Cox Site
Wetland and Stream Restoration Plan
Johnston County, North Carolina

Submitted by:

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March 2005

DRAFT REPORT

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Prepared for EBX Neuse-I, LLC

Design Report Prepared by Buck Engineering PC

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EXECUTIVE SUMMARY

Environmental Banc and Exchange Neuse-I, LLC (EBXN-I), proposes to restore 7,263 linear feet (LF) and enhance 285 LF of stream and restore 25 acres of riverine and 16.9 acres of non-riverine wetlands along an unnamed tributary to Mill Creek. This unnamed tributary to Mill Creek will be referred to as Cox Branch throughout the restoration plan. The Cox Site is located in Johnston County, south of Smithfield, NC, within cataloging unit 03020201, and NC Division of Water Quality (NCDWQ) sub-basin 03-04-04 of the Neuse River Basin (Exhibits 1.1 and 1.2). The project site is located within targeted local watershed 03020201150050 and is immediately adjacent to the Westbrook Stream and Wetland Mitigation Site that was developed as part of the Neu-Con Wetland and Stream Umbrella Mitigation Bank within the Neuse River Basin. .

Cox Branch is a moderate size, perennial stream with a drainage area of 1.8 square miles at the downstream end of the site (Exhibit 1.3). Historically, the site has been used for agricultural production. Cleared areas in the upstream portion of the project area are currently used for livestock production. The riparian vegetation in this area is predominantly herbaceous, as it was once maintained for hay production. This curtailed any efforts for native woody vegetation to establish along the stream banks. Fields in the downstream portion of the site are currently used for row crop agricultural production.

Based on field evaluations of intermittent / perennial status, the stream channel is considered perennial using NCDWQ stream assessment protocols. Currently, Cox Branch is classified as an incised "E5/G5c" stream type using the Rosgen stream classification (Rosgen, 1996). The bank height ratios range from 1 to 2.5 along the existing channel. The channel shape is trapezoidal and the stream is not protected by adequate riparian vegetation except for within the forested areas of the project reach. Cox Branch is considered moderately unstable, both vertically and laterally, throughout the upper and lower fields and exhibits areas of high erosion. Pool formation is poor with very little habitat diversity or woody debris.

The site is bordered to the east by bottomland hardwood forest. All of the cleared fields on the site have been designated as prior converted (PC) farmland by the Natural Resources Conservation Service (NRCS) as shown in Exhibit 5.1. The on-going nature of the farming operations and prior converted status of the site present a significant opportunity for ecosystem-based restoration. On-site investigations reflect that all acreage to be restored is underlain by "A" list hydric soils. Areas targeted for restoration are mapped as the Pantego soil series.

The proposed restoration areas are shown in Exhibit 1.4. The design goals of the project include:

- Restoration of 7,263 LF of stream channel
- Enhancement of 285 LF of stream channel
- Restoration of 25 acres of riverine wetlands
- Restoration of 16.9 non-riverine wetland acres
- Continued separation of cattle from stream, wetland and riparian buffer areas
- Restoration within a targeted local watershed
- An ecosystem-based restoration design
- Improvements to habitat functions
- Significant water quality benefits.

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Project Feature	Existing Condition	Design Condition	Approach
Cox Branch	6,160 LF	7,548 LF	Priority 1/Priority IV Restoration
Riverine Wetland Restoration	0.88 acres	25.88 acres	Grading, Soil Roughing, and Planting
Non-Riverine Wetland Restoration	0 acres	16.9 acres	Grading, Soil Roughing, and Planting

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1.0 INTRODUCTION AND BACKGROUND

1.1 Brief Project Description and Location

Environmental Banc and Exchange Neuse-I, LLC (EBXN-I), proposes to restore 7,263 linear feet (LF) and enhance 285 LF of channelized stream and restore 25 acres of riverine wetlands and 16.9 acres of non-riverine wetlands along an unnamed tributary to Mill Creek. This unnamed tributary to Mill Creek will be referred to as Cox Branch throughout the restoration plan. Exhibits 1.1 and 1.2 provide an overview of the project site. The project site is located in Johnston County in the Neuse River Basin.

Cox Branch is a moderate size, perennial stream with a drainage area of 1.8 square miles at the downstream end of the site (Exhibit 1.3). Historically, the site has been used for agricultural production. Cleared areas in the upstream portion of the project area are currently used for livestock production. The riparian vegetation in this area is predominantly herbaceous, as it was once maintained for hay production. This curtailed any efforts for native woody vegetation to establish along the stream banks. Fields in the downstream portion of the site are currently used for row crop agricultural production.

Based on field evaluations of intermittent/perennial status, the stream channel is considered perennial using NCDWQ stream assessment protocols. Currently, Cox Branch is classified as an incised "E5/G5c" stream type using the Rosgen stream classification (Rosgen, 1996). The bank height ratios range from 1 to 2.5 along the existing channel. Cox Branch is a trapezoidal channel that is considered moderately unstable, both vertically and laterally, throughout the upper and lower fields and exhibits areas of high erosion. Pool formation is poor with very little habitat diversity or woody debris. Additionally, the stream is not protected by adequate riparian vegetation except for within the forested areas of the project reach.

1.2 Project Goals and Objectives

The proposed restoration areas are shown in Exhibit 1.4. The proposed stream and wetland restoration project will provide numerous ecological benefits within the Neuse River basin. While many of these benefits are limited to the project area, others, such as pollutant removal and improved aquatic and terrestrial habitat, have more far-reaching effects. Expected improvements to water quality, hydrology, and habitat are outlined below as project goals.

Water Quality

- Nutrient removal
- Sediment removal
- Increased dissolved oxygen concentrations
- Improved streambank stability
- Wetland filtering

Water Quantity/Flood Attenuation

- Increased water storage/flood control
- Reduced downstream flooding by reconnecting stream with its floodplain
- Improved ground water recharge
- Improved/restored hydrologic connections

Aquatic and Terrestrial Habitat

- Improved substrate and in-stream cover
- Addition of large woody debris
- Reduced water temperature by increasing shading
- Restoration of terrestrial habitat
- Improved aesthetics

1.3 Report Overview

This report has been arranged and formatted to maximize its utility. Readers unfamiliar with stream and wetland restoration science and methodology may wish to review the background material in Sections 2 and 3. Those familiar with Buck Engineering's design processes and procedures may wish to focus on Sections 4, 5, 6, 7, 8, and 9 of the report, which are specific to the project site. These sections cover the site assessment findings, selection and application of design criteria, and site design. Section 10 summarizes post-construction monitoring and evaluation procedures.

2.0 STREAM RESTORATION BACKGROUND SCIENCE AND METHODS

2.1 Application of Fluvial Processes to Stream Restoration

A stream and its floodplain comprise a dynamic environment where the floodplain, 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 reflect all of these factors (Leopold et al., 1992; Knighton, 1988). The result is a dynamic equilibrium where the stream maintains its dimension, pattern, and profile over time, and neither degrades nor aggrades. Land use changes in the watershed, including increases in imperviousness and removal of riparian vegetation, 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). By understanding and applying natural stream processes to stream restoration projects, a self-sustaining stream can be designed and constructed that maximizes stream and biological potential (Leopold et al., 1992; Leopold, 1994; Rosgen, 1996).

In addition to transporting water and sediment, natural streams provide the habitat for many aquatic organisms including fish, amphibians, insects, mollusks, and plants. Trees and shrubs along the banks provide a food source and regulate water temperatures. Channel features such as pools, riffles, steps, and undercut banks provide diversity of habitat, oxygenation, and cover (Dunne and Leopold, 1978). Stream restoration projects can repair these features in concert with the return of a stable dimension, pattern, and profile. The following sections provide an overview of the primary channel forming process and typical stream morphology.

2.1.1 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 states 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 minimized (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 considered to be incised.

2.1.2 Bedform Diversity and Channel Substrate

The profile of a stream bed and its bed materials are 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%, while alluvial channels have slopes less than 2%. 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).

2.1.2.1 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 plunge pool downstream. Smaller particles collect in the interstices of steps creating stable, interlocking structures (Knighton, 1988).

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.

2.1.2.2 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, and the resulting turbulence provide 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, 1988). 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: 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.

2.1.2.3 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 in diameter (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. We use "riffle" in this report as equivalent to the 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 random sediment accumulations 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 the low flow features and the high flow regime 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 that is opposite of ripples and dunes. Antidunes can also move downstream or remain stationary for short periods (Knighton, 1998).

2.1.3 Stream Classification

The Rosgen stream classification system categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system presents several stream types based on a hierarchical system. The classification system is illustrated on Exhibit 2.1. The first level of classification distinguishes between single and multiple thread channels. Streams are then separated based on 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 was provided in Section 2.1.1.

2.1.4 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 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.

2.1.5 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 runoff 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, including:

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 results in an increase in stream power that causes degradation, often referred to as channel incision (Lane, 1955). According to research summarized by the Federal Interagency Stream Restoration Working Group (FISRWG), 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).

2.1.6 Priority Levels of Restoring Incised Rivers

Though incised streams can occur naturally in certain landforms, they are often the product of disturbance. High, steep stream banks, poor or absent in-stream or riparian habitat, increased erosion and sedimentation, and low sinuosity are all characteristics of incised streams. Complete restoration of the stream, where the incised channel's grade is raised so that an abandoned floodplain terrace is reclaimed, is ideally the overriding project objective. There may be scenarios, however, where such an objective is impractical due to encroachment into the abandoned floodplain terrace by homes, roadways, utilities, etc. 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's 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.

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.

2.2 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 2.5. 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 2.6.

After the sediment transport assessment, additional structural elements are then added to the design to provide grade control, protect stream banks, and enhance habitat. Section 2.7 describes these in-stream structures in detail.

Once the design is finalized, detailed drawings are prepared showing 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.)
- Determine the extent to which the restoration objectives have been met.

2.3 Geomorphic Characterization Methodology

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

2.3.1 Bankfull Identification

Correct identification of bankfull is important to the determination of geomorphic criteria such as stream type, bank height ratios, width to depth ratios, and entrenchment ratios. 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.
- Go to 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 bank.
- 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, along with regional curve information, to estimate bankfull elevation in a project reach that lacks bankfull indicators.

2.3.2 Bed Material Characterization

Buck Engineering typically performs bed material characterization 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 being 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 bed material classification is shown on 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 sandbed 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 back 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.

2.3.3 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 associated with each bed material classification used are used 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.

2.4 Channel Stability Assessment Methodology

Buck Engineering uses a modified version of stream channel stability assessment methodology developed by Rosgen (2001). 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
- Channel Evolution.

This field exercise is followed by the evaluation of various channel dimension relationships. The evaluation of the above characteristics leads to a determination of a channel's current state, potential for restoration, and appropriate restoration activities. A description of each category is provided in the following sections.

2.4.1 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 – such as 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
- Altered states due to direct disturbance – such as channelization, berm construction, and floodplain alterations.

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.

2.4.2 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 (2001).

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).

2.4.3 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, and 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.

2.4.4 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.

2.4.5 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 the head of a 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.

2.4.6 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 (2001).

Table 2.2
Conversion of Width/Depth Ratios to Adjective Ranking of Stability (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*. 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.

2.4.7 Channel Evolution

Simon's channel evolution model (introduced in Section 2.1.5) relies on a qualitative, visual assessment of the existing stream channel characteristics (bank height, evidence of degradation/aggradation, presence of bank slumping, direction of bed and bank movement, etc.). 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.

2.5 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.

2.5.1 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.

2.5.2 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. The search 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 U.S. Geological Survey (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 field-evaluated 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 any survey work being conducted.

2.5.3 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.

2.5.4 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* (Copeland et al., 2001) by the US Army Corps of Engineers (USACE). 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. However, the USACE 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 USACE-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.

2.5.5 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 post-construction site conditions. 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 7.0.

2.6 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/ft2) 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)

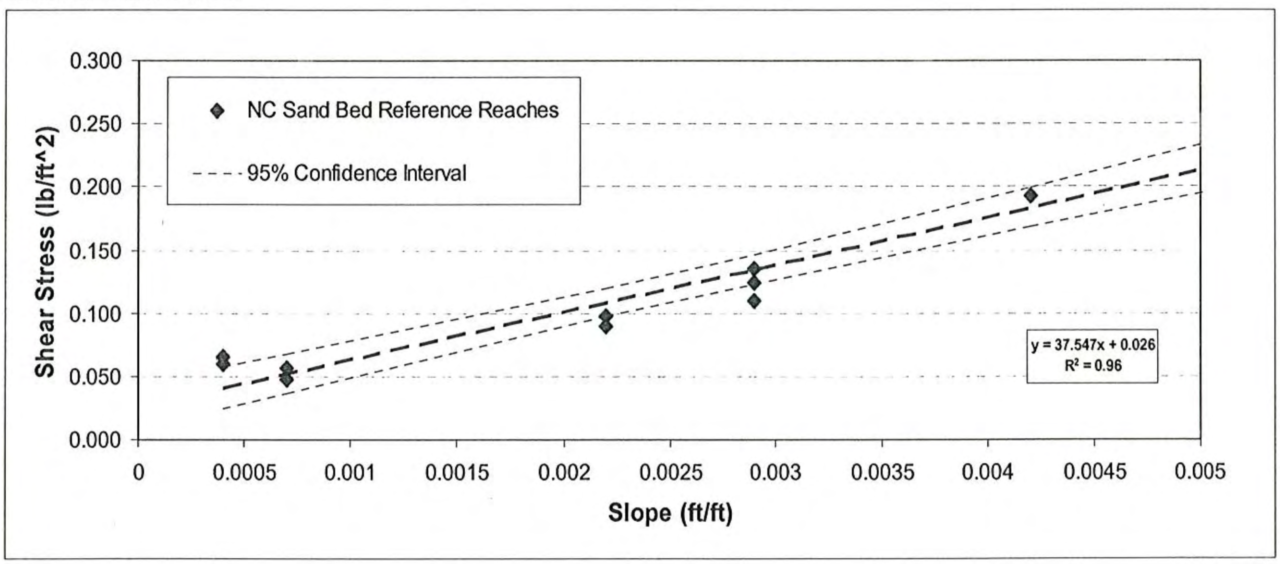
γ = specific gravity of water (62.4 lb/ft^3)

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:

$$\omega = \gamma QS/W, \text{ where} \qquad \text{Equation (2)}$$

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)

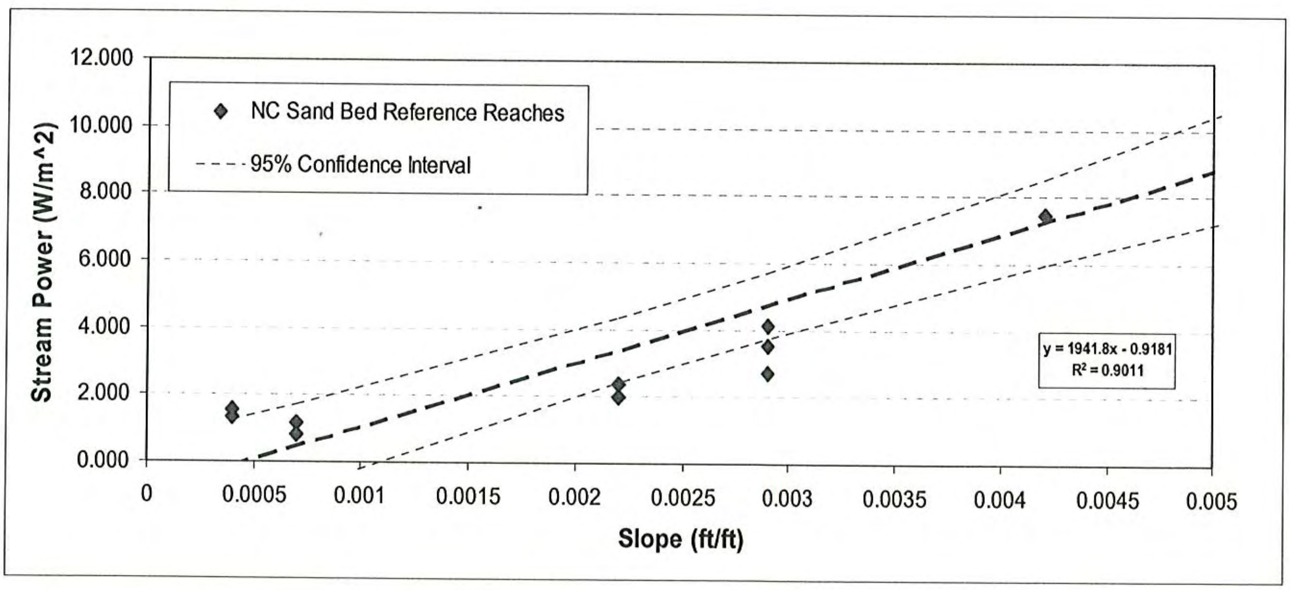
W = bankfull channel width in meters

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

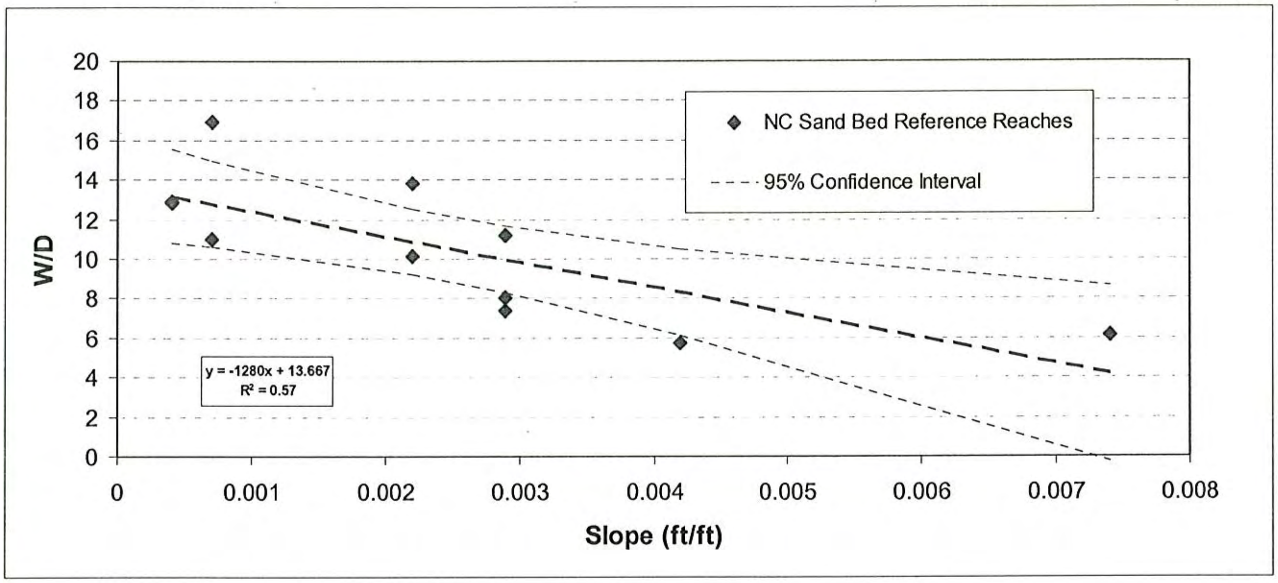
Comparison between stream power and channel slope for the design reaches and Coastal Plain reference reach data.



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.



2.7 In-Stream Structures

There are a variety of in-stream structural elements used in restoration. Exhibit 2.8 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.

2.7.1 Grade Control

Grade control pertains mainly to the design bed profile. A newly excavated gravel stream bed with a slope greater than 0.5% is seldom able to maintain the desired slopes and bed features (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.

2.7.2 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 is typically providing 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.

2.7.3 Habitat Enhancement

Habitat enhancement can take several forms and is often a secondary function of grade control and bank protection structures. The flow of water 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.

2.7.4 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		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, structure installation comprises the main, or possibly only, effort required 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.

2.8 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 a food source 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 typically includes live dormant staking of the stream banks, riparian buffer plantings, 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. Establishing vegetation along the stream banks is a very 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.

2.8.1 Live Staking

Live staking is a method of revegetation 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 provide 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 in diameter and no more than 2 inches in diameter, between 2 and 3 feet in length, and living based on 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.

2.8.2 Riparian Buffer Re-Vegetation

Riparian buffers are areas of perennial vegetation 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 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 runoff 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 greater 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.

2.9 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 importantly, the execution of the construction phase. There are many factors that ultimately determine the success of these projects and many of the factors are beyond the influence of a designer. To compile all of the factors is beyond the scope of this report. Further, it is impossible to consider and to design for all of them. However, it is important to acknowledge those factors such as daily temperatures, the 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. However, 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 WETLAND RESTORATION BACKGROUND SCIENCE AND METHODS

3.1 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.

3.2 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; US Department 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. Wetland soils help to return excess nitrogen to the atmosphere through denitrification. 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 to 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.

3.3 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. 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 rhizospheres 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 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.

3.4 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 USACE's Wetland Research Program (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.

3.5 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., (1991) 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.

3.6 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 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 computer aided design and drafting (CADD) applications and submitted to USACE and the NCDWQ for jurisdictional determination and verification when required.

3.7 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.

3.8 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.

3.8.1 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.

<u>Restoration of Stream Channels</u> – 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 2.1, 2.2, and 2.5.

<u>Filling and Blocking of Drainage Features</u> – 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.

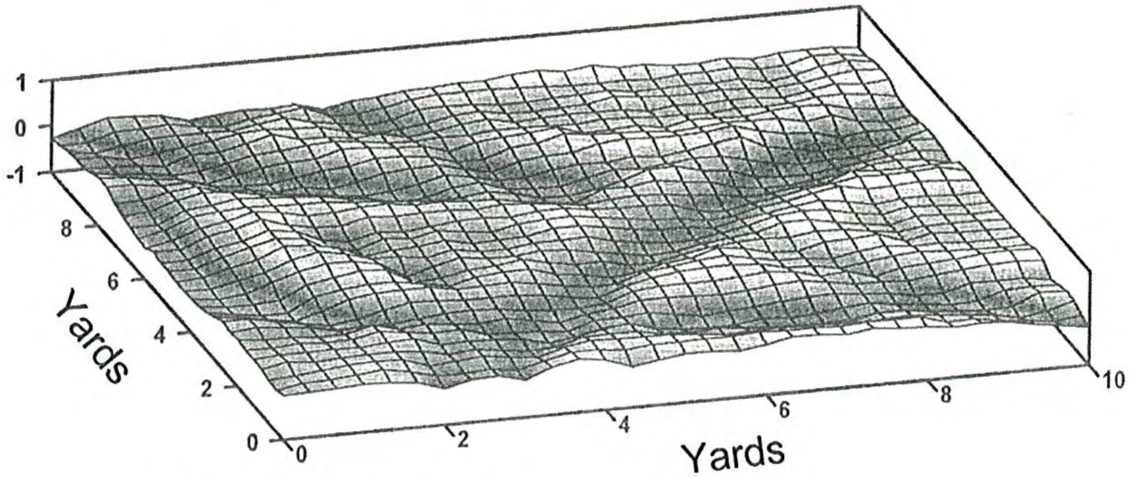
Shallow Depressions and Floodplain Pools – To increase the diversity of hydrologic conditions across the site, shallow depressions and floodplain pools can be excavated or created by leaving sections of ditches only partially filled in certain areas. The depressions are constructed to mimic the function 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 3.1. 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 3.1
Typical Pattern of Restored Wetland Microtopography (Scherrer, 2000)



3.8.2 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 to 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.

3.8.3 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.

3.9 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.

4.0 WATERSHED ASSESSMENT RESULTS

4.1 Watershed Delineation

The Cox Site lies in the Neuse River Basin within North Carolina NCDWQ sub-basin 03-04-04 and USGS hydrologic unit 03020201150050. Exhibit 1.3 shows the watershed boundaries of this project. The 1.8-square-mile drainage area contains less than 1 percent impervious surface. The watershed is mainly agricultural, with single family homes and rural highways.

4.2 Site Hydrology/Hydraulics

4.2.1 Surface Water Classification

NCDWQ designates surface water classifications for water bodies 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.

All surface waters within the Neuse River Basin have been given a supplemental classification of Nutrient Sensitive Water (NSW) by NCDWQ (NCDWQ 2000). North Carolina has adopted the Neuse Basin Nutrient Sensitive Waters Management Strategy. The strategy includes a provision to maintain and protect riparian buffers in the basin (15A NCAC 2B .0233).

Cox Branch is a moderate size, perennial stream with a drainage area of 1.8 square miles at the downstream end of the site (Exhibit 1.3). This stream was previously channelized to improve drainage in the surrounding fields. Based on field evaluations of intermittent / perennial status, the stream channel is considered perennial using NCDWQ stream assessment protocols, receiving a NCDWC stream classification score of 40.5. Cox Branch flows into Mill Creek, which is classified as a Class C NSW. Based on North Carolina's tributary rule, Cox Branch is considered a Class C stream.

Currently, Cox Branch is classified as an incised "E5/G5c" stream type using the Rosgen stream classification (Rosgen, 1996) with one reach that classes out as a G5 as a result of the degree of incision. The bank height ratios range from 1 to 2.5 along the existing channel. The channel shape is trapezoidal and the stream is not protected by adequate riparian vegetation until it reaches the forested area midway through the project reach. Cox Branch is considered moderately unstable, both vertically and laterally, throughout the upper and lower fields and exhibits areas of high erosion. Pool formation is poor with very little habitat diversity or woody debris.

4.3 Site Hydrologic and Hydraulic Characteristics

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) for Johnston County, NC (Community Number 37101) indicates that the Cox Branch falls in Zone A, which is designated as a special flood hazard area inundated by the 100-year flood. Zone A indicates that no base flood elevations have been determined.

4.4 Geology

Cox Branch is located in southeastern Johnston County, N.C., in the Coastal Plain of eastern North Carolina. The Black Creek Formation is exposed in the project area. This formation was deposited in the Upper Cretaceous Period, and consists of thinly laminated sands and clays. Cross bedded sands are common as is lignitic clay associated with marcasite. Glauconite is found in some of the sands. Clays are characteristically dark grey to black.

The upper part of the Black Creek Formation contains abundant marine fauna within calcareous greensand and marine clay. The bedded and cross-bedded sands, clays, and lignites were probably deposited in shallow seas or in bays and estuaries while the calcareous deposits in the upper portion suggest deeper sea water (Stuckey and Conrad 1958).

4.5 Soils

Soils types at the site were determined using Natural Resource Conservation Service (NRCS) Soil Survey data for Johnston County (USDA 2000), along with on-site evaluations to verify areas of hydric soil. A map depicting the boundaries of each soil type is presented in Exhibit 4.1. There are three general soil types found within the project boundaries: Pantego, Bibb, and Alta Vista.

Soils within the proposed restoration area are mapped as the Pantego series by the NRCS. The Pantego series falls in the Hydric "A" list which means that units consist of all hydric soils or have hydric soils as a major component. Pantego consists of very deep, very poorly drained, moderately permeable soils that formed in thick loamy sediments on broad stream terraces of the Coastal Plain. It has moderate permeability, with available water capacity considered to be moderate to high. Surface runoff is slow and the seasonal high water table is within 1 foot of the surface in the winter and spring under undrained conditions. Slopes are 0 to 2 percent. Pantego soils generally have inclusions of Augusta or Bibb soils.

Bibb and Altavista soils are found on the northern boundary of the project. They have less clay throughout than the Pantego soil and are along small streams or at the edge of larger floodplains and stream terraces, respectively. Permeability, water capacity, surface runoff, and seasonal high water tables are consistent with those found in the Pantego series.

Preliminary soil borings were conducted across the site during March 2004 to verify the presence of hydric soils and the potential for restoration. Soil borings within the area targeted for restoration indicated the entire area contains reduced soils with hydric indicators. The presence of alluvial hydric soils across the site is evidence that the site historically supported a riverine wetland system. Soils at the site ranged from 60 to 80 inches in depth.

Detailed descriptions of soils found at the Cox Site are provided in Table 4.1 below.

Table 4.1
Project Soil Types and Descriptions (from Johnston County Soil Survey, USDA-NRCS, 1986)

Soil Name	Location	Hydric List	Description
Pantego loam	Broad stream terraces on Coastal Plain	A	This soil type occurs on slopes from 0 to 2 percent in areas formed in thick loamy sediments on broad stream terraces on the Coastal Plain. The soil is very deep, very poorly drained, and moderately permeable. It has an available water capacity considered to be moderate to high. Surface runoff is slow and the seasonal high water table is within 1 foot of the surface in the winter and spring under undrained conditions.
Bibb sandy loam	Floodplains and narrow drainageways	A	Poorly drained soil located throughout the Coastal Plain. Slopes are 0-2 percent. Permeability and available water capacity are moderate. Surface run-off is very slow.
Altavista	Stream terraces	B (Hydric Inclusions)	This soil series consists of very deep, moderately well drained soils that formed in fluvial sediments on stream terraces. Slopes range from 0-2 percent. Soil is occasionally flooded.

4.6 Land Use

Cox Branch drains surrounding agricultural, forested, and isolated residential areas. The overall Cox Branch watershed is mostly rural with land uses that include crop and livestock agriculture, forested areas and some residential property. Paved roads bound the project site on the west and south boundaries, and unpaved farm roads cross Cox Branch only once with a culvert.

4.7 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 Johnston 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 U.S. Fish and Wildlife Service (USFWS) lists under federal protection for Johnston County as of August 16, 2004 are listed in Table 4.2. A brief description of the characteristics and habitat requirements of these species follow the table, along with a conclusion regarding potential project impact. A letter from the NC Department of Environment and Natural Resources Natural Heritage Program dated October 2004 stated that no occurrences of any rare species, significant natural communities, or priority natural areas are known within a mile of the site (Appendix B).

Table 4.2
Species Under Federal Protection in Johnston County

Family	Scientific Name	Common Name	Federal Status	Date Listed	State Status	Habitat Present / Biological Conclusion
Vertebrates						
Accipitridae	*Haliaeetus leucocephalus*	Bald eagle	T	08-11-1995 (originally E 04-11-1967) PD 07-06-1999	T	No /No Effect
Picidae	*Picoides borealis*	Red-cockaded woodpecker	E	10-13-1970	E	No /No Effect
Invertebrates						
Unionidae	*Alasmidonta heterodon*	Dwarf wedgemussel	E	10-08-1992	E	No /No Effect
Unionidae	*Elliptio steinstansana*	Tar River spinymussel	E	6-27-1985	E	No /No Effect
Vascular Plants						
Anacardiaceae	*Rhus michauxii*	Michaux's sumac	E	8/28/1998	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

4.7.1 Federally Protected Species

4.7.1.1 Vertebrates

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 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 on November 3, 2004 and 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.

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 is the only one that 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 present in the immediate area of the proposed project. A search of the NHP database, conducted on November 3, 2004, does not record a historic occurrence of the red-cockaded woodpecker in the project vicinity. It is concluded that the project will not impact this endangered species.

4.7.1.2 Invertebrates

Dwarf-Wedge Mussel

The dwarf wedgemussel is relatively small, rarely exceeding 1.5 inches in length. The shell's outer surface (periostracum) is usually brown or yellowish brown in color, with faint green rays that are most noticeable in young specimens. Unlike some mussel species, the male and female shells differ slightly, with the female being wider to allow greater space for egg development. A distinguishing characteristic of this mussel is its dentition pattern; the right valve possesses two lateral teeth, while the left valve has only one. This trait is opposite of all other North American species having lateral teeth (Clarke, 1981).

This mussel is considered to be a long-term brooder, with gravid females reportedly observed in fall months. The dwarf wedgemussel inhabits creek and river areas with a slow to moderate current and a sand, gravel, or muddy bottom. Individuals are often found burrowed into clay banks among root systems of trees. They may also be found associated with mixed substrates of cobble, gravel, and sand. Occasionally they may be found in very soft silt substrates. The associated landscape is largely wooded; trees near the stream are relatively mature and tend to form a closed canopy over smaller streams, creeks, and headwater river habitats. The dwarf wedgemussel requires good to excellent water quality.

Water quality is not considered to be good to excellent on this site (surveys conducted at the adjacent Westbrook Site had similar land use and macroinvertebrate indicator organisms (EPT) were found infrequently and in low abundance, thus indicating poor water quality). In addition, the site is currently used for agricultural purposes and most of the stream channels are not buffered. A NHP database search on November 3, 2004 did not record historic occurrence of the dwarf wedgemussel in the project vicinity. It is therefore concluded that this project will not impact this species.

Tar River Spinymussel

The Tar River spinymussel is only known to occur in North Carolina. Historically it is believed to have occurred in the Neuse and Tar River Basins in the Costal Plain and Piedmont. Today, only a few populations are known to exist.

The Tar River spinymussel is one of three freshwater mussels with spines. Juveniles may have up to 12 spines; however, they tend to lose them as they mature. It is a medium sized mussel reaching about 2.5 inches (6.35 cm) in length. It is found in rivers and large creeks in relatively silt-free gravel and or course sand with fast-flowing, well oxygenated riffles.

The habitat for the Tar River spinymussel is not present on the Cox Site. UT to Mill Creek is a small creek with high silt content and very little gravel. The water flow is slow and riffles are poorly oxygenated. It is therefore concluded that this project will not impact this species.

4.7.1.3 Vascular Plants

Michaux's Sumac

Michaux's sumac is a densely pubescent rhizomatus shrub that grows 0.7 to 3.3 feet (0.2 to 1.0 meter) in height. The narrowly winged or wingless rachis supports nine to thirteen sessile, oblong-lanceolate leaflets that are 1.6 to 3.6 inches (4 to 9 centimeters) long, 0.8 to 2 inches (2 to 5 centimeters) wide, acute, and acuminate. The bases of the leaves are rounded and their edges are simple or doubly serrate. Plants flower in June, producing a terminal, erect, dense cluster of four to five greenish-yellow to white flowers.

This plant occurs in rocky or sandy open woods and roadsides. It is dependent on disturbance (mowing, clearing, fire) to maintain the openness of its habitat. It grows in open habitat where it can get full sunlight and is often found with other members of its genus as well as with poison ivy. Michaux's sumac is endemic to the inner Coastal Plain and Piedmont physiographic provinces of North Carolina. In the North Carolina Sandhills region, naturally occurring Michaux's sumac appears to be restricted to slightly loamy, but still well-drained, sites which are scattered through longleaf pine/scrub oak/wiregrass woodlands. Loamy soil sites are usually found in slight depressions, swales, or along lower slopes and are quickly recognized by their high diversity of herbs, especially with regard to their high number of legume, composite and grass species.

The habitat for this plant is not present on site. A search of the NHP database on November 3, 2004 did not reveal a historic occurrence anywhere in the project vicinity. Soils on the site tend to be poorly drained loams. Furthermore, there are very few areas that have full sunlight without frequent disturbance for agriculture (livestock, plowing, mowing) that would regularly disrupt the plants reproductive cycle. In areas with minimized disturbance, early succession vegetation is most likely too dense and tall, out-competing the small plant for necessary sunlight. Other areas on site have a dense riparian buffer, which is not suitable habitat. It is therefore concluded that this project will not impact this species.

4.7.2 Federal Species of Concern and State Status

Federal Species of Concern (FSC) are not legally protected under the Endangered Species Act and are not subject to any of its provisions, including Section 7, until they are formally proposed or listed as Threatened or Endangered. Table 4.3 includes FSC species listed for Johnston County and their state classifications. Organisms that are listed as Endangered (E), Threatened (T), or Special Concern (SC) on the NHP list of Rare Plant and Animal Species are afforded state protection under the State Endangered Species Act and the North Carolina Plant Protection and Conservation Act of 1979. However, the level of protection given to state-listed species does not apply to NCDENR EEP activities.

The Carolina bogmint and bog spicebush are listed on the NHP database for the USGS quadrant. However, their habitat requirements are not present on the site.

Table 4.3
Federal Species of Concern in Johnston County

Scientific Name	Common Name	Federal Status	State Status
Dendroica cerulea	Cerulean Warbler	FSC	SR
Lythrurus matutuinus	Pinewoods Shiner	FSC	SR
Elliptio lanceolata	Yellow Lance	FSC	E
Fusconaia masoni	Atlantic Pigtoe	FSC	E
Lampsilis cariosa	Yellow Lampmussel	FSC	E
Lasmigona subviridis	Green Floater	FSC	E
Lindera subcoriacea	Bog Spicebush	FSC	T
Macbridea caroliniana	Carolina Bogmint	FSC	T
Trillium pusillum var pusillum	Carolina Least Trillium	FSC	E
Solidago verna	Spring-flowering Goldenrod	FSC	SR-L

4.8 Cultural Resources

Buck Engineering sent a letter on August 17, 2004 requesting that the North Carolina State Historic Preservation Office (SHPO) review the potential for cultural resources in the vicinity of the UT to Mill Creek restoration site. A response was received on September 21, 2004 indicating that the SHPO had reviewed the proposed project and was not aware of any historic resources which would be affected by the project. A copy of the SHPO correspondence is included in Appendix B.

4.9 Potentially Hazardous Environmental Sites

Buck Engineering obtained an EDR Transaction Screen Map Report 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 C. 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 the prior landowners did not reveal any further knowledge of hazardous environmental sites in the area.

4.10 Potential Constraints

Buck Engineering assessed the Cox Branch project site in regards to potential fatal flaws and site constraints. No constraints or fatal flaws have been identified during project design development.

4.10.1 Property Ownership and Boundary

EBX-Neuse I, LLC (EBXN-I) has entered into an Agreement of Sale for the acquisition of an easement with the landowner on the upstream side of the Cox Site. EBXN-I has entered into an Agreement of Sale for the acquisition of the property on the downstream side of the Cox Site. The agreements allow EBXN-I to proceed with the restoration and to restrict the land use through a permanent conservation easement.

4.10.2 Hydrologic Trespass

The topography of the site supports the design without creating the potential for hydrologic trespass. Based on FEMA mapping, Cox Branch is classified in Zone A, which is designated as a special flood hazard area inundated by the 100-year flood. No specific base flood elevations have been determined for Zone A areas.

4.10.3 Site Access

The site is connected to NCDOT ROW and can be accessed for construction and post-restoration monitoring.

4.10.4 Utilities

No known utilities are located on site.

4.10.5 Threatened and Endangered Species

Rare, threatened, and endangered species occurrences were examined as part of the existing conditions survey (Section 4.7). It is anticipated that no rare, threatened, or endangered species will be affected by this project.

4.10.6 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.

4.10.7 Farm Operations

The Cox Parcel is actively used for agricultural purposes. Therefore, the project must not interfere with the operational needs of the farm. The final project design will need to incorporate stream crossings, fencing, and field access.

4.10.8 Soils

Soils have been investigated and no constraints or fatal flaws were identified.

5.0 EXISTING WETLAND CONDITIONS

5.1 Wetlands

The proposed project area was 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)). The areas in the project area that displayed one or more wetland characteristics were reviewed to determine the presence of wetlands. The wetland characteristics included:

1. Prevalence of hydrophytic vegetation.
2. Permanent or periodic inundation or saturation.
3. Hydric soils.

5.1.1 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 7,100 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 (Exhibit 5.1).

5.1.2 Jurisdictional Wetland Findings

During initial site investigations, potential jurisdictional wetlands were located on the southern end of the Cox Site. On December 22, 2004, Buck Engineering staff delineated one wetland area. The wetland showed all of the characteristics of a wetland: hydrology, vegetation, and soils. Primary indicators of wetland hydrology observed included inundation, saturated soils, water marks, and drainage patterns. Secondary indicators noted included oxidized root channels, water-stained leaves, and positive facultative species (FAC)-neutral results. The percentage of hydrophytic vegetation at the site ranges from 90 to 100 percent, indicating a wetland system. Soils at the site were listed by the Soil Survey of Johnston County as Pantego loam, a poorly drained hydric soil. The boundary of the wetland was flagged and delineated using global positioning satellite (GPS) technology. The total existing wetland area is 0.88 acres as shown on Exhibit 5.2. For more information on the wetlands delineation, and the wetland delineation forms, please refer to Appendix A. Wetland delineation forms describe one jurisdictional wetland point at the low end of the project site within the floodplain for Mill Creek and one non-jurisdictional point in the lower field. As of this time, this boundary has not been verified by the USACE however a request for a jurisdictional determination meeting has been sent to the U.S. Army Corps of Engineers.

5.2 Soils

Soils in all areas identified for wetland restoration were confirmed to be hydric by a trained professional. Table 4.1 and Exhibit 4.1 contain information on soils at the Cox Site. The primary soil found at the site was in the A list hydric soil series Pantego, which consists of very deep, very poorly drained, moderately permeable soils that formed in thick loamy sediments on broad stream terraces of the Coastal Plain. It has moderate permeability, with available water capacity considered to be moderate to high. Surface runoff is slow and the seasonal high water table is within 1 foot of the surface in the winter and spring under undrained conditions. Slopes are 0 to 2 percent. Pantego soils at the site generally have inclusions of Augusta or Bibb soils.

5.3 Climatic Conditions

The average growing season (defined as the period in which temperatures are maintained above 28 degrees Fahrenheit under average conditions) for Johnston County is 240 days long, beginning on March 21 and ending November 16. Johnston County has an average annual rainfall of 45.95 inches (NRCS, 2004). In much of the Coastal Plain of North Carolina, approximately 36 inches of water are lost to evapotranspiration during an average year (Evans and Skaggs, 1985). Since average rainfall exceeds average evapotranspiration losses, the Coastal Plain of North Carolina experiences a moisture excess during most years. Excess water leaves a site by groundwater flow, runoff, channelized surface flow, or deep seepage. Annual losses due to deep seepage, or percolation of water to confined aquifer systems, are typically less than 1 inch of water for most Coastal Plain areas and are not a significant loss pathway for excess water. Although groundwater flow can be significant in some systems, most excess water is lost via surface and shallow subsurface flow.

5.4 Site Hydrology

The presence of hydric soils over much of the project site is evidence that the site historically supported a wetland ecosystem. As is the case in much of the Coastal Plain and lower Piedmont of North Carolina, local drainage patterns have been altered over the last two centuries to increase drainage and promote agricultural production. A hydrography map for the site, shown in Exhibit 5.2, demonstrates the amount of ditching and channelization that has been performed on Cox Branch, the main stream that runs through the property. During conversion of the site, stream channels and wetland systems through the site were channelized to improve drainage. The drainage area of the stream at the outlet of the project area is approximately 1.80 square miles.

Several lateral ditches on the west side of the site come together and drain into Cox Branch. These ditches receive some surface runoff from adjacent woodland, but flow in the laterals appears to be limited to ephemeral surface runoff. Based on topography information, the ditches intercept surface runoff and shallow subsurface flow from most of the southwestern corner of the project site.

During October 2004, six groundwater monitoring wells were installed to monitor water table depth on the project site. The locations of these monitoring wells are shown in Exhibit 5.3. The wells were located in areas where hydrology would likely be affected by restoration efforts to provide a base for comparing pre- and post-restoration hydrology.

These recently installed water level recorders have not been installed long enough to portray a complete assessment of the site. Because the period of data is insufficient to provide model data of sufficient validity, data collected from the adjacent Westbrook Site were used to model wetland hydrology. The Westbrook Site was chosen because it has a similar valley type, the same mapped soils, and is located adjacent to the Cox Site. Both sites contain unnamed tributaries to Mill Creek that have been channelized and have undergone significant channel incision. Bank height ratios in the pre-restoration channel on the Westbrook Site were generally greater than 2.0, similar to the current Cox Branch conditions.

The Westbrook Site was developed as part of the Neu-Con Wetland and Stream Umbrella Mitigation Bank within the Neuse River Basin. EBXN-I was the bank sponsor. The goal of the project was to restore 5,400 feet of Coastal Plain stream and 65 acres of associated wetlands. The restoration was accomplished through a Priority I stream restoration, filling of existing lateral ditches, development of microtopography, and planting of the entire site. The project was completed in February 2003 and is currently in its second year of post restoration monitoring.

Pre-restoration wells were installed at Westbrook in June 2001 and recorded groundwater data through February 2002 when the project was constructed. Figures 5.1 and 5.2 compare the hydrographs of the two sites over the same period of time for two different years. The response of the hydrographs to rainfall events is similar for the pre-restoration condition of the two sites. Hydrographs for both sites show moderately fast falling limbs following rain events as a result of the similar drainage effect on the sites. The similarity of the hydrographs from the two sites provides confidence in the use of the Westbrook model to describe the existing hydrologic state of the Cox Site.

Figure 5.1
Hydrographs of the Groundwater Monitoring Wells Compared to Local Rainfall on the Westbrook Site (October 2001 through January 2002)

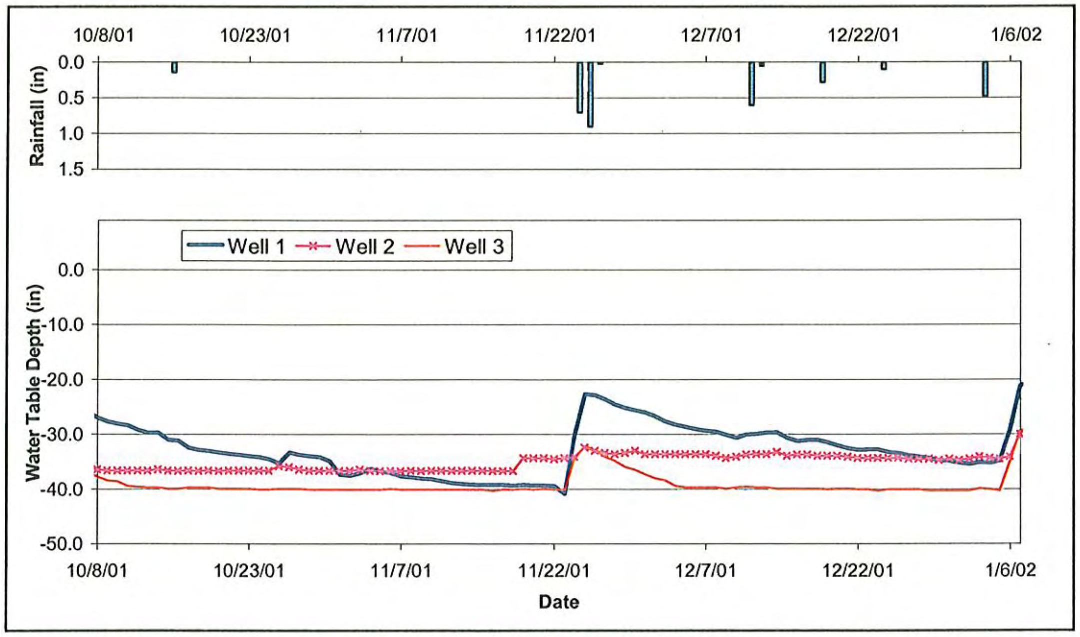
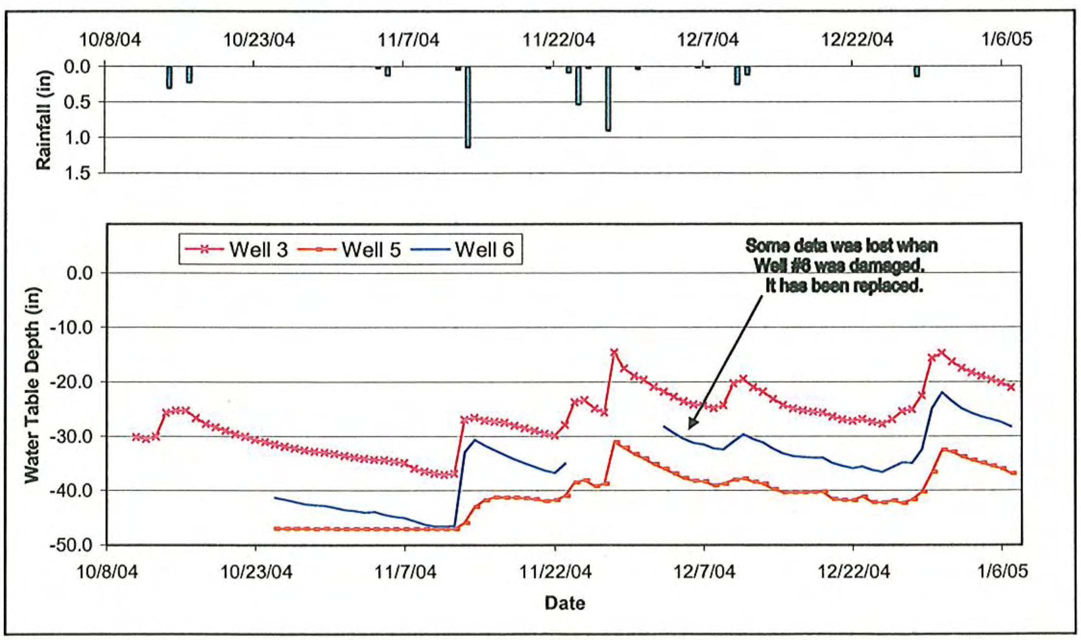


Figure 5.2
Hydrographs of the Groundwater Monitoring Wells Compared to Local Rainfall on the Cox Site (October 2004 through January 2005)



Since water table response has been shown to be very similar on the Cox and Westbrook Sites, the detailed hydrologic analysis performed for the Westbrook Site, as part of the mitigation plan development for that site, is used here to estimate the hydrologic conditions of the Cox Site. A complete record of the analyses performed on the Westbrook Site is provided in Appendix E, and is summarized in the paragraphs that follow.

Hydrologic assessments performed on the Westbrook Site revealed that the site was exhibiting hydrologic conditions significantly drier than wetland conditions. For the period of monitored data, the longest consecutive period of high water table conditions (less than 12 inches deep) for any of the monitored well locations was 2 days, or approximately 1% of the growing season.

DRAINMOD models were developed to describe the existing conditions of the Westbrook Site, and long-term simulations were run to approximate the average hydrologic conditions of the site in its current drained condition. The model results confirmed that the site was exhibiting hydrology significantly drier than would be expected for wetland conditions. Approximately 42% of the precipitation falling on the site was being lost to drainage (31%) and runoff (11%).

Since water table response has been shown to be similar between the Cox and Westbrook Sites, similar hydrologic conditions as those described above currently exist on the drained Cox Site. The short period of monitoring data collected at the Cox Site (collected during the wet season) also confirms the assessment that the site currently exhibits conditions much drier than wetland conditions.

6.0 STREAM CORRIDOR ASSESSMENT RESULTS

6.1 Reach Identification

For analysis purposes, Buck Engineering divided Cox Branch into five reaches based on changing site conditions, not on changing drainage area. The reach locations are shown on Exhibit 6.1. Reach 1 is located at the furthest point upstream and flows through a densely wooded riparian buffer. Reach 2 begins at the edge of the wooded area and extends to the next wooded buffer. Reach 2 is not wooded. Reach 3 flows through a wooded buffer and is the most stable area of the site with low bank height ratios and a defined bankfull bench. Reach 4 begins at the point where the bank height ratios exceed 1.3 and continues to the edge of the woodline. Reach 5 is cleared on the left bank of the stream, but is wooded on the right bank a short distance flowing through agricultural row crops (soybeans and/or corn). Reach 5 continues to the confluence with Mill Creek.

Cox Branch is a blue-line stream on the USGS topographic map of the area as shown on Exhibit 1.3. The total current length of the Cox Site is approximately 6,160 LF.

6.2 Geomorphic Characterization

Buck Engineering performed cross-section surveys of the stream reaches to assess the current condition and overall stability of the channels. A longitudinal survey was performed at the top and bottom ends with additional topography pulled from Light Detection and Ranging (LIDAR) data. The following report sections summarize the survey results for the Cox Branch reaches.

6.2.1 Channel Geomorphology

6.2.1.1 Cox Branch Channel Geomorphology

The lengths of the various Cox Branch reaches and the associated watershed sizes are shown in Table 6.1. Lengths were calculated from the point where the main channel enters the site and at the terminus of each analysis reach.

Table 6.1
Cox Branch Reach Lengths and Watershed Size

Reach	Existing Reach Length (linear feet)	Watershed Size at Downstream End of Reach (square miles)
Reach 1	595	1.5
Reach 2	1,876	1.6
Reach 3	773	1.7
Reach 4	1,052	1.8
Reach 5	1,864	1.8
Total Length	6,160	--

Cox Branch has been channelized and ditched for agricultural purposes. The channelized geometry creates a range of stream types as the stream attempts to reach equilibrium. These stream types range from an incised E5 stream type to a G5c in the Rosgen classification system. An E5 stream type is characterized by a very low width/depth ratio, high sinuosity, a high entrenchment ratio, and sandy bed material. A G5c is entrenched, with a very low width/depth ratio, moderate sinuosity, and less than 2 percent channel slope. The overall sinuosity for the reaches was low due to the past channelization. Much of the substrate is composed of sand but in isolated sections, small gravel were observed on the pavement layer. No debris jams were observed but woody debris was present and contributing to isolated scour pools.

Reach 1 is located in a slightly constricted valley that transitions from small rolling hills of minimal relief to a wide, flat floodplain. Channelization has not been maintained for 20 years or more (based on the maturity of trees along the streambanks). Reach 1 is currently in Stage II of Simon's channel evolution model (Simon, 1989). The reach is currently classified as a Rosgen G5c. The most obvious bankfull indicators were a break in slope and a small bankfull bench at the same elevation which ranged from 1.5 to 1.7 feet above baseflow water surface. Bank height ratios were observed to be between 1.5 and 2.2. Incised streams are highly susceptible to bank erosion when bank height ratios exceed 1.3 because high flows are maintained within the channel. The banks are well vegetated with a mature riparian buffer on both sides. Some scour was observed on the streambanks, but the majority of the streambanks were protected by the dense woody root mats. There was more diversity of bed form in this reach than the other four reaches due to the effect of dense root mats in the bed.

Reach 2 is downstream of Reach 1 and begins where Cox Branch breaks into the open agricultural field. At the beginning of the reach, the valley opens into a flat, alluvial floodplain. Here, the channelized system shows signs of regular maintenance of the channel depth, dimension, and of the riparian vegetation. The riparian area contains primarily dense, herbaceous vegetation. The channel is most likely fluctuating between Stage II and Stage III of Simon's channel evolution model (Simon, 1989) where the narrow, channelized system is continuing to down-cut due to high-energy flows. Bankfull indicators were less obvious as a result of increased erosional pressures acting against the banks. A distinct bankfull indicator existed on cross-section 5 that correlated with a scour line on the other two cross-sections (3 and 4). Bank height ratios in the upper section ranged from 1.7 to 2.2, which indicates that the channel is very susceptible to erosion. The bank height ratio for cross-section 5 was 1.0 where a small bench and break in slope both confirmed the bankfull elevation. Bank erosion was visible and some minor channel migration was taking place. The banks are primarily composed of unconsolidated sand and are weak due to the lack of woody vegetation. Pool formation is minimal, as a result of the lack of pattern and woody debris.

Reach 3 is the most stable portion of the project area. The reach passes through a wooded area, and the valley type remains unchanged as a flat, alluvial floodplain. The system still shows signs of historic channelization, however, Reach 3 is similar to Reach 1 in that the channelization has not been maintained for over 20 years (based on observations of the vegetation along the streambanks). It has evolved to Stage VI in Simon's evolution model (Simon, 1989) and has achieved a quasi-equilibrium state. The dimension and pattern of the stream show significant signs of recovery. The channel is wider allowing flows above bankfull to access a small, active floodplain. A relic floodplain (terrace) is also present. Bankfull indicators were very strong with a wide, bankfull bench consistently 1.5 to 1.6 feet above baseflow water surface. There was also a break in slope on the opposite bank at a similar elevation. Bank height ratios are 1.0 to 1.1. Both cross-sections were taken in riffles, and both were classified as Rosgen E5's. Pool formation was minimal, which is typical in channelized systems.

The boundary between Reach 3 and Reach 4 was chosen based on a change in stability. Geomorphic indicators of stability such as bank height ratio, entrenchment ratio, and obvious signs of channel degradation were used to determine the exact boundary. Based on the densely wooded area, it is assumed that the channel was once altered but has not been maintained within the last 20 years. This reach appears to have undergone significant incision and is now experiencing widening through bank erosion. Bankfull indicators were present as some benches were beginning to form. The back of the forming benches correlated with a consistent scour line 1.5 to 1.7 feet above the baseflow water surface, which was consistent with the other reaches. Banks were actively eroding as a result of the channel incision and vertical angle of the banks. Bank height ratios were 1.8 to 2.5. Flows up to twice the bankfull stage are unable to access a floodplain. The reach was classified as a Rosgen G5c.

Reach 5 begins where the stream flows into an agricultural field. This reach is different from the agriculturally influenced conditions of Reach 2 in that the right side of the stream is forested and the left side is virtually free of vegetation. This channel has most likely experienced continued channel maintenance. The left side of the stream also abuts an existing farm road for some distance and in some cases is within feet of eroding the road bed. This reach is in Stage II of Simon's channel evolution model (Simon, 1989) with some degradation and widening. This reach had the most active bank erosion. Bankfull indicators were a break in slope on the left bank and a newly forming bench on the right side. The elevation of the back of the bench matched the elevation of the break in slope on the opposite side. Bank height ratios were 1.7 and the system was not as entrenched as it was in the wooded area of Reach 4. This reach was classified as an incised Rosgen E5.

Table 6.2 summarizes the existing geomorphologic conditions of Cox Branch.

Table 6.2
Existing Condition Data for Cox Branch – Stream Classification

Parameter	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Riparian Vegetation	Forested	Open Field Herbaceous Vegetation	Forested	Forested	Left Bank – Mowed Right Bank – Forest
Drainage Area, DA (sq mi)	1.5	1.6	1.7	1.8	1.8
Stream Type (Rosgen)	G5c	E5	E5	G5c	E5
Bankfull (bkf) Discharge, Qbkf (cfs)	36	36	36	36	36
Bankfull Mean Velocity, Vbkf (ft/s)	2.3	2.4-3.4	2.0-2.1	2.1	3.1
Bankfull Riffle XSEC Area, Abkf	16.0	10.7-14.9	17.5-18.3	17.2	11.8
Bankfull Riffle Width, Wbkf (ft)	9.8	6.4-6.8	11.1-11.7	11.4	9.9
Bankfull Riffle Mean Depth, Dbkf	1.6	1.7-2.2	1.5-1.7	1.5	1.2
Width to Depth Ratio, W/D (ft/ft)	6.0	3.1-3.8	6.7-7.8	7.6	8.3
Width Floodprone Area, Wfpa (ft)	20	18-39	25-46	14	26
Entrenchment Ratio, Wfpa/Wbkf	2.0	2.2-6.1	2.1-4.1	1.2	2.6
Riffle Max Depth @ bkf, Dmax (ft)	2.3	2.2-2.7	1.7-2.3	1.8	2.3
Riffle Max Depth Ratio, Dmax/Dbkf	1.4	1.2-1.3	1.1-1.4	1.2	1.9

Table 6.2
Existing Condition Data for Cox Branch – Stream Classification

Parameter	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Bank Height Ratio, Dtob/Dmax	2.2	1.0-2.3	1.0-2.5	2.6	1.7
Meander Length, Lm (ft)	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Meander Length Ratio, Lm/Wbkf	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Radius of Curvature, Rc (ft)	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Rc Ratio, Rc/Wbkf *	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Belt Width, Wblt (ft)	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Meander Width Ratio, Wblt/Wbkf	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Sinuosity, K	1.1	1.0	1.0	1.0	1.0
Valley Slope, Sval (ft/ft)	0.0055	0.0035	0.0034	0.0034	0.0016
Channel Slope, Schan (ft/ft)	0.0050	0.0035	0.0034	0.0034	0.0016
Pool Max Depth, Dmaxpool (ft)	3.4	N/A[2]	N/A[2]	2.2	2.3
Pool Max Depth Ratio,	1.5	N/A[2]	N/A[2]	1.2	1.0
Pool Width, Wpool (ft)	8.9	N/A[2]	N/A[2]	8.6	12.3
Pool Width Ratio, Wpool/Wbkf	0.9	N/A[2]	N/A[2]	0.8	1.2
Simon Evolution Class	II	II	VI	II	IV

Notes:

1) Due to past channelization, this reach has a very low sinuosity therefore, no pattern measurements were taken.

2) This reach has very low sinuosity and poor bedform diversity. No pools existed in this reach.

6.2.2 Channel Stability Assessment

6.2.2.1 Cox Branch Channel Stability

The stream channel within the Cox Site project area is a perennial, channelized stream with a flow regime dominated by stormwater runoff from a forested and agricultural watershed. Throughout the site, the channel is adversely impacted by the lack of substantial riparian vegetation. Generally, the channel is highly incised. The majority of the banks are experiencing moderate to high erosion with non-cohesive soils. Dense herbaceous and woody vegetation has protected the banks in some locations. Following past channelization, numerous side channel bars and alternating areas of high bank erosion indicate that meanders are beginning to re-develop. This is typical in this stream in areas with and without good floodplain vegetation.

6.2.3 Bankfull Verification

Correct field identification of bankfull stage is crucial to the natural channel design process. Dimensions for the new channel are based on the bankfull cross-sectional area identified by field assessments. If bankfull is identified incorrectly, the new channel may be designed either too small or too large, resulting in channel instability. For this reason, verification of bankfull stage should be conducted to assure that the bankfull stage has been identified correctly.

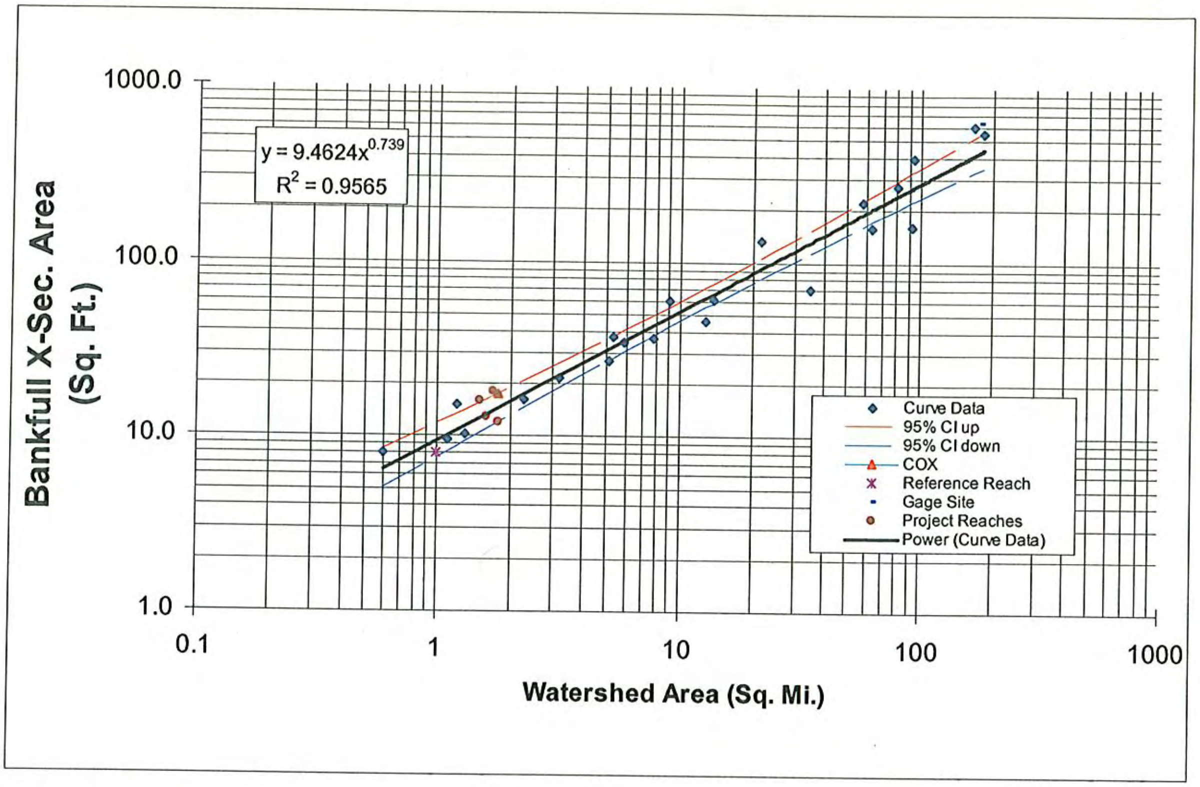
The bankfull stage in the Cox Branch was identified as the upper scour line, or the back of an alluvial bench. These indicators are consistent with other North Carolina Coastal Plain streams. Bankfull data for the project reach are compared with the North Carolina Coastal regional curve, a nearby gage site, and the project reference site shown in Figure 6.1. The project's cross-sectional areas consistently plot close to the regional curve data, indicating that bankfull stage was adequately selected within acceptable limits. 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 6.3.

Table 6.3
NC Rural Coastal Plain 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)	
$Q_{bkf} = 100.64\ A_w^{0.76}$	$R^2=0.88$
$A_{bkf} = 21.61\ A_w^{0.68}$	$R^2=0.89$
$W_{bkf} = 19.05\ A_w^{0.37}$	$R^2=0.83$
$D_{bkf} = 1.11\ A_w^{0.31}$	$R^2=0.79$

A gage survey was conducted to verify the bankfull stage identified for Cox Branch. The gage survey was conducted on the Little River near the Town of Princeton, approximately 13 miles from the project site, at a U.S. Geological Survey gaging station (# 02088500). Bankfull stage was identified at the gage site and flood frequency data for the gage were used to correlate bankfull stage and discharge to watershed size. The gage plotted well within the 95% confidence intervals of the NC Coastal Plain Regional Curve.

Figure 6.1
NC Coastal Regional Curves with Bankfull Discharge for Project Reaches and Reference Cross-Sections



Note: Project data points were not used in determining the regression line.

6.3 Vegetation

The existing stream buffer on the Cox Site varies. Impacts to the riparian buffer are directly linked to the existing adjacent land use. As the stream drains under the road and through gentle hills, cropland is somewhat limited, leaving the stream with a wide forested buffer. As the valley flattens to an alluvial floodplain, there is more arable land. As a result, the majority of the flat floodplain is used as cropland and encroaches on the stream. The farm was managed under a North Carolina Agricultural Cost Share Program for the last 10 years, which excluded cattle (that rotate along with crops on the land) from 25 feet on either side of the stream. Mowing and vegetation maintenance still occurred within the fenceline, but cattle were excluded. As a result, there is currently a portion of the channel with a 50-foot herbaceous riparian area that buffers the stream from surrounding cropland.

There is a mix of cropland and forest land, which is typical for agricultural properties. Reaches 1, 3, and 4 are forested. Reach 2 is herbaceous with a buffer greater than 25 feet on either side. Reach 5 has a mixed buffer with a forested buffer on the right bank side and a mowed herbaceous buffer on the left bank side. Although there are some forested sections, 60 percent of the stream has no woody riparian vegetation on one or both sides.

Mature vegetation in Reach 1 consists of hackberry (*Celtis occidentailis*), swamp chestnut oak (*Quercus michauxii*), red maple (*Acer Rubrum*), American holly (*Ilex opaca*), yellow poplar (*Liriodendron tulipifera*), and Chinese privet (*Ligustrum sinense).* Understory plant communities are dominated by giant cane (*Arundinaria gigantea*), greenbriar (*Smilax herbacea*), and microstegium (*Microstegium vineum*).

Reach 2 is dominated by herbaceous vegetation. The woody vegetation that is present is sporadic and young (3 to 4 ft in height). Sweet gum (*Liquidambar styraciflua*), black willow (*Salix nigra*), winged sumac (*Rhus copallinum*), and smooth sumac (*Rhus glabra*) were present. Herbaceous vegetation was dominated by Pokeberry (*Phytolacca americana),* big bluestem (*Andropogon gerardii*), sicklepod (*Cassia obtusifolia*), deer tongue (*Dichanthelium clandestinum*), giant cane, greenbriar, and a dense variety of other plants.

Reach 3 begins at the point where the stream re-enters a wooded forest. Mature vegetation included: red maple, swamp chestnut oak, southern red oak *(Quercus rubra),* water oak (*Quercus nigra*), sweet gum, giant cane, coastal mountain laurel (*Kalmia latifolia*), greenbriar, microstegium, and pokeberry.

Reach 4 is within the same, contiguous wooded area that began in Reach 3. Persimmon (*Diospyros virginiana*) and southern arrow-wood (*Viburnum dentatum)* were found in this area, as well as the species seen in Reach 3. Microstegium was less dense here than in previous reaches.

Reach 5 is dominated by microstegium on both banks. The left bank had previously been mowed and the right bank is forested, but due to the lack of canopy shade on the left bank early succession herbaceous vegetation is dense. Aside from microstegium, jewelweed (*Impatiens capensis*), trumpet creeper (*Campsis radicans*), and goldenrod (*Solidago nemoralis*) were the dominant species. Red maple, yellow poplar, swamp chestnut oak, and giant cane are present on the right streambank.

Much of the area adjacent to the stream on the Cox Site consists of cropland or woodland. Sorghum was planted and harvested on the right side of the stream while soybeans and corn were the additional crops in the other fields. When the site was visited in the winter months, cattle were turned out to feed on small grain, but were excluded from the riparian areas of the Cox Branch. A few side ditches were wet during the winter months and were used as the cattle's watering source. The pasture areas were heavily grazed at that time.

6.4 Biological Assessment

Benthic macroinvertebrate samples were collected from two sites on December 13, 2004 (see Exhibit 6.2). Sites 1 and 2 are located in UT to Mill Creek within the project area and upstream of the project area, respectively. The sampling methodology followed the Qual-4 protocol listed in the NCDWQ's Standard Operating Procedures for Benthic Macroinvertebrates (NCDENR, 2003). A summary of the benthic macroinvertebrate sampling results is presented in Table 6.4, with complete results presented in Appendix F.

The components of the benthic macroinvertebrate community that are commonly used to evaluate water quality are the EPT taxa. The EPT taxa include specimens belonging to the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). These groups are generally the least tolerant to water pollution and therefore are very useful indicators of water quality. Therefore, the presence of substantial numbers of EPT taxa and individuals is considered indicative of relatively undisturbed "higher quality" streams. EPT metrics commonly used include EPT taxa richness, EPT biotic index, and EPT abundance which are shown in Table 6.4.

Table 6.4
Benthic Summary Table

Metrics	Site 1 Project Restoration Reach	Site 2 Upstream Reference Reach
Total Taxa Richness	18	34
EPT Taxa Richness	7	8
Total Biotic Index	6.21	6.17
EPT Biotic Index	5.06	4.77
EPT Abundance	38	55
Habitat Assessment	38	76

The benthic macroinvertebrate community of Site 1 is slightly more disturbed than in Site 2. A healthier community is characterized by higher total and EPT taxa richness values and lower biotic index values. Lower total and EPT taxa richness and higher total and EPT biotic indices recorded for Site 1 as compared to Site 2 (upstream of Site 1) indicate water quality decline downstream of Site 2. Water quality decline downstream corresponds to decrease of suitable habitat downstream (habitat assessment scores of 76 and 38 for Sites 2 and 1, respectively). Site 1 reach has very limited canopy cover and woody riparian vegetation to provide adequate shade, organic matter, or habitat such as root mats for aquatic organisms. As habitat degrades, species diversity declines and more tolerant organisms replace organisms sensitive to impairment.

Establishing a well-forested riparian buffer along the restoration reach would provide shading, reduce the photosynthetic rate of algae and macrophytes, reduce siltation and sedimentation, and provide additional habitat and organic matter to aquatic organisms. As a result, recruitment of additional species, especially shredders, should occur. While the upstream reference site (Site 2) provides refugia to Site 1 for some additional species, recruitment of additional intolerant species for the restoration reach will also most likely come from Mill Creek located just downstream or from Johannah Creek (Westbrook Project), a tributary to Mill Creek located near the project site.

7.0 SELECTED DESIGN CRITERIA

7.1 Potential for Restoration

There are few potential obstacles for achieving Priority 1 stream restoration throughout the majority of the project site. The project is located in a rural watershed, with no plans indicating land use changes in the foreseeable future. Therefore, there are no known present or future constraints at the site associated with structure and/or infrastructure encroachments. The Cox Branch channel is under severe pressure from human impacts both past and present and impacts from past agricultural practices that allowed cattle access to the channel. The majority of the stream length has incised and is showing a tendency toward lateral migration. If left alone, it is possible that incision would stop but the redevelopment of meanders would continue through erosion. As a result, the restoration on the main channel at the Cox Branch site will expedite the evolutionary process already occurring.

7.2 Design Criteria Selection

Natural channel design criteria are based on a combination of approaches including reference reach surveys, review of reference reach databases, regime equations, and evaluation of results from past projects, as discussed in Section 2.5.

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

7.2.1 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 Johannah Creek reference reach described below, 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. Table 7.1 summarizes the geomorphic data for Johannah Creek and the sand bed streams from the reference reach database. Shear stress and stream power relationships developed for these reference sites are used in the sediment transport analysis given in Section 8.3.

7.2.2 Reference Reach Survey Overview

One reference reach was identified off the project site in Johnston County. The reference site for this project is located along an adjacent stream (Johannah Creek) that flows through the Westbrook Project site, a stream and wetland mitigation project that was completed by EBXN-I in February 2003 (see Exhibit 7.1). 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" and "brownwater" streams in which separate fluvial features and associated vegetation are too small or poorly developed to distinguish. It is difficult to define whether the site is of the "brownwater" or "blackwater" subtype, since the site exhibits features of both subtypes. Schafale and Weakley characterize the "brownwater" subtype as having its headwater originating in the Piedmont, while the "blackwater" subtype originates in the Coastal Plain. Although the reference site lies very near the fall line between the Piedmont and Coastal Plain physiographic regions, most delineations of the fall line boundary would place the origin of the reference site stream in the Coastal Plain, and therefore the system would be considered the "blackwater" subtype. 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 site will be used as a template for the restoration of the project site. Wetland delineation forms for the site are provided in Appendix A.

7.2.3 Reference Stream Assessment

The stream flowing through the reference site is a small, meandering, sand-bed channel. The drainage area for the stream is approximately 0.9 sq. mi. in size and land use in the watershed is primarily forest with some agriculture on the upland terraces. Along nearly the entire length from its headwaters to the reference site, the stream is wooded. One paved road crosses the stream (Bentonville Road, SR 1197) approximately 3,000 feet upstream of the reference site.

Field surveys of the reference site were conducted in the summer of 2001. 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 8.1.

The stream is classified as an E5/C5 channel using the Rosgen Stream Classification method (Rosgen, 1994). The channel is classified as an E/C channel since the average width/depth ratio is 12, the breakpoint between classifying a channel as an E (< 12) or C (> 12). Both E and C channels typically have high entrenchment ratios due to the relatively wide associated floodplains and are commonly found in the Coastal Plain where nearly level land slopes and dense vegetation promote the establishment of meandering stream channels. For both type streams, 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. 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 stream systems located in agricultural watersheds, the section of channel surveyed for the reference reach shows no evidence of having been altered or channelized in the recent past. Some trees found within the riparian area appear to be over 50 years old. The channel has good meander pattern with low bank heights. As a result, flooding of the adjacent riparian wetland areas occurs frequently.

Bankfull verification for the reference reach followed the same procedure as described for the project reach (Section 6.2.3). For the reference reach section, the field indicator of bankfull stage was the top of the streambank. Bankfull cross-section areas were plotted on the same regional curve information presented in Section 6.2, as shown in Figure 6.1 below. The plotted cross-sectional areas match closely with the local data and the project reach data, indicating that bankfull was correctly identified in the field. Table 7.1 summarizes the geomorphic data for Johannah Creek and the sand bed streams from the reference reach database.

Table 7.1
Reference Parameters Used to Determine Design Ratios

Parameter	Johannah Creek		Composite Reference Data from NC Coastal Plain[1]	
	MIN	MAX	MIN	MAX
Drainage Area, DA (sq mi)	0.9			
Stream Type (Rosgen)	E5	C5		
Bankfull Discharge, Qbkf (cfs)	14			
Bankfull Riffle XSEC Area, Abkf (sq ft)	7.2	7.8		
Bankfull Mean Velocity, Vbkf (ft/s)	1.8	1.9		
Width to Depth Ratio, W/D (ft/ft)	10.1	19.7	8	14
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	8.0	9.6		
Riffle Max Depth Ratio, Dmax/Dbkf	1.4	1.8	1.2	1.8
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0			
Meander Length Ratio, Lm/Wbkf	4.0	5.9	4	17
Rc Ratio, Rc/Wbkf	1.5	2.8	1.5	3.0
Meander Width Ratio, Wblt/Wbkf	1.4	2.1	2.0	6.3
Sinuosity, K	1.22		1.22	1.77
Valley Slope, Sval (ft/ft)	0.0027		0.0007	0.0029
Channel Slope, Schan (ft/ft)	0.0022		0.0004	0.0022
Pool Max Depth Ratio, Dmaxpool/Dbkf	1.9		1.8	2.0
Pool Width Ratio, Wpool/Wbkf	0.8	1.0	0.8	1.4
Pool-Pool Spacing Ratio, Lps/Wbkf	16.0	59.0		
d16 (mm)	0.35			
d35 (mm)	0.6			
d50 (mm)	0.7			
d84 (mm)	0.8			
d95 (mm)	1.8			

Notes:
1 Composite reference reach information from Johannah Creek, Johnston County; Panther Branch, Brunswick County; and Rocky Swamp, Halifax County

7.2.4 Reference Reach Vegetation

The reference site is well buffered along both stream banks with tree species that include sweet gum, red maple, willow oak (*Quercus phellos*), water oak, swamp chestnut oak, and green ash (*Fraxinus pennsylvanica*). The small tree/shrub layer is dominated by sweetbay magnolia (*Magnolia virginiana*), American holly, sugarberry saplings, giant cane, 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, cinnamon fern (*Osmunda cinnamomea*), sensitive fern (*Onoclea sensibilis*), greenbriar. Virginia creeper (*Parthenocissus quinquefolia*), grape (*Vitis* spp.), poison ivy (*Toxicodendron radicans*), and Japanese honeysuckle (*Lonicera japonica*).

7.2.5 Reference Reach Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected at the reference reach site on January 17, 2002. Sampling was not conducted during the summer months due to drought conditions which resulted in low flow conditions in the stream. The sampling methodology followed the Qual-5 protocol listed in the NCDWQ's *Standard Operating Procedures for Benthic Macroinvertebrates*. Discussion of the sampled macroinvertebrate data for the project site is presented in Section 6.4.

7.2.6 Design Criteria Selection Method

Specific design parameters were developed using a combination of reference reach data, past project experiences, and best professional judgment. Dimensionless ratios from an internal reference reach database were also used to develop the design values. The design philosophy at the Cox Branch Site is to use average values for the selected stream types and to allow the extremes to form over long periods of time under the processes of flooding, re-colonization of vegetation, and geologic influences.

7.3 Design Criteria for Cox Branch

After examining the assessment data collected at the site, exploring the site's potential for restoration, and assessing "lessons learned" from the Westbrook wetland and stream mitigation site, an approach to the stream restoration was developed. First, an appropriate stream type for the valley type present at the site 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, existing wetlands, and channel incision were considered as well. The proposed stream types for the project are summarized in Table 7.2.

Table 7.2
Project Design Stream Types

Reach	Proposed Stream Type	Rationale
Cox Mainstem	C	Impacts from cattle and property owner continue to degrade stream stability and function. Sinuosity and pool formation is poor with riparian vegetation consisting of fescue and privet. 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.

8.0 STREAM RESTORATION DESIGN

8.1 Restoration Approach

The primary objectives of the stream restoration design are to re-establish floodplain access at bankfull flows, improve habitat quality, and decrease bank erosion. The primary objective of the wetland restoration and enhancement design is to restore remnant riverine and non-riverine wetlands. Riparian vegetation will be established in the permanent buffer. The proposed design includes the following elements:

- Priority 1 Stream Restoration
  - Cox mainstem reach – entire reach will be restored to a C stream type. A short upstream section will require limited floodplain grading and will use a Rosgen Priority 2 restoration approach in order to tie in with the incised upstream channel. A series of instream grade control structures will be used to raise the channel up to connect to the relic floodplain.
- Wetlands Restoration and Enhancement
  - Project-wide planting to restore native wetland vegetation.
  - Restoration of remnant wetland areas by decreasing the drainage effect of the stream through a Priority I restoration approach, removing an existing drain tile, and routing an ephemeral ditch into a wetland restoration zone.
  - Enhancement of remnant wetlands that currently support a bottomland forest through improved hydrology.
- Riparian Buffer Enhancement
  - Project-wide planting and preservation of the riparian zone.

Preliminary plans for the Cox Site restoration are attached. Details of the design are discussed in the following sections.

8.2 Design Rationale (Channel Dimension, Pattern, and Profile)

8.2.1 UT Mainstem Channel Restoration

The stream banks are unstable along the Cox Site mainstem because the channel has incised and is in the process of widening and riparian vegetation has been removed. A stable cross-section will be achieved by increasing the width/depth ratio and raising the streambed thus decreasing the bank height ratio and increasing the entrenchment ratio. The channel will be restored to a C-type stream, and the sinuosity will be increased by adding meanders to lengthen the channel. Grade control at the bed will be provided by in-stream structures such as constructed riffles, cross vanes, and log weirs. These in-stream structures will also help to improve bedform diversity.

Table 8.1 presents the stream restoration dimensions and design criteria for the Cox mainstem channel.

Table 8.1
Natural Channel Design Parameters for the Cox Branch Restoration Site

Parameter	Cox Branch Design Values		Design Criteria		Rationale
	MIN	MAX	MIN	MAX	
Drainage Area, DA (sq mi)	1.4	1.8	--	--	
Design Stream Length (feet)	7,548		--	--	
Stream Type (Rosgen)	C5		--	--	Note 1
Bankfull (bkf) Discharge, Qbkf (cfs)	21.3		--	--	Note 2
Bankfull Mean Velocity, Vbkf (ft/s)	1.6		--	--	V=Q/A
Bankfull Riffle XSEC Area, Abkf (sq ft)	13.5		--	--	Note 3
Bankfull Riffle Width, Wbkf (ft)	13.7		--	--	$\sqrt{Abkf*W/D}$
Bankfull Riffle Mean Depth, Dbkf (ft)	1.0		--	--	d=A/W
Width to Depth Ratio, W/D (ft/ft)	14.0		10	15	Note 3
Width Floodprone Area, Wfpa (ft)	160	400	--	--	
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	11.6	29.1	5.5	>10	Note 4
Riffle Max Depth @ bkf, Dmax (ft)	1.2	1.4	--	--	
Riffle Max Depth Ratio, Dmax/Dbkf	1.2	1.4	1.2	1.6	Note 5
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0		1.0		Note 6
Meander Length, Lm (ft)	110	165	--	--	
Meander Length Ratio, Lm/Wbkf *	8.0	12.0	8.0	12.5	Note 7
Radius of Curvature, Rc (ft)	27	41	--	--	
Rc Ratio, Rc/Wbkf *	2.0	3.0	2.0	3.0	Note 7
Belt Width, Wblt (ft)	69	110	--	--	
Meander Width Ratio, Wblt/Wbkf *	5.0	8.0	3.0	8.0	Note 7
Sinuosity, K	1.47		1.3	1.8	TW length/ Valley length
Valley Slope, Sval (ft/ft)	0.0034		--	--	
Channel Slope, Schan (ft/ft)	0.0019	0.0037	--	--	Sval / K
Slope Riffle, Srif (ft/ft)	0.0027	0.0093	--	--	
Riffle Slope Ratio, Srif/Schan	1.4	2.5	--	--	Note 8
Slope Pool, Spool (ft/ft)	0.0000	0.0007	--	--	
Pool Slope Ratio, Spool/Schan	0.0	0.2	--	--	Note 8
Pool Max Depth, Dmaxpool (ft)	2.2	2.5	--	--	
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.2	2.5	2.0	3.0	Note 7
Pool Width, Wpool (ft)	16.5	20.6	--	--	
Pool Width Ratio, Wpool/Wbkf	1.2	1.5	1.2	1.5	Note 9
Pool-Pool Spacing, Lps (ft)	55.0	82.5	--	--	
Pool-Pool Spacing Ratio, Lps/Wbkf	4.0	6.0	4.0	6.0	Note 7
d_{16} – mm	< 0.062		< 0.062		
d_{35} – mm	0.125		0.125		
d_{50} – mm	2.0		2.0		
d_{84} – mm	22		22		
d_{95} – mm	64		64		

Table 8.1 Continued

Notes:

[1] A C5 stream type is appropriate for a very low-slope, wide, alluvial valley with a sand streambed. 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 Johannah Creek 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.

8.2.1.1 Dimension

The existing channel dimension is unstable throughout the project area due mainly to a lack of the dense and deep root structure provided by an intact, woody, riparian buffer. To address the erosion throughout the project, the stream cross-section (dimension) will be adjusted in order to reduce velocities and near bank shear stress. A Rosgen C type stream with a w/d ratio of 14 will be created with the cross-section. The ratio of low bank height to maximum bankfull depth (BHR) will be set to 1.0. In areas along the mainstem channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, minimal grading will be used to transition bankfull stage to the floodplain. Once flood water rises above the bankfull stage, erosion-causing stress in the near bank region will be reduced when the storm flow is able to spread out on the floodplain. Root wads, brush mattresses, and log vanes will be used to provide bank protection and maintain pool cross-sections at the outside of meander bends where necessary. Typical cross-sections are shown on the plan sheets.

8.2.1.2 Pattern

The existing mainstem channel through the project site has a sinuosity measurement of less than 1.05. The proposed project will increase the sinuosity of the stream to 1.47 by adding 1,353 linear feet of stream. The pre-construction length of the design area is approximately 6,160 linear feet; the stream length after restoration will be approximately 7,548 LF. The meander length ratio on the restored channel will be between 8.0 and 12.0, based on reference reach data and as recommended by the USACE *Hydraulic Design of Stream Restoration Projects* (Copeland et al., 2001). Curve radii will range between 27 and 41 feet, or two to three times the channel's proposed bankfull width. The surveyed reference reaches exhibited radius of curvature ratios of less than 2; however, the project was designed with larger ratios in an effort to enhance stability immediately after construction before a stabilizing vegetative root mass is established. The meander width ratio (MWR) of the stream will be increased as part of the restoration. Belt width will be 5.0 to 8 times wider than bankfull width. This meander width ratio range is supported by the range of data from the project reference reach and the composite data from other Coastal Plain sand bed reference reaches. Plan views of the main channel are shown on the attached plan sheets. The channel slope will be effectively decreased by the addition of the meandering length, helping to slow the mean velocity in the channel.

8.2.1.3 Profile/Bedform

The profile of the existing mainstem channel is somewhat stable but is threatened by cattle access and removal of vegetation. There is very little diversity in the existing channel bedform: pools, riffles, glides, and runs are nearly indistinguishable from each other with few exceptions. The stream restoration will include the construction of a riffle-pool stream bed with additional habitat and diversity provided by constructed riffles, cross vanes, and log weirs at selected locations. The slopes for the constructed riffles vary from 1.5 to 3 times the proposed channel slope. The reference reaches indicated that this ratio range will be appropriate for this stream size and type. Similarly, pool slopes were designed using the reference reach guidance of slope ratios 0.2 to 0.4 times the design channel slope. The maximum pool depth (two to three times the riffle mean depth) in the pool will be constructed from the meander curve apex to a point one-third of the distance along the profile from the apex to the head of the next downstream riffle. This maximum pool location was selected based on guidance from the USACE manual (Copeland et al., 2001).

8.3 Sediment Transport

8.3.1 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 2.6.

Shear stress, stream power, and W/D values for the design reaches are plotted against stable reference stream data in Figures 8.1, 8.2, and 8.3. The values were calculated for existing conditions on each of the five reaches described in Section 6.2, design conditions for the range of design slopes, and for the Johannah Creek reference reach. A summary of the data is provided in Table 8.2.

The existing condition stream power and shear stress values plot well above the range of data from Coastal Plain sand bed reaches, including Johannah Creek (with the exception of Reach 5). These data indicate that bankfull flows are capable of moving significantly more sediment than is supplied to the system. Additionally, these data are only for bankfull flows. Bank height ratios in the existing channel range from 1.0 to 2.5. In the incised reaches, flows greater than bankfull are contained within the channel. Therefore, shear stress and stream power continue to increase with increasing stream stage up to the top of bank instead of dispersing the energy across an active floodplain. This excess energy results in bed and bank scour that has resulted in the observed channel incision and bank erosion. Reach 5 is moderately stable at the low end just before it ties into Mill Creek. This is the section of channel that the design channel will tie into.

The design shear stress and stream power values plot within the scatter of data points collected from reference reaches. This analysis provides evidence that the stresses predicted for the design channel are well within the range of stable values calculated for the reference reaches. Therefore, the design channel is expected to have adequate stream power to move its sediment load without resulting in excessive scour.

Figure 8.1
Comparison Between Bankfull Shear Stress and Channel Slope for Design Reaches and Coastal Plain Reference Reach Data

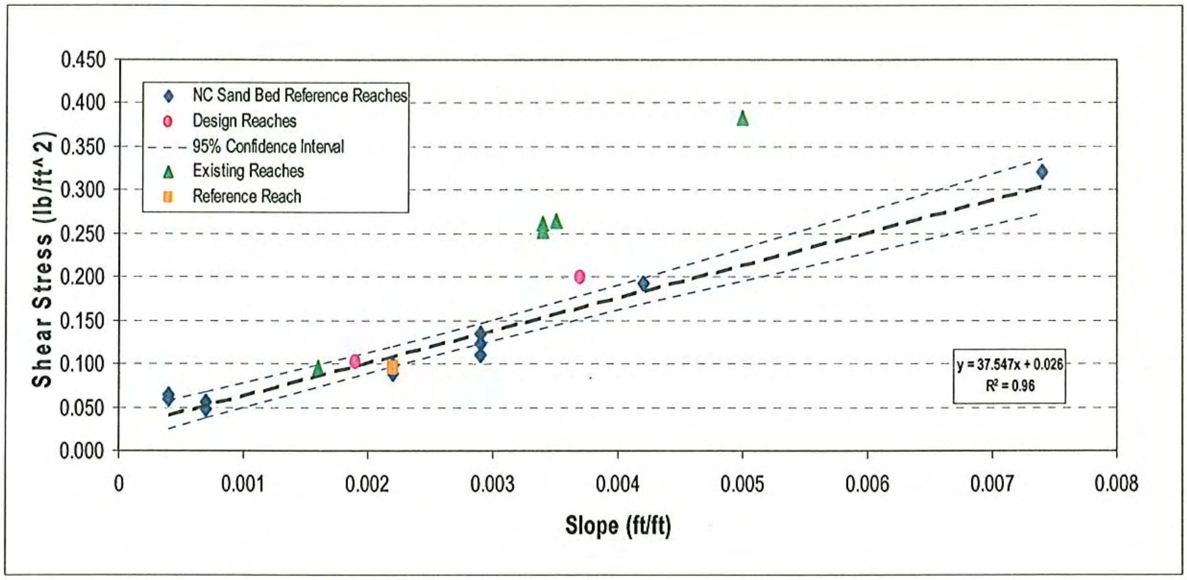


Figure 8.2.
Comparison Between Stream Power and Channel Slope for Design Reaches and Coastal Plain Reference Reach Data

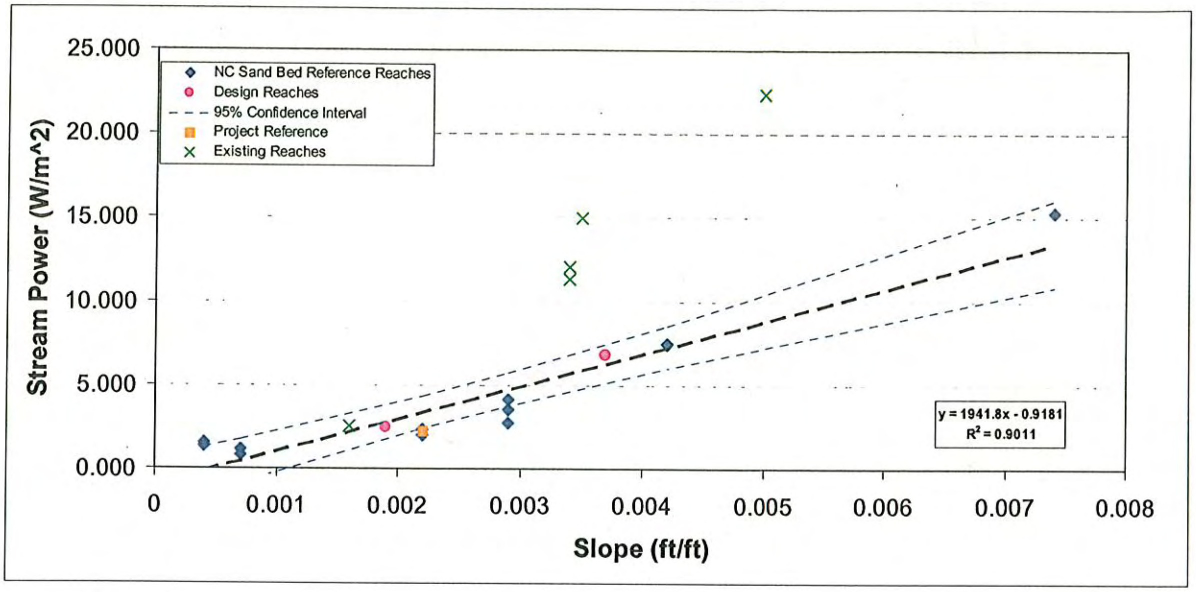


Figure 8.3
Comparison Between Width-to-Depth Ration (W/D) and Channel Slope for Design Reaches and Coastal Plain Reference Reach Data

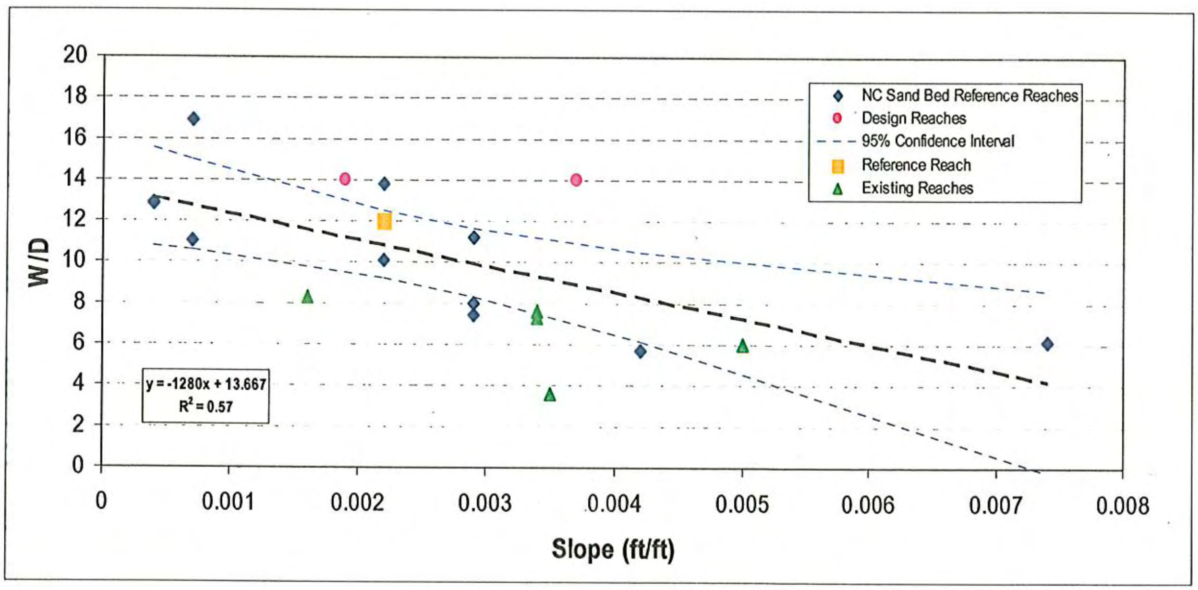


Table 8.2
Calculated Sediment Transport Data for Design Reaches

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)
Cox Mainstem – High end of Slope Range	13.5	23.7	1.75	0.198	6.75
Cox Mainstem – Low end of Slope Range	13.5	23.7	1.75	0.102	2.48

8.4 In-Stream Structures

A variety of in-stream structures are proposed for the Cox Branch site. Structures such as root wads, constructed riffles, and log vanes will be used to stabilize the newly-restored stream. Table 8.3 summarizes the use of in-stream structures at the site.

Table 8.3
In-Stream Structure Types and Locations for Cox Branch

Structure Type	Location
Root Wad	Cox Mainstem – Outside of Meander Bends
Constructed Riffle	Cox Mainstem – Riffle Areas
Cross Vane	Cox Mainstem – Enhancement Section
Log Vane	Cox Mainstem - Outside of Meander Bends
Log Weir	Cox Mainstem – Riffle Areas
Cover Log	Cox Mainstem – Outside of Meander Bends

8.4.1 Root Wad

Root wads are placed at the toe of the stream bank in the outside of meander bends for the creation of habitat and for stream bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. They also serve as a food source for aquatic insects. Root wads will be placed throughout the Cox Branch mainstem.

8.4.2 Constructed Riffle

A constructed riffle consists of the placement of coarse bed material in the stream at the specific riffle locations along the profile. A buried log at the upstream and downstream end of each riffle will control the slope through the riffle. The purpose of this structure is to provide grade control and improve riffle habitat. Constructed riffles will be placed throughout the Cox Branch mainstem.

8.4.3 Cross Vane

Cross vanes are used to provide grade control, keep the thalweg in the center of the channel, and protect the stream bank. A cross vane consists of two rock vanes joined by a center structure installed perpendicular to the direction of flow. This center structure sets the invert elevation of the stream bed. Vanes are located just downstream of the point where the stream flow intercepts the bank at acute angles. These structures will be placed in the main channel at both the upstream and downstream project limits. They are also a critical component of the restoration of the high slope step-pool channels (Rosgen 2001b).

8.4.4 Log Vane

A log vane is used to protect the stream bank. The length of a single vane structure can span one-half to two-thirds the bankfull channel width. Vanes are located just downstream of the point where the stream flow intersects the bank at an acute angle in a meander bend. Log vanes will be placed in the Cox Branch mainstem.

8.4.5 Log Weir

A log weir consists of placing a header log and a footer log in the bed of the stream channel, perpendicular to the stream flow. The logs extend into the stream banks on both sides of the structure to prevent erosion and bypassing of the structure. The logs are installed flush with the channel bottom upstream of the log. The footer log is placed to the depth of scour expected to prevent the structure from being undermined. Although a pool is often excavated downstream of the weir during installation, a pool will typically form naturally downstream of the structure. Log weirs provide bedform diversity, maintain channel profile, and provide pool and cover habitat.

8.4.6 Cover Log

A cover log is placed in the outside of a meander bend to provide habitat in the pool area. The log is buried into the outside bank of the meander bend; the opposite end extends through the deepest part of the pool and may be buried in the inside of the meander bend, in the bottom of the point bar. The placement of the cover log near the bottom of the bank slope on the outside of the bend encourages scour in the pool. This increased scour provides a deeper pool for bedform variability. Cover logs will be used on the Cox Branch mainstem reaches.

8.5 Vegetation

The vegetative components of this project include stream bank, floodplain, and wetland planting. In addition, any areas of the site that are disturbed, lack diversity, or might be adversely impacted by the construction process will be replanted.

8.5.1 Stream Bank, Floodplain, and Wetland Re-Vegetation

The stream banks and the adjacent riparian area, including wetland areas, will be planted with both woody and herbaceous vegetation as shown on the attached plan sheets. Any stream banks with a 2:1 slope or steeper will be vegetated using live stake or brush mattress techniques. A buffer of woody and herbaceous species will be installed within the buffer limits.

A schedule of plants for use on this project is shown in Table 8.4

Table 8.4
Cox Branch Site Plant Schedule

Common Name	Botanical Name
Riparian Buffer/Wetland Plantings on Upper End of Project Site	
Preferred Species	
Blackgum	*Nyssa sylvatica*
Black Walnut	*Juglans nigra*
Swamp Chestnut Oak	*Quercus michauxii*
Overcup Oak	*Quercus lyrata*
Willow Oak	*Quercus phellos*
Sycamore	*Platanus occidentalis*
River Birch	*Betula nigra*
Alternate Species	
Shortleaf Pine	*Pinus echinata*
Sugarberry	*Celtis laevigata*
Red Mulberry	*Morus rubra*
Riparian Buffer/Wetland Plantings on Lower End of Project Site	
Preferred Species	
Swamp Tupelo	*Nyssa sylvatica var.biflora*
Sycamore	*Platanus occidentalis*
Swamp Chestnut Oak	*Quercus michauxii*
Overcup Oak	*Quercus lyrata*
Willow Oak	*Quercus phellos*
Sugarberry	*Celtis laevigata*
River Birch	*Betula nigra*
Alternate Species	
Shortleaf Pine	*Pinus echinata*
Red Mulberry	*Morus rubra*
Tulip Poplar	*Liriodendron tulipifera*
Native Seed Mix for Stream Banks and Wetlands	
Switchgrass	*Panicum virgatum*
Soft Rush	*Juncus effusus*
Fringed Sedge	*Carex crinata*
Virginia Wild Rye	*Elymus virginicus*
Joe Pye Weed	*Eupatorium fistulosum*

Table 8.4 Cox Branch Site Plant Schedule	
Common Name	**Botanical Name**
Riparian Buffer/Wetland Plantings on Upper End of Project Site	
Woody Vegetation for Live Stakes	
Silky Dogwood	*Cornus amomum*
Silky Willow	*Salix sericea*
Elderberry	*Sambucus canadensis*

8.5.2 Invasive Species Removal

The site has minimal existing native riparian vegetation other than field grasses with the exception of one forested block. Invasive species such as Multiflora rose (*Rosa multiflora)* and privet (*Ligustrum sinense*) are present, although in relatively small amounts. Grading operations will remove these invasive species. If these or other invasive species re-establish and persist for more than three years after the stream restoration has been constructed, hand cutting and herbicide treatment will be required. If any invasive species are determined to pose potential problems within the first three years following restoration, corrective actions may be taken earlier.

9.0 WETLAND RESTORATION PLAN

9.1 Restoration of Wetland Hydrology

The existing agricultural fields across the site are currently drained by a field ditch and the channelized and highly incised Cox Branch. To restore wetland hydrology to the site, the lateral field ditch and existing stream will be fully to partially filled depending on the amount of fill material that can be produced from minor land grading and excavation of the new stream channel. When complete filling of the stream and 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 stream channel. In these locations, the existing stream 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. Some sections of existing channel may be only partially filled depending on the amount of fill material that can be produced. These partially filled areas will be discontinuous and will mimic small vernal pools or tree throws within the wetland areas that will add to the diversity of habitat on the project site.

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.

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 3.8.

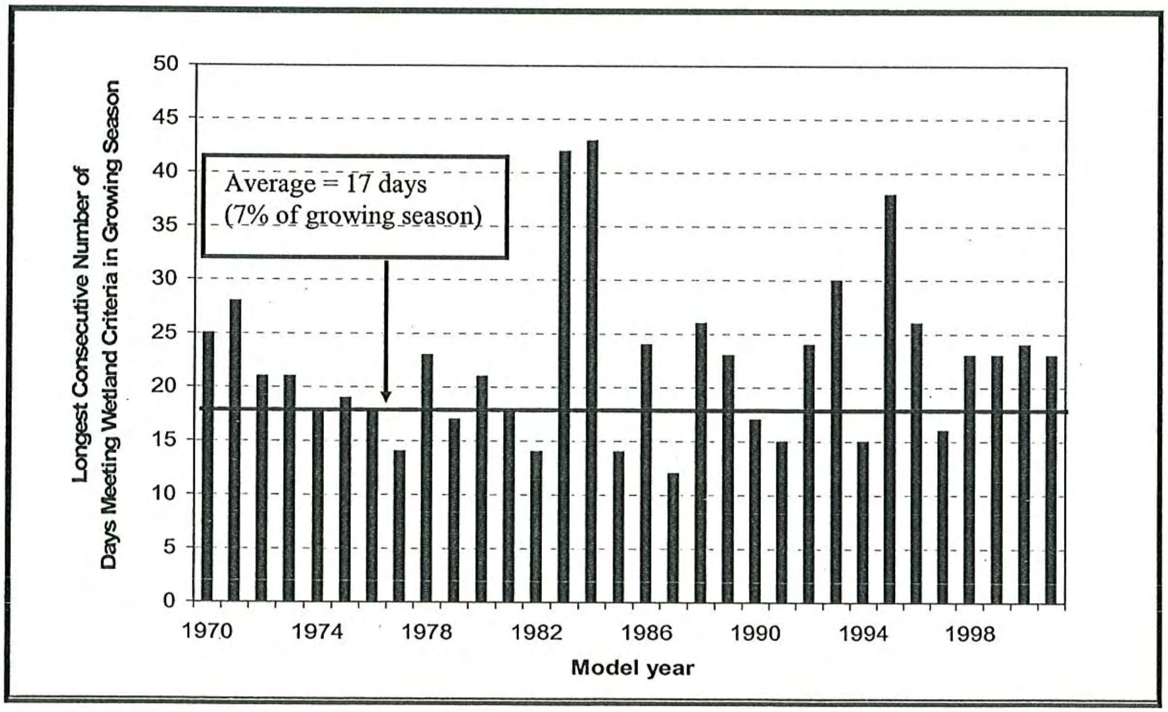
The restoration design for the wetland is based on the reference wetland area (Section 9.3). The targeted type of riverine wetland would be a Coastal Plain small stream swamp as identified by Schafale and Weakley (1990). Hydrology of this system will be palustrine, "intermittently, temporarily, or seasonally flooded", as the restored channel is designed to carry the bankfull flow, and to flood (flow out of its banks) at discharges greater than bankfull. This riverine wetland would transition into a non-riverine wetland system. This non-riverine wetland will mimic the non-riverine wet hardwood forest as identified by Schafely and Weakley (1990). Hydrology of the wet hardwood forest will be palustrine, seasonally to intermittently flooded. Vegetation of both systems will mimic that of the reference wetland.

9.2 Hydrologic Model Analyses

The DRAINMOD simulations developed to evaluate the current hydrologic status of the restoration site (Section 3.5) were used 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 approximately 37 cm to represent the water level in the restored, meandering channel. Surface storage parameters were increased from 2 to 4 cm to represent surface roughing practices. Input files that describe cropping conditions were changed to represent forested conditions.

To estimate the average hydrologic condition of the restored site, a model scenario was evaluated for an average distance from the restored channel with a surface storage of 2 cm. Since wetlands are being restored from the restored stream channel out to a distance of approximately 400 feet, an average distance of 250 feet was used in the model. In a similar manner, a maximum surface storage of two cm was chosen based on reference site information and represents typical topographic conditions across the restored site. A 30-year simulation was run following the procedure described in Section 3.5. Results of the simulation are presented in Figure 9.1, and the DRAINMOD input file is provided in Appendix D.

Figure 9.1
Thirty-Year Model Simulation for the Longest Period of Consecutive Days Meeting Wetland Criteria for Conditions Encountered at Restoration Site



The simulation runs indicate that, on average, the water table will be less than 30 cm deep continuously for approximately 7% of the growing season. This scenario can be assumed to represent average conditions across the site, with the majority of the restored acreage on the site being represented by this hydrologic scenario. It is probable that there will be areas slightly drier or slightly wetter than the modeled scenario within the restoration area. The modeled scenario provides a basis for estimating the average hydrologic condition over the restored site, based on the proposed restoration practices. However, it is important to note that the hydrology of the targeted restored wetland system (Coastal Plain small stream swamp) is highly variable across a given site, supporting the ecological and functional diversity that makes these systems so valuable.

Further confidence is provided in the Model accuracy through comparison of monitoring data from the Westbrook Site to Model predictions. Groundwater levels have been monitored on the Westbrook Site for two years since restoration activities were completed. The Westbrook monitoring wells have shown groundwater within the upper 12 inches of the soil for 7 to 12 percent of the growing season, which is the range predicted by the Model.

9.3 Wetland Reference Site Overview

The reference site for this project is located approximately 1,000 feet west of Cox Branch. It is located near another unnamed tributary to Mill Creek that flows adjacent to 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. It is difficult to define whether the site is of the "brownwater" or "blackwater" subtype, since the site exhibits features of both subtypes. Schafale and Weakley characterize the "brownwater" subtype as having its headwater originating in the Piedmont, while the "blackwater" subtype originates in the Coastal Plain. Although the reference site lies very near the fall line between the Piedmont and Coastal Plain physiographic regions, most delineations of the fall line boundary would place the origin of the reference site stream in the Coastal Plain, and therefore the system would be considered the "blackwater" subtype. 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 site will be used as a template for the restoration of the project site. Wetland data forms for the site are provided in Appendix A.

9.3.1 Reference Site Soils

The reference site is located in the transition area between the Coastal Plain and Piedmont physiographic regions of North Carolina adjacent (to the west) of the project site. Soils located within the wetland areas of the reference site are mapped as the Bibb and Pantego series (SCS, 1994). The Bibb series consists of poorly drained soils typically found on floodplains along streams in the Coastal Plain. Permeability is moderate, and the seasonal high water table is within 0.5 to 1.5 feet of the soil surface. The Pantego series consists of poorly drained soils typically found on broad stream terraces on the Coastal Plain and is the same soil that underlies all of the restoration acreage. In the undrained condition, permeability is moderate, and the seasonal high water table is within one foot of the soil surface in winter and spring. The Pantego and Bibb soil series are listed as "A" list hydric soils by the Natural Resources Conservation Service (NRCS, 1995). On the upslope areas adjacent to the wetland areas, soils of the Uchee, Blanton, and Bonneau series are found.

Two auger hole tests were performed within the wetland area to verify soil information obtained from the Johnston County soil survey maps. These tests revealed that the soils on the reference site match most closely with the soil description for the Pantego series, which is the primary soil found on the restoration site. The reference site soils have a deep, dark loamy layer to a depth of approximately two to three feet, underlain by a layer of sandy clay loam material to a depth of approximately 4.5 feet. At a depth of approximately 4.5 feet, a layer of sand is reached and extends to an undetermined depth.

Saturated hydraulic conductivity measurements were conducted in the reference site using the method described by van Beers (1970). Hydraulic conductivity in the surface layers (0 to 0.6 m depth) was approximately 3 to 4 m/day, while that in the underlying layers (0.6 to 1.5 m depth) ranged from 1 to 2 m/day.

Reference Site Hydrology

Climatic conditions of the reference site are the same as those described for the project site (Section 5.3). The reference site is classified as a "Coastal Plain small stream swamp" (Schafale and Weakley, 1990). It is difficult to distinguish the site as either the "blackwater" or "brownwater" subtype, as the site displays characteristics of both communities. Small stream swamp communities are palustrine with variable flows and are intermittently, temporarily, or seasonally flooded (Shafale and Weakly, 1990). Site hydrology is controlled by the main stream channel that flows through the site, as well as several small drainages that flow onto the site and provide additional water to the floodplain areas during wet periods. Due to the shallow, unincised condition of the main stream through the site and drainage from upland side slopes, high water table conditions are sustained across the active floodplain (see Figure 9.2).

Water table monitoring wells were installed within the reference site, and monitoring data were collected from June 2001 to the present. An example subset of the data is shown in Figure 9.3. Based on the data collected, the site exhibits wetland hydrology, and exhibits a range of saturation and wetness during the wetter periods of the year (late fall, winter, and early spring).

Figure 9.2
Cross-Section for the Johannah Creek Reference Reach

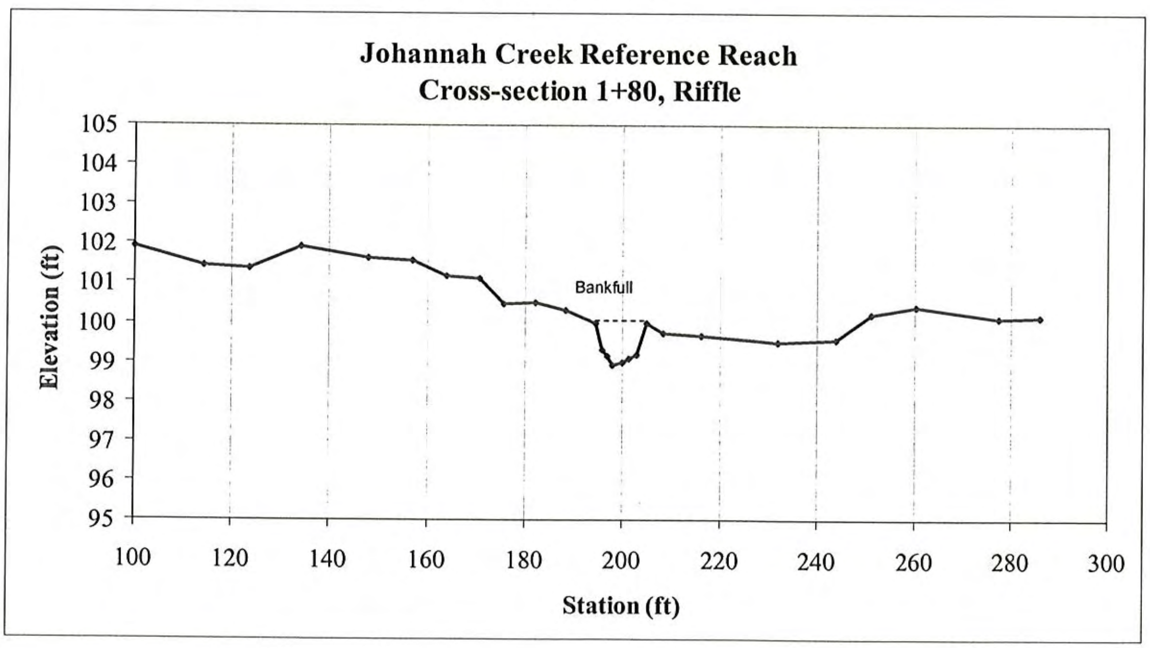
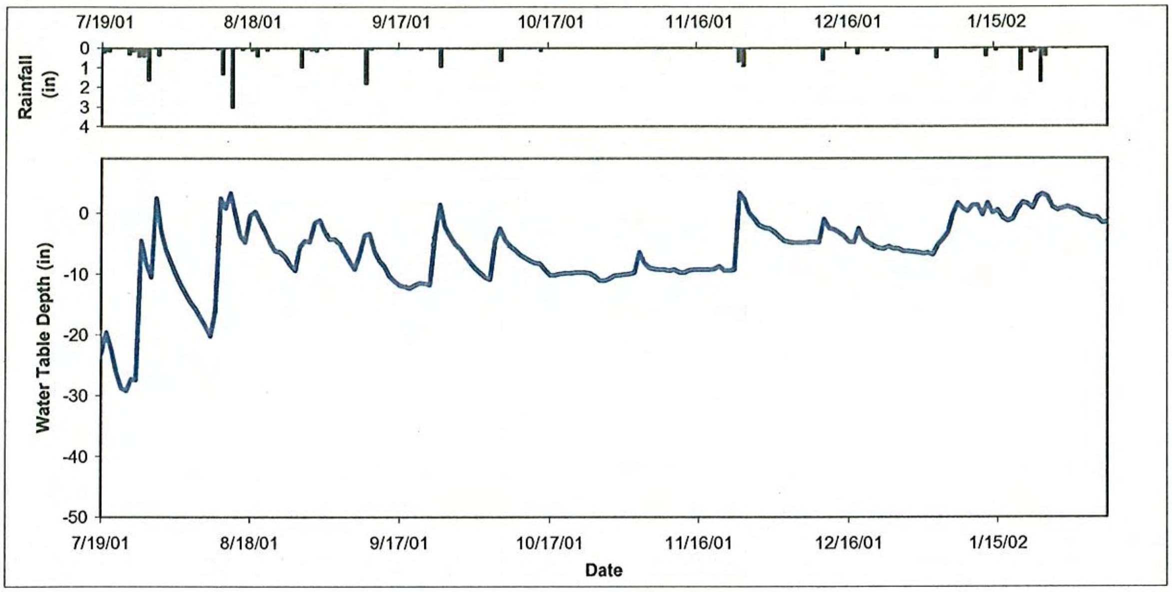


Figure 9.3
Water Table Depths Recorded in a Monitoring Well Installed within the Reference Site



10.0 MONITORING AND EVALUATION

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

10.1 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 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.

10.1.1 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.

10.1.2 Pattern

Annual measurements taken for the plan view of the restoration site will include sinuosity, meander width ratio, and radius of curvature. The radius of curvature measurements will be taken on newly constructed meanders for the first year of monitoring only.

10.1.3 Longitudinal Profile

A longitudinal profile will be completed in years one, three, and five of the monitoring period. The profile will be conducted for 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.

10.1.4 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.

10.1.5 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. Site photographs are presented in Appendix G.

The stream will be photographed longitudinally beginning at the downstream end of the restoration site and moving upstream to the end of the site. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be close enough together to provide an overall view of the reach. The angle of the shot will depend on what angle provides the best view and will be noted and continued in future shots. When modifications to photo position must be made due to obstructions or other reasons, the position will be noted along with any landmarks and the same position will used in the future.

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.

10.2 Wetland Monitoring

10.2.1 Wetland Hydrologic Monitoring

Groundwater-monitoring stations will be installed across the project area to document hydrologic conditions of the restored site. Eight groundwater monitoring stations will be installed, with four stations being automated groundwater gauges, and four stations being manually read stations. Ground water 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 Johnston County WETS Station.

The objective is for the monitoring data to show the site is saturated within 12 inches of the soil surface for at least 7% of the growing season as indicated by the DRAINMOD model in Section 9.2 and that the site exhibits an increased frequency of flooding. The restored site will be compared to a reference site where the groundwater and surface water levels (overbank events) will be monitored. In addition, the restored site's hydrology will be compared to pre-restoration conditions both in terms of groundwater and frequency of overbank events.

10.3 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 monitoring plots. 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.

Herbaceous vegetation, primarily native grasses, planted at the site shall have at least 95% coverage of the seeded/planted area. No bare patches shall exceed 10 square feet. Any herbaceous vegetation not meeting these criteria shall be replaced. At a minimum, at all times ground cover at the project site shall be in compliance with the North Carolina Erosion and Sedimentation Control Ordinance.

10.4 Reporting Requirements

A mitigation plan and 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 transacts
- 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
- Reference wetland hydrology and stream data.

10.5 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.
- Local wildlife can impact the rate at which the native buffer can be established.
- 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 which may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

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Exhibits

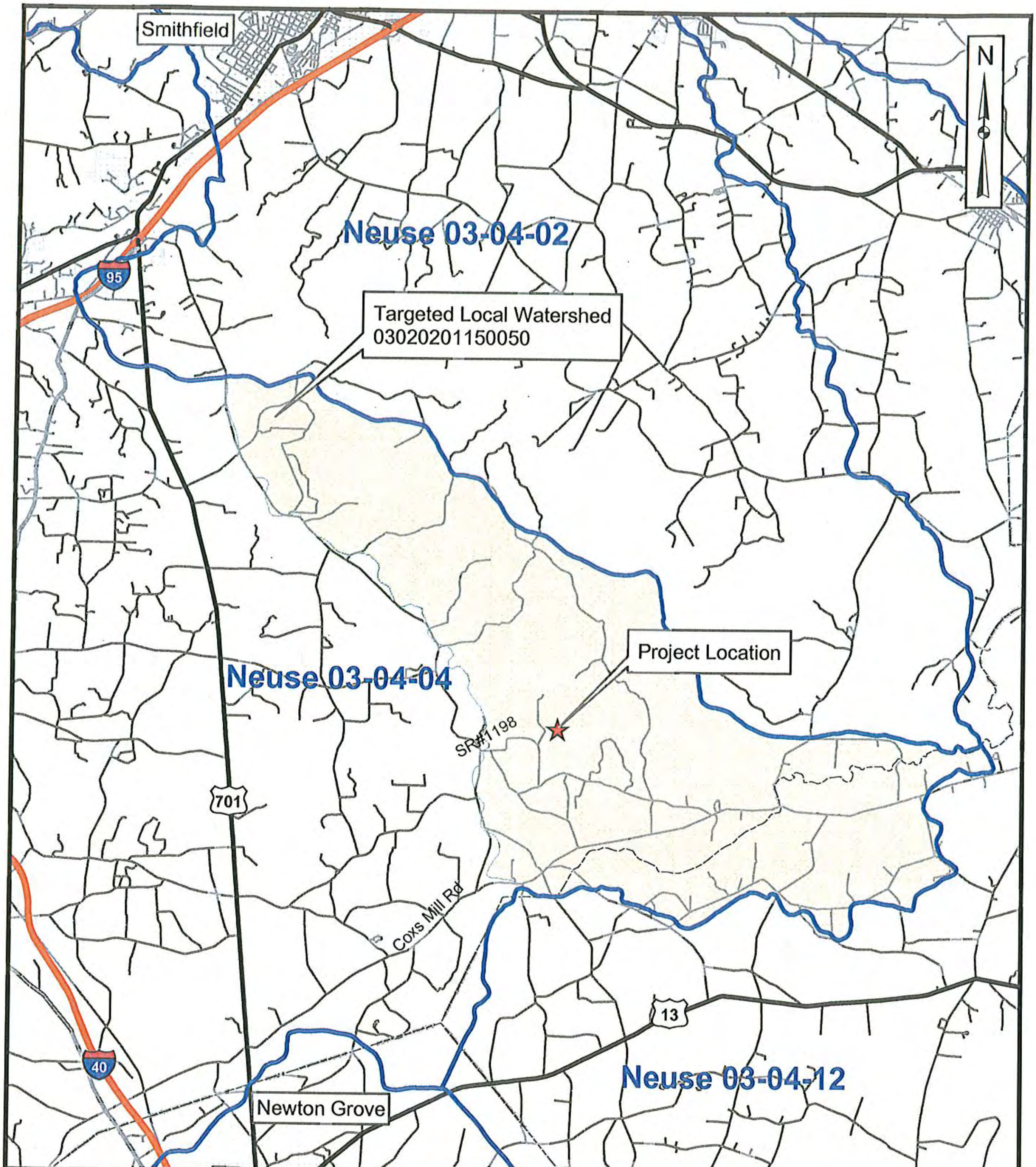

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Exhibit 1.1.
Site Location Map

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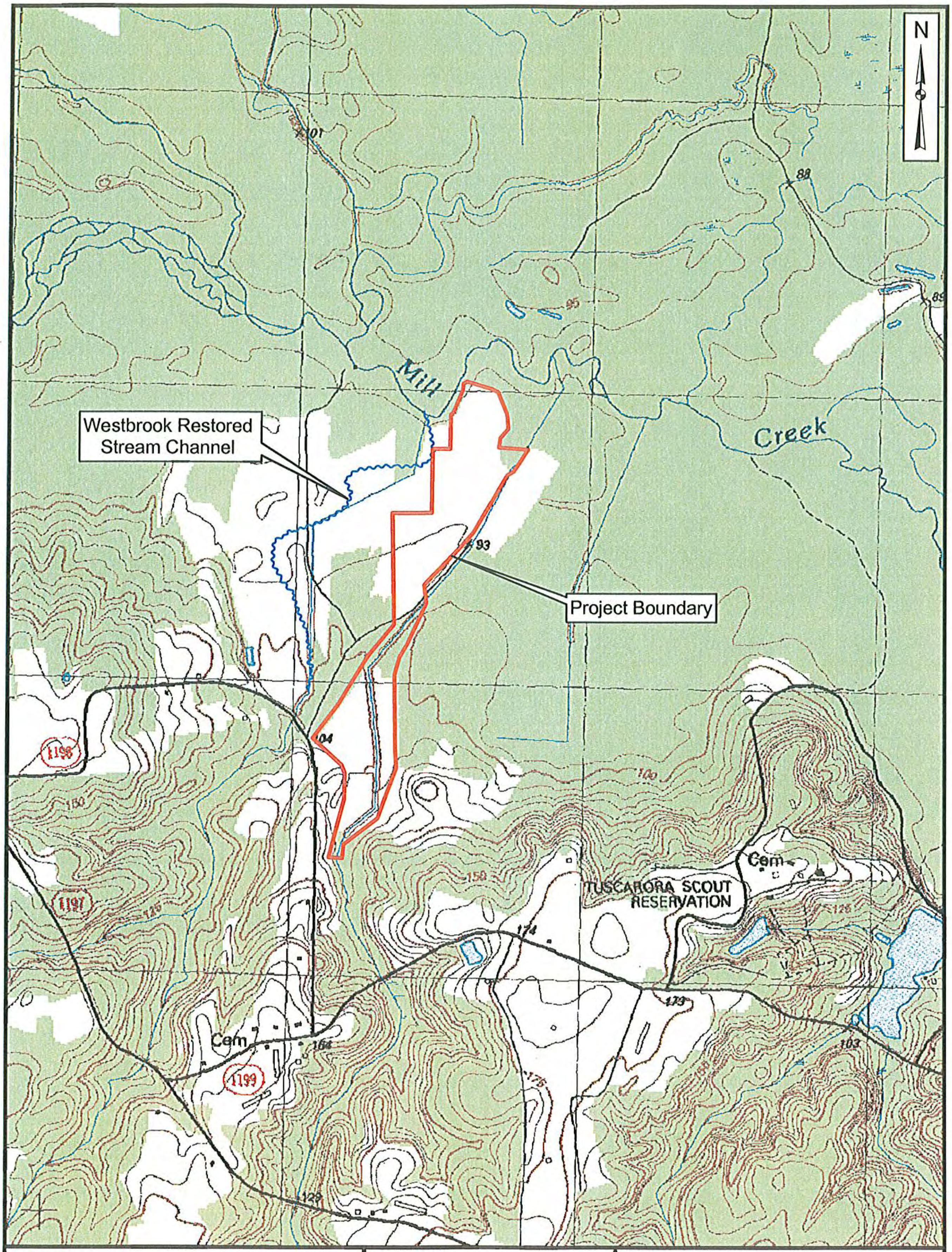

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Exhibit 1.2.
Project Vicinity Map

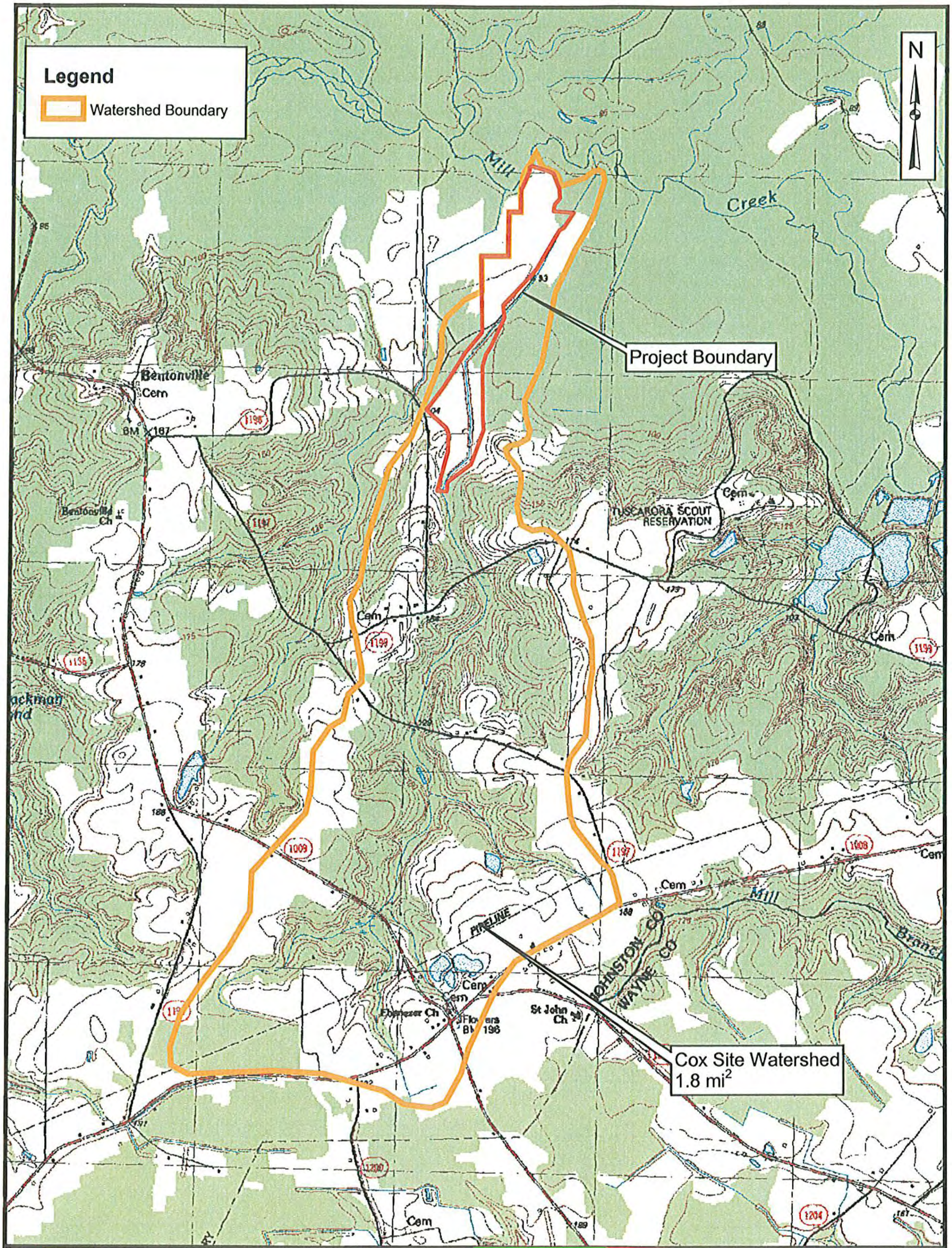

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Exhibit 1.3.
Watershed Map

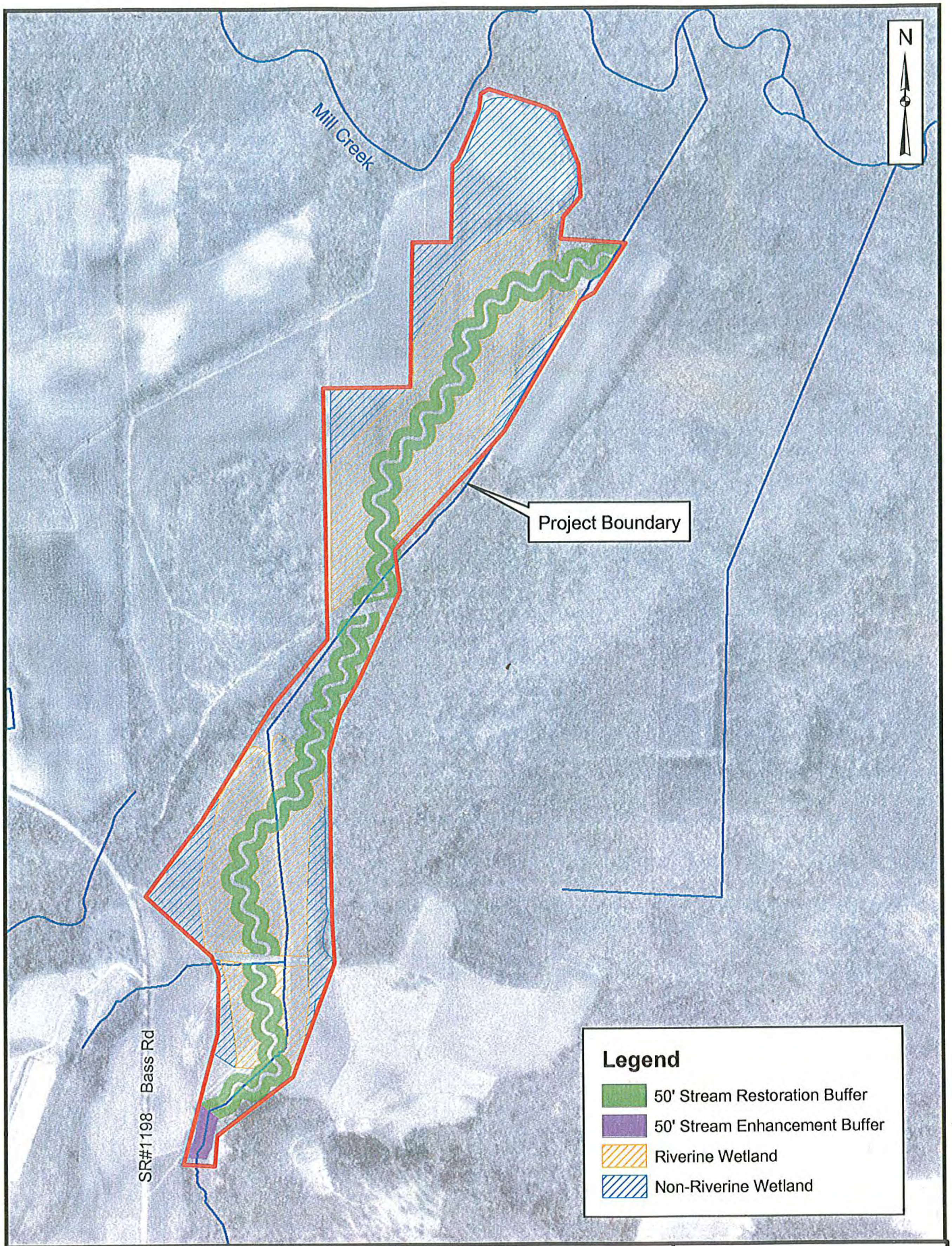

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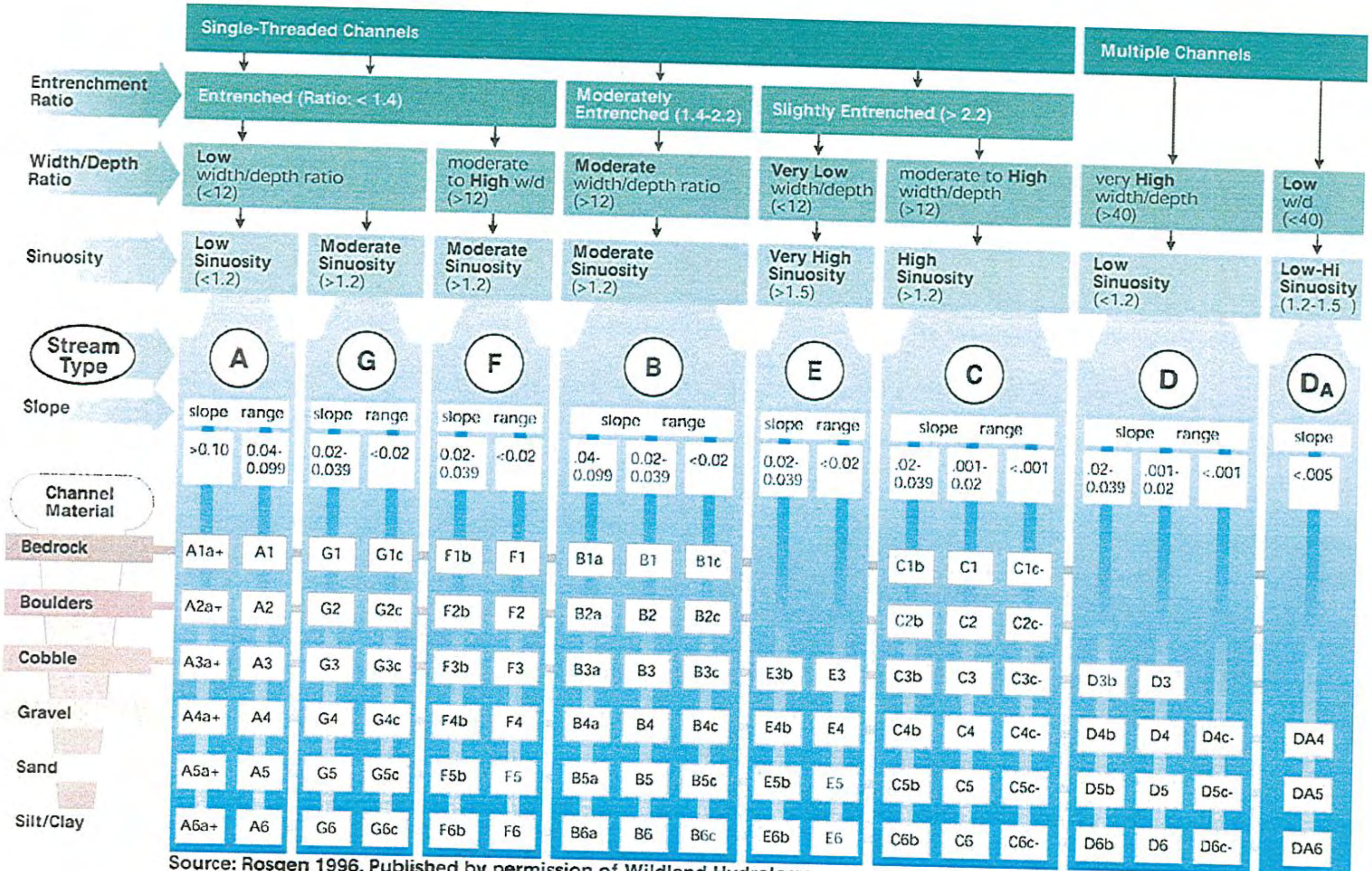
Exhibit 1.4.
Proposed Wetland
Restoration Areas

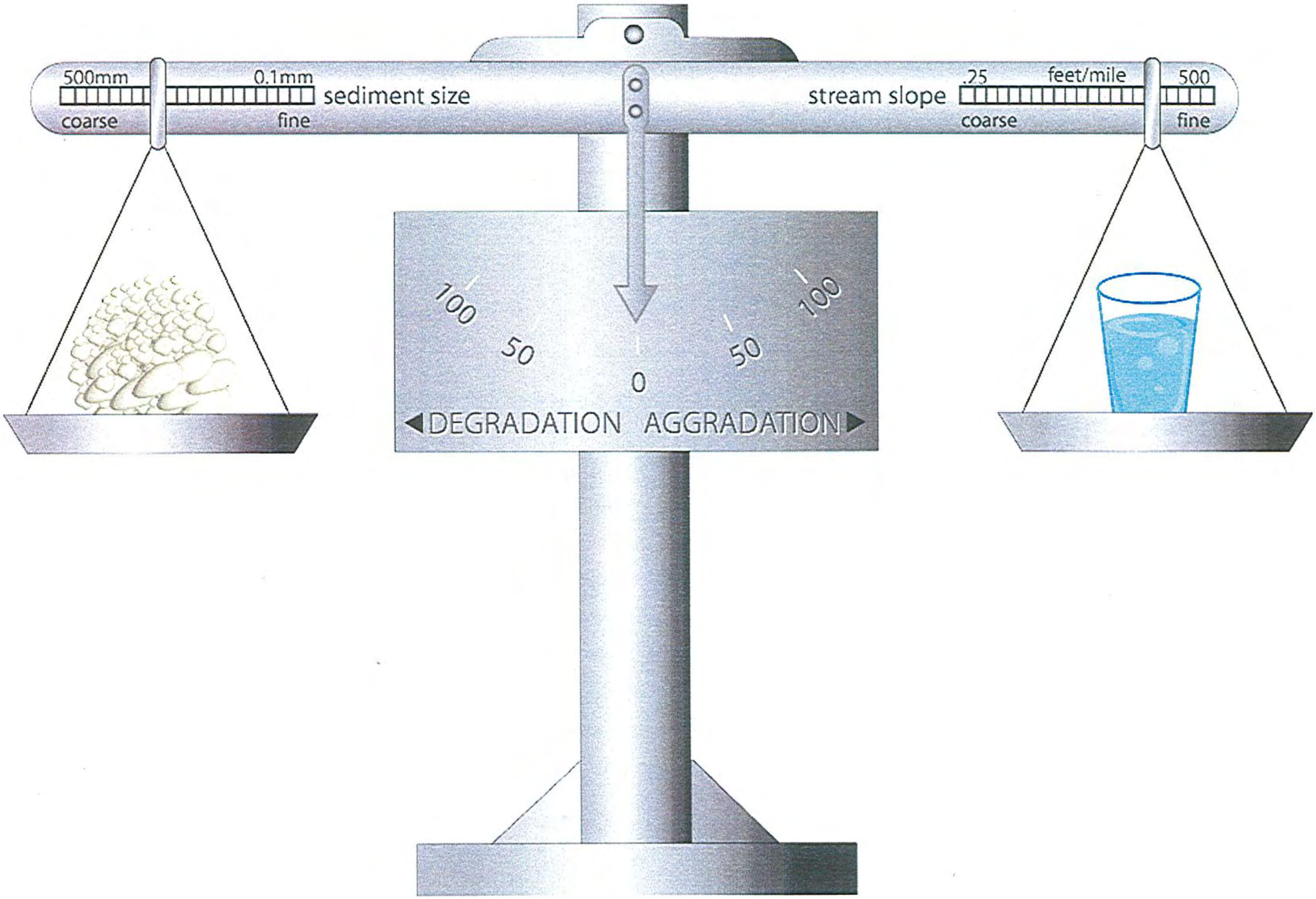


Source: Rosgen 1996. Published by permission of Wildland Hydrology.

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).

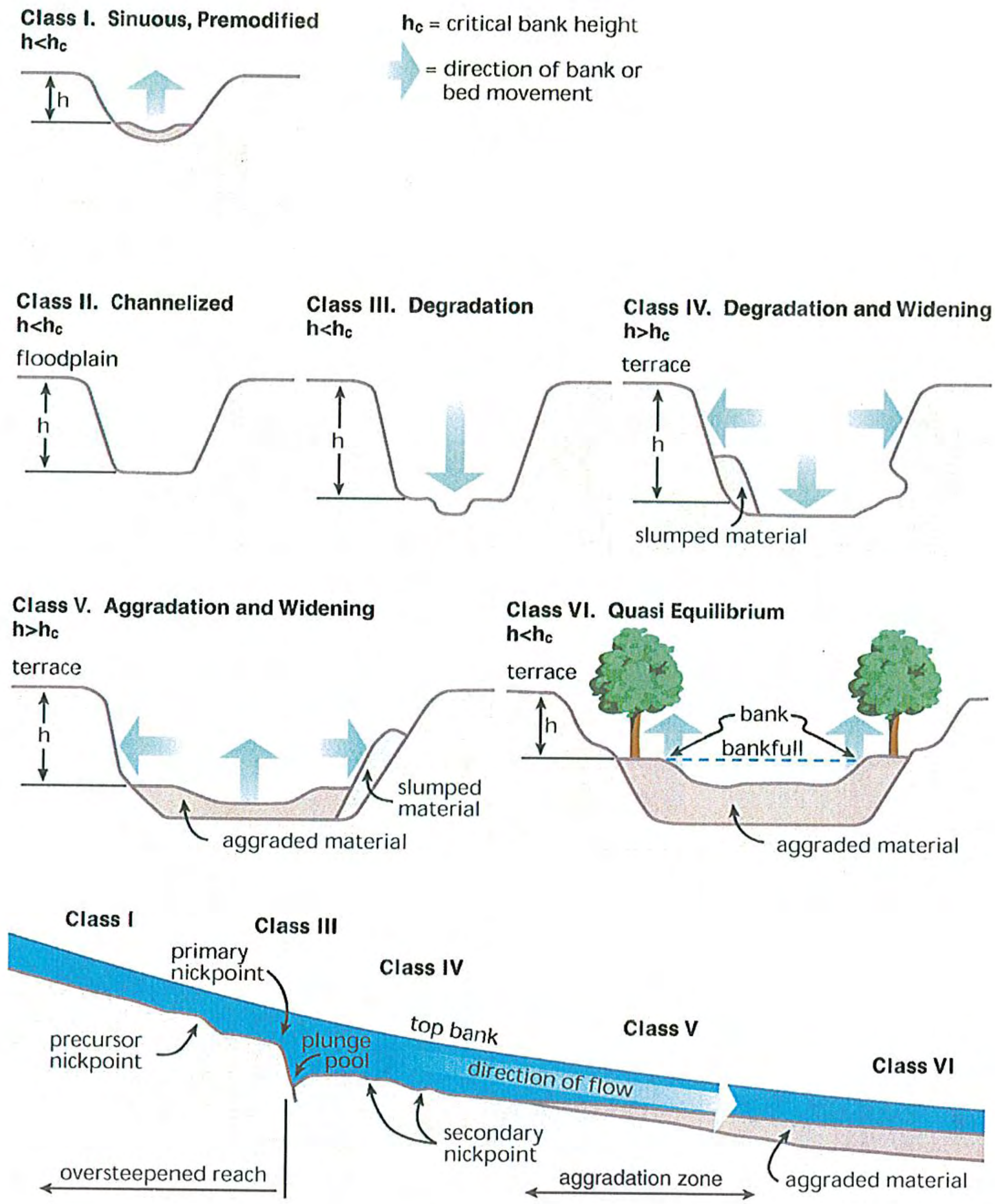
Source: Rosgen, David L., *Applied River Morphology*, Wildland Hydrology, 1996

Exhibit 2.1
Rosgen Stream Classification



After: Lane, 1955

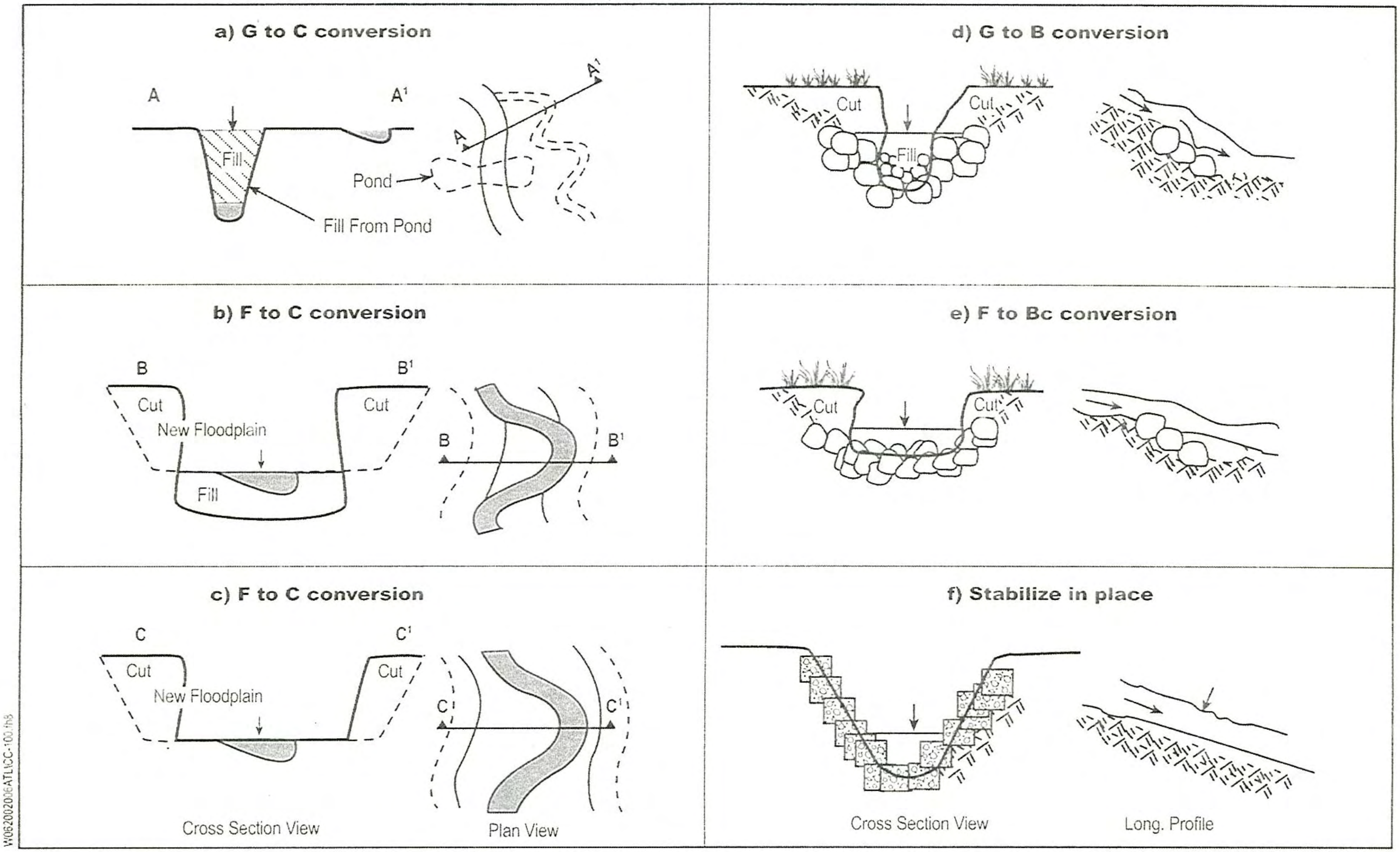
Exhibit 2.2
Factors Influencing Stream Stability



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).

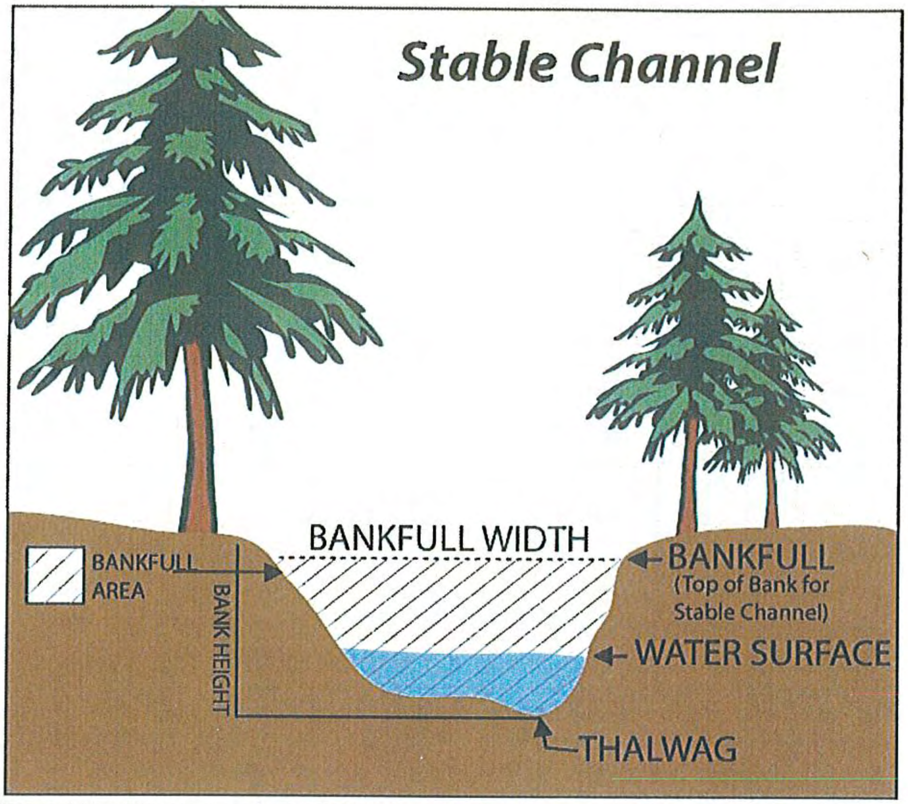
Source: Simon, 1989

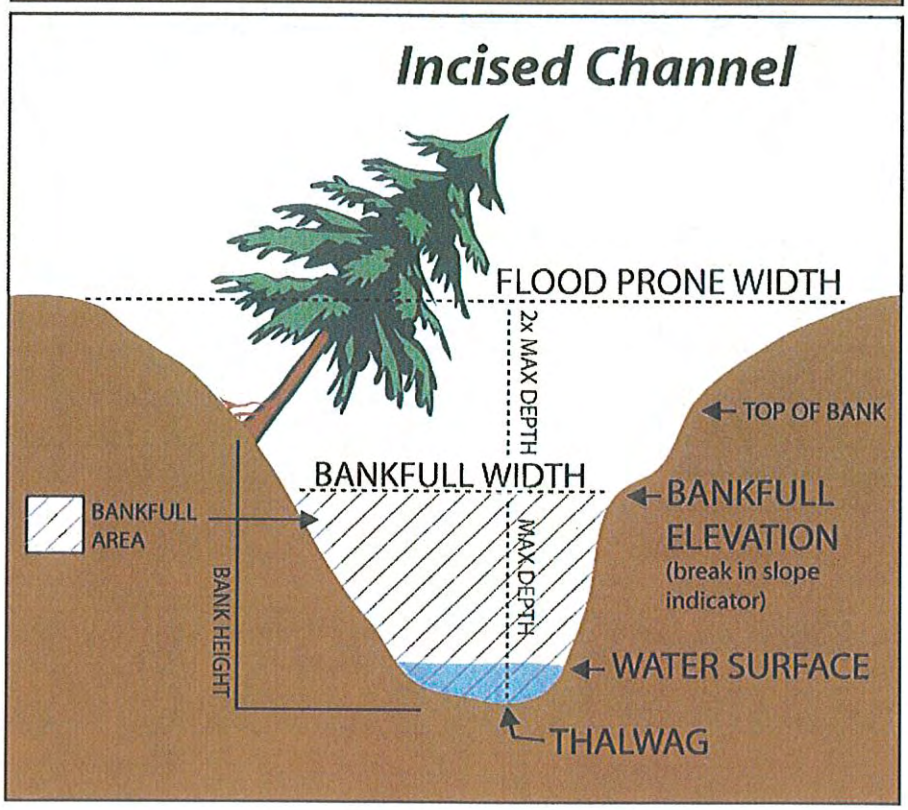
Exhibit 2.3
Simon Channel Evolution Model



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

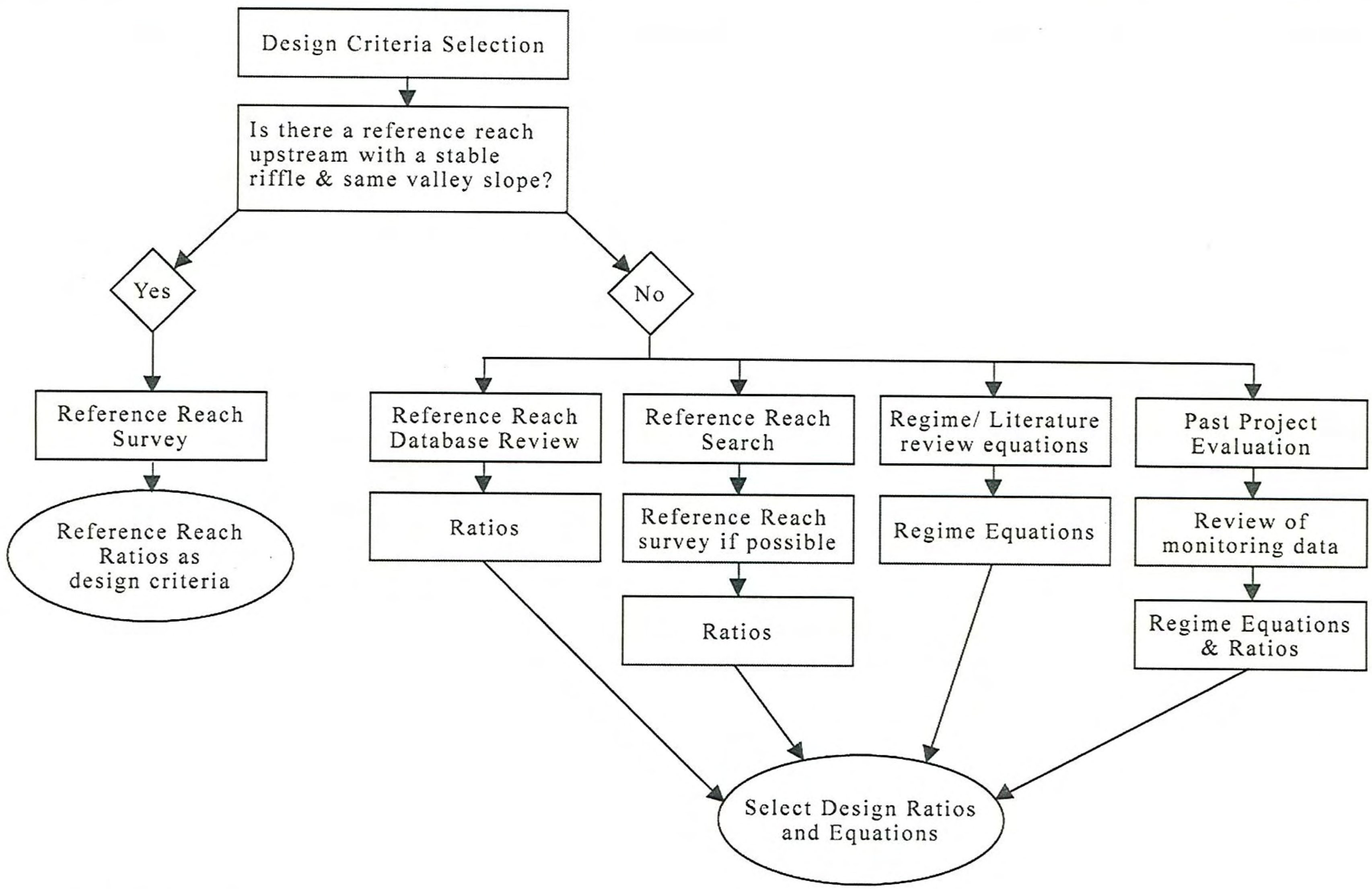
Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

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

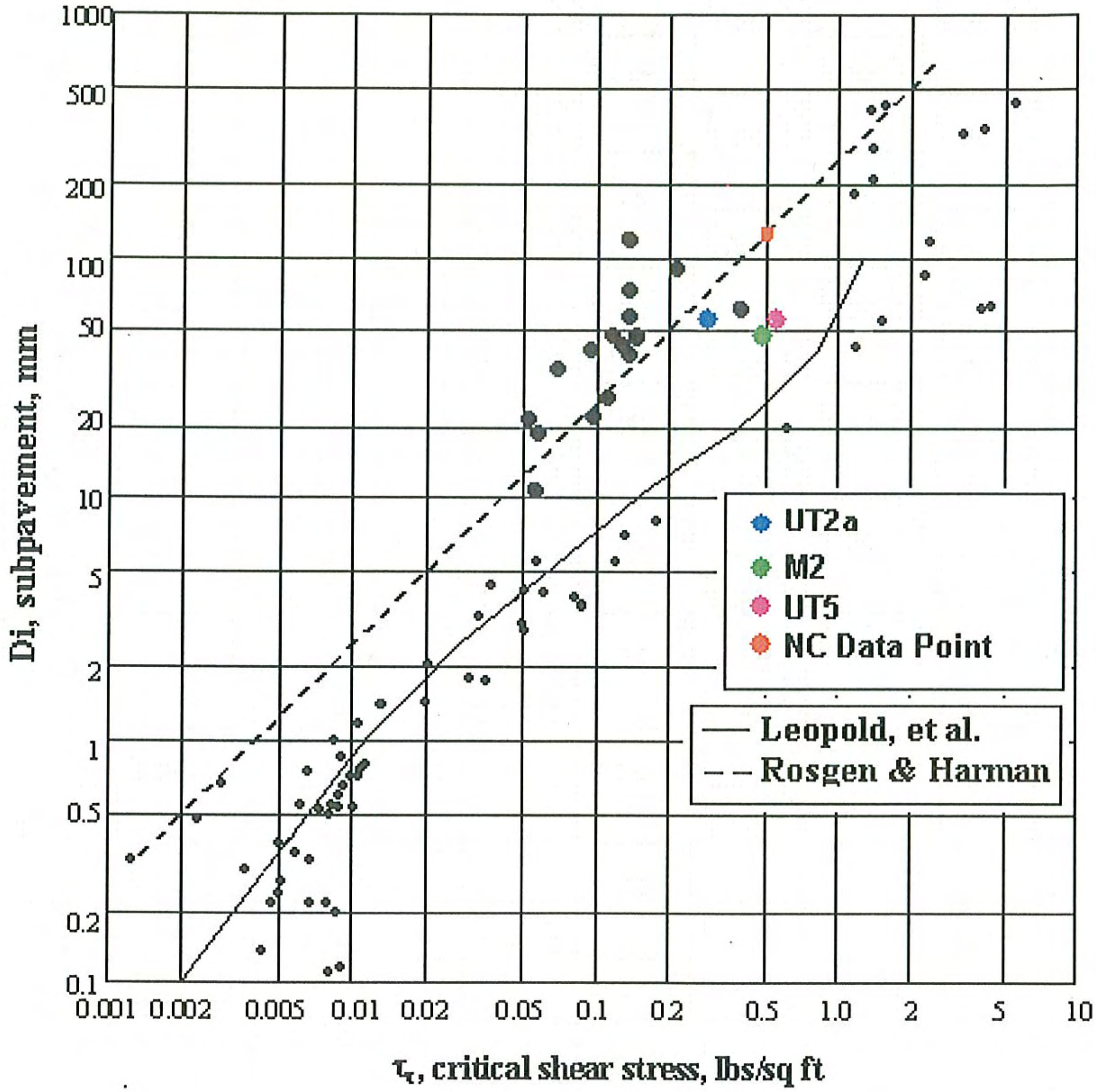
Exhibit 2.5
Channel Dimension Measurements



BUCK ENGINEERING

Exhibit 2.6
Design Criteria Selection

Exhibit 2.7. Modified Shields Curve with Project Data Points



Log Vane

Log Weir

Root Wads

Exhibit 2.8
Examples of Instream Structures

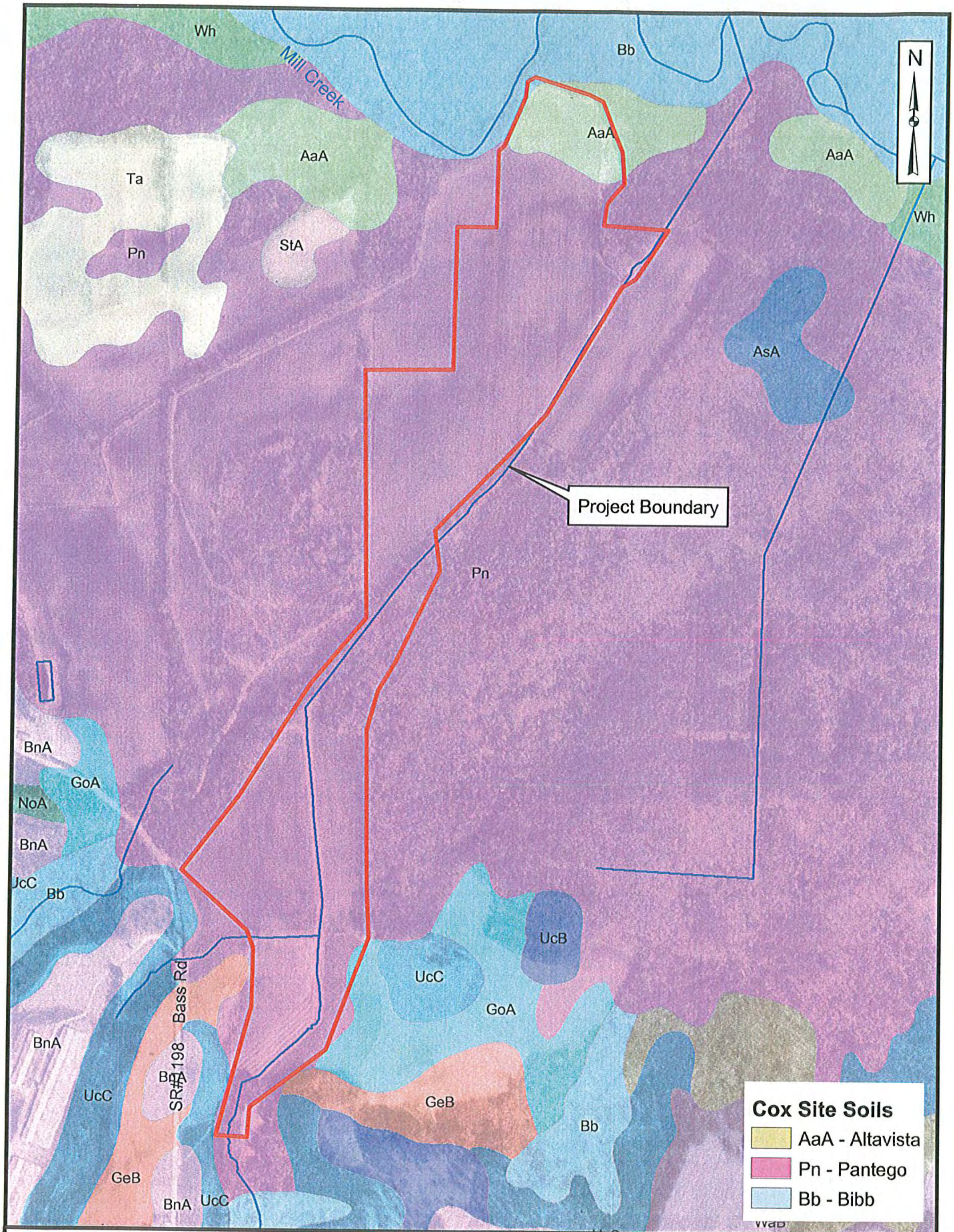


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Exhibit 4.1.
Soils Map

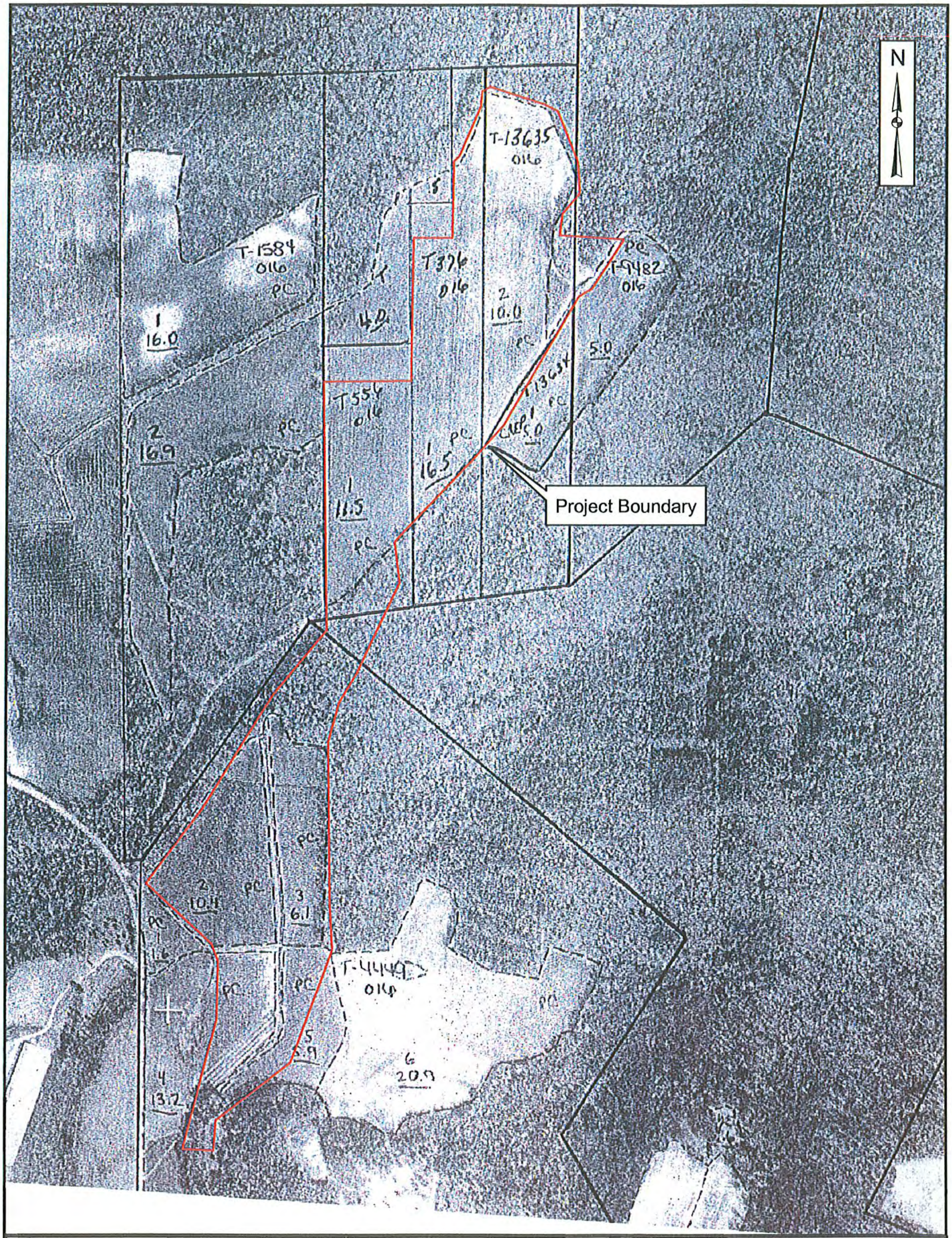

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Exhibit 5.1.
Prior Converted Wetland Map

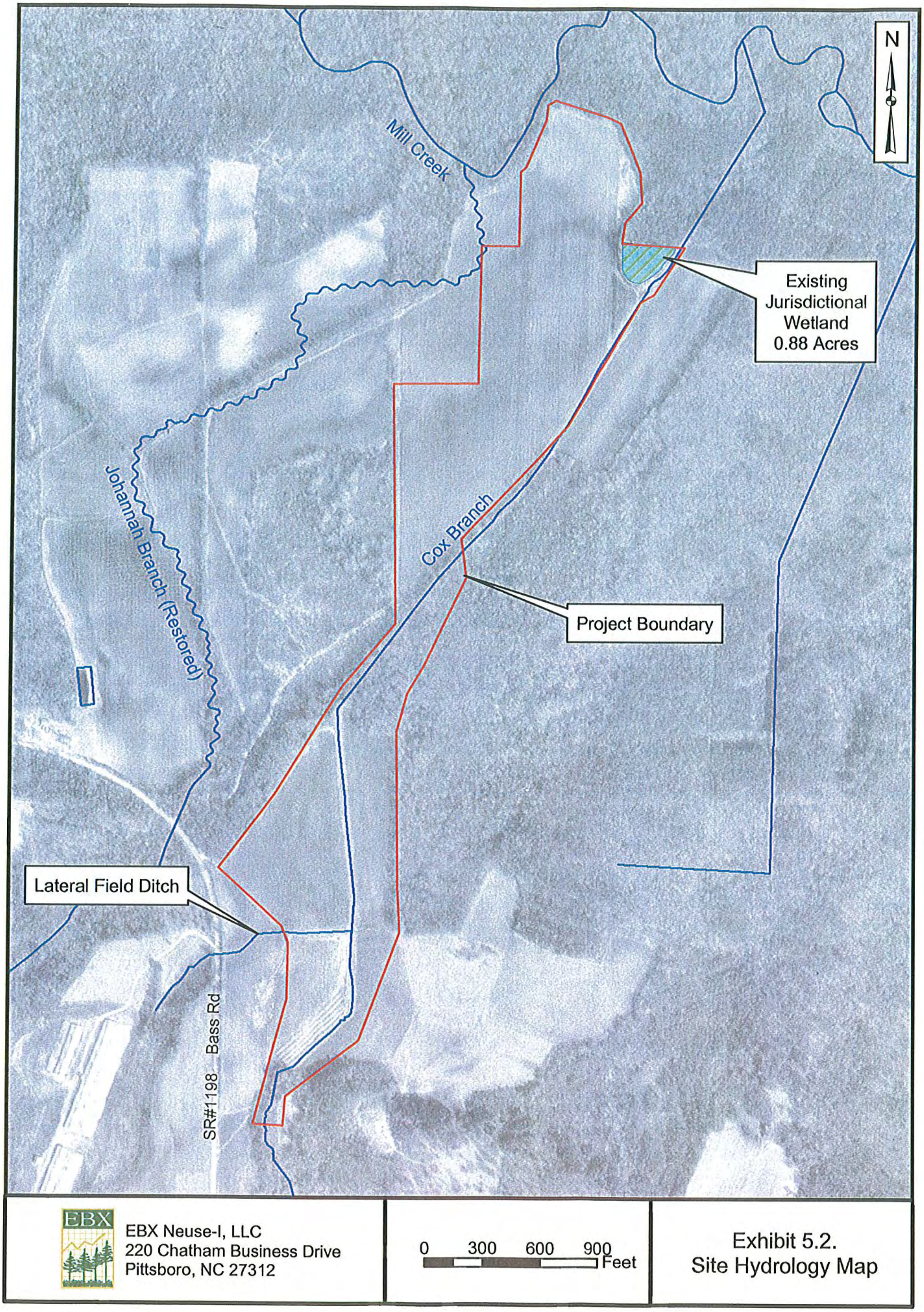

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Exhibit 5.2.
Site Hydrology Map

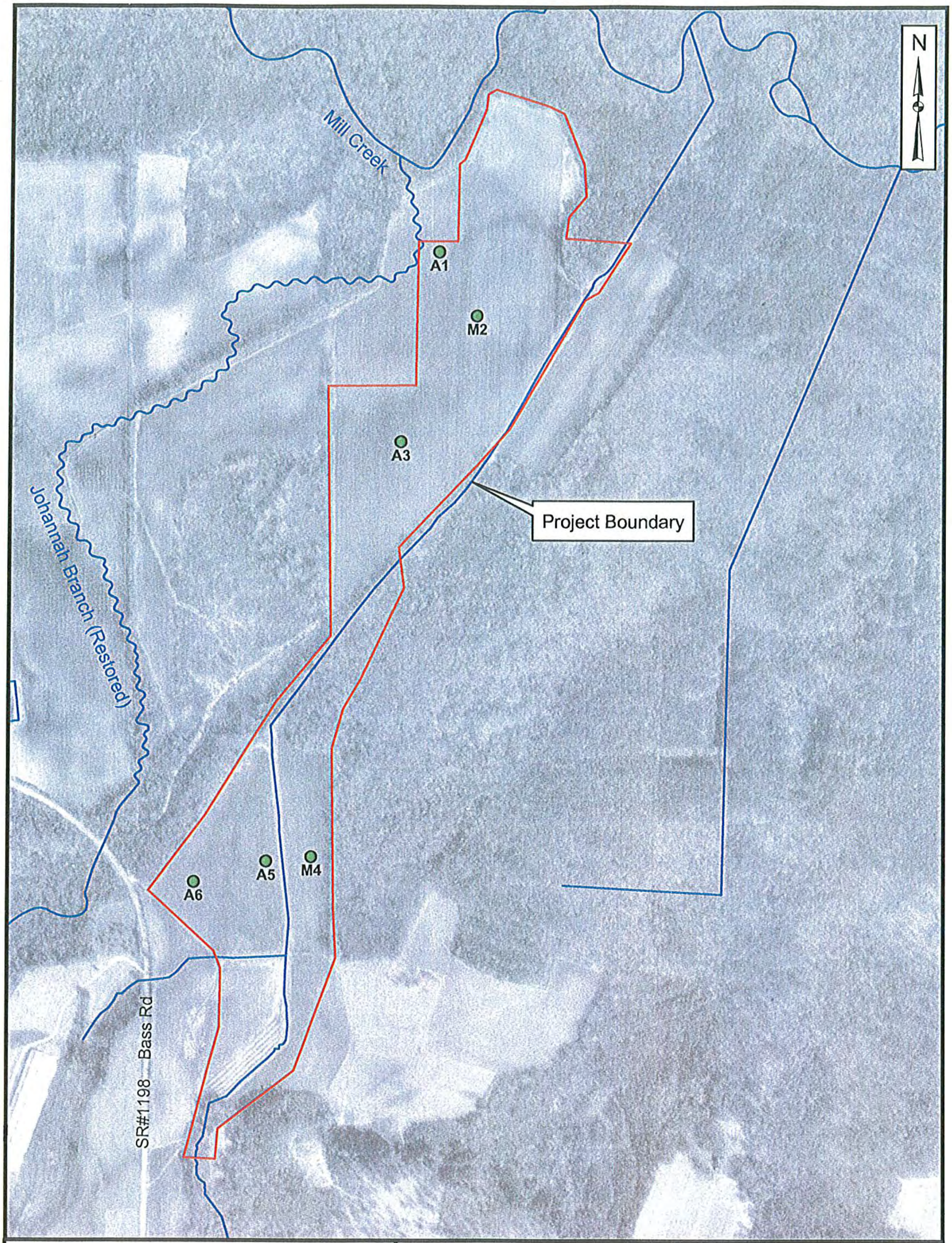

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Exhibit 5.3.
Locations of Water Table Monitoring Wells

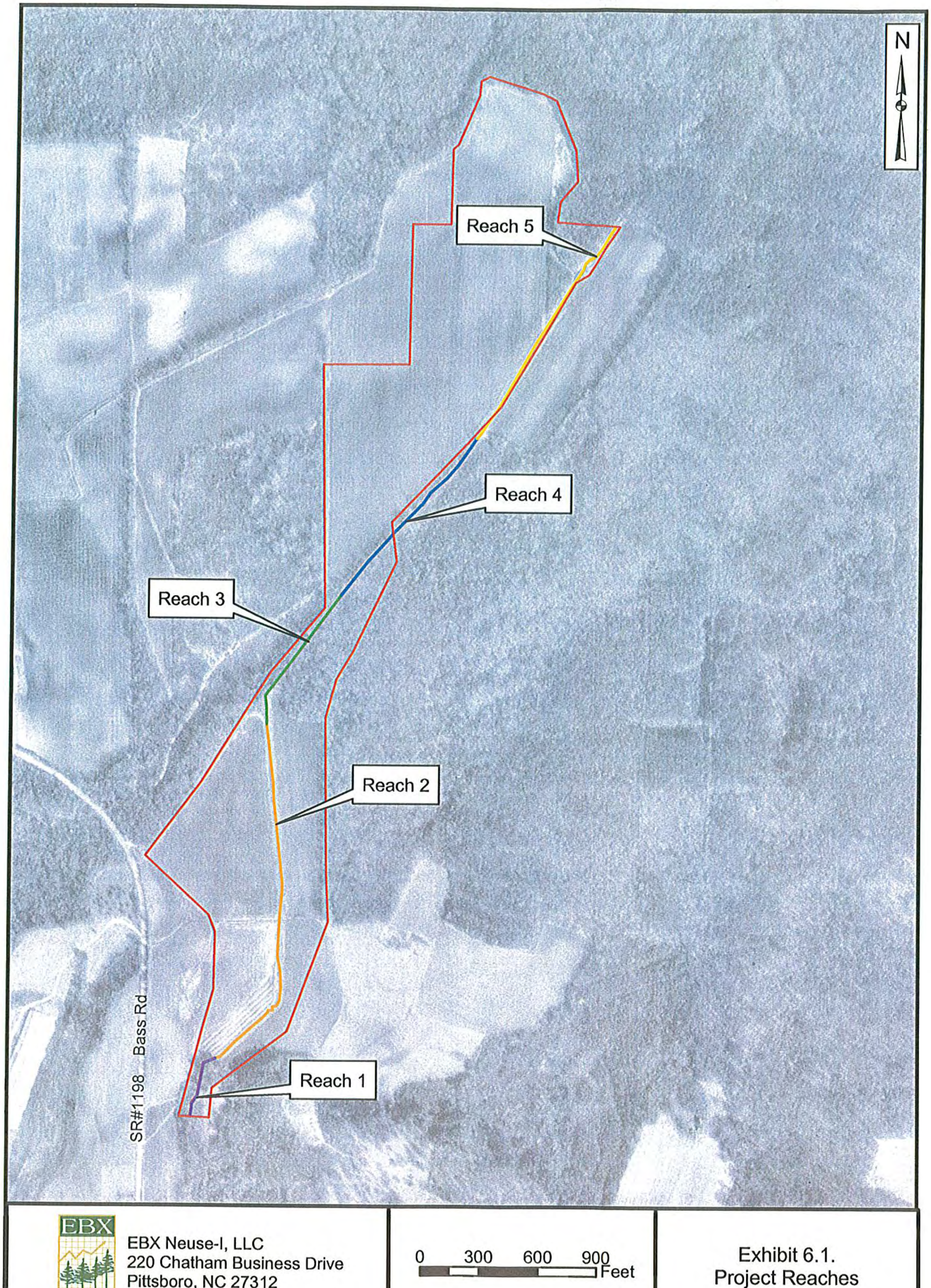

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Exhibit 6.1.
Project Reaches

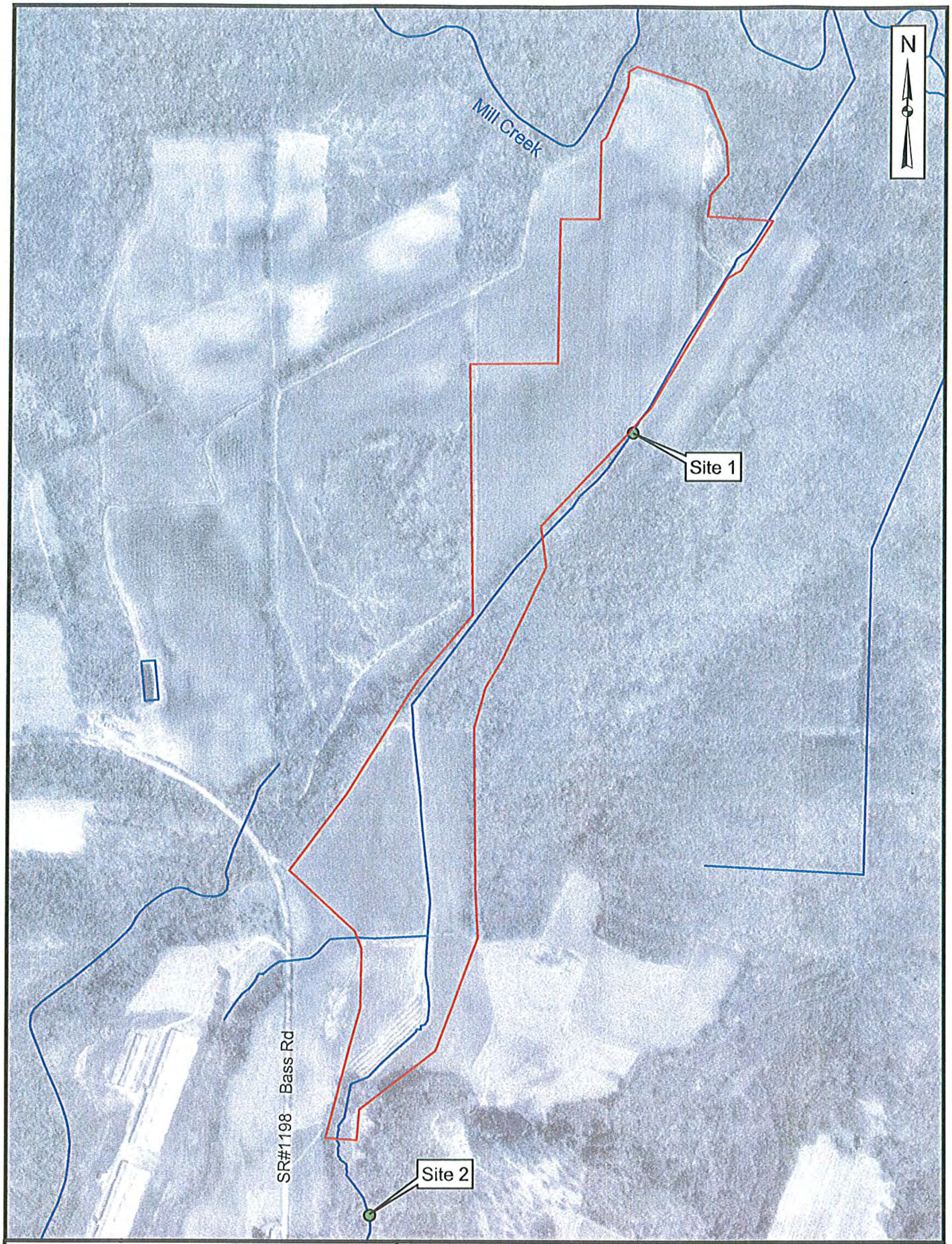

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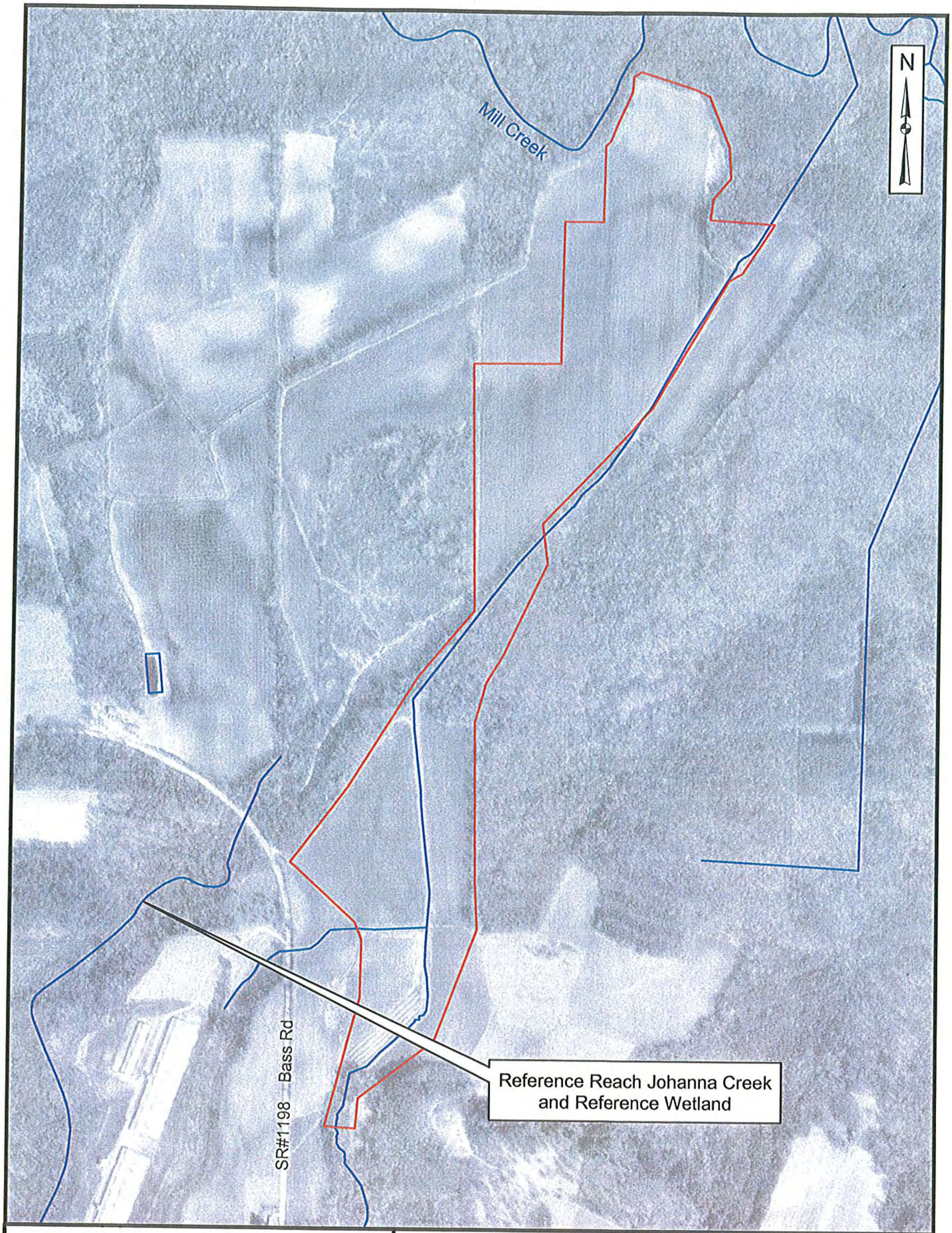
Exhibit 6.2.
Biomonitoring Site Locations



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0 300 600 900 Feet

Exhibit 7.1.
Location Map of Reference Reach and Reference Wetland

Appendix A

Wetland Delineation Data and Forms

BUCK ENGINEERING
8000 Regency Parkway
Suite 200
Cary, NC 27511
Phone: (919) 463-5488
Fax: (919) 463-5490
www.buckengineering.com

MEMO

To: Ken Gilland & John Hutton

From: George Buchholz

Date: February 2, 2005

Re: Cox Site Restoration Plan; Johnston County, North Carolina; Buck Project # 0214R

I am pleased to forward to you a summary letter detailing the jurisdictional wetland delineation that was performed for a section of forested area located at the referenced subject project site. Attached are completed wetland data forms that correspond to the delineation. Jurisdictional wetlands were identified, flagged, and GPS located. I believe you should already have the GPS points ready for processing.

A. Wetland Delineation

Identification of jurisdictional wetlands on the subject project site was based on guidelines presented in the *Corps of Engineers Wetland Delineation Manual* (1987). The *Corps Manual* identifies three mandatory criteria that must be satisfied for making wetland determinations: hydric soils, a prevalence of hydrophytic ("water-loving") vegetation, and wetland hydrology.

1. Delineation Criteria

- <u>Hydrophytic Vegetation</u>

The *Corps Manual* states that an area has hydrophytic vegetation when, "under normal circumstances more than 50 percent of the composition of the dominant species from all strata are obligate wetland (OBL), facultative-wetland (FACW), and/or facultative (FAC) species" (*Corps Manual*, Section 35.a). As defined in the Corps Manual, obligate wetland species "occur almost always (estimated probability > 99%) in wetlands", facultative-wetland species "occur usually (estimated probability >67% to 99%) in wetlands", and facultative species are those "with a similar likelihood (estimated probability 33% to 67%) of occurring in both wetlands and non-wetlands". Two additional indicator statuses are designated for non-wetland plants. Facultative-upland (FACU) species "occur sometimes (estimated probability 1% to <33%) in wetlands" and obligate upland (UPL) species "occur rarely (estimated probability <1%) in wetlands". The scientific names of all species identified were recorded and dominants were determined as recommended in the *Corps Manual* (Section 65.7).

- Hydric Soils

The *Corps Manual* states criteria that render a soil hydric based on drainage class and the duration of soil saturation. Due to the seasonal nature of these conditions, soil saturation may not always be observed, but the *Corps Manual* provides specific field indicators that provide evidence of this criterion being met. Of these indicators, one of the most readily utilized in the field is soil color. Soil colors are categorized into numerical codes using *Munsell Soil Color Charts*, a collection of predetermined color codes organized in a systematic soil color identification book. The *Corps Manual* identifies and discusses the color codes that usually characterize a hydric mineral soil (Section 44.f). Hydric mineral soils usually have one of the following features in the soil layer immediately below the surface material, or the A-horizon:

1) matrix chroma of 2 or less in mottled soils
2) matrix chroma of 1 or less in un-mottled soils

Field samples for color readings are taken immediately below the A horizon (surface layer) or to at least a depth of 10 inches and compared to color samples in the *Munsell Charts*.

- Wetland Hydrology

The *Corps Manual* defines wetland hydrology as "... all hydrologic characteristics of areas that are periodically inundated or have soils saturated to the surface at some time during the growing season."

"Areas with evident characteristics of wetland hydrology are those where the presence of water has an overriding influence on characteristics of vegetation and soils due to anaerobic and reducing conditions, respectively. Such characteristics are usually present in areas that are inundated or have soils that are saturated to the surface for sufficient duration to develop hydric soils and support vegetation typically adapted for life in periodically anaerobic soil conditions" (p. 34).

Subsequent guidance published October 7, 1991, and March 16, 1992, by the U.S. Army Corps of Engineers' Headquarters further clarifies the minimum thresholds that define wetland hydrology. The three conditions necessary to establish whether hydrology is present include: 1) the time-frame of the "growing season", 2) near-surface groundwater levels, and 3) the consecutive period of time groundwater must be present within this surface zone. The Norfolk District Corps Office has mandated the growing season for the region as being the period each year beginning March 1 and ending December 6. The *Corps Manual* stipulates that areas which posses wetland hydrology are seasonally inundated and/or saturated to within 12 inches the surface for a consecutive period of time that constitutes at least 5% of the growing season, while areas that are not saturated to within 12 inches of the surface consecutively for at least 5% of the growing season do not possess wetland hydrology. If an area is saturated within 12 inches of the surface for more than 5% of the growing season but less than 12.5% of the growing season, other indicators of hydrology must be used to determine whether or not the area possesses wetland hydrology. If saturation exists for longer than 12.5% of the growing season, it is there is considered to be conclusive evidence that the area possesses wetland hydrology.

However, as a result of the substantial amount of time and effort required to determine whether wetland hydrology exists in a given area over time, the *Corps Manual* lists readily observable, "primary" field indicators that aid in evaluating whether wetland hydrology is present. Examples of these indicators include: observed inundation, soil saturation, watermarks, drift lines, sediment deposits, and wetland drainage patterns. Areas observed to contain at least one primary indicator of wetland hydrology are generally considered to satisfy the wetland hydrology criterion. The March 16, 1992 Memorandum lists "secondary indicators" as well which, when two or more of occur together, also constitute evidence of wetland hydrology. These "secondary" indicators are: oxidized root channels in the upper 12 inches of soil, water-stained leaves, local soil survey data, passage of the FAC-neutral test, and other morphological or physiological plant adaptations to wetland conditions.

Of these "secondary" indicators, passage of the FAC-neutral test and observations of plant adaptations are mainly independent of short-term fluctuations in water-table and precipitation levels, and are thus viewed by the Corps as important indicators of long-term site conditions. A sampling point "passes" the FAC-neutral test "when more than 50 percent of all considered species are wetter than FAC". In essence, the FAC species are considered as neutral, and the decision regarding hydrology is based upon whether the majority of species are typically found in wetlands (OBL, FACW±, FAC+) or non-wetlands (UPL, FACU±, FAC-) (*Corps Manual* page 23, paragraph 35a).

2. Review of Published Information

Before the on-site inspection of the property was initiated, existing reference materials were reviewed to identify the location of possible wetland boundaries. This review included the U.S. Geological Survey "Newton Grove North, North Carolina" 7.5 minute quadrangle, U.S. Fish and Wildlife Service "National Wetland Inventory" (NWI) Maps, U.S. Department of Agriculture *Soil Survey of Johnston County, NC*, and aerial photographs.

The U.S.G.S. "Newton Grove North" quadrangle indicate that the site has little topographic variation and the NWI map shows PFO1A (palustrine forested broad-leaved deciduous temporarily flooded) wetland areas within the section of forested that was examined as part of this wetland delineation. This wetland community was confirmed to be jurisdictional wetlands during the field findings.

3. Field Findings

- Vegetation

The field delineation revealed that the section of the subject project site to be delineated consists of a forested community with the following dominant vegetation: loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), greenbrier (*Smilax rotundifolia*), Virginia creeper (*Parthenocissus quinquefolia*), muscadine grape (*Vitis rotundifolia*), high bush blueberry (*Vaccinium corymbosum*), black gum (*Nyssa sylvatica*), giant cane (*Arundinaria gigantea*) American holly (*Ilex opaca*), Japanese honeysuckle (*Lonicera japonica*), yellow jasmine (*Gelseminium sempervirens*), and wax myrtle (*Morella cerifera*). The percent of dominant of species comprised from all strata that are considered to be hydrophytic vegetation ranged from 90 to 100 percent. Therefore, the composition of dominant vegetation within the delineated forested community meets the vegetation criteria of a wetland system according to the *Corps Manual.*

- Soils

According to the *Soil Survey of Johnston County, North Carolina,* the soils within that section of the subject project site to be delineated are listed and described as Pantego loam (occasionally flooded - Typic Endoquepts) which is a deep, nearly level, and poorly drained, hydric soil. Soil samples taken within that confirmed the presence hydric soils which measured a color ranging from 10YR2/1 to 10YR3/1. No mottles were present within the soil samples. Oxidized roots channels within the upper 12 inches of the soil surface and slight reducing conditions were observed within the soil samples. Soil samples with low chroma colors are considered hydric soils according to the *Corps Manual*; and therefore, meet the soil criteria of a wetland system.

- Hydrology

During the field investigations, primary and secondary indicators of wetland hydrology were observed within that section of the subject project site to be delineated. Primary indicators of wetland hydrology that were observed include: inundation, saturation, water marks, and drainage patterns. Secondary wetland hydrology indicators that were observed include: oxidized root channels, water stained leaves, and satisfying the FAC-neutral test. The presence of primary and secondary indicators of wetland hydrology within the forested community is evidence that the forested community is periodically inundated or has soils saturated to the surface at some time during the growing season; and therefore, meets the hydrology criteria of a wetland system according to the *Corps Manual.*

4. Wetlands Delineation

Based on the review of published information and field findings, the forested community section of the subject project site to be delineated has been determined to be jurisdictional wetlands. The boundary of the jurisdictional wetland was flagged and GPS located. The wetland system would be classified as a PFO1A headwater wetland system; and therefore, regulated under Section 404 of the Clean Water Act.

Currently, the jurisdictional wetland delineation has not been confirmed by the U.S. Army Corps of Engineers. If it is determined that a jurisdictional determination is required, I would be glad to assist.

Appendix B

Cultural and Natural Resources Correspondence

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 Cox Site; Johnston 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., Zoologist
Natural Heritage Program

HEL/hel

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 • FAX: 919-715-3060 • Internet: www.enr.state.nc.us

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

September 21, 2004

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

Re: Mitigation plan for stream and wetland restoration on Cox Farm, Johnston County, ER 04-2292

Dear Ms. Ricks:

Thank you for your letter of August 17, 2004, concerning the above project.

We have conducted a review of the project and are aware of no historic resources which would be affected by the project. Therefore, we have no comment on the project as proposed.

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, please 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 B. Sandbeck

PBS:w

Appendix C

EDR Transaction Screen Map Report

The EDR Radius Map™ Report
with ToxiCheck®

Cox Site
Westbrook Lowgrounds Rd
FOUR OAKS, NC 27524

Inquiry Number: 01291448.1r

October 20, 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

FORM-ERN

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Map Findings Summary ---- 5

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Orphan Summary ---- 8

Government Records Searched/Data Currency Tracking ---- GR-1

GEOCHECK ADDENDUM

GeoCheck - Not Requested

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

TOXICHECK®

Subject Property: COX SITE
WESTBROOK LOWGROUNDS RD
FOUR OAKS, NC 27524

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 an 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.

EXECUTIVE SUMMARY

A search of available environmental records was conducted by Environmental Data Resources, Inc. (EDR). The report meets the government records search requirements of ASTM Standard Practice for Environmental Site Assessments, E 1527-00. Search distances are per ASTM standard or custom distances requested by the user.

TARGET PROPERTY INFORMATION

ADDRESS

WESTBROOK LOWGROUNDS RD
FOUR OAKS, NC 27524

COORDINATES

Latitude (North):	35.352300 - 35˚ 21' 8.3"
Longitude (West):	78.276500 - 78˚ 16' 35.4"
Universal Tranverse Mercator:	Zone 17
UTM X (Meters):	747490.8
UTM Y (Meters):	3915319.2
Elevation:	94 ft. above sea level

USGS TOPOGRAPHIC MAP ASSOCIATED WITH TARGET PROPERTY

Target Property:	35078-C3 NEWTON GROVE NORTH, NC
Source:	USGS 7.5 min quad index

TARGET PROPERTY SEARCH RESULTS

The target property was not listed in any of the databases searched by EDR.

DATABASES WITH NO MAPPED SITES

No mapped sites were found in EDR's search of available ("reasonably ascertainable ") government records either on the target property or within the ASTM E 1527-00 search radius around the target property for the following databases:

FEDERAL ASTM STANDARD

NPL	National Priority List
Proposed NPL	Proposed National Priority List Sites
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERC-NFRAP	CERCLIS No Further Remedial Action Planned
CORRACTS	Corrective Action Report
RCRIS-TSD	Resource Conservation and Recovery Information System
RCRIS-LQG	Resource Conservation and Recovery Information System
RCRIS-SQG	Resource Conservation and Recovery Information System
ERNS	Emergency Response Notification System

STATE ASTM STANDARD

SHWS	Inactive Hazardous Sites Inventory

EXECUTIVE SUMMARY

SWF/LF	List of Solid Waste Facilities
LUST	Regional UST Database
UST	Petroleum Underground Storage Tank Database
OLI	Old Landfill Inventory
INDIAN UST	Underground Storage Tanks on Indian Land
INDIAN LUST	Leaking Underground Storage Tanks on Indian Land
VCP	Responsible Party Voluntary Action Sites

FEDERAL ASTM SUPPLEMENTAL

CONSENT	Superfund (CERCLA) Consent Decrees
ROD	Records Of Decision
Delisted NPL	National Priority List Deletions
FINDS	Facility Index System/Facility Identification Initiative Program Summary Report
HMIRS	Hazardous Materials Information Reporting System
MLTS	Material Licensing Tracking System
MINES	Mines Master Index File
NPL Liens	Federal Superfund Liens
PADS	PCB Activity Database System
ODI	Open Dump Inventory
UMTRA	Uranium Mill Tailings Sites
FUDS	Formerly Used Defense Sites
INDIAN RESERV	Indian Reservations
DOD	Department of Defense Sites
RAATS	RCRA Administrative Action Tracking System
TRIS	Toxic Chemical Release Inventory System
TSCA	Toxic Substances Control Act
SSTS	Section 7 Tracking Systems
FTTS INSP	FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)

STATE OR LOCAL ASTM SUPPLEMENTAL

NC HSDS	Hazardous Substance Disposal Site
AST	AST Database
LUST TRUST	State Trust Fund Database
DRYCLEANERS	Drycleaning Sites
IMD	Incident Management Database

EDR PROPRIETARY HISTORICAL DATABASES

Coal Gas	Former Manufactured Gas (Coal Gas) Sites

BROWNFIELDS DATABASES

US BROWNFIELDS	A Listing of Brownfields Sites
Brownfields	Brownfields Projects Inventory
INST CONTROL	No Further Action Sites With Land Use Restrictions Monitoring
VCP	Responsible Party Voluntary Action Sites

SURROUNDING SITES: SEARCH RESULTS

Surrounding sites were not identified.

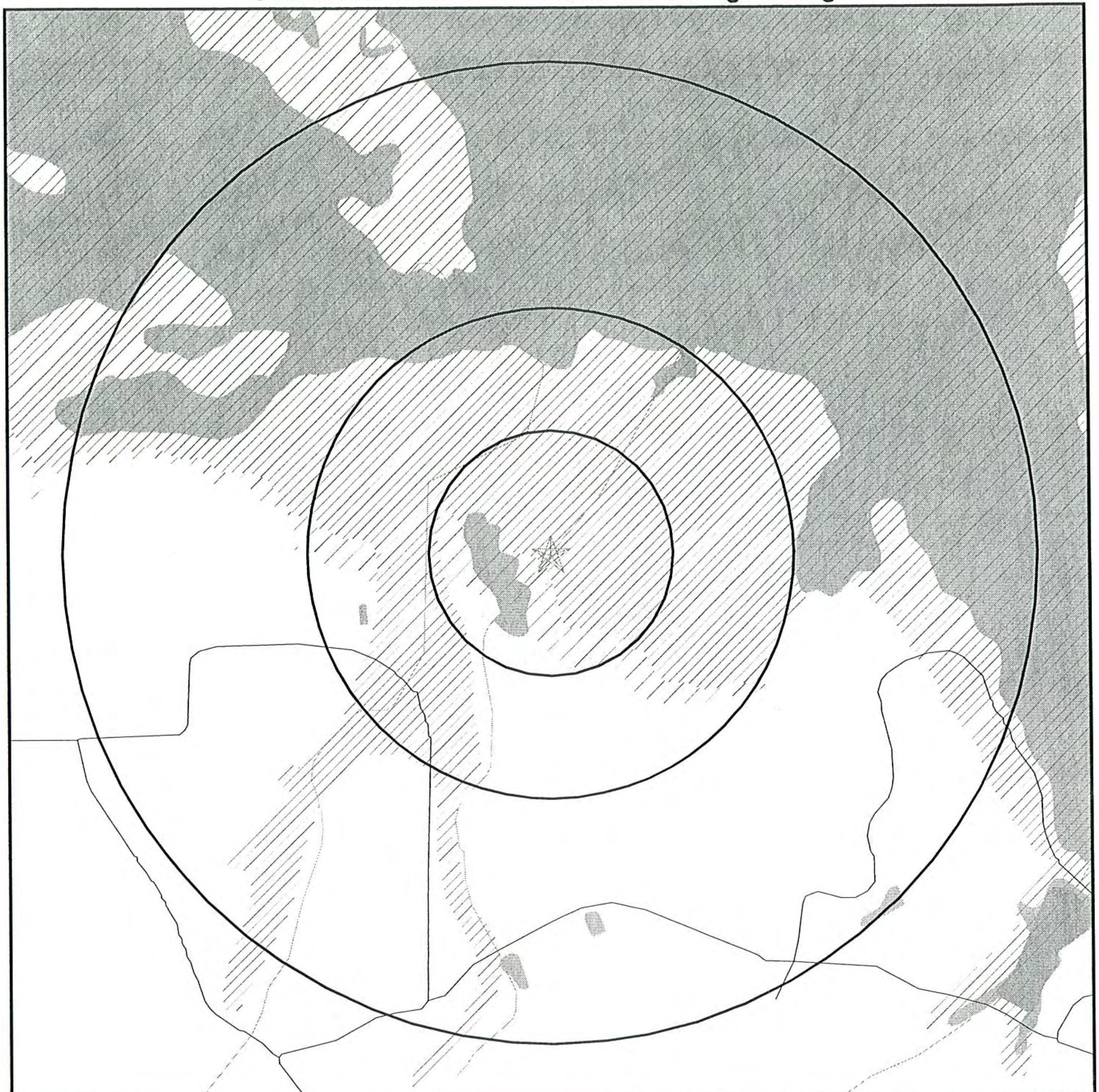
Unmappable (orphan) sites are not considered in the foregoing analysis.

EXECUTIVE SUMMARY

Due to poor or inadequate address information, the following sites were not mapped:

Site Name	Database(s)
NORRIS GAS & GROCERY	IMD, LUST
HOLTS LAKE LIFT STATION	IMD, LUST
KING BUILDING	IMD, LUST
CLOVERLEAF GULF SVC	IMD, LUST, UST
MCLAMBS AMOCO	IMD, LUST, UST, LUST TRUST
WALLENS RES./M.J. ALLEN STORE	IMD, LUST
BEASLEYS STORE	IMD, LUST
MARLER PROPERTY - AMOCO 539	IMD, LUST
HANSLEY HANDI MART	IMD, LUST
NORRIS GAS & GROCERY	UST, LUST TRUST
BEASLEY'S STORE	LUST TRUST
ELDRIDGE GENERAL MERCHANDISE	LUST TRUST
BENTONVILLE BATTLEGROUND HST	UST
ALSTON R BAREFOOT	UST
MILLER'S GROC	UST
BEASLEY'S STORE	UST
JIFF MART 2	UST
COUNTRY STORE	UST
SOUTH JOHNSTON HIGH SCHOOL	UST
PAUL'S RESTAURANT	UST
BAKER'S GAS & GROCERY	UST
TRADE MART 108	UST
JOHNSON & ELDRIDGE GROC	UST
701 GULF SER	UST
SOUTHERN STATES	UST
C & C SUNOCO	UST

OVERVIEW MAP - 01291448.1r - Buck Engineering

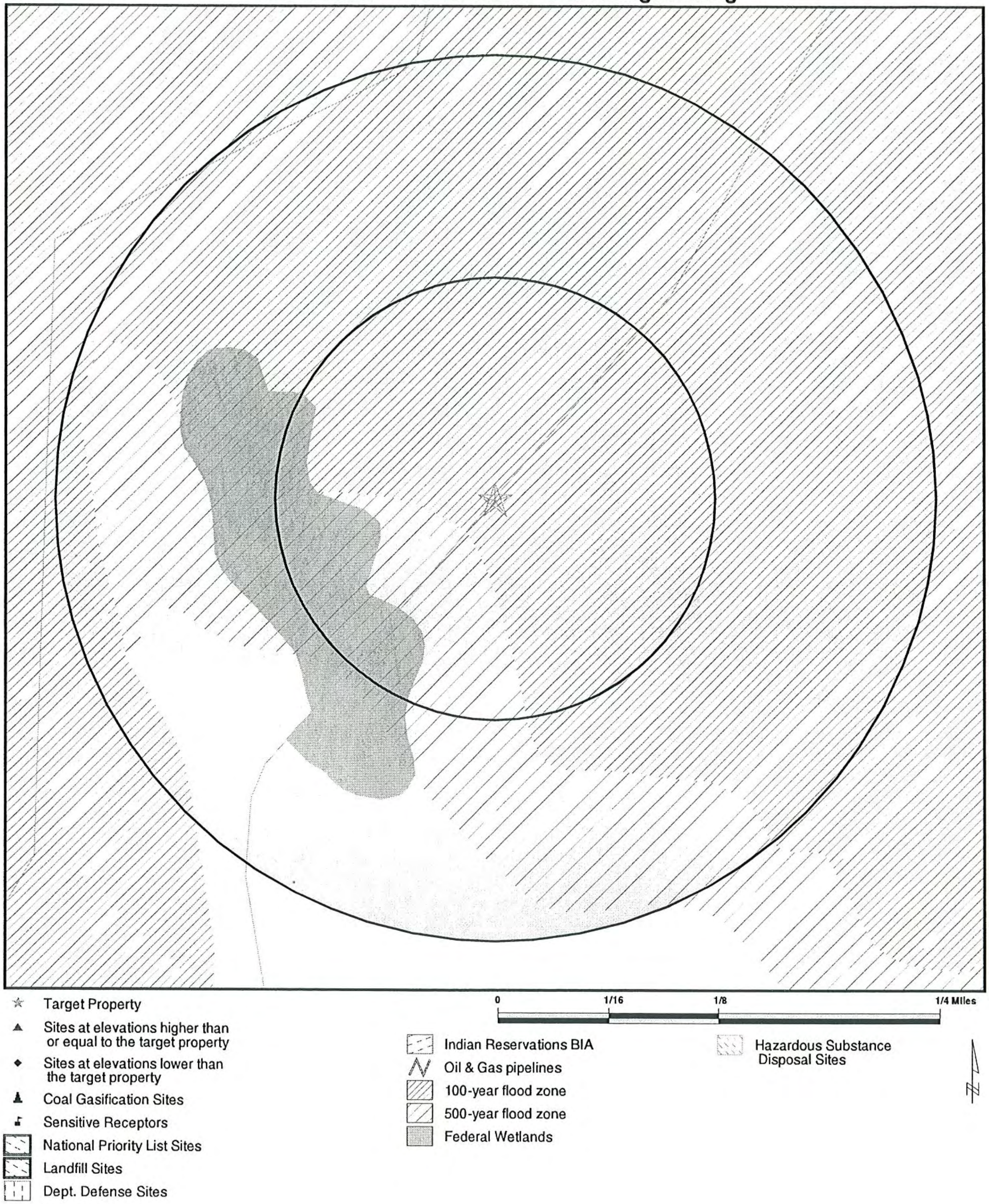


0 | 1/4 | 1/2 | 1 Miles

- 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
- Oil & Gas pipelines
- 100-year flood zone
- 500-year flood zone
- Federal Wetlands
- Hazardous Substance Disposal Sites

TARGET PROPERTY:	Cox Site	CUSTOMER:	Buck Engineering
ADDRESS:	Westbrook Lowgrounds Rd	CONTACT:	Jessica Rohrach
CITY/STATE/ZIP:	FOUR OAKS NC 27524	INQUIRY #:	01291448.1r
LAT/LONG:	35.3523 / 78.2765	DATE:	October 20, 2004 9:58 am

DETAIL MAP - 01291448.1r - Buck Engineering



TARGET PROPERTY:	Cox Site	CUSTOMER:	Buck Engineering
ADDRESS:	Westbrook Lowgrounds Rd	CONTACT:	Jessica Rohrach
CITY/STATE/ZIP:	FOUR OAKS NC 27524	INQUIRY #:	01291448.1r
LAT/LONG:	35.3523 / 78.2765	DATE:	October 20, 2004 9:58 am

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
INDIAN LUST		0.500	0	0	0	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0
FEDERAL ASTM SUPPLEMENTAL								
CONSENT		1.000	0	0	0	0	NR	0
ROD		1.000	0	0	0	0	NR	0
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		0.250	0	0	NR	NR	NR	0
NPL Liens		TP	NR	NR	NR	NR	NR	0
PADS		TP	NR	NR	NR	NR	NR	0
ODI		0.500	0	0	0	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
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

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
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
IMD		0.500	0	0	0	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 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)
FOUR OAKS	U001437976	BENTONVILLE BATTLEGROUND HST	ROUTE 1	27524	UST
FOUR OAKS	U001439794	ALSTON R BAREFOOT	ROUTE 1, BOX 41B	27524	UST
FOUR OAKS	U001438570	NORRIS GAS & GROCERY	ROUTE 2 BOX 175A	27524	UST, LUST TRUST
FOUR OAKS	S105763870	NORRIS GAS & GROCERY	RT. 2, BOX 175A	27524	IMD, LUST
FOUR OAKS	S105218775	BEASLEY'S STORE	HIGHWAY 210	27524	LUST TRUST
FOUR OAKS	U001436377	MILLER'S GROC	RT 3	27524	UST
FOUR OAKS	U001436379	BEASLEY'S STORE	RT 3 BENSON	27524	UST
FOUR OAKS	U001436616	JIFF MART 2	ROUTE 3, BOX 472/HWY. 301 SOUTH	27524	UST
FOUR OAKS	U003144548	COUNTRY STORE	ROUTE 3, BOX 44-E	27524	UST
FOUR OAKS	S104914451	HOLTS LAKE LIFT STATION	HWY 301 SOUTH	27524	IMD, LUST
FOUR OAKS	S105763864	KING BUILDING	HWY 301 SOUTH	27524	IMD, LUST
FOUR OAKS	U001434600	CLOVERLEAF GULF SVC	HIGHWAY 301 NORTH	27524	IMD, LUST, UST
FOUR OAKS	U001436318	MCLAMBS AMOCO	201 HWY 301 S	27524	IMD, LUST, UST, LUST TRUST
FOUR OAKS	U001436403	SOUTH JOHNSTON HIGH SCHOOL	HWY. 301 SOUTH ROUTE 3	27524	UST
FOUR OAKS	U001439629	PAUL'S RESTAURANT	HWY 301 NORTH	27524	UST
FOUR OAKS	U003146156	BAKER'S GAS & GROCERY	HIGHWAY 301 NORTH / ROUTE 4	27524	UST
FOUR OAKS	U003914045	TRADE MART 108	HWY 301 NORTH	27524	UST
FOUR OAKS	U001436375	JOHNSON & ELDRIDGE GROC	RT 4 BLACKMANS X RD	27524	UST
FOUR OAKS	S102001170	ELDRIDGE GENERAL MERCHANDISE	ROUTE 4, BLACKMAN'S CROSSROADS	27524	LUST TRUST
FOUR OAKS	U001436376	701 GULF SER	HWY 701 E	27524	UST
FOUR OAKS	S105764358	WALLENS RES./M.J. ALLEN STORE	3000 BLOCK OF NC RT. 96	27524	IMD, LUST
FOUR OAKS	U003144409	SOUTHERN STATES	PO BOX 700/HWY 301 N	27524	UST
FOUR OAKS	S105764352	BEASLEYS STORE	11268 NC HWY 210	27524	IMD, LUST
FOUR OAKS	S105764318	MARLER PROPERTY - AMOCO 539	US I-95 AT NC HWY 701	27524	IMD, LUST
FOUR OAKS	S102554460	HANSLEY HANDI MART	I-95 SOUTH / SR 1178 (ADAMS ST	27524	IMD, LUST
GOLDSBORO	U001187604	C & C SUNOCO	HWY 117 SO - RTE 12 BOX 489	27524	UST

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: 07/30/04
Date Made Active at EDR: 09/09/04
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 08/03/04
Elapsed ASTM days: 37
Date of Last EDR Contact: 08/03/04

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: 07/22/04
Date Made Active at EDR: 09/09/04
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 08/03/04
Elapsed ASTM days: 37
Date of Last EDR Contact: 08/03/04

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: 09/21/04

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: 09/21/04

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: 09/07/04

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: 08/10/04
Date Made Active at EDR: 10/11/04
Database Release Frequency: Varies

Date of Data Arrival at EDR: 08/24/04
Elapsed ASTM days: 48
Date of Last EDR Contact: 08/24/04

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: 09/20/04
Date of Next Scheduled EDR Contact: 12/13/04

CONSENT: Superfund (CERCLA) Consent Decrees
Source: Department of Justice, Consent Decree Library
Telephone: Varies
Major legal settlements that establish responsibility and standards for cleanup at NPL (Superfund) sites. Released periodically by United States District Courts after settlement by parties to litigation matters.

Date of Government Version: 03/05/04
Database Release Frequency: Varies

Date of Last EDR Contact: 07/30/04
Date of Next Scheduled EDR Contact: 10/25/04

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

ROD: Records Of Decision
Source: EPA
Telephone: 703-416-0223
Record of Decision. ROD documents mandate a permanent remedy at an NPL (Superfund) site containing technical and health information to aid in the cleanup.

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

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: 07/30/04
Database Release Frequency: Quarterly
Date of Last EDR Contact: 08/03/04
Date of Next Scheduled EDR Contact: 11/01/04

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: 07/15/04
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: 06/04/04
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 09/28/04
Date of Next Scheduled EDR Contact: 12/27/04

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: 08/23/04
Date of Next Scheduled EDR Contact: 11/22/04

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: 06/29/04
Database Release Frequency: Annually

Date of Last EDR Contact: 08/10/04
Date of Next Scheduled EDR Contact: 11/08/04

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: 08/12/04
Date of Next Scheduled EDR Contact: 11/08/04

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: 08/12/04
Date of Next Scheduled EDR Contact: 11/08/04

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: 12/31/03
Database Release Frequency: Varies

Date of Last EDR Contact: 07/06/04
Date of Next Scheduled EDR Contact: 10/04/04

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: 02/04/04
Database Release Frequency: Quarterly

Date of Last EDR Contact: 07/06/04
Date of Next Scheduled EDR Contact: 10/04/04

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: 05/27/04
Database Release Frequency: Varies

Date of Last EDR Contact: 08/23/04
Date of Next Scheduled EDR Contact: 11/22/04

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: 09/20/04
Date of Next Scheduled EDR Contact: 12/20/04

ODI: Open Dump Inventory
Source: Environmental Protection Agency
Telephone: 800-424-9346
An open dump is defined as a disposal facility that does not comply with one or more of the Part 257 or Part 258 Subtitle D Criteria.

Date of Government Version: 06/30/85
Database Release Frequency: No Update Planned

Date of Last EDR Contact: 05/23/95
Date of Next Scheduled EDR Contact: N/A

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: 09/07/04
Date of Next Scheduled EDR Contact: 12/06/04

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: 12/31/02
Database Release Frequency: Annually

Date of Last EDR Contact: 09/20/04
Date of Next Scheduled EDR Contact: 12/20/04

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: 09/07/04
Date of Next Scheduled EDR Contact: 12/06/04

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: 09/07/04
Date of Next Scheduled EDR Contact: 12/20/04

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: 09/07/04
Date of Next Scheduled EDR Contact: 12/20/04

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: 08/25/04
Date Made Active at EDR: 10/18/04
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 09/20/04
Elapsed ASTM days: 28
Date of Last EDR Contact: 10/13/04

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: 07/27/04
Date Made Active at EDR: 08/31/04
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 07/27/04
Elapsed ASTM days: 35
Date of Last EDR Contact: 07/26/04

LUST: Regional UST Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1308
This database contains information obtained from the Regional Offices. It provides a more detailed explanation of current and historic activity for individual sites, as well as what was previously found in the Incident Management Database. Sites in this database with Incident Numbers are considered LUSTs.

Date of Government Version: 09/03/04
Date Made Active at EDR: 10/06/04
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 09/08/04
Elapsed ASTM days: 28
Date of Last EDR Contact: 09/08/04

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: 08/27/04
Date Made Active at EDR: 10/07/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 09/08/04
Elapsed ASTM days: 29
Date of Last EDR Contact: 09/08/04

OLI: Old Landfill Inventory
Source: Department of Environment & Natural Resources
Telephone: 919-733-4996
Old landfill inventory location information. (Does not include no further action sites and other agency lead sites).

Date of Government Version: 08/25/04
Date Made Active at EDR: 10/06/04
Database Release Frequency: Varies
Date of Data Arrival at EDR: 08/26/04
Elapsed ASTM days: 41
Date of Last EDR Contact: 08/25/04

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: 09/14/04
Date Made Active at EDR: 10/18/04
Database Release Frequency: Varies
Date of Data Arrival at EDR: 09/15/04
Elapsed ASTM days: 33
Date of Last EDR Contact: 08/23/04

INDIAN LUST: Leaking Underground Storage Tanks on Indian Land
Source: EPA Region 4
Telephone: 404-562-8677
LUSTs on Indian land in Florida, Minnesota, Mississippi and North Carolina.

Date of Government Version: 09/14/04
Date Made Active at EDR: 10/18/04
Database Release Frequency: Varies
Date of Data Arrival at EDR: 09/15/04
Elapsed ASTM days: 33
Date of Last EDR Contact: 09/07/04

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: 08/30/04
Date of Next Scheduled EDR Contact: 11/29/04

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: 08/06/04
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 08/10/04
Date of Next Scheduled EDR Contact: 11/08/04

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: 06/15/04
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.

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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: 03/31/04
Database Release Frequency: Varies

Date of Last EDR Contact: 08/03/04
Date of Next Scheduled EDR Contact: 11/01/04

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.

Oil/Gas Pipelines: This data was obtained by EDR from the USGS in 1994. It is referred to by USGS as GeoData Digital Line Graphs from 1:100,000-Scale Maps. It was extracted from the transportation category including some oil, but primarily gas pipelines.

Electric Power Transmission Line Data
Source: PennWell Corporation
Telephone: (800) 823-6277
This map includes information copyrighted by PennWell Corporation. This information is provided on a best effort basis and PennWell Corporation does not guarantee its accuracy nor warrant its fitness for any particular purpose. Such information has been reprinted with the permission of PennWell.

Sensitive Receptors: There are individuals deemed sensitive receptors due to their fragile immune systems and special sensitivity to environmental discharges. These sensitive receptors typically include the elderly, the sick, and children. While the location of all sensitive receptors cannot be determined, EDR indicates those buildings and facilities - schools, daycares, hospitals, medical centers, and nursing homes - where individuals who are sensitive receptors are likely to be located.

AHA Hospitals:
Source: American Hospital Association, Inc.
Telephone: 312-280-5991
The database includes a listing of hospitals based on the American Hospital Association's annual survey of hospitals.

Medical Centers: Provider of Services Listing
Source: Centers for Medicare & Medicaid Services
Telephone: 410-786-3000
A listing of hospitals with Medicare provider number, produced by Centers of Medicare & Medicaid Services, a federal agency within the U.S. Department of Health and Human Services.

Nursing Homes
Source: National Institutes of Health
Telephone: 301-594-6248
Information on Medicare and Medicaid certified nursing homes in the United States.

Public Schools
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on elementary and secondary public education in the United States. It is a comprehensive, annual, national statistical database of all public elementary and secondary schools and school districts, which contains data that are comparable across all states.

Private Schools
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on private school locations in the United States.

Daycare Centers: Child Care Facility List
Source: Department of Health & Human Services
Telephone: 919-662-4499

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

Appendix D

DRAINMOD Input Data

DRAINMOD .GEN File Used to Simulate the Existing Hydrology at Well 1.

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*** Job Title ***
EBX Westbrook Lowgrounds Mitigation Site - Well 1 Existing Condition Simulations
Smithfield Weather Data - Jan 1970 to Early February 2002
*** Printout and Input Control ***
 3 101 C:\Drainmod\outputs
*** Climate ***
100000 L:\PROJECTS\043. EBX-WESTBROOK\DRAINMOD\SMITHFIELD_1970-2002.RAI
100000 L:\PROJECTS\043. EBX-WESTBROOK\DRAINMOD\SMITHFIELD_1970-2002.TEM
1970  1 2002  2 3530  77 0
 2.01 2.32 2.10 1.72 1.23 1.00  .86  .82  .92 1.05 1.22 1.44
*** Drainage System Design ***
 1    .00
    116.00     66.57  13420.00       .70       2.50       .50       6.98      20.00
           0     2.000000E-02    10000.000000
           0       130.000000       10.000000     1.000000E-03
           0     0.000000E+00    0.000000E+00     0.000000E+00    0.000000E+00
    120.00      1.00       .00
 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120
*** Soils ***
    183.00     10.00
  10. 2.00  45. 2.00  70.10.00 140.15.00 183.15.00
99     .00
*** Trafficability ***
 4 1 5 1 820             3.9        1.2        2.0
12321232 820             3.9        1.2        2.0
*** Crop ***
      .190
 410 818        30.00
 410 818
11
 1 1  3.00 416  3.00 5 4  4.00 517 15.00 6 1 25.00 620 30.00 718 30.00 820 20.00
 924 10.00 925  3.001231  3.00
*** Wastewater Irrigation ***
 0    1 1  10   1  6
 0 0        0 0        0 0        0 0
   7.00000   1.00000  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
WET *** Wetlands Information ***
 1
  81 304
 30.0  27
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) ***
    1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00
MRA *** Monthly Ranking ***
 0
FAC *** Daily PET Factors ***
 0
```

DRAINMOD .GEN File Used to Simulate the Existing Hydrology at Well 2.

```
*** Job Title ***
EBX Westbrook Lowgrounds Mitigation Site - Well 2 Existing Condition Simulations
Smithfield Weather Data - Jan 1970 to Early February 2002
*** Printout and Input Control ***
 3 101 C:\DRAINMOD\outputs
*** Climate ***
100000 L:\PROJECTS\043. EBX-WESTBROOK\DRAINMOD\SMITHFIELD_1970-2002.RAI
100000 L:\PROJECTS\043. EBX-WESTBROOK\DRAINMOD\SMITHFIELD_1970-2002.TEM
2001  1 2002  2 3530  77 0
 2.01 2.32 2.10 1.72 1.23 1.00  .86  .82  .92 1.05 1.22 1.44
*** Drainage System Design ***
 1     .00
    116.00      95.49   8500.00        .70      2.50        .50      6.73     20.00
           0     2.000000E-02    10000.000000
           0       130.000000       10.000000     1.000000E-03
           0     0.000000E+00    0.000000E+00     0.000000E+00    0.000000E+00
    120.00       1.00       .00
 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120
*** Soils ***
    214.00     10.00
  10. 2.00  45. 2.00  70.10.00 140.15.00 183.15.00
99     .00
*** Trafficability ***
 4 1 5 1 820              3.9       1.2       2.0
12321232 820              3.9       1.2       2.0
*** Crop ***
      .190
 410 818       30.00
 410 818
11
 1 1  3.00 416  3.00 5 4  4.00 517 15.00 6 1 25.00 620 30.00 718 30.00 820 20.00
 924 10.00 925  3.001231  3.00
*** Wastewater Irrigation ***
 0    1 1  10   1  6
 0 0       0 0      0 0      0 0
   7.00000   1.00000  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
WET *** Wetlands Information ***
 1
  81 304
 30.0  27
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
FPE *** Fixed Avg Daily PET for the month(cm) ***
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
MRA *** Monthly Ranking ***
 0
FAC *** Daily PET Factors ***
```

DRAINMOD .GEN File Used to Simulate the Existing Hydrology at Well 3.

```
*** Job Title ***
EBX Westbrook Lowgrounds Mitigation Site - Well 3 Existing Condition Simulations
Smithfield Weather Data - Jan 1970 to Early February
*** Printout and Input Control ***
 3 101 C:\DRAINMOD\outputs
*** Climate ***
100000 L:\PROJECTS\043. EBX-WESTBROOK\DRAINMOD\SMITHFIELD_1970-2002.RAI
100000 L:\PROJECTS\043. EBX-WESTBROOK\DRAINMOD\SMITHFIELD_1970-2002.TEM
2001  1 2002  2 3530  77 0
 2.01 2.32 2.10 1.72 1.23 1.00  .86  .82  .92 1.05 1.22 1.44
*** Drainage System Design ***
 1    .00
    120.00      62.66  13420.00        .70      2.50       .50      7.13     20.00
           0    2.000000E-02    10000.000000
           0     130.000000       10.000000     1.000000E-03
           0    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00
    120.00       1.00       .00
 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120
*** Soils ***
    183.00      10.00
  10. 2.00  45. 2.00  70.20.00 140.25.00 183.25.00
99     .00
*** Trafficability ***
 4 1 5 1 820             3.9       1.2       2.0
12321232 820             3.9       1.2       2.0
*** Crop ***
     .190
 410 818        30.00
 410 818
11
 1 1  3.00 416  3.00 5 4  4.00 517 15.00 6 1 25.00 620 30.00 718 30.00 820 20.00
 924 10.00 925  3.001231  3.00
*** Wastewater Irrigation ***
 0    1 1  10   1  6
 0 0       0 0       0 0       0 0
   7.00000   1.00000  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
WET *** Wetlands Information ***
 1
  81 304
 30.0  27
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
 0  0  0    .0
FPE *** Fixed Avg Daily PET for the month(cm) ***
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
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
```

DRAINMOD .GEN File Used to Simulate the Proposed Restoration Hydrology.

```
*** Job Title ***
EBX Westbrook Lowgrounds Mitigation Site - Design, 250 ft from stream
Smithfield Weather Data - Jan 1970 to Mid October 2001
*** Printout and Input Control ***
 3 101 C:\DRAINMOD\outputs
*** Climate ***
100000 C:\DRAINMOD\WEATHER\SMITHFIELD_1970-2002.RAI
100000 C:\DRAINMOD\WEATHER\SMITHFIELD_1970-2002.TEM
2000  1 2001 12 3530  77 0
 2.01 2.32 2.10 1.72 1.23 1.00  .86  .82  .92 1.05 1.22 1.44
*** Drainage System Design ***
 1    .00
     40.00    136.49  15000.00       4.00       2.50       4.00       5.49      20.00
          0     2.000000E-02    10000.000000
          0       130.000000       10.000000     1.000000E-03
          1        12.000000      150.000000     7500.000000         2.000000
    120.00      1.00       .00
 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120 1120
*** Soils ***
    183.00      5.00
  10. 2.00  45. 2.00  70.25.00 140.30.00 183.30.00
99     .00
*** Trafficability ***
 4 1 5 1 820               3.9       1.2       2.0
12321232 820               3.9       1.2       2.0
*** Crop ***
      .190
 410 818       30.00
 410 818
11
 1 1  3.00 416  3.00 5 4  4.00 517 15.00 6 1 25.00 620 30.00 718 30.00 820 20.00
 924 10.00 925  3.001231  3.00
*** Wastewater Irrigation ***
 0    1 1  10   1  6
 0 0       0 0       0 0       0 0
   7.00000   1.00000  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
WET *** Wetlands Information ***
 1
  76 309
 30.0  29
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) ***
    1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00
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
```

Appendix E

Westbrook Hydrology Analysis

This Appendix is copied directly from the Westbrook Lowgrounds Wetland and Stream Mitigation Project Mitigation Plan, December 2002 and details a complete record of the pre-restoration wetland analyses performed on the Westbrook site.

2.4 Site Hydrology

The presence of hydric soils over much of the project site is evidence that the site historically supported a wetland ecosystem. As is the case in much of the Coastal Plain and lower Piedmont of North Carolina, local drainage patterns have been altered over the last two centuries to increase drainage and promote agricultural production. The main stream through the site, Johannah Creek, has been channelized and straightened to provide drainage for agricultural crops. The stream experiences intermittent flow, with continuous flow during the fall, winter, and spring months. The drainage area of the stream at the outlet of the project area is approximately 1.18 square miles.

Several lateral ditches on the west side of the site come together and drain into Johannah Creek. These ditches receive some surface runoff from adjacent woodland, but flow in the laterals appears to be limited to ephemeral surface runoff. Based on topography information, the ditches intercept surface runoff and shallow subsurface flow from most of the southwestern corner of the project site.

During June 2001, three water table monitoring wells were installed and maintained by Wetland and Natural Resource Consultants, Inc. to monitor water table depth on the project site. The wells were located in areas where hydrology would likely be affected by restoration efforts to provide a base for comparing pre- and post-restoration hydrology. Water table data were collected from June 2001 through February 2002 with hydrographs shown in Figure 2.3.

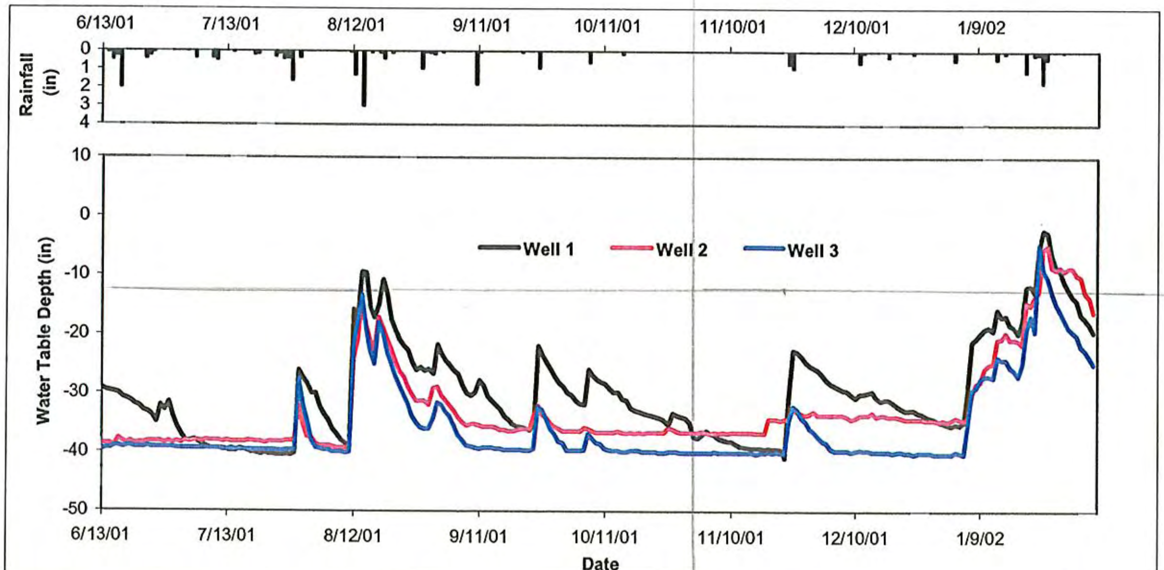


Figure 2-3 Water table data for three monitoring wells located on the project property.

Rainfall data were collected for the monitoring period to correlate climatic conditions with water table hydrology. Rainfall data were obtained from the Smithfield WETS Station. Monthly precipitation amounts from July 2001 through January 2002 are compared with average monthly rainfall (NRCS WETS data) in Table 2.1.

Well data from the project site were analyzed to determine the current hydrologic state of the site. Data were used to determine 1) the longest number of days with the water table less than 12 inches deep during the partial growing season, 2) the number of times that the water table was less than 12 inches deep for at least one day during the partial growing season, 3) the longest number of days with the water table less than 12 inches deep during the entire monitoring period, and 4) the number of times that the water table was less than 12 inches deep for at least 1 day during the entire monitoring period. Calculated values are presented in Table 2.2.

The growing season for Johnston County is 232 days long, beginning on March 17 and ending November 5, according to NRCS WETS data for Johnston County. For the period of monitoring data available, the longest consecutive number of days with the water table less than 12 inches deep during the partial growing season was 2 days (Well #1, 8/14/01 to 8/15/01 or roughly 1% of the partial growing season). This would indicate that the current hydrologic state of the project site is drier than would be expected for a site meeting jurisdictional wetland hydrology requirements. However, drier than average conditions were experienced over much of the monitoring period. To further examine the existing hydrologic condition of the site, simulation models were developed to describe the existing hydrologic condition of the project site.

Table 2-1 Comparison between monthly rainfall amounts for the project site and the long-term average.

Month/Year	Observed Monthly Precipitation (in)	Average Monthly Precipitation (in)	Deviation of Observed from Average
July 2001	5.01	5.47	-0.46
August 2001	6.27	4.48	1.79
September 2001	2.87	4.06	-1.19
October 2001	0.76	3.11	-2.35
November 2001	1.62	3.04	-1.42
December 2001	1.03	3.21	-2.18
January 2002	4.58	3.96	0.62
Overall	**22.14**	**27.33**	**-5.19**

Table 2-2 Hydrologic parameters observed for the project site.

Well	Longest consecutive number of days with WT < 12 inches deep from 6/13/01 through 11/5/01 (partial growing season)	Total number of days with WT < 12 inches deep from 6/13/01 through 11/5/01 (partial growing season)	Longest consecutive number of days with WT < 12 inches deep from 6/13/01 through 2/6/02 (entire period of record)	Total number of days with WT < 12 inches deep from 6/13/01 through 2/6/02 (entire period of record)
Well #1	2	3	7	12
Well #2	0	0	10	10
Well #3	0	0	3	3

2.5 Hydrologic Modeling

To further investigate the current hydrologic status of the site and provide a means for evaluating proposed restoration plans, hydrologic models were developed to simulate site hydrology. DRAINMOD v.5.1 was used to develop three (3) hydrologic simulation models to represent conditions at the locations of the three (3) monitoring wells. DRAINMOD is identified as an approved hydrologic tool for assessing wetland hydrology by the US Department of Agriculture (USDA), Natural Resources Conservation Service (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 Smithfield WETS Station. Field measured 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. Results of model simulations are compared with observed data in Figures 2.4 through 2.6. Model inputs are presented in Appendix 2.

Trends in the observed data are well represented by the model simulations. Although hydrograph peaks between observed and simulated data do not match exactly, relative changes in water table hydrology as a result of precipitation events correspond well between observed and modeled data. As noted above, rainfall data was collected from the nearest automated weather station, located in Smithfield, NC. Most of the differences between observed and modeled hydrographs can be explained by the spatial variability of rainfall patterns between the location of the weather station and the project site.

To estimate existing long-term site hydrology, model simulations were run for 30 years using weather data from the Smithfield WETS station. DRAINMOD computes daily water balance information and outputs summaries that describe the loss pathways for rainfall over the model simulation period. Table 2.3 summarizes the average annual amount of rainfall, infiltration, drainage, runoff, and evapotranspiration estimated for the existing condition of the project site. 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 via drainage and runoff to the field ditches. Restoration of the site will involve restoring the stream through the site and increasing the amount of surface storage available to pond water. In this way, the respective amounts of drainage and runoff are decreased. The excess water storage will allow the water table to remain higher throughout the year, thus restoring wetland hydrology.

Table 2-3 Water balance for the existing condition of the project site.

Hydrologic Parameter	Average Annual Amount over 30 Year Simulation Period (cm of water)	Average Annual Amount over 30 Year Simulation Period (% of rainfall)
Drainage	37.40	31.3
Runoff	12.48	10.5
Evapotranspiration	69.57	58.3
Precipitation	119.32	100.0

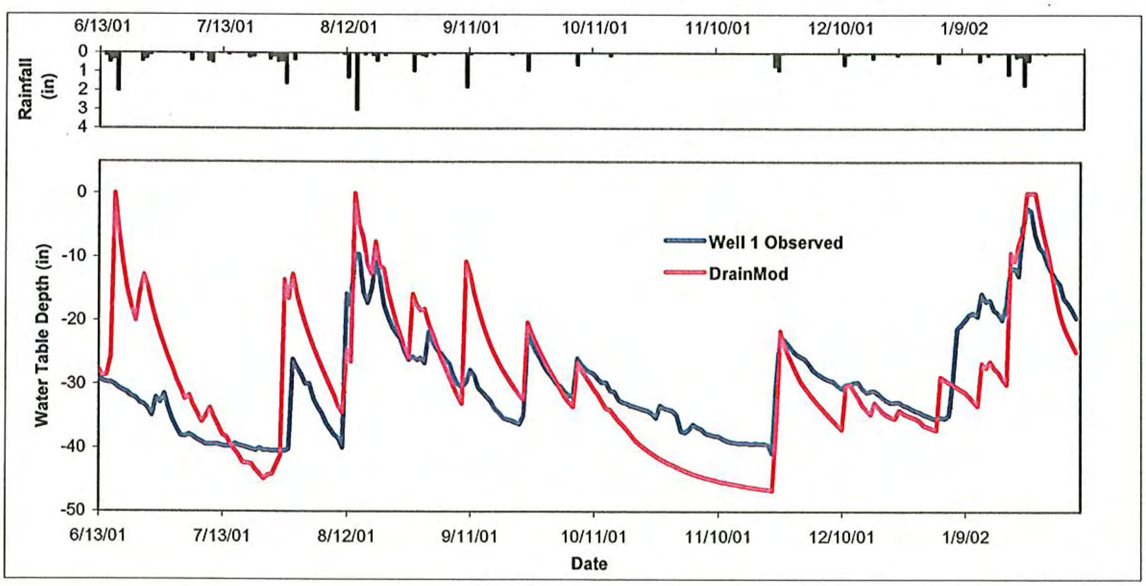


Figure 2-4 Comparison between observed and simulated water table depths for Well 1 for existing condition.

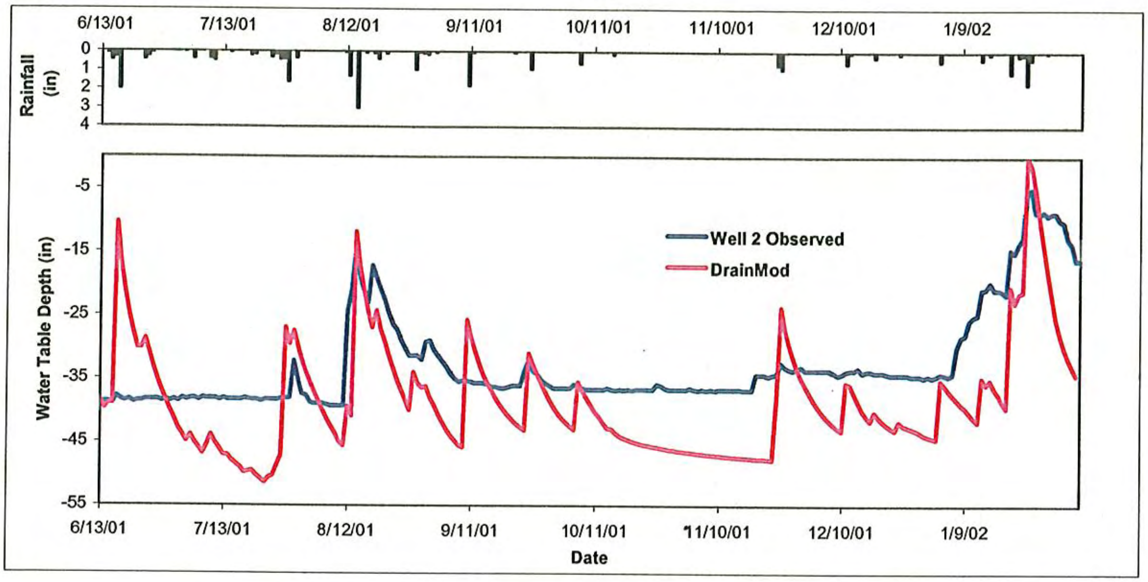


Figure 2-5 Comparison between observed and simulated water table depths for Well 2 for existing condition.

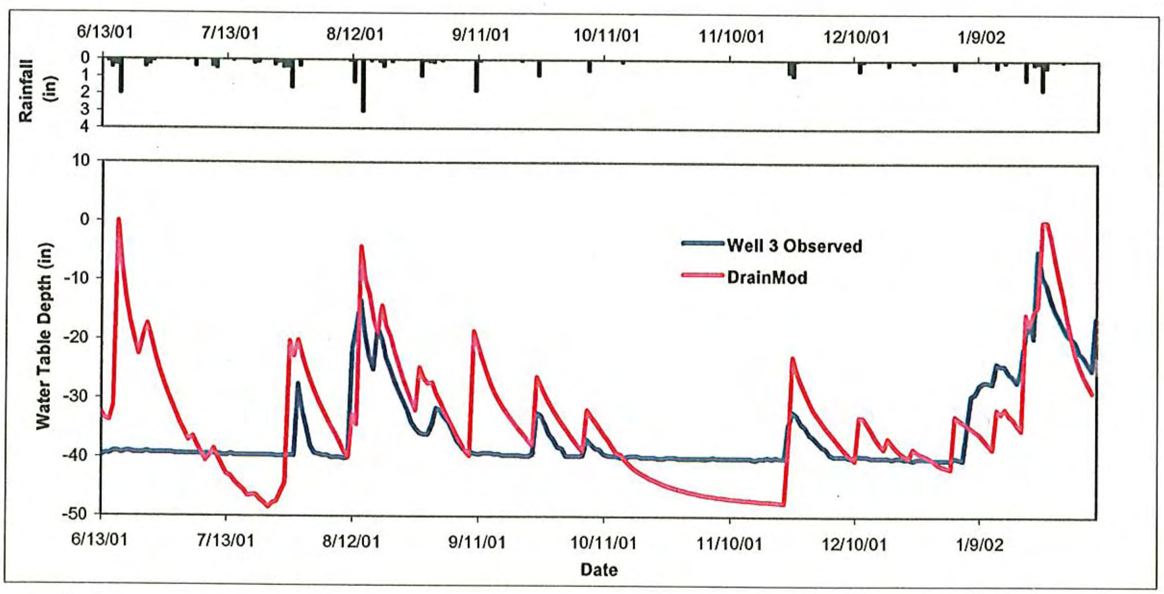


Figure 2-6 Comparison between observed and simulated water table depths for Well 3 for existing condition.

Appendix F

Benthic Macroinvertebrate Data

Benthos Data for Cox Site Project Collected on December 13, 2004

SPECIES	Tolerance Value	Functional Feeding Group	Site 1 Project Reach	Site 2 Reference Reach
MOLLUSCA				
Gastropoda				
Physidae				
Physella spp.	**8.8**	**CG**	**R**	**R**
ANNELIDA				
Oligochaeta				
Megadrile	**9.0**	**CG**		**R**
ARTHROPODA				
Crustacea				
Amphipoda				
Talitridae				
Hyallela azteca	**7.8**	**CG**		**R**
Decapoda				
Cambaridae		**OM**	**C**	**C**
Insecta				
Ephemeroptera				
Heptageniidae				
Stenonema modestum	**5.5**	**SC**	**A**	**A**
Leptophlebiidae				
Leptophlebia spp.	**6.2**	**CG**		**R**
Plecoptera				
Capniidae				
Allocapnia spp.	**2.5**	**SH**	**C**	**C**
Perlodidae				
Clioperla clio	**4.7**	**PR**	**A**	**A**
Isoperla bilineata	**5.4**	**PR**	**R**	**A**
Taeniopterygidae				
Taeniopteryx sp.	**5.4**	**SH**		**R**
Trichoptera				
Hydropsychidae				
Cheumatopsyche sp.	**6.2**	**FC**	**A**	**A**
Hydropsyche betteni	**7.8**	**FC**	**R**	
Limnephilidae				
Pycnopsyche spp.	**2.5**	**SH**	**C**	**A**
Odonata				
Aeshnidae				
Boyeria vinosa	**5.9**	**PR**		**C**
Calopterygidae				
Calopteryx spp.	**7.8**	**PR**	**C**	**A**
Cordulegastridae				
Cordulegaster spp.	**5.7**	**PR**		**R**

SPECIES	Tolerance Value	Functional Feeding Group	Site 1 Project Reach	Site 2 Reference Reach
Gomphidae				
Gomphus spp.	5.8	PR	R	R
Progomphus obscurus	8.2	PR	A	A
Coleoptera				
Dryopidae				
Helichus spp.	4.6	SH	C	C
Dytiscidae				
Neoporus spp.	8.6	PR		R
Elmidae				
Ancyronyx variegatus	6.5	OM		R
Macronychus glabratus	4.6	OM		R
Hydrophilidae				
Tropisternus spp.	9.7	PR		R
Megaloptera				
Corydalidae				
Nigronia serricornis	5.0	PR		C
Diptera				
Chironomidae				
Brillia spp.	5.2	SH		R
Conchapelopia spp.	8.4	PR	C	A
Diplocladius cultriger	7.4	CG		R
Orthocladius oliveri		CG		C
Paratanytarsus spp.	8.5	CG		R
Polypedilum illinoense gp.	9.0	SH		R
Polypedilum scalaenum gp.	8.4	SH	C	C
Ptychopteridae				
Bittacomorpha spp.		CG		R
Simuliidae				
Simulium spp.	6.0	FC	C	A
Tipulidae				
Hexatoma spp.	4.3	SH	R	C
Tipula spp.	7.3	SH	A	A
DWQ Habitat Assessment			38	76
Total Taxa Richness			18	34
EPT Richness			7	8
EPT Abundance			38	55
Biotic Index			6.21	6.17
EPT Biotic Index			5.06	4.77

Tolerance Values: ranges from 0 (least tolerant to organic pollution) to 10 (most tolerant to organic pollution).
Functional Feeding Group: CG = Collector-Gatherer, FC = Filterer-Collector, OM = Omnivore, PR = Predator, SC = Scraper, SH = Shredder
Abundance Values: R=Rare (1-2 individuals); C=Common (3-9 individuals); A=Abundant (10 or more individuals)

Appendix G

Site Photographs

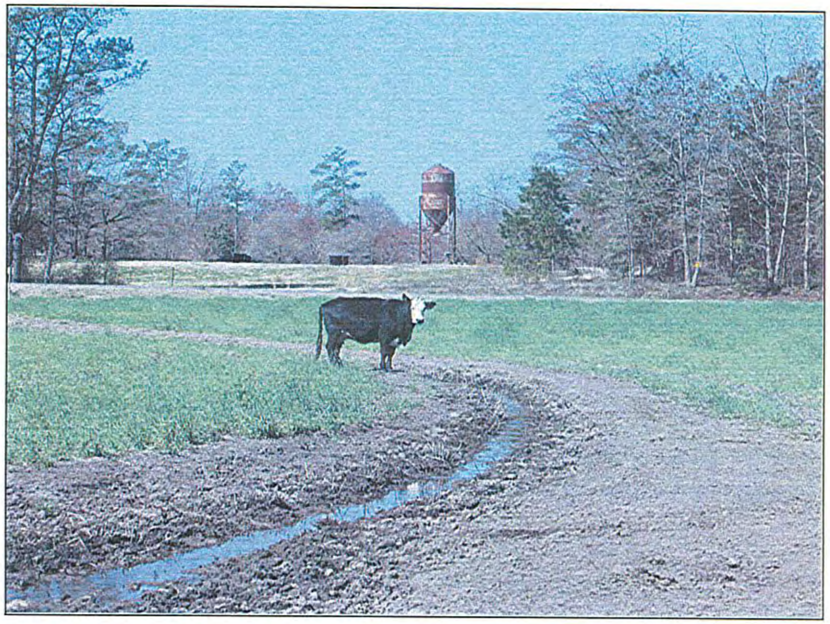
Cox Branch Cross-Section 1.

Cox Branch Cross-Section 2.

Cox Branch Channel Showing Incision.

Cox Branch through Agricultural Field.

Bank Erosion in Cox Branch.



Cattle in Project site.

Cox Branch in Vicinity of Road.

Cox Branch Assessment.

Aerial Photography of Cox Branch.

Aerial Photography of Cox Branch.

Aerial Photography of Cox Branch