Haw Branch Wetland and Stream Restoration Plan
Onslow County, North Carolina

Submitted by:

Environmental Banc and Exchange, LLC
220 Chatham Business Drive
Pittsboro, NC 27312

January 2005

DRAFT REPORT

Haw Branch Wetland and Stream Restoration Plan
Onslow County, North Carolina

Prepared For Environmental Banc and Exchange, LLC

Design Report Prepared By Buck Engineering PC

8000 Regency Parkway
Suite 200
Cary, North Carolina 27511
Phone: 919.463.5488
Fax: 919.463.5490
www.buckengineering.com

John Hutton
Project Manager

William A. Harman, PG
Principal in Charge

January 2005

DRAFT REPORT

EXECUTIVE SUMMARY

Environmental Banc and Exchange, LLC (EBX), proposes to restore approximately 25 acres of riverine wetlands and approximately 10,060 linear feet (LF) of stream along several unnamed tributaries to Back Swamp. The site is located in Onslow County, NC, approximately six miles southwest of the town of Richlands (Exhibit 1.1). The site lies in the Cape Fear River Basin, within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-06-22 and United States Geologic Survey (USGS) hydrologic unit 03030007-080010. The purpose of the project is to restore wetland functions to prior-converted cropfields on the site and to restore stream functions to the impaired stream channels that flow through it.

Wetland functions on the site have been severely impaired as a result of agricultural conversion. Streams flowing through the site were channelized many years ago to reduce flooding and provide drainage for adjacent farm fields. Field areas were graded to promote rapid surface drainage, and additional drainage ditches were excavated to improve sub-surface drainage. As a result, nearly all wetland functions were destroyed within the project area. The channelized streams flowing through the site function more as drainage ditches and canals than Coastal Plain streams, with areas of active bank erosion and an overall poor habitat condition.

Data collected in October and November of 2004 indicate that the site currently exhibits hydrologic conditions drier than jurisdictional wetland conditions. Even though the data were collected in the dormant season, when the water table is typically at its highest for the year, jurisdictional wetland hydrology does not exist across the project fields. The ditches and channelized streams on the site transport surface and shallow, subsurface drainage from the prior-converted crop fields, lowering the water table and keeping soil conditions favorable for agricultural production. Examination of the available hydrology and soil data indicate that there is good potential for the restoration of a productive wetland and stream ecosystem.

The Haw Branch Restoration Project will restore a "Coastal Plain small stream swamp" system, as described by Schafale and Weakley (1990). Due to the productivity and accessibility of these systems, most have experienced heavy human disturbance. Wetland restoration of the prior-converted farm fields on the site will involve raising the local water table and restoring a natural flooding regime. The streams through the site will be restored to a stable dimension, pattern, and profile, such that riverine wetland functions are restored to the adjacent hydric soil areas. Drainage ditches within the restoration areas will be filled to decrease surface and subsurface drainage and raise the local water table. In addition, scarification of the fields and breaking of the local plow pan will provide increased surface storage of water and provide favorable conditions for a variety of native wetland plant species.

TABLE ES.1
Restoration Overview

Wetland Type / Project Feature	Size	Approach
Coastal Plain Small Stream Swamp	25 AC	Plug ditch network, restore flooding functions through stream restoration
Stream Reach UT1	6,138 LF	Restoration of dimension, pattern, and profile
Stream Reach UT2	2,928 LF	Restoration of dimension, pattern, and profile
Stream Reach UT3	994 LF	Restoration of dimension, pattern, and profile

Table of Contents

List of Exhibits

*** All Exhibits are located at the back of the report, immediately preceding the appendices.**

List of Figures

List of Tables

List of Appendices

Appendix	**1**	EDR Transaction Screen Map Report, SHPO Letter, and Natural Heritage Letter
Appendix	**2**	Restoration Site Water Table Data
Appendix	**3**	Existing Conditions Summaries, Cross Sections, Bed Material Analyses, and NCDWQ Stream Forms
Appendix	**4**	Reference Reach Summary – Beaverdam Branch, Jones County
Appendix	**5**	DRAINMOD Analysis Files
Appendix	**6**	Photographic Log
Appendix	**7**	Reference Wetland Delineation Forms

1.0 INTRODUCTION AND BACKGROUND

1.1 Brief Project Description and Location

The Haw Branch restoration site is located approximately six miles southwest of the town of Richlands, in Onslow County, North Carolina (Exhibit 1.1), along State Route 1230 (Haw Branch Road). The site is part of a small, privately-owned farm that is used primarily for row crop agriculture and production of pine timber. The streams on the project site have been channelized, and riparian vegetation has been cleared in the field areas such that row crops are planted up to the top of the streambanks. Drainage ditches were excavated in parts of the site to provide additional drainage for agricultural production.

The site lies in the Cape Fear River Basin, within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-06-22 and United States Geologic Survey (USGS) hydrologic unit (HU) 03030007-080010. All tributaries that flow through the site are unnamed tributaries that drain to Back Swamp, just south of the project area.

For analysis and design purposes, the on-site streams were divided into three reaches. The reach locations are shown on Exhibit 1.2. The reaches were numbered sequentially, moving from north to south, with unnamed tributaries carrying a "UT" designation. UT1 begins off site, flows into the project area from the north, and flows out of the project site on the south end. UT2 begins off site, flows into the project area from the northeast, and ends at its confluence with UT1. UT3 begins off site, flows into the project area from the east, and ends at its confluence with UT1. For design purposes, UT1 was further divided into UT1a, upstream of its confluence with UT2, and UT1b, downstream of the confluence. UT1 ultimately drains into Back Swamp, approximately 4,000 feet south of the project site.

1.2 Project Goals and Objectives

The primary design goal of the project is to restore wetland function to areas of prior-converted farm fields and drained wetland areas. To achieve this goal the following objectives have been identified:

- Restore approximately 25 acres of small stream swamp riverine wetlands,
- Restore dimension, pattern, and profile to approximately 10,060 feet of streams,
- Improve floodplain functionality by matching floodplain elevation with bankfull stage,
- Establish native wetland and floodplain vegetation within the permanent conservation easement,
- Improve water quality by reducing bank erosion, reducing inputs of nutrients to the stream system, and providing for improved retention of flood waters, and
- Improve wildlife habitat functions of the site.

Areas of drained historic wetlands will be restored through the restoration of incised stream channels on site, along with the plugging of ditches that have severely affected the site's hydrology. New meandering channels will be constructed across the floodplain, and existing drainage ditches will be filled. Native vegetation will be re-established across the restoration site, and the entire restoration site will be protected through a permanent conservation easement.

1.3 Report Overview

This report is organized as described below. Section 2 provides new readers with a review of the background science and methodologies applied by Buck Engineering in the practice of wetland restoration science and natural channel design. It does not contain information specific to this project. Sections 3 through 7 of the report discuss site-specific project details, including watershed assessment findings, existing wetland area assessments, stream corridor assessments, design criteria, and the restoration design, respectively. Section 8 presents the monitoring and evaluation plan for the post-implementation period. References are included in Section 9, and appendices are included that summarize cultural resources, correspondence, hazardous waste screening, existing site conditions, reference reach data, site photographs, and water balance / model analyses.

2.0 BACKGROUND SCIENCE AND METHODS

2.1 The Importance of Wetlands

Wetlands are unique landscape features that can provide numerous benefits to ecosystems. They are usually delineated based on three components: hydric soils, wetland hydrology, and hydrophytic vegetation. Natural wetlands are generally formed when the geology and hydrology of an area allow for surface or groundwater to accumulate near the soil surface. Wetlands offer unique habitats for flora and fauna, remove nutrients and other contaminants, allow for surface water storage, and recharge groundwater aquifers. Wetlands help to reduce the impacts of floods, improve water quality, and provide aesthetic and recreational benefits (Mitsch and Gosselink, 2000; King et al, 2000). The functions performed by wetlands are site-specific, depending on the location in the ecosystem and environmental conditions.

Many natural processes or anthropogenic activities can impact wetlands. Wetland restoration seeks to restore wetland functions to areas that currently possess hydric soils but no longer support wetland hydrology or vegetation. Wetland restoration design must take into consideration each of the three components of wetlands (soils, hydrology, and vegetation). The following sections will provide an overview of the restoration process used by Buck Engineering.

2.2 Hydric soils

Hydric soils are defined as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper horizons (Federal Register, July 13, 1994). Soil development is directly affected by the hydrology of an area, as well as by its climate, parent material, time, soil organisms, and topography. Anaerobic conditions result in specific soil biogeochemical processes, such as the retention of organic matter, the chemical reduction of nitrogen (NO_3), iron (Fe), manganese (Mn), sulfur (S), and carbon (C). When a soil is saturated, aerobic microorganisms deplete the remaining oxygen in the system. As oxygen becomes more and more limiting, anaerobic organisms begin to utilize oxidized soil components that are further reduced (Mausbach et al, 1994). The first reaction that occurs under anaerobic conditions is the reduction of nitrate. As the oxidation-reduction (redox) potential continues to decrease, manganese is reduced, then iron, and finally, sulfur and carbon. The soil pH, temperature, and mineral content are all important factors in the rates of transformation (Mitsch and Gosselink, 2000). These reduction processes result in characteristic hydric soil indicators, such as the retention of organic matter, gleyed soils, soils with low-matrix chromas, sulfur odor, etc.

There are two main types of hydric soils: organic soils and mineral soils. Organic soils, or Histosols, are soils that have more than 30% organic matter to a depth of 40 centimeters and that develop under nearly continuous saturation or inundation (Buol et al, 1989). These soils are also called peat or mucks. All organic soils are considered to be hydric except for Folists, which occur on dry slopes.

Hydric soils with less than 30% organic matter are classified as mineral soils. When saturated or inundated for extended periods of time, mineral soils develop characteristic indicators, which are a result of depletion of oxygen within the soil (Mitsch and Gosselink, 2000; USDepartment of Agriculture (USDA), 1996). The reduction of nitrogen, iron, and manganese forms hydric soil indicators that are referred to as redoximorphic features (Vepraskas, 1996). Redoximorphic features include, but are not limited to: gleyed soils, soils with low-matrix chroma, redox concentrations, oxidized rhyzospheres, and iron and manganese concretions.

Wetlands are commonly referred to as the kidneys of the landscape (Mitsch and Gosselink, 2000). The analogy is applicable because wetlands filter the water that flows through them, trapping sediment and sequestering nutrients, including carbon, nitrogen, and phosphorous (Craft, 2000). Wetland soils may be factors in changing the global cycles of nitrogen, sulfur, methane, and carbon dioxide (Mitsch and Gosselink, 2000). Wetland soils help to return excess nitrogen to the atmosphere through denitrification (Mitsch and

Gosselink, 2000). The use of fossil fuels has greatly increased the amount of atmospheric sulfate. When these sulfates are washed out of the atmosphere into wetlands, they can be reduced and even removed permanently from the sulfur cycle (Mitsch and Gosselink, 2000). Carbon can be sequestered into wetland soils, helping to reduce carbon dioxide concentrations.

When hydric soils are converted to agriculture, changes to the soils' chemistry and structure often occur. Once drained, wetland areas are typically graded smooth to improve surface drainage, a process that removes much of the sites' natural topographic variability. The organic content of the soils often decreases due to the oxidation caused by aeration. Concentrations of major and micro-nutrients are often increased due to the application of fertilizers. "Loose" soil structures of many wetland soils are typically converted to more blocky and massive structures, due to years of mechanized equipment traffic. Plow pans, or layers of highly compacted soil, are often present approximately 12 – 18 inches below the surface.

Assessment of on-site hydric soils begins with collected soil survey data from the Natural Resources Conservation Service (NRCS). Since soil survey data are collected on a regional scale, on-site investigations begin by evaluating the accuracy of NRCS mapping. Soil borings are conducted across the restoration site to confirm the presence of hydric soil series and the boundaries. Soil profiles are recorded for each location. For hydrologic analysis purposes, measurements of in-situ saturated hydraulic conductivity are also conducted. Under high water table conditions, the auger hole method, as described by van Beers (1970), is used. Under lower water table conditions, a constant head permeameter (amoozemeter) is used. Measurements are made at representative locations across the site to determine the variability in hydraulic conductivity across the site.

2.3 Wetland Vegetation

Wetland hydrology and hydric soils create what can be considered a harsh environment for many biotic organisms. Since many wetlands are only periodically inundated or saturated, water levels may not be consistently high or low. Many aquatic plants are not able to flourish when wetlands temporarily dry, and many xeric species are not able to adapt to conditions that are periodically wet. Wetland plants have adapted to life in this unpredictable environment.

Wetland plants, also referred to as hydrophytic vegetation, possess a range of adaptations that enable them to tolerate or avoid water stress (Mitsch and Gosselink, 2000). The three major types of adaptations are morphological, physiological, and reproductive. Morphological adaptations enable plants to increase the oxygen supply, either by growing into aerobic environments or by allowing oxygen to penetrate the anoxic zone (Mitsch and Gosselink, 2000). Various morphological adaptations that vascular plants may exhibit are buttressed tree trunks, adventitious roots, shallow root systems, floating leaves, hypertrophied lenticels, and/or multi-trunks.

Physiological adaptations to wetland environments include oxidized rhizospheres, changes in water uptake, nutrient absorption, and respiration. Some species are capable of transferring oxygen from the root system into the adjacent soil, producing oxidized rhyzospheres surrounding the root. Under saturated conditions, many hydric plants have no change in their nutrient uptake, whereas flood-intolerant species lose the ability to control nutrient absorption (Mitsch and Gosselink, 2000).

Reproductive adaptations allow wetland vegetation to establish and grow within inundated soil conditions. Some of these adaptations include prolonged seed viability (including production of a large seed bank), timing of seed production in the non-saturated season, production of buoyant seeds, flood-tolerant species, and germination of seeds while fruit is attached to the tree. These reproductive, morphological, and hydrophytic adaptations allow wetland plants to flourish in relatively harsh environments and create communities of plants adapted to wetland conditions.

Plant communities generally exist along a topographic gradient. Hill tops or southwest-facing slopes tend to have the most xeric vegetation, whereas bottomlands tend to have the most mesic species. These topographic gradients tend to have plant communities directly associated with them. It should be noted that some species will be found in both xeric and mesic community types. Plant communities are based on species assemblages and not on individual species. Hydrophytic vegetation is defined by the United States Army Corps of Engineers (USACE) Wetland Delineation Manual as "the sum total of macrophytic plant life that occurs in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present" (USACE, 1987). According to the manual, species that have an indicator status of Obligate Wetland Plants (OBL), Facultative Wetland Plants (FACW), or Facultative Plants (FAC) are considered to be typically adapted for life in wetlands or anaerobic soil conditions. Typically, a wetland plant community contains more than 50 percent of the dominant species as OBL, FACW, or FAC species.

When restoring wetlands, Buck Engineering utilizes native plants to approximate the community that would naturally live within that physiographic community type. Species selection is based on reference wetland vegetation analyses, professional knowledge of availability and viability of specific plants, and expected post-restoration hydrologic conditions. Special emphasis is placed on re-creating a community type that is adapted to the conditions of the restoration site. The re-creation is accomplished by planting hard mast tress, lightly-seeded trees, and various understory or midcanopy, woody species. The utilization of hard mast species creates additional wildlife food sources and allows for late, successional species to become established. The utilization of lightly-seeding species allows for the faster development of wildlife cover and habitat. The planting of understory species helps to ensure a more diverse plant community that will provide long-term benefits to wildlife.

2.4 Wetland Hydrology

Wetland hydrology is often sited as the primary driving force influencing wetland development, function, and persistence (Gosselink and Turner, 1978; Sharitz et al., 1990)and also one of the hardest variables to assess and predict accurately. Hydrology drives the development of hydric soil characteristics, water and soil chemistry, and hydrophytic plant communities. Most functions commonly attributed to wetlands (water filtering, nutrient cycling, sediment trapping, ecosystem diversity, etc.) are a direct result of the hydrologic characteristics of wetland systems. For these reasons, Buck Engineering places significant emphasis on the correct assessment of wetland hydrologic conditions, under both pre- and post-restoration conditions.

Assessment of wetland hydrology begins by touring the project site to observe hydrologic conditions. When possible, site tours are conducted during dry times (several weeks following the last rainfall event) and wet times (immediately following large rainfall events). Evaluation of site conditions during dry periods provides valuable evidence about existing site function and indicates the hydrologic variability across the site. Wetland hydrology assessments during dry periods focus on the following key questions:

1. *Are there areas that are currently exhibiting wetland hydrology?* These areas require special attention and will likely be subject to regulatory permit conditions.
2. *Where are the areas of the site that appear especially dry?* These areas will likely require the greatest attention to restore wetland hydrology.
3. *What are the sources of water on the site that can be manipulated during restoration?* Sources may include groundwater discharge, run-off, surface water flows, and stream flows. Various design techniques are available for storing more water within the restoration site to increase wetness. The primary source of water available will directly affect the type of design that will be most effective at restoring wetland hydrology.

Evaluation during wet periods allows for observations regarding runoff patterns, areas of ponding and water storage, flow routing, and surface flow interactions. Wetland hydrology assessments during wet periods focus on the following key questions:

1. *How is runoff currently being routed across the site?* Most degraded sites have been topographically manipulated to direct runoff to a drainage outlet as quickly as possible. Restoration must reduce the loss of water from the site and restore water storage functions of natural wetland sites.
2. *Are there any surface water sources that could be used in the restoration design?* Sources may include ephemeral and intermittent ditches, drainage swales, and overland flow.
3. *If steam flow or overbank flow is believed to have once contributed to wetland hydrology, can these sources be restored?* Evaluation of stream channels primarily involves the evaluation of bankfull stage in relation to existing bank heights, whether streambed elevations can be altered, and hydrologic trespass.

When necessary for accurate assessment of existing hydrologic conditions, monitoring wells are installed to document local water table conditions. Wells are installed to a depth of approximately 40 inches, following the procedures outlined under WRP Technical Note ERDC TN-WRAP-00-02 (July, 2000). Monitoring wells are typically installed as combinations of automated and manually-read wells. Automated wells are installed in areas where precise measurement of hydrologic conditions is necessary. Such areas may include areas near drainage features, where the prediction of the drainage effect is needed, areas where the hydrologic functioning is difficult to predict through visual assessments, and areas where the hydrologic status of an area is questionable (i.e. does wetland hydrology exist?). Manually-read wells are typically read on a monthly basis and are used to supplement the data collected with automated wells. Manual wells are typically installed in areas where the hydrologic status is predictable based on visual assessments, but measured data will allow for more conclusive evaluation of pre- and post-restoration conditions. Manual wells, installed as piezometers, can also be installed in nests to determine the direction of groundwater movement.

Accurate site mapping is essential to the evaluation of site hydrology and restoration design. Topographic maps of the site are produced using either ground or aerial survey methods. Digital elevation models (DEM's) are developed that include topographic contours (typically 1.0 foot contours or less), locations of all drainage features and outlets, structures, existing wetland areas, and monitoring well locations. DEM's are used to visually depict the hydrologic features of the site, develop hydrologic model inputs, and evaluate proposed restoration practices.

2.5 Wetland Hydrologic Analyses

Hydrology data collected at the proposed restoration site is essential for documenting the hydrologic conditions of the site at the time of collection; however, data collected over several months to a year are limited for evaluating the site's long-term performance under varying rainfall and climatic conditions. Existing condition data alone also provides little insight into how the site will perform once restoration activities are completed. For these reasons, hydrologic modeling is often used to further evaluate the potential restoration site.

The most common hydrologic model used by Buck Engineering to evaluate wetland hydrology is DRAINMOD (version 5.1). DRAINMOD has been identified as an approved hydrologic tool for assessing wetland hydrology by the NRCS (1997). DRAINMOD was developed by NC State University for the study and design of water management systems on poorly-drained, shallow water table soils. A combination of methods is used in the model to simulate infiltration, drainage, surface runoff, evapotranspiration, and seepage processes on an hour-by-hour, day-by-day basis. DRAINMOD was modified by Skaggs et al. (1991b) for application to wetland determinations by the addition of a counter that calculates the number of times the water table rises above a specified depth and remains there for a given period during the growing season. For more information on DRAINMOD and its application to high water table soils, the reader is referred to Skaggs (1980).

DRAINMOD is used to develop hydrologic simulation models to represent conditions at a variety of locations across the proposed restoration area. Model parameters are selected based on field measurements and professional judgment about site conditions. Rainfall and air temperature information are collected from the nearest automated weather station. If automated weather stations are too far away, automated rain gauges may be installed on site. Soil parameters are determined from on-site evaluations of soil stratification and in-situ-measured hydraulic conductivity.

Measured field parameters are entered into the model, and initial model simulations are compared with observed data collected from monitoring wells. To calibrate the model, parameters not measured in the field are adjusted within the limits typically encountered under similar soil and geomorphic conditions, until model simulations most closely match observed well data.

It is important to note that DRAINMOD uses simplifying assumptions to estimate water table depths. When applied to a site with complex hydrologic processes, the model can be used to assess overall trends and relationships but is unlikely to offer exact predictions of water table hydrology. Calibration of the model is aimed at matching the relative response of water table drawdown and the overall depth that the water table reaches at different times during the year. Once these objectives are met, the model is assumed to adequately reflect the hydrologic response of the site to varying precipitation and climatic events.

Once model simulations are developed that reflect the existing conditions of the site, other simulations may be developed to represent the hydrology of the site after restoration practices have been implemented. Inputs that describe the drainage features of the site are altered to represent the restoration conditions. Inputs typically include: drainage feature spacing (increased due to the removal of ditches), drainage feature depth (typically decreased when restoring an associated stream and raising the streambed or filling and plugging drainage ditches), surface storage (increased through scarification practices), and crop inputs (conversion to trees instead of row crops). Model simulations are used to predict the changes in water table hydrology as a result of the proposed restoration practices.

DRAINMOD computes daily water balance information and develops summaries that describe the loss pathways for rainfall over the model simulation period. To compare long-term results, the amounts of rainfall, infiltration, drainage, runoff, and evapotranspiration estimated for the existing condition can be compared with simulations run for the proposed restoration practices. Infiltration represents the amount of water that percolates into the soil and is lost via drainage or runoff. Drainage is the loss of infiltrated water that travels through the soil profile and is discharged to the drainage ditches or to underlying aquifers. Runoff is water that flows overland and reaches the drainage ditches before infiltration. Evapotranspiration is water that is lost by the direct evaporation of water from the soil or through the transpiration of plants. Comparisons may include average annual amounts, annual maximums and minimums, and even day-to-day comparisons of hourly water table hydrographs.

2.6 Assessment of Existing Wetland Areas

Conditions across a potential restoration site will often vary dramatically. While much of the site may be targeted for restoration due to lack of wetland hydrology and functions, there may be areas of the site that still support wetland hydrology and wetland functions to some degree. These areas require special consideration as part of a proposed restoration design.

The proposed project area is reviewed for the presence of wetlands and waters of the United States in accordance with the provisions of Executive Order 11990, the Clean Water Act, and subsequent federal regulations. Wetlands have been defined by the USACE as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" [33 CFR 328.3(b) and 40 CFR 230.3 (t)]. Within the project area, locations that display one or more wetland components are reviewed to determine the presence of wetlands using hydrophytic vegetation, permanent or periodic inundation or saturation, and hydric soils.

Following an in-office review of the National Wetland Inventory (NWI) maps, NRCS Soil Surveys, and United States Geological Survey (USGS) Quadrangle maps, a pedestrian survey of the project area is made to investigate suspect areas and to delineate all wetlands and waters of the U.S. The project area is examined utilizing the jurisdictional definition detailed in the USACE Wetlands Delineation Manual. Supplementary information to further support wetland determinations is found in the *National List of Plant Species that Occur in Wetlands: Southeast (Region 2)* (Reed, 1988).

Buck Engineering collects data on the three wetland components and completes USACE wetland determination field sheets for each identified wetland area. These sheets document the wetland conditions that were observed on-site, including the presence of hydrophytic (wetland) vegetation, hydric soils, and wetland hydrology. The wetland systems are also classified using the *Classification of the Natural Communities of North Carolina, Third Approximation,* by Schafale and Weakley (1990). This classification system includes descriptions of all the natural community types in North Carolina (112 types and subtypes), including vegetation, soils, physical environment, dynamics, distinguishing features, examples, and associated rare plants. Wetlands are also classified using the *Hydrogeomorphic Classification of Wetlands* (HGM) by Brinson (1993). Since HGM subtypes are still being developed for North Carolina, HGM principles are used to describe the geomorphic setting, water sources, hydrodynamics, and functioning of identified wetland systems.

Where jurisdictional wetlands are identified, the wetland boundary is flagged with marking tape, at intervals of 25 to 50 feet. Buck Engineering follows the USACE Wilmington District procedures for survey and recordation of wetland boundaries. Surveys of wetland boundaries are conducted with either sub-meter accuracy Global Positioning System (GPS) equipment or total station survey equipment. A professional land surveyor (PLS) oversees any detailed land surveys. Wetland drawings are prepared using Geographic Information Systems (GIS) and/or CADD applications and submitted to USACE and the NC Division of Water Quality for jurisdictional determination and verification when required.

2.7 Reference Wetlands

Reference wetlands are natural wetland systems that are similar in function and geomorphic setting to the proposed restoration site. Reference wetlands can be used as templates for the proposed restoration design. Data collected from reference wetland sites, including vegetation communities, hydrologic characteristics, and topographic features, can provide valuable information for the evaluation of proposed restoration practices. Analysis of the vegetation communities within the reference site is used as a tool for developing the planting plan for the restoration site. Reference wetlands can also be used for comparison purposes to determine whether the restored wetland site is on a trajectory for success during the required monitoring period.

The reference wetland site should be located as close to the proposed restoration site as possible. The reference wetland should be of the same hydrogeomorphic classification as the proposed restoration site, and generally located within the same climatic, physiographic, and ecological region. Soil characteristics should closely match those of the proposed restoration site. Fully functioning wetland systems appropriate for reference sites may be difficult to locate in some areas; as a result, reference sites are often located some distance from the restoration site.

Once a potential reference site is located, Buck Engineering secures landowner permission to further evaluate the area as a potential reference site. On-site evaluations are similar to those previously described for jurisdictional wetland areas on restoration sites and include the documentation of vegetation communities, soil series, and visual observations regarding wetland hydrology. USACE wetland determination field sheets are completed for the reference wetland.

If the reference site is found to be appropriate for the restoration project, several groundwater wells are installed across the reference site to capture the range of hydrologic conditions. Automated and manual wells are generally installed in combination, with automated wells installed at the wettest and driest extremes of conditions and manual wells installed in more average conditions. This approach allows for accurate documentation of the hydrologic range of conditions across the site. Well data are downloaded monthly throughout the required monitoring period.

2.8 Wetland Restoration Techniques

Restoration techniques will vary by the type of wetland to be restored and the goals of the restoration. The purpose of this section is to describe some of the techniques that Buck Engineering commonly uses to restore lost functions and values on wetland restoration sites.

2.8.1 Restoration Techniques for Wetland Hydrology

The restoration of appropriate hydrology is the cornerstone of any wetland restoration project. Without the appropriate hydrology, all other wetland functions will be compromised. Several commonly used techniques are described below.

Restoration of Stream Channels – Many wetland restoration sites will contain stream channels that have been channelized and straightened. Channelization of streams lowers the baseflow water elevation in the channel, lowers the adjacent water table, increases the loss of water from the site through both increased surface and subsurface drainage, and decreases the frequency and severity of flooding events on adjacent lands.

The restoration of stream channels to restore wetland hydrology involves raising the streambed elevation such that the stream is reconnected to the abandoned hydric floodplain (i.e., agricultural fields). This process raises the local water table by raising the elevation of the drainage outlet, and restores a natural flooding regime to the site. For more information on stream restoration practices, see Sections 2.9, 2.10, and 2.11.

Filling and Blocking of Drainage Features – Drainage features may include ditches, channels, swales, and subsurface drains. Ditches are the most common drainage feature encountered on agricultural sites. Ditches are generally constructed on parallel spacings that are based on the drainage characteristics of the soils. Ditches and subsurface drains provide an outlet for subsurface drainage that is often several feet lower than the surrounding ground elevation. The effect is that groundwater moves toward the ditches where it is discharged, thus lowering the water table elevation.

Filling and blocking of drainage features removes the drainage effect they provide. The choice between partially blocking and completely filling the drainage features is primarily driven by the amount of soil that must be disposed of during construction. When there is an excess of soil to be disposed of, ditches and swales are completely filled. When the quantity of soil for disposal is limited, ditches and swales are blocked by partially filling, or plugging, the features at specific locations. Plugs are at least 50 to 100 feet in length, and soil material placed for the plugs is compacted with heavy equipment, used on site during construction. The actual length of the plugs will be based on the predicted hydraulic conductivity of the compacted fill material. The spacing between plugs will vary, depending on the slope of the site and the amount of soil for disposal.

Once ditches have been filled in or plugged, additional fill material will be piled over the filled ditch to a height of no more than 6 inches, to allow for subsidence and settling of the fill over time. Without additional material, settling of the fill could cause the drainage feature to partially reform over time and affect the hydrology of the site.

Subsurface drains, such as tiles and plastic pipe, are located and excavated so that they no longer function. Once drains have been removed, excavated soil material is placed back in the excavated trench and compacted.

Run-off Diversions – In some areas, it is beneficial to construct shallow diversions and swales to direct surface water run-off into the site. This practice is commonly used when restoration areas are adjacent to long hill slopes, where significant amounts of run-off may be produced during large rain events. The diversions are used to direct the run-off to areas of the restoration site where the additional water inputs are most needed.

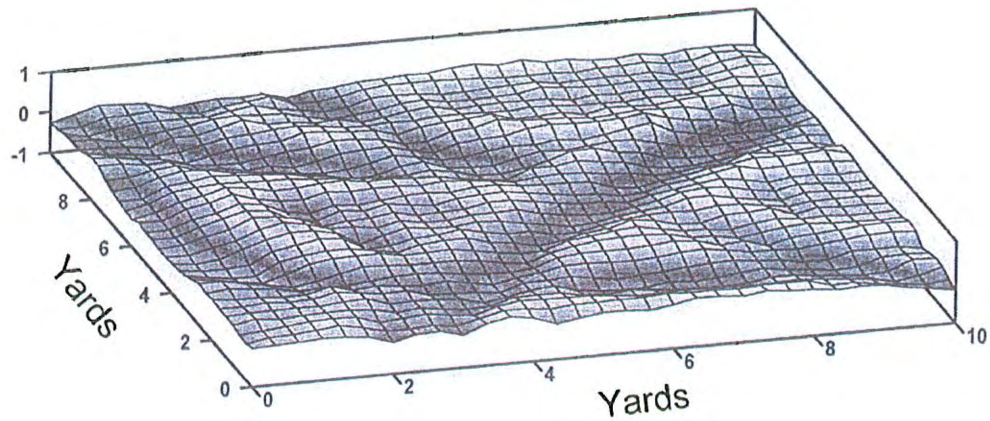
Shallow Depressions and Floodplain Pools – To increase the diversity of hydrologic conditions across the site, shallow depressions and floodplain pools can be excavated or created by leaving sections of ditches only partially filled in certain areas. The depressions are constructed to mimic the function of natural sloughs and pools commonly found across many wetland ecosystems. These areas provide increased surface storage of precipitation and floodwaters, improve biotic diversity, and provide breeding areas for a number of amphibian and reptile species.

Depressions and pools are generally constructed to be less than 1 foot deep. The size of depressions can vary, depending on the site; however, depressions 200 feet by 100 feet are typical of many sites. The depressions are designed to hold water for extended periods, ranging from several weeks to many months. For many amphibian species, it is crucial that the pools dry up completely during the late summer months. These ephemeral pools are typically constructed in higher elevation areas away from the active stream channel. For other species, pools that retain some degree of ponded water throughout the year are most beneficial. These features, which represent backwater sloughs, oxbow ponds, and floodplain pools, are typically constructed near the active stream channel, where the high water table conditions and frequent flooding will maintain water levels in the pools.

Restoration of Microtopography – In order to improve drainage and increase agricultural production, farmed wetland soils are often graded to a smooth surface and crowned to enhance run-off. Microtopography contributes to the properties of forest soils and to the diversity and patterns of plant communities (Lutz, 1940; Stephens, 1956; Bratton, 1976; Ehrnfeld, 1995). The introduction of microtopography also increases surface storage on the site, reducing run-off and erosion and enhancing infiltration.

Microtopography is established on the restored site after design grades have been achieved, using the procedures described by Scherrer (2000). The equipment should leave a furrow approximately 7 feet wide and 6 inches deep, and a corresponding mound approximately 7 feet wide and 6 inches high. The equipment should be run in parallel lines approximately 25 feet apart, and then over the same area in "figure 8" patterns to create a random pattern of interconnected and isolated furrows and ridges, as shown in Figure 2.1. The actual distance between furrows and mounds and the height of the mounds can be adjusted depending on the targeted amount of surface storage to be restored.

Figure 2.1
Typical pattern of restored wetland microtopography (from Scherrer, 2000).



2.8.2 Restoration Techniques for Wetland Soils

Soil Scarification and Tillage – Disking and tillage practices commonly used in agriculture can be used to break the plow pan and reduce compaction of the soil caused by years of agricultural production. Tillage practices will also be used to remove any field crowns, restoring a more natural topography to the site. When necessary, rippers will be used to till to depths of 12 – 18 inches to break any compacted pan layers.

Soil Amendments – Samples of top soil from the site can be collected and tested to determine soil fertility and chemical properties. If necessary, soil amendments (fertilizer, lime, etc.) will be applied at rates appropriate for the target vegetation. For land which has been in agricultural production for a number of years, it is likely that soil fertility will be high and amendments will not be necessary.

2.8.3 Restoration Techniques for Wetland Vegetation

Tree Planting Techniques – Under typical conditions, bare-root tree species will be planted within all areas of the site conservation easement. Bare-root vegetation is typically planted at a target density of 680 stems per acre, or an 8 by 8 foot grid. Experience has shown this density to be favorable for overall survival of at least 320 planted stems at the end of 5 years, which is a common success criterion for mitigation sites. Planting of bare-root trees is conducted during the dormant season, which lasts from late November to early March for most of the state.

Species selection is based on reference wetland vegetation analyses, professional knowledge of availability and viability of specific plants, and expected post-restoration hydrologic conditions. Species selection for revegetation of the site will generally follow those suggested by Schafale and Weakley (1990) and tolerances cited in the USACE Wetland Research Program (WRP) Technical Note VN-RS-4.1 (1997). Tree species selected for restoration will generally range from weakly tolerant to tolerant of flooding. Weakly tolerant species are able to survive and grow in areas where the soil is saturated or flooded for relatively short periods of time. Moderately tolerant species are able to survive on soils that are saturated or flooded for several months during the growing season. Flood tolerant species are able to survive on sites in which the soil is saturated or flooded for extended periods during the growing season (WRP, 1997).

Observations are made during construction of the site regarding the relative wetness of areas to be planted. Planting zones are determined based on these assessments, and planted species will be matched according to their wetness tolerance and the anticipated wetness of the planting area.

When feasible, trees are transported to the site from the nursery and stored on-site in a refrigerated cooler prior to planting. If on-site refrigeration is not available, trees are planted within two days of being transported to the site. Soils across the site are sufficiently disked and loosened prior to planting. Trees are planted by manual labor, using a dibble bar, mattock, planting bar, or other similar method. Planting holes for the trees are made sufficiently deep to allow the roots to spread out and down without "J-rooting." Soil is loosely compacted around trees once they have been planted to prevent them from drying out.

Permanent Seed Mixtures – Permanent seed mixtures are applied to all disturbed areas of the project site. Different mixtures may be specified for different areas of the site, depending on the wetness and degree of stabilization required at the site. Mixtures will also include temporary seeding to allow for application with mechanical broadcast spreaders and rapid ground cover following application. Temporary seeding is applied to all disturbed areas of the site that are susceptible to erosion, including constructed streambanks, access roads, side-slopes, spoil piles, etc.

2.9 Application of Fluvial Processes to Stream and Wetland Restoration

A stream and its wetland floodplain (referred to here as the riparian area) comprise a dynamic environment where the floodplain, wetland areas, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflects all of these factors (Leopold et al., 1992; Knighton, 1998). The size and flow of the stream channel also influence the size and functioning of wetland areas adjacent to the channel. The result is a dynamic equilibrium in which the stream maintains its dimension, pattern, and profile over time, and adjacent wetland areas evolve with the meandering of the stream across its floodplain. Land use changes in the watershed, including increases in imperviousness, removal of riparian vegetation, and drainage of adjacent wetlands can upset this balance. A new equilibrium may eventually result, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). These adjustments in channel form often have negative effects on associated wetland areas, as processes of channel incision increase drainage of adjacent areas. By understanding and applying the processes of riparian form and function to stream and wetland restoration projects, a self-sustaining riparian system can be designed and constructed that maximizes ecosystem function and potential.

In riparian systems, wetland functions cannot be restored without also addressing the restoration of stream functions; therefore, it is crucial that the degraded stream system be restored to the appropriate dimension, pattern, and profile while allowing the stream access to the abandoned floodplain and associated wetland areas. In this way, the stream becomes one of the primary sources of water and nutrient inputs to the wetland system. As such, the development of stream and wetland design components becomes an iterative process. The following sections describe the processes which Buck Engineering uses when developing stream restoration projects using natural channel design concepts.

2.10 Channel-Forming Discharge

The channel-forming discharge, also referred to as bankfull discharge, effective discharge, or dominant discharge, creates a natural and predictable channel size and shape (Leopold et al., 1992; Leopold, 1994). Channel-forming discharge theory proposes that there is a unique flow that over a long period of time would yield the same channel morphology that is shaped by the natural sequence of flows. At this discharge, equilibrium is most closely approached, and the tendency to change is the least (Inglis, 1947). Uses of the channel-forming discharge include channel stability assessment, river management using hydraulic geometry relationships, and natural channel design (Soar and Thorne, 2001).

Proper determination of bankfull stage in the field is vital to stream classification and the natural channel design process. The bankfull discharge is the point at which flooding occurs on the floodplain (Leopold, 1994). This flood stage may or may not be the top of the stream bank. On average, bankfull discharge occurs every 1.5 years (Leopold, 1994; Harman et al., 1999; McCandless, 2003). If the stream has incised due to changes in the watershed or streamside vegetation, the bankfull stage may be a small, depositional bench or scour line on the stream bank (Harman et al., 1999); in this case, the top of the bank, which was formerly the floodplain, is called a terrace. A stream with terraces at the top of its banks is incised.

2.10.1 Bedform Diversity and Channel Substrate

The profile of a stream bed and its bed materials is largely dependent on valley slope and geology. In simple terms, steep, straight streams are found in steep, colluvial valleys, while flat, meandering streams are found in flat, alluvial valleys. Colluvial valleys have slopes between 2 and 4 percent, while alluvial channels have slopes less than 2 percent. A colluvial valley forms through hillslope processes. Sediment supply in colluvial valleys is controlled by hillslope erosion and mass wasting; i.e., the sediments in the stream bed originated from the hillslopes. Sediments reaching the channel in a colluvial valley are typically poorly-sorted mixtures of fine and coarse-grained materials, ranging in size from sand to boulders. In contrast, an alluvial valley forms through stream and floodplain processes. Sediments in alluvial valleys include some coarse gravel and cobble transported from steeper upland areas, but are predominantly fine-grained particles, such as gravel and sand. Grain size generally decreases with valley slope (Leopold et al., 1992).

2.10.1.1 Step/Pool Streams

A step/pool bed profile is characteristic of steep streams formed within colluvial valleys. Steep mountain streams demonstrate step/pool morphology as a result of episodic sediment transport mechanisms. Because of the high energy associated with the steep channel slope, the substrate in step/pool streams contains significantly larger particles than streams in flatter alluvial valleys. Steps form from accumulations of boulders and cobbles that span the channel, resulting in a backwater pool upstream and a plunge pool downstream. Smaller particles collect in the interstices of steps, creating stable, interlocking structures (Knighton, 1998).

In contrast to meandering streams that dissipate energy through meander bends, step/pool streams dissipate energy through drops and turbulence. Step/pool streams have relatively low sinuosity. Pattern variations are commonly the result of debris jams, topographic features, and bedrock outcrops.

2.10.1.2 Gravel Bed Streams

Meandering gravel bed streams in alluvial valleys have sequences of riffles and pools that maintain channel slope and bed stability. The riffle is a bed feature composed of gravel or larger-size particles. During low-flow periods, the water depth at a riffle is relatively shallow, and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, providing oxygen to the stream. Riffles control the stream bed elevation and are usually found entering and exiting meander bends. The inside of the meander bend is a depositional feature called a point bar, which also helps maintain channel form (Knighton, 1998). Pools are typically located on the outside bends of meanders, between riffles. Pools have a flat slope and are much deeper than the average depth of the channel. At low flows, pools are depositional features, and riffles are scour features.

At high flows, the water surface becomes more uniform; i.e., the water surface slope at the riffles decreases, and the water surface slope at the pools increases. The increase in pool slope coupled with the greater water depth at the pools causes an increase in shear stress at the bed elevation. The opposite is true at riffles. With a relative increase in shear stress, pools scour. The relative decrease in shear stress at riffles causes bed material deposits at these features during the falling limb of the hydrograph.

2.10.1.3 Sand-bed Streams

While gravel bed streams have riffle/pool sequences, with riffles composed of gravel-size particles, sand-bed channels are characterized by median bed material sizes less than 2 millimeters (Bunte and Abt, 2001). Bed material features called ripples, dunes, planebeds, and antidunes characterize the sand-bedform. Although sand-bed streams technically do not have riffles, the term is often used to describe the crossover reach between pools. The term "riffle" may be used in this report to mean the same as "crossover section."

The size, stage, and variation of sand-bedforms are formed by changes in unit stream power as described below. These bedforms are symptomatic of local variations in the sediment transport rate and cause minor to major variations in aggradation and degradation (Gomez, 1991). Sand-bedforms can be divided between low-flow regimes and high-flow regimes, with a transitional zone between the two. Ripples occur at low flows, where the unit stream power is just high enough to entrain sand size particles. This entrainment creates small wavelets, from the random accumulation of sediment, that are triangular in profile, with gentle upstream and steep downstream slopes. The ripple dimensions are independent of flow depth, and heights are less than 0.02 meters.

As unit stream power increases, dunes eventually replace ripples. Dunes are the most common type of sand-bedform and have a larger height and wavelength than ripples. Unlike ripples, dune height and wavelength are proportional to flow depth. The movement of dunes is the major cause of variability in bed-load transport rates in sand-bed streams. Dunes are eventually washed out, to leave an upper-flow plane bed characterized by intense bedload transport. This plane bed prevents the patterns of erosion and deposition required for dune development. This stage of bedform development is called the transitional flow regime, between low-flow regime features and high-flow features (Knighton, 1998).

As flow continues to increase, standing waves develop at the water surface, and the bed develops a train of sediment waves (antidunes) which mirror the surface forms. Antidunes migrate upstream by way of scour on the downstream face and deposition on the upstream face, a process which is opposite that of ripples and dunes. Antidunes can also move downstream or remain stationary for short periods (Knighton, 1998).

2.10.2 Stream Classification

The Rosgen Stream Classification System categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system, illustrated in Exhibit 2.1, presents several stream types, based on a hierarchical system. The first level of classification distinguishes between single and multiple-thread channels. Streams are then separated according to degrees of entrenchment, width/depth ratio, and sinuosity. Slope range and channel materials are also evaluated to subdivide the streams. Stream types are further described according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern.

Bankfull stage is the basis for measuring the width/depth and entrenchment ratios, two of the most important delineative criteria; therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures. A detailed discussion of bankfull stage is provided in Section 2.12.1.

2.10.3 Stream Stability

A naturally stable stream must be able to transport the sediment load supplied by its watershed while maintaining dimension, pattern, and profile over time so that it does not degrade or aggrade (Rosgen, 1994). Stable streams migrate across alluvial landscapes slowly, over long periods of time, while maintaining their form and function. Instability occurs when scouring causes the channel to incise (degrade) or when excessive deposition causes the channel bed to rise (aggrade). A generalized relationship of stream stability proposed by Lane (1955) is shown as a schematic drawing in Exhibit 2.2. The drawing shows that the product of sediment load and sediment size is proportional to the product of stream slope and discharge or stream power. A change in any one of these variables causes a rapid physical adjustment in the stream channel.

2.10.4 Channel Evolution

A common sequence of physical adjustments has been observed in many streams following disturbance. This adjustment process is often referred to as channel evolution. Disturbance can result from channelization, increase in run-off due to build-out in the watershed, removal of streamside vegetation, and other changes that negatively affect stream stability. All of these disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream. The Simon (1989) Channel Evolution Model characterizes evolution in six steps:

I	sinuous, pre-modified,
II	channelized,
III	degradation,
IV	degradation and widening,
V	aggradation and widening, and
VI	quasi-equilibrium.

Exhibit 2.3 illustrates the six steps of the Simon Channel Evolution Model.

The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Disturbance commonly causes increased in-stream power that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the banks, and when critical bank heights are exceeded, the banks begin to fail, and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream in the form of a head-cut. Eventually, the mass wasting slows, and the stream begins to aggrade. A new, low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form, with a new floodplain constructed of alluvial material (FISRWG, 1998).

2.10.5 Priority Levels of Restoring Incised Rivers

Though incised streams can occur naturally in certain landforms, they are often the product of disturbance. Characteristics of incised streams include high, steep stream banks; poor or absent in-stream or riparian habitat; increased erosion and sedimentation; and low sinuosity. Complete restoration, in which the incised channel's grade is raised so that an abandoned floodplain terrace is reclaimed, is the ideal, overriding objective of stream restoration; such an objective may be impractical, however, when homes, roadways, utilities, or other structures have encroached upon the abandoned floodplain. A priority system for the restoration of incised streams, developed and used by Rosgen (1997), considers a range of options to provide the best level of stream restoration possible for the given setting. Exhibit 2.4 illustrates various restoration/stabilization options for incised channels within the framework of the Rosgen priority system. Generally:

- Priority 1 – Re-establishes the channel on a previous floodplain (i.e., raises channel elevation); meanders a new channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel. This option requires that the upstream start point of the project not be incised.
- Priority 2 – Establishes a new floodplain at the existing bankfull elevation (i.e., excavates a new floodplain); meanders channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel.
- Priority 3 – Converts a straight channel to a different stream type while leaving the existing channel in place, by excavating bankfull benches at the existing bankfull elevation. Effectively, the valley for the stream is made more bowl-shaped. This approach uses in-stream structures to dissipate energy through a step/pool channel type.
- Priority 4 – Stabilizes the channel in place, using in-stream structures and bioengineering to decrease stream bed and stream bank erosion. This approach is typically used in highly-constrained environments.

2.11 Natural Channel Design Overview

Restoration design of degraded stream reaches first involves accurately diagnosing their current condition. Understanding valley type, stream type, channel stability, bedform diversity, and potential for restoration is essential to developing adequate restoration measures (Rosgen, 1996). This combination of assessment and design is often referred to as natural channel design.

The first step in a stream restoration design is to assess the reach, its valley, and its watershed, to understand the relationship between the stream and its drainage basin and to evaluate the causes of stream impairment. Bankfull discharge is estimated for the watershed. After sources of stream impairment are identified and channel geometry is assessed, a plan for restoration can be formulated.

Design commences at the completion of the assessment stage. A series of iterative calculations are performed using data from reference reaches, pertinent literature, and evaluation of past projects to develop an appropriate, stable cross section, profile, and plan form dimensions for the design reach. A thorough discussion of design parameter selection is provided in Section 2.14. The alignment should avoid an entirely symmetrical layout to mimic natural variability, create a diversity of aquatic habitats, and improve aesthetics.

Once a dimension, pattern, and profile have been developed for the project reach, the design is tested to ensure that the new channel will not aggrade or degrade. A discussion of sediment transport methodology is provided in Section 2.15.

After the sediment transport assessment, additional structural elements are added to the design to provide grade control, protect stream banks, and enhance habitat. Section 2.16 describes these in-stream structures in detail.

Once the design is finalized, detailed drawings are prepared to show dimension, pattern, profile, and location of additional structures. These drawings are used in the construction of the project.

Following the implementation of the design, a monitoring plan is established to:

- Ensure that stabilization structures are functioning properly;
- Monitor channel response in dimension, pattern and profile, channel stability (aggradation/degradation), particle size distribution of channel materials, and sediment transport and stream bank erosion rates;
- Determine biological response (food chains, standing crop, species diversity, etc.); and
- Determine the extent to which the restoration objectives have been met.

2.12 Geomorphic Characterization Methodology

Geomorphic characterization of stream features includes the bankfull identification, bed material characterization and analysis, and stream classification.

2.12.1 Bankfull Identification

Buck Engineering's field techniques for bankfull identification are as follows:

- Identify the most consistent bankfull indicators along the reach that were obviously formed by the stream, such as a point bar or lateral bar. Bankfull is usually the back of this feature, unless sediment supply is high; in that case, the bar may flatten, and bankfull will be the front of the feature at the break in slope. The indicator is rarely the top of the bank or lowest scour mark.
- Measure the difference in height between the water surface and the bankfull indicator; for example, the indicator may be 2.2 feet above water surface. Bankfull stage corresponds to a flow depth. It should not vary by more than a few tenths of a foot throughout the reach, unless a tributary enters the reach and increases the size of the watershed.
- Look for bankfull indicators at a stable riffle. If a bankfull indicator is not present at this riffle, use the height measured in the previous step to establish the indicator; for example, measure 2.2 feet above water surface, and place a flag in both the right and left banks.
- Measure the distance from the left bank to the right bank between the indicators. Calculate the cross-sectional area.
- Obtain the appropriate regional curve (e.g., rural Piedmont, urban Piedmont, Mountain, or Coastal Plain) and determine the cross-sectional area associated with the drainage area of the reach.
- Compare the measured cross-sectional area to the regional curve cross-sectional. If the measured cross-sectional area is not a close fit, look for other bankfull indicators, and test them. If there are no other indicators, look for reasons to explain the difference between the two cross-sectional areas; for example, if the cross-sectional area of the stable riffle is lower than the regional curve area, look for upstream impoundments, wetlands, or a mature forested watershed. If the cross-sectional area is higher than the regional curve area, look for stormwater drains, parking lots, or signs of channelization.

It is important to perform the bankfull verification at a stable riffle, using indicators from depositional features. The cross-sectional area will change with decreasing stability. In some streams, bankfull indicators will not be present due to incision or maintenance. In such cases, it is important to verify bankfull through other means, such as a gauge station survey or reference bankfull information that is specific to the geographic location. The gauge information can be used to verify the applicability of the regional curve to a localized area.

2.12.2 Bed Material Characterization

Buck Engineering performs bed material characterizations using a modified Wolman procedure (Wolman, 1954; Rosgen, 1996). A 100-count pebble count is performed in transects across the streambed, with the number of riffle and pool transects proportional to the percentage of riffles and pools within the longitudinal distance of a given stream type. As stream type changes, a separate pebble count is performed. The median particle size of the modified Wolman procedure is known as the D_{50}. The D_{50} describes the bed material classification for that reach. The Rosgen bed material classification is shown in Exhibit 2.1 and ranges from a classification of 1, for a channel D_{50} of bedrock, to a classification of 6, for a channel D_{50} in the silt/clay particle size range.

The modified Wolman pebble count is not appropriate for sand-bed streams. When working in sand-bed systems, a bulk sampling procedure is used to characterize the bed material. Cores (2" - 3" deep) are sampled from the bed along the entire reach. These cores are taken to a lab and dry-sieved to obtain a sediment size distribution. This information is used to classify the stream and to complete the sediment transport analysis.

2.12.3 Stream Classification

Cross sections are surveyed along stable riffles for the purpose of stream classification. Values for entrenchment ratio and width/depth ratio, along with sinuosity and slope, are used to classify the stream. The entrenchment ratio (ER) is calculated by dividing the flood-prone width (width measured at twice the maximum bankfull depth) by the bankfull width. The width/depth ratio (w/d ratio) is calculated by dividing bankfull width by mean bankfull depth. Exhibit 2.5 shows examples of the channel dimension measurements used in the Rosgen Stream Classification System.

Finally, the numbers that coincide with each bed material classification are to further classify the stream type; for example, a Rosgen E3 stream type is a narrow and deep, cobble-dominated channel, with access to a floodplain that is greater than two times its bankfull width.

2.13 Channel Stability Assessment Methodology

Buck Engineering uses a modified version of stream channel stability assessment methodology developed by Rosgen (2001a). The Rosgen method is a field assessment of the following stream channel characteristics:

- Stream Channel Condition,
- Vertical Stability,
- Lateral Stability,
- Channel Pattern,
- River Profile and Bed Features,
- Channel Dimension Relations, and
- Channel Evolution.

This field exercise is followed by the evaluation of various channel dimension relationships.

Evaluation of the above characteristics and relationships leads to a determination of a channel's current state, potential for restoration, and appropriate restoration activities. A description of each characteristic is provided in the following sections.

2.13.1 Stream Channel Condition Observations

Stream channel conditions are observed during initial field inspection (stream walk). Buck Engineering notes the follow characteristics:

- Riparian vegetation – concentration, composition, and rooting depth and density;
- Sediment depositional patterns – mid-channel bars and other depositional features that indicate aggradation and can lead to negative geomorphic channel adjustments;
- Debris occurrence – presence or absence of woody debris;
- Meander patterns – general observations with regard to the type of adjustments a stream will make to reach equilibrium; and
- Altered states due to direct disturbance – channelization, berm construction, and floodplain alterations, etc.

These qualitative observations are useful in the assessment of channel stability. They provide a consistent method of documenting stream conditions that allows comparison across different sets of conditions. The observations also help explain the quantitative measurements described below.

2.13.2 Vertical Stability – Degradation/Aggradation

The bank height and entrenchment ratios are measured in the field to assess vertical stability. The bank height ratio is measured as the ratio of the lowest bank height divided by a maximum bankfull depth. Table 2.1 shows the relationship between bank height ratio (BHR) and vertical stability developed by Rosgen (2001a).

TABLE 2.1
Conversion of Bank Height Ratio (Degree of Incision) to Adjective Rankings of Stability (Rosgen, 2001a)

Adjective Stability Rating	Bank Height Ratio
Stable (low risk of degradation)	1.0 – 1.05
Moderately unstable	1.06 – 1.3
Unstable (high risk of degradation)	1.3 – 1.5
Highly unstable	> 1.5

The entrenchment ratio is measured as the width of the floodplain at twice the maximum bankfull depth. If the entrenchment ratio is less than 1.4 (+/- 0.2), the stream is considered entrenched (Rosgen, 1996).

2.13.3 Lateral Stability

The degree of lateral containment (confinement) and potential lateral erosion are assessed in the field by measuring the meander width ratio (MWR) and the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001a). The MWR is the meander belt width divided by the bankfull channel width. This measurement provides insight into lateral channel adjustment processes, depending on stream type and degree of confinement; for example, a MWR of 3.0 often corresponds with a sinuosity of 1.2, which is the minimum value for a stream to be classified as meandering. If the MWR is less than 3.0, lateral adjustment is probable. BEHI ratings along with near bank shear stress estimates can be compared to data from monitored sites and used to estimate the annual lateral stream bank erosion rate.

2.13.4 Channel Pattern

Channel pattern is assessed in the field by measuring the stream's plan features, including radius of curvature, meander wavelength, meander belt width, stream length, and valley length. Results are used to compute the meander width ratio (described above), ratio of radius of curvature to bankfull width, sinuosity, and meander wavelength ratio (meander wavelength divided by bankfull width). These dimensionless ratios are compared to reference reach data for the same valley and stream type to assess whether channel pattern has been impacted.

2.13.5 River Profile and Bed Features

A longitudinal profile is created by measuring and plotting elevations of the channel bed, water surface, bankfull, and low bank height. Profile points are surveyed at prescribed intervals and at significant breaks in slope, such as the head of a riffle or pool. This profile can be used to assess changes in river slope compared to valley slope, which affect sediment transport, stream competence, and the balance of energy; for example, the removal of large woody debris may increase the step/pool spacing and result in excess energy and subsequent channel degradation. Facet (e.g., riffle, run, pool) slopes of each individual feature are important for stability assessment and design.

2.13.6 Channel Dimension Relations

The bankfull width/depth ratio provides an indication of departure from reference reach conditions and relates to channel instability. A greater width/depth ratio compared to reference conditions may indicate accelerated stream bank erosion, excessive sediment deposition, stream flow changes, and alteration of channel shape (e.g., from channelization). A smaller width/depth ratio compared to reference conditions may indicate channel incision and downcutting. Both increases and decreases in width/depth ratio can indicate evolutionary shifts in stream type (i.e., transition of one stream type to another). Table 2.2 shows the relationship between the degree of width/depth ratio increase and channel stability developed by Rosgen (2001a).

TABLE 2.2
Conversion of Width/depth Ratios to Adjective Ranking of Stability from Stability Conditions (Rosgen, 2001a)

Stability Rating	Ratio of Project to Reference Width/depth
Very stable	1.0
Stable	1.0 – 1.2
Moderately unstable	1.21 – 1.4
Unstable	> 1.4

While an *increase* in width/depth ratio is associated with channel *widening*, a *decrease* in width/depth ratio is associated with channel *incision*; hence, for incised channels, the ratio of channel width/depth ratio to reference reach width/depth ratio will be less than 1.0. The reduction in width/depth ratio indicates excess shear stress and movement of the channel toward an unstable condition.

2.13.7 Channel Evolution

Simon's Channel Evolution Model (introduced in Section 2.10.4) relies on a qualitative, visual assessment of the existing stream channel characteristics, such as bank height, evidence of degradation/aggradation, presence of bank slumping, and direction of bed and bank movement. Establishing the evolutionary stage of the channel helps ascertain whether the system is moving towards greater stability or instability. The model also provides a better understanding of the cause and effect of channel change. This information, combined with Rosgen's (1994) priority levels of restoration, aids in determining the restoration potential of unstable reaches.

2.14 Stream Design Parameter Selection Methodology

Buck Engineering uses a combination of approaches to develop design criteria for channel dimension, pattern, and profile. These approaches are described in the following sections. A flow chart for selecting design criteria is shown in Exhibit 2.6.

2.14.1 Upstream Reference Reaches

The best option for developing design criteria is to locate a reference reach upstream of the project site. A reference reach is a channel segment that is stable—neither aggrading nor degrading— and is of the same morphological type as the channel under consideration for restoration. The reference reach should also have a similar valley slope as the project reach. The reference reach is then used as the blueprint for the channel design (Rosgen, 1998). To account for differences in drainage area and discharge between a reference site and a project site, data on channel characteristics (dimension, pattern, and profile), in the form of dimensionless ratios, are developed for the reference reach. If the reach upstream of the project does not have sufficient pattern, but does have a stable riffle cross section, only dimension ratios are calculated. It is ideal to measure a reference bankfull dimension that was formed under the same environmental influences as the project reach.

2.14.2 Reference Reach Searches

If a reference reach cannot be located upstream of the project reach, a review of a reference reach database is performed. A database search is conducted to locate known reference reaches in close proximity to the project site and includes streams with the same valley as the project reach and stream type as the design. If references are found meeting these criteria, the reference reach is field-surveyed for validation and comparison with the database values, which may have been originally collected and provided by a third party. If a search of the database reveals no references which meet the appropriate criteria, a field search is performed locally to identify a reference reach which has not yet been surveyed.

Potential reference reaches are identified by first evaluating USGS topographic quadrangles and aerial photography for an area. In general, the search is limited to subwatersheds within or adjacent to the project watershed. In certain cases, a reference reach may be identified farther away that matches the same valley and stream type as the proposed design of the project site. In such a case, care is taken to ensure that the potential reference reach lies within the same physiographic region as the project reach. Potential reference sites identified on maps are then evaluated in the field to determine if they are stable systems of the appropriate stream and valley type. If appropriate, reference reach surveys are conducted. When potential sites are located on private property, landowner permission is acquired prior to conducting any survey work.

2.14.3 Reference Reach Databases

If a reference reach is not found in close proximity to the project site, a reference reach database is consulted, and summary ratios are acquired for all streams with the same valley and stream type within the project's physiographic region. These ratios are then compared to literature values and regime equations, along with ratios developed through the evaluation of successful projects.

2.14.4 Regime Equations

Buck Engineering uses a variety of published journals, books, and design manuals to cross-reference North Carolina database values with peer-reviewed regime equations. Examples include *Fluvial Forms and Processes,* by David Knighton (1998), *Mountain Rivers,* by Ellen Wohl (2000), and the *Hydraulic Design of Stream Restoration Projects,* by the US Army Corps of Engineers (Copeland et al., 2001). The most common regime equations used in our designs are for pattern; for example, most reference reach surveys in the eastern United States show radius of curvature divided by bankfull width ratios much less than 1.5. The Corps manual recommends a ratio greater than 2.0 to maintain stability in free-forming systems. Since most stream restoration projects are constructed on floodplains denude of woody vegetation, we often use the Corps-recommended value rather than reference reach data. Meander wavelength and pool-to-pool spacing ratios are examples of other parameters that are sometimes designed with higher ratios than those observed on reference reaches, for similar reasons as described for radius of curvature.

2.14.5 Comparison to Past Projects

All of the above techniques for developing ratios and/or regime equations are compared to past projects built with similar conditions. Ultimately, these sites provide the best pattern and profile ratios because they reflect site conditions after construction. While most reference reaches are in mature forests, restoration sites are in floodplains with little or no mature woody vegetation. This lack of mature woody vegetation severely alters floodplain processes and stream bank conditions. If past ratios did not provide adequate stability or bedform diversity, they are not used; conversely, if past project ratios created stable channels with optimal bedform diversity, they will be incorporated into the design.

Ultimately, the design criteria are selections of ratios and equations made upon a thorough evaluation of the above tasks. Combinations of approaches may be used to optimize the design. The final selection of design criteria for the restoration site is discussed in Section 6.

2.14.6 Considerations Regarding Wetland Hydrology

Special considerations must be used during the stream restoration design process if there is also a goal of restoring wetland hydrology to adjacent hydric soil areas; specifically, stream dimension and pattern will have a significant effect on wetland hydrology. Collected data have shown that the water table of wetland areas adjacent to the stream channel is directly influenced by the baseflow water level in the stream. Higher width-to-depth channels are more conducive to supporting wetland hydrology, because the baseflow water level of the channel is at a higher elevation. Surveys of sand-bed streams in existing wetland areas have shown that high width-to-depth ratios (typically 10 to 14) are common.

Stream pattern is also an important consideration for wetland restoration. The location of the restored stream channel will have a direct effect on which areas of the restoration site are flooded and how frequently. While stream pattern is primarily controlled by the topography of the site, minor adjustments to stream pattern can be used to provide additional hydrologic inputs to crucial wetland restoration areas.

2.15 Sediment Transport Competency and Capacity Methodology

The purpose of sediment transport analysis is to ensure that the stream restoration design creates a stable channel that does not aggrade or degrade over time. The overriding assumption is that the project reach should be transporting all the sediment delivered from upstream sources, thereby being a "transport" reach and classified as a Rosgen "C" or "E" type channel. For sand-bed channels, empirical relationships from stable sand-bed channels in North Carolina are used for this analysis.

Sediment transport is typically assessed by computing channel competency, capacity, or both. Sediment transport competency is a measure of force (lbs/ft^2) that refers to the stream's ability to move a given grain size. Quantitative assessments include shear stress, tractive force, and critical dimensionless shear stress. Since these assessments help determine a size class that is mobile under certain flow conditions, they are most important in gravel bed studies in which the bed material ranges in size from sand to cobble (of which only a fraction are mobile during bankfull conditions). In sand-bed systems, all particle sizes are mobile during bankfull flows; therefore, there is no need to determine the maximum particle size that the stream can transport. Comparing the design shear stress values for a project reach to those computed for sand-bed reference reaches does provide a useful comparison to determine if the stresses predicted for the design channels are within the range of those found in stable systems.

Shear stress placed on sediment particles within a stream channel may be estimated by the following equation:

$$\tau = \gamma RS, \text{ where} \qquad \text{Equation (1)}$$

τ = shear stress (lb/ft^2)

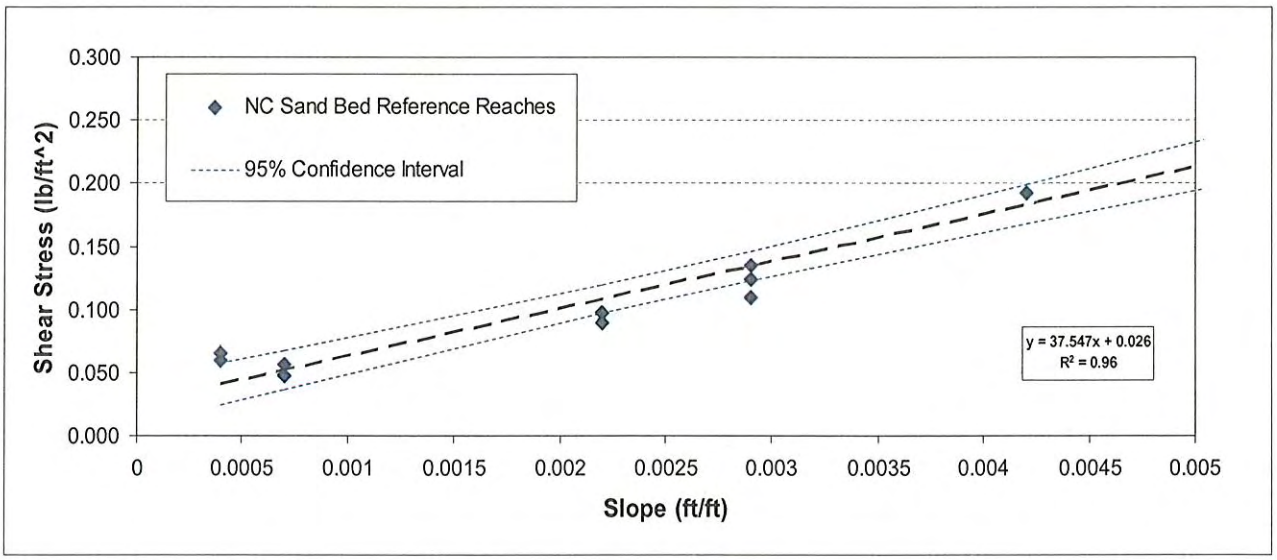
γ = specific gravity of water (62.4 lb/ft^3)

R = hydraulic radius (ft)

S = average channel slope (ft/ft)

Shear stress values are calculated for each design reach and plotted against values from sand-bed reference stream data from the Coastal Plain, as shown in Figure 2.2. If the predicted design shear stress values fall within the range of values documented for stable reference channels, it is assumed that shear stresses within the design reaches will be appropriate to maintain a stable channel.

Figure 2.2
Comparison between bankfull shear stress and channel slope for the design reaches and Coastal Plain reference reach data.



For sand-bed streams, sediment transport capacity is a much more important analysis tool than competency. Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross section per unit of time, expressed in pounds/second or tons/year. Sediment transport capacity can be assessed directly, using actual monitored data from bankfull events, if a sediment transport rating curve has been developed for the project site. Since this is extremely difficult, other empirical relationships are used to assess sediment transport capacity. The most common capacity equation is stream power. Stream power can be calculated a number of ways, but the most common among geomorphologists is:

$\omega = \gamma QS/W$, where Equation (2)

ω = mean stream power in W/m^2

γ = specific weight of water (9,810 N/m^3); $\gamma = \rho g$ where ρ is the density of the water-sediment mixture (1,000 kg/m^3) and g is the acceleration due to gravity (9.81 m/s^2)

Q = bankfull discharge in m^3/s

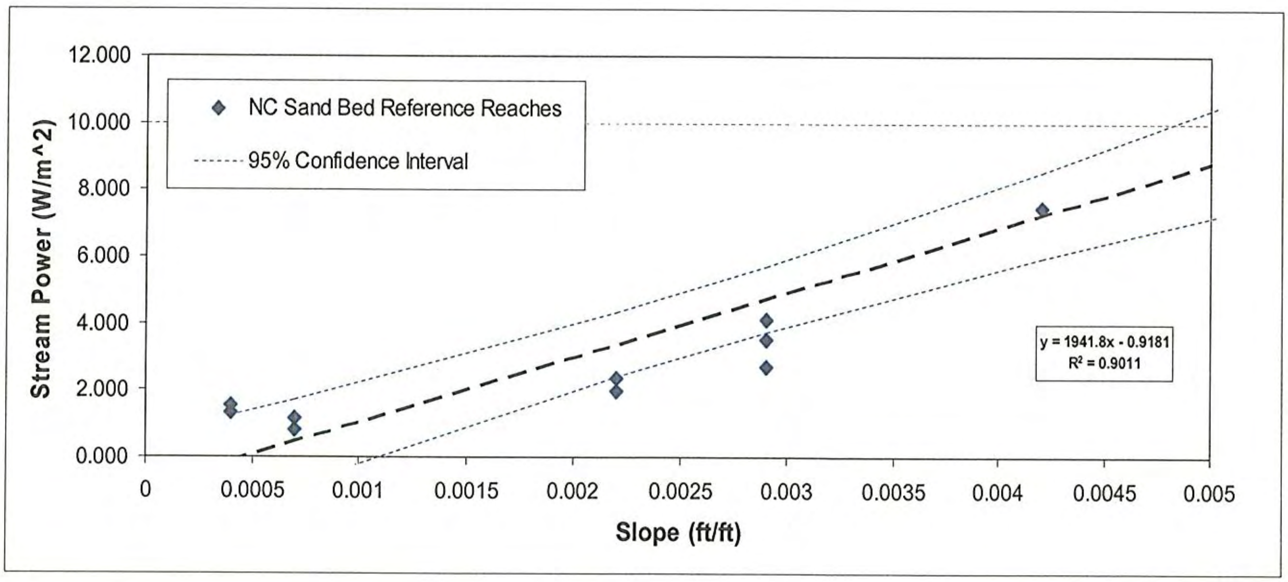
S = design channel slope (dimensionless)

W = bankfull channel width in meters

Note: 1 ft-lb/sec/ft^2 = 14.56 W/m^2

Equation 2 does not provide a sediment transport rating curve; however, it does describe the stream's ability to accomplish work (i.e. move sediment). For this analysis, stream power values are calculated and plotted against the range of stream power values documented for stable reference streams, as shown in Figure 2.3. If the design values fall within the range of values given for stable reference streams, then the analysis provides confidence that the design stream will be able to transport its sediment load.

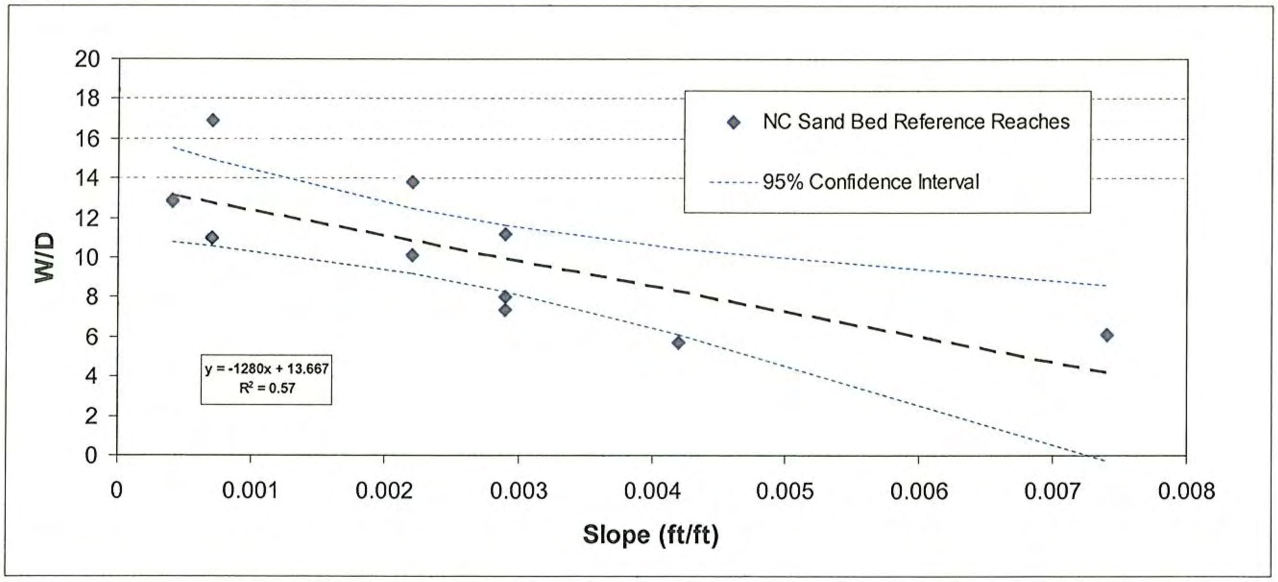
Figure 2.3
Comparison between stream power and channel slope for the design reaches and Coastal Plain reference reach data.



As an additional check of stream design stability, the design width-to-depth ratios (W/D) are plotted against slope and compared with data from sand-bed reference reaches in the Coastal Plain. Data collected on sand-bed systems in the Coastal Plain of North Carolina indicate a strong correlation between W/D and slope, with W/D decreasing as channel slope increases. The design W/D ratios are compared with reference reach data in Figure 2.4, which shows bankfull W/D ratio versus channel slope. If the design points for the design reaches fall within the range of W/D values shown for reference reaches under similar slope conditions, it is even more likely that the design dimensions of the restored channels will remain stable.

Figure 2.4

Comparison between width-to-depth ratio (W/D) and channel slope for the design reaches and Coastal Plain reference reach data.



2.16 In-Stream Structures

There are a variety of in-stream structural elements used in restoration. Exhibit 2.7 illustrates a few typical structures. These elements are comprised of natural materials, such as stone, wood, and live vegetation. Their shape and location works with the flow dynamics to reinforce, stabilize, and enhance the function of the stream channel. In-stream structures provide three primary functions: grade control, stream bank protection, and habitat enhancement.

2.16.1 Grade Control

Grade control pertains mainly to the design bed profile. A newly excavated gravel stream bed with a slope greater than 0.5 percent is seldom able to maintain the desired slopes and bed features, such as riffles, runs, pools, and glides, until a pavement/subpavement layer has been established. Stone and/or log structures installed at the bed elevation and at critical locations in the plan view help to set up the new stream bed for long-term vertical stability. Over time, as the new channel adjusts to its sediment transport regime and vegetative root mass establishes on the banks, the need for grade control diminishes.

2.16.2 Bank Protection

Bank protection is critical during and after construction, as bank and floodplain vegetation is establishing a reinforcing root mass. This vegetation establishment lasts for several years, but vegetation typically provides meaningful bank protection after two to four growing seasons. Bank protection structures generally provide both reinforcement to the stream banks and re-direction of flow away from the banks and toward the center of the channel.

2.16.3 Habitat Enhancement

Habitat enhancement can take several forms and is often a secondary function of grade control and bank protection structures. Flow over vanes and wing deflectors creates scour pools, which provide diversity of in-stream habitat. Boulder clusters form eddies that provide resting places for aquatic species. Constructed riffles and vane structures encourage oxygenation of the water. Root wads provide cover and shade and encourage the formation of deep pools at the outside of meander bends.

2.16.4 Selection of Structure Types

Table 2.3 summarizes the names and functions of several in-stream structures.

TABLE 2.3
Functions of In-Stream Structures

Structure	Function (Primary = 1, Secondary = 2)		
	Grade Control	Bank Protection	Habitat Enhancement
Cross Vane	1	1	2
Single Arm Vane		1	2
J-Hook Vane	2	1	2
Constructed Riffle	1	1	2
Log Weir	1		2
Wing Deflector	2	1	1
Boulder Cluster			1
Root Wad		1	1
Brush Mattress		1	2
Cover Log			1

The selection of structure types and locations typically follows dimension, pattern, and profile design. In some situations, structures comprise the main, or possibly only, effort to restore a stream. More often, structures are used in conjunction with grading, realignment, and planting, in an effort to improve channel stability and aquatic habitat.

2.17 Stream and Buffer Vegetation

The planting of additional and/or more desirable vegetation is an important aspect of the restoration plan. Vegetation helps stabilize stream banks, creates habitat and food sources for wildlife, lowers water temperature by stream shading, improves water quality by filtering overland flows, and improves the aesthetics of the site.

The reforestation component of a restoration project may include live dormant staking of the stream banks, riparian buffer planting, invasive species removal, and seeding for erosion control. The stream banks and the riparian area are typically planted with both woody and herbaceous vegetation to establish a diverse streamside buffer. Planting the stream banks is a desirable means of erosion control because of the dynamic, adaptive, and self-repairing qualities of vegetation. Vegetative root systems stabilize channel banks by holding soil together, increasing porosity and infiltration, and reducing soil saturation through transpiration.

During high flows, plants lie flat, and stems and leaves shield and protect the soil surface from erosion. In most settings, vegetation is more aesthetically appropriate than engineered stabilization structures.

Stream banks are delineated into four zones when considering a planting scheme:

1. Channel bottom - extending up to the low-flow stage; emergent, aquatic plants dominate bank range, extending from the low-flow stage to the bankfull stage;
2. Lower bank - frequently flooded, extending from the low-flow stage to the bankfull stage; a mix of herbaceous and woody plants including sedges, grasses, shrubs and trees;
3. Upper bank – occasionally flooded, but most often above water; dominated by shrubs and small trees;
4. Riparian area – infrequently flooded, terrestrial, and naturally forested with canopy-forming trees.

The most appropriate source of plant material for any project is the site itself. Desirable plants that need to be removed in the course of construction should be salvaged and transplanted as part of the restoration plan. The next best alternative is to obtain permission to collect and transplant native plants from areas nearby. This transplant process ensures that the plants are native and adapted to the locale. Finally, plants may need to be purchased. They should be obtained from a nearby reputable nursery that guarantees that the plants are native and appropriate for the locale and climate of the project site.

2.17.1 Live Staking

Live staking is a method of re-vegetation that utilizes live, dormant cuttings from appropriate species to cheaply and effectively establish vegetation. The installation of live stakes on stream banks serves to protect the banks from erosion and, at the same time, provides habitat, shade, and improved aesthetics. Live staking must take place during the dormant season (November to March in the Southeast US). Live stakes can be gathered locally or purchased from a reputable, commercial supplier. Stakes should be at least ½ inches and no more than 2 inches in diameter, between 2 and 3 feet in length, and living, as evidenced by the presence of young buds and green bark. Stakes are cut at an angle on the bottom end and driven into the ground with a rubber mallet.

2.17.2 Transplanted Vegetation

Transplanting is a method of removing desirable vegetation from one location on the project site and replanting it at another location on the site. In most cases, the vegetation which is being moved would otherwise be destroyed during restoration; for example, vegetation growing along the toe of a deeply-incised channel would be destroyed when water was routed into a new stream channel, and the old channel was backfilled. Transplanted vegetation provides immediate shading to the restored stream, as well as living root mass to increase streambank stability and create holding areas for fish and aquatic biota.

Transplants are excavated using a loader or mechanized excavator, such that the complete root mass and surrounding soil are removed intact. The transplant is then placed in an excavated hole along the streambank, generally around the outside of a meander bend, where establishment of vegetation is crucial to streambank stability. Species which are commonly used for transplanting include giant cane (*Arundinaria gigantea*), small oak saplings (*Quercus spp.*), sedge and rush species (*Juncus spp.* and *Carex spp.*), and other hydrophytic species with deep root masses.

2.17.3 Riparian Buffer Re-Vegetation

Riparian buffers are naturally occurring ecosystems adjacent to rivers and streams and are associated with a number of benefits. Buffers are important in nutrient and pollutant removal in overland flow and may provide for additional subsurface water quality improvement in the shallow groundwater flow. Buffers also provide habitat and travel corridors for wildlife populations and are an important recreational resource. It is also important to note that riparian buffer areas help to moderate the quantity and timing of run-off from the upland landscape and contribute to the groundwater recharge process.

Buffers are most valuable and effective when comprised of a combination of trees, shrubs, and herbaceous plants. Although width generally increases the capacity of riparian buffers to improve water quality and provide habitat value, even buffers less than 85 feet wide have been shown to improve water quality and habitat (Budd et al., 1987). An estimated minimum width of 30 feet is required for creating beneficial forest structure and riparian habitat.

In stream and wetland restoration, where buffer width is often limited, the following design principles apply:

- Design for sheet flow into and across the riparian buffer area.
- If possible, the width of the riparian buffer area should be proportional to the watershed area, the slope of the terrain, and the velocity of the flow through the buffer.
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and to create habitat.
- Use native plants that are adapted to the site conditions (e.g., climate, soils, and hydrology). In suburban and urban settings, riparian forested buffers do not need to resemble natural ecosystems to improve water quality and habitat.

2.18 Risk Recognition

It is important to recognize the risks inherent in the assessment, design, and construction of environmental restoration projects. Such endeavors involve the interpretation of existing conditions to deduce appropriate design criteria, the application of those criteria to design, and most important, the execution of the construction phase. There are many factors that ultimately determine the success of these projects; many are beyond the influence of a designer, and compiling all of them is beyond the scope of this report. It is impossible to consider and to design for all of them, but it is important to acknowledge those factors, such as daily temperatures, amount and frequency of rainfall during and following construction, subsurface conditions, and changes in watershed characteristics, that are beyond the control of the designer.

Many restoration sites will require some post-construction maintenance, primarily because newly-planted vegetation plays a large role in channel and floodplain stability. Stream restoration projects are most vulnerable to adjustment and erosion immediately after construction, before vegetation has had a chance to become fully established. Risk of instability diminishes with each growing season. Streams and floodplains usually become self-maintaining after the second year of growth, although unusually heavy floods often cause erosion, deposition, and/or loss of vegetation in even the most stable channels and forested floodplains.

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. Factors that may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

3.0 WATERSHED ASSESSMENT RESULTS

3.1 Watershed Boundaries

The Haw Branch restoration site is located approximately four miles south of the town of Haw Branch, in Onslow County, North Carolina (Exhibit 1-1), along State Route 1230 (Haw Branch Road), in the Cape Fear River Basin. The site lies within the NCDWQ sub-basin 03-06-22 and hydrologic unit 03030007-080010.

Watershed areas for the project reaches were determined by delineating watersheds on the USGS 7.5 minute topographic quadrangle for Potters Hill. Exhibit 1.3 shows the watershed boundaries for the three project reaches (UT1, UT2, and UT3). Watershed areas are summarized in Table 3.1 below.

TABLE 3.1
Watershed Size and Land Use for the Project Reaches.
From Onslow County Soil Survey, USDA-NRCS, 1984

Reach Name	Watershed Area	Predominant Watershed Land Use
UT1	246 acres (0.38 sq. mi.)	Forest and agricultural cropland
UT2	91 acres (0.14 sq. mi.)	Agricultural cropland
UT3	174 acres (0.27 sq. mi.)	Forest

3.2 Geology

The project area is in northwestern Onslow County, which is located within the Inner Coastal Plain of North Carolina. The underlying geology of the project area consists of Bryozoan-echinoid skeletal limestone and phosphate-pebble conglomerate. These are tertiary sediments and are part of the Comfort and New Hanover member (Geologic Map of North Carolina, NC Geological Survey, 1998).

3.3 Soils

Soils at the site were determined using NRCS Soil Survey data for Onslow County (USDA 1984), along with on-site evaluations to confirm any hydric soil areas. A map depicting the boundaries of each soil type is presented in Exhibit 3.1. The map is based on NRCS soil survey data, with boundaries edited based on field-assessed hydric soil limits. Soils along the stream floodplains of the site consist primarily of the Torhunta (To) series. The Torhunta series is described as a nearly level, very poorly-drained soil on stream terraces. Permeability is moderately rapid, and available water capacity is medium. The seasonal high water table is at the surface. The Torhunta series is mapped along other stream and swamp floodplains near the project area. The Torhunta series is considered an "A" list hydric soil by the NRCS.

Small areas of the Stallings (St) and Foreston (FoA) series are also shown on the map within the project area. The Stallings series is described as a nearly level, somewhat poorly-drained soil found on uplands. Permeability is moderately rapid, with a seasonal high water table 1.5-2.5 feet below ground surface. The Foreston series is moderately well-drained and is also found on uplands. Permeability is moderately rapid, and the water table is 2.5-3.5 feet below ground surface. Neither the Stallings nor the Foreston series are considered hydric soils.

TABLE 3.2 Project Soil Types and Descriptions From Onslow County Soil Survey, USDA-NRCS, 1984			
Soil Name	**Location**	**Description**	**Hydric List**
Torhunta	Along floodplains throughout most of project area	Very poorly drained soil	A
Stallings	Nearly level interstream divides	Deep, somewhat poorly drained, moderately rapidly permeable soil	Not Listed
Foreston	High ridges and slight rises within broad flat interstream divides	Well drained, moderately rapidly permeable soil	Not Listed

On-site soils investigations were performed during October 2004 to determine the accuracy of NRCS soil mapping, to confirm hydric soil areas, and to conduct hydraulic conductivity measurements. Soil profiles were examined at locations across the project site to determine the boundaries of hydric soil units. Hydric soil boundaries were located using sub-meter accuracy Global Positioning System (GPS) equipment. Soils within these areas were confirmed hydric, generally with a depleted matrix (10YR 4/1) below a dark surface (10YR 2/1), or a thick dark surface (10YR 2/1). These descriptions match closely with the Torhunta series description provided in the Onslow County Soil Survey.

3.4 Land Use

All creeks within the Haw Branch restoration project drain surrounding agricultural cropland, forested, and isolated residential areas (impervious surface < 5 percent). Within the project area, current land uses consist entirely of row crop agriculture and forestry. The predominant land uses for each project watershed are summarized in Table 3.1.

The project site is located in rural Onslow County and no changes in local land use are anticipated in the foreseeable future.

3.5 Habitat Descriptions

The habitat within and adjacent to the proposed project area primarily consists of agricultural cropland (cleared land) and degraded, small stream swamp communities (wooded areas). A general description of the agricultural cropland and degraded small stream swamp communities follows.

Agricultural Cropland

This community is the predominant community, which includes over 95% of the project site. A corn / soybean rotation is typically planted within these field areas, and crops are planted to within 5 to 10 feet of the ditches and channelized streams that flow through the site. The narrow buffer along ditches and streams consists primarily of herbaceous species such as Tearthumb (*Polygonum sagittatum*), Smartweed (*Polygonum sp.*), Dogfennel (*Eupatorium capillifolium*), Blackberry (*Rubus sp.),* Hempweed (*Mikania scandens*), and Giant Cane (*Arundinaria gigantea*).

Degraded Small Stream Swamp Community

This ecological community is found in the wooded valleys of the site, where the channelized streams exit the woodlands and flow into the agricultural cropland. Historically, these areas likely functioned as small stream swamp communities as described by Schafele and Weakley (1990), with vegetative communities typical of these systems. These areas have been impacted in recent times by timber harvest and channelization of the streams through the systems. Stream channels are straight, "U" shaped, and have spoil piles along the tops of the banks, all evidence of past channelization. As a result, wetland hydrology has been lost in most areas adjacent to the channels. The dominant species in this community include sweetbay (*Magnolia virginiana*), water oak (*Quercus nigra*), maple (*Acer rubrum*), pine (*Pinus sp.*), giant cane (*Arundinaria gigantea*), coastal doghobble (*Leucothoe axillaris*), grapevine (*Vitus sp.*), and greenbrier (*Smilax sp.*).

3.6 Endangered/Threatened Species

Some populations of plants and animals are declining either as a result of natural forces or their difficulty competing with humans for resources. Plants and animals with a federal classification of Endangered (E), Threatened (T), Proposed Endangered (PE), and Proposed Threatened (PT) are protected under the provisions of Section 7 and Section 9 of the Endangered Species Act of 1973. Federally-classified species listed for Onslow County, and any likely impacts to these species as a result of the proposed project construction, are discussed in the following sections.

Species that the North Carolina Natural Heritage Program (NHP) lists under federal protection for Onslow County as of November 3, 2004, are listed in Table 3.3. A brief description of the characteristics and habitat requirements of these species follows the table, along with a conclusion regarding potential project impact.

TABLE 3.3
Species Under Federal Protection and Species of Concern in Onslow County

Family	Scientific Name	Common Name	Federal Status	Date Listed	State Status	Habitat Present / Biological Conclusion
Vertebrates						
Alligatoridae	*Alligator mississippiensis*	American alligator	T (S/A)	6-4-1987	T	No / No Effect (S/A)
Accipitridae	*Haliaeetus leucocephalus*	Bald eagle	T	08-11-1995 (originally E 04-11-1967) PD 07-06-1999	T	No /No Effect
Cheloniidae	*Chelonia mydas*	Green sea turtle	T	7-28-1978	T	No /No Effect
Cheloniidae	*Caretta caretta*	Loggerhead sea turtle	T	7-28-1978	T	No /No Effect
Charadriidae	*Charadrius melodus*	Piping plover	T	12-11-1985	T	No /No Effect
Felidae	*Puma concolor couguar*	Eastern cougar	E	6-4-1973	E	No /No Effect

Dermochelyidae	*Dermochelys coriacea*	Leatherback sea turtle	E	6-2-1970	E	No /No Effect
Picidae	*Picoides borealis*	Red-cockaded woodpecker	E	10-13-1970	E	No /No Effect
Acipenseridae	*Acipenser brevirostrum*	Shortnose sturgeon	E	3-11-1967	E	No /No Effect
Trichechidae	*Trichechus manatus*	West Indian Manatee	E	3-11-1967	E	No /No Effect
Vascular Plants						
Amaranthaceae	*Amaranthus pumilus*	Seabeach amaranth	T	4-7-1993	T	No /No Effect
Cyperaceae	*Carex lutea*	Golden sedge	E	1-23-2002	E	No /No Effect
Primulaceae	*Lysimachia asperulaefolia*	Rough-leaved loosestrife	E	6-12-1987	E	No /No Effect
Ranunculaceae	*Thalictrum cooleyi*	Cooley's Meadowrue	E	2-7-1989	E	No/ No Effect

Notes:

E	An Endangered species is one whose continued existence as a viable component of the state's flora or fauna is determined to be in jeopardy.
T	Threatened
PE	Proposed Endangered
PT	Proposed Threatened
PD	These species have been proposed for delisting from the current status.
FSC	Federal Species of Concern
S/A	Threatened due to similar appearance
SC	A Special Concern species is one that requires monitoring but may be taken or collected and sold under regulations adopted under the provisions of Article 25 of Chapter 113 of the General Statutes (animals) and the Plant Protection and Conservation Act (plants).
SR	A Significantly Rare species is not listed as "E," "T," or "SC," but which exists in the state in small numbers and has been determined to need monitoring.

3.6.1.1 Vertebrates

American Alligator

Alligators are large, lizard-like reptiles with broadly rounded snouts. Adults are 6 to 12 feet long and can reach lengths of 15 feet or more. They are blackish in appearance, but have pale crossbands on the back and vertical markings on the sides. Alligators inhabit rivers, swamps, estuaries, lakes, and marshes throughout the southeastern United States, from North Carolina to Texas.

Sightings of alligators have been recorded along the Northeast Cape Fear River, upstream and downstream of the project area.

A Biological Conclusion is not required, since Threatened Due to Similarity of Appearance [T (S/A)] species are not afforded full protection under the ESA; however, there is no suitable habitat present within the project boundaries, and the project is not expected to have any impact on this species.

Bald Eagle

Bald eagles are large raptors, 32 to 43 inches long, with a white head, white tail, yellow bill, yellow eyes, and yellow feet. The lower section of the leg has no feathers. Wingspread is about seven feet. The characteristic plumage of adults is dark brown to black, with young birds completely dark brown. Juveniles have a dark bill, pale markings on the belly, tail, and under the wings and do not develop the white head and tail until five to six years old.

Bald eagles in the Southeast frequently build their nests in the transition zone between forest and marsh or open water. Nests are cone-shaped, six to eight feet from top to bottom, and six feet or more in diameter. They are typically constructed of sticks and lined with a combination of leaves, grasses, and Spanish moss. Nests are built in dominant live pines or cypress trees that provide a good view and clear flight path, usually less than 0.5 miles from open water. Winter roosts are usually in dominant trees, similar to nesting trees, but may be somewhat farther from water. In North Carolina, nest building takes place in December and January, with egg laying (clutch of one to three eggs) in February and hatching in March. Bald eagles are opportunistic feeders, consuming a variety of living prey and carrion. Up to 80% of their diet is fish, which is self-caught, scavenged, or robbed from osprey. They may also take various small mammals and birds, especially those weakened by injury or disease.

Potential habitat for the bald eagle does not exist in the study area. The site does not provide suitable nesting areas less than 2 miles from open water. In addition, a search of the NHP database, conducted on August 16, 2004, found no occurrences of the bald eagle within the vicinity of the proposed project; therefore the proposed project is not expected to have an impact on this species.

Green Sea Turtle

The green sea turtle grows to a maximum size of about 4 feet (1.2 meters) and a weight of 440 pounds (200 kilograms). It has a heart-shaped shell, small head, and single-clawed flippers. Color is variable. Hatchlings generally have a black carapace, white plastron, and white margins on the shell and limbs. The adult carapace is smooth, keelless, and light to dark brown with dark mottling; the plastron is whitish to light yellow. Adult heads are light brown with yellow markings. Identifying characteristics include four costal plates, none of which borders the nuchal shield, no jagged marginals and only one pair of prefontals between the eyes. Adult green turtles feed largely on marine algae and grasses in shallow water areas. They may also consume small mollusks, sponges, crustaceans, and jellyfish.

The study area does not support habitat (beaches) that could be utilized for nesting by the green sea turtle. A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of the green sea turtle in the study area. Construction of the proposed project will not result in any impacts to the green sea turtle.

Loggerhead sea turtle

The loggerhead is characterized by a large head with blunt jaws. The carapace and flippers are a reddish-brown color; the plastron is yellow. The carapace has five or more costals, with the first touching the nuchal. There are three large, inframarginal scutes on the bridges between the plastron and carapace. Adults grow to an average weight of about 200 pounds (91 kilograms), although some specimens may occasionally reach 1,000 pounds (454 kilograms). The species feeds on mollusks, crustaceans, fish, and other marine animals.

No areas (beaches) that could function as potential nesting sites for the loggerhead sea turtle are found in the study area. A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of this species in the vicinity of the proposed project. The construction of the proposed project will not affect the loggerhead sea turtle.

Piping Plover

The piping plover is a small, stocky shorebird resembling a sandpiper. The adults weigh 1.5 to 2 ounces (42.5 to 56.6 grams); they have a length of 7 inches (17.8 centimeters) and a wingspread of 15 inches (38.1 centimeters). Both sexes are similar in size and color; upper parts are pale brownish, underparts are white. A black band across the forehead over the eye and a black ring around the base of the neck are distinguishing marks in adults during the summer, but are obscure during the winter.

The bird's call is a plaintive "peep-lo" whistle. Like other plovers, it runs in short starts and stops. The piping plover eats worms, fly larvae, beetles, crustaceans, mollusks, and other invertebrates that are plucked from the sand. Chicks begin feeding on smaller sizes of these same foods shortly after they hatch.

Piping plovers nest along the sandy beaches of the Atlantic Coast, the gravelly shorelines of the Great Lakes, and on river sandbars and alkali wetlands throughout the Great Plains region. They prefer to nest in sparsely-vegetated areas that are slightly raised in elevation (like a beach berm). Piping plover breeding territories generally include a feeding area, such as a dune pond or slough, near the lakeshore or ocean edge. These birds are primarily coastal during the winter, preferring areas with expansive sand or mudflats for feeding, in close proximity to sandy beaches for roosting.

The primary threats to the piping plover are habitat modification and destruction, and human disturbance to nesting adults and flightless chicks. Recreational and commercial development and dune stabilization have contributed greatly to the loss of piping plover breeding habitat along the Atlantic Coast. Wintering habitat has probably also been lost to coastal development and inlet and shoreline stabilization.

Recreational pressure and pedestrian and vehicular traffic can seriously affect breeding success. Over the past 40 years, the number of vehicles and people on beaches has increased significantly. Human presence can indirectly lower productivity by disrupting territorial establishment, courtship, egg laying, and incubation activities. Foot traffic, dune buggies and other vehicles, and other activities, including raking of beaches for trash, can directly crush eggs or chicks, and the ruts left by off-road vehicles can trap flightless chicks.

Suitable habitat for the piping plover is not found in the study area. Communities found in the study area do not contain the open sand flats that this species utilizes as nesting habitats. A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of the piping plover in the vicinity of the study area. Construction of the proposed project will not result in any impacts to the piping plover.

Eastern Cougar

The eastern cougar is a large, long-tailed cat measuring up to 7.5 feet in total length and 150 pounds at adulthood. Its fur is light yellowish to tawny brown, with dull white underparts. The sides of the muzzle, the back of the ears, and the tip of the tail are dark brown to black. Paw prints are up to four inches; the claws are retractable and therefore are usually not seen in paw prints. Cubs are light brown with irregular brownish to black spots and a ringed tail.

Preferred habitat for the eastern cougar includes remote areas with dense vegetation and rocky crevices, such as hilly woodlands, mountains, gorges, and southern swamps with large deer populations. It often uses caves as temporary shelter. The preferred food is deer, but cougars will prey upon rabbits, rodents, turkey, squirrel, beaver, fish, birds, and arthropods. An adult may require a 25-mile area for range.

In North Carolina, the eastern cougar is thought to occur in remote areas of the Coastal Plain and mountains. Within the past couple of decades, undocumented sightings have been reported from the Great Smoky Mountains National Park, Pisgah and Nantahala National Forests, the Blue Ridge Parkway, northern portions of the Uwharrie National Forest, and from southeastern counties. The USFWS, United States Forest Service (USFS), and the National Park Service (NPS) have conducted tracking surveys and constructed scent stations, but have found no hard evidence of eastern cougars to date.

Potential habitat for the eastern cougar does not exist in the study area. The site does not provide the remote areas preferred by the cougar. In addition, a search of the NHP database, conducted on August 16, 2004, found no occurrences of the eastern cougar within the vicinity of the proposed project; therefore the proposed project is not expected to have an impact on this species.

Leatherback Sea Turtle

Largest of all turtles, the leatherback sea turtle is recognized by its covering of ridged, leathery skin rather than a hard shell. The back, head, and neck are dark brown or black, with a few white or yellow blotches. The lower shell is whitish and ridged. The flippers are paddle-like, without claws. The average adult length is 61 inches; the average weight is 640 to 1,300 pounds.

The study area does not support habitat (beaches) that could be utilized for nesting by the leatherback sea turtle. A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of the leatherback sea turtle in the study area or project vicinity. Construction of the proposed project will not result in any impacts to the leatherback sea turtle.

Red-Cockaded Woodpecker

The red-cockaded woodpecker once occurred from New Jersey to southern Florida and west to eastern Texas. It occurred inland in Kentucky, Tennessee, Arkansas, Oklahoma, and Missouri. The red-cockaded woodpecker is now found only in coastal states of its historic range and inland in southeastern Oklahoma and southern Arkansas. In North Carolina, moderate populations occur in the Sand Hills and southern Coastal Plain. The few populations found in the Piedmont and northern Coastal Plain are believed to be relics of former populations.

The red-cockaded woodpecker is approximately eight inches long with a wingspan of 14 inches. Plumage includes black and white horizontal stripes on its back, with white cheeks and under parts. Its flanks are streaked black. The cap and stripe on the throat and side of neck are black, with males having a small, red spot on each side of the cap. Eggs are laid from April through June. Maximum clutch size is seven eggs, with an average of three to five.

Red-cockaded woodpeckers are found in open pine stands that are between 80 and 120 years old. Longleaf pine stands are most commonly utilized. Dense stands are avoided. A forested stand must contain at least 50% pine, lack a thick understory, and be contiguous with other stands to be appropriate habitat for the red-cockaded woodpecker. These birds forage in pine and pine hardwood stands, with preference given to pine trees that are 10 inches or larger in diameter. The foraging range of the red-cockaded woodpecker is up to 500 acres. The acreage must be contiguous with suitable nesting sites. While other woodpeckers bore out cavities in dead trees where the wood is rotten and soft, the red-cockaded woodpecker alone excavates cavities exclusively in living pine trees. The older pines favored by the red-cockaded woodpecker often suffer from a fungus called red heart disease which attacks the center of the trunk, causing the inner wood to become soft. Cavities generally take one to three years to excavate. The red-cockaded woodpecker feeds mainly on beetles, ants, roaches, caterpillars, wood-boring insects and spiders, and occasionally fruits and berries.

Mature pinewoods and pocosin species are not prevalent in the immediate area of the proposed project. A search of the NHP database, conducted on August 16, 2004, found no occurrences of the red-cockaded woodpecker in the project vicinity. It is concluded that the project will not impact this endangered species.

Shortnose Sturgeon

The shortnosed sturgeon is a large fish with a heterocercal tail, bluntly V-shaped snout (not upturned at tip), large fleshy barbels, ventral mouth, and large, bony scutes on the head, back, and sides (paler than the adjacent skin). Its anal fin origin is beneath the dorsal fin origin. The shortnosed sturgeon is dark brown to black above, light brown to yellow on the lower sides, and white below. It grows to 109 centimeters.

The shortnosed sturgeon's habitat occurs in rivers, estuaries, and the sea along the Atlantic coast, from southern Canada to northeastern Florida (Wilk and Silverman, 1976), and it is usually most abundant in estuaries. When at sea, it is generally within a few miles of the shore. Shortnose sturgeons in southern waters tend to exhibit limited distributions during the summer within habitats at the saltwater/freshwater interface; therefore, estuarine habitat at the salt/fresh interface constitutes critical habitat in southern river systems.

Spawning generally occurs well upriver from summer foraging and nursery grounds. Laboratory studies indicate that newly-hatched larvae go through a 2-day downstream migration to riverine habitats, where they remain for approximately one year. A resumption of downstream movement resumes the following spring, at which time yearlings appear in samples of estuarine habitats, completing downstream migration from spawning areas. The timing of downstream movements likely varies among population segments with latitudinal variation in temperature regimes.

Juveniles are found in the saltwater/freshwater interface of a river in deep, cool channels with sand-silt substrate. They occur in the lower salinity waters of this interface in the summer (Pottle and Dadswell, 1979).

Critical habitats for the shortnose sturgeon should be designated and protected from point source and non-point source pollution, introduced species, and other anthropogenic actions in compliance with the Endangered Species Act of 1973.

A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of this species in the vicinity of the proposed project. Furthermore, habitat does not exist within small, channelized ditches in the project area. It is concluded that the project will not impact this endangered species.

West Indian Manatee

The West Indian manatee is a large, gray or brown, aquatic mammal. Adults average about 10 feet (3 meters) long and weigh 1,000 pounds (454 kilograms). They have no hind limbs, and their forelimbs are modified as flippers. Manatee tails are flattened horizontally and rounded. Their body is covered with sparse hairs and their muzzles with stiff whiskers. Sexes are distinguished by the position of the genital openings and the presence or absence of mammary glands. Manatees will consume any aquatic vegetation available to them and sometimes even shoreline vegetation. Although primarily herbivorous, they will occasionally feed on fish. Manatees may spend about 5 hours a day feeding and may consume 4 to 9 percent of their body weight in a day.

During summer months, they may migrate as far north as coastal Virginia, on the east coast, and as far south as the Louisiana coast, on the Gulf of Mexico. Manatees inhabit both salt and fresh water of sufficient depth [5 to 20 feet (1.5 to 6 meters)] throughout their range. They may be encountered in canals, rivers, estuarine habitats, saltwater bays, and on occasion, they have been observed as much as 3.7 miles (6 kilometers) off the Florida Gulf coast. Between October and April, Florida manatees concentrate in areas of warmer water. When water temperatures drop below about 21 to 22 degrees Centigrade, they migrate to south Florida or form large aggregations in natural springs and industrial outfalls. Severe cold fronts have been known to kill manatees when the animals did not have access to warm water refuges. During warmer months they appear to choose areas based on an adequate food supply, water depth, and proximity to fresh water.

The study area does not support habitat that could be used by the West Indian manatee. A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of this species in the study area or project vicinity. Construction of the proposed project will not result in any impacts to the West Indian manatee.

3.6.1.2 Vascular Plants

Seabeach Amaranth

Seabeach amaranth is an annual plant found, as its name implies, on Atlantic Ocean beaches. The stems are fleshy and pink-red or reddish, with small, rounded leaves that are 0.5 to 1 inch (1.3 to 2.5 centimeters) in diameter. The leaves, normally a spinach-green color, are clustered toward the tip of the stem and have a small notch at the rounded tip. Flowers and fruits are relatively inconspicuous, borne in clusters along the stems. Germination occurs over a relatively long period of time, generally from April to July. Upon germinating, this plant initially forms a small, unbranched sprig, but soon begins to branch profusely into a clump. This clump often reaches a foot in diameter and consists of 5 to 20 branches. Occasionally, a clump may get as large as 3 feet (0.9 meter) or more across, with 100 or more branches.

The proposed project will not impact any primary dune habitats and therefore, will not impact any suitable habitat for this species. A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no records of this species in the project vicinity. Project construction will not impact the seabeach amaranth.

Golden Sedge

Golden sedge grows in small to large clumps. The three to seven grass-like leaves are mostly found at the base of the plant, are 2 to 11 inches (5 to 28 centimeters) long, are much shorter than the flowering stem, and are 0.7 to 1.5 inches (1.8 to 3.8 centimeters) wide. Flower spikes develop in early and mid-April. Fruits mature by mid-May, with most or all fruits fallen by late June. Leaves and naked flowering stems persist through the summer. This plant appears to be dependent on occasional to frequent fire associated with adjacent savannas. It grows in partially-wooded ecotones, between longleaf pine savannas and non-riverine tree swamps. Associates include other rare plants, such as Cooley's meadowrue (*Thalictrum cooleyi*), pineland plantain (*Plantago sparsiflora*), and Thorne's beakrush (*Rhynchospora thornei*).

A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found that a current occurrence of this species is known to exist in the Potters Hill Quadrangle; however, suitable habitat for golden sedge is not present within the project area. Longleaf pine savannas and non-riverine tree swamps do not currently exist on the property. It can be concluded that the project will not impact this species.

Rough-leaved loosestrife

The slender stems of this perennial herb grow from a rhizome and reach heights of 1 to 2 feet (0.3 to 0.6 meter). Whorls of 3 to 4 leaves encircle the stem at intervals beneath the showy yellow flowers. Flowering occurs from mid-May through June, with fruits present from July through October.

Rough-leaved loosestrife is a species endemic to the coastal plain and sandhills of North Carolina and South Carolina. It is currently known from 35 populations in North Carolina and one in South Carolina. North Carolina's extant populations are in the following counties: Brunswick (8 populations); Pender (1 population); Bladen (1 population); Carteret (8 populations); Scotland (3 populations); Cumberland (5 populations); Onslow (3 populations); Hoke (5 populations); and Pamlico (1 population). Historically, rough-leaved loosestrife was known from 15 other sites in Brunswick, Pender, Cumberland, Onslow, Beaufort, Columbus, Pamlico, and Richmond Counties, North Carolina, and Darlington County, South Carolina. Most of the populations are small, both in area covered and in number of stems.

This species generally occurs in the ecotones, or edges, between longleaf pine uplands and pond pine pocosins, on moist to seasonally-saturated sands, and on shallow, organic soils overlaying sand. Rough-leaved loosestrife has also been found on deep peat in the low shrub community of large Carolina bays. The grass-shrub ecotone, where rough-leaved loosestrife is found, is fire-maintained, as are the adjacent plant communities (longleaf pine-scrub oak, savanna, flatwoods, and pocosin). Suppression of naturally-occurring fire in these ecotones results in shrubs increasing in density and height and expanding to eliminate the open edges required by this plant. Fire suppression, drainage, and to a lesser extent, residential and industrial development have altered and eliminated habitat for this species and continue to be the most significant threats to the species' continued existence.

Suitable habitat for rough-leaved loosestrife is not present within the project area. Longleaf pine uplands and ecotones between longleaf pine uplands and pond pine pocosins are not present within the project area. A search of the NHP database, conducted on August 16, 2004, found no occurrences of rough-leaved loosestrife within the project area. It can be concluded that the project will not impact this species.

Cooley's Meadowrue

Cooley's meadowrue is a perennial herb that grows from an underground rhizome. Its stems are usually 3 feet (0.9 meter) in height, but sometimes grow as high as 6 feet (1.8 meters) on recently-burned sites. Under ideal conditions, in full sun, these stems are erect; in shade they are lax and may trail along the ground or lean on other plants. The species' green leaflets are lance-shaped and less than 0.8 inches (2 centimeters) long. Both basal and stem leaves are present on the plant, and the leaves are usually in groups of threes. Each plant is unisexual, and the male to female ratio is 3 to 1. The flowers have no petals. The sepals on the male plants are pale yellow to white; there are numerous stamens, and the filaments are pale lavender. Female plants have green sepals, and their short-stalked, ribbed carpels develop into narrowly ellipsoidal achemes. Cooley's meadowrue flowers in mid to late June; its fruits mature in August or September and remain on the plant into October. If the plants grow in partial shade instead of full sun, their flowering may be delayed by as much as 2 weeks.

Eleven populations of this plant remain in Pender, Onslow, Brunswick, and Columbus counties in North Carolina. All of the plant sites are on privately-owned land. The remaining North Carolina populations are probably fragments of three larger populations. All 6 sites in Onslow and Pender counties are within a 4-mile (6.5-kilometer) radius; the 3 sites in Columbus County are within a 2.5-mile (4-kilometer) radius; and the 2 sites in Brunswick County are within a 1-mile (1.6-kilometer) radius.

Cooley's meadowrue occurs in sunny, moist to wet bogs. Within savannas it can be found along forest edges and clearings, over calcareous clays, and within the ecotones between wet savannas and non-riverine swamp forests. It grows along fireplow lines, roadside ditches, woodland clearings, and powerline rights-of-way, and it requires some type of disturbance to maintain its open habitat. This species is not tolerant of drainage, excessive disturbance, or agricultural activities. Plants often found growing with the meadowrue include tulip poplar growing with cypress and/or Atlantic white cedar. The plant grows in soils that are sandy loams with a basic pH.

A search of the NHP database of rare species and unique habitats, conducted on August 16, 2004, found no occurrences of this species in the vicinity of the proposed project. The site is drained and currently under agricultural row crop production. Construction of the proposed project will not result in any impacts to the Cooley's meadowrue.

3.7 Cultural Resources

A letter was sent to the North Carolina State Historic Preservation Office (SHPO) on August 18, 2004, requesting a review for the potential of cultural resources in the vicinity of the Haw Branch restoration site. A response was received on October 8, 2004, indicating that the SHPO had reviewed the proposed project and was not aware of any archeological resources that would be affected by the project. A house of historical and architectural significance (ON247) was noted in the SHPO response; however, the house is located more than one mile from the proposed project site and will not be affected in any way by the proposed project. A copy of the SHPO correspondence is included in Appendix 1.

3.8 Potentially Hazardous Environmental Sites

Buck Engineering obtained an EDR Transaction Screen Map Report, dated August 19, 2004, that identifies and maps real or potential hazardous environmental sites within the distance required by the American Society of Testing and Materials (ASTM) Transaction Screen Process (E 1528). A copy of the report with an overview map is included in Appendix 1. The overall environmental risk for this site was determined to be low. Environmental sites, including Superfund (National Priorities List, NPL); hazardous waste treatment, storage, or disposal facilities; the Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS); suspect state hazardous waste, solid waste, or landfill facilities; or leaking underground storage tanks were not identified by the report in the proposed project area. During field data collection, there was no evidence of these sites in the proposed project vicinity, and conversations with landowners did not reveal any further knowledge of hazardous environmental sites in the area.

3.9 Potential Constraints

Buck Engineering assessed the Haw Branch project site for potential fatal flaws and site constraints. No constraints or fatal flaws have been identified during the production of the proposed restoration plan.

3.9.1 Property Ownership and Boundary

EBXN-I has entered into an Agreement of Sale for the acquisition of an easement with the landowner for the Haw Branch Site. The Agreement allows EBXN-I to proceed with the restoration and to restrict the land use through a permanent conservation easement.

3.9.2 Hydrologic Trespass

The topography of the site supports the design without creating the potential for hydrologic trespass outside of the project area. The site is not mapped within a FEMA-regulated floodplain.

3.9.3 Site Access

EBXN-I has legal site access to the site through the conservation easement agreement with the landowner. Access to the site for construction and post-restoration monitoring has been provided.

3.9.4 Utilities

No utility lines or utility easements have been identified for the project area, and therefore, utilities are not considered to restrict the proposed work on the site.

3.9.5 Threatened and Endangered Species

Rare, threatened and endangered species occurrences were examined as part of the existing conditions survey and were discussed earlier. It is anticipated that no rare, threatened or endangered species will be affected by this project, as discussed in Section 3.6.

3.9.6 Cultural Resources

No known cultural or archaeological sites are recorded within the property boundary. It is anticipated that this project will have no impact on such sites.

3.9.7 Farm Operations

The Haw Branch Site is actively used for agricultural and forestry purposes; therefore, the project must not interfere with the operational needs of the farm. The final project design will incorporate a stream crossing, fencing, and field access.

3.9.8 Soils

Soils have been investigated, and no constraints or fatal flaws were identified. Soils within proposed wetland restoration areas have been confirmed hydric by on-site investigations.

4.0 WETLAND ASSESSMENT RESULTS

4.1 Wetland Impacts

Much of the project area once existed as a wetland ecosystem, as evidenced by hydric soils across the bottomland fields of the site. Wetland areas that once existed on the site were drained and manipulated to promote agricultural uses. Approximately 10,000 feet of drainage ditches and channelized streams were constructed within the project area, to improve surface and subsurface drainage and to decrease flooding. As a result, the open field areas of the site have been designated "prior-converted," or PC, by the NRCS.

4.2 Jurisdictional Wetland Findings

On-site surveys of the project area were conducted during October and November of 2004 to determine the extent of COE jurisdiction in the project area. No jurisdictional wetland areas were identified within the project limits. All open field areas of the site that contain hydric soils have been designated "prior-converted," or PC, by the NRCS.

One area of drained wetlands was identified at the upstream end of UT1. This area contains wetland vegetation, including sweetbay (*Magnolia virginiana*), water oak (*Quercus nigra*), maple (*Acer rubrum*), pine (*Pinus sp.*), giant cane (*Arundinaria gigantea*), coastal doghobble (*Leucothoe axillaris*), grapevine (*Vitus sp.*), and greenbrier (*Smilax sp.*); however, the stream channel through the area has been ditched and channelized to a depth of approximately 4 feet. Channelization has resulted in a loss of wetland hydrology in areas near the stream, due to the increased drainage effect of the channel, and therefore, this area is not considered to be jurisdictional under COE guidelines.

4.3 Climatic Conditions

Onslow County has an average annual rainfall of 58 inches (NRCS WETS Table NC4144 for Hoffman Forest). In much of the Coastal Plain of North Carolina, approximately 36 inches of water are lost to evapotranspiration in an average year (Evans and Skaggs, 1985). Since average rainfall exceeds average evapotranspiration losses, the Coastal Plain experiences a moisture excess during most years. Excess water must leave a site by groundwater flow, run-off, channelized surface flow, or deep seepage (the percolation of water to confined aquifer systems). Annual losses due to deep seepage are typically less than 1 inch of water for most Coastal Plain areas and are not typically a significant pathway for loss excess water. Although groundwater flow can be significant in some systems, most excess water is lost via surface and shallow subsurface flow.

Buck Engineering collected rainfall data for the monitoring period from the nearest automated weather station, located within Hoffman State Forest, approximately 15 miles east of the project site (UCAN: 14151, COOP: 314144). Monthly precipitation amounts from January through November, 2004, are compared with Onslow County WETS table average monthly rainfall, in Table 4.1. These data indicate that over the entire year, total rainfall was within one inch of the long-term average; however, during the fall monitoring period (October through November), the project site experienced drier than average conditions. Rainfall totals for October and November were 2.83 inches below the long-term average.

The growing season for Onslow County is 243 days long, as reported by the NRCS WETS Tables for NC4144. The growing season begins on March 18 and ends on November 16.

TABLE 4.1.
Comparison between monthly rainfall amounts for the project site and the long-term average.

Month-Year	Observed Monthly Precipitation (in)	WETS Table Average Monthly Precipitation (in)	Deviation of Observed from Average
Jan-04	1.8	5.17	-3.37
Feb-04	5.47	4.16	1.31
Mar-04	2.61	4.64	-2.03
Apr-04	3.23	3.15	0.08
May-04	6.25	3.67	2.58
Jun-04	6.28	4.95	1.33
Jul-04	8.45	7.22	1.23
Aug-04	11.86	7.55	4.31
Sep-04	3.45	6.77	-3.32
Oct-04	1.32	3.7	-2.38
Nov-04	3.22	3.67	-0.45
Sum	**53.94**	**54.65**	**-0.71**

4.4 Hydric Soils

Soils in all areas identified for wetland restoration were confirmed to be hydric by a trained professional. Hydric soil boundaries were identified by inspection of soil profiles, and boundaries were located with sub-meter accuracy GPS equipment. Soils within the wetland restoration areas of the project site are mapped as the Torhunta series by the NRCS. The Torhunta series is described as a nearly level, very poorly-drained soil on stream terraces. Permeability is moderately rapid, and available water capacity is medium. The seasonal high water table is at the surface. The Torhunta series is mapped along other stream and swamp floodplains near the project area. A description of other non-hydric soils on the project site is provided in Section 3.3, and a soils map for the site is provided as Exhibit 3.1.

4.5 Water Table Hydrology

A hydrography map for the site, shown in Exhibit 4.1, demonstrates the amount of ditching and channelization that has been performed on the site. UT1 begins in an existing wetland area directly north of the project site, while UT2 begins in agricultural fields to the northeast of the project area. UT3 begins within wooded areas to the east of the project site. During conversion of the site, stream channels and wetland systems through the site were channelized to improve drainage. Additional field ditches were constructed to further improve drainage.

Buck Engineering collected water table data for the site from 3 automated and 1 manual groundwater wells from October 2004 through November 2004. The 3 automated wells were installed in open field areas that are typical of average conditions across the site. The 1 manual well was installed in a small, wet depression within one of the farm fields to evaluate an area of noticeably poor drainage. All of the wells are located within the area proposed for wetland restoration. The wells (Infinities USA pressure transducer units) were installed to a depth of 40 inches, and automated wells were programmed to record water table levels every 12 hours.

The data from the 4 wells on the site are provided in Appendix 2. The majority of the data were collected during the dormant season, as the growing season for Onslow County ends on November 16. Precipitation data collected during the monitoring period indicate that less than average rainfall occurred. Although data were collected during the wet season, the data indicate that wetland hydrology is no longer present across the site. Of the 3 automated wells, the number of consecutive days meeting wetland hydrologic criteria during the monitoring period ranged from 1 to 4. To meet minimum wetland hydrology in Onslow County, 12 consecutive days (5% of the growing season) would be required. Data collected from the manual well location indicate much wetter conditions than the other 3 well locations, as a result of the manual well's location in a small field depression, where rainwater ponds for extensive periods due to poor surface drainage. Data from this well location were used to evaluate the effect that increased surface storage (a restoration technique) would have across the site.

Table 4.2
Site Wetland Hydrologic Parameters.

Gauge #	Lowest Recorded Water Table Depth (inches)	Highest Recorded Water Table Depth (inches)	Longest Consecutive Wet Period[1] During Growing Season (days)	Number of Wet Periods[1] During Growing Season
A1	-39	0	1	1
A2	-29	0	4	3
M3	-2.2	-1.2	----[2]	----[2]
A4	-30	0	2	2

1 A wet period is defined as the number of separate occurrences when the water table rises to within 12 inches of the ground surface.
2 Not enough data collected to evaluate wet period for the manual well.

4.6 Hydrologic Modeling

To further investigate the current hydrologic status of the site and provide a means for evaluating proposed restoration plans, Buck Engineering developed hydrologic models to simulate site hydrology. DRAINMOD (version 5.1) was used to develop hydrologic simulation models to represent conditions at a variety of locations across the proposed restoration area. DRAINMOD was identified as an approved hydrologic tool for assessing wetland hydrology by the NRCS (1997). For more information on DRAINMOD and its application to high water table soils, the reader is referred to Skaggs (1980).

Model parameters were selected based on field measurements and professional judgment of site conditions. Rainfall and air temperature information were collected from the nearest automated weather station located in Hoffmann Forest near Maysville, approximately 15 miles east of the project site (UCAN: 14151,COOP: 314144). Since the data from the Hoffman Forest station had data missing from October 1998 and January 1999, the weather station at Trenton, NC (UCAN: 14378, COOP: 318706) was used for these months. The weather data from August 2004 to present were collected from the stations at the Kenansville and Jacksonville, NC airports, due to a malfunction with the station in Hofmann Forest.

Measured field parameters were entered into the model and initial model simulations were compared with observed data collected from the monitoring wells. To calibrate the model, parameters not measured in the field were adjusted within the limits typically encountered under similar soil and geomorphic conditions until model simulations most closely matched observed well data.

Trends in the observed data were well represented by the model simulations, however, it should be noted that a limited amount of observed data were available for comparison. It is important to note that DRAINMOD uses simplifying assumptions in the estimation of water table depths. When applied to a site such as Haw Branch with complex hydrologic processes, the model can be used to assess overall trends and relationships but is unlikely to offer exact predictions of water table hydrology.

DRAINMOD computes daily water balance information and outputs summaries that describe the loss pathways for rainfall over the model simulation period. Table 4.3 summarizes the average annual amount of rainfall, infiltration, drainage, runoff, and evapotranspiration estimated for the existing condition of the Haw Branch restoration project area, based on 58 year simulations. The average amounts for the simulated areas, as well as the minimum and maximum values, are presented in the table. Infiltration represents the amount of the water that percolates into the soil and is lost via drainage or runoff. Drainage is the loss of infiltrated water that travels through the soil profile and is discharged to the drainage ditches or to underlying aquifers. Runoff is water that flows overland and reaches the drainage ditches before infiltration. Evapotranspiration is water that is lost by the direct evaporation of water from the soil or through the transpiration of plants.

From the data provided, it is clear that a significant amount of the rainfall that falls on the site is lost to evapotranspiration, which is typical for farm fields in the North Carolina Coastal Plain. Drainage is also a significant loss pathway for water under the existing farm conditions. Restoration of the site will involve raising the bottom elevation of the adjacent stream and increasing the amount of surface storage available to pond water. In this way, the respective amounts of drainage and runoff are decreased and the excess water allows the water table to remain higher throughout the year, thus restoring wetland hydrology.

TABLE 4.3
Water balance data for the existing conditions of the project site.

Hydrologic Parameter	Annual Amount over 58 Year Simulation Period (cm of water)	Annual Amount over 58 Year Simulation Period (% of average rainfall)
Precipitation	144.7 (*93.0 to 217.5*)	100
Drainage	36.7 (*16.4 to55.5*)	25.4 (*11.3 to38.4*)
Run-off	30.7 (*2.6 to 102.2*)	21.2 (*1.8 to 70.6*)
Evapotranspiration	77.4 (*65.7 to95.8*)	53.4 (*45.4 to 66.2*)

4.7 Wetland Reference Site

An existing wetland and stream system that is representative of the system to be restored on the Haw Branch site was identified near the project site. This site falls within the same climatic, physiographic, and ecological region as the restoration site.

The reference site is located within the Hoffman State Forest, approximately 15 miles east of the Haw Branch restoration site. The area was originally identified as a reference site by the North Carolina Forestry Foundation, Inc., and has been used for the past five years as a reference site for their Hoffman Forest Wetland Mitigation Bank project. The reference site is an example of a "Coastal Plain small stream swamp," as described by Schafale and Weakley (1990). These systems exist as the floodplains of small blackwater or brownwater streams in which separate fluvial features and associated vegetation are too small or poorly developed to distinguish. Hydrology of these systems is palustrine – intermittently, temporarily, or seasonally flooded. Flows tend to be highly variable, with floods of short duration, and periods of very low flow.

The reference site has experienced disturbances in the past, primarily due to timber harvest; however, cutting of timber occurred long ago, and a mature canopy of vegetation exists across the site, especially near the stream channel itself. It also appears that the hydrology of the site was affected little by timber harvest.

Two locations within the reference site, referred to as the Bear Prong and Wide Open sites, were chosen to serve as reference monitoring locations for the Haw Branch restoration project. Both sites are located in the southern portion of Hoffman State Forest (Exhibit 1.1). Soils, hydrology, and vegetation for each of these sites are described in the sections that follow.

4.7.1 Soils

Muckalee loam and Rains soils are the primary series mapped on the reference site. Muckalee soils are loamy, poorly drained, and positioned along stream floodplains. Muckalee soils are the dominant soil series found at the Bear Prong area of the reference site. The Rains series consists of poorly-drained, sandy clay loam soils commonly positioned along interstream divides. For the reference site, however, Rains soils are mapped along several floodplain areas of the site. The Rains series is the dominant soil series found at the Wide Open area of the reference site, and soil descriptions closely match the soils evaluated on the Haw Branch restoration site. The area is prone to frequent flooding from the adjacent stream channel.

4.7.2 Hydrology

The site classifies as a wetland, utilizing criteria identified in the USACE 1987 Wetlands Delineation Manual. These criteria include the FAC Neutral Test, oxidized root channels, and local soil survey data. Climatic conditions of the reference site are the same as those described for the project site (Section 4.3). The reference site is classified as a "Coastal Plain small stream swamp" (Schafale and Weakley, 1990). Site hydrology is controlled primarily by the small unnamed tributaries that flow through the site. Due to the shallow, un-incised condition of the streams through the site, high water table conditions are sustained across the active floodplain for prolonged periods.

Since the site has been used as a reference site for the Hoffman Forest Wetland Mitigation Bank project, water table hydrology data have been collected from the site by the North Carolina Forestry Foundation, Inc., for the past five years (2000 through 2004). A water table monitoring well (RDS WL40 logging units) was installed in both the Bear Prong and Wide Open areas. Hydrologic conditions observed at each of the two locations are summarized in Table 4.4 below.

As expected, the data indicate that the two monitored locations vary in regards to their hydrologic wetness. At the Wide Open area, hydroperiods (defined as a consecutive period of saturation within the growing season, expressed as a percentage of the growing season) ranged from 7% to 11% for the data collected. For the Bear Prong area, hydroperiods ranged from 8% to 24%. The wetter conditions documented at the Bear Prong area are expected, since Murville soils are typically quite wet when evaluated under undrained conditions. The Wide Open area has Rains soils, which are more similar to the Torhunta soils of the Haw Branch site. The hydroperiods documented for the Wide Open area are similar to those that have been collected from other, similar reference systems in the Coastal Plain.

Table 4.4
Reference Wetland Hydrologic Parameters – Hoffman Forest Reference Site.

Gauge #	Lowest Recorded Water Table Depth (inches)	Highest Recorded Water Table Depth (inches)	Longest Consecutive Wet Period[1] During Growing Season in Days (% of Growing Season)	Number of Wet Periods[1] During Growing Season
2000				
Bear Prong[2]	-24	> 0	20.5 (8%)	2
Wide Open	-40	> 0	19.5 (8%)	9
2001				
Bear Prong	-41	> 0	46 (19%)	7
Wide Open	-40	> 0	16.5 (7%)	6
2002				
Bear Prong[2]	-41	> 0	55 (23%)	2
Wide Open[2]	-40	> 0	21.5 (9%)	2
2003				
Bear Prong[2]	-19	> 0	36.5 (15%)	1
Wide Open[2]	-18	> 0	18.5 (8%)	2
2004				
Bear Prong	-37	> 0	59.5 (24%)	6
Wide Open	-29	> 0	26 (11%)	8

1 A wet period is defined as the number of separate occurrences when the water table rises to within 12 inches of the ground surface.
2 Some portions of the data during the growing season were missing.

4.7.3 Vegetation

The sub-canopy of the system is an expression of the native seed bank. Herbaceous wetland plants and immature hardwood species are found within the area utilized as a reference wetland. The reference site is comprised of greater than 50% facultative and wetter species and therefore meets the hydrophytic vegetation requirement.

Within the the Bear Prong area, the canopy vegetation community is dominated by water oak (*Quercus nigra*), red maple (*Acer rubrum*), sweetbay (*Magnolia virginiana*), blackgum (*Nyssa sylvatica*), and sweetgum (*Liquidambar styraciflua*). Understory species primarily consist of giant cane (*Arundinaria gigantea*), wax myrtle (*Morella cerifera*), red maple, American holly (*Ilex opaca*), cinnamon fern (*Osmunda cinnamomea*), fetterbush (*Lyonia lucida*), and greenbrier (*Smilax sp.*).

The Wide Open area exhibits a vegetation community similar to that of the Bear Prong area. Species within the vegetative canopy include a few loblolly pines (*Pinus taeda),* water oak, red maple, sweetbay, blackgum, and sweetgum. Understory species primarily consist of giant cane, wax myrtle, red maple, American holly, cinnamon fern, fetterbush, and greenbrier.

5.0 STREAM CORRIDOR ASSESSMENT RESULTS

5.1 Reach Identification

For analysis and design purposes, Buck Engineering divided on-site streams into three reaches. The reach locations are shown on Exhibits 1.2 and 4.1. The reaches were numbered sequentially, from north to south. UT1 begins off site, flows into the project from the north, and flows to the southern end of the project. UT2 flows into the project area from the northeast, makes a turn to the south at a culverted stream crossing, and ends at its confluence with UT1. UT3 also begins outside of the project area. It flows through a wooded area from the east to its confluence with UT1.

5.2 Site Hydrology/Hydraulics

The total current length of stream on the project site is 4,370 ft. All the reaches have been channelized in the past and are incised. All project reaches are intermittent blue-line streams on the USGS topographic map of the area as shown on Exhibit 1.2. All project reaches were determined to be perennial streams (based on a minimum score of 30 for perennial streams and presence of biological life) using the NCDWQ *Determination of the Origin of Perennial Streams* guidelines (see forms in Appendix 3).

5.2.1 Surface Water Classification

The NCDWQ designates surface water classifications for bodies of water, such as streams, rivers, and lakes, which define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply). These classifications carry with them an associated set of water quality standards to protect those uses. All surface waters in North Carolina must at least meet the standards for Class C (fishable/swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water supplies (WS). Class C waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Classifications and their associated protection rules may also be designed to protect the free-flowing nature of a stream or other special characteristics.

The small, unnamed tributaries of the project site flow into Back Swamp, which is classified by the NCDWQ as C; Sw [DWQ Index No. 18-74-26-1]. The "Sw" designation is used to denote swamp systems.

5.2.2 FEMA Designations

The Federal Emergency Management Agency Flood Insurance Rate Map (FIRM) for Onslow County, NC (Community Number 370340), indicates that there is no regulatory floodplain associated with the project site.

5.3 Geomorphic Characterization and Channel Stability Assessment

EBXN-I contracted with Matrix East to perform general topographic and planimetric surveying of the project site. Matrix East produced a DEM based on their survey data, which is used as the plan set base mapping. Buck Engineering performed a cross-section survey of the stream reaches to assess the current condition and overall stability of the channels. The following report sections summarize the survey results for all project reaches. UT1, UT2, and UT3 watersheds are shown in Exhibit 1.3. Watershed sizes were calculated at the terminus of each reach and are summarized in Table 5.1. Appendix 3 contains summaries of existing condition parameters, cross-section survey results, and bed material distribution graphs for all reaches.

Table 5.1
Watershed and Reach Summaries.

Reach	Reach Length (linear feet)	Watershed Size (acres)	NCDWQ Intermittent/Perennial Stream Form Score
UT1	3,230	250	UT1 = 33
UT2	540	64	UT2 = 30
UT3	600	192	UT3 = 34

5.3.1 UT1

UT1 is classified as a G5c stream type (Rosgen, 1994). The modified Wolman pebble count (Rosgen, 1994) is not appropriate for sand-bed streams; therefore, a bulk sampling procedure was used to characterize the bed material. The majority of the reach had an organic muck stream bottom due to the low velocity caused by backwater from blockages and high culverts. In areas where riffle flow is evident, the channel substrate was sandy. Bed material samples were collected from these areas. The samples were taken back to a lab and dry sieved to obtain a sediment size distribution. The sieve data show that UT1 has a D_{50} of 0.50-mm and a D_{84} of 3.22-mm, indicating that the dominant bed material in the stream channel is sand to very fine gravel.

UT1 is highly incised and regularly maintained in order to promote drainage of the surrounding agricultural fields. Bank height ratios ranged from 3.1 - 4.8 in the surveyed cross sections. These values fall into the highly unstable range in Rosgen's comparison of bank height ratio to vertical stability ranking. The stream displays no measurable meander geometry due to its channelized condition. These conditions generally lead to lateral instability over time; however, a low-flow regime and thick, herbaceous vegetation on the banks have served to maintain some stability along the reach.

UT1 is overly straight (sinuosity = 1.00) and has poor bedform diversity. Bed features are poorly formed along the reach, due primarily to backwater from blockages and culverts. A few sections along the reach showed signs of a bankfull bench developing, accompanied by narrowing of the channel.

5.3.2 UT2

UT2 is classified as a F5 stream type in the upper section above the culvert and a Gc stream type below the culvert (Rosgen, 1994). The culvert is set high, which causes water to back up in the upper section. The bed material is primarily made up of an organic silt/muck due to the backwater condition; therefore, sediment samples were not collected on this reach.

UT2 is highly incised and regularly maintained in order to promote drainage of the surrounding agricultural fields. Bank height ratios ranged from 3.6 - 4.5 in the surveyed cross sections. These values fall into the highly unstable range in Rosgen's comparison of bank height ratio to vertical stability ranking. The stream displays no measurable meander geometry due to its channelized condition. These conditions generally lead to lateral instability over time; however, a low-flow regime and thick, herbaceous vegetation on the banks have served to maintain some stability along the reach.

UT2 is overly straight (sinuosity = 1.00) and has poor bedform diversity. Bed features are poorly formed along the reach due primarily to backwater from blockages and culverts. UT2 runs through open agricultural fields were the buffer is narrow (< 10 feet wide).

5.3.3 UT3

UT3 is classified as a straightened G5c stream type (Rosgen, 1994). The modified Wolman pebble count (Rosgen, 1994) is not appropriate for sand-bed streams; therefore, a bulk sampling procedure was used to characterize the bed material. The majority of the reach had an organic muck stream bottom due to the low velocity caused by backwater from blockages. In areas where riffle flow is evident, the channel substrate was sandy. Bed material samples were collected from these areas. The samples were taken back to a lab and dry sieved to obtain a sediment size distribution. The sieve data show that UT1 has a D_{50} of 0.27-mm and a D_{84} of 0.46-mm, indicating that the dominant bed material in the stream channel is medium sand.

UT3 is highly incised and regularly maintained in the lower section in order to promote drainage of the surrounding agricultural fields. Bank height ratios ranged from 4.5 - 4.9 in the surveyed cross sections. These values fall into the highly unstable range in Rosgen's comparison of bank height ratio to vertical stability ranking. Meander width ratios are extremely low compared to reference C stream types in the North Carolina Coastal Plain. This departure is indicative of a condition of lateral instability; however, a low-flow regime and thick, herbaceous vegetation on the banks in the lower section as well as a fairly extensive woody buffer in the upper, wooded area have served to maintain some stability along the reach.

UT3 is overly straight (sinuosity = 1.00) and has poor bedform diversity. Bed features are poorly formed along the reach due primarily to backwater from blockages. The project reach of UT3 runs through open agricultural fields where the buffer is narrow (< 10 feet wide).

5.4 Bankfull Verification

An accurate identification of bankfull stage could not be made on all reaches on the Haw Branch Site due to backwater conditions from blockages and culverts, as well as periodic farm maintenance of the channels. Some indicators were apparent, but the reliability of the indicators was questionable due to the highly-degraded condition of the stream channels. For this reason, bankfull stage was identified through the use of regional curve information.

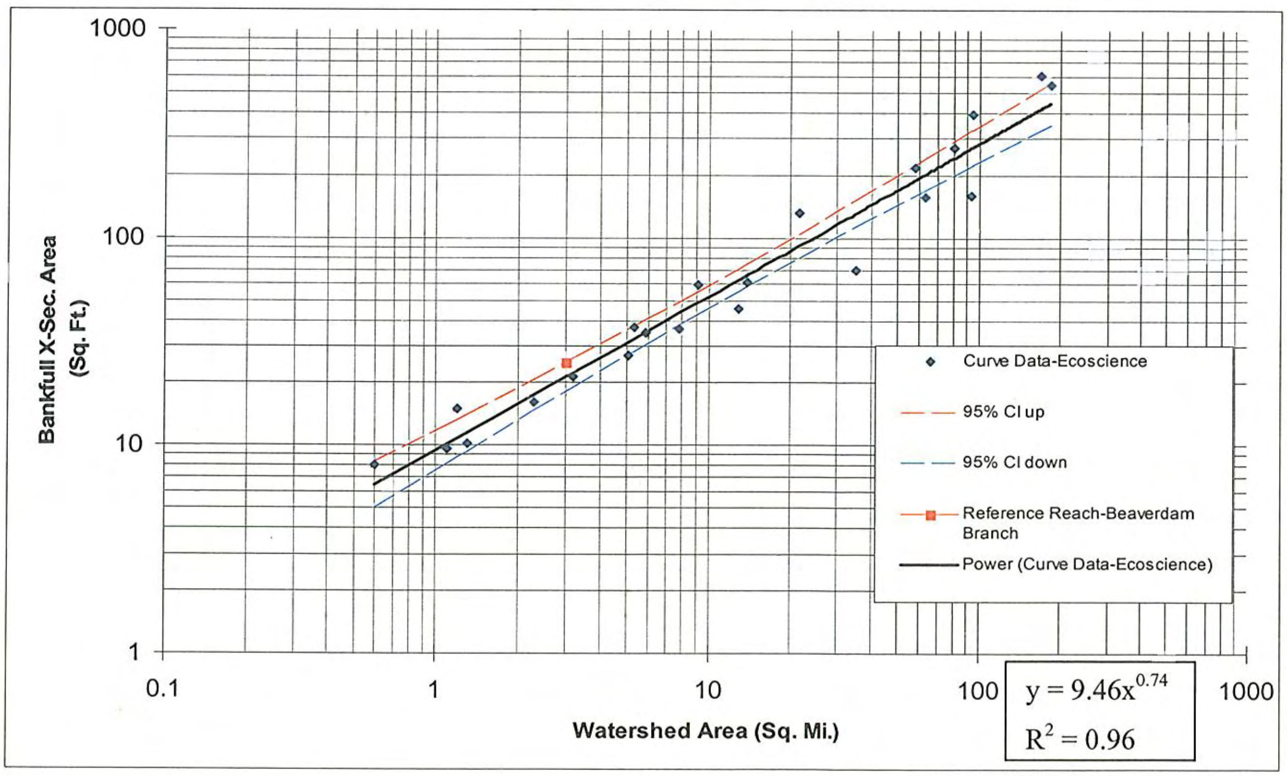
Regional curve equations developed from the North Carolina rural Coastal Plain study are provided by Sweet and Geratz (2003) and Doll (2003) and are shown in Table 5.2.

Bankfull verification for the Haw Branch site involved the analysis of local bankfull cross-sectional area versus drainage area relationships, and then comparison of those relationships to the NC Coastal Plain Regional Curve to determine if the relationships are similar. If so, the bankfull relationships used elsewhere in the Coastal Plain are considered valid for the subject site. A reference reach was located within close proximity to the project site (discussed in Section 5.6). Detailed riffle cross sections were surveyed on the reference reach. This reference site was selected based on the confidence with which bankfull features were selected. The drainage area and the bankfull cross-sectional area were plotted on the NC Coastal Plain Regional Curve (Figure 5.1) to ensure that the reference reach is within the same hydrophysiographic region. This reference reach plotted within the 95% confidence interval of the NC Coastal Plain Regional Curve. The agreement with other Coastal Plain data provides confidence that hydraulic geometry relationships in this basin are similar to those of the entire Coastal Plain region.

TABLE 5.2
NC Rural Coastal Plain Regional Curve Equations.

North Carolina Coastal Plain Rural Regional Curve Equations	
EcoScience Data (Sweet and Geratz, 2003)	
$Q_{bkf} = 8.79\ A_w^{0.76}$	R^2=0.92
$A_{bkf} = 9.43\ A_w^{0.74}$	R^2=0.96
$W_{bkf} = 9.64\ A_w^{0.38}$	R^2=0.95
$D_{bkf} = 0.98\ A_w^{0.36}$	R^2=0.92
NCSU Data (Doll, 2003)	
$Q_{bkf} = 16.56\ A_w^{0.72}$	R^2=0.90
$A_{bkf} = 14.52\ A_w^{0.66}$	R^2=0.88
$W_{bkf} = 10.97\ A_w^{0.36}$	R^2=0.87
$D_{bkf} = 1.29\ A_w^{0.30}$	R^2=0.74

Figure 5.1
NC Coastal Plain Regional Curve, including data from the Beaverdam Branch reference reach.



5.5 Riparian Vegetation

Existing riparian vegetation within the open field areas of UT1, UT2, and UT3 are similar. Buffers for all open field areas are generally less than 10 feet wide and consist primarily of herbaceous species such as tearthumb (*Polygonum sagittatum*), smartweed (*Polygonum sp.*), dogfennel (*Eupatorium capillifolium*), blackberry (*Rubus sp.),* hempweed (*Mikania scandens*), and giant cane.

The riparian buffer in the short, wooded, upstream section of UT1 consists mostly of young trees and vines, including sweetbay (*Magnolia virginiana*), water oak (*Quercus nigra*), maple (*Acer rubrum*), pine (*Pinus sp.*), giant cane (*Arundinaria gigantea*), Coastal doghobble (*Leucothoe axillaris*), grapevine (*Vitus sp.*), and greenbrier (*Smilax sp.*).

5.6 Stream Reference Site

The Beaverdam Branch stream reference site is located in Jones County, approximately six miles southeast of the town of Trenton, North Carolina, and approximately 21 miles northeast of the project site (see Exhibit 1.1). The site is an example of a "Coastal Plain small stream swamp," as described by Schafale and Weakley (1990). These systems exist as the floodplains of small "blackwater" and "brownwater" streams in which separate fluvial features and associated vegetation are too small or poorly developed to distinguish. Hydrology of these systems is palustrine – intermittently, temporarily, or seasonally flooded. Flows tend to be highly variable, with floods of short duration, and periods of very low flow. The "Coastal Plain small stream swamp" wetland system would be typical for the watershed size and the geomorphologic setting of the site. It appears that the site has experienced little disturbance in recent time and is believed to be representative of undisturbed conditions on the project site. The reference stream site will be used along with evaluation data from past projects to develop design criteria. These procedures are described in Section 6.

Field surveys of the reference site were conducted in early spring, 2002. Survey data were used to evaluate the natural channel parameters describing the dimension, pattern, and profile of the stream. Natural channel parameters are summarized in Table 7.1.

The reference stream is classified as a "C5c" channel using the Rosgen Stream Classification System (Rosgen, 1994). Longitudinal profile and cross sections are presented in Appendix 4. The channel is classified as a "C" channel since the average width/depth ratio is 14. "C" type channels are more typical of lower gradient sand-bed stream systems that meander through alluvial valleys. "C" type streams typically form point-bar features as a result of the relatively high amount of bedload that is transported. Out-of-bank flooding occurs at stages greater than the bankfull flow. The "5" indicates that the stream is a sand-bed system. Median particle size of the bed material is approximately 0.7 mm (see Appendix 4 for particle size distribution data). The "c" indicates that the slope of the channel is less than 0.001 feet/feet. The reference reach stream has appropriate bed features for a sand-bed system, with shallow pools in the meander bends, and deeper pools formed by scour features such as roots and debris jams.

Unlike many other Coastal Plain stream systems, the section of channel surveyed for the reference reach shows no evidence of having been altered or channelized in the recent past. Trees can be found within the riparian area that appear to be in excess of 50 years of age. The channel has good meander pattern with low bank heights. As a result, flooding of the adjacent riverine wetland areas occurs frequently.

5.6.1 Reference Stream Vegetation

The reference stream is well buffered along both stream banks, with tree species that include sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), willow oak (*Quercus phellos*), water oak (*Quercus nigra*), swamp chestnut oak (*Quercus michauxii*), and green ash (*Fraxinus pennsylvanica*). The small tree/shrub layer is dominated by sweetbay magnolia (*Magnolia virginiana*), American holly (*Ilex opaca*), sugarberry saplings (*Celtis laevigata*), giant cane

(*Arundinaria gigantea*), elderberry (*Sambucus canadensis*), leucothoe (*Leucothoe axillaris*), sweet pepperbush (*Clethra alnifolia*), beautyberry (*Callicarpa americana*), and blackberry (*Rubus* spp.). The herb and vine strata contain false nettle (*Boehmeria cylindrica*), jewel-weed (*Impatiens capensis*), cinnamon fern (*Osmunda cinnamomea*), sensitive fern (*Onoclea sensibilis*), green-briar (*Smilax* spp.), Virginia creeper (*Parthenocissus quinquefolia*), grape (*Vitis* spp.), poison ivy (*Toxicodendron radicans*), and honeysuckle (*Lonicera japonica*).

6.0 SELECTED DESIGN CRITERIA

6.1 Potential for Restoration

There are few potential obstacles for achieving a successful wetland and stream restoration project on the project site. The project is located in a rural watershed, with no plans for land use changes in the foreseeable future. There are no known present or future constraints at the site associated with structure and/or infrastructure encroachments. There is one situation (described below) where site conditions necessitate the use of techniques that will not fully reclaim the abandoned floodplain at the site.

6.1.1 UT3 Channel Restoration Potential

The UT3 channel flows through a forested area east of the project site before entering the open field areas of the project site. Although straightened and channelized through the forested area, the reach is moderately stable and is providing some riparian functions due to a dense canopy cover and large, wooded buffer. Full restoration of the stream would require clearing of a significant amount of wooded land, as well as extensive excavation at the upstream end of the project due to the elevation of a road culvert. The decision was made to leave the wooded portions of UT3 intact and focus on stabilizing and improving functions in the open field areas of UT3, where the stream is more degraded.

Due to the existing streambed elevations at the upstream and downstream ends of the UT3 project reach, the streambed of UT3 cannot be raised as part of the restoration work. Such an approach would cause significant backwater upstream, and the need to "step" the stream back down at the downstream end; therefore, a Rosgen Priority Level II approach will be utilized for UT3, which is further described in Section 7. This approach will result in the restoration of stream and riparian buffer functions and will likely create wetland hydrology on the excavated floodplain, but it will not restore wetland hydrology to adjacent fields outside the excavated floodplain, since the bed elevation of the stream will be essentially unchanged.

6.2 Design Criteria Selection

Selection of natural channel design criteria and associated wetland design criteria is based on a combination of approaches, including review of reference reach databases, regime equations, and evaluation of results from past projects, as discussed in Section 2.6.

Selection of a general restoration approach was the first step in selecting design criteria for the streams on the Haw Branch site. The approach was based on each reach's potential for restoration as determined during the site assessment. After selection of the general restoration approach, specific design criteria were developed so that each reach's plan view layout, cross-section dimensions, and profile could be described for the purpose of developing construction documents.

6.2.1 Reference Reach Survey

As discussed in Section 5.6, a stream reference reach was identified and surveyed approximately 21 miles northeast of the project site. The Beaverdam Branch site is an example of a reference quality C5c channel under similar geomorphological conditions as the project site. The site has associated wetland areas adjacent to the channel which classify as a "Coastal Plain small stream swamp," as described by Schafale and Weakley (1990). Specific natural channel parameters are provided in Table 7.1.

6.2.2 Reference Reach Database

An internal reference reach database has been developed by Buck Engineering for the evaluation of reference reach parameters from multiple sites within a geographic area. The database includes four sand-bed reference reaches, in addition to the Beaverdam Branch reference reach, that were surveyed in the Coastal Plain and have been used for design purposes on other projects. Collectively, the data provide valuable information regarding the range of conditions documented for similar headwater stream and wetland systems. Shear stress and stream power relationships developed for these reference sites are used in the sediment transport analysis given in Section 7.4.

6.2.3 Design Criteria Selection Method

Specific design parameters were developed using a combination of reference reach data, past project experiences, and best professional judgment. The design philosophy at the Haw Branch site is to use conservative values for the selected stream types and to allow natural variability in stream dimension, facet slope, and bed features to form over long periods of time under the processes of flooding, re-colonization of vegetation, and watershed influences.

6.3 Design Criteria for the Haw Branch Site

After examining the assessment data collected at the site and exploring the site's potential for restoration, an approach to the stream restoration was developed. First, an appropriate stream type for the valley type was selected. The design stream types were further refined based on the channel evolution sequence exhibited by the stream after examination of existing conditions survey data and other field observations, as well as conditions observed on reference streams under similar conditions. Available belt width and channel incision were considered as well. The proposed stream types for the project are summarized in Table 6.1.

TABLE 6.1
Project Design Stream Types.

Reach	Proposed Stream Type	Rationale
UT1a	Cc	Restoration of the stream to its historic floodplain is required to restore wetland hydrology. Restoration of dimension, pattern, and profile will return the reach to its original stream type with functioning floodplain and adjacent wetland areas. "C" stream type is based on information from reference reaches under similar slope and sediment supply conditions.
UT1b	Cc	Restoration of the stream to its historic floodplain is required to restore wetland hydrology. Restoration of dimension, pattern, and profile will return the reach to its original stream type with functioning floodplain and adjacent wetland areas. "C" stream type is based on information from reference reaches under similar slope and sediment supply conditions.
UT2	Cc	Restoration of the stream to its historic floodplain is required to restore wetland hydrology. Restoration of dimension, pattern, and profile will return the reach to its original stream type with functioning floodplain and adjacent wetland areas. "C" stream type is based on information from reference reaches under similar slope and sediment supply conditions.
UT3	Cc	Restoration of the stream to its historic floodplain is not feasible, due to the bed elevations that must be maintained at the upstream and downstream ends of the project. Restoration of dimension, pattern, and profile will be achieved through the excavation of a bankfull bench and re-meandering of the channel through the excavated bench.

7.0 RESTORATION DESIGN

7.1 Overview

The objective of this project will be the restoration of approximately 25 acres of riverine wetland and approximately 10,060 feet of stream. The restoration design will seek to restore a "Coastal Plain small stream swamp system," as described by Schafale and Weakley (1990). "Coastal Plain small stream swamp systems" exist as the floodplain wetland areas of small, Coastal Plain streams in which hydrology is driven by poorly drained soils, lack of adequate drainage, and periodic flooding from overbank events.

The hydrology of these systems is driven by the interaction between the stream channel and its adjacent wetland areas. Emphasis is placed on proper design of the stream channel itself, such that the flow of groundwater and overbank flooding events will drive the hydrologic restoration of the wetland areas. The first few sections that follow discuss the design of the stream channel components, followed by discussion of the wetland restoration components.

7.2 Natural Channel Design Summary

The proposed natural channel designs for Haw Branch tributaries are the highest level of restoration feasible given the valley and stream types. Selection of restoration type follows Rosgen's priority restoration approach for incised streams (Rosgen, 1997), which has an overriding objective of re-establishing contact between the channel and a floodplain. For the purposes of this discussion, the four Rosgen restoration approaches have been defined below in order of decreasing restoration benefit:

- Priority I – Re-establish the channel on a previous floodplain (i.e., raise channel elevation); meander new channel to achieve dimension, pattern, and profile characteristic of a stable stream for the particular valley type; fill or isolate existing incised channel.
- Priority II – Establish a new floodplain for the existing bankfull elevation (i.e., excavate a new floodplain); meander channel to achieve dimension, pattern, and profile characteristics of a stable stream for the particular valley type; fill or isolate existing incised channel.
- Priority III – Establish a new floodplain at the existing bankfull elevation (i.e., using bankfull benches); leave existing channel in place; use in-stream structures to dissipate energy through a step/pool channel type.
- Priority IV – Stabilize the channel in place using in-stream structures and bioengineering to decrease streambed and streambank erosion.

The entire length of the restored stream channel along reaches UT1 and UT2 will involve Priority I restoration approaches. A short section of Priority II restoration will be constructed at the downstream end of UT1 to tie the channel back into the elevation of the incised existing channel at the end of the project. UT3 will be restored using a Priority II approach, due to the streambed elevations at the upstream and downstream ends of the project reach. The new channel will be constructed as described below.

7.3 Natural Channel Design

See project design plans for detailed design information.

Restoration of site hydrology will involve the restoration of natural stream and wetland systems on the site. The stream system that historically flowed through the site was channelized and as a result, is now highly incised (predominantly "Gc" type streams). For UT1 and UT2, the design for the restored streams will involve the construction of a new, meandering channel across the existing agricultural fields. For UT3, the design will involve construction of a new floodplain at a lower elevation. The stream type for the restored streams will be Rosgen "C" channels, with design dimensions based on the design criteria discussed in Section 6. Selected design parameters, based on the information provided in Table 7.1, are provided in Tables 7.2 through 7.3. Total stream length across the Haw Branch Restoration Project will be increased from 4,370 feet to approximately 10,060 feet. Actual restored length will be determined after as-built plan sheets have been developed for the project.

The design will allow stream flows larger than bankfull flows to spread onto the floodplain, dissipating flow energies and reducing stress on streambanks. In-stream structures will be used to control streambed grade, reduce stresses on streambanks, and promote bedform sequences and habitat diversity. The in-stream structures will consist of root-wads, log vanes, log weirs, and other wood structures that will promote a diversity of habitat features in the restored channel. Where grade control is an issue, constructed riffle structures will be constructed to provide long-term stability. It is anticipated that constructed riffle structures will be needed only at the downstream end of reach UT1 to "step" the restored stream channel down to the existing incised channel. Streambanks will be stabilized using a combination of erosion control matting, bare-root planting, and transplants. Transplants will provide immediate shading to the restored stream, as well as living root mass to increase streambank stability and create holding areas for fish and aquatic biota.

The entire new stream channel will be constructed "in the dry," and all stabilization practices will be in place prior to routing stream water into the new sections of channel. When it is time to route water into the new sections, plugs will be installed in the old channel to re-direct the water into the new channel. Immediately after the water has been routed into the new channel, the process of filling the old channel with soil will begin.

One stream crossing will be incorporated into the stream restoration design. The crossing will be located at approximate station 47+00 along Reach UT1b, as shown on the design plans. The crossing will be constructed as a rock ford, using a gradation of stone to maintain the streambed elevation and allow for equipment traffic across the stream without causing damage upstream or downstream.

TABLE 7.1
Reference parameters used to determine design ratios.

Parameter	Beaverdam Branch (See Appendix 4) MIN	MAX	Composite Reference Data from NC Coastal Plain[1] MIN	MAX
Drainage Area, DA (sq mi)	3	3		
Stream Type (Rosgen)	C5c			
Bankfull Discharge, Qbkf (cfs)	37	37		
Bankfull Riffle XSEC Area, Abkf (sq ft)	24	24		
Bankfull Mean Velocity, Vbkf (ft/s)	1.5	1.5		
Width to Depth Ratio, W/D (ft/ft)	11	17	8	14
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	10	11		
Riffle Max Depth Ratio, Dmax/Dbkf	1.5	1.7	1.2	1.7
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.3		
Meander Length Ratio, Lm/Wbkf	4.9	6.7	11	17
Rc Ratio, Rc/Wbkf	1.8	2.4	1.5	3.0
Meander Width Ratio, Wblt/Wbkf	2.9	6.3	2.0	6.3
Sinuosity, K	1.66		1.22	1.77
Valley Slope, Sval (ft/ft)	0.0007		0.0007	0.0029
Channel Slope, Schan (ft/ft)	0.0004		0.0004	0.0022
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.1	2.4	1.8	2.0
Pool Width Ratio, Wpool/Wbkf	0.8	1.0	0.8	1.4
Pool-Pool Spacing Ratio, Lps/Wbkf	2.5	3.4		
d16 (mm)	0.3			
d35 (mm)	0.4			
d50 (mm)	0.5			
d84 (mm)	0.9			
d95 (mm)	1.2			

NOTES:

[1] Composite reference reach information from Johannah Creek, Johnston County; Panther Branch, Brunswick County; and Rocky Swamp, Halifax County.

TABLE 7.2
Natural channel design parameters for the Haw Branch site - UT1.

Parameter	Reach UT1a Design Values		Reach UT1b Design Values		Rationale
	MIN	MAX	MIN	MAX	
Drainage Area, DA (sq mi)	0.39	0.39	0.73	0.73	
Design Stream Length (feet)	3,150	3,150	2,988	2,988	
Stream Type (Rosgen)	C5c	C5c	C5c	C5c	Note 1
Bankfull (bkf) Discharge, Qbkf (cfs)	3.6	3.6	9.6	9.6	Note 2
Bankfull Mean Velocity, Vbkf (ft/s)	0.73	0.73	1.2	1.2	V=Q/A
Bankfull Riffle XSEC Area, Abkf (sq ft)	5.0	5.0	8.0	8.0	Note 2
Bankfull Riffle Width, Wbkf (ft)	8.4	8.4	10.6	10.6	$\sqrt{Abkf*W/D}$
Bankfull Riffle Mean Depth, Dbkf (ft)	0.6	0.6	0.8	0.8	d=A/W
Width to Depth Ratio, W/D (ft/ft)	14	14	14	14	Note 3
Width Floodprone Area, Wfpa (ft)	~ 200	~ 200	~ 200	~ 200	
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	~ 22	~ 22	~ 22	~ 22	Note 4
Riffle Max Depth @ bkf, Dmax (ft)	0.7	0.8	0.9	1.0	
Riffle Max Depth Ratio, Dmax/Dbkf	1.2	1.3	1.2	1.3	Note 5
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.2	1.0	1.2	Note 6
Meander Length, Lm (ft)	67	100	85	127	
Meander Length Ratio, Lm/Wbkf *	8	12	8	12	Note 7
Radius of Curvature, Rc (ft)	17	33	21	42	
Rc Ratio, Rc/Wbkf *	2.0	4.0	2.0	4.0	Note 7
Belt Width, Wblt (ft)	42	67	53	85	
Meander Width Ratio, Wblt/Wbkf *	5	8	5	8	Note 7
Sinuosity, K	1.9	1.9	1.62	1.62	TW length/ Valley
Valley Slope, Sval (ft/ft)	0.0025	0.0025	0.0021	0.0021	
Channel Slope, Schan (ft/ft)	0.0013	0.0013	0.0013	0.0013	Sval / K
Slope Riffle, Srif (ft/ft)	n/a	n/a	n/a	n/a	
Riffle Slope Ratio, Srif/Schan	n/a	n/a	n/a	n/a	Note 8
Slope Pool, Spool (ft/ft)	n/a	n/a	n/a	n/a	
Pool Slope Ratio, Spool/Schan	n/a	n/a	n/a	n/a	Note 8
Pool Max Depth, Dmaxpool (ft)	1.1	1.2	1.4	1.5	
Pool Max Depth Ratio, Dmaxpool/Dbkf	1.8	2.0	1.8	2.0	Note 7
Pool Width, Wpool (ft)	10.9	14.2	13.8	18.0	
Pool Width Ratio, Wpool/Wbkf	1.3	1.7	1.3	1.7	Note 9
Pool-Pool Spacing, Lps (ft)	17	42	21	53	
Pool-Pool Spacing Ratio, Lps/Wbkf	2.5	5	2.5	5	Note 7

TABLE 7.3
Natural channel design parameters for Haw Branch site – UT2 and UT3.

Parameter	Reach UT2 Design Values		Reach UT3 Design Values		Rationale
	MIN	MAX	MIN	MAX	
Drainage Area, DA (sq mi)	0.14	0.14	0.30	0.30	
Design Stream Length (feet)	2,928	2,928	994	994	
Stream Type (Rosgen)	C5c	C5c	E5	E5	Note 1
Bankfull (bkf) Discharge, Qbkf (cfs)	2.0	2.0	9.2	9.2	Note 2
Bankfull Mean Velocity, Vbkf (ft/s)	0.5	0.5	1.8	1.8	V=Q/A
Bankfull Riffle XSEC Area, Abkf (sq ft)	4.0	4.0	5.0	5.0	Note 2
Bankfull Riffle Width, Wbkf (ft)	7.5	7.5	6.7	6.7	$\sqrt{Abkf * W/D}$
Bankfull Riffle Mean Depth, Dbkf (ft)	0.6	0.6	0.7	0.7	d=A/W
Width to Depth Ratio, W/D (ft/ft)	14	14	9	9	Note 3
Width Floodprone Area, Wfpa (ft)	~ 200	~ 200	~ 200	~ 200	
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	~ 24	~ 24	~ 24	~ 24	Note 4
Riffle Max Depth @ bkf, Dmax (ft)	0.6	0.7	1.0	1.1	
Riffle Max Depth Ratio, Dmax/Dbkf	1.2	1.3	1.5	1.6	Note 5
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.2	1.0	1.2	Note 6
Meander Length, Lm (ft)	60	90	54	80	
Meander Length Ratio, Lm/Wbkf *	8	12	8	12	Note 7
Radius of Curvature, Rc (ft)	15	30	14	27	
Rc Ratio, Rc/Wbkf *	2.0	4.0	2.0	4.0	Note 7
Belt Width, Wblt (ft)	37	60	34	54	
Meander Width Ratio, Wblt/Wbkf *	5	8	5	8	Note 7
Sinuosity, K	1.76	1.76	1.47	1.47	TW length/ Valley
Valley Slope, Sval (ft/ft)	0.0009	0.0009	0.0069	0.0069	
Channel Slope, Schan (ft/ft)	0.0005	0.0005	0.0047	0.0047	Sval / K
Slope Riffle, Srif (ft/ft)	n/a	n/a	n/a	n/a	
Riffle Slope Ratio, Srif/Schan	n/a	n/a	n/a	n/a	Note 8
Slope Pool, Spool (ft/ft)	n/a	n/a	n/a	n/a	
Pool Slope Ratio, Spool/Schan	n/a	n/a	n/a	n/a	Note 8
Pool Max Depth, Dmaxpool (ft)	1.0	1.1	1.5	1.6	
Pool Max Depth Ratio, Dmaxpool/Dbkf	1.8	2.0	2.0	2.2	Note 7
Pool Width, Wpool (ft)	9.7	12.7	8.7	11.4	
Pool Width Ratio, Wpool/Wbkf	1.3	1.7	1.3	1.7	Note 9
Pool-Pool Spacing, Lps (ft)	15	38	17	34	
Pool-Pool Spacing Ratio, Lps/Wbkf	2.5	5	2.5	5	Note 7

Notes for Tables 7.2 and 7.3:

[1] *A C5 stream type is appropriate for a very low-slope (generally less than 0.002), wide, alluvial valley with a sand streambed. An E5 stream type is more appropriate for a steeper slope (generally greater than 0.002) alluvial valley. The choice between a C5 and E5 channel dimension was based on relationships of W/D ratio to slope in NC Coastal Plain reference reach streams, as well as sediment transport analyses.*
[2] *Bankfull discharge was estimated using Manning's equation.*
[3] *A final W/D ratio was selected based on relationships of W/D ratio to slope in NC Coastal Plain reference reach streams, as well as sediment transport analyses.*
[4] *Required for stream classification.*
[5] *This ratio was based on past project evaluation of similar C5 and E5 design channels.*
[6] *A bank height ratio near 1.0 ensures that all flows greater than bankfull will spread onto a floodplain. This minimizes shear stress in the channel and maximizes floodplain functionality, resulting in lower risk of channel instability.*
[7] *Values were chosen based on Beaverdam Branch reference reach data, other sand-bed reference reach data, and past project evaluation.*
[8] *Due to the extremely low channel slopes, facet slopes were not calculated for the proposed design. Past project experience has shown that these minor changes in slope between features form naturally within the constructed channel, provided that the overall design channel slope is maintained during construction.*
[9] *Values were chosen based on reference reach database analysis and past project evaluation. It is more conservative to design a pool wider than the riffle. Over time, the pool width may narrow, which is a positive evolutionary step.*

7.4 Sediment Transport Analysis

The purpose of sediment transport analysis is to ensure that the stream restoration design creates a stable sand-bed channel that does not aggrade or degrade over time. The overriding assumption is that the project reach should be transporting all the sediment delivered from upstream sources, thereby being a "transport" reach and classified as a Rosgen "C" or "E" type channel. Empirical relationships from stable sand-bed channels in North Carolina are used in this analysis, as described in Section 2.15.

Shear stress, stream power, and W/D values for the design reaches are plotted against stable reference stream data in Figures 7.1, 7.2, and 7.3. The values were calculated based on average design conditions on each of the design reaches, and a summary of the data are provided in Table 7.4 The design shear stress and stream power values plot within or slightly lower than the scatter of data points collected from reference reaches. This analysis provides evidence that the stresses predicted for the design channels are well within the range of stable values calculated for the reference reaches. Therefore, excessive scour of design channels is not expected.

Figure 7.1

Comparison between bankfull shear stress and channel slope for the design reaches and Coastal Plain reference reach data.

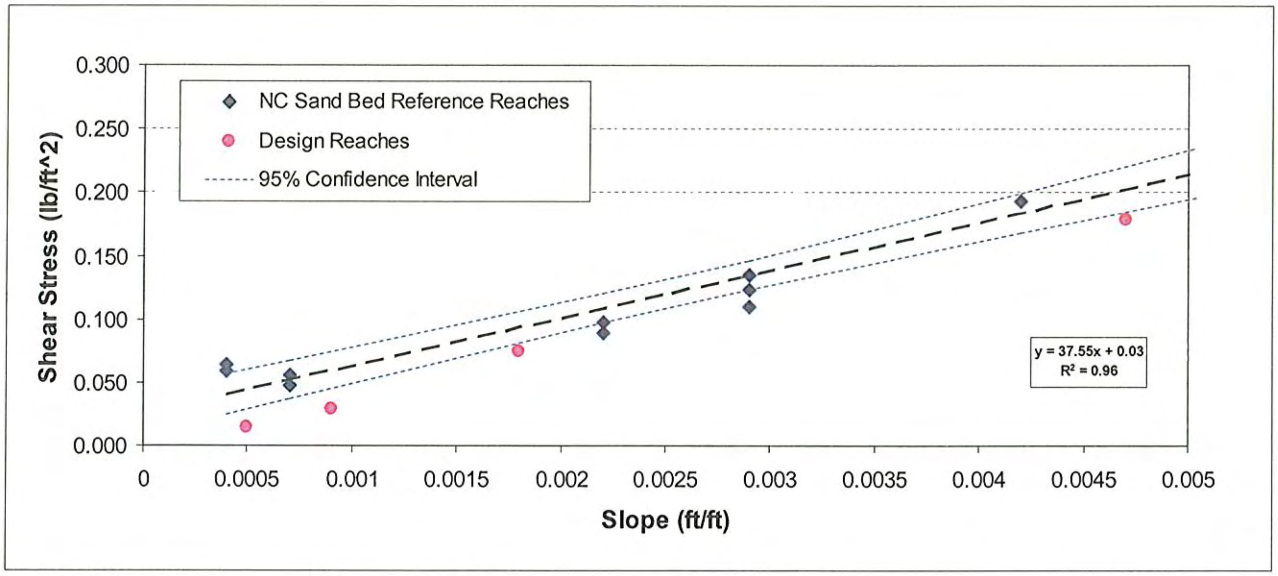


Figure 7.2.

Comparison between stream power and channel slope for the design reaches and Coastal Plain reference reach data.

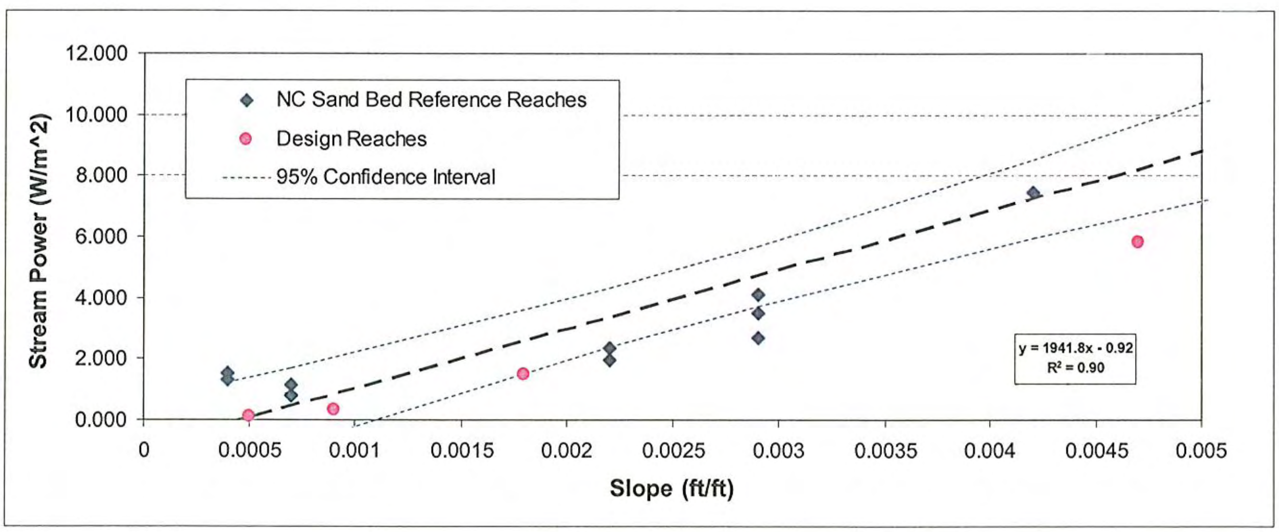


Figure 7.3

Comparison between width-to-depth ratio (W/D) and channel slope for the design reaches and Coastal Plain reference reach data.

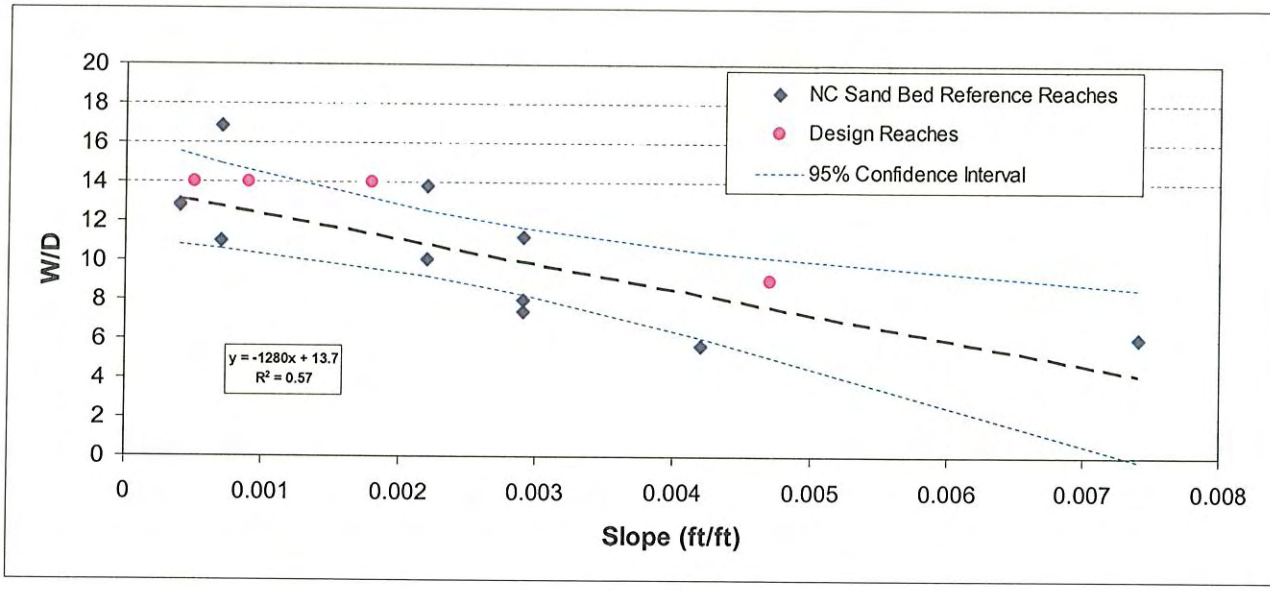


Table 7.4 Calculated sediment transport data for design reaches.					
Design Reach	**Design Bankfull Area (ft^2)**	**Bankfull Discharge (ft^3/sec)**	**Bankfull Velocity (ft/sec)**	**Shear Stress (lbs/ft^2)**	**Stream Power (W/m^2)**
Reach UT1a	5	3.6	0.73	0.029	0.354
Reach UT1b	8	9.6	1.20	0.074	1.481
Reach UT2	4	2.0	0.50	0.015	0.122
Reach UT3	5	9.2	1.84	0.179	5.836

7.5 Restoration of Wetland Hydrology

The existing agricultural fields across the site are currently drained by a series of lateral ditches and channelized streams. To restore wetland hydrology to the site, the lateral field ditches will be partially filled, depending on the amount of fill material that can be produced from minor land grading and excavation of the new stream channels. When complete filling of lateral ditches is not possible, ditch plugs will be installed from compacted earth for a distance of at least 100 feet. Ditch plugs will also be used in locations where the restored stream channel will cross existing lateral ditches. In these locations, the ditch will be plugged for at least 100 feet on both sides of the restored channel to prevent drainage losses and channel avulsion. In areas where restored stream flows will contact fill material, root wads will be installed to provide additional protection and deflect stream energies. Due to the relatively small size of the restored channel and the low energy nature of the system, these practices will be sufficient to prevent erosion and channel avulsion. These practices have been used on numerous other projects with excellent results.

Grading activities will focus on removing any field crowns, surface drains, or swales that were imposed during conversion of the land for agriculture. Existing and proposed graded contours are provided in the plan sheets. In general, grading activities will be minor since the site exhibits a rather flat existing topography. Grading cuts will generally be less than 0.7 feet in most areas.

The topography of the restored site will be patterned after natural floodplain wetland reference sites, and will include the restoration of minor depressions and tip mounds (microtopography) that promote diversity of hydrologic conditions and habitats common to natural wetland areas. These techniques will be instrumental to the restoration of site hydrology by promoting surface ponding and infiltration, decreasing drainage capacity, and imposing higher water table conditions across the restoration site. In order to improve drainage and increase agricultural production, farmed wetland soils are often graded to a smooth surface and crowned to enhance runoff (Lilly, 1981). Microtopography contributes to the properties of forest soils and to the diversity and patterns of plant communities (Lutz, 1940; Stephens, 1956; Bratton, 1976; Ehrnfeld, 1995). Microtopography will be established after floodplain areas have been established to design grades, using the procedures described in Section 2.8.

7.6 Hydrologic Model Analyses

The DRAINMOD simulations that were developed to evaluate the current hydrologic status of the restoration site (Section 4.6) were modified to estimate the hydrologic conditions of the site under the proposed restoration practices. Model parameters that describe the depth of stream and topographic surface storage were changed to values representative of the described restoration practices; for example, drain depths were reduced to represent average water levels in the restored, meandering channel. Surface storage parameters were increased, within a range of two to four centimeters to represent soil scarification practices. Input files that describe cropping conditions were changed to represent forested conditions.

Three scenarios were simulated to evaluate the restored hydrologic conditions: 1) a location 50 feet from the restored channel, 2) a location 200 feet from the restored channel, and 3) a location 500 feet from the restored channel. These scenarios were chosen to represent a range of wetness conditions expected across the restored site. Scenario #1 was chosen to represent the drier areas of the site located near the restored stream where the drainage effect would be greatest, however these areas are most susceptible to occasional flooding. Scenarios #2 and #3 were chosen to approximate conditions in areas away from the restored stream channel. These areas will receive less of a drainage effect and will exhibit the greatest surface storage due to topographic undulations. Fifty-eight (58) year simulations were run following the procedures described in Section 2.5, and DRAINMOD input files are provided in Appendix 5.

The results of the simulations indicate that hydrologic conditions imposed across the restored site will vary from location to location, depending on the distance from the restored stream channel and topographic variability. The 50 foot scenario is influenced more by the drainage effect of the stream channel and therefore is predicted to experience drier conditions than the 200 and 500 foot scenarios. In locations near the stream channel, hydrology will primarily be controlled by the baseflow water level in the restored stream and overbank flooding. In areas farther from the restored stream, the drainage effect becomes insignificant and water loss through evapotranspiration and runoff begin to dominate the water balance. Hydrology of these areas will be restored through topographic manipulations imposed to increase surface storage and infiltration of water on the site.

These modeled scenarios provide an indication of the hydrologic conditions that are expected across the restored site. The data indicate that under average conditions, wetland hydrology will occur for at least 8 to 13% of the growing season across the restored wetland site. Since no wetland system is homogeneous throughout, hydrology will vary across the restored site. Factors that will affect hydrology in any particular location include seepage inputs and outputs, degree of ponding, frequency of stream flooding events, local soil and subsoil conditions, runoff, and run-on.

7.7 Vegetation Plan

The planting plans for the site (see restoration plan sheets) indicate that bare-root trees will be planted within all areas of the conservation easement. A 50-foot (minimum) buffer will be established along all restored stream reaches. In most areas, the protected buffer area will exceed 50 feet in width and will include restored wetland areas. In general, bare-root vegetation will be planted at a target density of 680 stems per acre, or an 8 by 8 foot grid. Planting of bare-root trees will be conducted during the dormant season, with all trees installed prior to March 15.

Species selection is based on reference wetland vegetation analyses, professional knowledge of availability and viability of specific plants, and expected post-restoration hydrologic conditions. Species selection for re-vegetation of the site will generally follow those suggested by Schafale and Weakley (1990) and tolerances cited in the USACE Wetland Research Program (WRP) Technical Note VN-RS-4.1 (1997). Selected species for hardwood re-vegetation are presented in Table 7.5 below. Tree species selected for restoration will generally range from weakly tolerant to tolerant of flooding. Weakly tolerant species are able to survive and grow in areas where the soil is saturated or flooded for relatively short periods of time. Moderately tolerant species are able to survive on soils that are saturated or flooded for several months during the growing season. Flood tolerant species are able to survive on sites in which the soil is saturated or flooded for extended periods during the growing season (WRP, 1997).

Observations will be made during construction of the site regarding the relative wetness of areas to be planted. Planting zones will be determined based on these assessments, and planted species will be matched according to their wetness tolerance and the anticipated wetness of the planting area.

Trees will be transported to the site from the nursery and planted within two days. Tree roots will be kept moist until placed in the ground. Soils across the site will be sufficiently disked and loosened prior to planting. Trees will be planted by manual labor, using a dibble bar, mattock, planting bar, or other approved method. Planting holes for the trees will be sufficiently deep to allow the roots to spread out and down without "J-rooting." Soil will be loosely compacted around trees once they have been planted to prevent them from drying out.

Permanent seed mixtures will be applied to all disturbed areas of the project site. Table 7.6 lists the species, mixtures, and application rates that will be used. A mixture is provided for both floodplain and streambank areas. Both mixtures will also include temporary seeding (rye grain or browntop millet) to allow for application with mechanical broadcast spreaders. The permanent seed mixture specified for floodplain areas will be applied to all disturbed areas outside the banks of the restored stream channel and is intended to provide rapid growth of herbaceous ground cover and biological habitat value. The seed mixture specified for restored streambanks will be applied to provide rapid, herbaceous vegetation growth to stabilize constructed streambanks. The species provided are deep rooted and have been shown to proliferate along restored stream channels, providing long-term stability.

Temporary seeding will be applied to all disturbed areas of the site that are susceptible to erosion. These areas include constructed streambanks, access roads, side slopes, spoil piles, etc. If temporary seeding is applied from November through April, rye grain will be used and applied at a rate of 130 lbs/acre. If applied from May through October, temporary seeding will consist of browntop millet, applied at a rate of 45 lbs/acre.

Table 7.5
Bare-root trees species selected for re-vegetation of the restoration site. Species selection may change due to availability of species at the time of planting.

Common Name	Scientific Name	Percent Planted by Species	Total Number of Stems	Wetness Tolerance [1]
River Birch	*Betula nigra*	17%	5,472	moderate
Sugarberry	*Celtis laevigata*	15%	4,869	moderate
Green Ash	*Fraxinus pennsylvanica*	2%	765	moderate
Black Walnut[2]	*Juglans nigra*	2%	765	weak - moderate
Swamp Tupelo	*Nyssa sylvatica var.biflora*	17%	5,472	tolerant
Sycamore	*Platanus occidentalis*	3%	1,020	moderate
Overcup Oak	*Quercus lyrata*	17%	5,472	moderate
Swamp Chestnut Oak	*Quercus michauxii*	3%	1,020	weak
Willow Oak	*Quercus phellos*	15%	4,869	weak - moderate
Bald Cypress	*Taxodium distichum*	8%	2,736	tolerant
		Total	32,460	

1. Based on information from US Army Corps of Engineers Wetland Research Program (WRP) Technical Note VN-RS-4.1 (1997).

2 Based on information from other literature sources.

Table 7.6
Permanent seed mixtures for the restoration site. Species selection may change due to availability at time of planting.

Common Name	Scientific Name	Percent of Mixture	Seeding Density (lbs/acre)	Wetness Tolerance
Floodplain and Buffer Areas				
Virginia wildrye	*Elymus virginicus*	25%	2	FAC
Switchgrass	*Panicum virgatum*	37.5%	3	FAC+
Fox sedge	*Carex vulpinoidea*	37.5%	3	OBL
Restored Streambanks				
Soft rush	*Juncus effusus*	25%	2	FACW+
Hop sedge	*Carex lupulina*	37.5%	3	OBL
Fox Sedge	*Carex vulpinoidea*	37.5%	3	OBL

7.8 Soils

Existing soils within the restoration site have been confirmed hydric. Samples of topsoil from the site will be collected and tested to determine soil fertility and chemical properties. If necessary, soil amendments (fertilizer, lime, etc.) will be applied at rates appropriate for the target vegetation. Since the land has been in agricultural production for a number of years, it is likely that soil fertility amendments will not be necessary.

Disking and tillage practices commonly used in agriculture will be applied to all restored farm field areas to break the plow pan and reduce compaction of the soil caused by years of agricultural production. Tillage practices will also be used to restore a more natural topography to the restored site, as discussed in Section 2.8.

7.9 Conservation Easement

The restored wetland and stream areas of the Haw Branch site will be protected by a perpetual conservation easement, following the format provided by the NC Ecosystem Enhancement Program. The easement will be conveyed to either EEP or another approved state agency and recorded at the Onslow County courthouse.

8.0 MONITORING AND EVALUATION

Channel stability, wetland hydrology, and vegetation survival will be monitored on the project site. Post-restoration monitoring will be conducted for five years following the completion of construction to document project success.

8.1 Stream Monitoring

Geomorphic monitoring of restored stream reaches will be conducted for five years to evaluate the effectiveness of the restoration practices. Monitored stream parameters include the occurrence of bankfull events, stream dimension (cross sections), pattern (longitudinal survey), profile (profile survey), and photographic documentation. The methods used and any related success criteria are described below for each parameter.

8.1.1 Bankfull Events

The occurrence of bankfull events within the monitoring period will be documented by the use of a crest gauge and photographs. The crest gauge will be installed on the floodplain within 10 feet of the restored channel. The crest gauge will record the highest watermark between site visits, and the gauge will be checked each time there is a site visit to determine if a bankfull event has occurred. Photographs will be used to document the occurrence of debris lines and sediment deposition on the floodplain during monitoring site visits.

Two bankfull flow events must be documented within the 5-year monitoring period. The two bankfull events must occur in separate years; otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years.

8.1.2 Cross Sections

Two permanent cross sections will be installed per 1,000 linear feet of stream restoration work, with one located at a riffle cross-section and one located at a pool cross-section. Each cross section will be marked on both banks with permanent pins to establish the exact transect used. A common benchmark will be used for cross sections and consistently used to facilitate easy comparison of year-to-year data. The annual cross-section survey will include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg, if the features are present. Riffle cross sections will be classified using the Rosgen Stream Classification System.

There should be little change in as-built cross sections. If changes do take place they should be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down-cutting or erosion) or a movement toward increased stability (e.g., settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross sections shall be classified using the Rosgen Stream Classification System, and all monitored cross sections should fall within the quantitative parameters defined for channels of the design stream type.

8.1.3 Longitudinal Profile

A longitudinal profile will be completed in years one, three, and five of the monitoring period. The profile will be conducted for the entire length of the project or for at least 3,000 feet of restored channel. Measurements will include thalweg, water surface, inner berm, bankfull, and top of low bank. Each of these measurements will be taken at the head of each feature (e.g., riffle, run, pool, glide) and the maximum pool depth. The survey will be tied to a permanent benchmark.

The longitudinal profiles should show that the bedform features are remaining stable; i.e., they are not aggrading or degrading. The pools should remain deep with flat water surface slopes, and the riffles should remain steeper and shallower than the pools. Bedforms observed should be consistent with those observed for channels of the design stream type.

8.1.4 Bed Material Analyses

Since the streams through the project site are dominated by sand-size particles, pebble count procedures would not show a significant change in bed material size or distribution over the monitoring period; therefore, bed material analyses are not recommended for this project.

8.1.5 Photo Reference Sites

Photographs will be used to document restoration success visually. Reference stations will be photographed before construction and continued for at least five years following construction. Reference photos will be taken once a year. Photographs will be taken from a height of approximately five to six feet. Permanent markers will be established to ensure that the same locations (and view directions) on the site are monitored in each monitoring period.

Lateral reference photos. Reference photo transects will be taken at each permanent cross section. Photographs will be taken of both banks at each cross section. The survey tape will be centered in the photographs of the bank. The water line will be located in the lower edge of the frame, and as much of the bank as possible will be included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time.

Structure photos. Photographs will be taken at each grade control structure along the restored stream. Photographers should make every effort to consistently maintain the same area in each photo over time.

Photographs will be used to evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of erosion control measures subjectively. Lateral photos should not indicate excessive erosion or continuing degradation of the banks. A series of photos over time should indicate successive maturation of riparian vegetation.

8.2 Wetland Hydrologic Monitoring

Groundwater monitoring stations will be installed across the project area to document hydrologic conditions of the restored site. Six groundwater monitoring stations will be installed, with three automated groundwater gauges and three manually-read stations. Groundwater monitoring stations will follow the USACE standard methods found in WRP Technical Notes ERDC TN-WRAP-00-02 (July 2000).

In order to determine if the rainfall is normal for the given year, rainfall amounts will be tallied using data obtained from the nearest automated weather station, located within Hoffman State Forest, approximately 15 miles east of the project site (UCAN: 14151, COOP: 314144).

The monitoring data will show the site has been saturated within 12 inches of the soil surface for at least 8% of the growing season and that the site has exhibited an increased frequency of flooding. This criterion is based on the modeling analysis presented in Section 7.6, and on reference site data presented in Section 4.7. For the Hoffman Forest reference site, the Wide Open location exhibits conditions similar to those expected for the restoration site. At the Wide Open location, the average hydroperiod documented over five years of monitoring data has been approximately 8%.

The restored site will be compared to a reference site data. In addition, the restored site's hydrology will be compared to pre-restoration conditions both in terms of groundwater and frequency of overbank events.

8.3 Vegetation Monitoring

Successful restoration of the vegetation on a wetland mitigation site is dependent upon hydrologic restoration, active planting of preferred canopy species, and volunteer regeneration of the native plant community. In order to determine if the criteria are achieved, vegetation-monitoring quadrants will be installed across the restoration site, as directed by EEP monitoring guidance. The number of quadrants required will be based on the species/area curve method, as described in EEP monitoring guidance documents, with a minimum of three quadrants. The size of individual quadrants will be 100 square meters for woody tree species, 25 square meters for shrubs, and 1 square meter for herbaceous vegetation. Vegetation monitoring will occur in spring, after leaf-out has occurred. Individual quadrant data will be provided and will include diameter, height, density, and coverage quantities. Relative values will be calculated, and importance values will be determined. Individual seedlings will be marked such that they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living, planted seedlings and the current year's living, planted seedlings.

At the end of the first growing season, species composition, density, and survival will be evaluated. For each subsequent year, until the final success criteria are achieved, the restored site will be evaluated between July and November.

Specific and measurable success criteria for plant density on the project site will be based on the recommendations found in the WRP Technical Note and correspondence from review agencies on mitigation sites recently approved under the Neu-Con Mitigation Banking Instrument.

The interim measure of vegetative success for the site will be the survival of at least 320 3-year old, planted trees per acre at the end of year three of the monitoring period. The final vegetative success criteria will be the survival of 260 5-year old, planted trees per acre at the end of year five of the monitoring period. While measuring species density is the current accepted methodology for evaluating vegetation success on restoration projects, species density alone may be inadequate for assessing plant community health. For this reason, the vegetation monitoring plan will incorporate the evaluation of additional plant community indices to assess overall vegetative success.

8.4 Reporting Methods

A mitigation plan, including an as-built report, documenting both stream and wetland restoration will be developed within 60 days of the completion of planting and the installation of wells on the restored site. The report will include all information required by current EEP mitigation plan guidelines, including elevations, photographs, well and sampling plot locations, a description of initial species composition by community type, and monitoring stations. The report will include a list of the species planted and the associated densities. The monitoring program will be implemented to document system development and progress toward achieving the success criteria referenced in the previous sections. Stream morphology, as well as the restored wetland hydrology and vegetation, will be assessed to determine the success of the mitigation. The monitoring program will be undertaken for 5 years, or until the final success criteria are achieved, whichever is longer. Monitoring reports will be prepared in the fall of each year of monitoring and submitted to EEP. The monitoring reports will include:

- A detailed narrative summarizing the condition of the restored site and all regular maintenance activities;
- As-built topographic maps showing location of monitoring gauges, vegetation sampling plots, permanent photo points, and location of transects;
- Photographs showing views of the restored site taken from fixed-point stations;

- Hydrologic information;
- Vegetative data;
- Identification of any invasion by undesirable plant species, including quantification of the extent of invasion of undesirable plants by either stem counts, percent cover, or area, whichever is appropriate;
- A description of any damage done by animals or vandalism;
- Wildlife observations; and
- Reference wetland hydrology and stream data.

8.5 Maintenance Issues

Maintenance requirements vary from site to site and are generally driven by the following conditions:

- Projects without established, woody floodplain vegetation are more susceptible to erosion from floods than those with a mature, hardwood forest.
- Projects with sandy, non-cohesive soils are more prone to short-term bank erosion than cohesive soils or soils with high gravel and cobble content.
- Alluvial valley channels with wide floodplains are less vulnerable than confined channels.
- Wet weather during construction can make accurate channel and floodplain excavations difficult.
- Extreme and/or frequent flooding can cause floodplain and channel erosion.
- Extreme hot, cold, wet, or dry weather during and after construction can limit vegetation growth, particularly temporary and permanent seed.
- The presence and aggressiveness of invasive species can affect the extent to which a native buffer can be established.

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. Factors that may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

9.0 REFERENCES

Bratton, S. P. 1976. Resource division in an understory herb community: responses to temporal and microtopographic gradients. The American Naturalist 110 (974):679-693.

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. U. S. Army Corps of Engineers, Waterways Exp. Stn, Tech. Rep. WRP-DE-4, Washington, D. C. 79 pp. +app.

Budd, W.W, P.L. Cohen, P.R. Saunders and F.R. Steiner. 1987. Stream Corridor Management in the Pacific Northwest: I. Determination of Stream Corridor Widths. Environmental Management.

Bunte, K. and S. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

Buol, S.W., F.D. Hole and R.J. McCracken. 1989. Soil Genesis and Classification. Iowa State University Press, 446 pp.

Copeland, R.R, D.N. McComas, C.R. Thorne, P.J. Soar, M.M. Jones, and J.B. Fripp. 2001. United States Army Corps of Engineers (USACOE). Hydraulic Design of Stream Restoration Projects. Washington, DC.

Craft, C.B., W.P. Casey. 2000. Sediment and Nutrient Accumulation in Floodplain and Depressional Freshwater Wetlands of Georgia, USA. Wetlands, Vol. 20, No. 2, June 2000, pp 323-332.

Doll, B.A. 2003. Stream Restoration Technical Guidebook and Coastal Stream Study Amendment. Division of Water Quality, 319 Program.

Ehrnfield, J. G. 1995. Microsite differences in surface substrate characteristics in Chamaecyparis swamps of the New Jersey pinelands. Wetlands 15(2):183-189.

Evans, R. O. and R. W. Skaggs. 1985. Agricultural water management for Coastal Plain soils. Published by the North Carolina Agricultural Extension Service. Paper AG-355.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices. National Technical Information Service, Springfield, VA.

Federal Register. July 13, 1994. Changes in Hydric Soils of the United States. Washington, DC.

Gomez, B. 1991. Bedload transport. Earth-Science Reviews 31, 89-132.

Gosselink, J. G., and R. E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems. In Freshwater Wetlands, 63-78. R. E. Good, D. F. Whigham, and R. L. Simpson, eds. Burlington, Mass.: Academic Press.

Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.O. Slate, A.G. Jessup, J.R. Everhart, and R.E. Smith, 1999. Bankfull Hydraulic Geometry Relationships for North Carolina Streams. Wildland Hydrology. AWRA Symposium Proceedings. Edited by: D.S. Olsen and J.P. Potyondy. American Water Resources Association. June 30-July 2, 1999. Bozeman, MT.

Inglis, C.C. 1947. Meanders and their Bearing on River Training. Institution of Civil Engineers, Maritime and Waterways Engineering Division, Paper No. 7, 54 pp.

King, R. 2000. Effects of single burn events on degraded oak savanna. Ecological Restoration 18:228-233.

Knighton, D. 1984. Fluvial Forms and Processes. Rutledge, Chapman, and Hall, Inc. New York, NY.

Knighton, D. 1998. Fluvial Forms and Processes – A New Perspective. Arnold Publishers. London.

Lane, E. W. 1955. Design of stable channels. Transactions of the American Society of Civil Engineers. Paper No. 2776. pp. 1234-1279.

Leopold, L. B., M. G. Wolman and J. P. Miller. 1992. Fluvial Processes in Geomorphology. Dover Publications, Inc. New York, NY.

Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, Mass.

Lilly, J. P. 1981. The blackened soils of North Carolina: Their characteristics and management for agriculture. North Carolina Agricultural Research Service Technical Bulletin No. 270.

Lutz, H. J. 1940. Disturbance of forest soil resulting from the uprooting of trees. Yale University School of Forestry Bulletin No. 45.

Mausbach, M.J., J.L. Richardson. 1994. Biogeochemical Processes in Hydric Soil Formation. Current Topics in Wetland Biogeochemistry, Vol. 1, 1994, pp 68-124.

McCandless, T. L. 2003. Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Allegheny Plateau and the Valley and Ridge Hydrologic Regions. U.S. Fish and Wildlife Service, Annapolis, MD.

McCuskey, S. A., A. W. Conger, and H. O. Hillestad. 1994. Design and Implementation of Functional Wetland Mitigation: Case Studies in Ohio and South Carolina. Water, Air and Soil Pollution, 77(3):513-532.

Mitsch, W.J., and J.G. Gosselink. 2000. Wetlands. John Wiley & Sons, Inc., 920 pp.

Reed, Jr., Porter B. 1988. National List of Plant Species That Occur in Wetlands: National Summary. U.S. Fish & Wildlife Service. Biol. Rep. 88 (24). 244 pp.

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

Rosgen, D.L. 2001a. A stream channel stability assessment methodology. Proceedings of the Federal Interagency Sediment Conference, Reno, NV, March, 2001.

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

Rosgen, D.L., 1997. A geomorphological approach to restoration of incised rivers. In: Wang, S.S.Y, E.J. Langendoen, and F.D. Shields, Jr. (Eds.). Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision. pp. 12-22.

Rosgen, D.L., 1998. The Reference Reach - a Blueprint for Natural Channel Design. Draft Presented at ASCE Conference on River Restoration in Denver Colorado - March, 1998. ASCE. Reston, VA.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communities of North Carolina, Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, NCDEHNR, Raleigh, North Carolina.

Scherrer, E. 2000. Using microtopography to restore wetland plant communities in Eastern North Carolina. MS Thesis, Forestry Department, North Carolina State University.

Schumm, S.A., 1960. The Shape of Alluvial Channels in Relation to Sediment Type. U.S. Geological Survey Professional Paper 352-B. U.S. Geological Survey, Washigton, DC.

Sharitz, R. R., R. L. Schneider, and L. C. Lee. 1990. Composition and regeneration of a disturbed river floodplain forest in South Carolina. In Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems, 195-218. J. G. Gosselink, L. C. Lee, and T. A. Muir, eds. Boca Raton, Fla.: Lewis Publishers.

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

Skaggs, R. W., D. Amatya, R. O. Evans, and J. E. Parsons. 1991b. Methods for evaluating wetland hydrology. American Society of Agricultural Engineers, St. Joseph, MI. Paper No. 91-2590.

Skaggs, R. W., J. W. Gilliam, and R. O. Evans. 1991a. A computer simulations study of pocosin hydrology. Wetlands, 11, Special Issue, pp. 399-416.

Skaggs, R. W. 1980. DRAINMOD Reference Report: Methods for design and evaluation of drainage-water management systems for soils with high water tables. U. S. Department of Agriculture, Soil Conservation Service. 329 pp.

Soar and Thorne. 2001. Channel Restoration Design for Meandering Rivers. U.S. Army Corps of Engineers, Engineering Research and Development Center. Coastal and Hydraulics Laboratory, ERDC\CHL CR-01-1. September, 2001.

Stephens, E. P. 1956. The uprooting of trees: a forest process. Soil Science Society of America Proceedings 20:113-116.

Sweet, W.V. and J.W. Geratz. 2003. Bankfull Hydraulic Geometry Relationships and Recurrence Intervals for North Carolina's Coastal Plain. Journal of the American Water Resources Association 39(4):861-871.

United States Department of Agriculture, Soil Conservation Service (SCS). 1984. Soil Survey of Onslow County, North Carolina.

US Army Corps of Engineers Wetland Research Program (WRP). 1997. Technical Note VN-RS-4.1.

US Army Corps of Engineers Wetland Research Program (WRP). July 2000. Technical Notes ERDC TN-WRAP-00-02.

US Army Corps of Engineers. Environmental Laboratory. 1987. "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

US Army Corps of Engineers. Wetland Research Program (WRP). July 2000. Technical Notes ERDC TN-WRAP-00-02.

US Department of Agriculture, Natural Resources Conservation Service (NRCS). 1997. Part 650, Chapter 19 of the NRCS Engineering Field Handbook: Hydrology Tools for Wetland Determination.

US Department of Agriculture, Natural Resources Conservation Service (NRCS). 1996. Field Indicators of Hydric Soils in the United States. G.W. Hurt, Whited, P.M., and Pringle, R.F. (eds,). USDA, NRSCS, Forth Worth, TX.

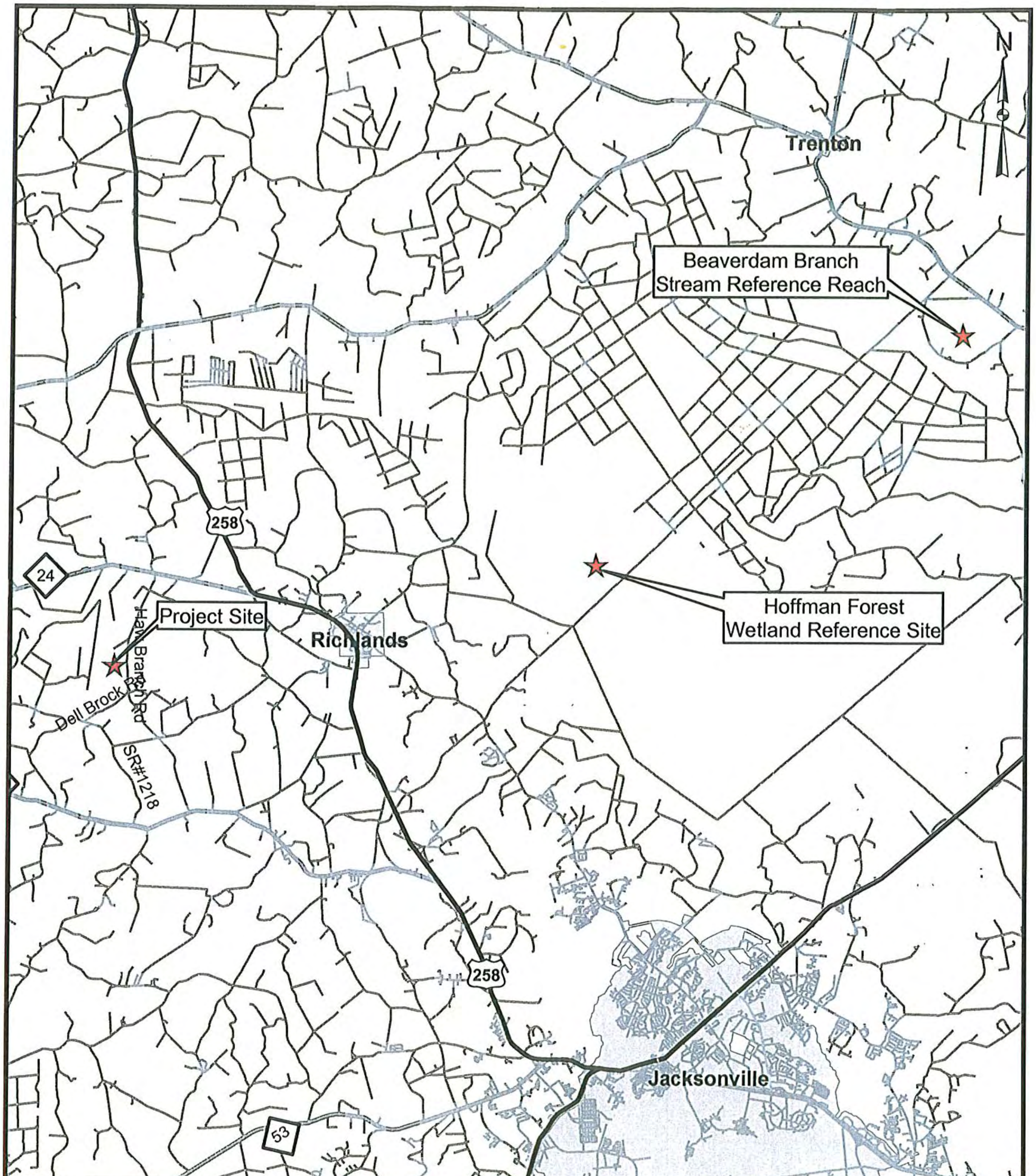
van Beers, W. F. J. 1970. The auger-hole method: a field measurement of hydraulic conductivity of soil below the water table. Rev. ed. ILRI Bulletin 1, Wageningen, 32 pp.

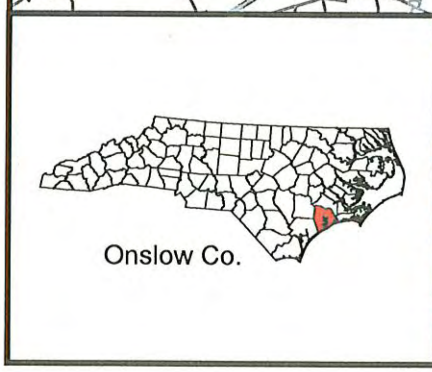
Vepraskas, M.J. 1996. Redoximorphic Features for Identifying Aquic Conditions. North Carolina Agricultural Research Service.

Wohl, E.E. 2000. Mountain Rivers. Am. Geophys. Union Press, 320 pp.

Wolman, M.G. and L.B. Leopold., 1957. River Floodplains: Some Observations on their Formation. USGS Professional Paper 282-C. U.S. Geological Survey, Washington, DC.

Exhibits

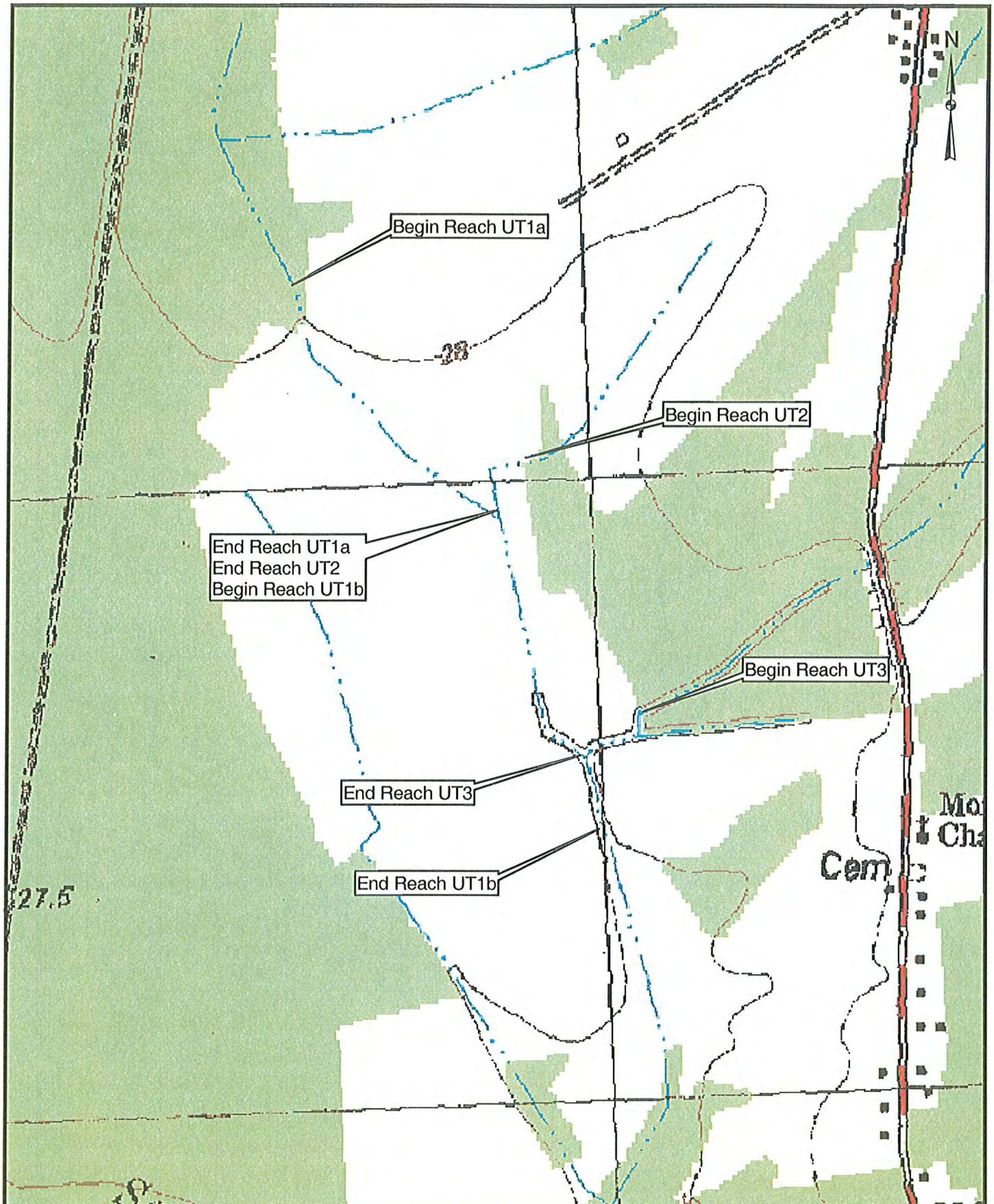




EBX
Environmental Banc and Exchange, LLC
220 Chatham Business Drive
Pittsboro, NC 27312

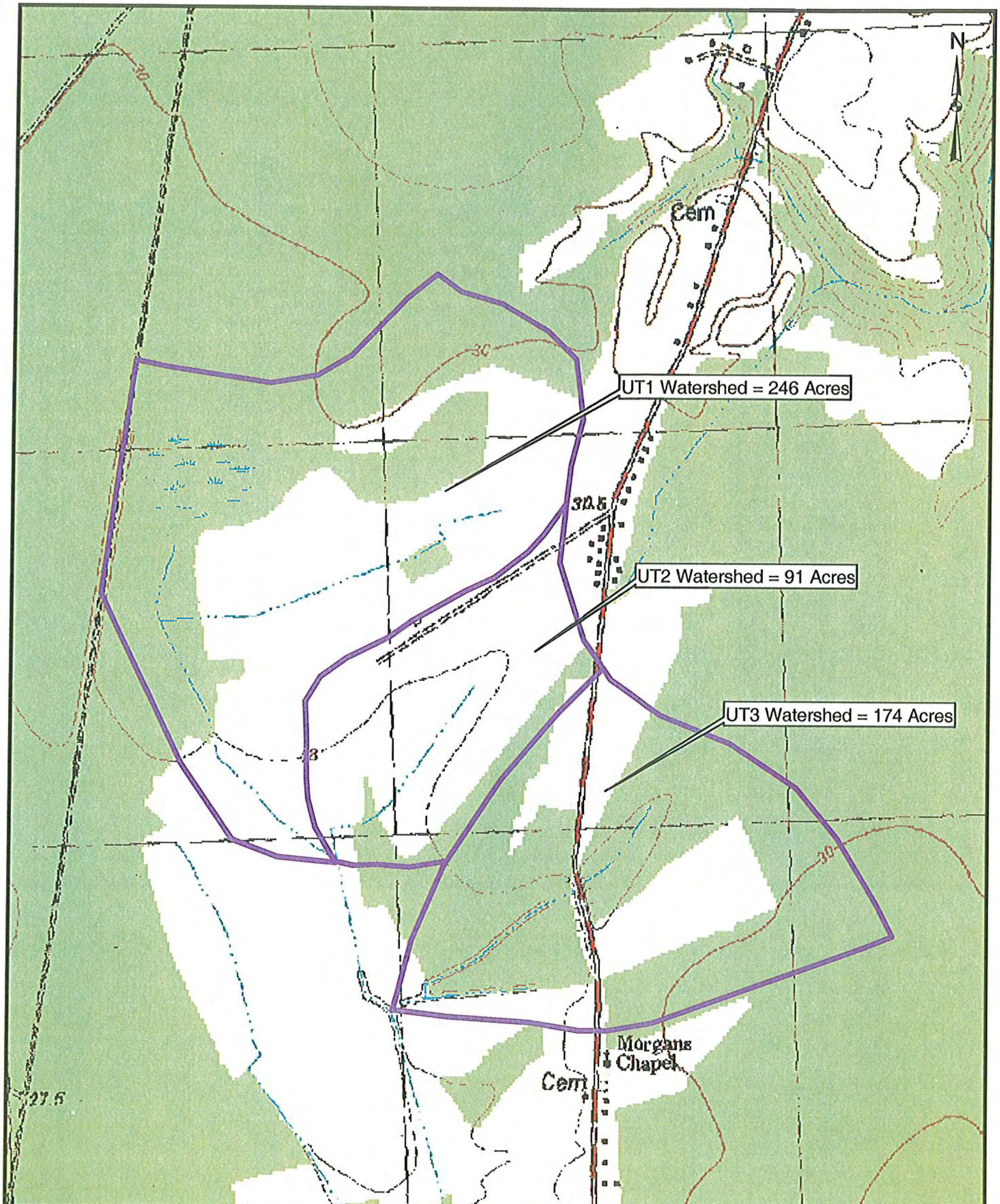
Exhibit 1.1. Project Vicinity Map
Haw Branch Site

0 1 2 4 6 Miles



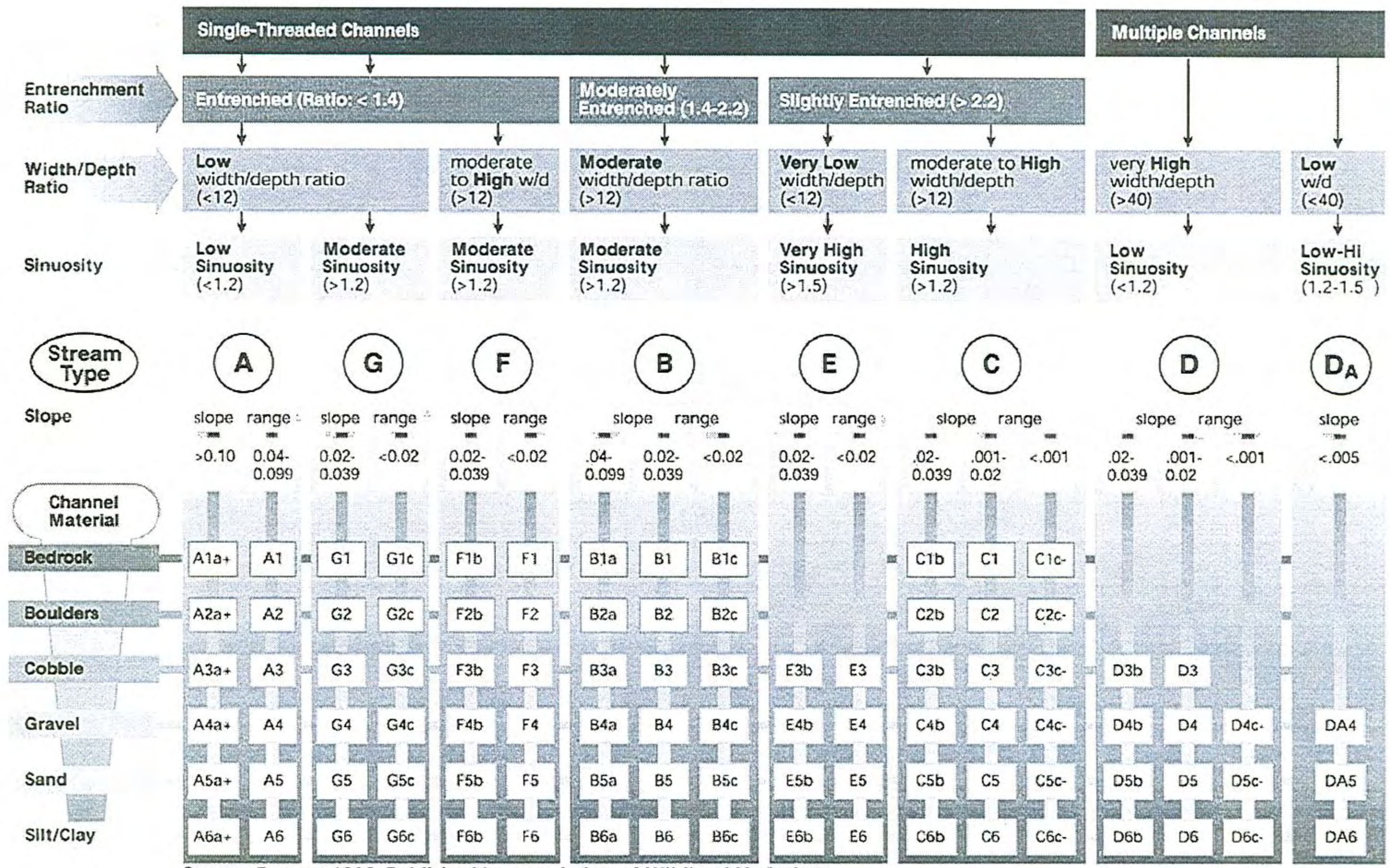
Environmental Banc and Exchange, LLC
220 Chatham Business Drive
Pittsboro, NC 27312

Exhibit 1.2. Site USGS Map
Haw Branch Site



Environmental Banc and Exchange, LLC
220 Chatham Business Drive
Pittsboro, NC 27312

Exhibit 1.3.
Project Watershed Boundaries
Haw Branch Site

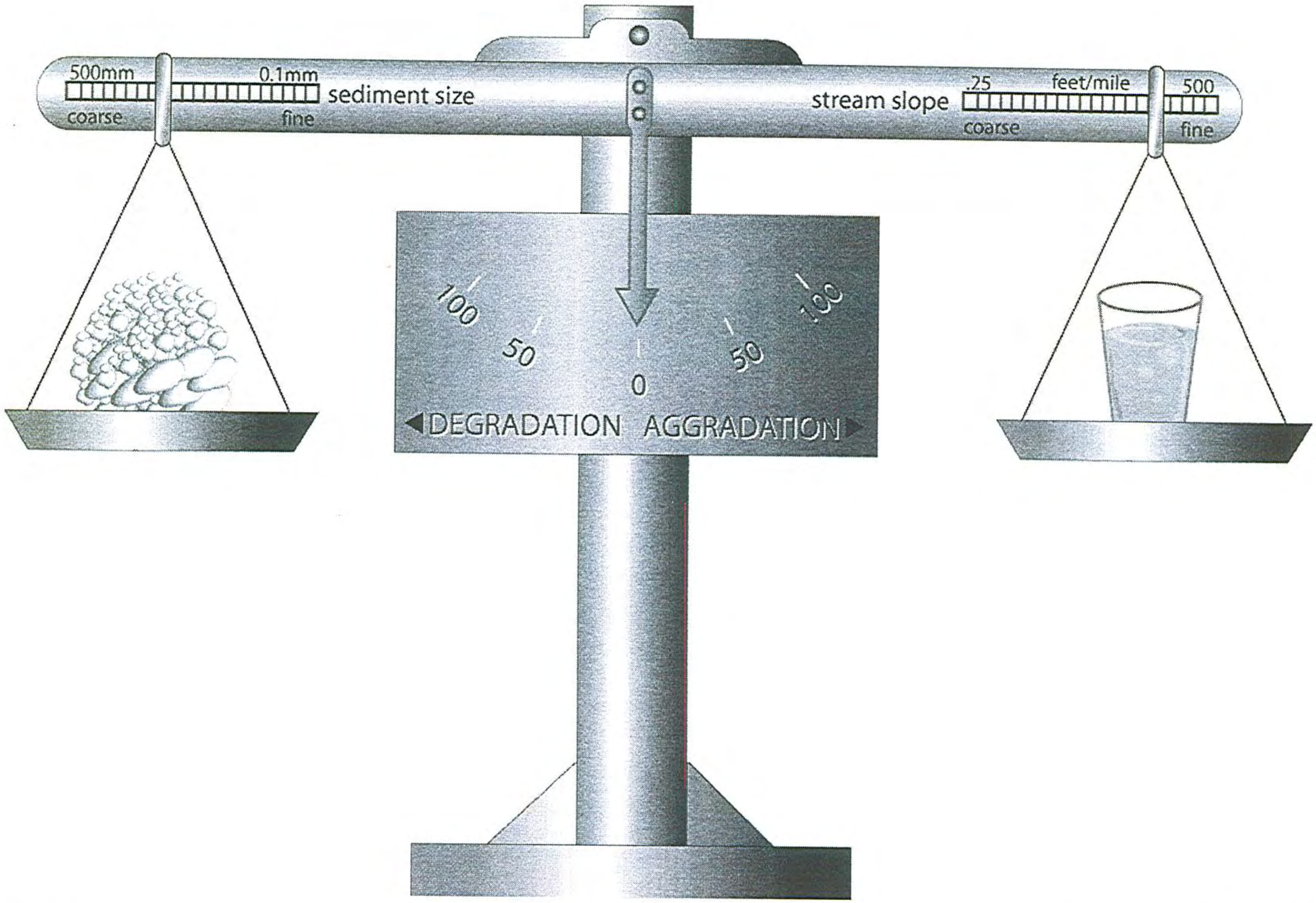


Source: Rosgen 1996. Published by permission of Wildland Hydrology.

Fig. 7.12 – Rosgen's stream classification system (Level II).
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

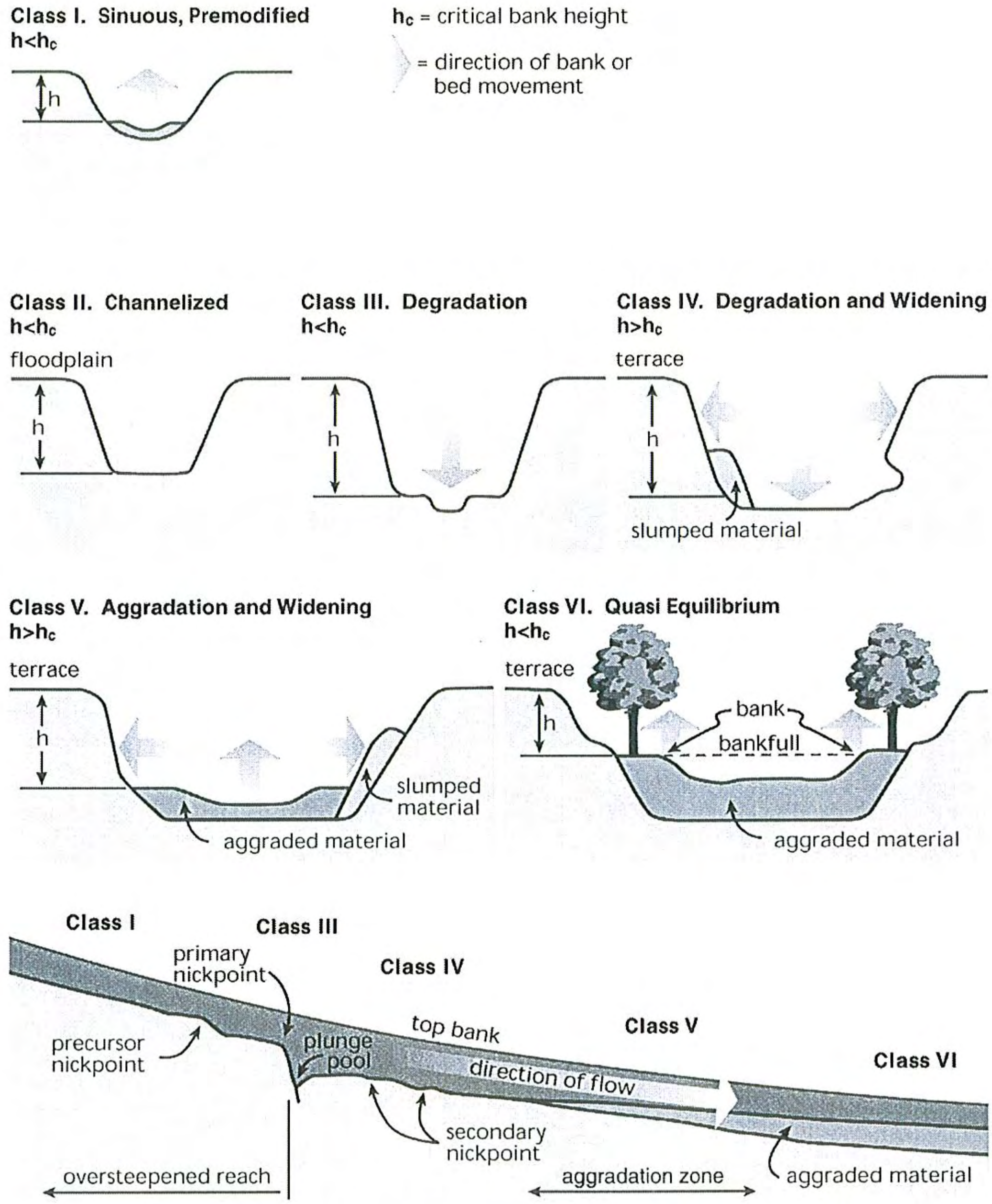
Exhibit 2.1
Rosgen Stream Classification
Haw Branch Restoration Plan

Source: Rosgen, David L., *Applied River Morphology*, Wildland Hydrology, 1996



After: Lane, 1955

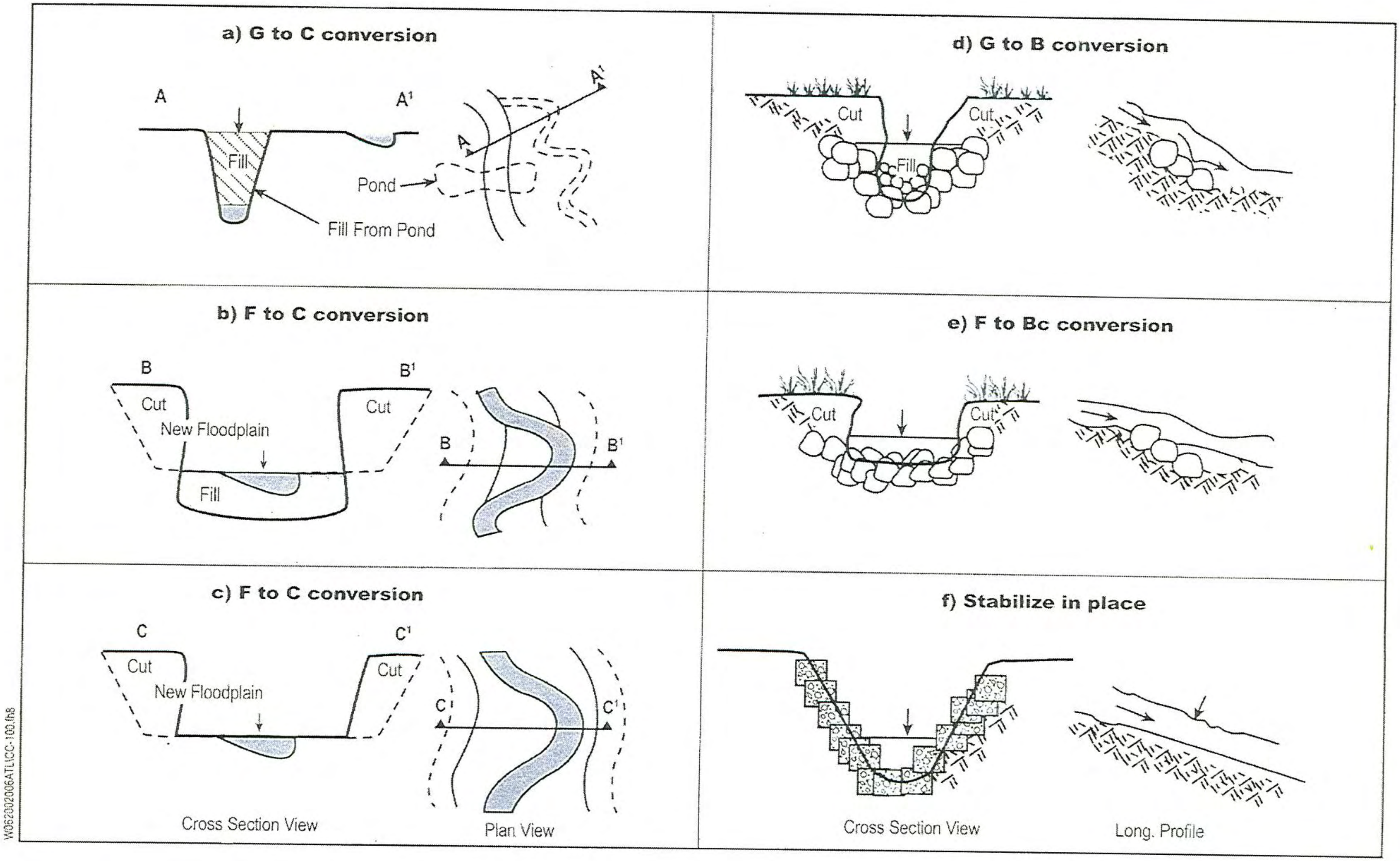
Exhibit 2.2
Factors Influencing Stream Stability



Source: Simon, 1989; US Army Corps of Engineers, 1990.
Fig. 7.14 -- Channel evolution model..
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

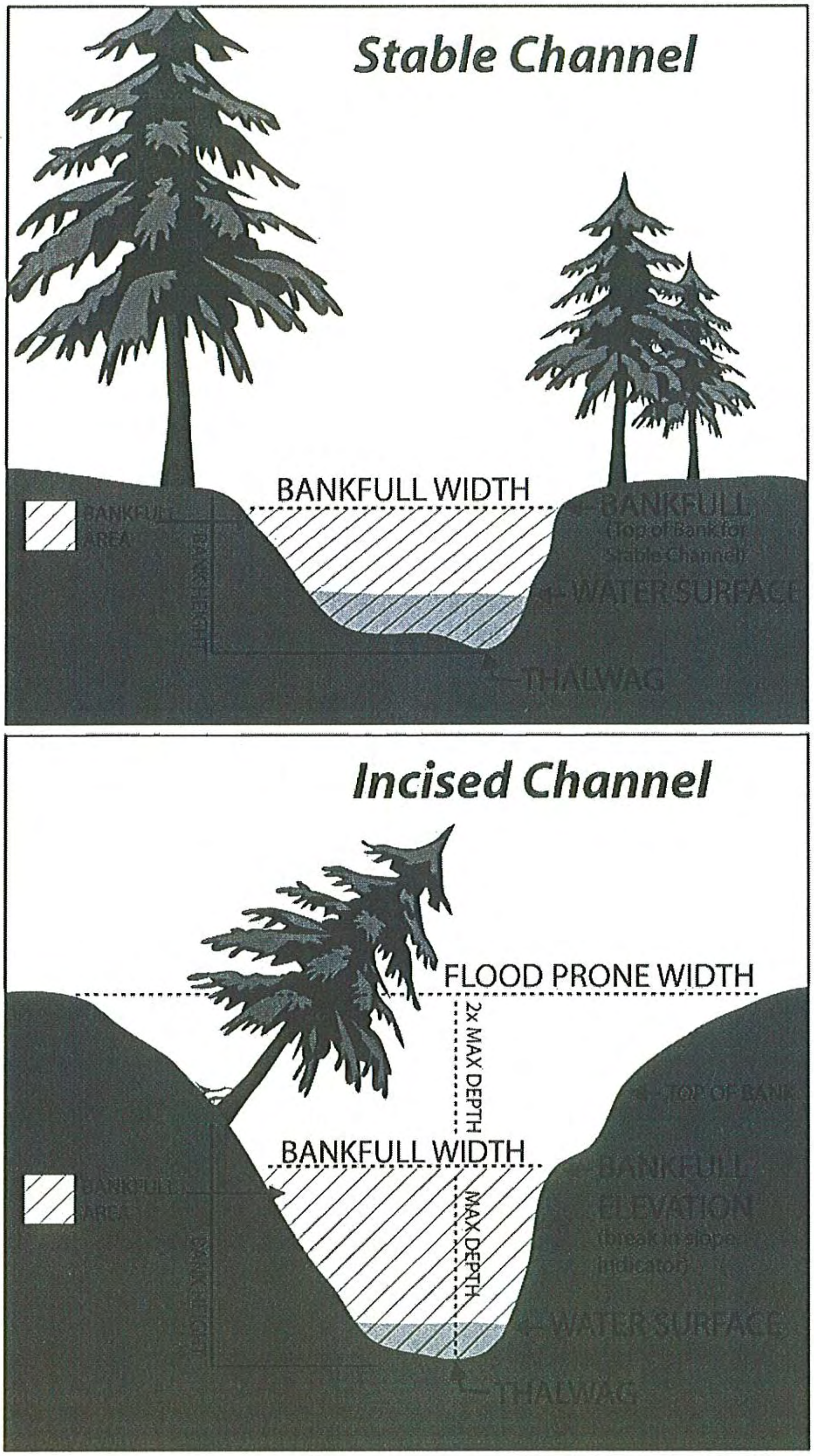
Exhibit 2.3
Simon Channel Evolution Model

Source: Simon, 1989



Source: Rosgen, David L., "A Geomorphological Approach to Restoration of Incised Rivers," *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*, 1997

Exhibit 2.4
Restoration Priorities for Incised Channels



Channel Dimension Measurements

Bankfull Elevation is associated with the channel forming discharge. It is the point where channel processes and flood plain processes begin.

Bankfull width: the distance between the left bank bankfull elevation and the right bank bankfull elevation

Bankfull mean depth: the average depth from bankfull elevation to the bottom of the stream channel

Max depth (dmax): the deepest point within the cross-section measured to the bankfull elevation

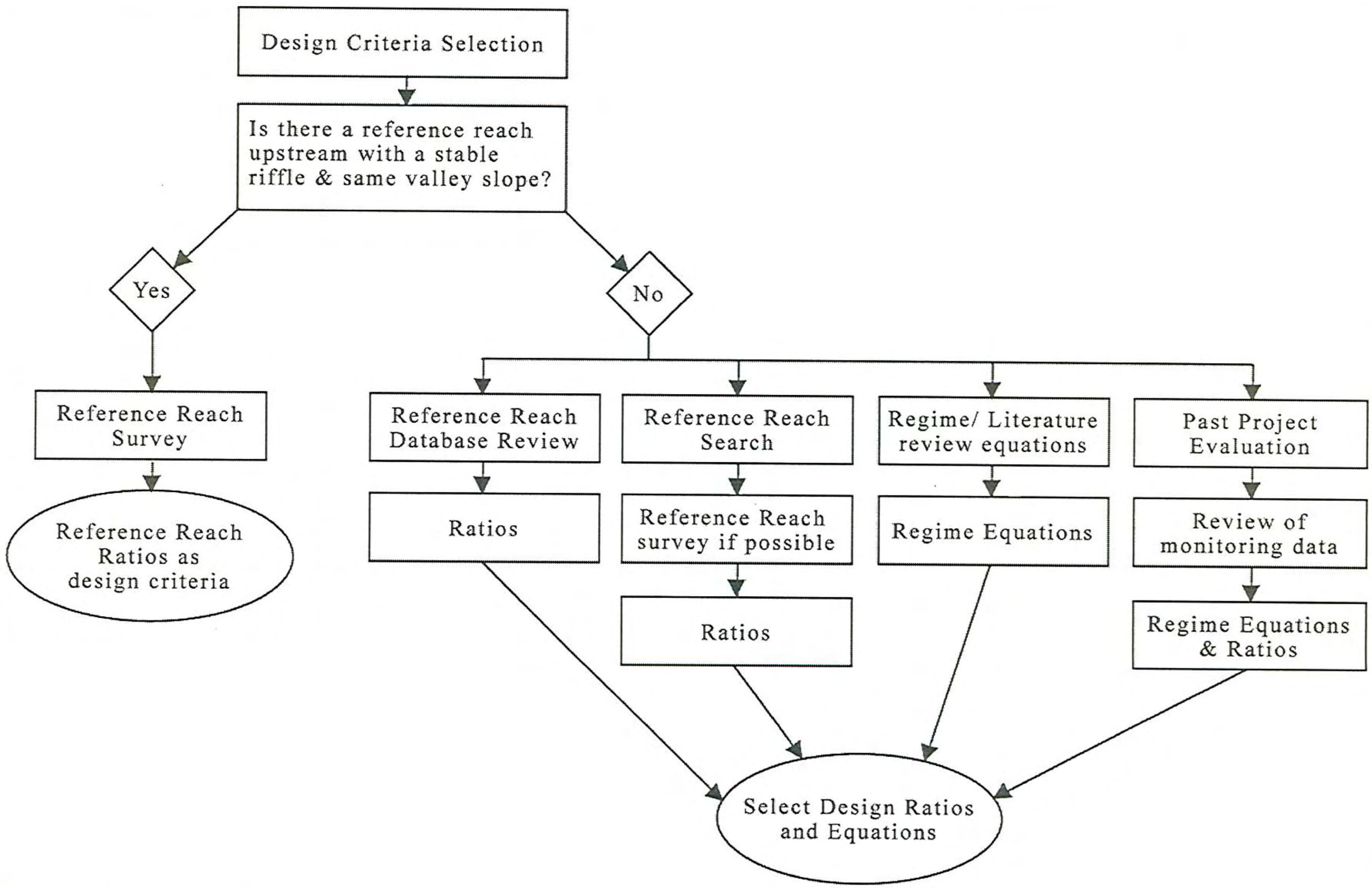
Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

Bank Height Ratio: Bank height (measured from top of bank to the bottom of the stream channel) ÷ the max depth of the bankfull elevation (dmax)

Flood Prone Width: Width measured at the elevation of two times (2x) the maximum depth at bankfull (dmax)

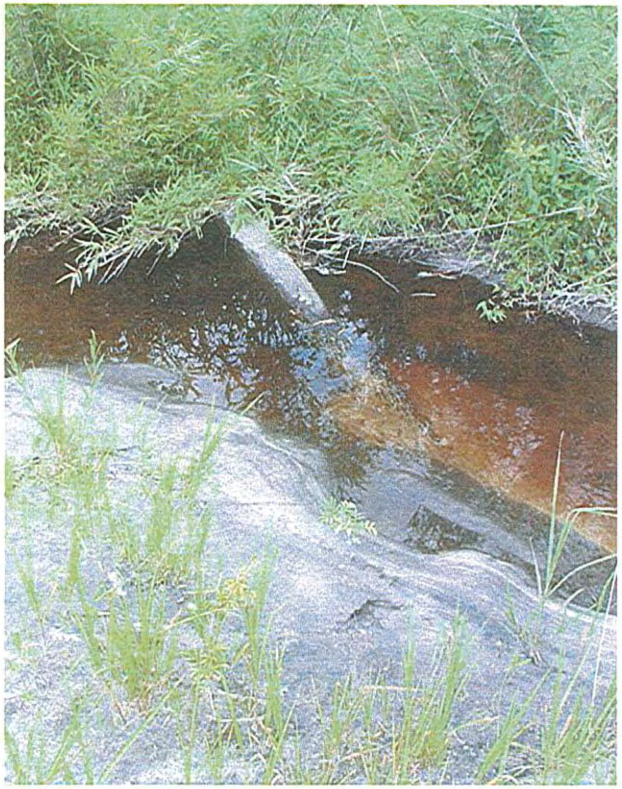
Entrenchment Ratio: Floodprone width ÷ bankfull width

Exhibit 2.5
Channel Dimension Measurements



BUCK ENGINEERING

Exhibit 2.6
Design Criteria Selection

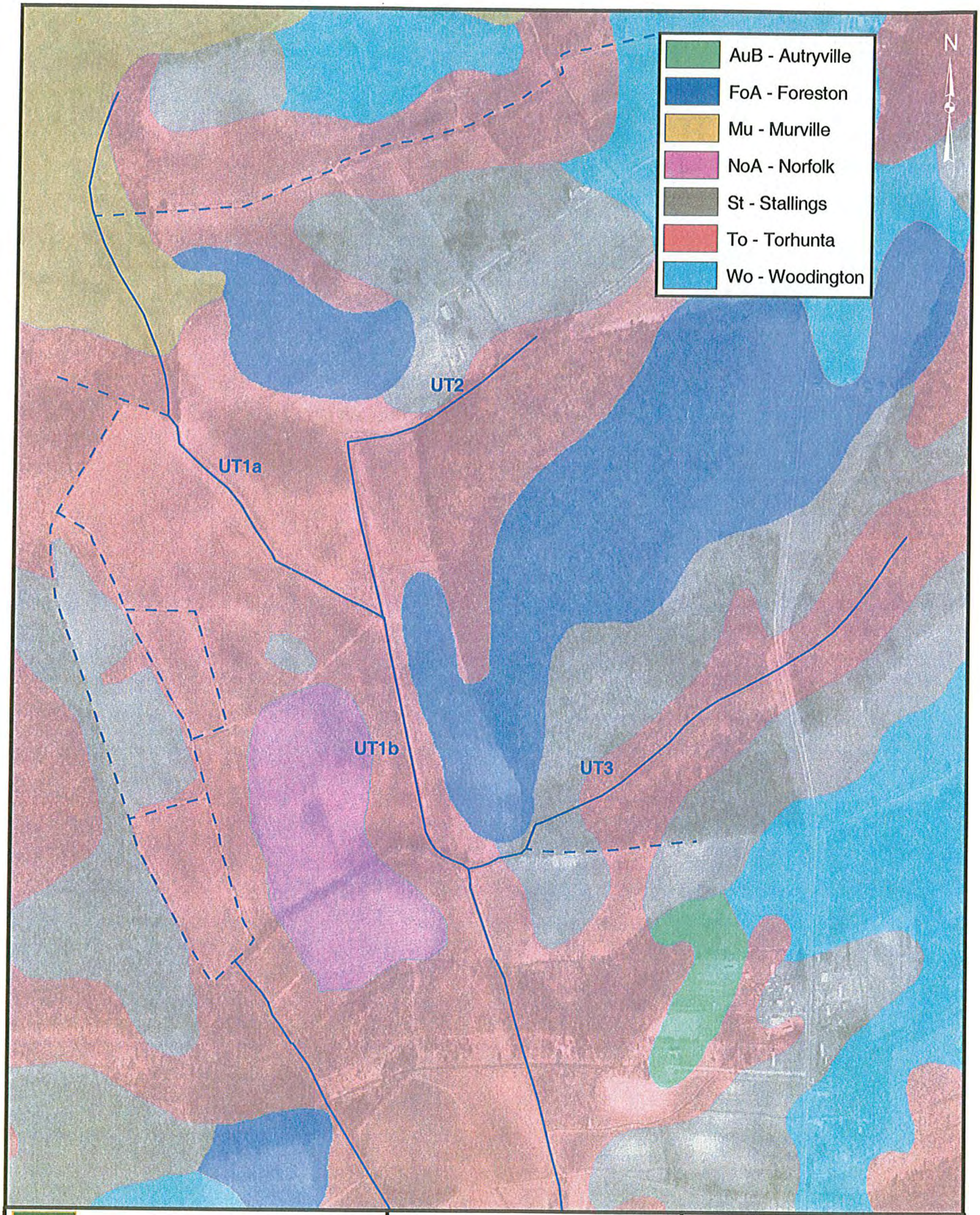


Log Vane

Log Weir

Root Wads

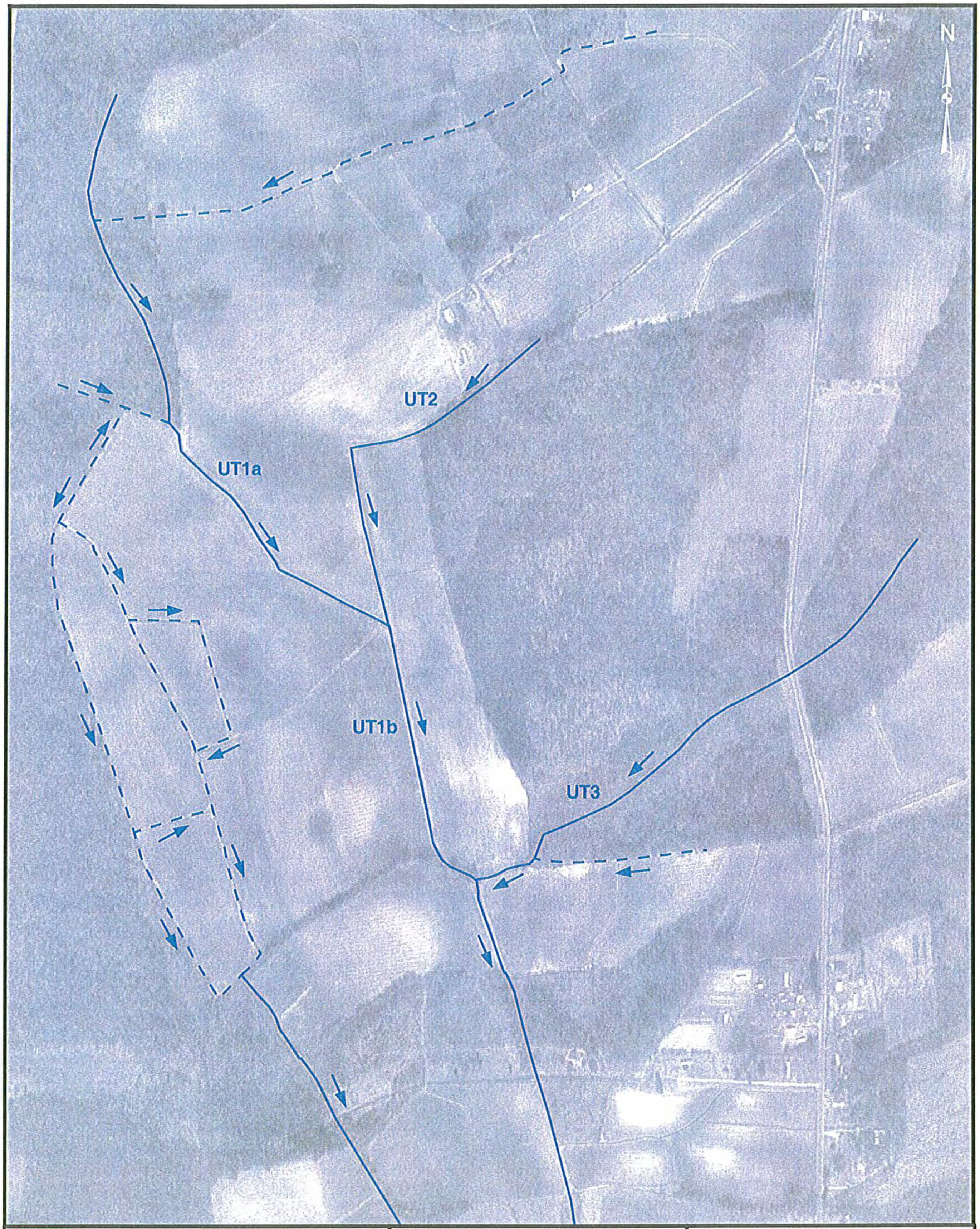
Exhibit 2.7
Examples of Instream Structures



EBX
Environmental Banc and Exchange, LLC
220 Chatham Business Drive
Pittsboro, NC 27312

0 500 1,000 Feet

Exhibit 3.1.
Project Site Soils Map
Haw Branch Site



EBX
Environmental Banc and Exchange, LLC
220 Chatham Business Drive
Pittsboro, NC 27312

Exhibit 4.1.
Site Hydrography Map
Haw Branch Site

Appendix 1

EDR Transaction Screen Map Report, SHPO Letter, and Natural Heritage Letter

The EDR-Transaction Screen™ Map Report
With Toxicheck/® Analysis

Haw Branch
Haw Branch Road
Beulaville, NC 28518

Inquiry Number: 01253166.1r

August 19, 2004

EDR™ Environmental Data Resources Inc

The Standard in Environmental Risk Management Information

440 Wheelers Farms Road
Milford, Connecticut 06460

Nationwide Customer Service

Telephone: 1-800-352-0050
Fax: 1-800-231-6802
Internet: www.edrnet.com

TABLE OF CONTENTS

Thank you for your business.
Please contact EDR at 1-800-352-0050
with any questions or comments.

TOXICHECK®

Subject Property: HAW BRANCH
HAW BRANCH ROAD
BEULAVILLE, NC 28518

Environmental Risk Code: **LOW**

This code results from the subject property not being listed in those databases as indicated in the Report and not located within : 1/2 mile of a reported Superfund Site (NPL) ; 1/2 mile of a reported Hazardous Waste Treatment, Storage or Disposal Facility (RCRIS-TSDF); 1/4 mile of a reported known or suspect CERCLIS hazardous waste site ; 1/4 mile of a reported known or suspect State Hazardous Waste site (SHWS); 1/2 mile of a reported Solid Waste Facility or Landfill (SWF/LF); or 1/8 mile of a site with a reported Leaking Underground Storage Tank incident (LUST).

This code is based solely on the results of searches of databases comprised of certain governmental records as made available to EDR and reflected in the attached report. Without further confirmation by completing the ASTM Standard E-1528 Transaction Screen and/or a Phase I Environmental Site Assessment, the conditions affecting the property are unknown. Further investigation by an environmental professional may be appropriate. **This Report is not a substitute for a Phase I Environmental Site Assessment conducted by an environmental professional .** Nothing in this Report should be construed to mean that any environmental remediation is or is not necessary with respect to the subject property.

If this information is being used for a commercial property transaction, the government records searched complies with the requirements of the ASTM Standard E-1528 Transaction Screen. However, the ASTM Standard's requirements are not fulfilled until the Applicant Questionnaire and Site Visit (including an investigation of the property's historical use) are completed and reviewed. If this information is being used for an industrial property transaction, the ASTM Standard requires that a Phase I Environmental Site Assessment be performed by an environmental professional.

EXECUTIVE SUMMARY

The EDR-Transaction Screen Map Report is a screening tool which maps sites with potential liability or existing environmental liabilities. Specified government databases are searched in accordance with ASTM Standard E 1528-00.

The ASTM E 1528-00 Transaction Screen property due diligence standard consists of four major components: a government records check, an historical inquiry, an owner/occupant questionnaire, and a site survey. This report contains the results of the government records search on the target property and surrounding area in accordance with the government records search requirements of the ASTM E 1528-00 standard.

The results of the government records search in accordance with **QUESTIONS 21 and 22** (page 15, E 1528-00) of the standard indicated the following:

QUESTION 21
*Do any of the following **Federal** government record systems list the property or any property within the circumference of the area noted below:*

National Priorities List (NPL)	☐ on the property	☐ Within 1 Mile
CERCLIS List	☐ on the property	☐ Within 1/2 Mile
CERCLIS NFRAP List	☐ on the property	☐ Within 1/4 Mile
RCRA-CORRACTS Facilities	☐ on the property	☐ Within 1 Mile
RCRA-TSD Non-CORRACTS Facilities	☐ on the property	☐ Within 1/2 Mile
RCRA LQG Facilities	☐ on the property	☐ Within 1/4 Mile
RCRA SQG Facilities	☐ on the property	☐ Within 1/4 Mile
ERNS	☐ on the property	

QUESTION 22
*Do any of the following **state** government record systems list the property or any property within the circumference of the area noted below:*

State equivalent to NPL	☐ on the property	☐ Within 1 Mile
State equivalent to CERCLIS	☐ on the property	☐ Within 1/2 Mile
Solid Waste/Landfill Facilities (SWF/LS)	☐ on the property	☐ Within 1/2 Mile
Leaking Underground Storage Tank List (LUST)	☐ on the property	☐ Within 1/2 Mile
Underground Storage Tank List (UST)	☐ on the property	☐ Within 1/4 Mile

*In accordance with Section 5.6 (page 10, E 1528) if the answer is **(yes) or unknown,** then the user will have to decide what further action, if any, is appropriate. Answers should be evaluated in light of the other information obtained in the transaction screen process. If the user decides no further inquiry is warranted, the rationale must be documented. If the user decides that further inquiry is warranted, it may be necessary to contact an environmental professional.*

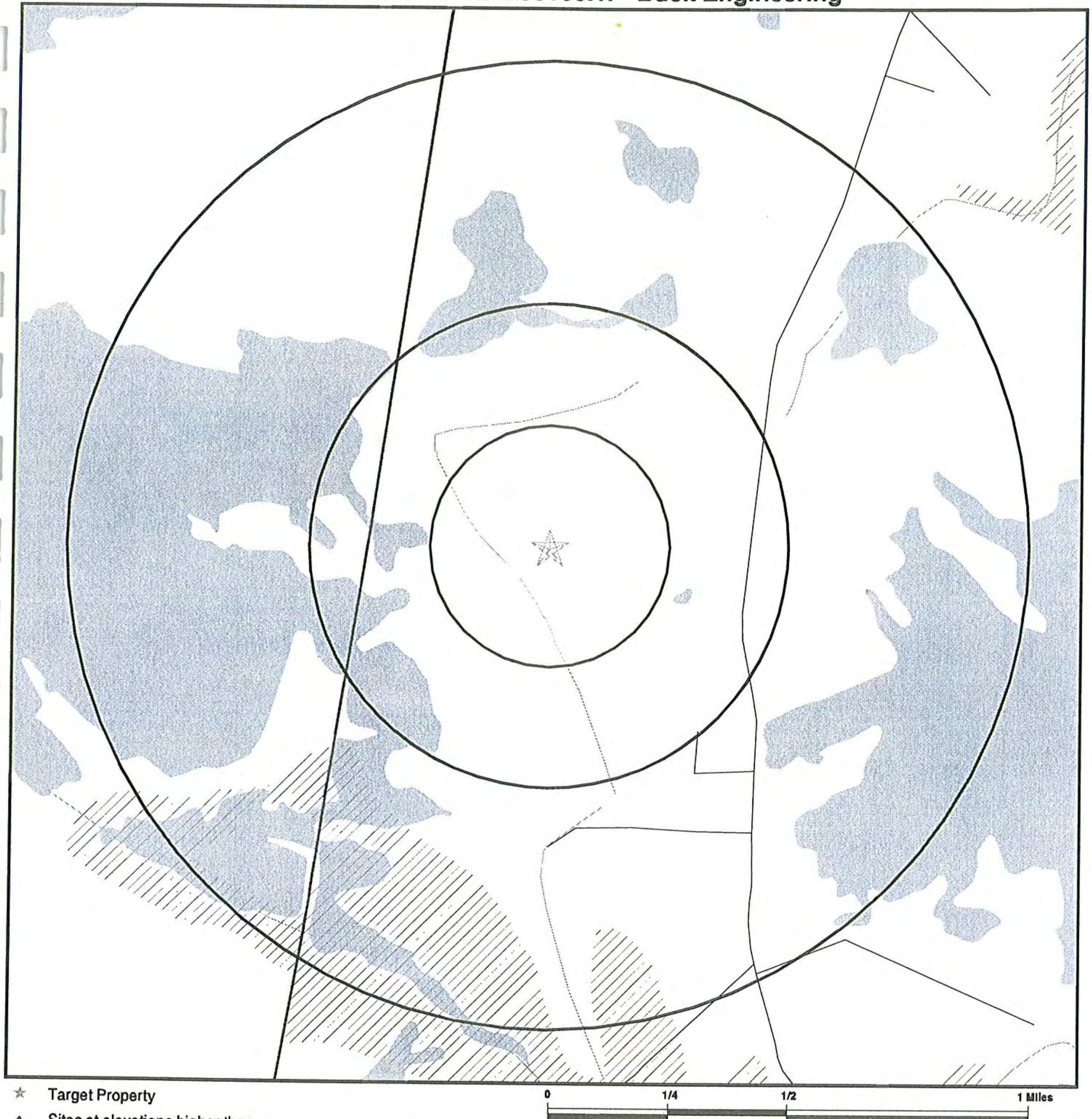
Additional Research - ASTM Supplemental Government Databases

To provide additional information which may assist in the assessment of other components of the ASTM E 1528-00 Transaction Screen, EDR also searches government databases ***not*** included in Questions 21 and 22 of ASTM E 1528-00. This information may be useful in completing the owner/occupant questionnaire.

The results of the search of these additional government records indicated affirmative **(yes)** responses on the target property for the following government databases:

No affirmative responses found in the non-ASTM E 1528-00 government databases.

OVERVIEW MAP - 01253166.1r - Buck Engineering



- ☆ Target Property
- ▲ Sites at elevations higher than or equal to the target property
- ◆ Sites at elevations lower than the target property
- Coal Gasification Sites
- National Priority List Sites
- Landfill Sites
- Dept. Defense Sites
- Indian Reservations BIA
- County Boundary
- Oil & Gas pipelines
- 100-year flood zone
- 500-year flood zone
- Federal Wetlands
- Hazardous Substance Disposal Sites

TARGET PROPERTY:	Haw Branch	CUSTOMER:	Buck Engineering
ADDRESS:	Haw Branch Road	CONTACT:	Staci Ricks
CITY/STATE/ZIP:	Beulaville NC 28518	INQUIRY #:	01253166.1r
LAT/LONG:	34.8933 / 77.6500	DATE:	August 19, 2004 12:28 pm

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
FEDERAL ASTM STANDARD								
NPL		1.000	0	0	0	0	NR	0
Proposed NPL		1.000	0	0	0	0	NR	0
CERCLIS		0.500	0	0	0	NR	NR	0
CERC-NFRAP		0.250	0	0	NR	NR	NR	0
CORRACTS		1.000	0	0	0	0	NR	0
RCRIS-TSD		0.500	0	0	0	NR	NR	0
RCRIS Lg. Quan. Gen.		0.250	0	0	NR	NR	NR	0
RCRIS Sm. Quan. Gen.		0.250	0	0	NR	NR	NR	0
ERNS		TP	NR	NR	NR	NR	NR	0
STATE ASTM STANDARD								
State Haz. Waste		1.000	0	0	0	0	NR	0
State Landfill		0.500	0	0	0	NR	NR	0
LUST		0.500	0	0	0	NR	NR	0
UST		0.250	0	0	NR	NR	NR	0
OLI		0.500	0	0	0	NR	NR	0
INDIAN UST		0.250	0	0	NR	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0
FEDERAL ASTM SUPPLEMENTAL								
Delisted NPL		1.000	0	0	0	0	NR	0
FINDS		TP	NR	NR	NR	NR	NR	0
HMIRS		TP	NR	NR	NR	NR	NR	0
MLTS		TP	NR	NR	NR	NR	NR	0
MINES		TP	NR	NR	NR	NR	NR	0
NPL Liens		TP	NR	NR	NR	NR	NR	0
PADS		TP	NR	NR	NR	NR	NR	0
UMTRA		0.500	0	0	0	NR	NR	0
FUDS		1.000	0	0	0	0	NR	0
INDIAN RESERV		1.000	0	0	0	0	NR	0
US BROWNFIELDS		0.500	0	0	0	NR	NR	0
DOD		1.000	0	0	0	0	NR	0
RAATS		TP	NR	NR	NR	NR	NR	0
TRIS		TP	NR	NR	NR	NR	NR	0
TSCA		TP	NR	NR	NR	NR	NR	0
SSTS		TP	NR	NR	NR	NR	NR	0
FTTS		TP	NR	NR	NR	NR	NR	0
STATE OR LOCAL ASTM SUPPLEMENTAL								
NC HSDS		1.000	0	0	0	0	NR	0
AST		TP	NR	NR	NR	NR	NR	0
LUST TRUST		0.500	0	0	0	NR	NR	0
DRYCLEANERS		0.250	0	0	NR	NR	NR	0

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
IMD		TP	NR	NR	NR	NR	NR	0
EDR PROPRIETARY HISTORICAL DATABASES								
Coal Gas		1.000	0	0	0	0	NR	0
BROWNFIELDS DATABASES								
US BROWNFIELDS		0.500	0	0	0	NR	NR	0
Brownfields		0.500	0	0	0	NR	NR	0
INST CONTROL		0.500	0	0	0	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0

NOTES:

TP = Target Property

NR = Not Requested at this Search Distance

Sites may be listed in more than one database

MAP FINDINGS

Map ID Direction Distance Distance (ft.) Elevation	Site	Database(s)	EDR ID Number EPA ID Number

Coal Gas Site Search: No site was found in a search of Real Property Scan's ENVIROHAZ database.

NO SITES FOUND

ORPHAN SUMMARY

City	EDR ID	Site Name	Site Address	Zip	Database(s)
BEULAVILLE	S106204765	EARL BLIZZARD-UST	RT. 1 BOX 269	28518	LUST
BEULAVILLE	U001195964	EARL BLIZZARD	RT 1,BOX 269	28518	UST
BEULAVILLE	S103717376	J.D. KENNEDY GROCERY	HWY 111 / 1700	28518	IMD, LUST
BEULAVILLE	U001196149	CEDAR FORK GROCERY & GRILL	S.R. 1715	28518	UST
BEULAVILLE	U001196517	LINWOOD RALPH KENNEDY	RT 2 BOX 33	28518	UST
BEULAVILLE	U001196128	HALL'S PETROLEUM EQUIPMENT CO	ROUTE 2, BOX 188-C	28518	UST
BEULAVILLE	U003144948	DESSIE THIGPEN	ROUTE 2, BOX 369	28518	UST
BEULAVILLE	S104914314	JARMAN OIL CO.	HWY 24 E	28518	IMD, LUST
BEULAVILLE	U003144860	JARMAN OIL CO.	HWY 24 EAST P.O. BOX 96	28518	UST
BEULAVILLE	S105766240	NORWOOD MILLER PROPERTY (DOT)	HWY 24-SR 1702	28518	IMD, LUST
BEULAVILLE	S105896214	NC DOT RIGHT OF WAY-B	NC 24-SR 1701	28518	LUST
BEULAVILLE	S101522770	SPEEDY MART-UST LEAK #2	HWY 41	28518	IMD, LUST, LUST TRUST
BEULAVILLE	S105766039	MOORE'S MINI MART # 3	HWY 41 S	28518	IMD, LUST
BEULAVILLE	S105766103	SPEEDY MART-KEROSENE	HWY 41	28518	IMD, LUST
BEULAVILLE	S105766362	SPEEDY MART	HWY 41	28518	IMD, LUST
BEULAVILLE	U001189500	MOORES MINI MART #3	HIGHWAY 41 SOUTH	28518	UST
BEULAVILLE	U001958842	RHODES GRILL	HWY 41 & 111	28518	IMD, LUST, UST
BEULAVILLE	U001958939	NC ARMY NATIONAL GUARD ARMORY	HWY 415 & JACKSON AVENUE	28518	UST
BEULAVILLE	S105766387	KENNEDY INCIDENT	BOX 33 RT. 2	28518	IMD, LUST
BEULAVILLE	S105896107	HALLS PETROLEUM EQUIPMENT CO.	BOX 188 C RT. 2	28518	LUST
BEULAVILLE	U001204105	THOMAS & HORNE OIL CO INC	PO BOX 171 (INTER HWY 24 & 41)	28518	UST
BEULAVILLE	U003144947	BEULAVILLE DRY CLEANERS	P.O. BOX 1016 - HIGHWAY 41 SOUTH	28518	UST
BEULAVILLE	S104914239	THIGPEN CENTER	MAIN ST. / HWY 41	28518	IMD, LUST, LUST TRUST
POTTERS HILL	U001196143	QUINNS SUPER VALUE	ROUTE 1	28518	UST
RICHLAND	S105218561	RICHLANDS SUNOCO	HIGHWAY 258	28574	LUST TRUST
RICHLANDS	S106204772	FOUNTAIN BROTHERS	HWY 111	28574	LUST
RICHLANDS	S106204825	NINE MILE GROCERY	HWY 111	28574	LUST
RICHLANDS	U001200848	GUYLIE FOUNTAIN	RT 2	28574	IMD, LUST, UST
RICHLANDS	S105766354	DESSULT PROPERTY	HWY 24	28574	IMD, LUST
RICHLANDS	S105896278	RICHLANDS EXXON	HWY. 24	28574	LUST
RICHLANDS	S101573478	HANDY MART	RT 258	28574	IMD, LUST
RICHLANDS	S103717689	K & M SHELL	HWY 258 / NC 24	28574	IMD, LUST
RICHLANDS	S105548403	RHODESTOWN GROCERY	HWY 258	28574	IMD, LUST
RICHLANDS	S105922633	RHODESTOWN GROCERY	HWY 258 N	28574	LUST TRUST
RICHLANDS	U001199160	LARRY'S GARAGE	HIGHWAY 258	28574	IMD, LUST, UST
RICHLANDS	U001199162	ONSLOW FEED AND GRAIN	HIGHWAY 258	28574	IMD, LUST, UST
RICHLANDS	U001202900	SUPER MART	HWY 258 BYPASS	28574	IMD, LUST, UST
RICHLANDS	S101573480	CATHERINE LAKE GROCERY	RT. 3	28574	IMD, LUST
RICHLANDS	S105593112	HARGETTS STORE	HWY 41 / US 258	28574	LUST TRUST

AREA RADON INFORMATION

- Federal EPA Radon Zone for DUPLIN County, NC: 3

Note : Zone 1 indoor average level > 4 pCi/L.
: Zone 2 indoor average level >= 2 pCi/L and <= 4 pCi/L.
: Zone 3 indoor average level < 2 pCi/L.

- Federal Area Radon Information for DUPLIN County, NC

Number of sites tested: 8

Area	Average Activity	% <4 pCi/L	% 4-20 pCi/L	% >20 pCi/L
Living Area - 1st Floor	0.488 pCi/L	100%	0%	0%
Living Area - 2nd Floor	Not Reported	Not Reported	Not Reported	Not Reported
Basement	Not Reported	Not Reported	Not Reported	Not Reported

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

To maintain currency of the following federal and state databases, EDR contacts the appropriate governmental agency on a monthly or quarterly basis, as required.

Elapsed ASTM days: Provides confirmation that this EDR report meets or exceeds the 90-day updating requirement of the ASTM standard.

FEDERAL ASTM STANDARD RECORDS

NPL: National Priority List
Source: EPA
Telephone: N/A
National Priorities List (Superfund). The NPL is a subset of CERCLIS and identifies over 1,200 sites for priority cleanup under the Superfund Program. NPL sites may encompass relatively large areas. As such, EDR provides polygon coverage for over 1,000 NPL site boundaries produced by EPA's Environmental Photographic Interpretation Center (EPIC) and regional EPA offices.

Date of Government Version: 04/27/04
Date Made Active at EDR: 05/21/04
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 05/04/04
Elapsed ASTM days: 17
Date of Last EDR Contact: 05/04/04

NPL Site Boundaries

Sources:

EPA's Environmental Photographic Interpretation Center (EPIC)
Telephone: 202-564-7333

EPA Region 1
Telephone 617-918-1143

EPA Region 3
Telephone 215-814-5418

EPA Region 4
Telephone 404-562-8033

EPA Region 6
Telephone: 214-655-6659

EPA Region 8
Telephone: 303-312-6774

Proposed NPL: Proposed National Priority List Sites
Source: EPA
Telephone: N/A

Date of Government Version: 04/27/04
Date Made Active at EDR: 05/21/04
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 05/04/04
Elapsed ASTM days: 17
Date of Last EDR Contact: 05/04/04

CERCLIS: Comprehensive Environmental Response, Compensation, and Liability Information System
Source: EPA
Telephone: 703-413-0223
CERCLIS contains data on potentially hazardous waste sites that have been reported to the USEPA by states, municipalities, private companies and private persons, pursuant to Section 103 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLIS contains sites which are either proposed to or on the National Priorities List (NPL) and sites which are in the screening and assessment phase for possible inclusion on the NPL.

Date of Government Version: 05/17/04
Date Made Active at EDR: 08/10/04
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 06/23/04
Elapsed ASTM days: 48
Date of Last EDR Contact: 06/23/04

CERCLIS-NFRAP: CERCLIS No Further Remedial Action Planned
Source: EPA
Telephone: 703-413-0223
As of February 1995, CERCLIS sites designated "No Further Remedial Action Planned" (NFRAP) have been removed from CERCLIS. NFRAP sites may be sites where, following an initial investigation, no contamination was found, contamination was removed quickly without the need for the site to be placed on the NPL, or the contamination was not serious enough to require Federal Superfund action or NPL consideration. EPA has removed approximately 25,000 NFRAP sites to lift the unintended barriers to the redevelopment of these properties and has archived them as historical records so EPA does not needlessly repeat the investigations in the future. This policy change is part of the EPA's Brownfields Redevelopment Program to help cities, states, private investors and affected citizens to promote economic redevelopment of unproductive urban sites.

Date of Government Version: 05/17/04
Date Made Active at EDR: 08/10/04
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 06/23/04
Elapsed ASTM days: 48
Date of Last EDR Contact: 06/23/04

CORRACTS: Corrective Action Report
Source: EPA
Telephone: 800-424-9346
CORRACTS identifies hazardous waste handlers with RCRA corrective action activity.

Date of Government Version: 06/15/04
Date Made Active at EDR: 08/10/04
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 06/25/04
Elapsed ASTM days: 46
Date of Last EDR Contact: 06/07/04

RCRIS: Resource Conservation and Recovery Information System
Source: EPA
Telephone: 800-424-9346
Resource Conservation and Recovery Information System. RCRIS includes selective information on sites which generate, transport, store, treat and/or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). Conditionally exempt small quantity generators (CESQGs): generate less than 100 kg of hazardous waste, or less than 1 kg of acutely hazardous waste per month. Small quantity generators (SQGs): generate between 100 kg and 1,000 kg of hazardous waste per month. Large quantity generators (LQGs): generate over 1,000 kilograms (kg) of hazardous waste, or over 1 kg of acutely hazardous waste per month. Transporters are individuals or entities that move hazardous waste from the generator off-site to a facility that can recycle, treat, store, or dispose of the waste. TSDFs treat, store, or dispose of the waste.

Date of Government Version: 06/15/04
Date Made Active at EDR: 07/20/04
Database Release Frequency: Varies

Date of Data Arrival at EDR: 06/23/04
Elapsed ASTM days: 27
Date of Last EDR Contact: 06/23/04

ERNS: Emergency Response Notification System
Source: National Response Center, United States Coast Guard
Telephone: 202-260-2342
Emergency Response Notification System. ERNS records and stores information on reported releases of oil and hazardous substances.

Date of Government Version: 12/31/03
Date Made Active at EDR: 03/12/04
Database Release Frequency: Annually

Date of Data Arrival at EDR: 01/26/04
Elapsed ASTM days: 46
Date of Last EDR Contact: 07/26/04

FEDERAL ASTM SUPPLEMENTAL RECORDS

BRS: Biennial Reporting System
Source: EPA/NTIS
Telephone: 800-424-9346
The Biennial Reporting System is a national system administered by the EPA that collects data on the generation and management of hazardous waste. BRS captures detailed data from two groups: Large Quantity Generators (LQG) and Treatment, Storage, and Disposal Facilities.

Date of Government Version: 12/01/01
Database Release Frequency: Biennially

Date of Last EDR Contact: 06/22/04
Date of Next Scheduled EDR Contact: 09/13/04

DELISTED NPL: National Priority List Deletions
Source: EPA
Telephone: N/A
The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) establishes the criteria that the EPA uses to delete sites from the NPL. In accordance with 40 CFR 300.425.(e), sites may be deleted from the NPL where no further response is appropriate.

Date of Government Version: 04/27/04
Database Release Frequency: Quarterly
Date of Last EDR Contact: 05/04/04
Date of Next Scheduled EDR Contact: 08/02/04

FINDS: Facility Index System/Facility Identification Initiative Program Summary Report
Source: EPA
Telephone: N/A
Facility Index System. FINDS contains both facility information and 'pointers' to other sources that contain more detail. EDR includes the following FINDS databases in this report: PCS (Permit Compliance System), AIRS (Aerometric Information Retrieval System), DOCKET (Enforcement Docket used to manage and track information on civil judicial enforcement cases for all environmental statutes), FURS (Federal Underground Injection Control), C-DOCKET (Criminal Docket System used to track criminal enforcement actions for all environmental statutes), FFIS (Federal Facilities Information System), STATE (State Environmental Laws and Statutes), and PADS (PCB Activity Data System).

Date of Government Version: 04/08/04
Database Release Frequency: Quarterly
Date of Last EDR Contact: 07/06/04
Date of Next Scheduled EDR Contact: 10/04/04

HMIRS: Hazardous Materials Information Reporting System
Source: U.S. Department of Transportation
Telephone: 202-366-4555
Hazardous Materials Incident Report System. HMIRS contains hazardous material spill incidents reported to DOT.

Date of Government Version: 02/17/04
Database Release Frequency: Annually
Date of Last EDR Contact: 04/20/04
Date of Next Scheduled EDR Contact: 07/19/04

MLTS: Material Licensing Tracking System
Source: Nuclear Regulatory Commission
Telephone: 301-415-7169
MLTS is maintained by the Nuclear Regulatory Commission and contains a list of approximately 8,100 sites which possess or use radioactive materials and which are subject to NRC licensing requirements. To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 04/19/04
Database Release Frequency: Quarterly
Date of Last EDR Contact: 07/06/04
Date of Next Scheduled EDR Contact: 10/04/04

MINES: Mines Master Index File
Source: Department of Labor, Mine Safety and Health Administration
Telephone: 303-231-5959

Date of Government Version: 03/05/04
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 06/30/04
Date of Next Scheduled EDR Contact: 09/27/04

NPL LIENS: Federal Superfund Liens
Source: EPA
Telephone: 202-564-4267
Federal Superfund Liens. Under the authority granted the USEPA by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, the USEPA has the authority to file liens against real property in order to recover remedial action expenditures or when the property owner receives notification of potential liability. USEPA compiles a listing of filed notices of Superfund Liens.

Date of Government Version: 10/15/91
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 05/24/04
Date of Next Scheduled EDR Contact: 08/23/04

PADS: PCB Activity Database System
Source: EPA
Telephone: 202-564-3887
PCB Activity Database. PADS Identifies generators, transporters, commercial storers and/or brokers and disposers of PCB's who are required to notify the EPA of such activities.

Date of Government Version: 03/30/04
Database Release Frequency: Annually
Date of Last EDR Contact: 05/12/04
Date of Next Scheduled EDR Contact: 08/09/04

DOD: Department of Defense Sites
Source: USGS
Telephone: 703-692-8801
This data set consists of federally owned or administered lands, administered by the Department of Defense, that have any area equal to or greater than 640 acres of the United States, Puerto Rico, and the U.S. Virgin Islands.

Date of Government Version: 10/01/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 05/14/04
Date of Next Scheduled EDR Contact: 08/09/04

STORMWATER: Storm Water General Permits
Source: Environmental Protection Agency
Telephone: 202 564-0746
A listing of all facilities with Storm Water General Permits.

Date of Government Version: N/A
Database Release Frequency: Quarterly
Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

INDIAN RESERV: Indian Reservations
Source: USGS
Telephone: 202-208-3710
This map layer portrays Indian administered lands of the United States that have any area equal to or greater than 640 acres.

Date of Government Version: 10/01/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 05/14/04
Date of Next Scheduled EDR Contact: 08/09/04

US BROWNFIELDS: A Listing of Brownfields Sites
Source: Environmental Protection Agency
Telephone: 202-566-2777
Included in the listing are brownfields properties addresses by Cooperative Agreement Recipients and brownfields properties addressed by Targeted Brownfields Assessments. Targeted Brownfields Assessments-EPA's Targeted Brownfields Assessments (TBA) program is designed to help states, tribes, and municipalities--especially those without EPA Brownfields Assessment Demonstration Pilots--minimize the uncertainties of contamination often associated with brownfields. Under the TBA program, EPA provides funding and/or technical assistance for environmental assessments at brownfields sites throughout the country. Targeted Brownfields Assessments supplement and work with other efforts under EPA's Brownfields Initiative to promote cleanup and redevelopment of brownfields. Cooperative Agreement Recipients-States, political subdivisions, territories, and Indian tribes become BCRLF cooperative agreement recipients when they enter into BCRLF cooperative agreements with the U.S. EPA. EPA selects BCRLF cooperative agreement recipients based on a proposal and application process. BCRLF cooperative agreement recipients must use EPA funds provided through BCRLF cooperative agreement for specified brownfields-related cleanup activities.

Date of Government Version: 04/14/04
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 06/14/04
Date of Next Scheduled EDR Contact: 09/13/04

RMP: Risk Management Plans
Source: Environmental Protection Agency
Telephone: 202-564-8600
When Congress passed the Clean Air Act Amendments of 1990, it required EPA to publish regulations and guidance for chemical accident prevention at facilities using extremely hazardous substances. The Risk Management Program Rule (RMP Rule) was written to implement Section 112(r) of these amendments. The rule, which built upon existing industry codes and standards, requires companies of all sizes that use certain flammable and toxic substances to develop a Risk Management Program, which includes a(n): Hazard assessment that details the potential effects of an accidental release, an accident history of the last five years, and an evaluation of worst-case and alternative accidental releases; Prevention program that includes safety precautions and maintenance, monitoring, and employee training measures; and Emergency response program that spells out emergency health care, employee training measures and procedures for informing the public and response agencies (e.g the fire department) should an accident occur.

Date of Government Version: N/A
Database Release Frequency: N/A
Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

FUDS: Formerly Used Defense Sites
Source: U.S. Army Corps of Engineers
Telephone: 202-528-4285
The listing includes locations of Formerly Used Defense Sites properties where the US Army Corps of Engineers is actively working or will take necessary cleanup actions.

Date of Government Version: 10/01/03
Database Release Frequency: Varies
Date of Last EDR Contact: 07/06/04
Date of Next Scheduled EDR Contact: 10/04/04

UMTRA: Uranium Mill Tailings Sites
Source: Department of Energy
Telephone: 505-845-0011
Uranium ore was mined by private companies for federal government use in national defense programs. When the mills shut down, large piles of the sand-like material (mill tailings) remain after uranium has been extracted from the ore. Levels of human exposure to radioactive materials from the piles are low; however, in some cases tailings were used as construction materials before the potential health hazards of the tailings were recognized. In 1978, 24 inactive uranium mill tailings sites in Oregon, Idaho, Wyoming, Utah, Colorado, New Mexico, Texas, North Dakota, South Dakota, Pennsylvania, and on Navajo and Hopi tribal lands, were targeted for cleanup by the Department of Energy.

Date of Government Version: 04/22/04
Database Release Frequency: Varies
Date of Last EDR Contact: 06/21/04
Date of Next Scheduled EDR Contact: 09/20/04

RAATS: RCRA Administrative Action Tracking System
Source: EPA
Telephone: 202-564-4104
RCRA Administration Action Tracking System. RAATS contains records based on enforcement actions issued under RCRA pertaining to major violators and includes administrative and civil actions brought by the EPA. For administration actions after September 30, 1995, data entry in the RAATS database was discontinued. EPA will retain a copy of the database for historical records. It was necessary to terminate RAATS because a decrease in agency resources made it impossible to continue to update the information contained in the database.

Date of Government Version: 04/17/95
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 06/07/04
Date of Next Scheduled EDR Contact: 09/06/04

TRIS: Toxic Chemical Release Inventory System
Source: EPA
Telephone: 202-566-0250
Toxic Release Inventory System. TRIS identifies facilities which release toxic chemicals to the air, water and land in reportable quantities under SARA Title III Section 313.

Date of Government Version: 12/31/01
Database Release Frequency: Annually
Date of Last EDR Contact: 06/22/04
Date of Next Scheduled EDR Contact: 09/20/04

TSCA: Toxic Substances Control Act
Source: EPA
Telephone: 202-260-5521
Toxic Substances Control Act. TSCA identifies manufacturers and importers of chemical substances included on the TSCA Chemical Substance Inventory list. It includes data on the production volume of these substances by plant site.

Date of Government Version: 12/31/02
Database Release Frequency: Every 4 Years
Date of Last EDR Contact: 06/07/04
Date of Next Scheduled EDR Contact: 09/06/04

FTTS INSP: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA
Telephone: 202-564-2501

Date of Government Version: 04/13/04
Database Release Frequency: Quarterly
Date of Last EDR Contact: 06/21/04
Date of Next Scheduled EDR Contact: 09/20/04

SSTS: Section 7 Tracking Systems
Source: EPA
Telephone: 202-564-5008
Section 7 of the Federal Insecticide, Fungicide and Rodenticide Act, as amended (92 Stat. 829) requires all registered pesticide-producing establishments to submit a report to the Environmental Protection Agency by March 1st each year. Each establishment must report the types and amounts of pesticides, active ingredients and devices being produced, and those having been produced and sold or distributed in the past year.

Date of Government Version: 12/31/01
Database Release Frequency: Annually
Date of Last EDR Contact: 07/20/04
Date of Next Scheduled EDR Contact: 10/18/04

FTTS: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA/Office of Prevention, Pesticides and Toxic Substances
Telephone: 202-564-2501
FTTS tracks administrative cases and pesticide enforcement actions and compliance activities related to FIFRA, TSCA and EPCRA (Emergency Planning and Community Right-to-Know Act). To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 04/13/04
Database Release Frequency: Quarterly
Date of Last EDR Contact: 06/21/04
Date of Next Scheduled EDR Contact: 09/20/04

STATE OF NORTH CAROLINA ASTM STANDARD RECORDS

SHWS: Inactive Hazardous Sites Inventory
Source: Department of Environment, Health and Natural Resources
Telephone: 919-733-2801
State Hazardous Waste Sites. State hazardous waste site records are the states' equivalent to CERCLIS. These sites may or may not already be listed on the federal CERCLIS list. Priority sites planned for cleanup using state funds (state equivalent of Superfund) are identified along with sites where cleanup will be paid for by potentially responsible parties. Available information varies by state.

Date of Government Version: 04/15/04
Date Made Active at EDR: 05/26/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 04/15/04
Elapsed ASTM days: 41
Date of Last EDR Contact: 07/12/04

SWF/LF: List of Solid Waste Facilities
Source: Department of Environment and Natural Resources
Telephone: 919-733-0692
Solid Waste Facilities/Landfill Sites. SWF/LF type records typically contain an inventory of solid waste disposal facilities or landfills in a particular state. Depending on the state, these may be active or inactive facilities or open dumps that failed to meet RCRA Subtitle D Section 4004 criteria for solid waste landfills or disposal sites.

Date of Government Version: 03/01/04
Date Made Active at EDR: 03/31/04
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 03/01/04
Elapsed ASTM days: 30
Date of Last EDR Contact: 07/26/04

LUST: Incidents Management Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
Leaking Underground Storage Tank Incident Reports. LUST records contain an inventory of reported leaking underground storage tank incidents. Not all states maintain these records, and the information stored varies by state.

Date of Government Version: 06/04/04
Date Made Active at EDR: 07/09/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 06/08/04
Elapsed ASTM days: 31
Date of Last EDR Contact: 06/08/04

UST: Petroleum Underground Storage Tank Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1308
Registered Underground Storage Tanks. UST's are regulated under Subtitle I of the Resource Conservation and Recovery Act (RCRA) and must be registered with the state department responsible for administering the UST program. Available information varies by state program.

Date of Government Version: 06/21/04
Date Made Active at EDR: 07/12/04
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 06/23/04
Elapsed ASTM days: 19
Date of Last EDR Contact: 06/11/04

OLI: Old Landfill Inventory
Source: Department of Environment & Natural Resources
Telephone: 919-733-4996

Date of Government Version: 04/05/04
Date Made Active at EDR: 05/26/04
Database Release Frequency: Varies

Date of Data Arrival at EDR: 04/28/04
Elapsed ASTM days: 28
Date of Last EDR Contact: 04/28/04

VCP: Responsible Party Voluntary Action Sites
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996

Date of Government Version: 07/14/04
Date Made Active at EDR: 08/16/04
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 07/15/04
Elapsed ASTM days: 32
Date of Last EDR Contact: 07/12/04

INDIAN UST: Underground Storage Tanks on Indian Land
Source: EPA Region 4
Telephone: 404-562-9424

Date of Government Version: 10/22/03
Date Made Active at EDR: 01/09/04
Database Release Frequency: Varies

Date of Data Arrival at EDR: 12/19/03
Elapsed ASTM days: 21
Date of Last EDR Contact: 05/24/04

STATE OF NORTH CAROLINA ASTM SUPPLEMENTAL RECORDS

HSDS: Hazardous Substance Disposal Site
Source: North Carolina Center for Geographic Information and Analysis
Telephone: 919-733-2090
Locations of uncontrolled and unregulated hazardous waste sites. The file includes sites on the National Priority List as well as those on the state priority list.

Date of Government Version: 06/21/95
Database Release Frequency: Biennially

Date of Last EDR Contact: 05/28/04
Date of Next Scheduled EDR Contact: 08/30/04

AST: AST Database
Source: Department of Environment and Natural Resources
Telephone: 919-715-6170
Facilities with aboveground storage tanks that have a capacity greater than 21,000 gallons.

Date of Government Version: 01/09/04
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 07/19/04
Date of Next Scheduled EDR Contact: 10/18/04

LUST TRUST: State Trust Fund Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
This database contains information about claims against the State Trust Funds for reimbursements for expenses incurred while remediating Leaking USTs.

Date of Government Version: 05/10/04
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 05/12/04
Date of Next Scheduled EDR Contact: 08/09/04

DRYCLEANERS: Drycleaning Sites
Source: Department of Environment & Natural Resources
Telephone: 919-733-2801
Potential and known drycleaning sites, active and abandoned, that the Drycleaning Solvent Cleanup Program has knowledge of and entered into this database.

Date of Government Version: 05/19/04
Database Release Frequency: Varies

Date of Last EDR Contact: 07/19/04
Date of Next Scheduled EDR Contact: 10/18/04

IMD: Incident Management Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
Groundwater and/or soil contamination incidents

Date of Government Version: 05/04/04
Database Release Frequency: Quarterly

Date of Last EDR Contact: 07/27/04
Date of Next Scheduled EDR Contact: 10/25/04

EDR PROPRIETARY HISTORICAL DATABASES

Former Manufactured Gas (Coal Gas) Sites: The existence and location of Coal Gas sites is provided exclusively to EDR by Real Property Scan, Inc. ©Copyright 1993 Real Property Scan, Inc. For a technical description of the types of hazards which may be found at such sites, contact your EDR customer service representative.

Disclaimer Provided by Real Property Scan, Inc.

The information contained in this report has predominantly been obtained from publicly available sources produced by entities other than Real Property Scan. While reasonable steps have been taken to insure the accuracy of this report, Real Property Scan does not guarantee the accuracy of this report. Any liability on the part of Real Property Scan is strictly limited to a refund of the amount paid. No claim is made for the actual existence of toxins at any site. This report does not constitute a legal opinion.

BROWNFIELDS DATABASES

Brownfields: Brownfields Projects Inventory
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996
A brownfield site is an abandoned, idled, or underused property where the threat of environmental contamination has hindered its redevelopment. All of the sites in the inventory are working toward a brownfield agreement for cleanup and liabitliy control.

Date of Government Version: 09/30/03
Database Release Frequency: Varies

Date of Last EDR Contact: 05/05/04
Date of Next Scheduled EDR Contact: 08/02/04

VCP: Responsible Party Voluntary Action Sites
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996

Date of Government Version: 07/14/04
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 07/12/04
Date of Next Scheduled EDR Contact: 10/11/04

INST CONTROL: No Further Action Sites With Land Use Restrictions Monitoring
Source: Department of Environment, Health and Natural Resources
Telephone: 919-733-2801

Date of Government Version: 07/14/04
Database Release Frequency: Quarterly

Date of Last EDR Contact: 07/12/04
Date of Next Scheduled EDR Contact: 10/11/04

US BROWNFIELDS: A Listing of Brownfields Sites
Source: Environmental Protection Agency
Telephone: 202-566-2777
Included in the listing are brownfields properties addresses by Cooperative Agreement Recipients and brownfields properties addressed by Targeted Brownfields Assessments. Targeted Brownfields Assessments-EPA's Targeted Brownfields Assessments (TBA) program is designed to help states, tribes, and municipalities--especially those without EPA Brownfields Assessment Demonstration Pilots--minimize the uncertainties of contamination often associated with brownfields. Under the TBA program, EPA provides funding and/or technical assistance for environmental assessments at brownfields sites throughout the country. Targeted Brownfields Assessments supplement and work with other efforts under EPA's Brownfields Initiative to promote cleanup and redevelopment of brownfields. Cooperative Agreement Recipients-States, political subdivisions, territories, and Indian tribes become BCRLF cooperative agreement recipients when they enter into BCRLF cooperative agreements with the U.S. EPA. EPA selects BCRLF cooperative agreement recipients based on a proposal and application process. BCRLF cooperative agreement recipients must use EPA funds provided through BCRLF cooperative agreement for specified brownfields-related cleanup activities.

Date of Government Version: N/A
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

OTHER DATABASE(S)

Depending on the geographic area covered by this report, the data provided in these specialty databases may or may not be complete. For example, the existence of wetlands information data in a specific report does not mean that all wetlands in the area covered by the report are included. Moreover, the absence of any reported wetlands information does not necessarily mean that wetlands do not exist in the area covered by the report.

Flood Zone Data: This data, available in select counties across the country, was obtained by EDR in 1999 from the Federal Emergency Management Agency (FEMA). Data depicts 100-year and 500-year flood zones as defined by FEMA.

NWI: National Wetlands Inventory. This data, available in select counties across the country, was obtained by EDR in 2002 from the U.S. Fish and Wildlife Service.

STREET AND ADDRESS INFORMATION

North Carolina Department of Cultural Resources

State Historic Preservation Office

Peter B. Sandbeck, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary

Office of Archives and History
Division of Historical Resources
David Brook, Director

October 8, 2004

Staci Ricks
Buck Engineering
8000 Regency Parkway
Suite 200
Cary, NC 27511

SUBJECT: Mitigation Plan for Stream and Wetland Restoration on Haw Branch, Onslow County, ER04-23656

Dear Ms. Ricks:

Thank you for your letter of August 17, 2004, concerning the above referenced undertaking. We apologize for our delayed response.

We have conducted a search of our maps and files and have located the following structures of historical or architectural importance within the general area of the project:

> ON247 House, end of lane SR 1230, 1.2 miles south of SR 1229, shown on enclosed section of the Potters Hill USGS sheet

There are no known archaeological sites within the proposed project area. Based on our knowledge of the area, it is unlikely that any archaeological resources that may be eligible for conclusion in the National Register of Historic Places will be affected by the project. We, therefore, recommend that no archaeological investigation be conducted in connection with this project.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919/733-4763. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley
for Peter Sandbeck

PBS:crs

Enclosure

cc: Mary Pope Furr, NCDOT
Matt Wilkerson, NCDOT

NCDENR

North Carolina Department of Environment and Natural Resources

Michael F. Easley, Governor William G. Ross Jr., Secretary

October 4, 2004

Ms. Jessica Rohrbach
Buck Engineering
8000 Regency Parkway, Suite 200
Cary, NC 27511

Subject: Plan for Stream and Wetland Restoration on Haw Branch Site; Onslow County

Dear Ms. Rohrbach:

The Natural Heritage Program has no record of rare species, significant natural communities, or priority natural areas at the site nor within a mile of the project area. Although our maps do not show records of such natural heritage elements in the project area, it does not necessarily mean that they are not present. It may simply mean that the area has not been surveyed. The use of Natural Heritage Program data should not be substituted for actual field surveys, particularly if the project area contains suitable habitat for rare species, significant natural communities, or priority natural areas.

You may wish to check the Natural Heritage Program database website at <www.ncsparks.net/nhp/search.html> for a listing of rare plants and animals and significant natural communities in the county and on the topographic quad map. Please do not hesitate to contact me at 919-715-8697 if you have questions or need further information.

Sincerely,

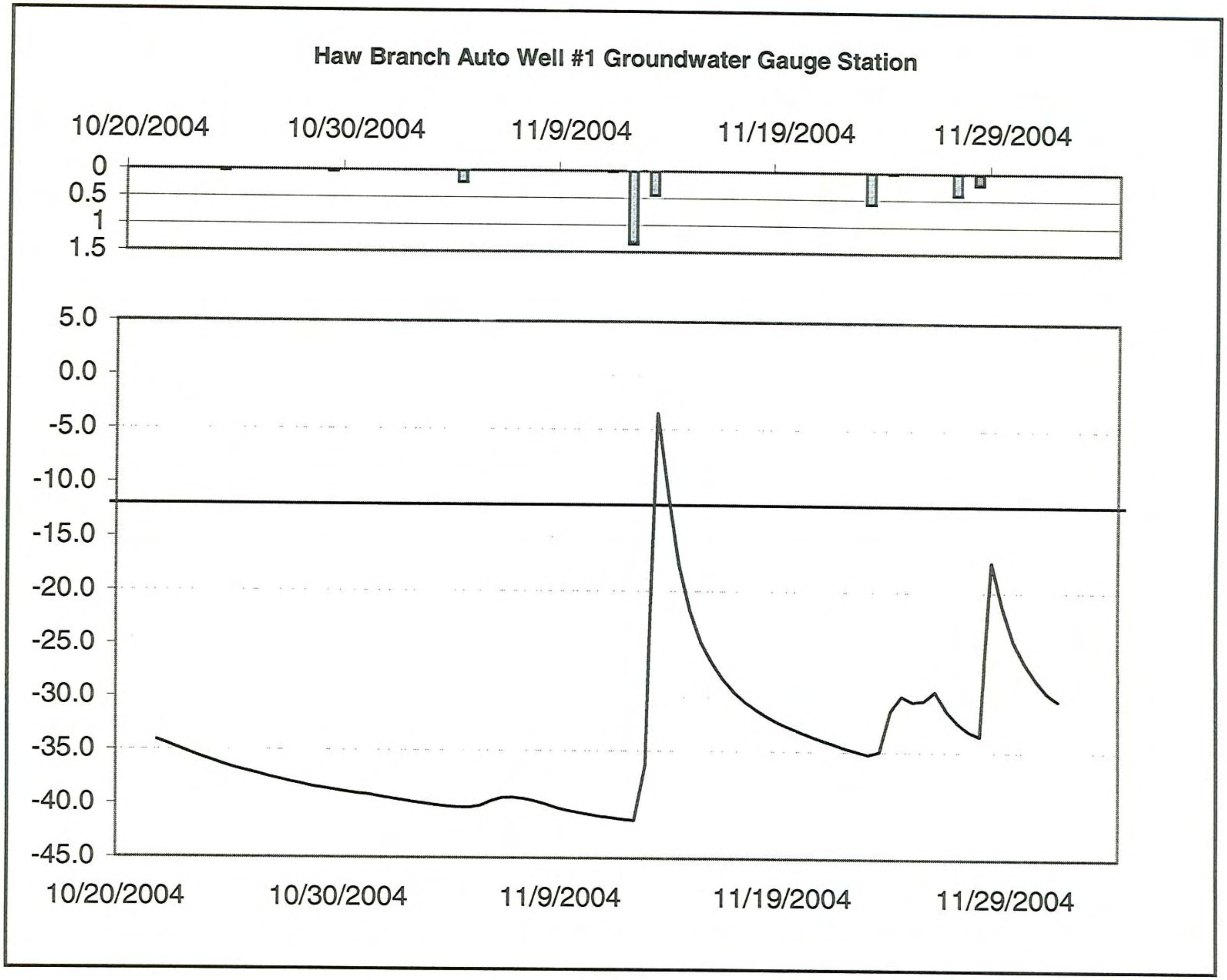
Harry E. LeGrand, Jr.

Harry E. LeGrand, Jr., Zoologist
Natural Heritage Program

HEL/hel

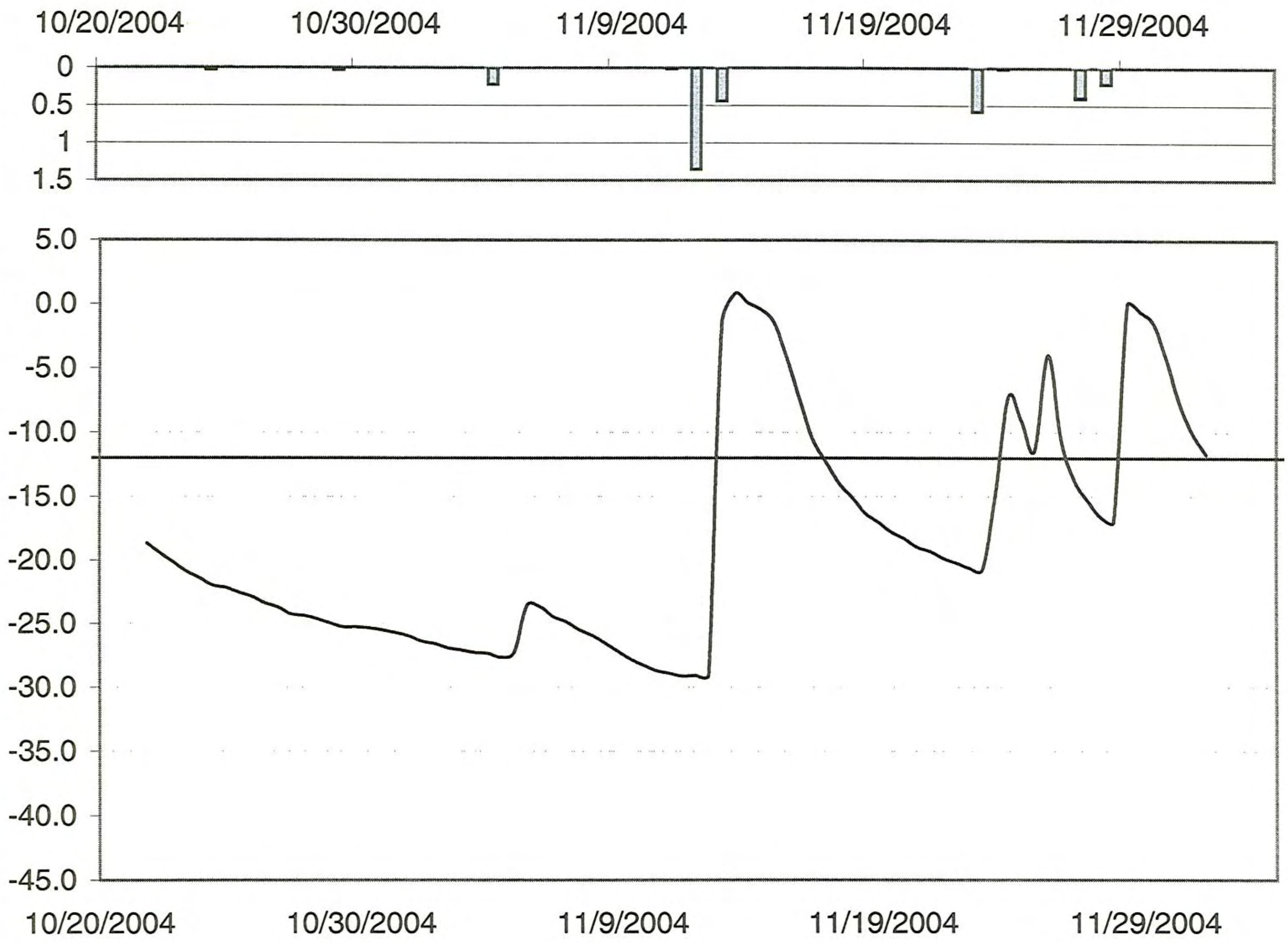
Appendix 2

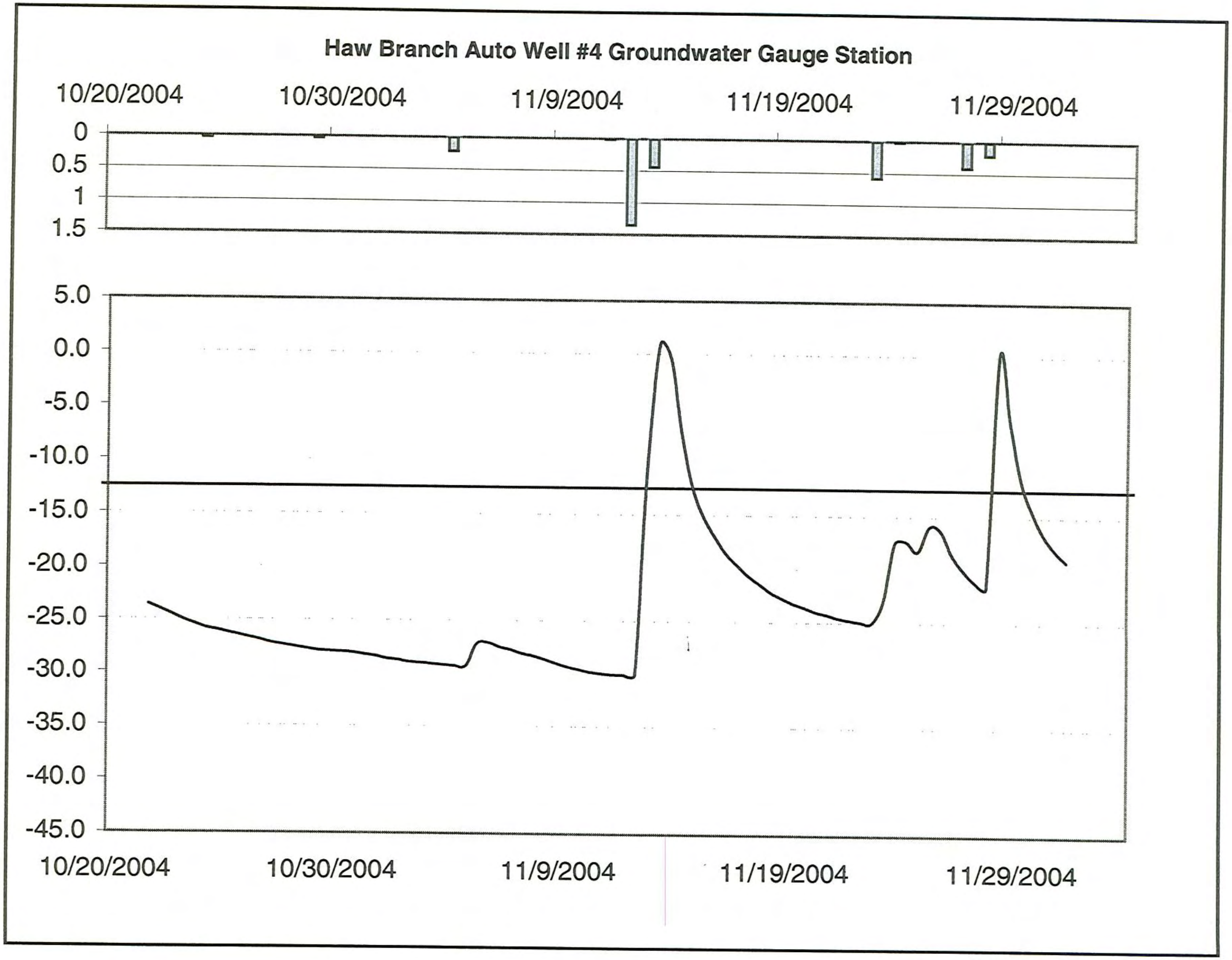
Restoration Site Water Table Data



Haw Branch Auto Well #1 Groundwater Gauge Station
10/20/2004
10/30/2004
11/9/2004
11/19/2004
11/29/2004
0
0.5
1
1.5
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
10/20/2004
10/30/2004
11/9/2004
11/19/2004
11/29/2004

Haw Branch Auto Well #2 Groundwater Gauge Station




Haw Branch Auto Well #4 Groundwater Gauge Station
10/20/2004
10/30/2004
11/9/2004
11/19/2004
11/29/2004
0
0.5
1
1.5
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
10/20/2004
10/30/2004
11/9/2004
11/19/2004
11/29/2004

Appendix 3

Existing Conditions Summaries, Cross Sections, Bed Material Analyses, and NCDWQ Stream Determination Forms

Haw Branch Reach UT1	Existing Stream Values	
Parameter	MIN	MAX
Drainage Area, DA (sq mi)	0.38	
Stream Type (Rosgen)	G5c,E5	
Bankfull Riffle XSEC Area, Abkf (sq ft)	3.9	4.7
Bankfull Riffle Width, Wbkf (ft)	4.9	7.4
Bankfull Riffle Mean Depth, Dbkf (ft)	0.6	0.9
Width to Depth Ratio, W/D (ft/ft)	5.4	12.1
Width Floodprone Area, Wfpa (ft)	6	11
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	1.3	2.6
Riffle Max Depth @ bkf, Dmax (ft)	1.2	1.3
Riffle Max Depth Ratio, Dmax/Dbkf	1.5	1.9
Max Depth @ tob, Dmaxtob (ft)	4.0	6.0
Bank Height Ratio, Dtob/Dmax (ft/ft)	3.1	4.8
Meander Length, Lm (ft)	Note 1	
Meander Length Ratio, Lm/Wbkf *	Note 1	
Radius of Curvature, Rc (ft)	Note 1	
Rc Ratio, Rc/Wbkf *	Note 1	
Belt Width, Wblt (ft)	Note 1	
Meander Width Ratio, Wblt/Wbkf *	Note 1	
Sinuosity, K	1.06	
Valley Slope, Sval (ft/ft)	0.0021	
Channel Slope, Schan (ft/ft)	0.0020	
Pool Max Depth, Dmaxpool (ft)	Note 2	
Pool Max Depth Ratio, Dmaxpool/Dbkf	Note 2	
Pool Width, Wpool (ft)	Note 2	
Pool Width Ratio, Wpool/Wbkf	Note 2	
d16 (mm)	0.2	
d35 (mm)	0.3	
d50 (mm)	0.5	
d84 (mm)	3.2	
d95 (mm)	5.6	

Note 1: This reach has a very low sinuosity therefore, no pattern measurements were recorded.

Note 2: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

Haw Branch Reach UT2	Existing Stream Values	
Parameter	**MIN**	**MAX**
Drainage Area, DA (sq mi)	0.14	
Stream Type (Rosgen)	E5, F5	
Bankfull Riffle XSEC Area, Abkf (sq ft)	2.2	2.3
Bankfull Riffle Width, Wbkf (ft)	4.1	5.9
Bankfull Riffle Mean Depth, Dbkf (ft)	0.4	0.6
Width to Depth Ratio, W/D (ft/ft)	7.4	15.8
Width Floodprone Area, Wfpa (ft)	6	10
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	1.3	2.8
Riffle Max Depth @ bkf, Dmax (ft)	0.7	1.4
Riffle Max Depth Ratio, Dmax/Dbkf	1.9	2.5
Max Depth @ tob, Dmaxtob (ft)	3.0	5.0
Bank Height Ratio, Dtob/Dmax (ft/ft)	3.6	4.5
Meander Length, Lm (ft)	Note 1	
Meander Length Ratio, Lm/Wbkf *	Note 1	
Radius of Curvature, Rc (ft)	Note 1	
Rc Ratio, Rc/Wbkf *	Note 1	
Belt Width, Wblt (ft)	Note 1	
Meander Width Ratio, Wblt/Wbkf *	Note 1	
Sinuosity, K	1.0	
Valley Slope, Sval (ft/ft)	0.0033	
Channel Slope, Schan (ft/ft)	0.0033	
Pool Max Depth, Dmaxpool (ft)	Note 2	
Pool Max Depth Ratio, Dmaxpool/Dbkf	Note 2	
Pool Width, Wpool (ft)	Note 2	
Pool Width Ratio, Wpool/Wbkf	Note 2	
d16 (mm)		
d35 (mm)		
d50 (mm)		
d84 (mm)		
d95 (mm)		

Note 1: This reach has a very low sinuosity therefore, no pattern measurements were recorded.

Note 2: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

Haw Branch Reach UT3	Existing Stream Values	
Parameter	**MIN**	**MAX**
Drainage Area, DA (sq mi)	0.27	
Stream Type (Rosgen)	G5c	
Bankfull Riffle XSEC Area, Abkf (sq ft)	3.1	3.6
Bankfull Riffle Width, Wbkf (ft)	5.5	6.0
Bankfull Riffle Mean Depth, Dbkf (ft)	0.6	0.6
Width to Depth Ratio, W/D (ft/ft)	9.6	9.9
Width Floodprone Area, Wfpa (ft)	6	7
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	1.3	1.5
Riffle Max Depth @ bkf, Dmax (ft)	0.9	1.0
Riffle Max Depth Ratio, Dmax/Dbkf	1.5	1.7
Max Depth @ tob, Dmaxtob (ft)	4.0	5.0
Bank Height Ratio, Dtob/Dmax (ft/ft)	4.5	4.9
Meander Length, Lm (ft)	Note 1	
Meander Length Ratio, Lm/Wbkf *	Note 1	
Radius of Curvature, Rc (ft)	Note 1	
Rc Ratio, Rc/Wbkf *	Note 1	
Belt Width, Wblt (ft)	Note 1	
Meander Width Ratio, Wblt/Wbkf *	Note 1	
Sinuosity, K	1.04	
Valley Slope, Sval (ft/ft)	0.0017	
Channel Slope, Schan (ft/ft)	0.0016	
Pool Max Depth, Dmaxpool (ft)	Note 2	
Pool Max Depth Ratio, Dmaxpool/Dbkf	Note 2	
Pool Width, Wpool (ft)	Note 2	
Pool Width Ratio, Wpool/Wbkf	Note 2	
d16 (mm)	0.2	
d35 (mm)	0.2	
d50 (mm)	0.3	
d84 (mm)	0.5	
d95 (mm)	0.7	

Note 1: This reach has a very low sinuosity therefore, no pattern measurements were recorded.

Note 2: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

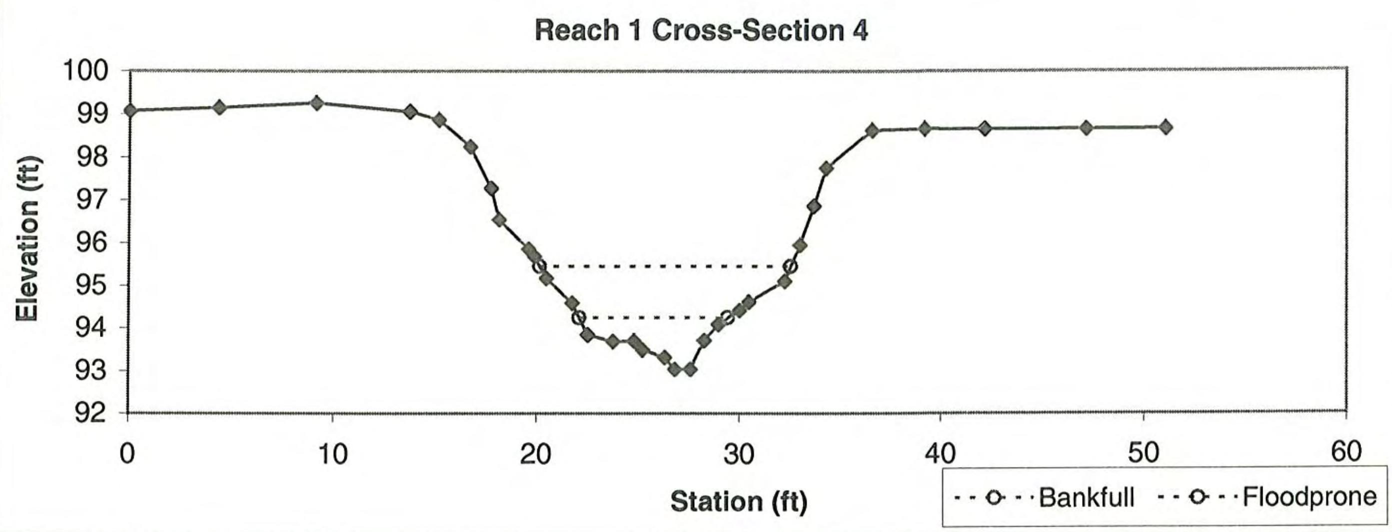
Summary of Cross-Section Data: **Haw Branch**

	Reach 1					Reach 2		Reach 3		
Cross-section Descriptor	X4	X5	X8	X11	X12	X3	X10	X6	X7	X9
Feature	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle
Rosgen Stream Type	G5c	E5	E5	G5c	G5c	E5	F5	G5	G5	G5
Bankfull Width (ft)	7.0	4.9	5.6	6.1	7.4	4.1	5.9	5.9	5.5	6.0
Bankfull Mean Depth (ft)	0.7	0.9	0.7	0.7	0.6	0.6	0.4	0.6	0.6	0.6
Width/Depth Ratio	10.5	5.4	8.0	8.8	12.1	7.4	15.8	9.6	9.6	9.9
Bankfull Area (sq ft)	4.7	4.4	3.9	4.3	4.6	2.3	2.2	3.6	3.1	3.6
Bankfull Max Depth (ft)	1.2	1.3	1.3	1.2	1.2	1.4	0.7	1.0	0.9	1.0
Entrenchment Ratio	1.8	2.7	2.6	1.3	2.0	2.8	1.3	1.3	1.4	1.5
Bank Height Ratio	4.6	4.1	3.6	4.8	3.1	3.6	4.5	4.6	4.9	4.5

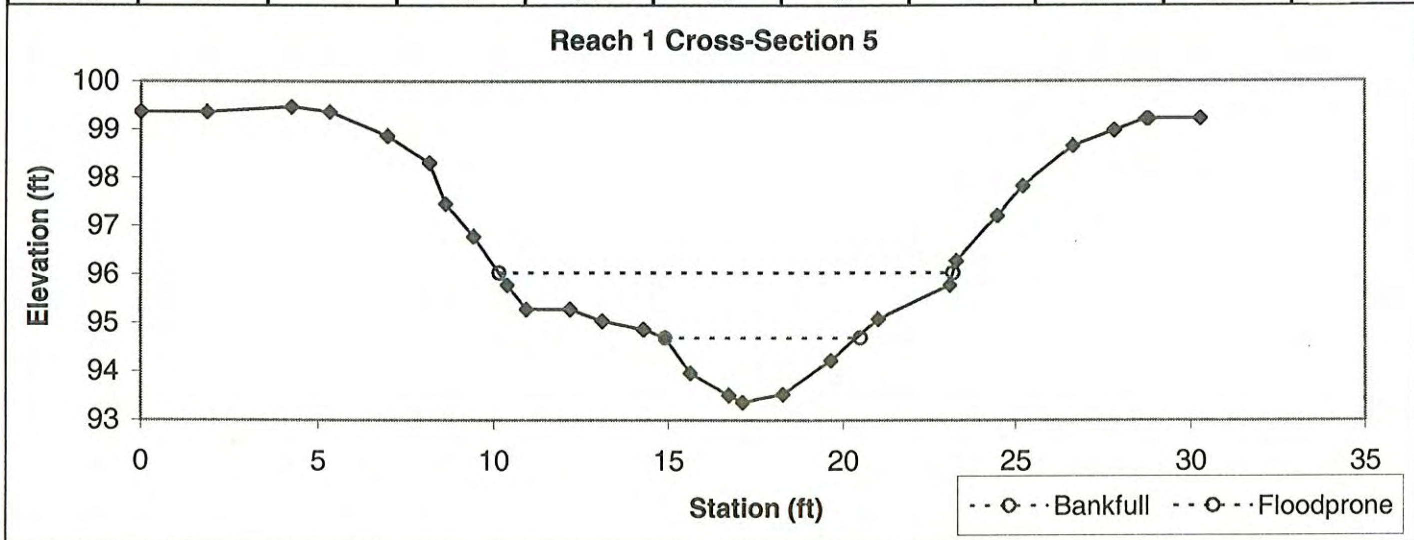
Summary of Bed Material Analyses:

Size Distribution			mm						mm	
D16			0.19						0.16	
D35			0.33						0.22	
D50			0.50						0.27	
D84			3.24						0.46	
D95			5.62						0.74	

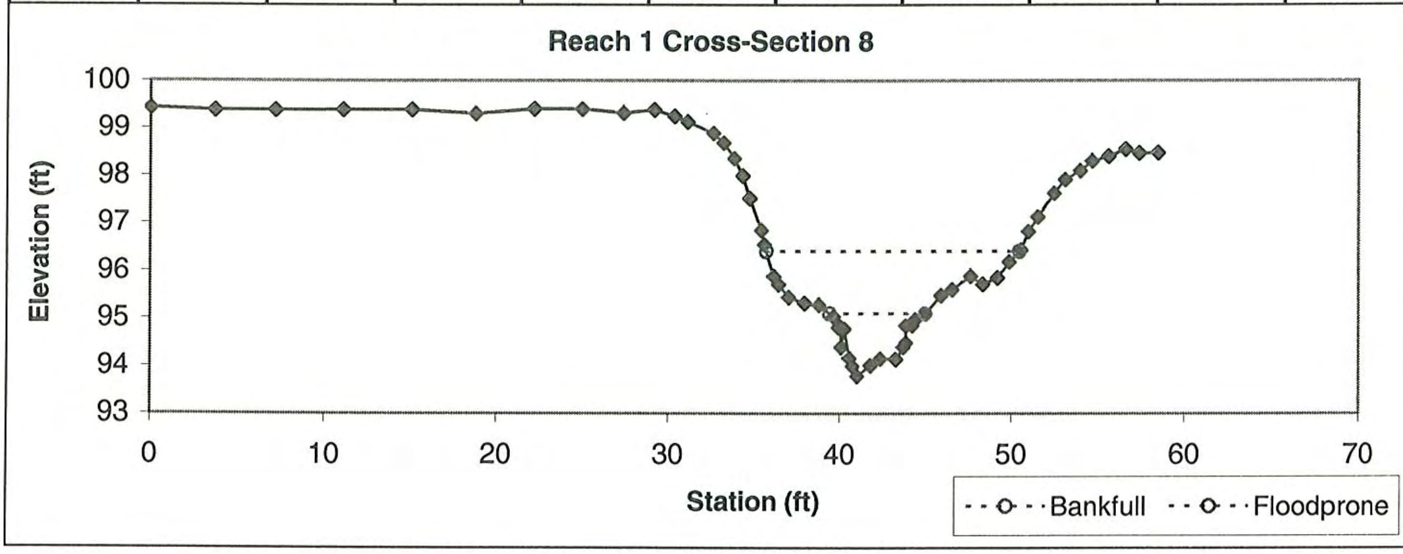
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	G5c	4.7	7.0	0.7	1.2	10.5	4.6	1.8	94.3	98.6



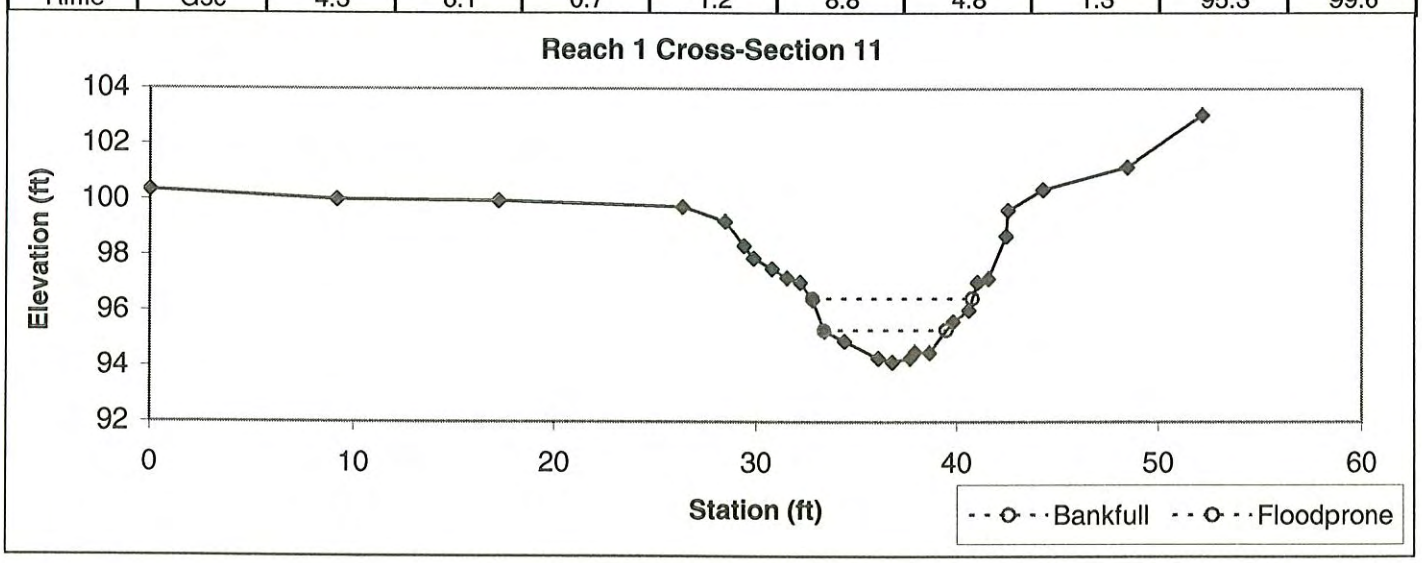
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	4.4	4.9	0.9	1.3	5.4	4.1	2.7	94.7	98.9



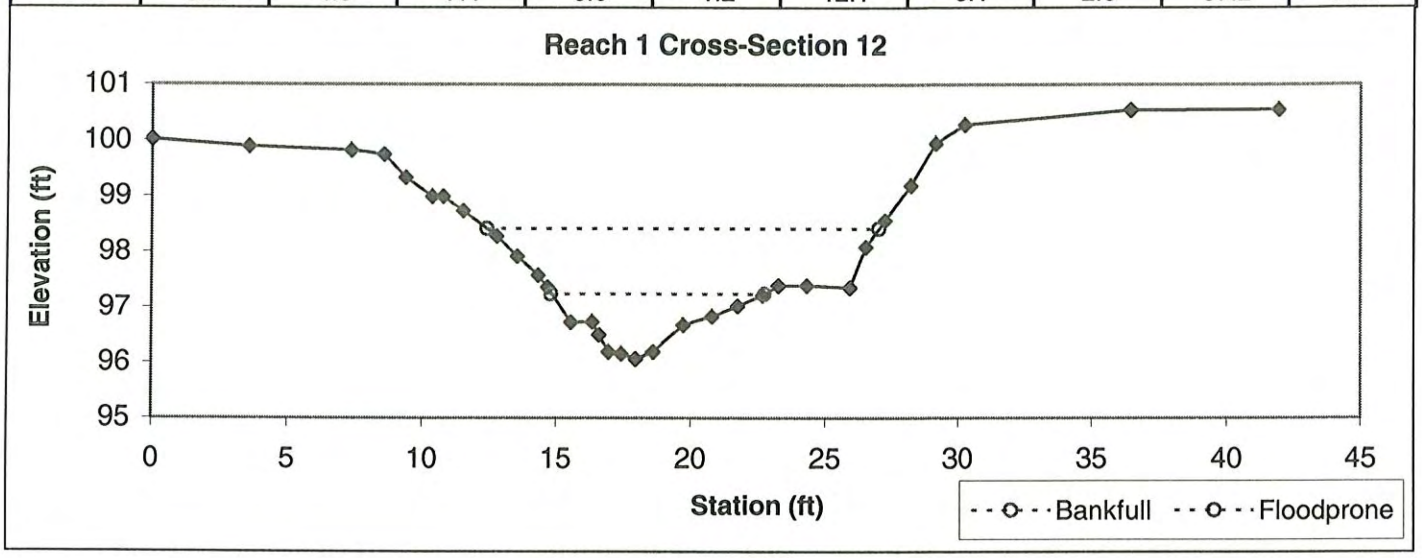
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	3.9	5.6	0.7	1.3	8.0	3.6	2.6	95.1	98.6



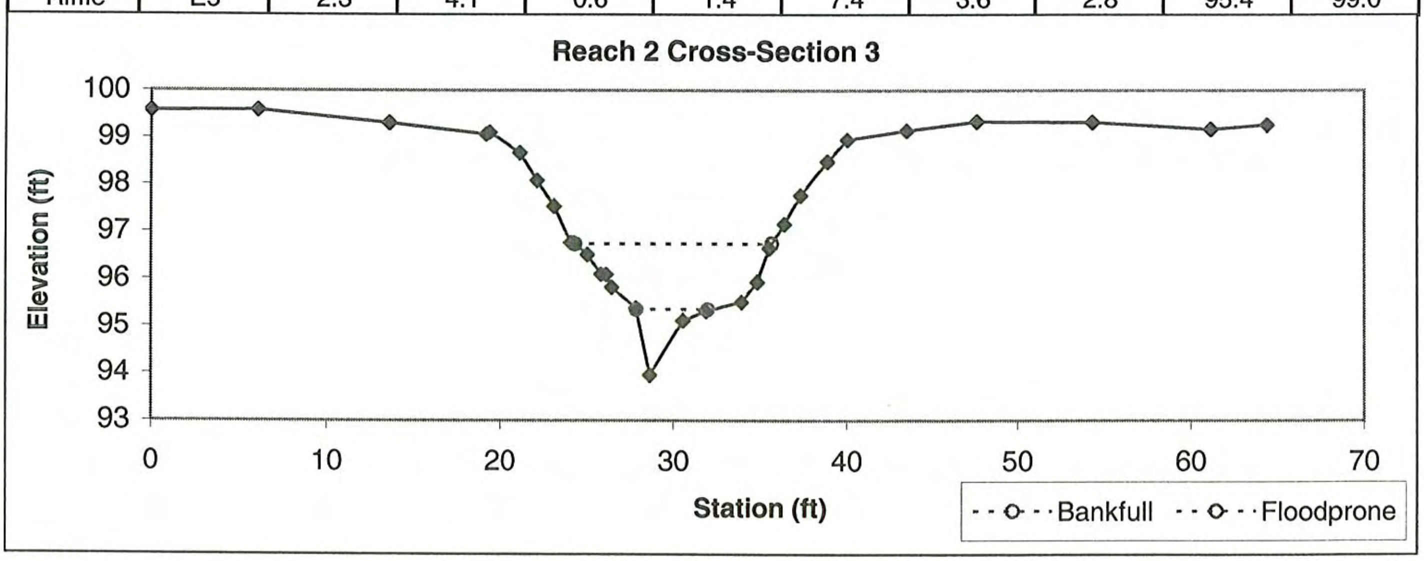
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	G5c	4.3	6.1	0.7	1.2	8.8	4.8	1.3	95.3	99.6



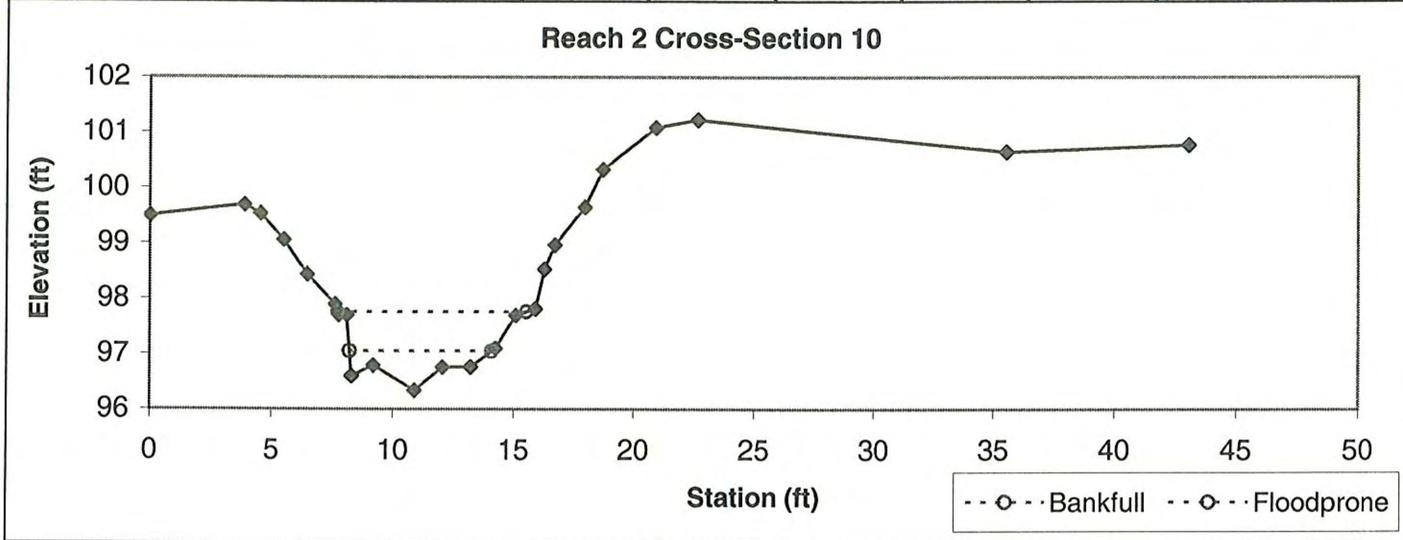
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	G5c	4.6	7.4	0.6	1.2	12.1	3.1	2.0	97.2	99.8



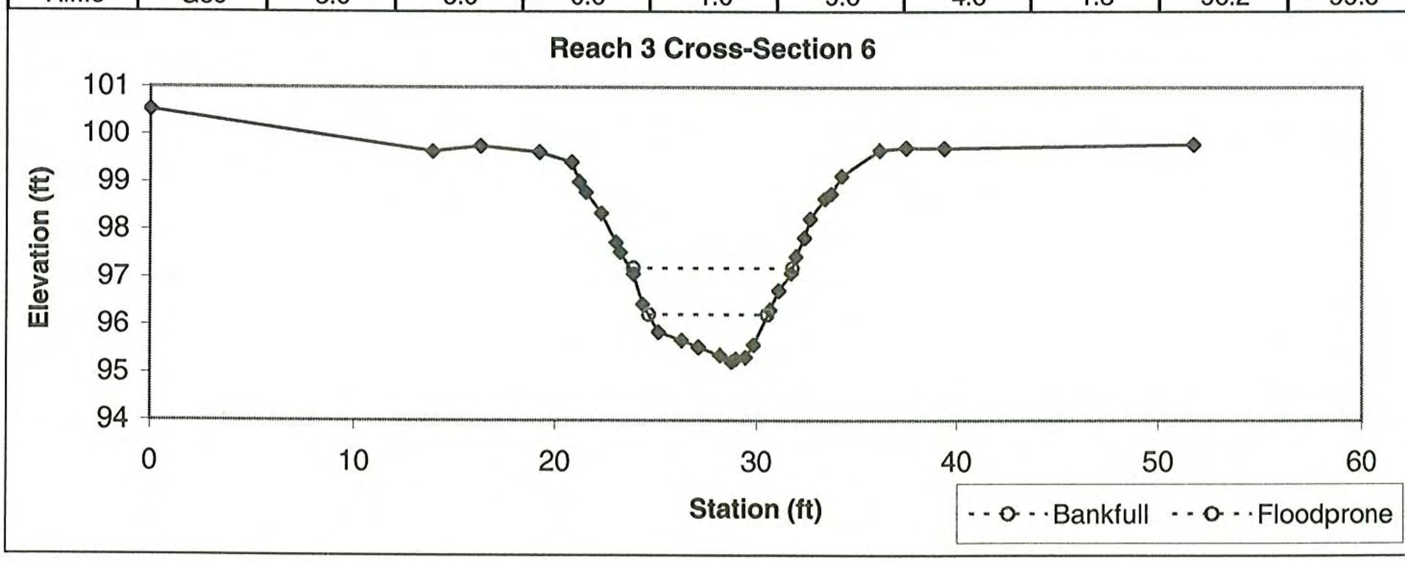
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	2.3	4.1	0.6	1.4	7.4	3.6	2.8	95.4	99.0



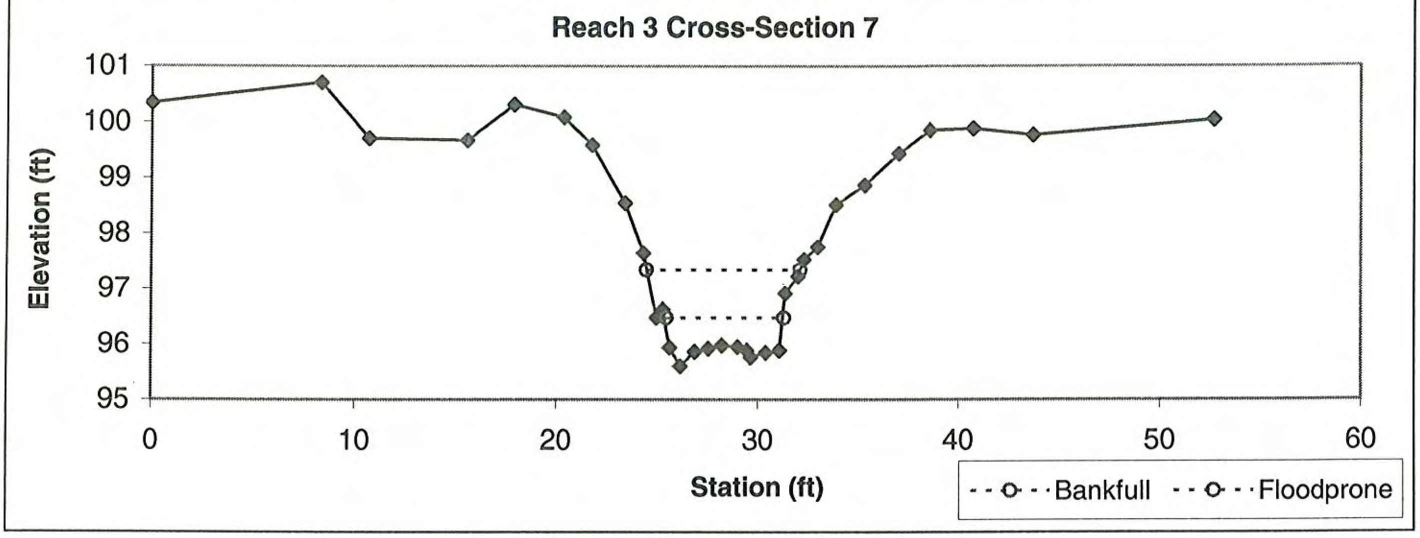
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	F5	2.2	5.9	0.4	0.7	15.8	4.5	1.3	97.1	99.5



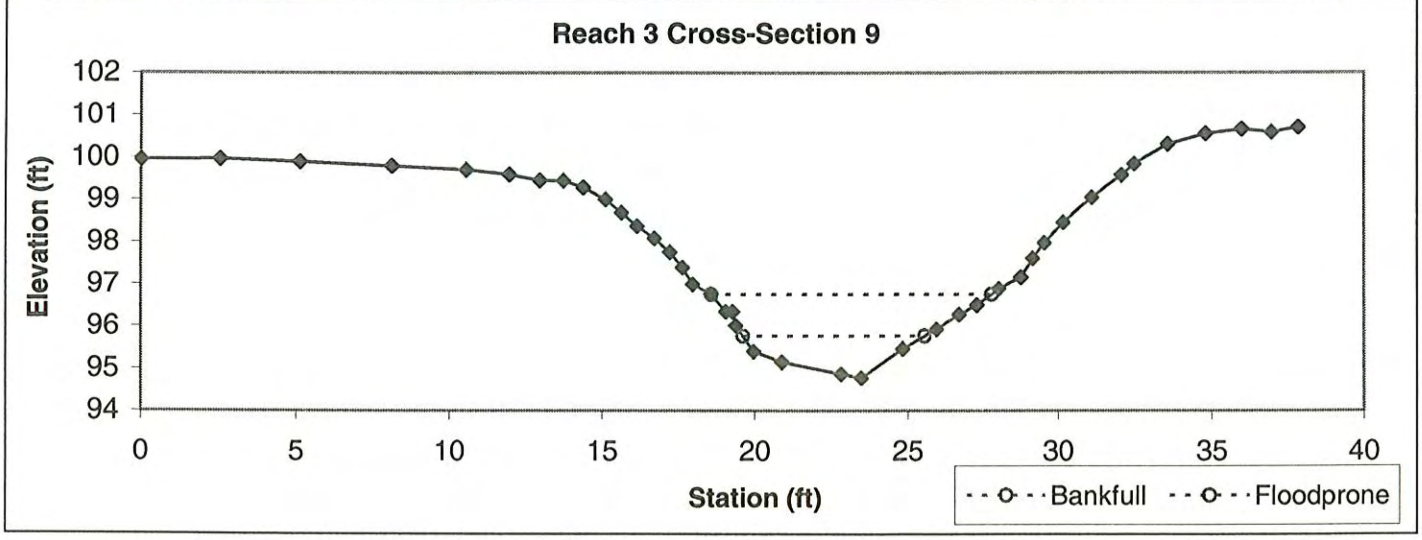
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	G5c	3.6	5.9	0.6	1.0	9.6	4.6	1.3	96.2	99.8



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	G5c	3.1	5.5	0.6	0.9	9.6	4.9	1.4	96.5	99.9



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	G5c	3.6	6.0	0.6	1.0	9.9	4.5	1.5	95.8	99.3



SITE OR PROJECT:	Haw Branch
REACH/LOCATION:	Reach 1 Cross Section 8
DATE COLLECTED:	31-Aug-04
FIELD COLLECTION BY:	JR
DATA ENTERED BY:	KS

SEDIMENT ANALYSIS DATA SHEET

MATERIAL	PARTICLE	SIZE (mm)	PARTICLE CLASS Riffle	Pool	Total	Reach Summary Class %	% Cum	Riffle Summary Class %	% Cum
SILT/CLAY	Silt / Clay	< .063	16.33		16	1.68	1.68	1.68	1.68
SAND	Very Fine	.063 - .125	18.14		18	1.87	3.56	1.87	3.56
	Fine	.125 - .25	205.48		205	21.20	24.76	21.20	24.76
	Medium	.25 - .50	245.11		245	25.29	50.05	25.29	50.05
	Coarse	.50 - 1.0	172.59		173	17.81	67.86	17.81	67.86
	Very Coarse	1.0 - 2.0	92.43		92	9.54	77.40	9.54	77.40
GRAVEL	Very Fine	2.0 - 2.8	39.44		39	4.07	81.47	4.07	81.47
	Very Fine	2.8 - 4.0	59.75		60	6.16	87.63	6.16	87.63
	Fine	4.0 - 5.6	70.93		71	7.32	94.95	7.32	94.95
	Fine	5.6 - 8.0	42.47		42	4.38	99.33	4.38	99.33
	Medium	8.0 - 11.0	5.55		6	0.57	99.90	0.57	99.90
	Medium	11.0 - 16.0	0.93		1	0.10	100.00	0.10	100.00
	Coarse	16 - 22.6					100.00		100.00
	Coarse	22.6 - 32					100.00		100.00
	Very Coarse	32 - 45					100.00		100.00
	Very Coarse	45 - 64					100.00		100.00
COBBLE	Small	64 - 90					100.00		100.00
	Small	90 - 128					100.00		100.00
	Large	128 - 180					100.00		100.00
	Large	180 - 256					100.00		100.00
BOULDER	Small	256 - 362					100.00		100.00
	Small	362 - 512					100.00		100.00
	Medium	512 - 1024					100.00		100.00
	Large-Very Large	1024 - 2048					100.00		100.00
BEDROCK	Bedrock	> 2048					100.00		100.00
			969	0	969			100	100

Cummulative Channel materials	
D_{16} =	0.19
D_{35} =	0.33
D_{50} =	0.50
D_{84} =	3.24
D_{95} =	5.62
D_{100} =	11.0 - 16.0

Riffle Channel materials	
D_{16} =	0.19
D_{35} =	0.33
D_{50} =	0.50
D_{84} =	3.24
D_{95} =	5.62
D_{100} =	11.0 - 16.0

SITE OR PROJECT:	Haw Branch
REACH/LOCATION:	Reach 3 Cross section 7
DATE COLLECTED:	31-Aug-04
FIELD COLLECTION BY:	JR
DATA ENTERED BY:	KS

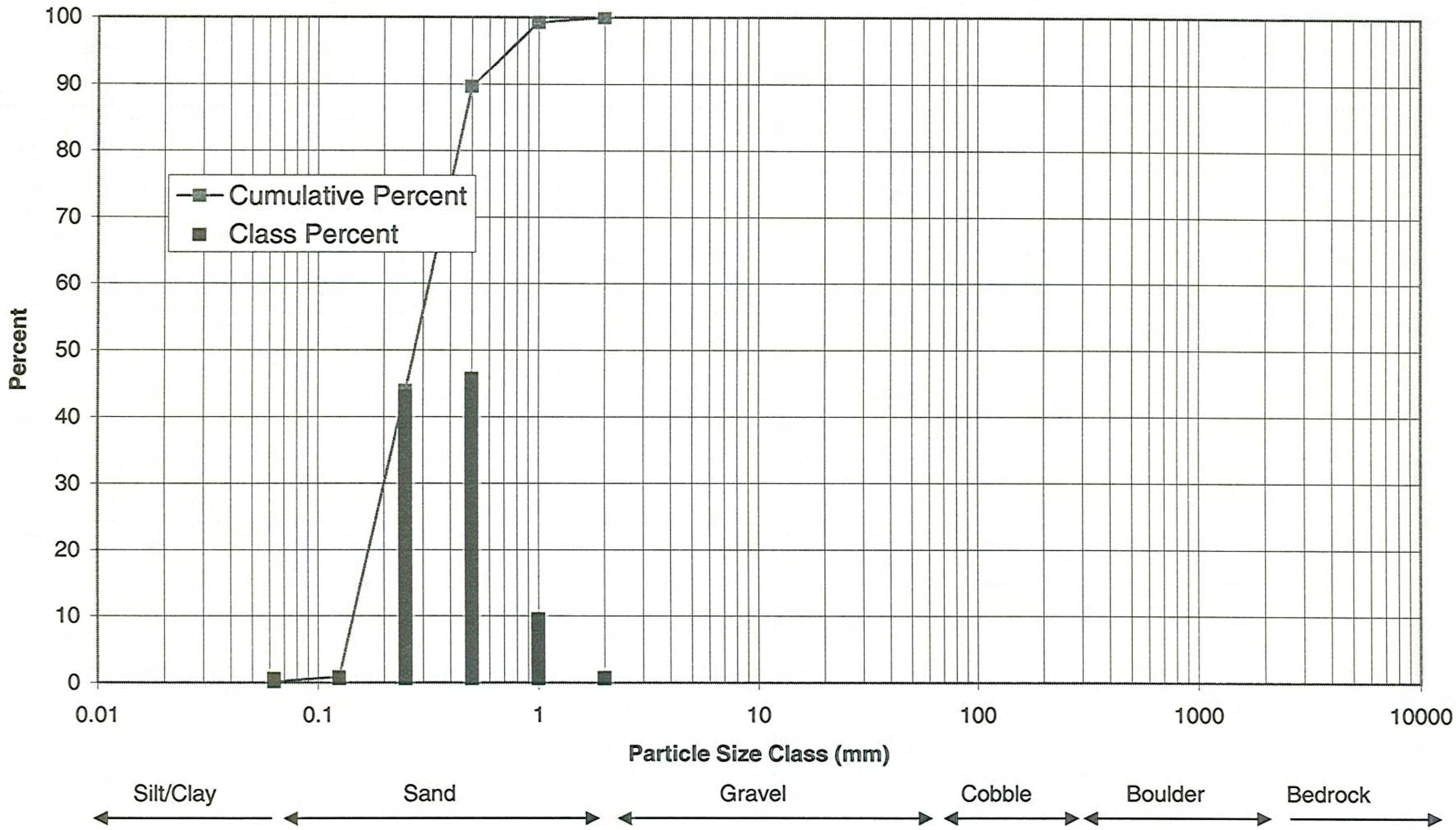
SEDIMENT ANALYSIS DATA SHEET

			PARTICLE CLASS			Reach Summary		Riffle Summary	
MATERIAL	PARTICLE	SIZE (mm)	Riffle	Pool	Total	Class %	% Cum	Class %	% Cum
SILT/CLAY	Silt / Clay	< .063	1		1	0.15	0.15	0.15	0.15
SAND	Very Fine	.063 - .125	5		5	0.76	0.91	0.76	0.91
	Fine	.125 - .25	257		257	43.01	43.92	43.01	43.92
	Medium	.25 - .50	273		273	45.74	89.67	45.74	89.67
	Coarse	.50 - 1.0	57		57	9.57	99.24	9.57	99.24
	Very Coarse	1.0 - 2.0	5		5	0.76	100.00	0.76	100.00
GRAVEL	Very Fine	2.0 - 2.8					100.00		100.00
	Very Fine	2.8 - 4.0					100.00		100.00
	Fine	4.0 - 5.6					100.00		100.00
	Fine	5.6 - 8.0					100.00		100.00
	Medium	8.0 - 11.0					100.00		100.00
	Medium	11.0 - 16.0					100.00		100.00
	Coarse	16 - 22.6					100.00		100.00
	Coarse	22.6 - 32					100.00		100.00
	Very Coarse	32 - 45					100.00		100.00
	Very Coarse	45 - 64					100.00		100.00
COBBLE	Small	64 - 90					100.00		100.00
	Small	90 - 128					100.00		100.00
	Large	128 - 180					100.00		100.00
	Large	180 - 256					100.00		100.00
BOULDER	Small	256 - 362					100.00		100.00
	Small	362 - 512					100.00		100.00
	Medium	512 - 1024					100.00		100.00
	Large-Very Large	1024 - 2048					100.00		100.00
BEDROCK	Bedrock	> 2048					100.00		100.00
			597	0	597			100	100

Cummulative	Riffle
Channel materials	Channel materials
D_{16} = 0.16	D_{16} = 0.16
D_{35} = 0.22	D_{35} = 0.22
D_{50} = 0.27	D_{50} = 0.27
D_{84} = 0.46	D_{84} = 0.46
D_{95} = 0.74	D_{95} = 0.74
D_{100} = 1.0 - 2.0	D_{100} = 1.0 - 2.0

Sediment Distribution

Haw Branch - Reach 3 Cross section 7



PEBBLE COUNT DATA SHEET

SITE OR PROJECT:	Haw Branch
REACH/LOCATION:	Reach 1 Cross Section 8
DATE COLLECTED:	31-Aug-04
FIELD COLLECTION BY:	JR
DATA ENTERED BY:	KS

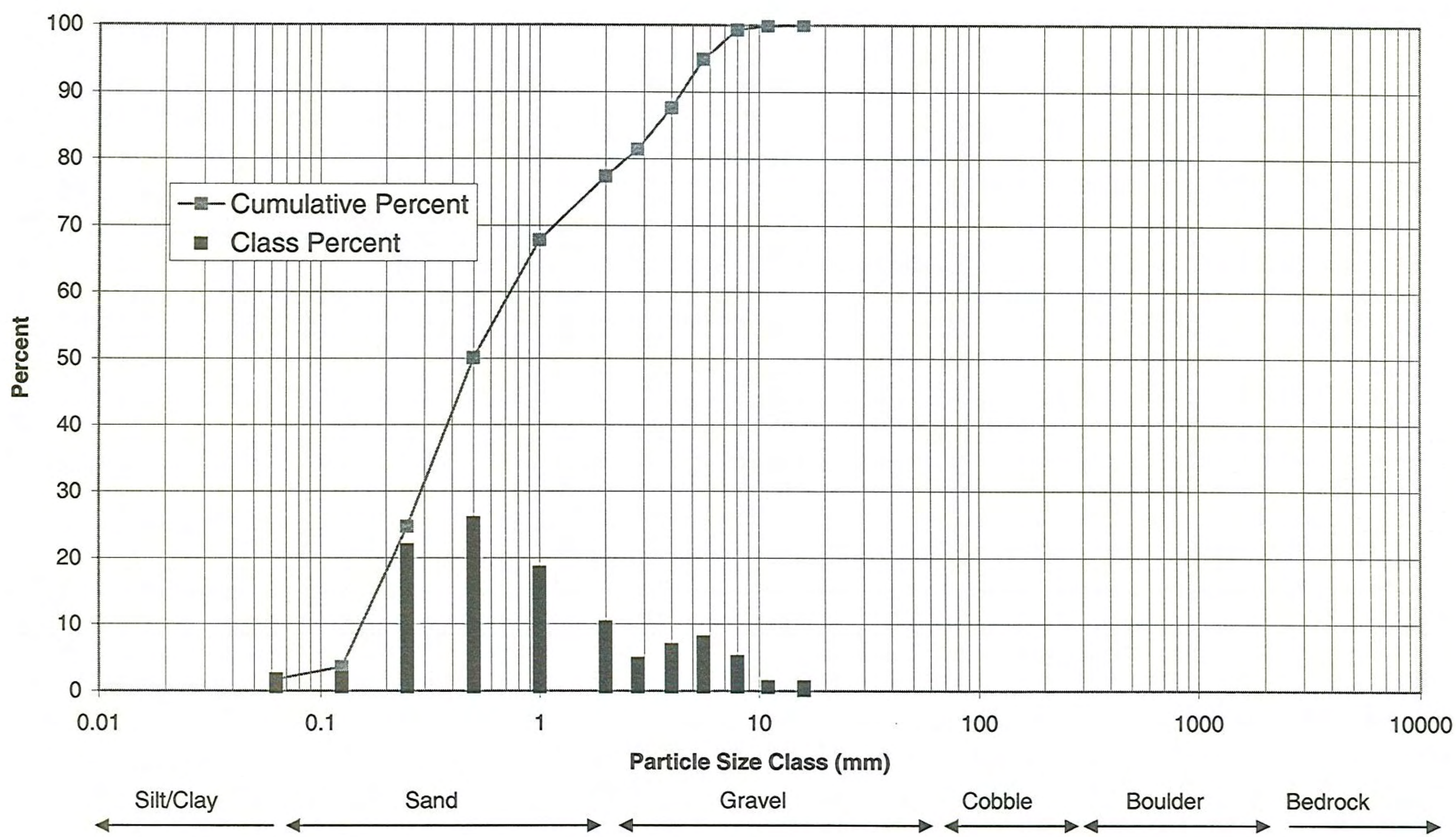
SEDIMENT ANALYSIS DATA SHEET

			PARTICLE CLASS			Reach Summary		Riffle Summary		Pool Summary	
MATERIAL	PARTICLE	SIZE (mm)	Riffle	Pool	Total	Class %	% Cum	Class %	% Cum	Class %	% Cum
SILT/CLAY	Silt / Clay	< .063	16.33		16	1.68	1.68	1.68	1.68		#DIV/0!
SAND	Very Fine	.063 - .125	18.14		18	1.87	3.56	1.87	3.56		#DIV/0!
	Fine	.125 - .25	205.48		205	21.20	24.76	21.20	24.76		#DIV/0!
	Medium	.25 - .50	245.11		245	25.29	50.05	25.29	50.05		#DIV/0!
	Coarse	.50 - 1.0	172.59		173	17.81	67.86	17.81	67.86		#DIV/0!
	Very Coarse	1.0 - 2.0	92.43		92	9.54	77.40	9.54	77.40		#DIV/0!
GRAVEL	Very Fine	2.0 - 2.8	39.44		39	4.07	81.47	4.07	81.47		#DIV/0!
	Very Fine	2.8 - 4.0	59.75		60	6.16	87.63	6.16	87.63		#DIV/0!
	Fine	4.0 - 5.6	70.93		71	7.32	94.95	7.32	94.95		#DIV/0!
	Fine	5.6 - 8.0	42.47		42	4.38	99.33	4.38	99.33		#DIV/0!
	Medium	8.0 - 11.0	5.55		6	0.57	99.90	0.57	99.90		#DIV/0!
	Medium	11.0 - 16.0	0.93		1	0.10	100.00	0.10	100.00		#DIV/0!
	Coarse	16 - 22.6					100.00		100.00		#DIV/0!
	Coarse	22.6 - 32					100.00		100.00		#DIV/0!
	Very Coarse	32 - 45					100.00		100.00		#DIV/0!
	Very Coarse	45 - 64					100.00		100.00		#DIV/0!
COBBLE	Small	64 - 90					100.00		100.00		#DIV/0!
	Small	90 - 128					100.00		100.00		#DIV/0!
	Large	128 - 180					100.00		100.00		#DIV/0!
	Large	180 - 256					100.00		100.00		#DIV/0!
BOULDER	Small	256 - 362					100.00		100.00		#DIV/0!
	Small	362 - 512					100.00		100.00		#DIV/0!
	Medium	512 - 1024					100.00		100.00		#DIV/0!
	Large-Very Large	1024 - 2048					100.00		100.00		#DIV/0!
BEDROCK	Bedrock	> 2048					100.00		100.00		#DIV/0!
			969	0	969			100	100	0	#DIV/0!

Cummulative Channel materials		Riffle Channel materials		Pool Channel materials	
D_{16} =	0.19	D_{16} =	0.19	D_{16} =	#N/A
D_{35} =	0.33	D_{35} =	0.33	D_{35} =	#N/A
D_{50} =	0.50	D_{50} =	0.50	D_{50} =	#N/A
D_{84} =	3.24	D_{84} =	3.24	D_{84} =	#N/A
D_{95} =	5.62	D_{95} =	5.62	D_{95} =	#N/A
D_{100} =	11.0 - 16.0	D_{100} =	11.0 - 16.0	D_{100} =	#N/A

Sediment Distribution

Haw Branch - Reach 1 Cross Section 8



NCDWQ Stream Classification Form

Project Name: Haw Branch – Reach UT1 River Basin: Cape Fear 07 | County: Onslow | Evaluator: S. Ricks
DWQ Project Number: | Nearest Named Stream: | Latitude: | Signature:
Date: 3-03-04 | USGS QUAD: | Longitude: | Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

Primary Field Indicators: (Circle One Number Per Line)

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	1	2	3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	2	3
3) Are Natural Levees Present?	0	1	2	3
4) Is The Channel Sinuous?	0	1	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	2	3
6) Is The Channel Braided?	0	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	2	3
8) Is There A Bankfull Bench Present?	0	1	2	3
9) Is A Continuous Bed & Bank Present?	0	1	2	3

*(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)*

10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map ***And/Or*** In Field) Present? *Yes*=3 *No*=0

PRIMARY GEOMORPHOLOGY INDICATOR POINTS:__15____

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	1	2	3

PRIMARY HYDROLOGY INDICATOR POINTS:__1___

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	2	1	0
2) Are Rooted Plants Present In Streambed?	3	2	1	0
3) Is Periphyton Present?	0	1	2	3
4) Are Bivalves Present?	0	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS:____3___

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	0	.5	1	1.5
2) Is There A Grade Control Point In Channel?	0	.5	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	.5	1	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS:___1___

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaflitter Present In Streambed?	1.5	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	.5	1	1.5
3) Are Wrack Lines Present?	0	.5	1	1.5
4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	1.5
5) Is There Water In Channel During Dry Conditions ***Or*** In Growing Season)?	0	.5	1	1.5

6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? *Yes*=1.5 *No*=0

SECONDARY HYDROLOGY INDICATOR POINTS:__7.5____

1) Are Fish Present?	0	.5	1	1.5
2) Are Amphibians Present?	0	.5	1	1.5
3) Are AquaticTurtles Present?	0	.5	1	1.5
4) Are Crayfish Present?	0	.5	1	1.5
5) Are Macrobenthos Present?	0	.5	1	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	0	.5	1	1.5
7) Is Filamentous Algae Present?	0	.5	1	1.5

8) Are Wetland Plants In Streambed?	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(**NOTE:** If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).*	2	1	.75	.5	0	0

SECONDARY BIOLOGY INDICATOR POINTS:__5.5____

TOTAL POINTS (Primary + Secondary)=__33.0__

(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)

NCDWQ Stream Classification Form

Project Name: Haw Branch – Reach UT2 River Basin: Cape Fear 07 County: Onslow Evaluator: S. Ricks
DWQ Project Number: Nearest Named Stream: Latitude: Signature:
Date: 3-03-04 USGS QUAD: Longitude: Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

Primary Field Indicators: (Circle One Number Per Line)

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	1	2	**3**
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	**2**	3
3) Are Natural Levees Present?	0	**1**	2	3
4) Is The Channel Sinuous?	0	**1**	2	3
5) Is There An Active (Or Relic) Floodplain Present?	0	**1**	2	3
6) Is The Channel Braided?	**0**	1	2	3
7) Are Recent Alluvial Deposits Present?	0	1	**2**	3
8) Is There A Bankfull Bench Present?	0	**1**	2	3
9) Is A Continuous Bed & Bank Present?	0	**1**	2	3

*(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)*

10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present? *Yes*=3 *No*=**0**

PRIMARY GEOMORPHOLOGY INDICATOR POINTS:__12____

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	**1**	2	3

PRIMARY HYDROLOGY INDICATOR POINTS:__1___

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	3	**2**	1	0
2) Are Rooted Plants Present In Streambed?	3	**2**	1	0
3) Is Periphyton Present?	**0**	1	2	3
4) Are Bivalves Present?	**0**	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS:____4___

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	**0**	.5	1	1.5
2) Is There A Grade Control Point In Channel?	**0**	.5	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	**.5**	1	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS:__0.5____

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaflitter Present In Streambed?	1.5	**1**	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	**.5**	1	1.5
3) Are Wrack Lines Present?	0	.5	**1**	1.5
4) Is Water In Channel *And* >48 Hrs. Since Last *Known* Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	**1.5**
5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)?	0	.5	1	**1.5**

6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? *Yes*=**1.5** *No*=0

SECONDARY HYDROLOGY INDICATOR POINTS:__7.0____

	Absent	Weak	Moderate	Strong
1) Are Fish Present?	0	.5	1	**1.5**
2) Are Amphibians Present?	0	.5	**1**	1.5
3) Are AquaticTurtles Present?	0	**.5**	1	1.5
4) Are Crayfish Present?	0	.5	1	**1.5**
5) Are Macrobenthos Present?	0	.5	**1**	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	**0**	.5	1	1.5
7) Is Filamentous Algae Present?	**0**	.5	1	1.5

8) Are Wetland Plants In Streambed?	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(**NOTE:** If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).*	2	1	.75	.5	**0**	0

SECONDARY BIOLOGY INDICATOR POINTS:__5.5____

TOTAL POINTS (Primary + Secondary)=__30___

(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)

NCDWQ Stream Classification Form

Project Name: Haw Branch – Reach UT3 River Basin: Cape Fear 07 County: Onslow Evaluator: S. Ricks
DWQ Project Number: Nearest Named Stream: Latitude: Signature:
Date: 3-03-04 USGS QUAD: Longitude: Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

Primary Field Indicators: (Circle One Number Per Line)

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	0	1	2	**3**
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	0	1	**2**	3
3) Are Natural Levees Present?	**0**	1	2	3
4) Is The Channel Sinuous?	0	1	**2**	3
5) Is There An Active (Or Relic) Floodplain Present?	0	1	**2**	3
6) Is The Channel Braided?	**0**	1	2	3
7) Are Recent Alluvial Deposits Present?	0	**1**	2	3
8) Is There A Bankfull Bench Present?	0	1	**2**	3
9) Is A Continuous Bed & Bank Present?	0	1	**2**	3
*(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)*				
10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map ***And/Or*** In Field) Present?		*Yes*=3	*No*=**0**	

PRIMARY GEOMORPHOLOGY INDICATOR POINTS:__14__

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	0	**1**	2	3

PRIMARY HYDROLOGY INDICATOR POINTS:__1__

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	**3**	2	1	0
2) Are Rooted Plants Present In Streambed?	3	**2**	1	0
3) Is Periphyton Present?	0	1	2	3
4) Are Bivalves Present?	0	1	2	3

PRIMARY BIOLOGY INDICATOR POINTS:__5__

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	**0**	.5	1	1.5
2) Is There A Grade Control Point In Channel?	**0**	.5	1	1.5
3) Does Topography Indicate A Natural Drainage Way?	0	.5	**1**	1.5

SECONDARY GEOMORPHOLOGY INDICATOR POINTS:__1__

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaflitter Present In Streambed?	**1.5**	1	.5	0
2) Is Sediment On Plants (Or Debris) Present?	0	**.5**	1	1.5
3) Are Wrack Lines Present?	0	.5	**1**	1.5
4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	0	.5	1	**1.5**
5) Is There Water In Channel During Dry Conditions ***Or*** In Growing Season)?	0	.5	1	**1.5**
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?		*Yes*=**1.5**		*No*=0

SECONDARY HYDROLOGY INDICATOR POINTS:__7.5__

1) Are Fish Present?	0	.5	**1**	1.5
2) Are Amphibians Present?	0	.5	**1**	1.5
3) Are AquaticTurtles Present?	0	.5	1	**1.5**
4) Are Crayfish Present?	0	**.5**	1	1.5
5) Are Macrobenthos Present?	0	.5	**1**	1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	**0**	.5	1	1.5
7) Is Filamentous Algae Present?	**0**	.5	1	1.5

8) Are Wetland Plants In Streambed?	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
(**NOTE:** If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).*	2	1	.75	**.5**	0	0

SECONDARY BIOLOGY INDICATOR POINTS:__5.5__

TOTAL POINTS *(*Primary + Secondary*)*=__34.0__

(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)

Appendix 4

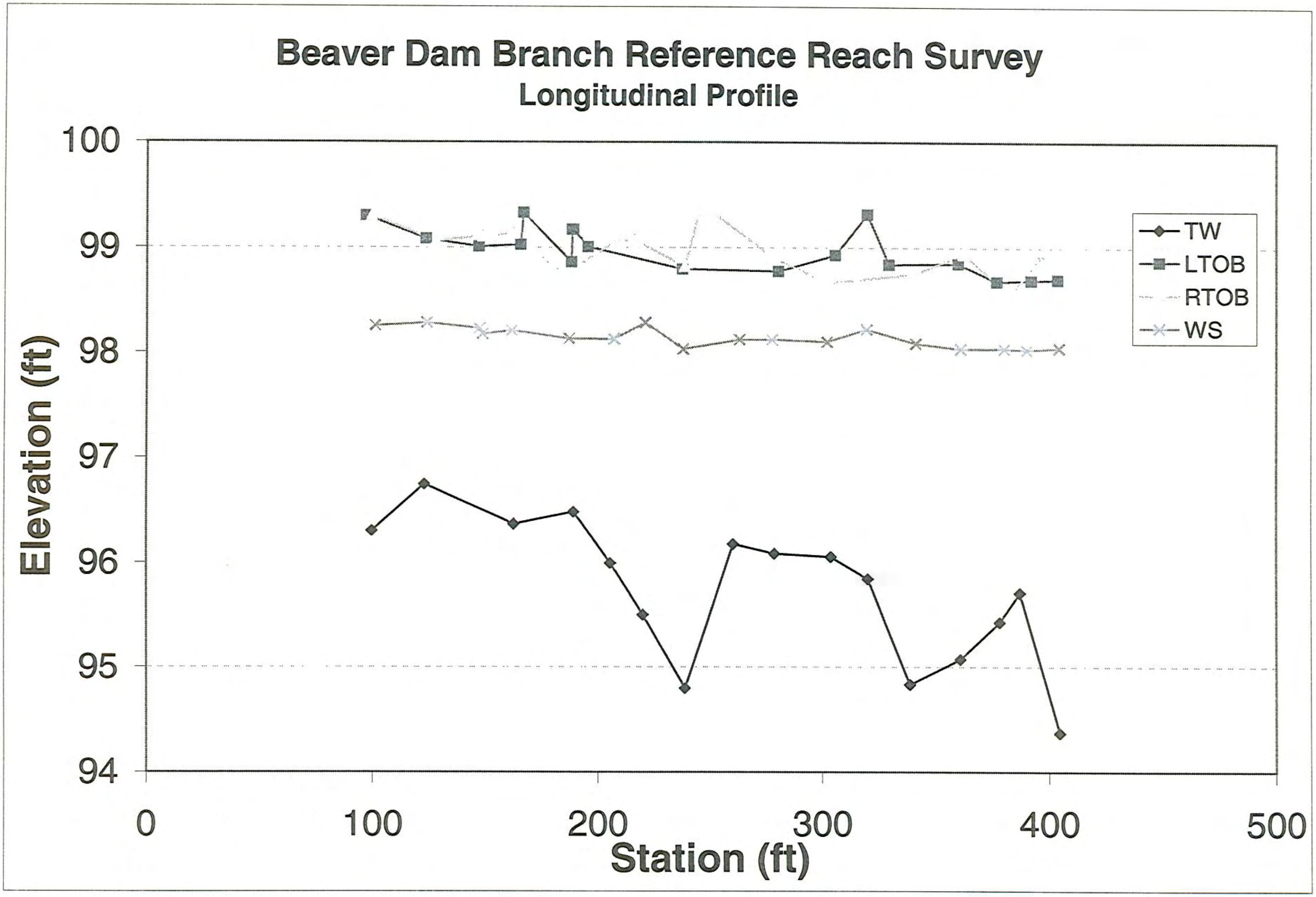
Reference Reach Summary - Beaverdam Branch, Jones County

Summary Sheet: Reference Reach

Beaver Dam Branch -Jones County, North Carolina

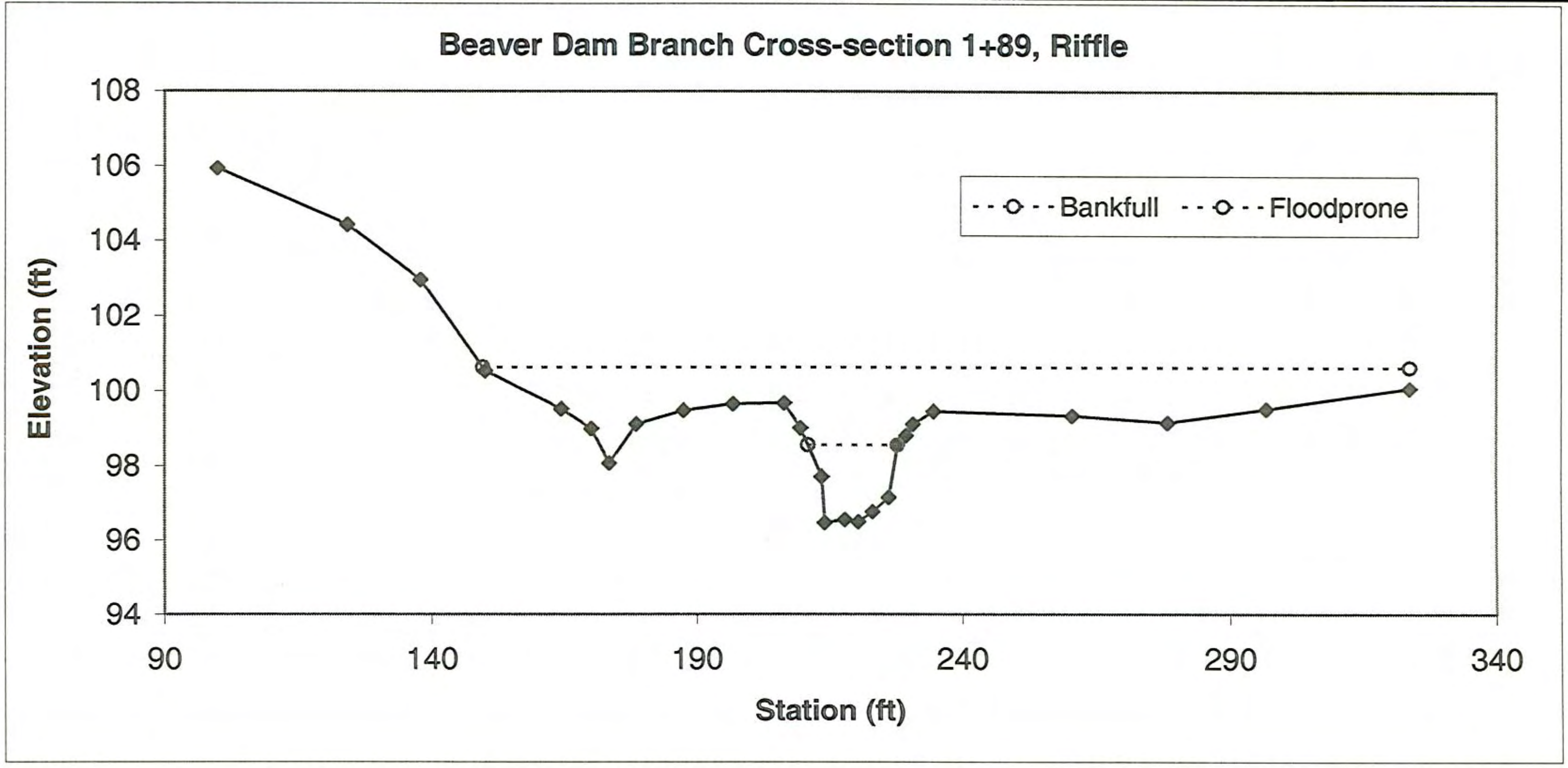
Rosgen Stream Type		E5 / C5
Drainage Area (sq mi)		3.00
Reach Length Surveyed (ft)		305
Dimension	Bankfull Width (ft)	18.6
	Bankfull Mean Depth (ft)	1.4
	Width/Depth Ratio	14
	Bankfull Area (sq ft)	25.3
	Bankfull Max Depth (ft)	2.3
	Width of Floodprone Area (ft)	>100
	Entrenchement Ratio	>10
	Max Pool Depth (ft)	3.3
	Ratio of Max Pool Depth to Bankfull Depth	2.4
	Pool Width (ft)	15.2
	Ratio of Pool Width to Bankfull Width	0.8
	Pool to Pool Spacing (ft)	100
	Ratio of Pool to Pool Spacing to Bankfull Width	5.4
	Bank Height Ratio	1.25
Pattern	Meander Length (ft)	92 - 125
	Meander Length Ratio	4.9 - 6.7
	Radius of Curvature (ft)	30 - 40
	Radius of Curvature Ratio	1.8 - 2.4
	Meander Belt Width (ft)	49 - 105
	Meander Width Ratio	2.9 - 6.3
	Sinuosity	1.66
Profile	Valley Slope* (ft/ft)	0.0007
	WS Slope* (ft/ft)	0.0004
	Pool Slope (ft/ft)	0.00001
	Ratio of Pool Slope to WS Slope	0.025

* Note: Surveyed during high water event

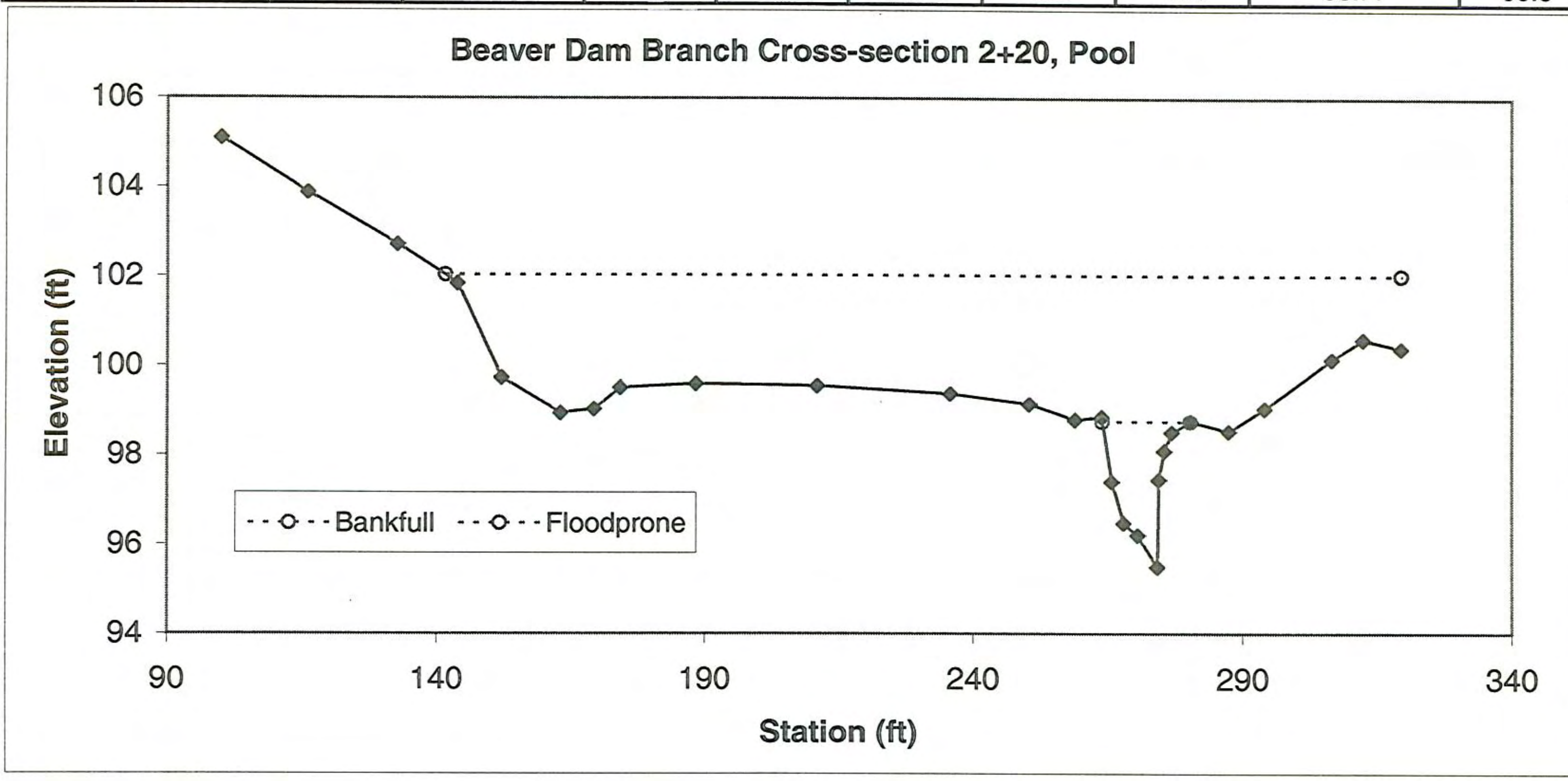


Beaver Dam Branch Reference Reach Survey
Longitudinal Profile
Elevation (ft)
100
99
98
97
96
95
94
0
100
200
300
400
500
Station (ft)
TW
LTOB
RTOB
WS

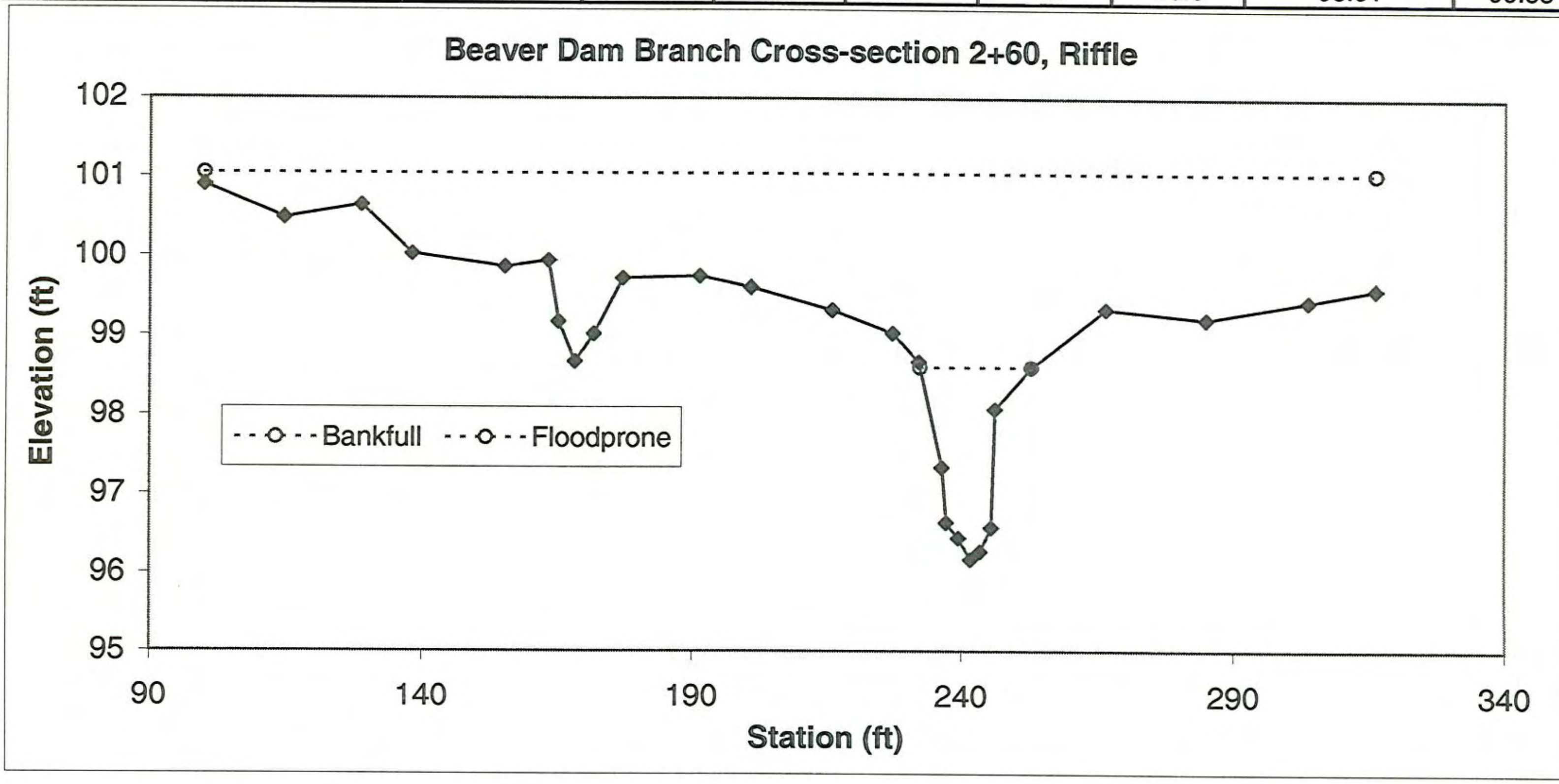
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	25.7	16.79	1.53	2.08	10.98	1.2	10.4	98.55	99.01



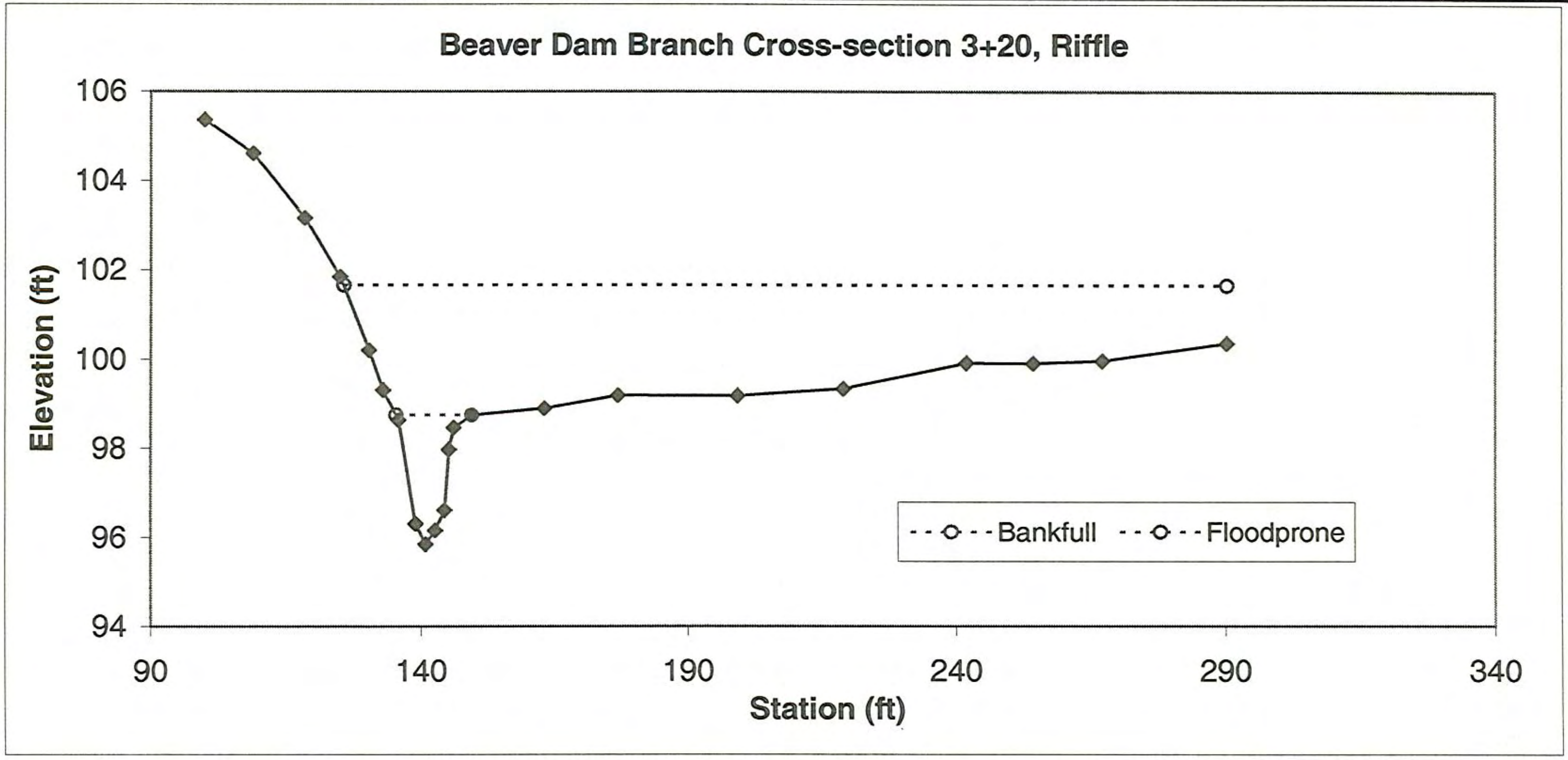
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		24.7	16.31	1.51	3.27	10.78	1.3	10.9	98.77	99.8



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C5	24.8	20.5	1.21	2.44	16.92	1.3	10.6	98.61	99.33



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		20.3	14.17	1.43	2.91	9.88	1.2	11.6	98.75	99.32

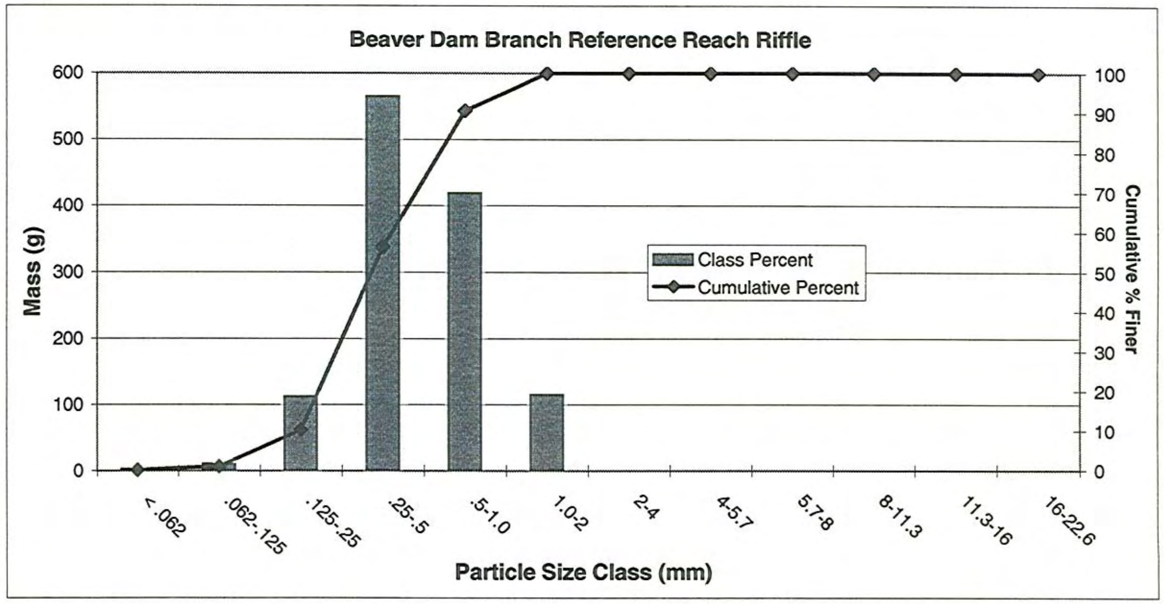


Project: EBX Marsten **Reach:** Beaver Dam Branch - near Trenton, NC
Party: Cook, Varnell **Date**

Size Distribution	mm
D16	0.27
D35	0.37
D50	0.5
D84	0.9
D95	1.5

CUMULATIVE DATA:

particle	millimeters		Riffle Total #	Cumul. %
silt/clay	< .062	S	3	0.2
very fine	.062-.125	A	10.5	1.1
fine	.125-.25	N	113	10.3
medium	.25-.5	D	566	56.3
coarse	.5-1.0		420.5	90.6
very coarse	1.0-2		116	100.0
very fine	2-4			100.0
fine	4-5.7			100.0
fine	5.7-8	G		100.0
medium	8-11.3	R		100.0
medium	11.3-16	A		100.0
coarse	16-22.6	V		100.0
coarse	22.6-32	E		100.0
very coarse	32-45	L		100.0
very coarse	45-64			100.0
small	64-90	CO		100.0
small	90-128	BB		100.0
large	128-180	LE		100.0
large	180-256			100.0
small	256-362	BO		100.0
small	362-512	UL		100.0
medium	512-1024	DER		100.0
large-very l	1024-2048			100.0
bedrock	bedrock	BEDROCK		100.0
			1229	

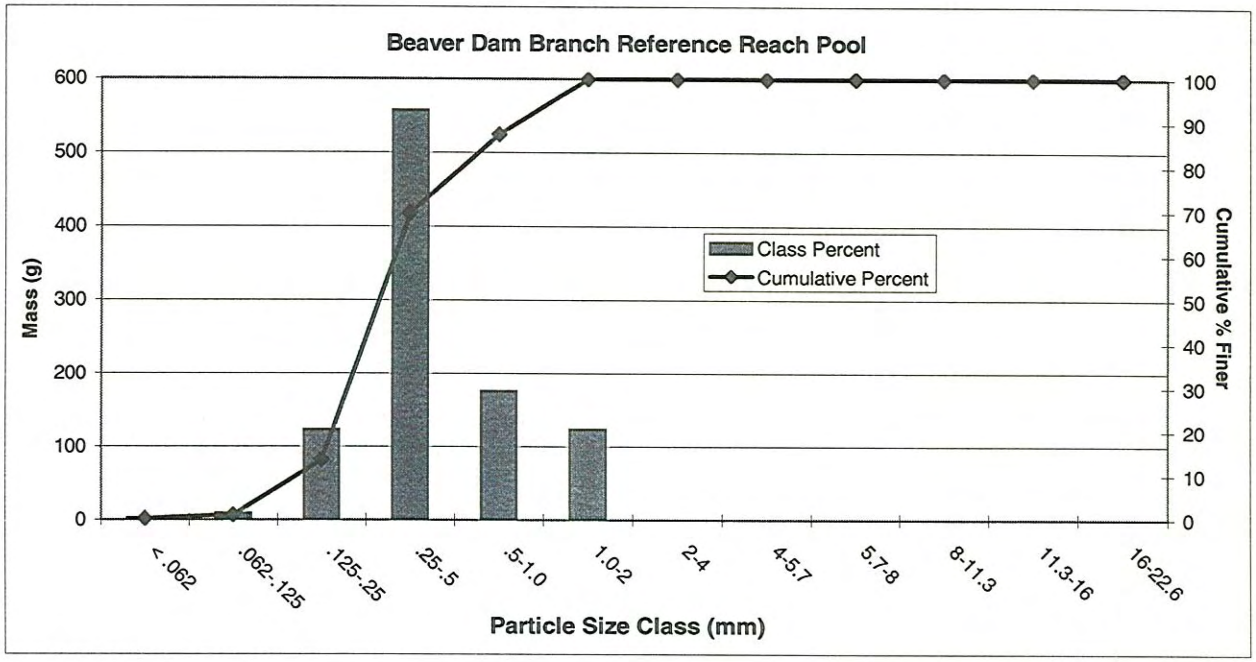


Project: EBX Marsten **Reach:** Beaver Dam Branch - near Trenton, NC
Party: Cook **Date**

Size Distribution	mm
D16	
D35	
D50	
D84	
D95	

CUMULATIVE DATA:

particle	millimeters		POOL Total #	Cumul. %
silt/clay	< .062	S	2.5	0.3
very fine	.062-.125	A	9	1.2
fine	.125-.25	N	124	13.6
medium	.25-.5	D	557.5	69.7
coarse	.5-1.0		176.5	87.5
very coars‹	1.0-2		124.5	100.0
very fine	2-4			100.0
fine	4-5.7			100.0
fine	5.7-8	G		100.0
medium	8-11.3	R		100.0
medium	11.3-16	A		100.0
coarse	16-22.6	V		100.0
coarse	22.6-32	E		100.0
very coars‹	32-45	L		100.0
very coars‹	45-64			100.0
small	64-90	CO		100.0
small	90-128	BB		100.0
large	128-180	LE		100.0
large	180-256			100.0
small	256-362	BO		100.0
small	362-512	UL		100.0
medium	512-1024	DER		100.0
large-very l	1024-2048			100.0
bedrock	bedrock	BEDROCK		100.0
			994	

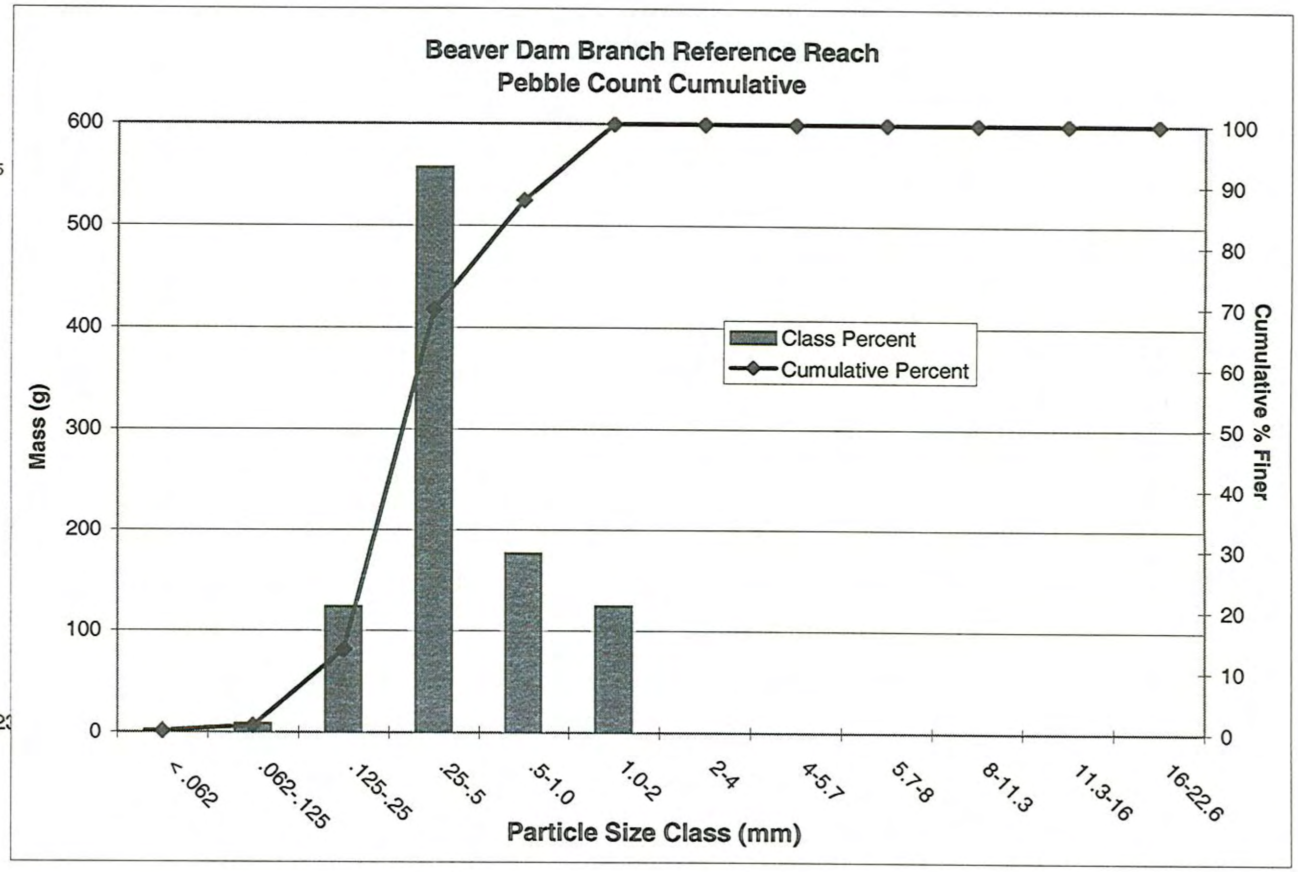


Project: EBX Marsten **Reach:** Beaver Dam Branch
Party: Cook & Varnell **Date** 3/13/2002

Size Distribution	mm
D16	0.3
D35	0.4
D50	0.5
D84	0.9
D95	1.2

CUMULATIVE DATA:

particle	millimeters		POOL Total #
silt/clay	< .062	SAND	5.5
very fine	.062-.125		19.5
fine	.125-.25		237
medium	.25-.5		1123.5
coarse	.5-1.0		597
very coarse	1.0-2		240.5
very fine	2-4	GRAVEL	
fine	4-5.7		
fine	5.7-8		
medium	8-11.3		
medium	11.3-16		
coarse	16-22.6		
coarse	22.6-32		
very coarse	32-45		
very coarse	45-64		
small	64-90	COBBLE	
small	90-128		
large	128-180		
large	180-256	BOULDER	
small	256-362		
small	362-512		
medium	512-1024		
large-very lar	1024-2048		
bedrock	bedrock	BEDROCK	
			2223



Appendix 5

DRAINMOD Analysis Files

```
*** Job Title ***
Water Balance for Haw Branch Project_Existing

*** Printout and Input Control ***
 3 111 c:\Drainmod\outputs
*** Climate ***
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANR.RAI
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANT.TEM
1946  1 2004 11 3628  85 0
 1.94 2.32 2.09 1.73 1.23 1.02  .89  .84  .95 1.07 1.23 1.38
*** Drainage System Design ***
 1
    137.00      82.46  23470.00      1.00       2.50        .50       7.30       5.00
           0     3.000000E-02    13720.000000
           0      1000.000000     1000.000000     1.200000E-03
           0     0.000000E+00    0.000000E+00     0.000000E+00    0.000000E+00
     60.00       1.00       1.00
 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85
*** Soils ***
    220.00      10.00
 100.30.00 200.10.00   0.  .00   0.  .00   0.  .00
99      .00
*** Trafficability ***
 4 1 5 1 820               3.0        1.2        2.0
12311231 820               3.0        1.2        2.0
*** Crop ***
      .170
 410 818       30.00
 410 818
 2
 1 1 15.001231 15.00
*** Wastewater Irrigation ***
 0    0 0   0   0  0
 0 0        0 0        0 0        0 0
    .00000     .00000  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
WET *** Wetlands Information ***
 1
  77 319
 30.0  12
COM *** Combo Drainage Weir Settings ***
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
```

```
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
FPE *** Fixed Avg Daily PET for the month(cm) ***
      .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
.00       .00
MRA *** Monthly Ranking ***
 0
FAC *** Daily PET Factors ***
 0
STM *** Soil Temperature ***
       ZA        ZB       TKA       TKB        TB      TLAG     TSNOW     TMELT      CDEG      CICE
     .000      .000      .000      .000        .0        .0        .0        .0        .0        .0
Initial Soil Temperature
 0
Initial snow depth(m) & density(kg/m3)
      .00       .00
Freezing characteristic curve
 0
```

```
*** Job Title ***
Water Balance for Haw Branch Project-DESIGN_50FT

*** Printout and Input Control ***
 3 111 c:\Drainmod\outputs
*** Climate ***
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANR.RAI
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANT.TEM
1946  1 2004 11 3628  85 0
 1.94 2.32 2.09 1.73 1.23 1.02  .89  .84  .95 1.07 1.23 1.38
*** Drainage System Design ***
 2
     20.00    111.74   1524.00      4.00      2.50      2.00      3.90      5.00
           0    3.000000E-02    13720.000000
           0     1000.000000     1000.000000    1.200000E-03
           0    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
     60.00      1.00      1.00
 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85
*** Soils ***
    220.00      5.00
 100.30.00 200.10.00   0.  .00   0.  .00   0.  .00
99     .00
*** Trafficability ***
 4 1 5 1 820               3.0       1.2       2.0
12311231 820               3.0       1.2       2.0
*** Crop ***
      .170
 410 818        30.00
 410 818
 2
 1 1 15.001231 15.00
*** Wastewater Irrigation ***
 0    0 0   0   0  0
 0 0       0 0      0 0       0 0
    .00000    .00000  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
WET *** Wetlands Information ***
 1
  77 319
 30.0  12
COM *** Combo Drainage Weir Settings ***
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
```

```
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
FPE *** Fixed Avg Daily PET for the month(cm) ***
      .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
.00      .00
MRA *** Monthly Ranking ***
 0
FAC *** Daily PET Factors ***
 0
STM *** Soil Temperature ***
       ZA       ZB      TKA      TKB       TB     TLAG    TSNOW    TMELT     CDEG     CICE
     .000     .000     .000     .000       .0       .0       .0       .0       .0       .0
Initial Soil Temperature
 0
Initial snow depth(m) & density(kg/m3)
      .00      .00
Freezing characteristic curve
 0
```

```
*** Job Title ***
Water Balance for Haw Branch Project-DESIGN_200FT

*** Printout and Input Control ***
 3 111 c:\Drainmod\outputs
*** Climate ***
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANR.RAI
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANT.TEM
1946  1 2004 11 3628  85 0
 1.94 2.32 2.09 1.73 1.23 1.02  .89  .84  .95 1.07 1.23 1.38
*** Drainage System Design ***
 2
     20.00    167.59   6096.00      4.00      2.50      2.00      3.90      5.00
            0    3.000000E-02    13720.000000
            0     1000.000000     1000.000000    1.200000E-03
            0    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
     60.00      1.00      1.00
 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85
*** Soils ***
    220.00      5.00
 100.30.00 200.10.00   0.  .00   0.  .00   0.  .00
99     .00
*** Trafficability ***
 4 1 5 1 820                3.0       1.2       2.0
12311231 820                3.0       1.2       2.0
*** Crop ***
      .170
 410 818       30.00
 410 818
 2
 1 1 15.001231 15.00
*** Wastewater Irrigation ***
 0    0 0   0   0  0
 0 0       0 0       0 0       0 0
    .00000    .00000  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
WET *** Wetlands Information ***
 1
  77 319
 30.0  21
COM *** Combo Drainage Weir Settings ***
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
```

```
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
 0  0  0     .0
FPE *** Fixed Avg Daily PET for the month(cm) ***
      .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
.00      .00
MRA *** Monthly Ranking ***
 0
FAC *** Daily PET Factors ***
 0
STM *** Soil Temperature ***
       ZA       ZB      TKA      TKB       TB     TLAG    TSNOW    TMELT     CDEG     CICE
     .000     .000     .000     .000       .0       .0       .0       .0       .0       .0
Initial Soil Temperature
 0
Initial snow depth(m) & density(kg/m3)
      .00       .00
Freezing characteristic curve
 0
```

```
*** Job Title ***
Water Balance for Haw Branch Project-DESIGN_500FT

*** Printout and Input Control ***
 3 111 c:\Drainmod\outputs
*** Climate ***
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANR.RAI
     1 L:\PROJECTS\0211R\DRAINMOD\HOFFMANT.TEM
1946  1 2004 11 3628  85 0
 1.94 2.32 2.09 1.73 1.23 1.02  .89  .84  .95 1.07 1.23 1.38
*** Drainage System Design ***
 2
     20.00    185.71  15240.00       4.00       2.50       2.00       3.90       5.00
          0    3.000000E-02    13720.000000
          0     1000.000000     1000.000000    1.200000E-03
          0    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
     60.00      1.00      1.00
 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85 1 85
*** Soils ***
    220.00      5.00
 100.30.00 220.10.00   0.  .00   0.  .00   0.  .00
99     .00
*** Trafficability ***
 4 1 5 1 820              3.0       1.2       2.0
12311231 820              3.0       1.2       2.0
*** Crop ***
      .170
 410 818       30.00
 410 818
 2
 1 1 15.001231 15.00
*** Wastewater Irrigation ***
 0    0 0   0   0  0
 0 0        0 0        0 0        0 0
    .00000    .00000  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00
WET *** Wetlands Information ***
 1
  77 319
 30.0  34
COM *** Combo Drainage Weir Settings ***
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
```

```
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
 0  0  0    .0
FPE *** Fixed Avg Daily PET for the month(cm) ***
       .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
.00       .00
MRA *** Monthly Ranking ***
 0
FAC *** Daily PET Factors ***
 0
STM *** Soil Temperature ***
        ZA        ZB       TKA       TKB        TB      TLAG     TSNOW     TMELT      CDEG      CICE
      .000      .000      .000      .000        .0        .0        .0        .0        .0        .0
Initial Soil Temperature
 0
Initial snow depth(m) & density(kg/m3)
        .00        .00
Freezing characteristic curve
 0
```

Appendix 6

Photographic Log

UT1 – upstream of project reach in wooded area.

UT1 – within the project area.

Confluence of UT1 and UT2.

UT2 – within the project area.

Culverted crossing on UT2.

UT2 – at the beginning of the reach.

UT3 – at the upstream end of the reach.

UT3 – at the downstream end of the reach.

Monitoring well used to document existing hydrology.

Open field areas of UT2 and UT1 – hydric soil areas.

Appendix 7

Reference Wetland Delineation Forms

SOILS

Map Unit Name (Series and Phase): Rains **Drainage Class:** poorly drained

Taxonomy (Subgroup): Typic Paleaquults **Confirm Mapped Type?** Soil Survey

Profile Description:

Depth (inches)	Horizon	Matrix Colors (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-7	A	10YR 3/1			sandy loam
7-12	Eg	10YR 6/2			sandy loam
12 – 40+	B	10YR 6/1			sandy clay loam

Hydric Soil Indicators:

- ____ Histosol
- ____ Histic Epipedon
- ____ Sulfidic Odor
- ____ Aquic Moisture Regime
- X Reducing Conditions
- X Gleyed or Low-Chroma Colors
- ____ Concretions
- ____ High Organic Content in Surface Layer in Sandy Soils
- ____ Organic Streaking in Sandy Soils
- X Listed On Local Hydric Soils List
- X Listed on National Hydric Soils List
- ____ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes X No ____
Wetland Hydrology Present? Yes X No ____
Hydric Soils Present? Yes X No ____

Is the Sampling Point Within a Wetland? Yes X No ____

Remarks: Location is classified as a wetland based upon the criteria set forth in the 1987 Army Corps of Engineers Wetlands Delineation Manual.

Buck Engineering - 8000 Regency Parkway, Suite 200 - Cary, NC 27511

DATA FORM - ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Determination Manual)

Project / Site: Hoffman Forest Reference Site – Bear Prong Area
Applicant / Owner:
Investigator: Buck Engineering – John Hutton

Date: 11-20-04
County: Onslow
State: NC

Do normal circumstances exist on the site? Yes X No ___
Is the site significantly disturbed (Atypical situation)? Yes ___ No X
Is the area a potential problem area? Yes ___ No X
(explain on reverse if needed)

Community ID: Small Stream Swamp
Transect ID:
Plot ID: Bear Prong

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. *Quercus nigra*	Tree	FAC	9. *Osmunda cinnamomea*	Herb	FACW
2. *Acre rubrum*	Tree	FAC	10. *Lyonia lucida*	Shrub	FACW
3. *Magnolia virginiana*	Shrub	FACW+	11. *Smilax sp.*	Herb	FAC
4. *Nyssa silvatica*	Tree	FAC	12.		
5. *Liquidambar styraciflua*	Tree	FAC+	13.		
6. *Arundinaria gigantea*	Herb	FACW	14.		
7. *Morella cerifera*	Shrub	FAC	15.		
8. *Ilex opaca*	Shrub	FAC-	16.		

Percent of Dominant Species that are OBL, FACW, or FAC excluding FAC-). ________

Remarks: Wetland Vegetation Present Based Upon Greater than 50% of the Plant Species are Classified as FAC-OBL in the National List of Plant Species that Occur in Wetlands.

HYDROLOGY

X **Recorded Data (Describe In Remarks):**
- ___ Stream, Lake, or Tide Gauge
- ___ Aerial Photographs
- X Other

___ **No Recorded Data Available**

Field Observations:

Depth of Surface Water: none (in.)

Depth to Free Water in Pit: 6 (in.)

Depth to Saturated Soil: 0 (in.)

Wetland Hydrology Indicators

Primary Indicators:
- ___ Inundated
- X Saturated in Upper 12"
- X Water Marks
- ___ Drift Lines
- ___ Sediment Deposits
- X Drainage Patterns in Wetlands

Secondary Indicators:
- ___ Oxidized Roots Channels in Upper 12"
- X Water-Stained Leaves
- X Local Soil Survey Data
- ___ FAC-Neutral Test
- ___ Other (Explain in Remarks)

Remarks: Water table data available from 2000 – 2004 indicate wetland hydrology ranging from approximately 8 – 24% of growing season. Hydrology criteria met.

SOILS

Map Unit Name (Series and Phase): Muckalee **Drainage Class:** poorly drained

Taxonomy (Subgroup): Typic Fluvaquents **Confirm Mapped Type?** Soil Survey

Profile Description:

Depth (inches)	Horizon	Matrix Colors (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-6	A	10YR 4/1			loam
6-40+	C	10YR 4/1			sandy loam

Hydric Soil Indicators:

____ Histosol
____ Histic Epipedon
____ Sulfidic Odor
____ Aquic Moisture Regime
_X_ Reducing Conditions
_X_ Gleyed or Low-Chroma Colors
____ Concretions
____ High Organic Content in Surface Layer in Sandy Soils
____ Organic Streaking in Sandy Soils
_X_ Listed On Local Hydric Soils List
_X_ Listed on National Hydric Soils List
____ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes _X_ No ____
Wetland Hydrology Present? Yes _X_ No ____
Hydric Soils Present? Yes _X_ No ____

Is the Sampling Point Within a Wetland? Yes _X_ No____

Remarks: Location is classified as a wetland based upon the criteria set forth in the 1987 Army Corps of Engineers Wetlands Delineation Manual.