-of-way along Pisgah Covered Bridge Road to the woodline east of the pond.

Little River, EII: enhancement II will be performed on a section of Little River beginning 704 feet downstream from the northern property boundary on the eastern side to the point where the river flows off of the property on the southern property boundary. This reach includes one 75-foot easement break for a bridge farm road crossing and the river within this break is not included in the enhancement credit total.

UT1A EII: Enhancement II will also be performed from the beginning of UT1A near the eastern property boundary to a point 117 feet upstream from the confluence with Little River. This reach includes one 75-foot easement break for a culvert farm road crossing that is not included in the enhancement II credit total.

UT1B EII: Enhancement II on this stream includes two reaches. Reach 2 begins at the woodline east of the pond and continues to the pond. Reach 3 begins at a point where the spillway channel from the pond enters UT1B below the pond and continues to the confluence with Little River. No credit is claimed for the pond or UT1B between the pond outlet and the confluence with the spillway channel. However, a restrictive covenant will be placed on the pond to require that cattle not have access to the pond.

UT2B EII: The enhancement 2 reach on this stream begins approximately 120 feet south of the northern property boundary on the western side. It extends to a point on the existing channel that is 114 feet upstream of the confluence with UT2B.

UT2C: Enhancement II will be performed from a point where perennial flow begins at a spring head approximately 415 feet eat of Mack Road to a point 1,215 feet downstream where a short section of restoration is planned to begin.

The project also includes preservation on two reaches:

Little River: The upstream 704 feet of Little River on the property is planned for preservation.

UT1A: The downstream 117 feet of UT1A between the EII section and the confluence with Little River is also planned for preservation.

The stream restoration reaches were designed to be similar to C type stream according to the Rosgen classification system (Rosgen, 1996). Type C streams are slightly entrenched, meandering streams with access to the floodplain (entrenchment ratios >2.2) and channel slopes of 2% or less. They occur within a wide range of valley types and are appropriate for the project landscape.

The morphologic design parameters as shown in Tables 13a and 13b for the restoration and enhancement I reaches fall within the ranges specified for C or Cb streams (Rosgen, 1996). However, the specific values for the design parameters were selected based on designer experience and judgment and were verified with morphologic data form reference reach data sets. The width to depth ratios range from 12 to 14. The design channel slopes of the restoration and enhancement I reaches ranged from 0.0075 to 0.038.

Each of the design reaches will be reconnected with the existing floodplain (Priority 1). In some cases a short section of Priority 2 restoration will be required to tie the restored channel to the downstream reach while maintaining cross-sectional design parameters. The restored channels will have entrenchment ratios significantly greater than 2.2. The sinuosity for the restoration reaches will be near 1.1. The sinuosity measurements for the enhancement I reaches will match the existing sinuosity.

The proposed channels for the restoration and enhancement I reaches will be threshold channels. This design approach is appropriate when the bedload supply is low and when it is desirable that the channel boundary be immobile. In these situations, the channel is not intended to be fully alluvial and is not expected to migrate laterally over time. Bed aggradation is not a concern and excess shear stresses are managed through grade control. For this design, various types of constructed riffles will be used to provide grade control (described in Section 8.5 below).

Table 13a. Design Morphologic Parameters for Enhancement 1 and Restoration Reaches

			UT1B R1		UT2 R1		UT2 R2		UT2A R1	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
stream type			Cb4		C4		C4		C4	
drainage area	DA	sq mi	0.03		0.38		0.59		0.10	

			UT1B R1		UT2 R1		UT2 R2		UT2A R1	
Parameter	Notation	Units	min	max	min	max	min	max	min	max
bankfull discharge	Q_{bkf}	cfs	6		40		54		15	
bankfull cross-sectional area	A_{bkf}	SF	1.9		12.0		14.3		5.7	
average velocity during bankfull event	v_{bkf}	fps	3.3		3.1		3.9		2.6	
width at bankfull	w_{bkf}	feet	5.0		12.5		14.0		9.0	
maximum depth at bankfull	d_{max}	feet	0.5		1.5		1.5		0.9	
mean depth at bankfull	d_{bkf}	feet	0.4		1.0		1.0		0.6	
bankfull width to depth ratio	w_{bkf}/d_{bkf}		13		13		14		14	
max depth ratio	d_{max}/d_{bkf}		1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5
bank height ratio	BHR		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
floodprone area width	w_{fpa}	feet	50	125	50	125	50	125	50	125
entrenchment ratio	ER		10.0	25.0	4.0	10.0	3.6	8.9	5.6	13.9
valley slope	S_{valley}	ft/ft	0.03		0.0093		0.0075		0.0102	
channel slope	$S_{channel}$	ft/ft	0.036		0.0083		0.0108		0.0081	
sinuosity	K		1.0		1. 0	1.2	1.0	1.2	1.0	1.2
riffle slope	S_{riffle}	ft/ft	0.02	0.021	0.0105	0.0225	0.0154	0.0330	0.1190	0.0255
riffle slope ratio	$S_{riffle}/S_{channel}$		1.0	1.1	1.4	3.0	1.4	3.0	1.4	3.0
pool slope	S_{pool}	ft/ft	NA	NA	0.00		0.00		0.00	
pool slope ratio	$S_{pool}/S_{channel}$		NA	NA	0.00		0.00		0.00	
pool-to-pool spacing	L_{p-p}	feet	8	33	19	81	21	91	14	59
pool spacing ratio	L_{p-p}/w_{bkf}		1.5	6.5	1.5	6.5	1.5	6.5	1.5	6.5

			UT1B R1		UT2 R1		UT2 R2		UT2A R1	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
maximum pool depth at bankfull	d_{pool}	feet	0.6	1.0	1.8	2.4	1.9	2.5	1.2	1.5
pool depth ratio	d_{pool}/d_{bkf}		1.5	2.5	1.8	2.4	1.9	2.5	2.0	2.5
pool width at bankfull	w_{pool}	feet	7.0		16.5		19		11.2	
pool width ratio	w_{pool}/w_{bkf}		1.4		1.3		1.4		1.3	
pool cross-sectional area at bankfull	A_{pool}	SF	3.0	5.0	18.4	25.1	23.5	31.9	8.8	11.2
pool area ratio	A_{pool}/A_{bkf}		1.6	2.6	1.6	2.1	1.6	2.2	1.6	2.1
belt width	w_{blt}	feet	18	30	20	75	22	84	14	54
meander width ratio	w_{blt}/w_{bkf}		3.5	6.0	1.6	6.0	1.6	6.0	1.6	6.0
meander length	L_m	feet	20	75	50	188	56	210	36	135
meander length ratio	L_m/w_{bkf}		4	15.0	4.0	15.0	4.0	15.0	4.0	15.0
radius of curvature	R_c	feet	9	15	23	38	25	42	16	27
radius of curvature ratio	R_c/ w_{bkf}		1.8	3.0	1.8	3.0	1.8	3.0	1.8	3.0

Table 13b. Design Morphologic Parameters for Enhancement 1 and Restoration Reaches

			UT2A R2		UT2B R2		UT2C R2		UT2C R3	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
stream type			C4		C4		C4		Cb4	
drainage area	DA	sq mi	0.16		0.03		0.08		0.08	
bankfull discharge	Q_{bkf}	cfs	21		7		13		13	
bankfull cross-sectional area	A_{bkf}	SF	7.0		2.1		4.3		4.3	
average velocity during bankfull event	v_{bkf}	fps	3.0		3.0		2.7		2.7	
width at bankfull	w_{bkf}	feet	10.0		5.0		7.8		7.8	

			UT2A R2		UT2B R2		UT2C R2		UT2C R3	
Parameter	**Notation**	**Units**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
maximum depth at bankfull	d_{max}	feet	0.8	1.1	0.5	0.6	0.7	0.8	0.7	0.8
mean depth at bankfull	d_{bkf}	feet	0.7		0.4		0.6		0.6	
bankfull width to depth ratio	w_{bkf}/d_{bkf}		14		12		14		14	
max depth ratio	d_{max}/d_{bkf}		1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5
bank height ratio	BHR		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
floodprone area width	w_{fpa}	feet	50	125	50	125	50	125	50	125
entrenchment ratio	ER		5.0	12.5	10.0	25.0	6.4	16.0	6.4	16.0
valley slope	S_{valley}	ft/ft	0.0110		0.0259		0.0154		0.024	
channel slope	$S_{channel}$	ft/ft	0.0104		0.0202		0.0158		0.038	
sinuosity	K		1.00	1.20	1.00	1.20	1.00	1.20	1.00	1.20
riffle slope	S_{riffle}	ft/ft	0.0130	0.028	0.030	0.065	0.018	0.038	0.018	0.038
riffle slope ratio	$S_{riffle}/S_{channel}$		1.4	3.0	1.4	3.0	1.4	3.0	1.4	3.0
pool slope	S_{pool}	ft/ft	0.00		0.00		0.00		0.00	
pool slope ratio	$S_{pool}l/S_{channel}$		0.00		0.00		0.00		0.00	
pool-to-pool spacing	L_{p-p}	feet	15	65	8	33	12	51	12	51
pool spacing ratio	L_{p-p}/w_{bkf}		1.5	6.5	1.5	6.5	1.5	6.5	1.5	6.5
maximum pool depth at bankfull	d_{pool}	feet	1.4	1.7	0.6	1.0	1.1	1.5	1.1	1.5
pool depth ratio	d_{pool}/d_{bkf}		2	2.5	1.5	2.5	1.8	2.5	1.5	2.5
pool width at bankfull	w_{pool}	feet	12.5		7.0		9.5		9.5	
pool width ratio	w_{pool}/w_{bkf}		1.3		1.4		1.2		1.2	
pool cross-sectional area at bankfull	A_{pool}	SF	11.3	14.0	3.0	5.0	6.8	9.8	6.8	9.8

			UT2A R2		UT2B R2		UT2C R2		UT2C R3	
Parameter	Notation	Units	min	max	min	max	min	max	min	max
pool area ratio	A_{pool}/A_{bkf}		1.6	2.0	1.4	2.4	1.6	2.3	1.6	2.3
belt width	w_{blt}	feet	16	60	8	30	12	47	12	47
meander width ratio	w_{blt}/w_{bkf}		1.6	6.0	1.6	6.0	1.6	6.0	1.6	6.0
meander length	L_m	feet	40	150	20	75	31	117	31	117
meander length ratio	L_m/w_{bkf}		4.0	15.0	4.0	15.0	4.0	15.0	4.0	15.0
radius of curvature	R_c	feet	18	30	9	15	14	23	14	23
radius of curvature ratio	R_c/ w_{bkf}		1.8	3.0	1.8	3.0	1.9	3.0	1.9	3.0

9.2 Target Buffer Communities

The target communities for the restored riparian buffer zones will be based on the following:

- Forested areas used as reference conditions for the project ;
- Existing mature trees throughout the project area;
- Vegetation listed for these community types in Classification of the Natural Communities of North Carolina (Shafale and Weakley,1990);
- Native trees with proven success in early successional restoration sites; and
- Consultation with native tree suppliers.

The primary reference sites are the semi-mature Piedmont bottomland hardwood forest along Spencer Creek and the mesic mixed hardwood forest along Dutchmans Creek (see section 6.7.2 for documented species).

9.3 Stream Project and Design Justification

Based on assessments of the watershed and existing channels (described above in Sections 4 and 5), the project design (Figure 8) has been developed to address specific stressors and improve the quality of the streams on the project site. Four different approaches to stream rehabilitation/preservation are planned for the site, depending on the degree of intervention necessary to remediate the problems. Some of the project reaches (UT2, UT2A, the downstream portion of UT2B, and the downstream portion of UT2C) are deeply incised and have been severely trampled by cattle so that the banks have become unstable and the bed morphologies are largely destroyed. As described in Section 5.3, these streams have reached an advanced state of departure from their natural condition. The incision on these channels increases in the downstream direction indicating that the channels may be actively head-cutting. Priority 1 restoration along with eradicating invasive plant species, re-planting the buffer, and fencing out cattle are planned for these reaches due to their severely impacted condition and the need to prevent further degradation. Reach 1 of UT1B is incised and is accessible to cattle but the bed morphology has been impacted less. For this reach, an enhancement I approach is planned that will include cutting a floodplain bench at the design bankfull stage but will leave the channel bed in place. This approach will provide floodplain access for this stream and reduce likelihood of further bank instability. Buffer planting and fencing will also be performed along this reach. Other streams on the project site have been less disturbed by cattle and have not incised as much as the other streams described above. For these reaches (most of Little River on the site, much of UT1A, the downstream portion of UT1B, the upstream portion of UT2B, and the upstream portion of UT2C), enhancement II is planned and the only mechanical alterations proposed for the channels will be repairs of isolated bank erosion as necessary. The main activities to improve and protect these reaches will be eradicating invasive plant species, planting riparian buffers, and fencing out cattle. For the upstream portion of the Little River and a small section at the downstream end of UT1A, the streams have not been impacted by cattle and invasive plants are less abundant. For these reaches, preservation is proposed and activities will include management of invasives and fencing out cattle.

If the activities described are not undertaken, additional incision, trampling of stream beds and banks by cattle, and spread of invasive plant species are likely. As described in Section 5.3, stream channels continue to incise and widen until they reach a new equilibrium point. At such time they will be at a lower position relative to the valley floor and disconnected from the original floodplain. Degradation of confluent reaches that are currently not incised (such as UT1A, downstream reaches of UT1B, and upstream portions of UT2C and others) is possible. In addition, as long as cattle continue to access the streams, banks will continue to erode, proper bed morphology will not become reestablished, fine sediments will wash onto the bed and downstream reaches, and water quality problems will continue. Without intervention, invasive species including Chinese privet, Japanese honeysuckle, and multiflora rose will continue to proliferate and dominate the riparian zones.

The design objectives described in Section 1 were developed to deal with the issues outlined in the paragraphs above and in Sections 4 and 5. The key factors driving the need for this intervention are:

- Without fencing to eliminate cattle access to the project streams and re-planting the riparian buffers, nutrient inputs to the stream from cattle wastes will continue.
- If stream banks are not stabilized on reaches where erosion and trampling by cattle are extensive problems, fine sediments will continue to wash into streams and channels will continue to enlarge.
- The intervention will also provide functional improvement by restoring riffle/pool sequences to promote aeration of water, lower water temperature, help maintain dissolved oxygen concentrations, and restore the aquatic, benthic, and riparian habitat.
- Habitat diversity can be improved in the project reaches by adding various wood and rock structures to the channels.
- Without proper treatment invasive plants such as Chinese privet, Japanese honeysuckle, and multiflora rose will continue to dominate the riparian zones and proliferate. The project planting plan will restore native vegetation to the floodplains and stream bank zones. This project will restore and enhance well over a mile of riparian buffers and will create a conservation corridor by connecting these lands to forested upstream and downstream properties. The project area will be protected in perpetuity with a conservation easement.

In addition to the restoration and enhancement activities described above, stream preservation will be performed on the upstream 704 feet of Little River on the project site and 117 feet of UT1A that connects to the preservation section of Little River. The justification for the preservation of these two stream segments include:

- There is a SNHA (Upper Little River Aquatic Habitat) that provides habitat for an NHEO approximately 2.8 miles downstream of the project site on the Little River. According to the December 5, 2012 document entitled "Use of Stream Preservation as Compensatory Mitigation in North Carolina," this site qualifies as "priority area for channel preservation."
- The resources to be preserved provide important physical, chemical, or biological functions for the watershed as documented in the mitigation plan;
- The preservation reaches connect UT1A and Little River (which also connects with UT1B) creating a continuous riparian corridor that will be preserved in perpetuity throughout the eastern portion of the project site.
- The streams in the preservation areas are stable and vegetated.
- Additional improvements beyond basic preservation practices will be made to the streams including removal of an invasive species (Chinese privet) from the portions of the existing buffer.
- This preservation is planned in conjunction with restoration and enhancement activities.

9.4 Sediment Transport Analysis

A sediment transport analysis was performed for the restoration and enhancement 1 reaches including UT1B Reach 1, UT2, UT2A, UT2B Reach 2, and UT2C Reaches 2 and 3. Two different types of sediment transport analyses were performed:

1. For each of these reaches a competence analysis was performed to determine the size bed material particles that will become entrained at flows at or near the bankfull discharge and
2. For the two major stream restoration components of the project (UT2 and UT2A) a capacity analysis was performed to determine if the streams have the ability to pass the sediment load supplied to them.

Stream competence can be determined through calculations performed with data commonly collected for stream restoration projects. The issue of capacity is much more difficult to analyze due to lack of reliable data on sediment supply for a given stream. The analysis typically includes a qualitative analysis of bedload supply and/or gross estimates or comparisons of transport rates.

9.4.1 Competence Analysis

A competence analysis was performed for each of the restoration and enhancement I reaches by computing the bankfull shear stress based on the design bankfull depth and slope. Standard equations were used to calculate the critical dimensionless shear stress needed to move the bed material and the depth and slope combination needed to produce that stress. The equations are:

(1) $\tau_{ci} = 0.0834(d_{50}/ds_{50})^{-0.872}$
(2) $\tau_{ci} = 0.0384(Di/d_{50})^{-0.887}$
(3) $\tau = \gamma_w Sd$
(4) $S = (\tau_{ci} * \gamma s * Di)/d$

where τ_{ci} is critical dimensionless shear stress, d_{50} is median diameter of pavement material, ds_{50} is median diameter of subpavement material, γs is specific weight of sediment, Di is the largest diameter of subpavement material, d is mean bankfull depth of channel, and S is the water surface slope at bankfull stage. The results are shown in Table 14.

Table 14. Bankfull Shear Stress Calculations

	UT1B Reach 1	UT2 Reach 1	UT2 Reach 2	UT2A Reach 1	UT2A Reach 2	UT2B Reach 2	UT2C Reach 2	UT2C Reach 3
Design Mean Bankfull Depth (ft)	0.4	1.0	1.0	0.6	0.7	0.4	0.6	0.6
Calculated $D_{critical}$ (ft)	---	0.3	0.9	1.7	1.5	0.6	0.7	0.4
Design bankfull water surface slope (ft/ft)	0.036	0.008	0.011	0.008	0.010	0.020	0.016	0.038
Calculated $S_{critical}$ (ft/ft)	---	0.00259	0.00994	0.02352	0.02016	0.03102	0.01702	0.01702
Critical shear stress required to move largest subpavement particle (lbs/ft2)	---	0.08	0.50	0.30	0.30	0.18	0.25	0.25
Design Discharge Boundary Shear Stress (lbs/ft^2)	0.61	0.39	0.61	0.3	0.36	0.49	0.46	0.72

The results shown in Table 14 indicate that the design depths and slopes are either comparable to the estimated depths and slopes needed to move the largest measured particle in the subpavement or, in the case of UT2 Reach 1 and UT2C Reach 3, there is greater depth and slope than needed. However, in the case of UT2A the design depth and slope both appear to be too low to move the largest substrate particle.

To provide more detailed information on the hydraulic performance of the primary restoration components of the design, HEC-RAS models were developed for representative sections of UT2 and UT2A. The model for UT2 includes a reach of the proposed channel from station 400+50 to station 409+43. The model for UT2A includes a reach of the proposed channel from station 507+96 to station 510+65.47. The results of both steady state models show that the design bankfull discharge fills the proposed channels to the top of the banks or slightly above the top of banks for all cross sections analyzed. The HEC-RAS model for each of the two modeled reaches was used to calculate boundary shear stresses throughout the reaches. The results are shown in Table 15. The range of shear stresses shown in Table 15 indicates that shear stresses are significantly higher in the riffles than in the pools as expected. The average riffle shear stress for UT2 is 0.69 lbs/sq. ft. and the average shear stress for UT2A is 0.55 lbs/sq. ft.

Table 15. Modeled Bankfull Shear Stress for Typical Reaches for UT2 and UT2A

	UT2 Riffle	UT2 Pool	UT2A Riffle	UT2A Pool
Minimum Shear Stress (lbs/sq. ft.)	0.54	0.12	0.29	0.1
Average Shear Stress (lbs/sq. ft.)	0.69	0.17	0.55	0.14
Maximum Shear Stress (lbs/sq. ft.)	1.12	0.29	0.93	0.17
Shear Stress to move largest particle in subpavement (ilbs/sq. ft.)	0.42		1.2	

The summary of shear stresses modeled with HEC-RAS shown in Table 15 can be compared with the critical shear stresses obtained from the revised Shields Diagram (Rosgen, 2001) shown in Table 15 to provide another rough estimate of the degree to which shear stress in the proposed stream will be able to move the bed material. For the UT2 reach, there appears to be excess shear stress and for the UT2A reach there appears to be slightly insufficient shear stress. These results compare to the results of the bankfull shear stress calculations in Table 14.

The results of the two competence analyses presented above indicate that, in most cases, the channel will move the existing bed material at design bankfull flow. UT2A does not appear to have enough boundary shear stress to move the largest particles. However, the restoration designs are intended to function as threshold channels in which the channel boundary is immobile at high flows. This design approach is appropriate for low sediment supply watersheds (Shields, et al., 2003). Evidence of low sediment supply to the channels is described above in Section 4.2. Grade control will be used to ensure that excess shear stresses do not degrade the stream beds. Grade control measures are described in Section 8.3.1.

9.4.2 Capacity Analysis

The competence analysis described above only provides an estimate of the necessary shear stress and related slope and flow depth needed to move the existing bed material. A capacity analysis is necessary to determine if the stream has the ability to pass its sediment load. A capacity analysis is much more difficult to perform and is prone to error (Wilcock, 2009).

The HEC-RAS models for the primary restoration reaches, UT2 and UT2A were used to evaluate sediment load capacity. The sediment transport capacity function of the hydraulic design module was used to perform this analysis. Because capacity is very difficult to analyze and prone to error, especially if no bedload measurements are performed, the best means to evaluate the sediment transport capacity of the proposed channels is to compare them to the existing channels. If the proposed channels are more efficient at transporting sediment than the existing and there are no signs of bed aggradation in the existing channels, then moving the sediment load supplied to them will not be a problem. Given that the restoration reaches are designed as threshold channels this is the expectation. In this case, moving the supplied sediment and managing excess shear stress through grade control are the objectives. Table 16 shows the results of the capacity analysis for the existing and proposed conditions for the modeled reaches of UT2 and UT2A. In both cases, the proposed conditions reaches are more efficient at moving supplied sediment. Excess shear stress is described above in the competence analysis discussion.

Table 16. Sediment Capacity Analysis Results

	Sediment Transport Capacity (tons/day)	
	Existing	**Proposed**
UT2	212.8	220.7
UT2A	37.45	66.59

9.5 Project Implementation Summary

The stream restoration will be constructed as described in this section. A full set of draft design plans are included with this mitigation plan for review.

9.5.1 Site Grading, Structure Installation, and Other Project Related Construction

Stream restoration is proposed for UT2, UT2A, and the downstream ends of UT2B and UT2C. Most of this stream restoration work will be Priority 1 restoration. Priority 1 restoration will include raising the bed of the channel so that bankfull stage is at the existing floodplain elevation. New channel will be excavated for much of the restored reaches, but in some locations the new stream will cross or run within the existing channel. Some short reaches will be constructed as Priority 2 restoration meaning that a floodplain bench will be cut at a lower elevation than the original floodplain. A short section at the downstream end of UT2 Reach 2 will be Priority 2 restoration in order to tie the restored channel to existing channel grade and the downstream end of the project. The Priority 2 section of Reach 2 will include 317 feet from station 420+00 to station 423+17. UT2C Reach 2 (from station 712+15 to station 713+60) will also necessarily be Priority 2 restoration in order to tie the new channel to existing channel grade at the edge of the property. This stream flows off the property for a short distance and then reenters the property before joining UT2. The stream reenters at station 800+00 and connects with UT2 at station 801+37. The lower portion of this reach (beginning at station 800+70) is also proposed as Priority 2 restoration to tie to UT2 at the downstream end of the project. All other portions of the restoration reaches will be constructed as Priority 1 restoration.

For all restoration reaches, the cross sections will be constructed to accommodate the design bankfull discharge, the pattern will be reconstructed so that the channel meanders through the floodplain, and riffle-pool bed morphology will be reestablished. The cross-sectional dimensions of the design channels will be constructed to flood the adjacent floodplain and existing wetlands frequently. The reconstructed channel banks will be built with stable side slopes, planted with native materials, and matted for long-term stability. The slightly meandering planform of the channels will be built to mimic natural Piedmont streams. Pools will generally be built in the outside of the meander bends and riffles will be built in the straight sections of channel between meanders. Various types of constructed riffles have been designed for the restoration reaches to provide grade control throughout the entire length of the restoration and enhancement I reaches. Constructed riffles will incorporate native stone and alluvium and, in many cases, woody materials. Quarry stone will only be used in constructed riffles in cases where on-site rock is not available. Details of each type of constructed riffle are included with the draft plans. Other wood structures will also be incorporated into the restoration reaches including root wads and brush toe for bank protection, angled log drops, and cover logs in bends where appropriate. Details for each of these structures are also included with the draft plans. Locations of all proposed structures can be seen of the plan and profile sheets.

Reach 1 of UT1B (station 300+00 to 305+45) will be constructed as Enhancement I. For this reach, a floodplain bench will be excavated so that the channel will have floodplain access without raising the channel bed or altering the existing channel pattern. Other components of design for this reach include constructed riffle and wood structures and bank stabilization as necessary but will not involve altering the existing channel pattern.

Reach 1 of UT1A (station 200+00 to 217+00), Reaches 2 and 3 of UT1B (station 305+62 to 353+17), Reach 1 of UT2B (station 600+00 to 608+48), and reach 1 of UT2C (station 700+00 to 712+15) are all proposed as Enhancement II. The only mechanical alterations to the Enhancement II channels will be minor bank repairs at specific locations as appropriate. The primary purpose of the Enhancement II approach for these streams will be to exclude cattle from the streams in order to let them recover on their own.

The majority of the existing channels will be filled where restoration is proposed. In some cases vernal pools will be constructed in locations where sections of existing channel exist. These vernal pools will create wetland features on the floodplain that will more than offset the minimal wetland impacts due to channel construction. A large vernal pool has also been designed for the left floodplain at the downstream end of UT2 to capture water from an existing ephemeral channel that drains approximately five acres. This vernal pool will provide treatment for the pasture runoff and create wetland and/or open water habitat. No mitigation credits will be requested for the vernal pool features.

Another significant component of the project will be the treatment and removal of invasive species which currently dominate large portions of the existing riparian buffers and are proliferating across the site. The invasives include Chinese privet, Japanese honeysuckle, and multiflora rose. The plants will be initially treated as needed and removed from the site during construction. Additional treatments will be applied as necessary through the monitoring period.

The riparian buffer along each restoration and enhancement reach will be planted with native floodplain species. The stream banks will be planted with native live stakes for stabilization. Vernal pools will be planted with native wetland species. The planting plan is described below in Section 8.3.2. All of these planted areas will be placed in a conservation easement and fencing will be installed around the easement to keep cattle from accessing the streams in the future. A restrictive covenant will be established to keep cattle out of the pond on UT1B after the project is implemented.

Easement breaks with culvert crossings are planned for UT1A (station 208+95 to 209+84), UT2 (station 415+27 to 416+13), and UT2A (station 516+20 to 517+00). There will be an easement break for a bridge crossing on Little River from station 127+28 to 128+07. No work is planned for the section of UT1B from the upstream end of the pond (station 308+25) to the point where the overflow spillway from the pond enters the stream (station 350+00). There are no other easement breaks throughout the project.

9.5.2 Natural Plant Community Restoration

As a final stage of construction, riparian stream buffers will be planted with native trees and herbaceous plants. The natural community at the Spencer Creek reference site can be classified as

Piedmont bottomland forest and the community at Dutchmans Creek is a mesic mixed hardwood forest (Schafale and Weakley, 1990). The woody and herbaceous species selected are based on these similar community types, observations of the occurrence of species in the reference site buffers, and best professional judgment on species establishment and anticipated site conditions in the early years following project implementation. Permanent herbaceous seed will be placed on stream banks and bench areas and all disturbed areas within the project easement. The stream banks will be planted with live stakes. The riparian buffers and wetland areas will be planted with bare root seedlings. Proposed permanent herbaceous species are shown in the plan set.

Individual tree and shrub species will be planted throughout the project easement including stream banks, floodplains zones, and vernal pools. These species will be planted as bare root (floodplain zones and vernal pools) and live stakes (stream banks) and will provide additional stabilization to the outsides of constructed meander bends and side slopes. Juncus plugs will be installed at the toe of banks of restoration and enhancement I reaches. Species planted as bare roots will be spaced at an initial density of 520 plants per acre (12 feet by 7 feet spacing). Live stakes will be planted on channel banks at 2-foot to 3-foot spacing on the outside of meander bends and 6-foot to 8-foot spacing on tangent sections. Point bars will not be planted with live stakes. Targeted densities after monitoring year 3 are 320 woody stems per acre. Juncus plug spacing will be five feet. Proposed tree and shrub species are representative of Piedmont bottomland forests. Species are detailed in the plan set.

10.0 Maintenance Plan

Wildlands will perform monitoring and maintenance on the mitigation project. The site shall be monitored on a regular basis and a physical inspection of the site shall be conducted a minimum of once per year throughout the post-construction monitoring period until performance standards are met. These site inspections may identify site components and features that require routine maintenance. Routine maintenance should be expected most often in the first two years following site construction and may include the following:

Table 17. Maintenance Plan

Component/Feature	Maintenance through project close-out
Stream	Routine channel maintenance and repair activities may include chinking of in-stream structures to prevent piping, securing loose coir matting, and supplemental installations of live stakes and other target vegetation along the channel. Areas where storm water and floodplain flows intercept the channel may also require maintenance to prevent bank failures and head-cutting.
Vegetation	Vegetation shall be maintained to ensure the health and vigor of the targeted community. Routine vegetation maintenance and repair activities may include supplemental planting, pruning, mulching, and fertilizing. Exotic invasive plant species shall be controlled by mechanical and/or chemical methods. Any vegetation control requiring herbicide application will be performed in accordance with NC Department of Agriculture (NCDA) rules and regulations.
Site boundary	Site boundaries shall be identified in the field to ensure clear distinction

Component/Feature	Maintenance through project close-out
	between the mitigation site and adjacent properties. Boundaries may be identified by fence, marker, bollard, post, tree-blazing, or other means as allowed by site conditions and/or conservation easement. Boundary markers disturbed, damaged, or destroyed will be repaired and/or replaced on an as-needed basis.
Utility Right-of-Way	Utility right-of-way within the site may be maintained only as allowed by Conservation Easement or existing easement, deed restrictions, rights of way, or corridor agreements.
Road Crossing	Road crossings within the site may be maintained only as allowed by Conservation Easement or existing easement, deed restrictions, rights of way, or corridor agreements.

If beaver dams are observed on site, Wildlands will remove the dams and attempt to remove the beavers from the site. If wildlife herbivory becomes a problem for the plantings, Wildlands will take measures to manage wildlife on the site.

11.0 Performance Standards

The stream restoration performance criteria for the project site will follow approved performance criteria presented in the EEP Mitigation Plan Template (version 2.1, 09/01/2011), the EEP Monitoring Requirements and Performance Standards for Stream and/or Wetland Mitigation (11/7/2011), and the Stream Mitigation Guidelines issued in April 2003 by the USACE and NCDWQ. Annual monitoring and semi-annual site visits will be conducted to assess the condition of the finished project. The stream restoration and enhancement level I reaches (UT1B, UT2, UT2A, UT2B Reach 2, and UT2C Reaches 2 and 3) of the project will be assigned specific performance criteria components for stream morphology, hydrology, and vegetation. The enhancement level II reaches (Little River, UT1A Reach 1, UT1B Reaches 2 and 3, UT2B Reach 1, and UT2C Reach 1) will be documented through photographs, visual assessments, hydrology, and vegetation to verify that no significant degradational changes are occurring in the stream channel or riparian corridor. Performance criteria will be evaluated throughout the seven year post-construction monitoring. If all performance criteria have been successfully met and two bankfull events have occurred during separate years, at the completion of year 5 Wildlands may propose to terminate stream and/or vegetation monitoring in accordance with the Early Closure Provision in the EEP Monitoring Requirements and Performance Standards for Stream and/or Wetland Mitigation (Nov. 7th, 2011). An outline of the performance criteria components follows.

11.1 Streams

11.1.1 Dimension

Riffle cross-sections on the restoration reaches should be stable and should show little change in bankfull area, maximum depth ratio, and width-to-depth ratio. Per EEP guidance, bank height ratios shall not exceed 1.2 and entrenchment ratios shall be at least 2.2 for restored channels to be considered stable. Riffle cross-sections should fall within the parameters defined for channels of the appropriate Rosgen stream type. If any changes do occur, these changes will be evaluated to assess whether the stream channel is showing signs of instability. Indicators of instability include trends in vertical incision or bank erosion. Changes in the channel that indicate a movement toward stability or enhanced habitat include a decrease in the width-to-depth ratio in meandering channels or an increase in pool depth. Remedial action would not be taken if channel changes indicate a movement toward stability.

In order to monitor the channel dimension, two permanent cross-sections will be installed per 1,000 feet along stream restoration/enhancement reaches, with riffle and pool sections in proportion to EEP guidance. Each cross-section will be permanently marked with pins to establish its location. Cross-section surveys will include points measured at all breaks in slope, including top of bank, bankfull, edge of water, and thalweg. For reaches with a bankfull width of greater than three feet, bank pins will also be installed on the outside bend of each surveyed pool cross-section in at least three locations (one in upper third of the pool, one at the permanent cross-section, and one in the lower third of the pool). Bank pins will be monitored by measuring exposed rebar and maintaining pins flush to bank to capture bank erosion. Annual cross-section and bank pin survey will be conducted in monitoring years one, two, three, five, and seven.

11.1.2 Pattern and Profile

Longitudinal profile surveys will not be conducted during the seven year monitoring period unless other indicators during the annual monitoring indicate a trend toward vertical and lateral instability. If a longitudinal profile is deemed necessary, monitoring will follow standards as described in the EEP Monitoring Requirements and Performance Standards for Stream and/or Wetland Mitigation (11/7/2011) and the 2003 USACE and NCDWQ Stream Mitigation Guidance for the necessary reaches. A longitudinal profile will be conducted as part of the as-built survey to provide a baseline for comparison should it become necessary to perform longitudinal profile surveys later during monitoring.

11.1.3 Substrate

Substrate materials in the restoration reaches should indicate a progression towards or the maintenance of coarser materials in the riffle features and smaller particles in the pool features.

A reach-wide pebble count will be performed in each restoration reach each year for classification purposes. A pebble count will be performed at each surveyed riffle to characterize the pavement.

11.1.4 Photo Documentation

Photographs will be taken once a year to visually document stability for seven years following construction. Permanent markers will be established and located with GPS equipment so that the same locations and view directions on the site are photographed each year. Photos will be used to monitor restoration and enhancement stream reaches as well as vegetation plots.

Longitudinal reference photos will be established at the tail of riffles approximately every 200 LF along the channel by taking a photo looking upstream and downstream. Cross-sectional photos will be taken of each permanent cross-section looking upstream and downstream. Reference photos will also be taken for each of the vegetation plots. Representative digital photos of each permanent photo point, cross-section and vegetation plot will be taken on the same day of the stream and vegetation assessments are conducted. The photographer will make every effort to consistently maintain the same area in each photo over time.

Photographs should illustrate the site's vegetation and morphological stability on an annual basis. Cross-section photos should demonstrate no excessive erosion or degradation of the banks. Longitudinal photos should indicate the absence of persistent bars within the channel or vertical incision. Grade control structures should remain stable. Deposition of sediment on the bank side of vane arms is preferable. Maintenance of scour pools on the channel side of vane arms is expected.

11.1.5 Bankfull Events

Two bankfull flow events must be documented on the restoration and enhancement reaches within the seven-year monitoring period. The two bankfull events must occur in separate years. Stream monitoring will continue until success criteria in the form of two bankfull events in separate years have been documented.

Bankfull events will be documented using a crest gage, photographs, and visual assessments such as debris lines. Three crest gages will be installed; one on UT1B Reach 1, one on UT2, and one on UT2A. The crest gages will be installed within a riffle cross-section of the restored channels in surveyed riffle cross-sections. The gages will be checked at each site visit to determine if a bankfull event has occurred. Photographs will be used to document the occurrence of debris lines and sediment deposition.

11.2 Visual Assessments

Visual assessments will be performed along all stream areas on semi-annual basis during the seven year monitoring period. Problem areas will be noted such as channel instability (i.e. lateral and/or vertical instability, in-stream structure failure/instability and/or piping, headcuts), vegetated buffer health (i.e. low stem density, vegetation mortality, invasive species or encroachment), beaver activity, or livestock access. Areas of concern will be mapped and photographed accompanied by a written description in the annual report. Problem areas with be re-evaluated during each subsequent visual assessment. Should remedial actions be required, recommendations will be provided in the annual monitoring report.

11.3 Vegetation

The final vegetative success criteria will be the survival of 210 planted stems per acre in the riparian corridor along restored and enhanced reaches at the end of the required monitoring period (year seven). The interim measure of vegetative success for the site will be the survival of at least 320 planted stems per acre at the end of the third monitoring year and at least 260 stems per acre at the end of the fifth year of monitoring. Planted vegetation must average 10 feet in height in each plot at the end of the seventh year of monitoring. If this performance standard is met by year five and stem density is trending towards success (i.e., no less than 260 five year old stems/acre), monitoring of vegetation on the site may be terminated provided written approval is provided by the USACE in consultation with the NC Interagency Review Team. The extent of invasive species coverage will also be monitored and controlled as necessary throughout the required monitoring period (seven years).

12.0 Monitoring Plan

Annual monitoring data will be reported using the EEP Monitoring Report Template (version 1.4, 11/7/11). The monitoring report shall provide a project data chronology that will facilitate an understanding of project status and trends, population of EEP databases for analysis, research purposes, and assist in decision making regarding close-out. The monitoring period will extend seven years beyond completion of construction or until performance criteria have been met. All survey will be tied to grid.

11.1 *Site Specific Monitoring*

Using the EEP Baseline Monitoring Plan Template (version 2.0, 10/14/10), a baseline monitoring document and as-built record drawings of the project will be developed within 60 days of the planting completion and monitoring installation on the restored site. Monitoring reports will be prepared in the fall of each year of monitoring and submitted to EEP. These reports will be based on the EEP Monitoring Report Template (version 1.4, 11/7/11). The monitoring period will extend seven years beyond completion of construction or until performance criteria have been met per the criteria stated in the EEP Monitoring Requirements and Performance Standards for Stream and/or Wetland Mitigation (11/7/2011). Project monitoring requirements are listed in more detail in Tables 18a and 18b.

Table 18a. Monitoring Requirements (R and EI Reaches)

Parameter	Monitoring Feature	Quantity/ Length by Reach					Frequency	Notes
		UT1 B R1	UT2	UT2A	UT2B	UT2C		
Dimension	Riffle Cross Sections	1	3	2	1	1	Annual	1
	Pool Cross Section	1	2	2	1	1	Annual	
Pattern	Pattern	n/a	n/a	n/a	n/a	n/a	Annual	
Profile	Longitudinal Profile	n/a	n/a	n/a	n/a	n/a	Annual	
Substrate	Reach wide (RW), Riffle (RF) 100 pebble count	1 RW, 1 RF	1 RW, 3 RF	1 RW, 2 RF	1 RW, 1 RF	1 RW, 1 RF	Annual	
Hydrology	Crest Gage	Y	Y	Y	Y	Y	Annual	2
Vegetation	Vegetation Plots	3	8	6	1	1	Annual	3
Visual Assessment	All Streams	Y	Y	Y	Y	Y	Semi-Annual	
Exotic and nuisance vegetation							Annual	4
Project Boundary							Annual	5
Reference Photos	Photos	4	12	9	2	2	Annual	6

Notes:
1. Cross-sections will be permanently marked with rebar to establish location. Surveys will include points measured at all breaks in slope, including top of bank, bankfull, edge of water, and thalweg. The number of cross-sections proposed was established using 2 cross-section2 per 1000 LF since the streams are smaller.
2. Device will be inspected quarterly or semi-annually, evidence of bankfull will be documented with a photo.
3. Vegetation monitoring will follow CVS Level 2 protocol.
4. Locations of exotic and nuisance vegetation will be recorded using a GPS and mapped.
5. Locations of fence damage, vegetation damage, boundary encroachments, etc. will be recorded using a GPS and mapped.
6. Markers will be established and recorded using a GPS so that the same locations and view directions on the site are monitored.

Table 18b. Monitoring Requirements (EII Reaches)

Parameter	Monitoring Feature	Quantity/ Length by Reach					Frequency	Notes
		Little River	U1 A	UT1B R2	UT2B	UT2C		
Dimension	Riffle Cross Sections	n/a	n/a	n/a	n/a	n/a	Annual	
	Pool Cross Section	n/a	n/a	n/a	n/a	n/a	Annual	
Pattern	Pattern	n/a	n/a	n/a	n/a	n/a	Annual	
Profile	Longitudinal Profile	n/a	n/a	n/a	n/a	n/a	Annual	
Substrate	Reach wide (RW), Riffle (RF) 100 pebble count	n/a	n/a	n/a	n/a	n/a	Annual	
Hydrology	Crest Gage	Y	Y	Y	Y	Y	Annual	1
Vegetation	Vegetation Plots	9	6	2	4	5	Annual	2
Visual Assessment	All Streams	Y	Y	Y	Y	Y	Semi-Annual	
Exotic and nuisance vegetation							Annual	3
Project Boundary							Annual	4
Reference Photos	Photos	12	8	3	4	6	Annual	5

Notes:
1. Device will be inspected quarterly or semi-annually, evidence of bankfull will be documented with a photo.
2. Vegetation monitoring will follow CVS Level 2 protocol.
3. Locations of exotic and nuisance vegetation will be recorded using a GPS and mapped.
4. Locations of fence damage, vegetation damage, boundary encroachments, etc. will be recorded using a GPS and mapped.
5. Markers will be established and recorded using a GPS so that the same locations and view directions on the site are monitored.

12.1 *Additional Monitoring Details*

Vegetation

Vegetation monitoring plots will be installed and evaluated within the restoration and enhancement areas to measure the survival of the planted trees (Figure 9). The number of monitoring quadrants required is based on the EEP monitoring guidance documents (version 1.4, 11/7/11). The size of individual quadrants will be 100 square meters for woody tree species and shrubs. Vegetation assessments will be conducted following the Carolina Vegetation Survey (CVS) Level 2 Protocol for Recording Vegetation (2006).

The initial baseline survey will be conducted within 21 days from completion of site planting and used for subsequent monitoring year comparisons. The first annual vegetation monitoring activities will commence at the end of the first growing season, during the month of September. The restoration and enhancement sites will then be evaluated each subsequent year between June 1 and September 31.

Species composition, density, and survival rates will be evaluated on an annual basis by plot and for the entire site. Individual plot data will be provided and will include diameter, height, density, vigor, damage (if any), and survival. Planted woody stems will be marked annually as needed and given a coordinate, based off of a known origin, so they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living planted stems and the current year's living planted stems.

13.0 Adaptive Management Plan

Upon completion of site construction EEP will implement the post-construction monitoring protocols previously defined in this document. Project maintenance will be performed as described previously in this document. If, during the course of annual monitoring it is determined the site's ability to achieve site performance standards are jeopardized, EEP will notify the USACE of the need to develop a Plan of Corrective Action. The Plan of Corrective Action may be prepared using in-house technical staff or may require engineering and consulting services. Once the Corrective Action Plan is prepared and finalized EEP will:

1. Notify the USACE as required by the Nationwide 27 permit general conditions.
2. Revise performance standards, maintenance requirements, and monitoring requirements as necessary and/or required by the USACE.
3. Obtain other permits as necessary.
4. Implement the Corrective Action Plan.
5. Provide the USACE a Record Drawing of Corrective Actions. This document shall depict the extent and nature of the work performed.

14.0 Financial Assurances

Pursuant to Section IV H and Appendix III of the Ecosystem Enhancement Program's In-Lieu Fee Instrument dated July 28, 2010, the North Carolina Department of Environment and Natural Resources has provided the US Army Corps of Engineers Wilmington District with a formal commitment to fund projects to satisfy mitigation requirements assumed by EEP. This commitment provides financial assurance for all mitigation projects implemented by the program.

15.0 References

Dalrymple, T. 1960. Flood-Frequency Analyses. Manual of Hydrology: Part 3. Flood-Flow Techniques. USGS Water Supply Paper #1543-a. USGPO, 1960.

Guise, G.L. and Mason, R. M., 1993. Low Flow Characteristics of Streams in North Carolina. USGS Water Supply Paper #2403 USGPO, 1993.

Griffith, G.E. and Omernik, J.M., 2008. Ecoregions of North Carolina and South Carolina. Retrieved from: http://www.eoearth.org/article/Ecoregions_of_North_Carolina_and_South_Carolina_(EPA)

Harman, W.H., et al. 1999. Bankfull Hydraulic Geometry Relationships for North Carolina Streams.

Interagency Advisory Committee on Water Data, 1981. Guidelines for Determining Flood Flow Frequency. Bulletin 17B. Washington, D.C.

Natural Resources Conservation Service (NRCS), 2011. Web Soil Survey. Retrieved from: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

North Carolina Center for Geographic Information and Analysis (NC CGIA), 2001. Landcover GIS layer. Retrieved from: http://data.nconemap.com/geoportal/catalog/main/home.page

North Carolina Division of Water Quality, 2008. Yadkin-Peed Dee Basinwide Water Quality Plan. Retrieved from: http://portal.ncdenr.org/web/wq/ps/bpu/basin/yadkinpeedee

North Carolina Division of Water Quality (NCDWQ), 2011. Surface Water Classifications. Retrieved from: http://portal.ncdenr.org/web/wq/ps/csu/classifications

North Carolina Ecosystem Enhancement Program (NCEEP), 2009. Lower Yadkin-Pee Dee River Basin Restoration Priorities. Retrieved from: http://portal.ncdenr.org/c/document_library/get_file?uuid=081b34ec-8b4c-434f-9e25-57c713cb136c&groupId=60329

North Carolina Geological Survey (NCGS) a, no date. Retrieved from: http://www.geology.enr.state.nc.us/usgs/carolina.htm

North Carolina Geological Survey (NCGS) b, no date. Retrieved from: http://www.geology.enr.state.nc.us/Mineral%20resources/mineralresources.html

North Carolina Natural Heritage Program (NHP), 2009. Natural Heritage Element Occurrence Database, Randolph County, NC. Retrieved from: http://portal.ncdenr.org/web/nhp/

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Richardson, J.R., and Chang, F., 2001. Stream Stability at Highway Structures, Second Edition. U.S. Department of Transportation, Report No. FHWA-IP-90-014, HEC-20-ED-2. Washington, DC.: Federal Highway Administration, 132 p.

Rosgen, D. L. 1994. A classification of natural rivers. Catena 22:169-199.

Rosgen, D.L. 1996. Applied River Morphology. Pagosa Springs, CO: Wildland Hydrology Books.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communities of North Carolina, 3rd approx. North Carolina Natural Heritage Program, Raleigh, North Carolina.

Shields, D. F., Copeland, R. R, Klingman, P. C., Doyle, M. W., and Simon, A. 2003. Design for Stream Restoration. Journal of Hydraulic Engineering 129(8): 575-582.

Simon, A. 1989. A model of channel response in disturbed alluvial channels. Earth Surface Processes and Landforms 14(1):11-26.

Simon, A., Rinaldi, M. 2006. Disturbance, stream incision, and channel evolution: The roles of excess transport capacity and boundary materials in controlling channel response. Geomorphology 79: 361-383.

United States Department of Agriculture (USDA), 2009. Natural Resources Conservation Service, Soil Survey Geographic (SSURGO) database for Randolph County, North Carolina. Retrieved from: http://SoilDataMart.nrcs.usda.gov

United States Department of Transportation, Federal Highway Administration (FHWA), 2006. Assessing Stream Channel Stability at Bridges in Physiographic Regions. Publication no. FHWA-HRT-05-072. McLean, VA.: Federal Highway Administration Office of Infrastructure Research and Development, 147 p.

United States Fish and Wildlife Service (USFWS), 2008. Endangered Species, Threatened Species, Federal Species of Concern and Candidate Species, Randolph County, NC. Retrieved from: http://www.fws.gov/nc-es/es/countyfr.html

URS Corporation, 2007. Unnamed Tributary to Cane Creek Restoration Plan. Morrisville, NC

Weaver, J.C., et al. 2009. Magnitude and Frequency of Rural Floods in the Southeastern United States, through 2006: Volume 2, North Carolina. U.S. Geological Survey Scientific Investigations Report 2009-5158, 111 p.

Wilcock, P., et al., 2009. Sediment Transport Primer: Estimating Bed-Material Transport in Gravel Bed Rivers. Gen. Tech. Rep. RMRS-GTR-226. Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 78 p.