# RESTORATION PLAN

*Overhills Stream and Wetland Restoration Project*

Nursery Road, Harnett County, North Carolina

*Prepared by*

BLUE Land Water Infrastructure, PA

*Submitted to*

NC Wetlands Restoration Program
320 West Jones Street
Raleigh, North Carolina 27603

March 28, 2003
BLWI Project Number 010263

**TABLE OF CONTENTS**

FIGURES



MAPS



TABLES

APPENDICES

# 1. Introduction

The NC Wetlands Restoration Program (NCWRP) has entered into an agreement with the Department of Defense (Fort Bragg and Pope Air Force Base) to restore streams and wetlands. NCWRP proposes to restore a third-order channelized stream and adjacent riparian wetlands on an approximately 70 acre property along Jumping Run Creek in Harnett County, North Carolina. This project is also intended to improve water quality in Jumping Run Creek (also and originally known as McLeod's Creek). The Jumping Run Creek watershed is approximately 15.9 square miles and comprised of a mixture of undeveloped forested land, wetlands, suburban residential areas, commercial areas and a large golf course community. The project itself is located within the boundaries of the Overhills acquisition on the Fort Bragg Military Reservation. Data collection in the restoration and reference sites began in January 2002, and monitoring will continue throughout the design and up to five (5) years beyond project implementation.

The site has been significantly altered from its natural state. Prior to 1955, the stream was straightened and moved to provide more room for agricultural practices. Currently, the stream is deeply incised with only the largest rain events resulting in overbank flow. The stream and wetland restoration are directly tied to one another. The stream is both a primary source of water to the wetland as well as the primary discharge location of water from the wetland. The hydrologic response of the wetland is directly affected, and to a large part determined, by the stream. Jumping Run Creek will be completely realigned along a portion of its current position above Nursery Road. The former wetland area of the project has been drained for at least 65 years and possibly more than 100 years. Various agricultural operations were conducted in this area from the initial draining of the wetland area until a few years ago. Due largely to population growth associated with the expansion of Fort Bragg and Pope Air Force Base, the contributing watershed is undergoing significant land use changes and this trend is expected to continue.

# 2. Goals and Objectives

The objective of the Jumping Run Creek stream and wetland restoration was to use an innovative approach to the stream and wetland design. Instead of only performing the basic Level 2 data collection on the proposed restoration and reference site, modeling was used to supplement and support the findings. With this technique, the existing and predicted watershed conditions can be used to design a more stable stream with a restored, functioning floodplain.

The goals of the stream and wetland restoration project are:

- Restore stream dimension, pattern and profile.
- Restore riparian wetland hydrology and vegetation.
- Improve water quality.
- Protect future water quality.

# 3. Location Information

**Site Background**

The Overhills Stream and Wetland Restoration Project is part of the Overhills tract, which was owned by the Rockefeller family as one of their retreats. This tract was purchased by the Department of Defense in the mid-1990’s. The project site is located in Harnett County north of Fayetteville and Spring Lake, approximately two miles east along Nursery Road from NC Highway 24/87 (Map 3A. Restoration and Reference Site Vicinity Map). The site and contributing watershed are located in the “Fall-Line” Sandhills region of North Carolina. This is a distinct region of sandy rolling hills which extends from south central North Carolina, through the middle of South Carolina and Georgia, into east central Alabama.

The project involves the restoration of a portion of Jumping Run Creek and its floodplain as described above in the Goals and Objectives section. The project was not named “Jumping Run Creek” as the NCWRP has already had projects with that name. To avoid confusion, the project was named for this area of Harnett County.

The site is located at N35$^{0}$ 15.39’, W78$^{0}$ 59.78’ on the southern portion of the United States Geological Survey (USGS) *Olivia* and *Anderson Creek* 7.5 Minute Topographic Quadrangles (Map 3B. USGS 7.5 Minute Topographic Quadrangle Map). The following table lists baseline watershed planning information for the site and for the entirety of Jumping Run Creek.

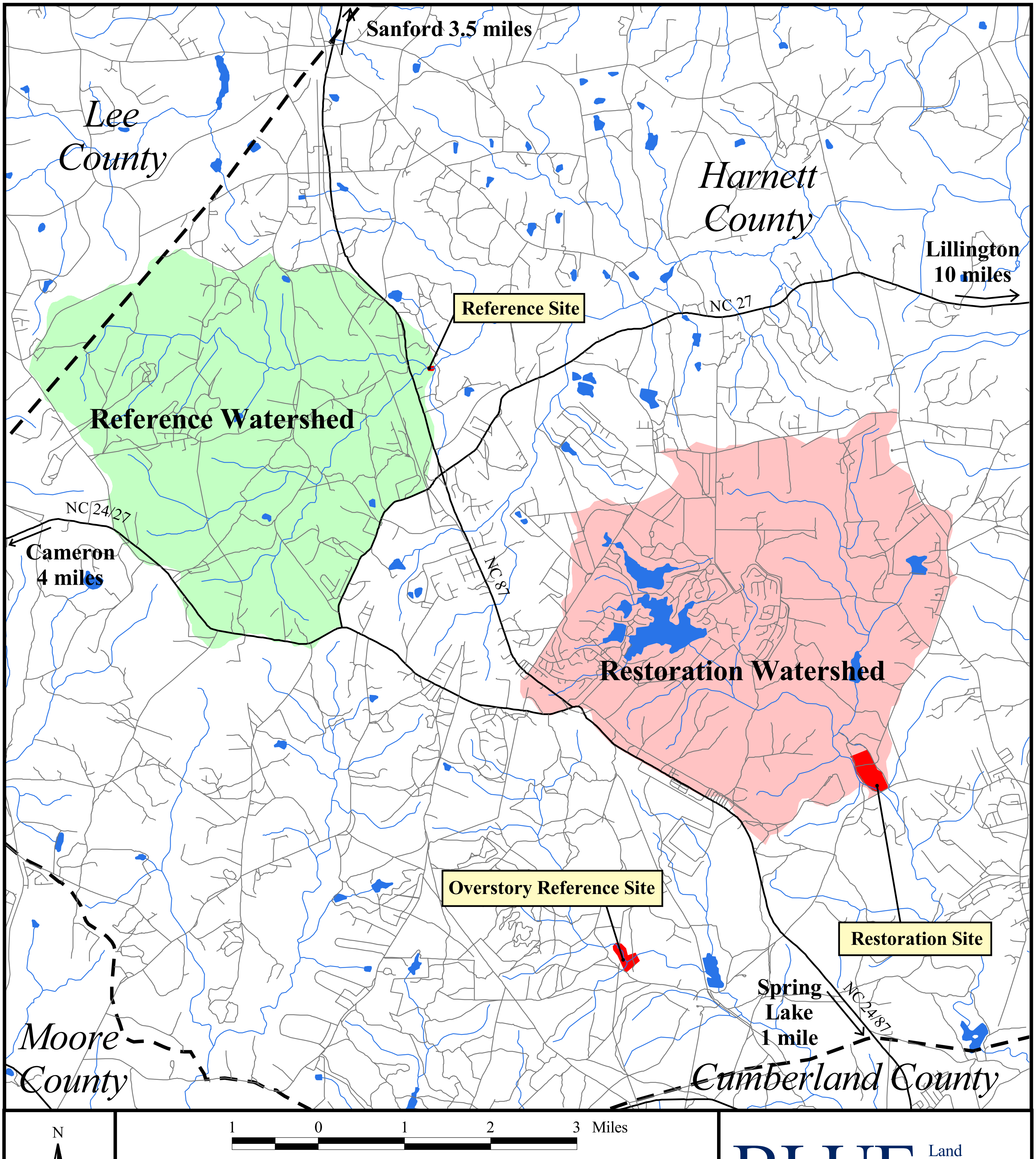
*Table 3-1. Jumping Run Creek Background Information*

| | |
|---|---|
| River Basin | Cape Fear |
| NCDWQ Stream Index # | 18-23-29 |
| NCDWQ Stream Class Rating | C |
| NCDWQ Use Rating | Fully Supporting |
| NCDWQ Use Basis | Monitored |
| NCDWQ Subbasin # | 03-06-14 |
| NCDWQ 1998 Jumping Run Creek Benthos Rating | Excellent |
| USGS 8-Digit Hydrologic Unit | 03030004 |
| USGS 14-Digit Hydrologic Unit | 03030004090010 |

# MAP 3A

# RESTORATION AND REFERENCE SITE VICINITY MAP

# Restoration & Reference Site Vicinity Map



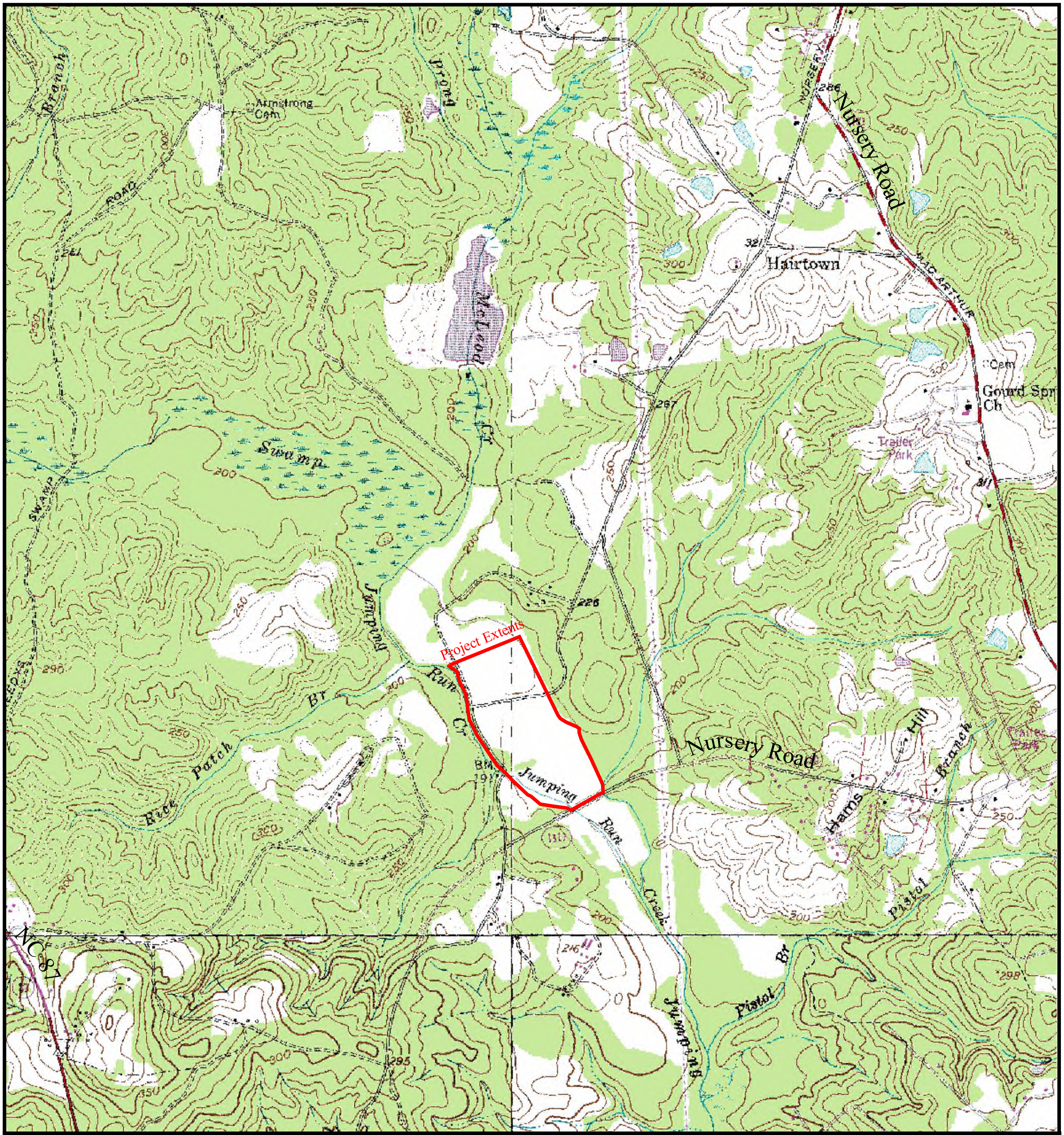

Scale: 1" = 1.5 miles
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

MAP 3B

USGS 7.5 MINUTE TOPOGRAPHIC
QUADRANGLE MAP

# USGS 7.5 Minute Topographic Quadrangle Map




N

2000 0 2000 4000 Feet

Scale: 1" = 2000 feet

Overhills Stream and Wetland Restoration Project - Restoration Plan

March 14, 2003

BLUE Land Water Infrastructure

# 4. General Watershed Information

**Watershed Background**

The contributing watershed for this project is approximately 15.9 square miles. The southwestern boundary of the watershed generally runs along NC 87/24, then turns northwest along Buffalo Lake Road. The boundary bounces back and forth across Buffalo Lake Road until it turns east along Micro Tower Road north of Buffalo Lake. The northern boundary of the watershed ends at the intersection of Micro Tower and Docs Road, where the boundary makes a turn to the south. The boundary then follows along Docs Road and Nursery Road until Nursery Road turns to the west. The watershed boundary then drops to the south end of the project site to close off the watershed for the site (Map 3A. Restoration and Reference Site Vicinity Map).

The watershed is comprised of a mixture of undeveloped forested land, wetlands, suburban residential areas, commercial areas, and a large golf course community. Several sizable lakes and ponds dot the watershed and a spattering of small agricultural operations are located throughout. The watershed ranges in elevation from approximately 450' above sea level to an average elevation of 190' at the site. The topography of the watershed is typical sandhills type topography which is largely rolling in nature. The soils in the watershed are primarily sandy soil types.

**Watershed Mapping**

A wide variety of data sources were investigated and many different GIS data layers were obtained for use on the project. The first layers utilized were the USGS 7.5 Minute Topographic Maps, the USGS 7.5 Minute Digital Elevation Models (DEMs) and the USGS 14-digit hydrologic units. This data provided the information needed to determine both the restoration and the reference site watershed boundaries, which is discussed in greater detail in the following section. After determination of the boundaries, the watershed characteristics were reviewed using Harnett County Digital Aerial Photography, 1993 Grayscale USGS Digital Orthophoto Quarter Quadrangles (DOQQ), 1999 Color Infrared USGS DOQQ, Fort Bragg Digital Aerial Photography, Fort Bragg Digital Topographic Map, 1996 Land Use/Land Cover, Digital Harnett Soil Survey, USGS Digital Line Graph (DLG) Hydrography, BASINS Dam data, North Carolina Center for Geographic Information and Analysis (NCCGIA) Dam data, NPDES sites, Harnett County Parcels, Harnett County Road Layer, Harnett County Zoning, and Census data. These datasets were then used in several different aspects of the project including siting of monitoring equipment, identification of important watershed features, preparation of plans for field surveying, development of input data for hydrologic and hydraulic, and development of a new high resolution Land Use/Land Cover map.

**Geographic Information Systems (GIS) Analysis**

A wide variety of GIS based analysis was performed during the assessment phase of the project. As an initial estimate, approximate watershed boundaries were delineated using the USGS DEMs and an automated watershed delineation tool. This boundary was then refined manually using the USGS topographic quadrangles. Subwatersheds were also delineated to separate drainage areas of interest, especially to isolate tributaries, lakes and ponds, and areas with specific land uses. Watershed boundaries were groundtruthed to make sure development activities have not caused significant changes.

A GIS was also used to locate hydraulic control features including culverts and dam outfalls. Aerial photography, USGS topography, and USGS DLG hydrography layers were used for this task. These features were then targeted for further investigation to determine their potential impacts on watershed hydrology. This data was refined for use in the modeling phase of this project.

The 1996 LULC data is 30 meter resolution, meaning one pixel of data equals 30 meters on the ground. This level of detail is not adequate for producing an accurate model of watershed hydrology. Therefore, a higher resolution land use/land cover data layer for the watershed was created by BLWI staff. The data layer was created using several sources of aerial photography, the 1996 LULC data, and the Harnett County parcel GIS layer.

**Land Uses and Soils**
Soil types from the USDA-NRCS Harnett County Soil Survey and land cover types from the 1996 Land Use/Land Cover (LULC) layer were analyzed using GIS. The watershed is comprised of a mixture of undeveloped forested land, wetlands, suburban residential areas, commercial areas, and a large golf course community. Several sizable lakes and ponds dot the watershed and a spattering of small agricultural operations are located throughout. Table 4-1 and Figure 4-1 show the percent of the watershed comprised of each land use. The forested portion of the watershed is primarily 'Southern Yellow Pine' (35.5%) and 'Bottomland Forest/Hardwood' (20.9%). The 'Southern Yellow Pine' category includes areas that are currently under forestry practices (Appendix A. Watershed Land Use/Land Cover Map).

*Table 4-1. Watershed Land Uses*

| **Land Use** | **Percentage of the Watershed** |
|---|---:|
| Agricultural | 7.6 |
| Commercial | 0.6 |
| Forest | 66.8 |
| Golf Course | 1.2 |
| Urban or Built-up | 14.9 |
| Water Bodies | 4.8 |
| Wetlands | 4.1 |

The most prevalent soil types are Gilead (25.4%), Blaney (19.6%), and Lakeland (15.9%) (Appendix B. Watershed Soil Type Distribution Map). All three are upland soils that formed in coastal plain sediments or thick sand deposits. Figure 4-2 shows the distribution of soil types across the watershed.

*Figure 4-1 Watershed Land Use Distribution*

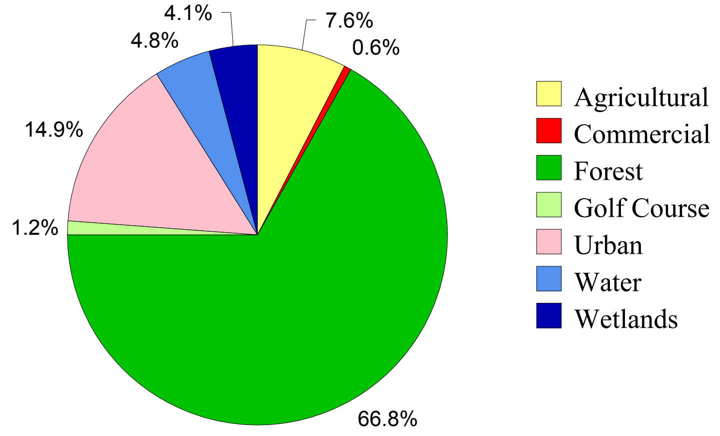
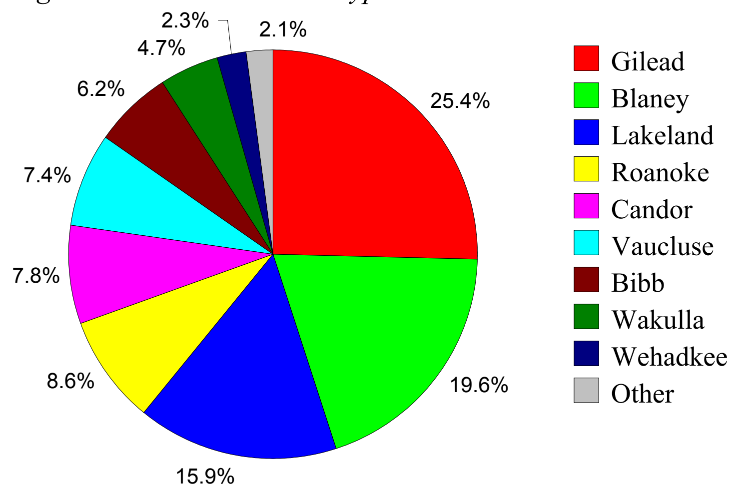



*Figure 4-2 Watershed Soil Type Distribution*




The developed portions of the watershed are concentrated in the northwestern portion near NC 87/24 and around Buffalo and Carolina Lakes. The Carolina Lake area is comprised of seven interconnected bodies of water. The northeastern portion of the watershed is sparsely developed with low density subdivisions and trailer type housing. The middle and lower portions of the watershed are largely undeveloped. Much of the land in this portion of the watershed is primarily used for timber or agricultural operations. Stream reaches in this area have sizable floodplain and riparian wetland areas associated with them.

**Growth Potential**

The watershed is currently developing rapidly, mostly with single family home neighborhoods. The proximity to Fort Bragg and the widening of Highway 87 through the watershed are both causes and indicators that the watershed is going to develop much more in the next 10-15 years. BLWI has taken this potential growth into consideration with the stream design. Populations projections from Harnett County based on the US Census data are shown below in Table 3. This data was obtained from the Harnett County Department of Economic Development. These projections give an indication of how much this watershed will develop.

*Table 4-2. Harnett County Population Projections*

| Year | Population | Growth |
|---|---|---|
| 2000 (Census Data) | 91,025 | |
| 2010 | 102,301 | 12% |
| 2020 | 118,383 | 30% |

**Watershed Investigation**

In addition to the GIS analysis performed on the watershed, a field scale investigation of various features was conducted. The purpose of this data collection effort was to gain further and more detailed information on watershed characteristics. This information was used extensively for the hydrologic and hydraulic modeling portions of this project. As a part of the investigation, BLWI staff visited 20-30 points of interest to assess the impact of structures, ponds, dams, and floodplains on the hydrology and hydraulic response of the watershed. These locations were also assessed for their potential to serve as "hydraulic control points" or monitoring locations for streamflow information. Data recorded at each location included a photo, brief description, and measurements of culvert sizes or other pertinent features. Another task completed during the watershed investigation included the acquisition of survey data for significant dams in the watershed. As noted above, lakes and their dams control streamflows from a significant portion of the watershed. Therefore, collection of accurate information was vital to precisely determine the relationship between stage, storage, and discharge of each dam for modeling purposes. First, all available design and study data was acquired from the NC Division of Land Resources for the lakes in the watershed. Also, EPA and statewide dam information was accessed using GIS. The data was compiled and information from the various sources was compared to determine where conflicts were occurring or where additional information was needed. Finally, BLWI staff performed surveys on the dams to acquire any data still needed. Surveys were performed at Silver Lake, Carolina Lake, and at Williams Pond. Survey data obtained for each lake included horizontal locations and elevation data along the dam, risers, spillways, and outfalls. Measurements of pipe sizes and other observations were also recorded during the investigations. See Appendix C for the USGS Topographic Quadrangle Watershed Map for a depiction of the lakes and hydrologic features of the watershed.

**Meteorological Monitoring**

Meteorological monitoring stations are located on the site and at various locations throughout the watershed. Monitoring stations were installed and began operating in February 2002 and will continue at least through the construction phase of the project. The purpose of this type of monitoring was primarily to provide actual weather data for use with site modeling efforts. By using as much actual data as possible, other model parameters were calibrated to attempt to produce the most accurate results possible. The placement of monitoring equipment throughout the watershed provided information on the spatial variability of precipitation. For the on-site meteorological monitoring we use a Davis GroWeather system. This integrated weather station and data logger measures/calculates, displays, and stores wind speed and direction, wind run, solar radiation, solar energy, air temperature, temperature/humidity index and wind chill (apparent temperature), soil temperature, humidity, dew-point, leaf wetness, barometric pressure, evapotranspiration, rainfall, and rate of rainfall. The weather station is programmed to record data hourly and the data is downloaded using a laptop computer. In addition to the weather station, we have an on-site rain gage and five rain gages placed strategically throughout the watershed. These gages are a tipping bucket type gage outfitted with a datalogger that records every hundredth of an inch (0.01") of rainfall. All of our monitoring equipment are chronologically synched and data is downloaded approximately once per month.

## 5. Description of Existing Conditions (Wetlands and Streams)

**Existing hydrologic features**
The on-site reach of Jumping Run Creek has been investigated thoroughly during the assessment phase of the project. Based on land use maps, hydrology information, and historical information, it is clear that Jumping Run Creek has been significantly altered from its natural path. As is the case with many streams in the sandhills area, the alteration likely involved relocating the channel to the far edge of the floodplain. The purpose of this type of relocation was typically to improve drainage of the surrounding area for agricultural purposes. To accomplish this, the channel is usually dug as deep and as straight as possible to maximize drainage potential. BLWI staff found this to be the case on the site. The existing channel was dug approximately 5-8 feet deep and about 15 feet wide at the streambed to 20 feet or more wide at the top of bank.

The main restoration site is a farmfield that may have contained the previous path of Jumping Run Creek. It is mapped in the 1994 USDA-NRCS Harnett County Soil Survey as primarily Bibb and Roanoke soil series, both of which are classified as hydric soils. However, the presence of ditches along the sides of the field and the depth at which the altered channel for Jumping Run Creek was dug has likely lowered the water table across the site (Map 5A. Hydrologic Reference Map).

**Soils Investigation**
Soils are a vital component of any stream and wetland restoration project. Soil properties can affect vegetation survival, stream stability, and groundwater hydrology, while at the same time exhibit indicators indicative of historic conditions. Multiple soil parameters were intensely investigated for the purposes of this project.

In March 2002, a trackhoe was used to dig 36 soil pits across the site in predetermined areas. Soil descriptions were completed at each pit and samples were taken from the topsoil and the soil horizon immediately below the topsoil. These samples were analyzed by the NC Department of Agriculture's Soil Testing Lab (Appendix D. On-site Soil Testing Lab Report).

The project area has been farmed for many years, and although no crops have been grown in the past few years, the soil tests indicate that the effects of lime are still present. The average topsoil pH on-site is 5.1 (average BS = 58%) compared to the reference site topsoil average pH of 4.5 (average BS = 17%). Organic material is also plentiful and should not limit vegetation growth on-site. The soils on-site have higher levels of nutrients than the reference area, most likely from past fertilizing. The lower nutrient and pH levels on the reference site likely allow wetland vegetation to grow while limiting upland and/or weedy species. On-site, conditions are currently favorable for weed growth. Introduction of higher water tables, as well as the passage of time, will create wetter and more acidic conditions favorable for hydrophitic vegetation.

Additional auger borings were completed to produce an on-site soil map (Map 5B. USDA-NRCS Harnett County Soil Survey Map and Appendix 5C. Restoration Site Soil Map). Like the soil survey, the majority of the site fell into the Roanoke soil series. The Roanoke map unit on-site consists of soils heavy in clay with a thick 8 to 18 inch layer of black, highly organic topsoil. Some of the Roanoke sample locations transitioned abruptly into sand or alternating layers of sand and clay around 50 to 72 inches deep, while a few remained heavy in clay throughout the depth observed. A few areas of Bibb soils were found. The Bibb mapunit on-site also had a thick 9 to 20 inch layer of black, highly organic topsoil, but the subsoil had much more sand than Roanoke soils on-site. Most of the Bibb samples were sandy throughout the depth sampled, and a few had thin alternating layers of loam or sandy clay loam. One area of Wehadkee is located along Jumping Run Creek. Wehadkee also has thick topsoil, more clay content than Bibb, and more sand content than Roanoke. One small area of Augusta was also found on the project site. This soil series is drier than Roanoke, Bibb, and Wehadkee. Roanoke, Bibb, and Wehadkee are all classified as hydric A soils, while Augusta is classified as a hydric B soil by USDA-NRCS. This means that the Augusta soils series itself is not hydric but may contain inclusions of soil series that are classified as hydric. Sampling locations were set up to test soils for bulk density. Bulk density was sampled across the site by taking undisturbed soil cores with an AMS Slide Hammer.

Other important observations were made during the soils investigation including the discovery of a tile drain. Prior to the site investigation, it was rumored that the site had been drained using tile drains. However, the status and even existence of these drains was unclear until one was found in pit 28. The terra cotta drain pipe was mostly full of sediment. (For a map of soil pits see Map 5C. Restoration Site Soil Map).

Characteristics were observed in a few of the soil pits that may point to the former location of Jumping Run Creek. Both pit 12 and pit 19 had a six to eight inch layer of small round pebbles characteristic of streambed material. Large woody debris was present in pit 14. This buried woody debris could have been placed in the old streambed when the stream was diverted.

**Existing Vegetation Investigation**

Vegetation was sampled on-site in both the open field and in the riparian buffer of the channels. For the purposes of this investigation, the riparian buffer is the area 3 meters on either side of the channels. The site was assessed using straight line transects across the open fields and channel cross sections every 15-20 meters within the channel buffers. The vegetation types can be clearly distinguished on the aerial photograph which is contained in Map 5A. Hydrologic Reference

Map. Dominant overstory tree species in and along the channels include red maple (*Acer rubrum*), loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*), and tulip poplar (*Liriodendron tulipifera*). Dominant shrub species include American snowbell (*Styrax americana*), swamp cyrilla (*Cyrilla racemiflora*) and privet (*Ligustrum* sp.), with the nonnative privet very dense in some areas. Dominant herbs and vines are grasses (*Arundinaria tecta* and *Chasmanthium laxum*), sedges (*Carex* spp.) and greenbriers (*Smilax* spp.). The dominant non-flowering ground cover species is peat moss (*Sphagnum* sp.).

The open fields have not had a natural vegetation community on them for some time. The fields were burned in Winter 2002 to ease topographic surveying while allowing the existing seed source to germinate. The dominant tree species that occur within the open fields as seedlings and saplings include loblolly pine, persimmon (*Diospyros virginiana*) and sweet gum. Dominant shrub species include blackberries (*Rubus* spp.) and flameleaf sumac (*Rhus copallinum*). The dominant herbaceous species that occur within the open fields include winter bentgrass (*Agrostis hyemalis*), bearded beggarticks (*Bidens aristosa*), sericea lespedeza (*Lespedeza cuneata*), Canada goldenrod (*Solidago canadensis* var. *scabra*), Canada rush (*Juncus canaensis*), forked rush (*Juncus dichotomus*), Virginia button-weed (*Diodia virginiana*) and common rush (*Juncus effusus*). The dominant non-flowering ground cover is peat moss. A more inclusive plant species list of the Restoration Site is presented in Appendix E. Restoration Site Plant Community Lists.

Some of these existing species may out-compete introduced wetland vegetation. The nonnative privet can grow in wet areas and could spread across the site. This invasive plant must be watched to ensure it does not overtake the site. Other species, such as blackberry, also have the potential to become dense stands. Herbicides may be necessary to control these volunteer species.

**Existing Stream Investigation**
The on-site reach of Jumping Run Creek has been investigated thoroughly during the assessment and design phase of the project. BLWI staff surveyed the entire length of the stream. During this time, photos were taken of eroding or failing bank areas, pool and riffle areas, point bars or deposition areas, stable areas, and other notable features (Appendix F. Photos). As previously stated, Jumping Run Creek has been significantly altered and relocated, most likely to improve drainage of the surrounding area for agricultural purposes.

Rather than a exhibit features of a typical sandhills stream, the existing channel has developed features that are more indicative of a piedmont stream. Riffles and pools have developed, and the presence of a sandy streambed was not prevalent. Observations indicate that in some reaches the channel has been dug in hard parent material. In these areas, teeth marks from a trackhoe bucket or similar digging device can still be seen in the channel bed. Due to the hard bed material, the channel exhibits little evidence of continued incision. However, in sections with higher slopes (the areas that most represent riffles) the dominant bed material was found to consist of larger gravel and cobbles. This feature has likely resulted because the sandier material has been stripped away by higher velocities in these parts of the stream. Other calmer pool areas of the channel still have sandy bottoms. The existing channel is straight and has very few curves. The bends that do exist exhibit erosion on the outer bank. Pine trees and cedars line both banks of Jumping Run Creek. The root systems of these trees likely help keep the upper portions of the banks stable. The lower portions of the banks, those that are frequently exposed to the stresses of higher flowrates and often remain wet, are composed of dense sandy clay material which also resists scour and erosion.

BLWI engineers and surveyors performed an on-site survey of Jumping Run Creek to collect information on the stream dimension, pattern, and profile. The survey also identified and located stream geomorphic features. As a result of the type of bed and bank material in the stream, the evolution of the channel and development of bankfull indicators has been kept at a minimum. Scour lines were the most frequently used bankfull indicator. Cross sections were surveyed at regular intervals beginning above the upper project limits and continuing downstream below the expected lower project boundary. More detailed survey information was obtained near potential stream tie-in points, at the beginning and end of the project, and at junction locations. A total of 41 cross sections were surveyed during this investigation. The data was used to calculate various stream dimension and profile parameters including longitudinal slope and bankfull width and depth. A chart showing summary data for Jumping Run Creek is shown below. This data was then used to classify the stream based on the Rosgen classification system as required by current State of North Carolina guidelines. Due to the low sinuosity and low slope of this stream, Jumping Run Creek technically falls between the A and G stream types. However, due to valley characteristics and its location in the coastal plain, this stream is classified between a G4 and G5c.

The survey data was used to develop several riverine hydraulic models of Jumping Run Creek. The models were used to make initial estimates of bankfull flowrate based on the observed indicators. Another model was also developed and calibrated for use with stream water level data to calculate actual flowrates for detailed modeling efforts (Appendix G, Existing Stream Data).

*Table 5-1. On-Site Stream Analysis Data Table*

| **Jumping Run Creek - Stream Dimensions Analysis** | |
|---|---:|
| Total XSEC Area (sq ft) | 72.5 |
| Bankfull XSEC Area, Abkf (sq ft) | 56.7 |
| Bankfull Width Wbkf(ft) | 14.5 |
| Bankfull Mean Depth Dbkf (ft) | 2.5 |
| Width to Depth Ratio (ft/ft) | 5.8 |
| Width Floodprone Area Wfpa (ft) | 16.5 |
| Entrenchment ratio Wfpa/Wbbkf (ft/ft) | 1.2 |
| Max Depth Ratio (Dmax/Dbkf) | 1 |
| Max Depth @ tob, Dmaxtob (ft) | 6.0 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 2.5 |
| D50 (mm) | 0.5, 9 |
| Stream Classification | G4, G5c |

| **Pattern and Profile Analysis** | |
|---|---|
| Stream Length (ft) | 3064 |
| Valley Length (ft) | 2808 |
| Belt Width, Wblt (ft) | 600 |
| Sinuosity, K | 1.1 |
| Valley Slope, Sval (ft/ft) | 0.0005 |
| Channel Slope, Schan (ft/ft) | 0.0016 |
| Radius of Curvature, Rc (ft) | 235 |
| Rc Ratio, Rc/Wbkf | 16.2 |
| Meander Length, Lm (ft) | 315.00 |
| Meander Length Ratio, Lm/Wbkf | 21.8 |
| Meander Length, Lm (ft) | 660 |
| Meander Length Ratio, Lm/Wbkf | 45.6 |

Streambed samples were taken and sent off to a lab for particle size analysis. Samples were taken of the dominant bed material in stable sections of the stream. The d50 of the first sample was found to be 0.5 mm, which falls into the category of medium sand. The d50 for the second sample was found to be 9 mm, which falls into the category of fine gravel (Appendix G. Existing Stream Data).

**Monitoring**

Site monitoring was undertaken to obtain an approximate data representation of the conditions and short-term history of soil and water level patterns for that area. On-site, information was gathered about groundwater levels, stream water levels, soil temperature, streambed particle fluidization and streambed aggradation/degradation (Appendix G. Existing Stream Data).

Infinity water level recorders are being used to collect both surface (stream) and groundwater level information. Two stream level recorders are taking readings every half hour while four groundwater level recorders are taking readings every hour. One stream level recorder is taking readings every ten minutes (Map  5A. Hydrologic Reference Map). The data obtained from the stream level recorders is used with channel dimensions to calculate flow volume.

A soil temperature probe and data recorder are used to measure the soil temperature. The probe was installed at the exact depth (50cm) to determine the length of the growing season. Readings are taken every 30 minutes.

A series of scour chains were installed to measure streambed particle fluidization and streambed aggradation/degreadation. Chains of a specific size were driven vertically into the streambed. In high, and sometimes low, storm flow events, the bed particles fluidize, or become suspended, and the stream bed degrades, or becomes deeper. As the storm flow becomes slower and nears completion, the bed particles begin to settle once again, thus altering the ways in which the chains were originally positioned. The chains can then be analyzed and conclusions can be made regarding bed movement.

**Endangered/Threatened Species Documentation**

Documentation for endangered/threatened species was prepared by Fort Bragg biologists. At the request of Ron Ferrell and Jason Guidry of NCWRP verification of threatened and endangered species was not performed by BLWI.

# MAP 5A

# HYDROLOGIC REFERENCE MAP

# Hydrologic Reference Map


N

600 0 600 1200 Feet

Scale: 1" = 600 feet
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

# MAP 5B

# USDA-NRCS HARNETT COUNTY SOIL SURVEY MAP

# USDA-NRCS Harnett County Soil Survey Map


Scale: 1" = 400 feet

Overhills Stream and Wetland Restoration Project - Restoration Plan

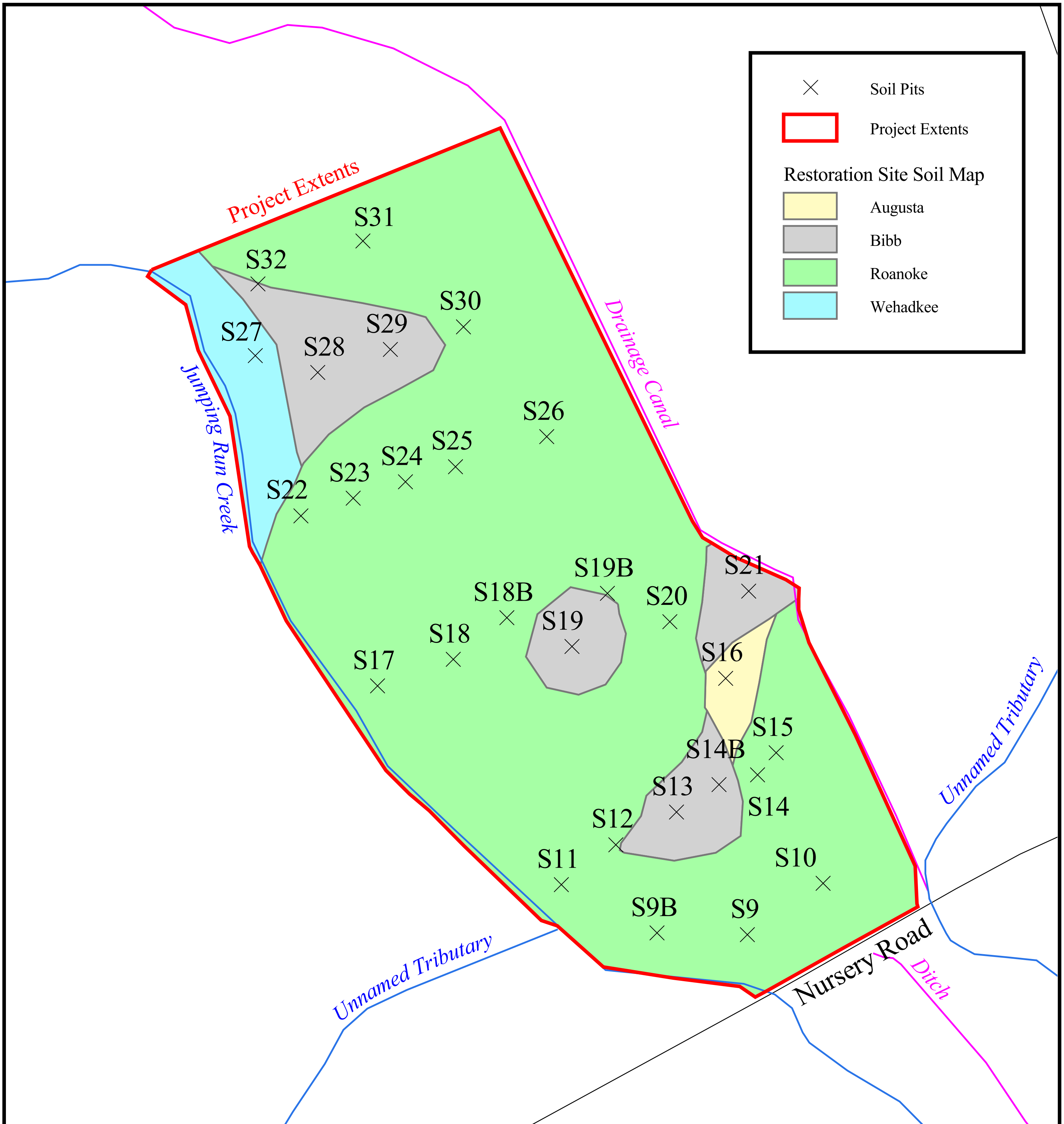
March 14, 2003

BLUE Land Water Infrastructure

# MAP 5C

# RESTORATION SITE SOIL MAP

# Restoration Site Soil Map




Scale: 1" = 400 feet
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

# 6. Wetland and Stream Reference Studies

**Reference Site Background**

The first step in a reference wetland and stream assessment was to identify and secure an appropriate reference location. The reference site search was first limited to the sandhills region of the Cape Fear River Basin. A GIS search was conducted based on desired characteristics derived from the restoration site. These included watershed size and hydrographic characteristics. Several potential sites were identified on private and public land. Sites closest to the restoration site were investigated in the field. These initial site searches identified an acceptable reference system on private land. BLWI identified a portion of this reach which was owned by one landowner. BLWI contacted the landowner and obtained permission to access the site for initial investigation work as well as for monitoring. This site will be referred to as the reference site throughout this report (Map 3A. Restoration and Reference Site Vicinity Map).

Upon commencement of the reference site investigation, the site was found to be in very good condition except that some of the overstory trees had been harvested in the past. It was determined that an additional overstory reference site would be utilized to obtain percent occurrence values for the overstory tree species. This site is very similar to the restoration site but was not used for the primary reference investigation site as the watershed and stream were too small to be used as an appropriate reference. This overstory reference site is located on public land within the Fort Bragg Military Reservation (Map 3A. Restoration and Reference Site Vicinity Map).

The restoration site, the reference site and the overstory reference site were assessed to determine baseline similarities to ensure hydrologic and physiographic consistency (Table 6-1. Hydrologic Site Comparisons Table). All of the sites are within the sandhills region of the same USGS 8-digit hydrologic unit. These sites are all located in adjacent 14-digit hydrologic units. Beyond this baseline assessment, only the reference site and the restoration site were investigated for all assessment parameters. The overstory reference site was investigated in detail only for vegetation.

*Table 6-1. Hydrologic Site Comparisons Table*

| **Site Name** | **Restoration Site** | **Reference Site** | **Overstory Reference Site** |
|---|---|---|---|
| Stream Name | Jumping Run Creek | Gum Swamp | Muddy Creek |
| River Basin | Cape Fear | Cape Fear | Cape Fear |
| USGS 8-digit HU | 3030004 | 3030004 | 3030004 |
| USGS 14-digit HU | 3030004090010 | 3030004050020 | 3030004080090 |
| NCDWQ Subbasin # | 03-06-14 | 03-06-13 | 03-06-14 |
| NCDWQ Stream Index # | 18-23-29 | 18-20-13-3 | 18-23-26 |
| NCDWQ Stream Class Rating | C | C | C |
| NCDWQ Use Rating | Fully Supporting | Fully Supporting | Fully Supporting |
| NCDWQ Use Basis | Monitored | Monitored | Monitored |

The reference site and the restoration site are located only 7 miles apart. The reference site drains approximately 14.8 $mi^2$ and is a third order stream, as compared to 15.9 $mi^2$ watershed size of the restoration site. Both sites have two main subwatersheds which merge short distances above the study areas. Both sites have relatively low development within their watersheds. Almost all of the soil types within the two watersheds are shared. The main difference between the two watersheds is that the reference site watershed has no large impoundments as is characteristic of the restoration site watershed. In terms of watershed similarities, the reference site and the restoration site are extremely close in all aspects.

The actual reference site has many site characteristics which are different from the restoration site. The primary difference is that the reference site has a stream with a stable pattern and profile and is connected to its wetland floodplain. The reference site also has a well established plant community which is providing, among other things, streambank stability. However, the soil types at the two sites are similar.

**Reference Site Plant Community Characterization**

Three different vegetation community sites were assessed for this project. The first vegetation community area was the restoration site which is described in detail in the Existing Vegetation Investigation portion of Section 5 of this report. The next area assessed was the reference site located off of NC 87. This area is a cut-over forested wetland that has the understory cover and diversity representative of an early successional riparian forest, but unfortunately, does not have the necessary overstory diversity and cover to be used as a reference for the target climax plant community. Therefore, another intact forested wetland, the overstory reference site, was chosen as a reference to define the primary target plant community for the restoration project.

The reference site is located on Cypress Creek, just east of NC 87. The site was assessed using meandering transects along the stream edge and in retention depressions within the streams' floodplain. Rare plant surveys were not performed for this vegetative assessment. The overstory of this Coastal Plain Small Stream Swamp has been cut-over, thereby releasing previously suppressed subcanopy trees and understory vegetation. The existing overstory canopy cover is now approximately $< 5\%$, and the midstory has released and expanded its coverage since the overstory removal. Dominant existing subcanopy tree species include swamp tupelo (*Nyssa biflora*), red maple, and willow oak (*Quercus phellos*). Dominant midstory species include American holly (*Ilex opaca*), swamp cyrilla, and red maple. Dominant shrub species include American snowbell, coastal dog-hobble (*Leucothoe axillaris*), and northern arrow-wood (*Viburnum recognitum*). The dominant herbs and vines are sedges (*Carex spp*.), switchcane, and greenbriers. Dominant non-flowering ground cover species include peat moss and common liverwort (*Marchantia polymorpha*). A more inclusive plant species list of the reference site is presented in Appendix H. Reference Site and Overstory Reference Site Plant Community Lists.

The significantly rare sarvis holly (*Ilex amelanchier*) was found at the watershed reference site during the vegetative assessment. No other rare plant species were noted.

The overstory reference site is a Coastal Plain Small Stream Swamp located along Muddy Creek west of Overhills Lake. The soil types occurring within the overstory reference site are Roanoke loams, one of the predominant types on the restoration site. The overstory reference site is below the convergence of two streams, another shared characteristic with the restoration site. This Coastal Plain Small Stream Swamp is fairly pristine with the overstory consisting of large diameter (up to 1 meter) trees with 75-95% crown cover. The dominant overstory tree species include swamp tupelo, bald cypress (*Taxodium distichum*), pond cypress (*Taxodium ascendens*), loblolly pine, and red maple. Dominant midstory species include red maple, American holly, and Atlantic white cedar (*Chamaecyparis thyoides*). Dominant shrub species include coastal sweet-pepperbush (*Clethra alnifolia*), inkberry (*Ilex glabra*), American snowbell, and coastal dog-hobble. The dominant herbs and vines are switchcane, cinnamon fern (*Osmunda cinnamomea*), netted chain-fern (*Woodwardia areolata*), greenbriers, and muscadine grape (*Vitis rotundifolia*). Dominant non-flowering ground cover species include mosses and common liverwort. A more inclusive plant species list of the overstory reference site is presented in Appendix H. Reference Site and Overstory Reference Site Plant Community Lists.

Scientific plot data were collected within the overstory reference site in order to determine relative occurrence percentages of all overstory tree species. Data collection methodology consisted of fixed radius plots 3 chains apart with each plot 0.10 hectares in size. Table 6-2. Overstory Reference Site Percent Occurrence summarizes these findings. This information was used to determine vegetative planting methodologies for the restoration site.

*Table 6-2. Overstory Reference Site Percent Occurrence*

| **Species** | **Percent Occurrence** |
|---|---:|
| *Nyssa biflora* | 43.7 |
| *Taxodium distichum* | 13.9 |
| *Taxodium ascendens* | 11.9 |
| *Pinus taeda* | 10.6 |
| *Acer rubrum* | 9.9 |
| *Liriodendron tulipfera* | 2.6 |
| *Pinus serotina* | 2.6 |
| *Liquidambar styraciflua* | 2.0 |
| *Quercus alba* | 2.0 |
| *Quercus* sp. (hybrid) | 0.7 |

**Reference Site Wetland Investigation**

The Reference Site was investigated to document the sites hydrology, soils, vegetation, topography. The entire reference area was surveyed to determine microtopographic relief and the floodplain extents (Map 6A. Reference Site Soil Map).

The near surface water table was assessed by installing an automatic water level recorder. This unit was installed on March 28, 2002 and has been taking hourly readings since that time (Appendix I - Reference Site Groundwater Data). During the period between March and January, approximately 10 overbank events have occurred, with 9 of those events occurring during the fall and winter. This results in an average bankfull recurrence interval (over this period) of once per month. An analysis of a single overbank event, the water ponded in the wetland floodplain to a depth of 9 inches. This corroborates all the physical features that indicated a properly functioning linkage between the stream and its wetland floodplain.

**Reference Wetland Soil Characterization**
Soils on the reference site were assessed in mid-April 2002. An auger was used to take samples along two transects perpendicular to the stream. Soil descriptions were completed at each sample location and samples were taken for analysis from the topsoil and the soil horizon immediately below the topsoil. These samples were analyzed by the NC Department of Agriculture's Soil Testing Lab (Appendix J. Reference Site Soil Testing Lab Report). The average topsoil pH is 4.5 (average BS = 17%) compared to the reference site topsoil average pH of 5.1 (average BS = 58%).

The soil descriptions from the auger borings were used to produce a reference site soil map (Map 6A. Reference Soil Map). The reference site was similar to the restoration site in that the majority of the site fell into the Roanoke soil series. The Roanoke mapunit on the reference site consists of soils heavy in clay with a 4 to 10 inch layer of dark, organic topsoil. Buried topsoil was commonly found within the Roanoke sample locations. The Roanoke areas on the reference site have shallower topsoil than the restoration site but exhibit more layering of topsoil and sediment, indicative of a natural floodplain area. Wehadkee soils were found to occur directly adjacent to both sides of the reference stream. Wehadkee soils has similar topsoil but does not contain as much clay as the Roanoke soils. This characteristic of a natural floodplain is due to the fact the bulkier sand particles drop out of the flood waters rather quickly leaving the courser sediment depositions close to the stream while the finer sediments are deposited further from the stream banks. The topsoil and sediment layering effects are even more common in the Wehadkee soils than the Roanoke soils on the reference site. One area of Augusta soil was also found on the northeast portion of the reference site. This soil contains a fair amount of clay but is drier than Roanoke and Wehadkee soils.

*Table 6-3. Reference Soil Permeabilities from USDA-NRCS Harnett County Soil Survey*

| **Soil** | **Permeability** | **Most Limiting Layer** |
|---|---|---|
| Augusta | 0.5 - 2 in/hr | 12 - 50 inches |
| Roanoke | 0.06 - 0.2 in/hr | 46 - 60 inches |
| Wehadkee | 0.6 - 2 in/hr | 6 - 40 inches |

*Table 6-4. Reference Soil Moist Bulk Densities from USDA-NRCS Harnett County Soil Survey*

| **Soil** | **Moist Bulk Density** | **Layer** |
|---|---|---|
| Augusta | 1.35 - 1.60 g/cc | 12 - 50 inches |
| Roanoke | 1.20 - 1.50 g/cc | 0 - 60 inches |
| Wehadkee | 1.30 - 1.50 g/cc | 6 - 40 inches |

*Table 6-5. Reference Soil Organic Matter Percentages and Taxonomic Classification from USDA-NRCS Harnett County Soil Survey*

| **Soil** | **Organic Matter** | **Classification** |
|---|---|---|
| Augusta | 0.5 - 2 % | Aeric Endoaquult |
| Roanoke | 0.5 - 2 % | Typic Endoaquult |
| Wehadkee | 2 - 5 % | Typic Fluvaquent |

**Reference Stream Investigation**

BLWI engineers and surveyors performed an in-depth survey on the reference stream to collect information on the reference stream dimension, pattern, and profile. The survey also identified and located stream geomorphic features. A reach of the stream was chosen so that data could be acquired for a continuous distance equal to at least 20 bankfull widths. The survey work was completed to the level of detail necessary to prepare a fully three dimensional representation of the stream and its floodplain. This required that the survey go beyond the traditional "cross section" method of stream surveying. Regular cross sections were surveyed, but additional survey points were taken to further define stream meanders and other features. A total of nearly 400 survey points were taken during the survey. This detailed survey generates more accurate measurements of stream pattern data such as radius of curvature and meander wavelength. It also provides a larger dataset of cross sections for determining dimension data such as bankfull width and bankfull depth. Data taken at this higher density is also valuable for analyzing the stream's longitudinal profile by providing a better indicator of microtopographical changes that cannot be seen in a traditional cross-sectional survey.

The survey data was used to generate a 3-D computer model of the stream. The model was used in combination with traditional analysis methods to determine critical classification information. The model was also used to make a more accurate determination of the bankfull flowrate for this stream. Rather than using summarized stream dimension information, a hydraulic model such as this can utilize all of the survey information to determine the bankfull flowrate. A table showing summary data for the reference stream is shown below. Graphs depicting stream pattern and profile are included in Appendix K. Reference Stream Data. Other graphics are also included showing the computer modeling and bankfull flowrate determinations.

*Table 6-6. Reference Stream Analysis Data Table*

| **Reference Stream Dimension Analysis** | |
|---|---|
| Bankfull XSEC Area, Abkf (sq ft) | 21.8 |
| Bankfull Width Wbkf(ft) | 14.4 |
| Bankfull Mean Depth Dbkf (ft) | 2.7 |
| Width to Depth Ratio (ft/ft) | 5.4 |
| Width Floodprone Area Wfpa (ft) | 200 |
| Entrenchment ratio Wfpa/Wbbkf (ft/ft) | 13.9 |
| Max Depth @ bkf Dmax (ft) | 3.2 |
| Max Depth Ratio (Dmax/Dbkf) | 1.2 |
| Bankfull Flowrate (cfs) | 42 |
| d50 (mm) | 0.62 |
| Stream Classification | E5 |

| **Reference Stream Pattern and Profile Analysis** | |
|---|---|
| Stream Length (ft) | 330 |
| Valley Length (ft) | 230 |
| Belt Width, Wblt (ft) | 77 |
| Sinuosity, K | 1.4 |
| Valley Slope, Sval (ft/ft) | 0.0007 |
| Channel Slope, Schan (ft/ft) | 0.009 |
| Water Surface Slope (ft/ft) | 0.00067 |
| Radius of Curvature, Rc (ft) | 23.4 |
| Rc Ratio, Rc/Wbkf | 1.6 |
| Meander Length, Lm (ft) | 150 |
| Meander Length Ratio, Lm/Wbkf) | 10.4 |

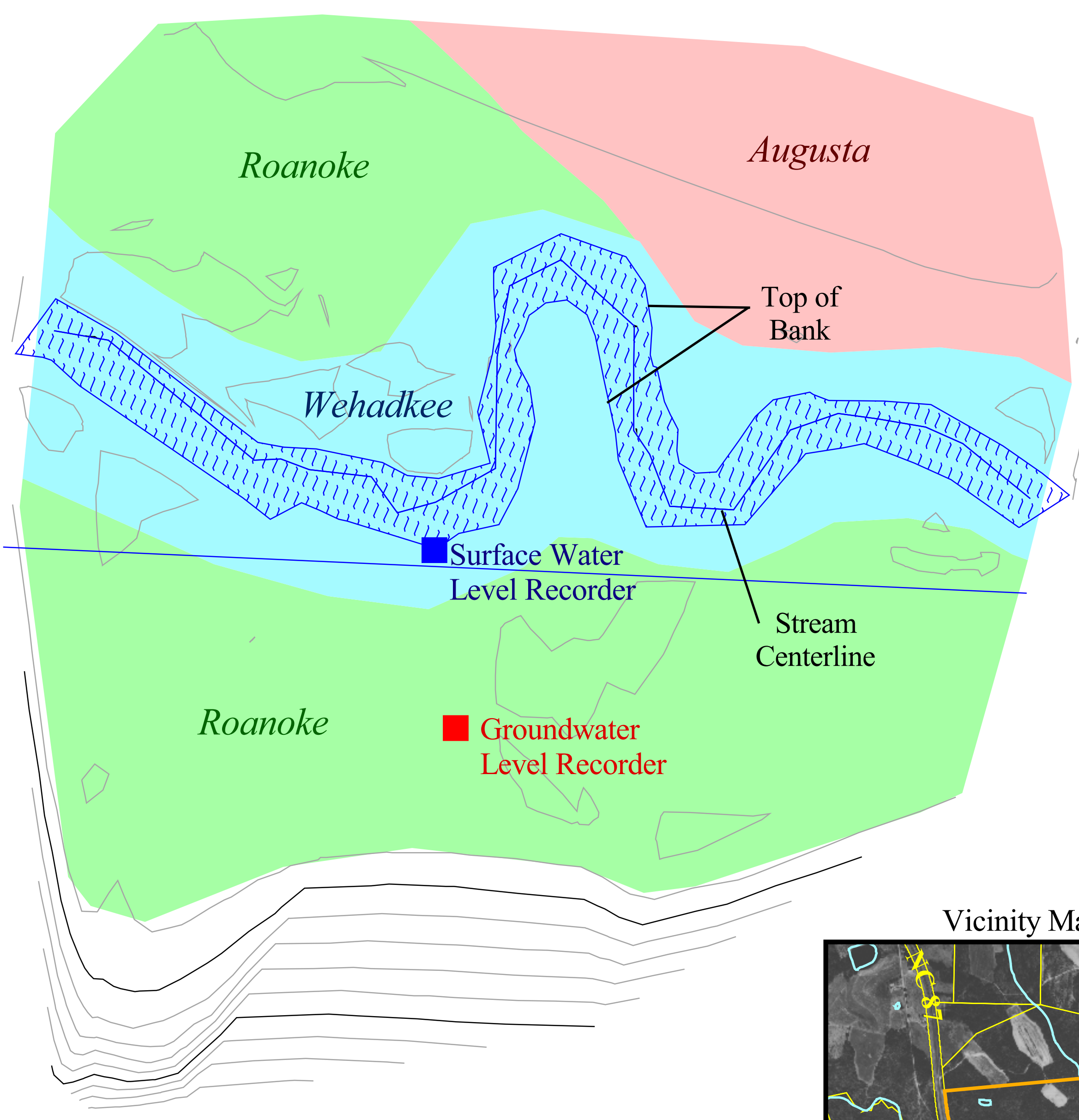
A water level recorder was placed in the stream to provide water level readings for further flow analysis. The recorder logs are reading of the water level in the stream every 30 minutes. When combined with rainfall information, this data provided insight to the relationship between rainfalls and various flow events. The data also provided information on the frequency of bankfull events and overbank flows. In between March and January, 10 events occurred which caused the stream stage to rise above the top of the bank or bankfull elevation.

In addition to the stream surveying, streambed samples were taken and sent off to a lab for particle size analysis. Several samples were taken of the dominant bed material and samples were also taken of the subpavement material. The d50 of the bed material was found to be around 0.6 mm, which falls into the category of medium sand. The d50 for the subpavement material was found to be approximately 0.25 mm, which falls into the category of fine sand (Appendix K. Reference Stream Data).

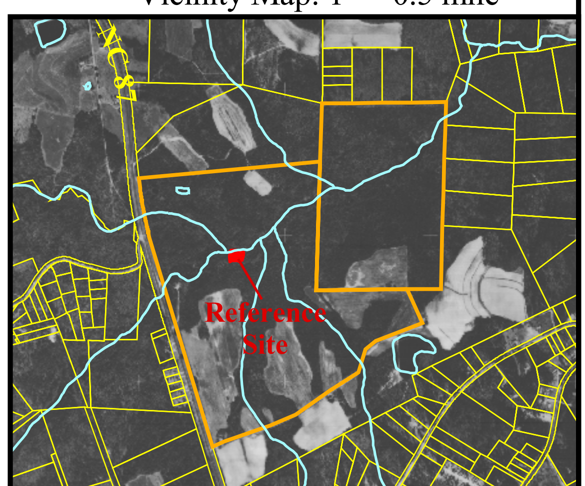
# MAP 6A

# REFERENCE SITE SOIL MAP

# Reference Site Soil Map




Vicinity Map: 1" = 0.5 mile




N

40 0 40 80 Feet

1 foot Contour Interval Scale: 1" = 40 feet

Overhills Stream and Wetland Restoration Project - Restoration Plan

March 14, 2003

BLUE Land Water Infrastructure

# 7. Wetland Restoration Plan

**Background**

The final restored stream reach and wetland areas will be highly dependent on each other to meet the stability and functional goals of the project. The potential wetland, floodplain, and floodprone widths of the site exceed 1,000 feet for most of the project length. This will help improve stream stability by providing adequate buffering and overbank flow capacity which will dramatically reduce stream stress. The restored stream in combination with plugging and other modifications to the existing channel will raise water tables and be a source of surface water influx during flood events. Due to their delicate hydrologic and functional interconnectivity, it is necessary to develop the wetland and stream restoration plans for the site concurrently. The wetland restoration plan has been developed to restore wetland hydrology, soils, and vegetative communities to a natural bottomland hardwood forest system. The potential wetland area that can be restored within the project boundary is 70 acres. The expected amount of restored wetland will be slightly less due to transitional areas near the upper and lower project tie-ins.

**Hydrologic Restoration**

Reestablishment of wetland groundwater table conditions will be paramount to successful wetland restoration at the site. The goals of the hydrologic restoration components are to meet the USACE hydrologic criterion and to restore the natural hydrology that will support the wetland community. As such, the stream and wetland design has been balanced to have a hydrologic response similar to the reference site. The primary method for raising the water table to meet these goals will be to restore the natural drainage system. This will be accomplished by performing a Priority 1 stream restoration and by reducing or eliminating existing (artificial) drainage pathways. The combination of these with influxes of surface water from the stream and surrounding groundwater interflow will constrain hydrologic drainage and improve water table conditions. Raising the streambed elevation will also reconnect the stream with its natural floodplain, providing regular influx of surface water to the wetland. The restoration of a surface water hydroperiod will improve overall site hydrology and the physical and chemical conditions that will support wetland vegetation and soil development.

In the wetland areas, a mixture of grading, channel plugs, berms, log structures and other woody debris, and microtopography will be used to manipulate and enhance the hydrology of the site. Once the stream has been constructed, channel plugs will be installed to redirect waters into the new stream and to prevent short circuiting. Ditch plugs will be constructed according to the materials and spacing recommendations of the Natural Resources Conservation Service. Berms will be used at various intervals along the existing stream and the ditch to promote wetland storage, flushing, and to prevent preferential drainage. A larger berm is planned for the lower end of the site to isolate the untouched portion of the existing stream from potentially erosive overflows. Log structures and woody debris will be placed at various locations in the wetland area. These structures will prevent channelization of overbank flows and improve circulation and temporary storage in the wetland. They will also provide soil stability and habitat functions. Minor grading will be used throughout the wetland to create small depressions and small hummocks that will improve hydrology and create diverse vegetative and habitat communities.

**Vegetation Community Restoration**

The wetland areas will be planted entirely with native, non-invasive vegetation. The targeted wetland community type will be riparian, bottomland hardwood forest. Planting densities throughout the wetland will be a minimum of 400 stems per acre. The site will be planted in a mixture of species in ratios similar to the reference overstory site. The expected composition is as follows:

*Table 7-1. Proposed Species Composition*

| Species | Composition |
|---|---:|
| Swamp tupelo (*Nyssa biflora*) | 50% |
| Bald cypress (*Taxodium distichum*) | 30% |
| Tulip poplar (*Liriodendron tulipifera*) | 8% |
| Willow oak (*Quercus phellos*) | 4% |
| Water oak (*Quercus nigra*) | 4% |
| Green ash (*Fraxinus pennsylvanica*) | 4% |

Across the restoration site, seedlings will be planted at a spacing equivalent to 400 stems/acre. Additional plantings will be used along the stream banks and in the near overbank areas to provide immediate cover and root mat for stream stability. Plantings will be placed in strategic locations on the outside of meander bends, near root wads, and near other structural devices to provide additional stability. Additional plantings will also be used in depressions and hummock areas. Selection of these plants will be based on the reference site and availability at the time of planting. The distribution of the plant communities are illustrated in Map 7A. Proposed Vegetative Communities.

A native wetland seed mix will be used throughout the wetland and in the near overbank areas to provide immediate cover, root stability, and to prevent sediment transport into the new stream. The wetland seed mix and straw cover will provide cover and an organic material base throughout the wetland. Very few plants were identified on the site which could be utilized as transplants. Some existing hardwoods may be used for in-stream or wetland structures. Therefore, a large number of plants will need to be acquired for the project. A large portion of trees will be planted using bare root stock. Some container stock may be used in strategic areas along the stream and near overbank areas. If costs allow, larger trees will be used in depression and hummock areas. An appropriate weed control management strategy will need to be implemented during the planting phase of the project. This will likely involve pre-emergent and post emergent herbicide application and should be managed by an experienced professional in the area.

**Soils Restoration**

Soils investigation found that natural wetland floodplain soils exist on the site. However, activities associated with agricultural production have lead to compaction, reduction of organic matter, and the alteration of proper wetland chemical conditions in these soils. Soil preparation activities on the site will include minimal grading work. The entire site will be tilled or scarified to a depth of at least 6”. Grading activities will be managed to maintain an appropriate A horizon in all wetland areas. If grading is likely to require excavation below existing A horizons or reduce the depth significantly, topsoil will be stripped and stockpiled for later replacement. Soil amendments will be kept to a minimum, but may include broadcast fertilizer application, some targeted fertilizer application, and possibly some organic matter addition.

Proper construction management will be critical to soils preparation and to avoid adverse impacts at the site. Traffic of heavy construction equipment must be limited to avoid compaction. Management must also ensure that tillage practices are completed correctly and to the specified extent. The manager must ensure that erosion control practices are followed to prevent the loss of topsoil from the site. Soil testing for bulk density, chemistry, or other parameters may be needed during the construction process to ensure that soil conditions will be appropriate for the restoration.

# 8. Wetland Performance Criteria and Monitoring Plan

**Success Criteria for Hydrology**

A total of 7 continuous water level recorders are planned for monitoring the hydrology of the wetland area. Recorders will be programmed to initially record water table data on an hourly basis. If water table changes are not found to occur rapidly, the recorders may be reprogrammed to record at longer intervals. One continuous transect of recorders will be installed across the wetland and others will be installed at strategic locations near the outer boundaries of the site (See Monitoring Plan Map at the end of Section 12, Stream Monitoring Design). Water level data will be compared with data recorded at the reference site to determine if water table response of the two is similar.

**Success Criteria for Vegetation**

Success for the vegetative plantings will be determined by the establishment of permanent plots (10 X 10 meter) within the two dominant soil series and sampling within these plots. There will be 2 plots placed within the Bibb soil series and three 3 placed within the Roanoke soil series. Data from each plot pertaining to species composition, presence of volunteer or invasive species, percent survival, and percent ground cover will be collected.

**Success Criteria for Soils**

As the soils at the site are already considered hydric, no monitoring or success criteria is proposed for soils.

**Monitoring Schedule and Methods**

The site will be monitored for a period of 5 years after implementation. During the first year of restoration, groundwater gage data will be downloaded and compile twice. Also during the first year, the vegetation will be sampled twice - once, shortly after planting to provide baseline data and then after the growing season. In subsequent years the data will be collected after the growing season. Five permanent plots will be established within the restoration area - 2 in the Bibb soil series, 3 in the Roanoke soil series. Within each plot, data will be collected pertain to species composition, presence of volunteer or invasive species, and percent survival will be collected. A map depicting the proposed water table recorders and vegetation plot locations is included at the end of Section 12, Stream Monitoring Plan.

# 9. Stream Restoration Plan

**Stream System Restoration Design Approach Discussion**

In the United States, most ecosystem restoration efforts focusing on streams and wetlands have been unsuccessful. Many reasons have been given for these failures, with the lack of detailed hydrologic and hydraulic investigation, modeling, and design being generally the most common cause. To be successful, ecosystem restoration efforts (as with any planning and design effort) require various methodologies to be employed dependent upon the individual type and character of the specific project.

Stream design methodologies can generally be separated into three categories: 1) Analog; 2) Empirical; 3) Analytical. Each of these methodologies has strengths and weaknesses. As such, various aspects of each methodology may be employed in any given project.

**Analog Methodology**

The Analog methodology is typified by the reference reach method popularized by Dave Rosgen of Wildland Hydrology and is the most simplistic of the three methodologies. The Analog methodology is based on the logical and statistical inference that if two systems are known to be alike in some respects, then they must be alike in other respects. In this methodology, sets of geometric and hydraulic parameters are measured relative to flow rate return intervals. This information is then applied to the design of the system being restored.

For a project to be successful using this methodology, several considerations must be met: 1) the project watershed matches the hydrologic character of the reference watershed(s) to a significant degree; 2) the site and reach parameters must match the reference site(s) to a significant degree (bank vegetation, channel slopes, bank slopes, water table depth, bed material, etc); 3) The reference watershed(s) and site(s) must be stable and have been so for a significant time period; 4) The project watershed must be stable, have been so for a significant time period, and continue to be so for the design life of the project. If these conditions are not met, this methodology is not applicable for project design.

As such, this methodology is generally not applicable to projects in urbanizing watersheds, watersheds which may experience development or redevelopment during the project's design life, watersheds where agricultural practices are changing or may change during the project's design life, watersheds where reservoirs may be constructed or removed, and various instances of watershed change. This method is generally suitable for sites at which the hydrologic response of the contributing watershed is significantly stable and will remain such for the intended lifetime of the project.

**Empirical Methodology**

As the name of this methodology suggests, the Empirical methodology is based on the application of statistically derived parameters from large datasets and intensive system studies. This methodology is somewhat similar to the analog method in that both methodologies are based on sets of measured data. The main difference is that the Empirical methodology utilizes much larger, refined, and more focused datasets than does the Analog methodology. A secondary difference is that the Empirical methodology often utilizes mean annual flow rate as the primary design parameter whereas the Analog methodology generally employs the bankfull flow rate as the primary design parameter, with the consideration that the bankfull flow is the channel forming discharge. The Empirical methodology is typified by the regime reach method.

As with the Analog methodology, for a project to be successful using the Empirical methodology, several considerations must be met: 1) specific project watershed response parameters of the project watershed must match specific watershed response parameters of the dataset watersheds to a significant degree; 2) specific project site and reach parameters must match specific parameters of the dataset sites and reaches to a significant degree (bank vegetation, channel slopes, bank slopes, water table depth, bed material, etc); 3) during the data collection period, the dataset watersheds, sites, and reaches must be equivalently stable or varying as the project watershed, site, and reach and continue to be so for the design life of the project (equal to, or less than, the data collection period if varying). If these conditions are not met, this methodology is not applicable for project design.

With the proper dataset and considerable understanding of this dataset, watershed hydrology, and fluvial geomorphology, it is potentially possible to apply the Empirical methodology to projects in urbanizing watersheds, watersheds which may experience development or redevelopment during the project's design life, watersheds where agricultural practices are changing or may change during the project's design life, and watersheds where reservoirs may be constructed or removed, and various instances of watershed change. This however, is generally well beyond the limits of available datasets as well as the statistical validity of such extrapolations. Again as with the Analog methodology, this method is generally suitable for sites at which the hydrologic response of the contributing watershed is significantly stable and will remain such for the intended lifetime of the project.

**Analytical Methodology**
The Analytical methodology is based on the application of physically based mathematical models of natural phenomena to the project site and watershed. This methodology is quite different from the Analog and Empirical methodologies as no dependence is placed on datasets external from the project. Temporally and spatially distributed phenomena may also be addressed with this methodology, as opposed to Analog and Empirical methodologies. The Analytical methodology is typified by the system simulation method and is the primary methodology employed by the US Army Corps of Engineers and the US Geological Survey.

To successfully employ the Analytical methodology, two considerations must be met: 1) the designer must be able to adequately mathematically describe the relevant primary natural phenomena within the system; 2) adequate environmental parameters must be available to drive the mathematical model of the system. If these conditions are not met, this methodology is not applicable for project design.

The Analytical methodology is the most flexible and robust of the three methodologies presented and the only one that can be used to design and analyze the system for specific project functions such as pollutant removal, flood attenuation, and habitat development. This methodology can be applied to projects in urbanizing watersheds, watersheds which may experience development or redevelopment during the project's design life, watersheds where agricultural practices are changing or may change during the project's design life, watersheds where reservoirs may be constructed or removed, and other various instances of watershed change as well as significantly stable watersheds.

**Project Analysis and Design Restoration Approach**

As noted previously, the Overhills (Nursery Road) stream and wetland restoration project is located in the Sandhills of North Carolina. The Sandhills is one of five distinct hydrophysiographic regions in the State. These are the Mountains, Piedmont, Sandhills, Coastal Plain, and Tidewater regions. Individual regions vary from other regions with regards to base flow, infiltration, heat flux, evapotranspiration, runoff response, and various other hydrologic phenomena. Compared with the other four hydrophyisographic regions in the State, relatively little surface water flow and stream stage data is available for the Sandhills region.

Undeveloped watersheds in the Sandhills region are typified by moderate to high infiltration potential sandy soil systems with moderate to high relief. This results in relatively high stream base flows and highly buffered precipitation runoff response. This is in contrast to much of the Piedmont region (bordering the Sandhills region to the West) which is typified by low to moderate infiltration potential clayey soil systems with moderate to high relief. This results in much lower stream base flows and much less precipitation runoff response buffering.

When developing the analysis and design approach, the system location, project goals, and available project timeline were particularly taken into consideration. A hybrid analysis and design approach was developed for the project which utilized aspects of the Analog (reference reach) and Empirical (regime reach) methodologies with the Analytical (system simulation) approach at the core. The approach developed involved a combination of a variety of stream restoration and hydraulic design techniques. The specific methods used included natural channel design, sandbed stream design methods, and other stable channel engineering methods. The approach also includes integration of advanced watershed hydrologic and stream hydraulic modeling, utilizing event based models such as HEC-HMS, a continuous simulation model HSPF, and the hydraulic model HEC-RAS to aid in the analysis. The methods and analyses used to develop the design for this project are well documented and have been used on many projects. A few of the main sources detailing these methods are referenced at the end of this section. Although modified slightly as the project progressed, the general analysis and design approach employed is as follows:

I. Rough Conceptual Stage
   A. Simulate watershed event response using SCS/CN method and 2 year return interval design storm
   B. Use HEC-15 for stream hydraulics analysis (simple channel)
   C. Compare parameters from simple channel analysis with reference stream parameters and regime equations
   D. Set bankfull elevation at floodplain elevation
   E. Run DRAINMOD (using controlled drainage option) to analyze site (wetland) hydrology and reanalyze

II. Refined Conceptual Stage
   A. Simulate watershed event response using HEC-HMS and 0.5, 1, 1.5, 2, 10, 25, and 50 year return interval design storms
   B. Use HEC-RAS for stream/floodplain hydraulics analysis
   C. Compare parameters from simple channel analysis with reference stream parameters and regime equations
   D. Set bankfull elevation at floodplain elevation
   E. Run DRAINMOD, EEAMOD, or similar (using controlled drainage option) to analyze site (wetland) hydrology
   F. Raise/lower bankfull/floodplain/berm elevations and modify channel parameters as needed and reanalyze

III. Schematic Design Stage
   A. Simulate continuous watershed response using calibrated HSPF and nearby precipitation gauge data
   B. Use BRI-STARS for stream/floodplain hydraulics and sediment transport analysis
   C. Analyze pollutant treatment processes using PREWET
   D. Run RefET to analyze site potential evapotranspiration
   E. Run calibrated MODFLOW to analyze site soil water hydraulics
   F. Raise/lower bankfull/floodplain/berm elevations and modify channel parameters as needed and reanalyze

IV. Detailed Design Stage
   A. Simulate continuous watershed response using calibrated HSPF and point adjusted NEXRAD areal precipitation data
   B. Use calibrated BRI-STARS for stream/floodplain hydraulics and sediment transport analysis
   C. Run RefET to analyze site potential evapotranspiration with modifications based on site weather station data
   D. Run calibrated MODFLOW (with wetland package) to analyze site soil water hydraulics and site pollutant transport/treatment
   E. Analyze pollutant treatment processes using HSPF, DRAINMOD-N, and EEAMOD
   F. Raise/lower bankfull/berm elevations and modify channel parameters and floodplain elevations as needed and reanalyze

**Restoration Potential**
The project site has excellent potential for a high quality stream restoration project. Located in a broad valley, the site provides adequate room to utilize a full range of belt width and meander forms. The significant floodplain available also means that floodprone area requirements will be easily achieved. There is no adjacent development that would restrict the design. The only constraint from a flooding and safety perspective is Nursery Road, which is at the southern boundary of the site. The combination of these allows a Priority 1 stream restoration design to be pursued. Priority 1 is the highest level of stream restoration and involves reestablishing a new stream channel near its original elevation and reconnecting it with its historical floodplain.

Although this site has many advantages, their are several distinct challenges with a Priority 1 project. Because the design requires changing the channel bed elevations,  special attention must be paid to structure design and installations to prevent the possibility of headcuts (downstream) and channel incision (upstream). A detailed hydraulics analysis is also necessary to prevent backwater effects, increased upstream flooding, and high shear stresses associated with velocity changes. Another challenge to this project was developing a design for a sandbed stream system. As discussed in the above design approach sections, many of the most recognized design procedures were developed for use with gravel bed streams with higher slopes, and have limited applicability in sandy systems with high water tables.

**Stream Dimensional Design**
The reference stream was found to have an average bankfull width of 14.4 feet. Sideslopes of the reference were found to be quite steep. These sideslopes are supported by dense vegetation on the channel banks including overhanging trees. Tree roots were prominent in the channel banks and were also found traversing the channel bed. Due to the sandy, non-cohesive soils in the area, steep bank angles would not be stable without dense vegetative root mass. This vegetative support will take years to develop and the proposed stream will have to be constructed to remain stable independent of such devices. As a result, the restored stream will be designed to remain stable based on its geometry and a limited amount of vegetative cover and protection. Although the bankfull depth will be similar to the reference reach, the result is a stream with a larger cross sectional area and sideslopes with a flatter, more stable repose angle.

Flat slopes, sandy soils, and high water tables create completely different hydrologic system dynamics in the sandhills than in the piedmont and mountain regions. The interaction between streams and high water tables in these areas effects stage return intervals and flooding frequency. Vegetation serves as a primary constraint to stream geometry and evolution. These factors complicate the relationship between bankfull flow and channel forming flow. As mentioned in the Reference Stream Investigation section, bankfull events were recorded frequently during the monitoring period. Over a period of 10 months, 10 bankfull or higher events were measured at our stream gage along with corresponding surface water ponding measurements in the wetland/floodplain. Research, completed on coastal plain stream gage data in North Carolina by Ecoscience Corporation, indicates bankfull return intervals with an average of 0.61 year. Another analysis indicated even more frequent return intervals, with an average of 0.18 year. Research by NCSU Stream Restoration Institute report coastal plain bankfull recurrence intervals around 1 year. Based on the data from our reference site, recent research data, and experience with sandhills stream and wetland systems, there is significant evidence that the stream should be designed with a bankfull flow return interval of less than the typically recommended 1.5 years.

The stream restoration design may skew from typical templates for piedmont, mountain, and even coastal plain streams. Cross sectional areas will be larger than the reference due to sandy material and the absence of vegetation. The size of the project dictates that flowrates and sediment loads will change along the length of the stream. Therefore, the stream dimensions and slope will vary slightly from upstream to downstream. The channel dimensions will be balanced to maintain water depths that remain near the surface for lengthy periods during the year. This will restrict drainage and support restoration of the riparian wetland water table. The channel capacity (geometry and slope) will be designed to encourage overbank flow at frequent return intervals that will promote extended flooding and storage in the wetland.

Initial dimensional designs were driven by bankfull flowrate determinations. Investigation of bankfull flowrates was completed using several methods, including draft regional relationships for the coastal plain, although they are not generally considered applicable in the sandhills. Regional curves have not been developed for the sandhills region, and due to the distinct differences in system response dynamics, applicability of data developed from coastal plain relationships should be considered carefully. Additional initial flowrate estimates were made using hydraulic analysis of the existing and reference streams (Manning's and HEC-RAS), the Copeland Method for mobile stream beds, and event watershed modeling (HEC-HMS). Calculations were then made to determine potential dimensions and slopes based on discharge capacity and stable channel design methods such as HEC-15 (limiting velocity, tractive force or shear stress/Shields Curve), and empirical sediment transport/mobile bed (Regime Equations, Copeland Method) techniques. The table below presents a summary of the results achieved using these methods. Further data and graphs are included in Appendix L.

*Table 9-1. Stream Dimensional Design  Options*

| **Stream Dimensional Design Methods** | **Q bkfl** | **Slope** | **Depths** | **Bankfull Width** |
|---|---|---|---|---|
| | cfs | ft/ft | ft | ft |
| **Regional Relationship Approaches - Coastal Plain** | | | | |
| NCSU SRI Draft Relationships | 131 | - | 2.9 | 30.7 |
| Ecoscience Draft Relationships | 71 | - | 2.6 | 27.4 |
| | | | | |
| **Stable Channel Method** | | | | |
| HEC-15, limiting velocity and critical shear stress | 40-70 | 0.0067-0.001 | 2-2.7 | 20.5-23.5 |
| | | | | |
| **Regime Equations** | | | | **Mean Widths** |
| Simon and Albertson Regime | 40-70 | 0.000046-0.000054 | 2.4-2.9 | 19.9-26.4 |
| Blench Regime | 40-70 | 0.00024-0.00027 | 1.3-1.6 | 23.2-30.7 |
| Chang Regime - Region 1 | 40-70 | 0.00039-0.00051 | 0.8 | 18.6-24.2 |
| **Summary - Regime Equations** | 40-70 | .000046-.00051 | 0.8-2.9 | 18.6-30.7 |
| | | | | |
| **Empirical Methods - Mobile Beds** | | | | **Bankfull Widths** |
| HEC-RAS, Copeland - Inflow 0ppm | 40-70 | 0.000067-0.000091 | 3.0-5.1 | 22-37.5 |
| HEC-RAS, Copeland - Inflow 75ppm | 40-70 | 0.00068-0.00081 | 1.9-2.9 | 16.5-26.5 |
| HEC-RAS, Copeland - Inflow 175ppm | 40-70 | 0.001-0.0012 | 1.8-2.6 | 16-25 |
| **Summary - Copeland Method** | 40-70 | .00068-.0012 | 1.8-2.9 | 16-37.5 |

The results of regional relationship, tractive force, and Copeland methods exhibited some similarities. Regime equations tended to generate results with much wider and shallower channels, with flatter longitudinal slopes. Using the results of these methods and sound engineering judgment, initial dimensions were chosen for further analysis and testing with the final pattern and profile designs. The base width of the design channel will vary from 10 feet to 12 feet. Sideslopes will be set to 2.5:1 (H:V) and will be protected with erosion control fabric. The bankfull depth will be the same as the reference reach at 2.5 feet. Design top widths range between 21 and 25 feet, with an average of 22.5 feet. This will create an average width to depth ratio of 9.0. Although this ratio is higher than at the reference site, it is consistent with data presented by various research projects.

**Stream Pattern Design**

The existing channel has no natural developed meander bends for channel analysis. The reference site has several meanders which were used to determine initial pattern information. However, it was found that the reference site is significantly supported by root mass and dense stream side vegetation. Radius of curvature measurements had large variations and were as tight as 12 feet. The new stream must be stable for a long period of time prior until vegetation can develop significantly enough to fully support the channel. Therefore, developed equations and ratios were used to generate estimates for the design pattern information. The pattern design was then developed utilizing site contours and a range of pattern values. The pattern design resulted in a restored channel length of 4,530 feet. With a valley length of 2,808 feet, this results in an average sinuosity of 1.6. Testing was then completed for shear stresses using a variety of flow conditions to ensure the stability of meander bends. In-stream structures will help add a safety factor to meander bends and erosion control fabric will be used to add temporary bank protection while vegetation develops. A plan view of the design stream alignment is included at the end of this section.

**Stream Profile Design**

The reference stream average hydraulic slope is 0.00067 ft/ft. This slope was used as a basis for slope analysis and determination. Our reference reach observations indicate a dynamic bedform. Due to the sandy material in the stream, bedforms such as glides and pools change with flow events. Typically, pools form on the outside of meander bends and around woody debris after storm events. These pools gradually fill in due to deposition during lower flow periods. The restored stream will likely develop similarly and attempts to force bedform development will lead to localized instability problems. As a result, the design has been developed to encourage a naturally dynamic bedform with the use of woody structure but will not include the initial creation of bedform features. A profile chart showing the existing channel bed, existing ground surface, and proposed stream bed is included at the end of this section.

As the restored stream will need to be stable under a variety of conditions, analysis was completed to determine a range of stable slope possibilities. The restored stream reach slopes will vary from 0.0007 to 0.001 ft/ft. Over the last 800 feet of the project, a series of log structures will be used to gently drop the streambed back down to reconnect it with the existing channel. The structures will be placed on approximately 50 foot intervals and will lower the streambed approximately 2.5 inches each. A morphological table comparing the existing, reference, and design stream is included at the end of this section.

**Sediment Transport and Shear Stress**

Typical sediment transport calculations for stream restoration projects involve either a limiting velocity approach or critical shear stress analysis and comparison using standards such as the Shield's Curve. These analyses are referred to as tractive force methods because they provide data that represents the force needed to initiate transport of a specifically sized bed particle. An important aspect of these methods is that determinations are made independently of incoming sediment loads. As a result, values that indicate movement may occur do not necessarily indicate corresponding erosion will occur. Such analysis can be computed using spreadsheets or with a variety of computer models. These are the simplest stability methods and involve a number of assumptions. However, determinations and comparisons must be adjusted based on the high degree of variability between stream factors such as flood (design storm) frequency, radius of curvature, surface width, slope angle, and water depth. A fair amount of engineering judgment is required and other factors such as roughness and protection should be incorporated to accurately utilize such analyses. These methods are applicable for use on streams with gravel or larger bed material and higher slopes which reduce the possibility of backwater effects. These methods are also typically used with the bankfull flowrate and a composite geometry and slope for the design stream.

It is especially difficult to apply tractive force methods to sandbed streams. Sediment transport in such systems occurs regularly and stability is a delicate balance between incoming sediment load and deposition and localized erosion and scour. In a sandy system, the potential for deposition and aggradation must be equally weighed with the potential for erosion and degradation. Therefore, approaches to determine channel stability must utilize the above procedures, but also incorporate additional detailed methods to assess this balance.

Both a limiting velocity and critical shear stress analysis were completed for the design stream. To improve applicability, these calculations were initially completed for a range of possible flowrates, channel dimensions, and slopes. The calculations will also be applied throughout the stream reach to account for localized slope and meander conditions. Velocity and shear stress will be calculated for a variety of storm events over the entire stream reach using HEC-RAS hydraulic analysis software. These values will then be compared to published thresholds. Velocity thresholds for sandy materials typically range between 2-2.5 ft/s. Critical shear stress values typically range between 0.02-0.04 lb/sf. Higher velocities and shear may be allowable depending on incoming sediment supply and bank protection. Additional protection measures such as rootwads and cross vanes will also be used to ensure bank stability and grade control in potential problem areas. An additional analysis of stream power will also be completed. This method involves a combination of velocity and shear stress to create a measure of stream stability. The method has published recommended minimums (to prevent aggradation) and maximums (to prevent degradation) for stream power. Brookes (referenced in Stream Corridor Restoration Handbook) developed thresholds for sandy streams. He found that sandy systems with stream powers above 0.685 ft lbs/s sf and below 6.85 ft lbs/s sf to be the most stable. A stream power analysis will be completed for a variety of design storm events and for time series flow predictions.

*Table 9-2. Tractive Force Analysis*

| **Tractive Force Analysis Summary** | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | **Output** | | **Thresholds** | **Results** |
| Flow Tested (cfs) | 40-70 | Depth (ft) | 2.2-2.8 | | |
| Base Width (ft) | 7-10 | Velocity (ft/s) | 1.4-2.1 | 2-2.5 | **STABLE** |
| Sideslope (ft/ft) | 2.5 | Shear Stress (lb/sf) | 0.01-0.03 | 0.02-0.04 | **STABLE** |
| Profile Slope (ft/ft) | 0.0067-0.001 | | | | |

Further analysis is also being completed using a dynamic hydraulic model, BRI-STARS, which was developed by the US Federal Highway Administration. BRI-STARS is a stream tube model, developed based on the USGS model GSTARS. BRI-STARS computes hydraulic pressures similar to HEC-RAS, but also has the capability to complete a full sediment transport analysis based on incoming sediment loads, shear stress, scour, and bank movement. This analysis will be used to test the stability of the design stream dimensions and pattern during design storms and over a long period of time. Predicted time series, modeled with HSPF, of inflows and sediment loads will be routed through the model. This analysis will not only predict the stability of the stream on an event basis, but will also provide a test of stream response to more naturally occurring storm shapes and frequencies.

**In-Stream Structures**

In-stream structures will be used along the length of the stream to provide grade control, extra bank protection, and encourage development of bedform features. The reference site has an abundance of woody debris in the stream. Roots from streamside trees traverse the bed and fallen trees and limbs were found frequently along the stream. Although it is expected that this random development of structure in the stream will develop over time, the effect of introduced structure would cause increase local stress on the new channel and banks. Therefore, structure placement will be limited to ensure grade control and stability while the streamside vegetative community develops. Root wads will be installed in every meander bend. A variety of different log structure designs will be used. Several typical designs are included in this document. These structures will be securely seated and sealed using compacted sand and clay or filter fabric. Log structures may be supported with vertically driven rootwads or other additional woody debris. Log cross vanes will be installed at grade.

**Restoration Background Information References**

Copeland, Ronald R, Dinah N McComas, Colin R Thorne, Philip J Soar, Meg M Jonas, and Jon B Fripp, 2001 Hydraulic Design of Stream Restoration Projects (ERDC/CHL TR-01-28) US Army Corps of Engineers, Coastal and Hydraulics Laboratory, Vicksburg, MS

Federal Interagency Stream Restoration Working Group, 1998 Stream Corridor Restoration: Principles, Processes, and Practices National Technical Information Service, US Department of Commerce, Springfield, VA

Millar, R G and B J MacVicar, 1998 An analytical method for natural channel design In: Proceedings of the ASCE Wetlands Engineering and River Restoration Conference, Denver, CO

Miller, D E and P B Skidmore, 2001 Natural Channel Design: How Does Rosgen Classification-Based Design Compare with Other Methods? In: Proceedings of ASCE Wetlands/River Restoration Conference, Reno, NV

Pope, Benjamin F, Gary D Tasker, and Jeanne C Robbins, 2001 Estimating the Magnitude and Frequency of Floods in Rural Basins of North Carolina - Revised (WRIR 01-4207) US Geological Survey, Raleigh, NC

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

Skidmore, P B, F D Shields, M W Doyle, and D E Miller, 2001 A Categorization of Approaches to Natural Channel Design In: Proceedings of ASCE Wetlands/River Restoration Conference, Reno, NV

Thorne, Colin R and Philip J Soar, 2001 Channel Restoration Design for Meandering Rivers (ERDC/CHL CR-01-1) US Army Corps of Engineers, Coastal and Hydraulics Laboratory, Vicksburg, MS

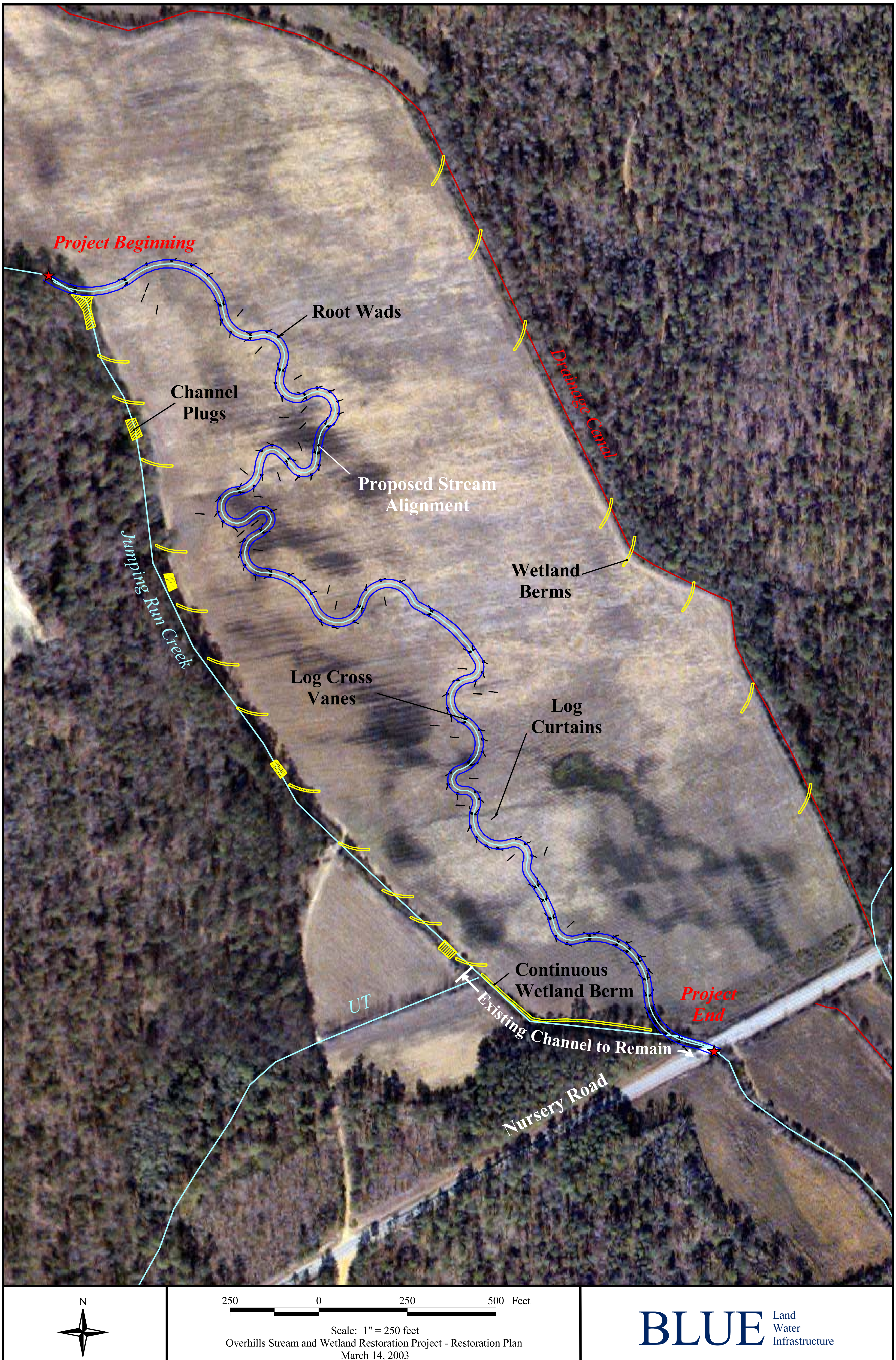
Weaver, J Curtis and Benjamin F Pope, 2001 Low-Flow Characteristics and Discharge Profiles for Selected Streams in the Cape Fear River Basin, North Carolina, through 1998 (WRIR 01-4094) US Geological Survey, Raleigh, NC

| | Existing Stream | | | Reference Reach | | | Design Stream | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **MIN** | **MAX** | **AVERAGE** | **MIN** | **MAX** | **AVERAGE** | **MIN** | **MAX** | **AVERAGE** |
| Drainage Area, DA (sq mi) | 15.5 | 15.9 | 15.7 | 14.7 | 14.8 | 14.8 | 15.5 | 15.9 | 15.7 |
| Stream Type (Rosgen) | G5c | G4 | G5c | E5 | C5 | E5 | E | C | E |
| Bankfull XSEC Area, Abkf (sq ft) | 54.6 | 77.5 | 56.7 | 13.5 | 22.1 | 21.8 | 35.0 | 46.0 | 41.0 |
| Bankfull Width, Wbkf (ft) | 11.7 | 15.9 | 14.5 | 10.8 | 20.4 | 14.4 | 21.0 | 25.0 | 22.5 |
| Bankfull Depth, Dbkf (ft) | 2.4 | 2.5 | 2.5 | 1.0 | 2.7 | 2.7 | 2.5 | 2.5 | 2.5 |
| Width to Depth Ratio, W/D (ft/ft) | 4.9 | 6.4 | 5.8 | 4.1 | 7.7 | 5.4 | 8.4 | 10.0 | 9.0 |
| Width Floodprone Area, Wfpa (ft) | - | - | 16.5 | - | - | 200 | - | - | 200 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | - | - | 1.2 | - | - | 13.9 | - | - | 8.9 |
| Max Depth @ bkf, Dmax (ft) | 2.4 | 2.5 | 2.5 | 1.8 | 4.2 | 3.2 | 2.5 | 2.5 | 2.5 |
| Max Depth Ratio, Dmax/Dbkf | | | 1.0 | 0.7 | 1.6 | 1.2 | 1.0 | 1.0 | 1.0 |
| Max Depth @ tob, Dmaxtob (ft) | 5.5 | 7.0 | 6.0 | 2.0 | 4.8 | 4.0 | 2.5 | 6.0 | 2.5 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 2.2 | 2.8 | 2.4 | 0.6 | 1.5 | 1.2 | 1.0 | 2.4 | 1.2 |
| Meander Length, Lm (ft) | 315 | 660 | 500 | 125 | 175 | 150 | 125 | 250 | 200 |
| Meander Length Ratio, Lm/Wbkf | 21.8 | 45.6 | 34.5 | 8.7 | 12.2 | 10.4 | 5.6 | 11.1 | 8.9 |
| Radius of Curvature, Rc (ft) | - | 235.0 | 235.0 | 12.0 | 30.0 | 23.4 | 30.0 | 175.0 | 80.0 |
| Rc Ratio, Rc/Wbkf | - | 16.2 | 16.2 | 0.8 | 2.1 | 1.6 | 1.3 | 7.8 | 3.6 |
| Belt Width, Wblt (ft) | - | - | 596.8 | 45.0 | 110.0 | 77.0 | 80.0 | 200.0 | 110.0 |
| Meander Width Ratio, Wblt/Wbkf (ft) | - | - | 41.2 | 3.1 | 7.6 | 5.3 | 3.6 | 8.9 | 4.9 |
| Sinuosity, K | - | - | 1.1 | - | 2.3 | 1.4 | - | 2.1 | 1.6 |
| Valley Slope, Sval (ft/ft) | - | - | 0.0005 | - | - | 0.0007 | - | - | 0.0005 |
| Channel Slope, Schan (ft/ft) | - | - | 0.0016 | - | - | 0.0090 | 0.0007 | 0.0010 | 0.0009 |
| | | | | | | | | | |
| d16 (mm) | 0.22 | 0.42 | 0.2 | 0.32 | 0.40 | 0.35 | 0.2 | 0.4 | 0.22 |
| d35 (mm) | 0.43 | 2.70 | 0.4 | 0.45 | 0.39 | 0.37 | 0.4 | 2.7 | 0.43 |
| d50 (mm) | 0.50 | 9.00 | 0.5 | 0.58 | 0.65 | 0.62 | 0.5 | 9.0 | 0.5 |
| d84 (mm) | 2.60 | 30.00 | 2.6 | 1.70 | 1.70 | 1.70 | 2.6 | 30.0 | 2.6 |
| d95 (mm) | 36.00 | 38.00 | 36.0 | 2.40 | 2.40 | 2.40 | 36.0 | 38.0 | 36 |

# MAP 9A

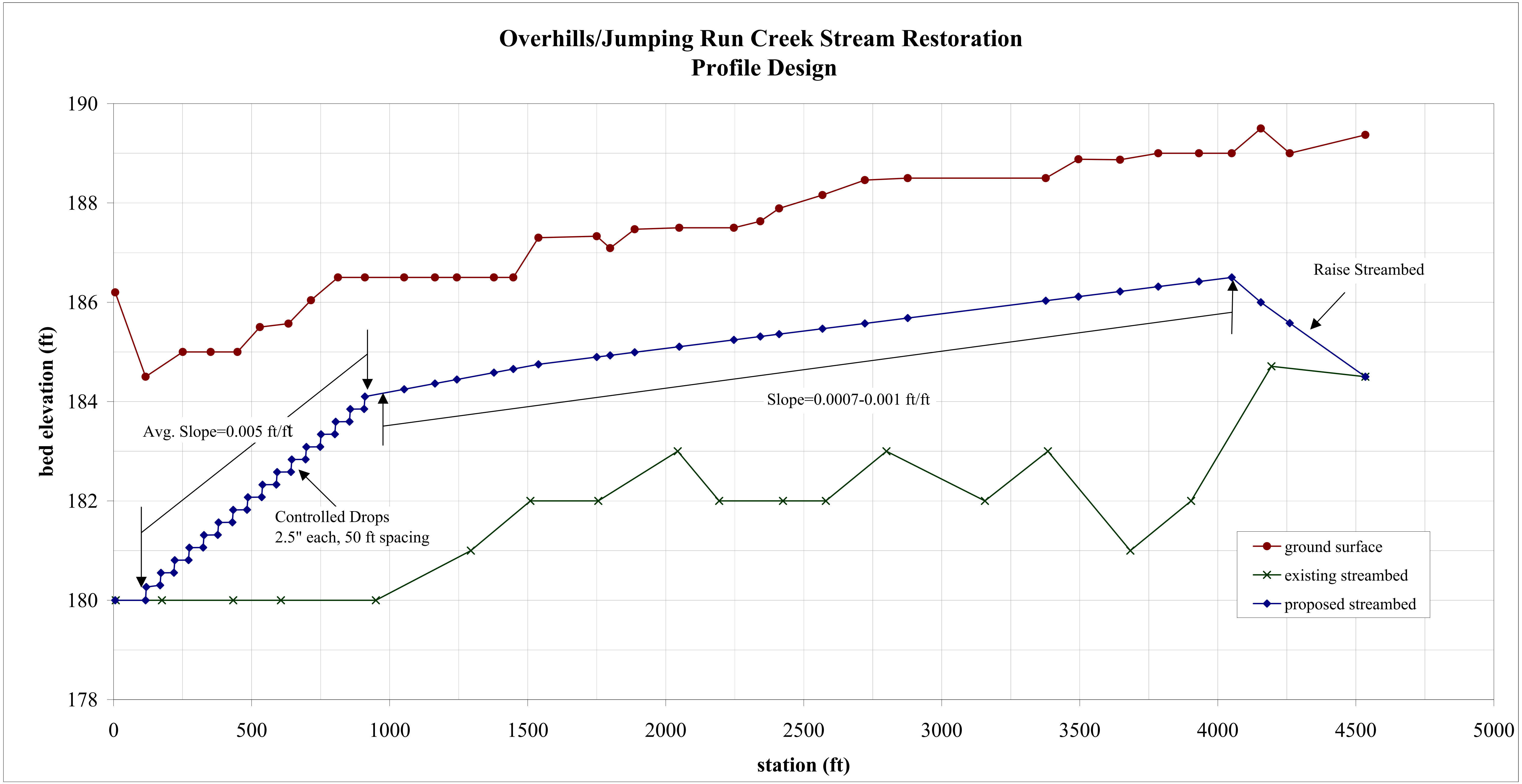
# PROPOSED STREAM ALIGNMENT AND STRUCTURES

# Proposed Stream Alignment and Structures



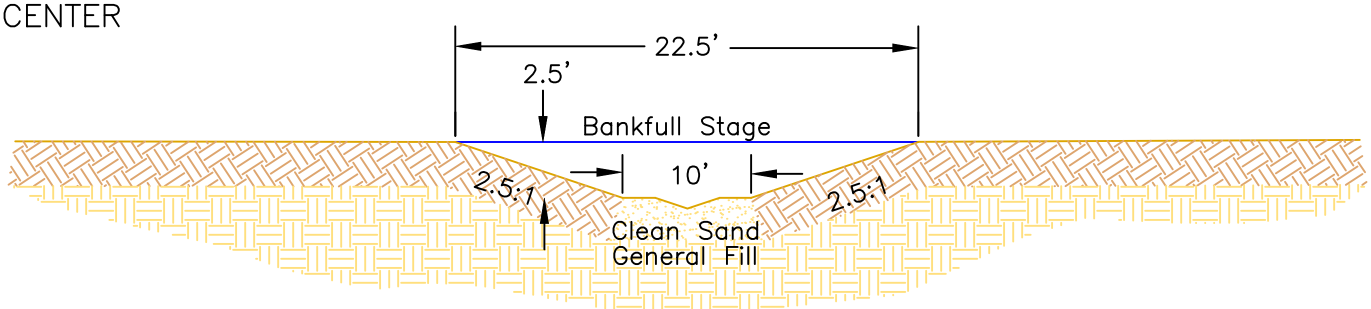

Scale: 1" = 250 feet
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

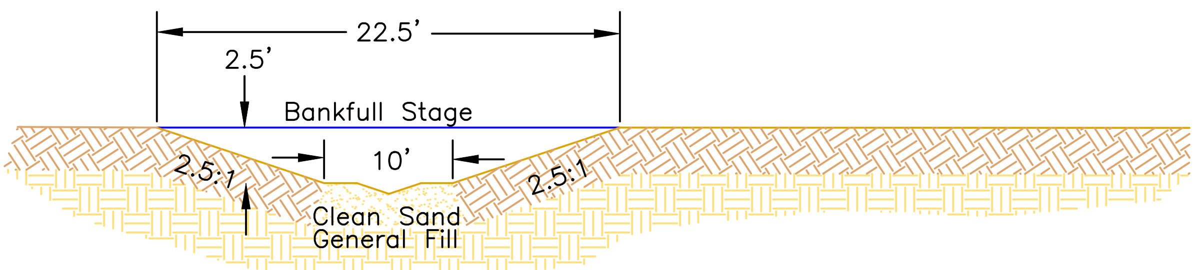

Overhills/Jumping Run Creek Stream Restoration
Profile Design
bed elevation (ft)
station (ft)
190
188
186
184
182
180
178
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Raise Streambed
Slope=0.0007-0.001 ft/ft
Avg. Slope=0.005 ft/ft
Controlled Drops
2.5" each, 50 ft spacing
ground surface
existing streambed
proposed streambed

# TYPICAL CHANNEL CROSS–SECTIONS
N.T.S.

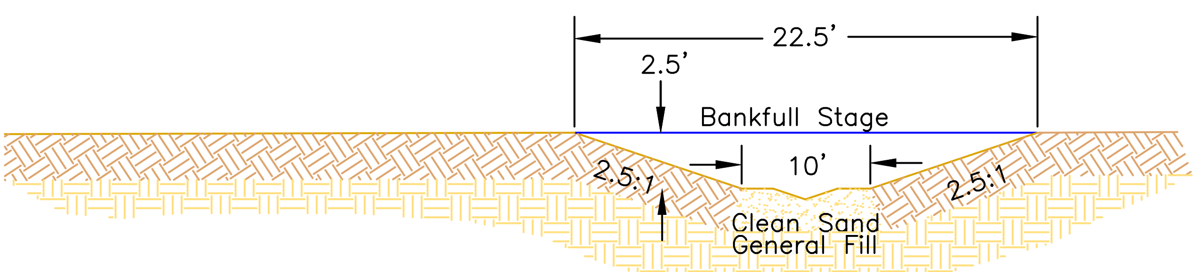
CENTER




LEFT

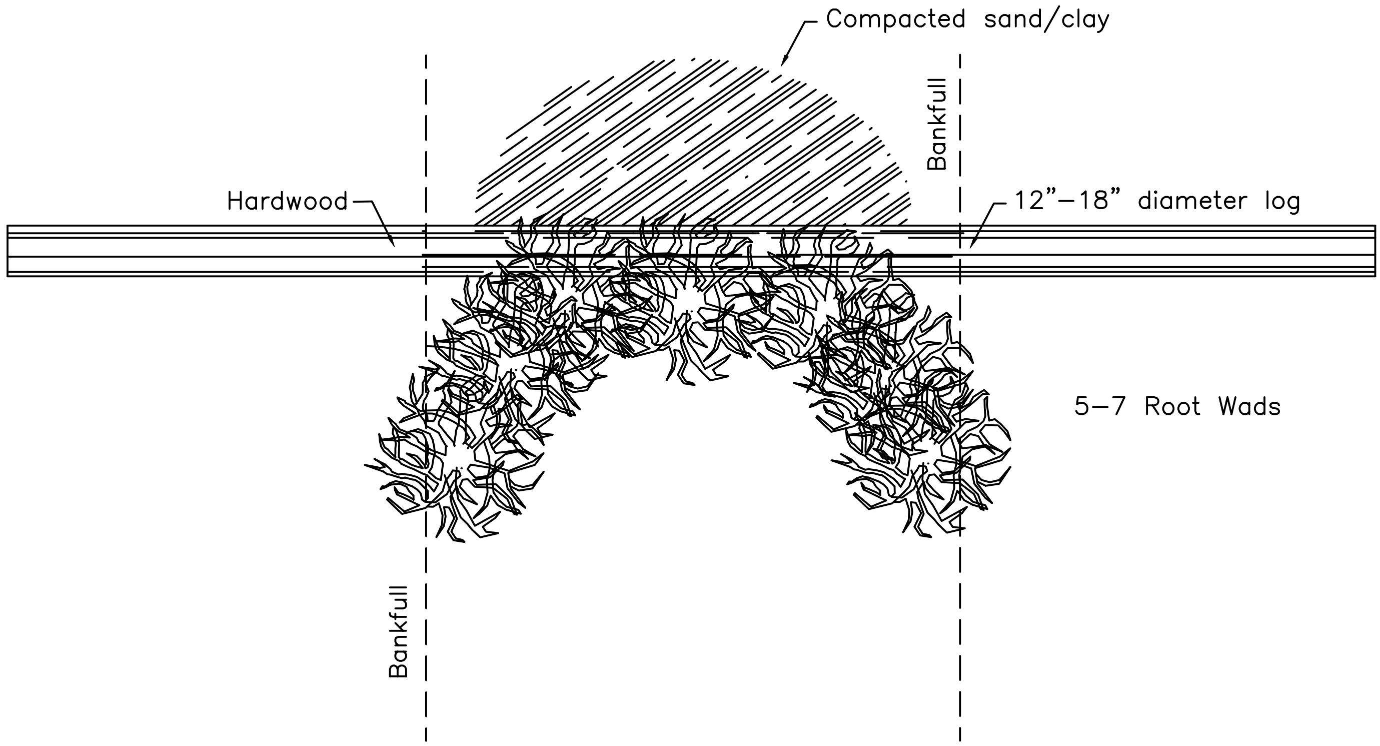


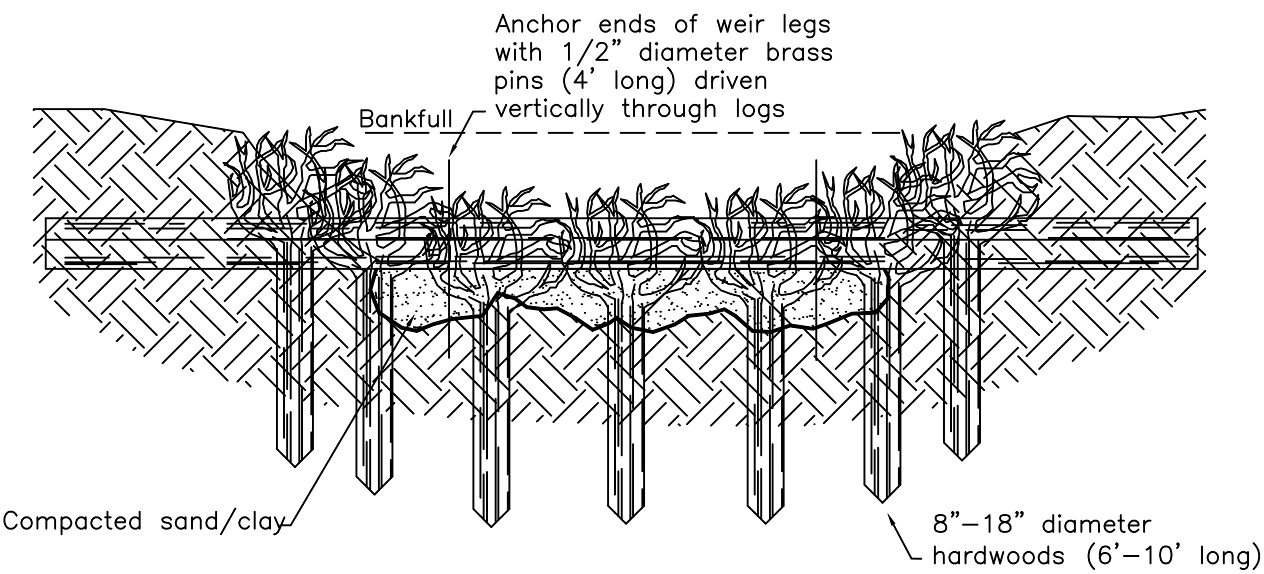

RIGHT



# Log Cross Vane

N.T.S.

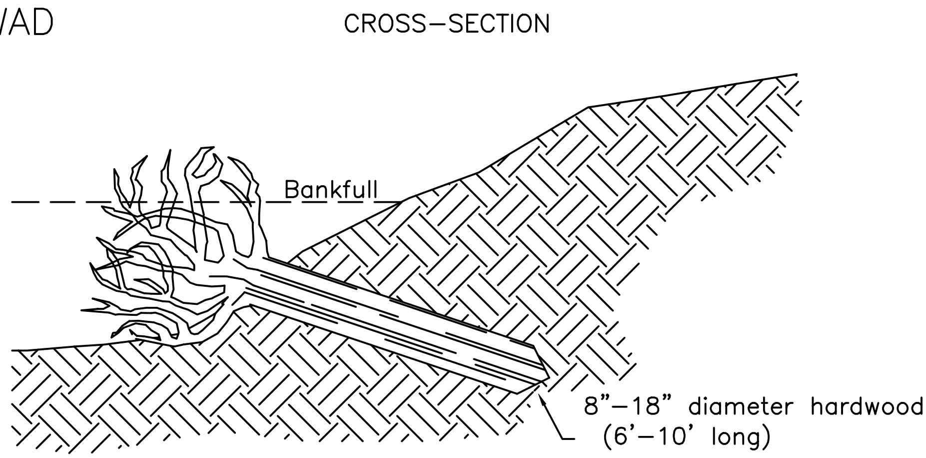


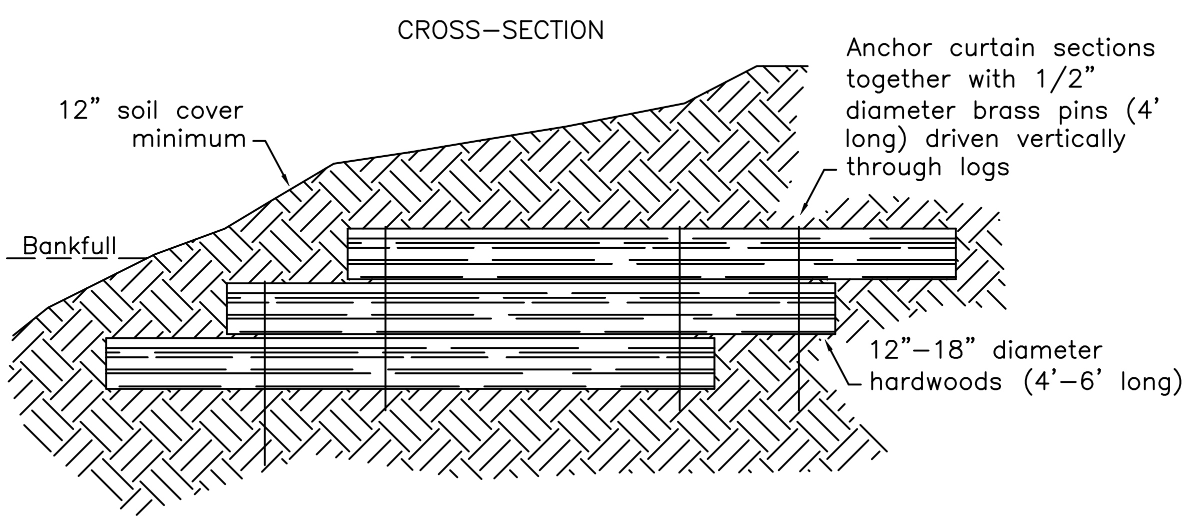




5–7 Root Wads

## ROOT WAD

N.T.S.


CROSS–SECTION
Bankfull
8"–18" diameter hardwood
(6'–10' long)


CROSS–SECTION
12" soil cover
minimum
Bankfull
Anchor curtain sections
together with 1/2"
diameter brass pins (4'
long) driven vertically
through logs
12"–18" diameter
hardwoods (4'–6' long)

## 11. Stream Riparian Planting Plan

The stream corridor will be planted with the same vegetation as proposed for the surrounding wetlands. Refer to Section 7 - Vegetation Community Restoration. Additional plantings will be used in strategic areas such the outside of meander bends and near structures to improve stability. Additional plantings will be based on the reference site plant list and availability at the time of planting.

## 12. Stream Monitoring Plan

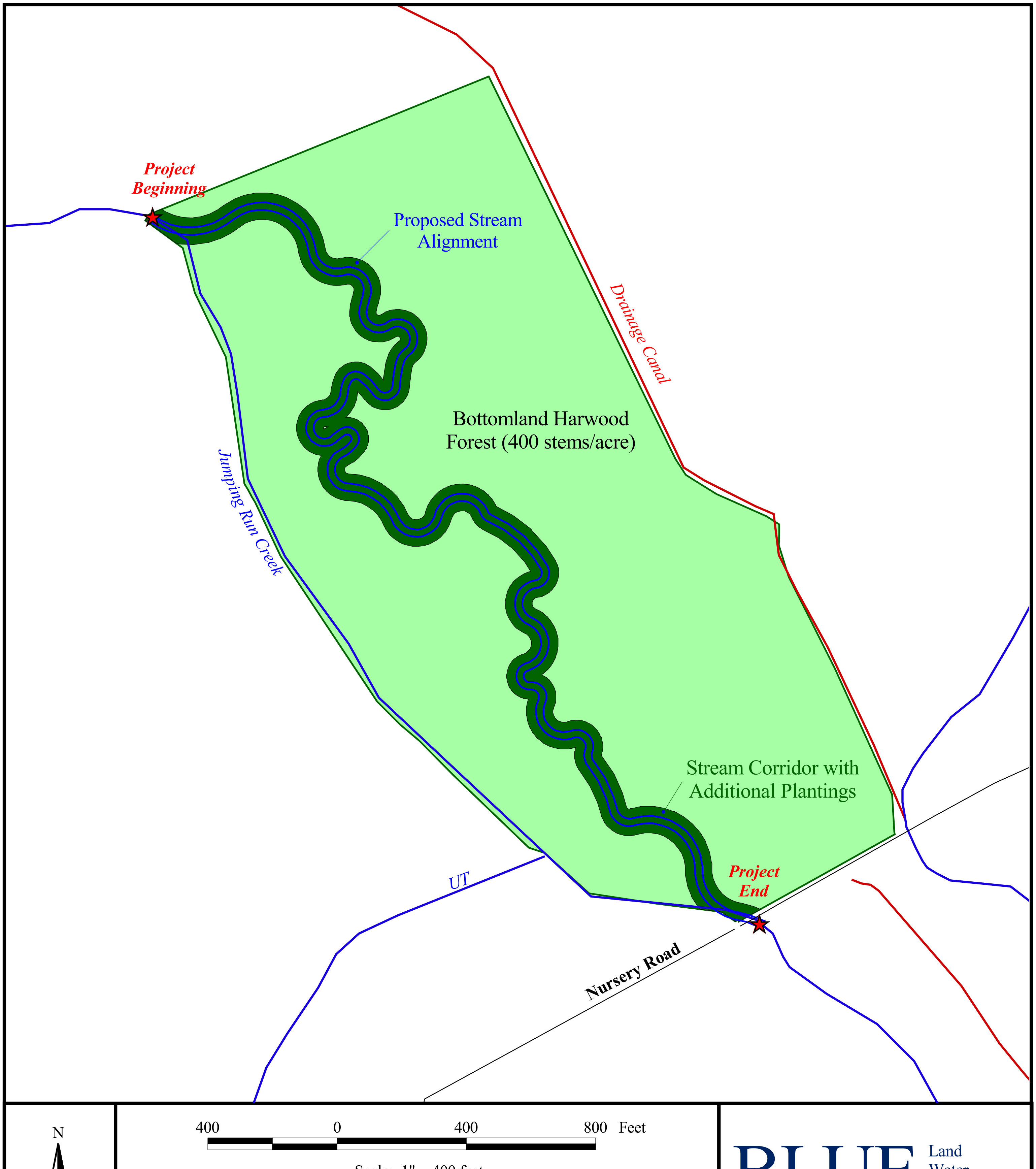
The stream will be monitored for a period of five (5) years. During the first year, the site will be visited 3 times for visual inspection for general site conditions, presence of eroding banks, condition of the installed structures and stability of the ditch plugs. Near the end of the first year of project implementation and each subsequent year, the stream will be surveyed for existing conditions and general evaluations will be made. Eight cross-sections will be surveyed along the stream channel (refer to map showing these locations) to determine stream development and for comparison to stream design parameters. The ditch plugs will be examined for stability and sufficient ground cover. Any invasive woody vegetation will be removed at this time.

Permanent photo stations will be established at key points for compiling a record of project success over the monitoring period. A map of the proposed monitoring survey, gage, and vegetation plot locations is located at the end of this section.

# MAP 12A

# PROPOSED VEGETATIVE COMMUNITIES

# Proposed Vegetative Communities




Scale: 1" = 400 feet
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

# MAP 12B

# MONITORING PLAN

# Monitoring Plan


N

250 0 250 500 Feet

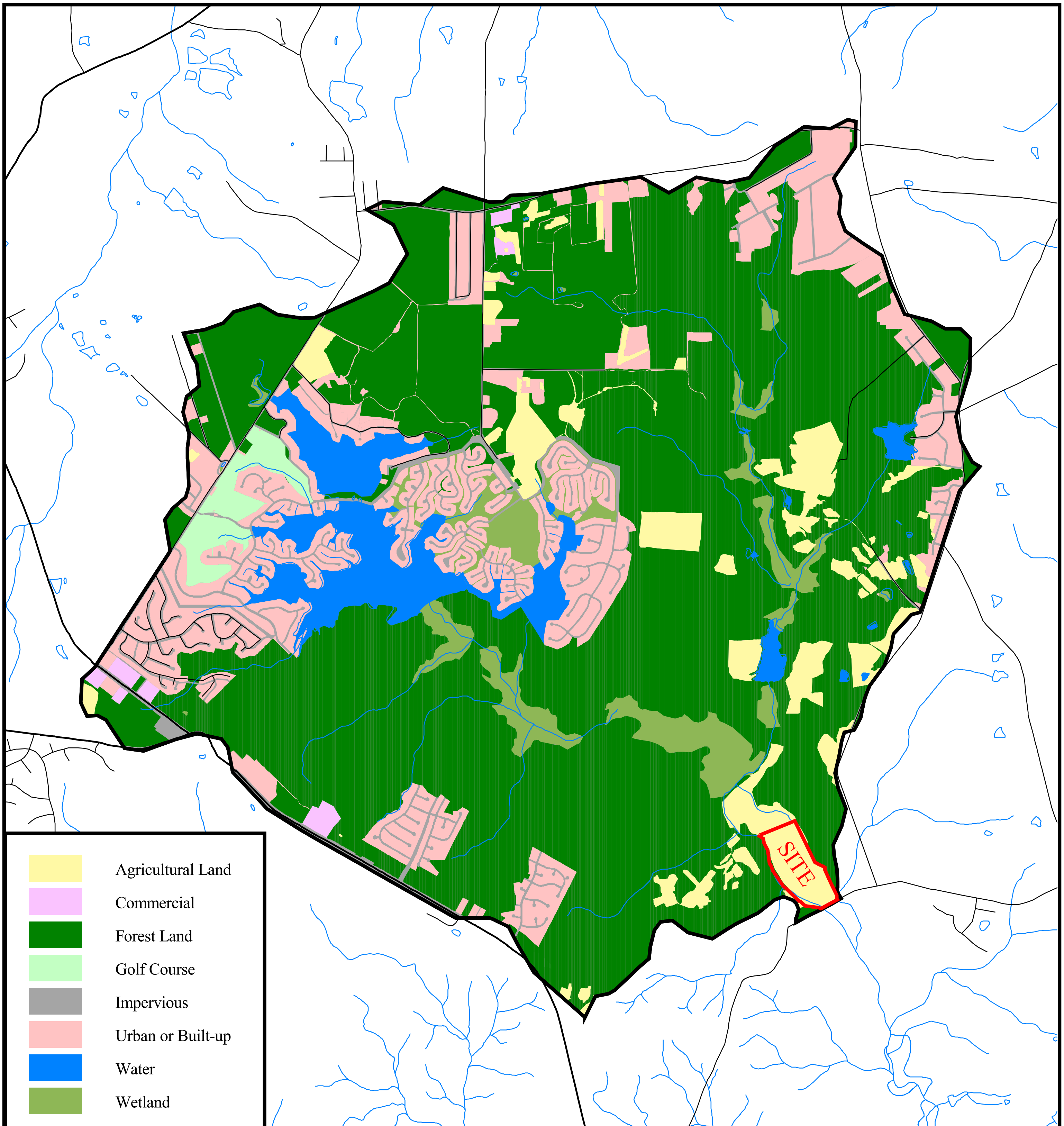
Scale: 1" = 250 feet
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

# APPENDIX A

# WATERSHED LAND USE/LAND COVER MAP

# Watershed Land Use/Land Cover Map




N

0.75 0 0.75 1.5 Miles

Scale: 1" = 0.75 mile

Overhills Stream and Wetland Restoration Project - Restoration Plan

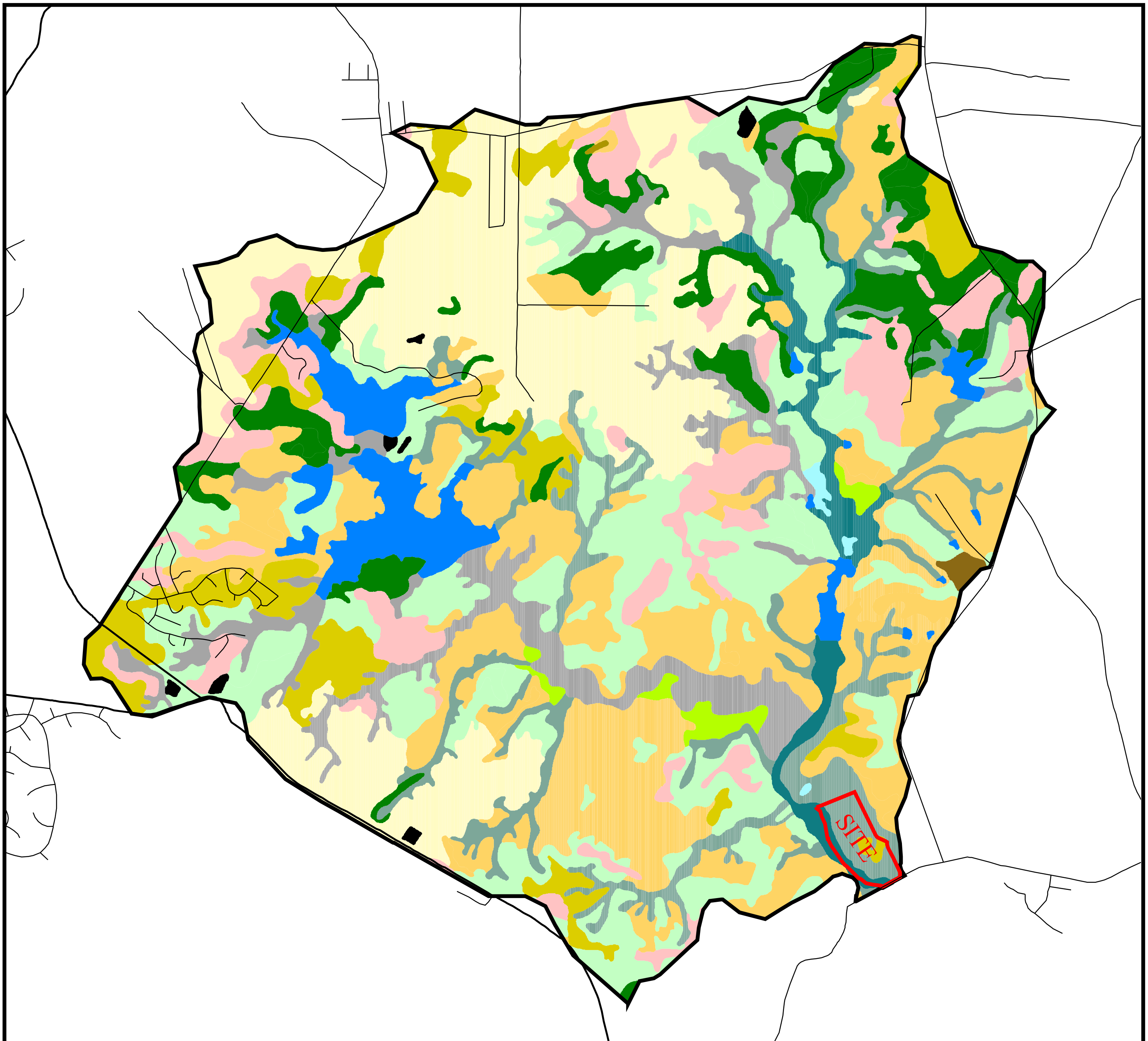
March 14, 2003

BLUE Land Water Infrastructure

# APPENDIX B

# WATERSHED SOIL TYPE DISTRIBUTION MAP

# Watershed Soils Map




| | | | | | |
|---|---|---|---|---|---|
| Altavista | Candor | Orangeburg | Roanoke | Wakulla | |
| Augusta | Gilead | Pits-Dumps | Vaucluse | Wehadkee | |
| Bibb | Goldsboro | Pocalla | Wahee | water | |
| Blaney | Lakeland | | | | |

N

0.75 0 0.75 1.5 Miles

Scale: 1" = 0.75 mile

Overhills Stream and Wetland Restoration Project - Restoration Plan

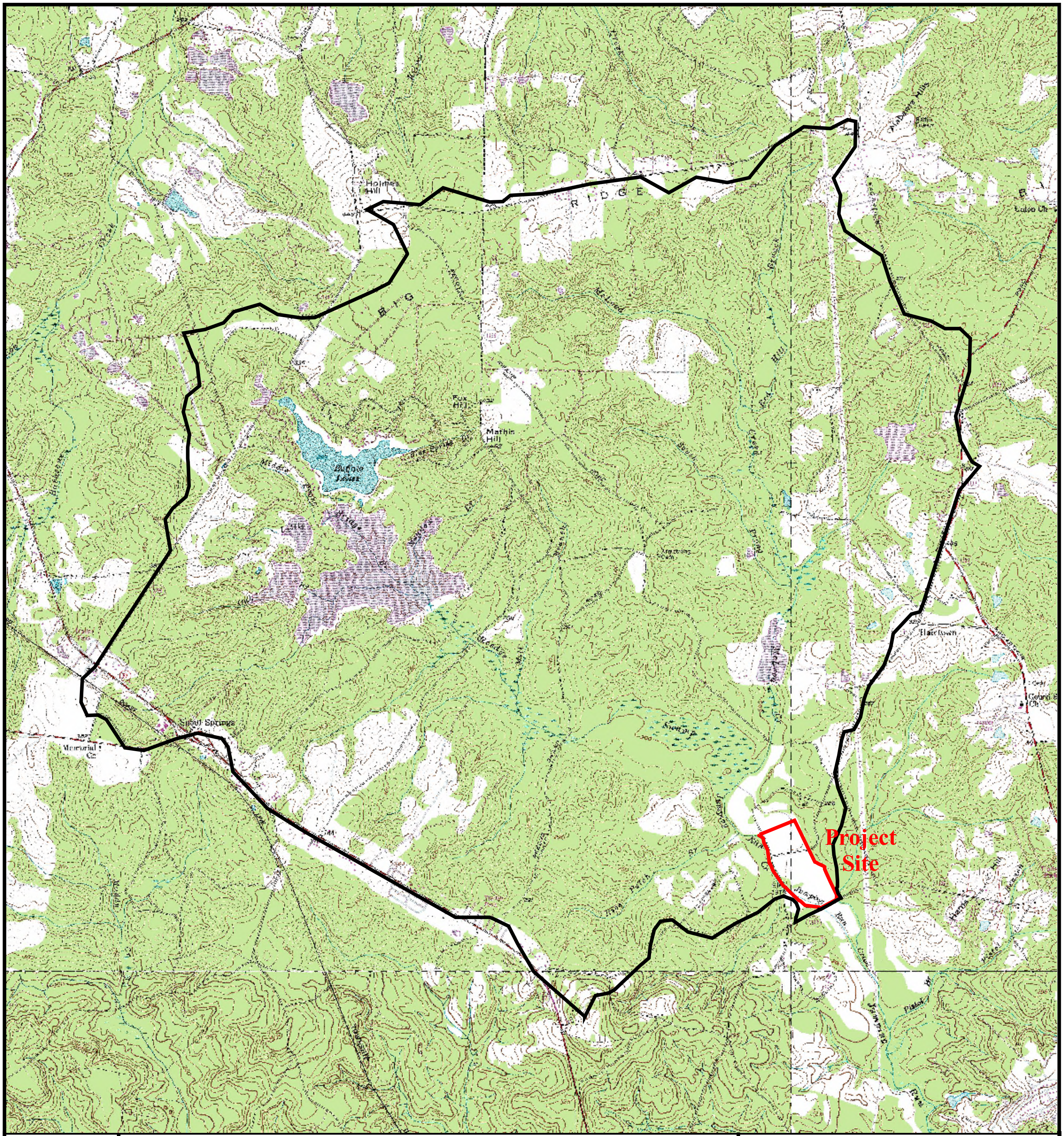
March 14, 2003

BLUE Land Water Infrastructure

# APPENDIX C

# WATERSHED USGS TOPOGRAPHIC QUADRANGLE MAP

# Watershed USGS Topographic Quadrangle Map




N

0.75 0 0.75 1.5 Miles

Scale: 1" = 0.75 mile

Overhills Stream and Wetland Restoration Project - Restoration Plan

March 14, 2003

BLUE Land Water Infrastructure

# APPENDIX D

# ONSITE SOIL TESTING REPORT

NCDA Agronomic Division 4300 Reedy Creek Road Raleigh, NC 27607-6465 (919) 733-2655

Report No: 34999

*Grower:* Coleman, Amber
139 G Technology Dr
Garner, NC 27529

*Copies to:* County Extension Director

# Soil Test Report

*Farm:*

4/30/02 SERVING N.C. CITIZENS FOR OVER 50 YEARS

Harnett County

Agronomist Comments: I -- 11, $

## Field Information / Applied Lime / Recommendations

| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 0-20 | 60-80 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.97 | 1.18 | 3.1 | 68.0 | 1.0 | 5.6 | 34 | 19 | 51.0 | 14.0 | 24 | | | 81 | 81 | 13 | 33 | | | | 0.0 |

## Field Information / Applied Lime / Recommendations

| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.04 | 1.19 | 3.2 | 88.0 | 0.4 | 6.0 | 0 | 13 | 55.0 | 31.0 | 1 | | | 5 | 5 | 26 | 25 | | | | 0.0 |

## Field Information / Applied Lime / Recommendations

| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 52BA | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 40-60 | 60-80 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.67 | 1.10 | 4.9 | 67.0 | 1.6 | 5.1 | 15 | 18 | 49.0 | 17.0 | 9 | | | 83 | 83 | 24 | 35 | | | | 0.0 |

## Field Information / Applied Lime / Recommendations

| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 52BB | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 70-90 | 60-80 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.81 | 1.05 | 8.5 | 84.0 | 1.4 | 5.2 | 0 | 18 | 46.0 | 37.0 | 2 | | | 8 | 8 | 40 | 43 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
| 53BA | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 20-40 | 60-80 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 3.01 | 1.03 | 5.7 | 68.0 | 1.8 | 5.2 | 22 | 18 | 52.0 | 16.0 | 6 | | | 50 | 50 | 23 | 38 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
| 53BB | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.27 | 1.24 | 1.7 | 53.0 | 0.8 | 5.0 | 2 | 5 | 33.0 | 16.0 | 1 | | | 5 | 5 | 9 | 24 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
| 54BA | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 0-20 | 40-60 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.94 | 1.02 | 3.8 | 79.0 | 0.8 | 5.0 | 35 | 33 | 53.0 | 22.0 | 17 | | | 99 | 99 | 17 | 39 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
| 54BB | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 50-70 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.36 | 1.15 | 3.4 | 68.0 | 1.1 | 5.0 | 7 | 5 | 42.0 | 25.0 | 2 | | | 9 | 9 | 19 | 33 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
| 55A | No Crop | | | | 1st Crop: Hardwood,E | .6T | 0.0 | 0 | 80-100 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.61 | 1.25 | 2.7 | 30.0 | 1.9 | 5.0 | 52 | 8 | 20.0 | 7.0 | 3 | | | 38 | 38 | 39 | 42 | | | | 0.0 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55B | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 70-90 | 70-90 | $ | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.08 | 1.31 | 1.7 | 35.0 | 1.1 | 4.9 | 2 | 14 | 24.0 | 9.0 | 2 | | | 5 | 5 | 37 | 32 | | | | 0.0 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56A | No Crop | | | | 1st Crop: Hardwood,E | .9T | 0.0 | 10-30 | 40-60 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 2.68 | 1.00 | 4.0 | 43.0 | 2.3 | 4.8 | 29 | 32 | 28.0 | 11.0 | 4 | | | 96 | 96 | 39 | 56 | | | | 0.1 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56B | No Crop | | | | 1st Crop: Hardwood,E | 1.1T | 0.0 | 50-70 | 80-100 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.31 | 1.08 | 3.5 | 31.0 | 2.4 | 4.6 | 10 | 7 | 21.0 | 8.0 | 3 | | | 11 | 11 | 17 | 37 | | | | 0.0 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57A | No Crop | | | | 1st Crop: Hardwood,E | .9T | 0.0 | 10-30 | 80-100 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 3.19 | 0.94 | 5.6 | 54.0 | 2.6 | 4.9 | 27 | 9 | 42.0 | 11.0 | 6 | | | 53 | 53 | 38 | 59 | | | | 0.1 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57B | No Crop | | | | 1st Crop: Hardwood,E | .5T | 0.0 | 60-80 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

## Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.46 | 1.20 | 2.7 | 52.0 | 1.3 | 4.9 | 3 | 6 | 34.0 | 17.0 | 3 | | | 14 | 14 | 11 | 32 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | | *See Note* |
| 58BA | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 10-30 | 50-70 | 0 | 0 | 0 | | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.14 | 1.15 | 5.3 | 81.0 | 1.0 | 5.6 | 27 | 27 | 63.0 | 16.0 | 19 | | | 161 | 161 | 26 | 32 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | | *See Note* |
| 58BB | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.18 | 1.09 | 5.1 | 80.0 | 1.0 | 5.2 | 2 | 9 | 44.0 | 36.0 | 3 | | | 14 | 14 | 20 | 33 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | | *See Note* |
| 59A | No Crop | | | | 1st Crop: Hardwood,E | .5T | 0.0 | 10-30 | 60-80 | 0 | 0 | 0 | | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 4.2 | 0.99 | 5.5 | 60.0 | 2.2 | 5.2 | 32 | 18 | 45.0 | 14.0 | 3 | | | 61 | 76 | 32 | 43 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | | *See Note* |
| 59B | No Crop | | | | 1st Crop: Hardwood,E | 1T | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.66 | 1.08 | 3.7 | 41.0 | 2.2 | 4.6 | 0 | 15 | 27.0 | 13.0 | 3 | | | 11 | 11 | 33 | 52 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | | *See Note* |
| 59BA | No Crop | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 0-20 | 20-40 | 0 | 0 | 0 | | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 4.81 | 0.90 | 6.0 | 53.0 | 2.8 | 5.1 | 33 | 54 | 37.0 | 12.0 | 9 | | | 81 | 101 | 38 | 45 | | | | 0.1 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 59BB | No Crop | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.92 | 1.18 | 2.5 | 40.0 | 1.5 | 4.6 | 1 | 9 | 26.0 | 14.0 | 3 | | | 17 | 17 | 14 | 33 | | | | 0.0 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 510A | No Crop | | | | 1st Crop: Hardwood,E | 1.2T | 0.0 | 10-30 | 70-90 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 4.2 | 0.84 | 5.4 | 41.0 | 3.2 | 4.8 | 27 | 12 | 32.0 | 9.0 | 4 | | | 34 | 43 | 31 | 72 | | | | 0.1 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 510B | No Crop | | | | 1st Crop: Hardwood,E | .8T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.71 | 1.22 | 2.4 | 33.0 | 1.6 | 4.4 | 0 | 9 | 20.0 | 12.0 | 2 | | | 8 | 8 | 9 | 48 | | | | 0.0 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 511A | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 30-50 | 50-70 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 3.77 | 0.96 | 4.9 | 63.0 | 1.8 | 5.3 | 19 | 28 | 47.0 | 13.0 | 20 | | | 28 | 35 | 38 | 48 | | | | 0.1 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 511B | No Crop | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.27 | 1.18 | 3.6 | 56.0 | 1.6 | 4.7 | 1 | 15 | 35.0 | 20.0 | 6 | | | 11 | 11 | 30 | 55 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 512A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 0 | 50-70 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 3.1 | 1.14 | 4.7 | 60.0 | 1.9 | 5.4 | 48 | 29 | 48.0 | 9.0 | 8 | | | 73 | 73 | 27 | 38 | | | | 0.1 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 512B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 60-80 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.76 | 1.45 | 1.9 | 63.0 | 0.7 | 5.5 | 6 | 7 | 46.0 | 14.0 | 2 | | | 9 | 9 | 10 | 17 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 513A | No Crop | | | | 1st Crop: Hardwood,E | .5T | 0.0 | 0-20 | 60-80 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 4.56 | 0.93 | 6.2 | 63.0 | 2.3 | 5.2 | 36 | 17 | 49.0 | 13.0 | 12 | | | 70 | 88 | 43 | 51 | | | | 0.1 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 513B | No Crop | | | | 1st Crop: Hardwood,E | .5T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.02 | 1.23 | 2.6 | 54.0 | 1.2 | 4.8 | 0 | 4 | 37.0 | 16.0 | 3 | | | 10 | 10 | 12 | 38 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 514A | No Crop | | | | 1st Crop: Hardwood,E | 1.2T | 0.0 | 10-30 | 40-60 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 4.56 | 0.85 | 5.3 | 40.0 | 3.2 | 4.8 | 30 | 32 | 27.0 | 10.0 | 16 | | | 47 | 59 | 36 | 51 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 514B | No Crop | | | | 1st Crop: Hardwood,E | .5T | 0.0 | 50-70 | 80-100 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.94 | 1.04 | 3.2 | 31.0 | 2.2 | 5.2 | 7 | 9 | 22.0 | 9.0 | 4 | | | 10 | 10 | 24 | 32 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 514BA | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 10-30 | 60-80 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 2.92 | 1.14 | 4.7 | 64.0 | 1.7 | 5.2 | 31 | 18 | 46.0 | 16.0 | 3 | | | 99 | 99 | 28 | 40 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 514BB | No Crop | | | | 1st Crop: Hardwood,E | 1.1T | 0.0 | 70-90 | 70-90 | $ | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.13 | 1.17 | 3.5 | 29.0 | 2.5 | 4.6 | 0 | 12 | 17.0 | 9.0 | 4 | | | 15 | 15 | 46 | 50 | | | | 0.0 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 515A | No Crop | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 0 | 30-50 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 3.57 | 1.10 | 4.1 | 49.0 | 2.1 | 4.9 | 47 | 44 | 31.0 | 12.0 | 4 | | | 82 | 103 | 22 | 38 | | | | 0.0 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 515B | No Crop | | | | 1st Crop: Hardwood,E | .8T | 0.0 | 70-90 | 70-90 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.92 | 1.13 | 3.4 | 47.0 | 1.8 | 4.6 | 1 | 16 | 27.0 | 17.0 | 3 | | | 27 | 27 | 38 | 32 | | | | 0.0 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 516A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 30-50 | 70-90 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.8 | 1.19 | 5.2 | 79.0 | 1.1 | 5.6 | 16 | 10 | 53.0 | 26.0 | 9 | | | 100 | 100 | 23 | 33 | | | | 0.1 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 516B | No Crop | | | | 1st Crop: Hardwood,E | 1.4T | 0.0 | 70-90 | 50-70 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.09 | 0.94 | 4.2 | 33.0 | 2.8 | 4.4 | 0 | 24 | 16.0 | 15.0 | 5 | | | 26 | 26 | 69 | 45 | | | | 0.1 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 517A | No Crop | | | | 1st Crop: Hardwood,E | .6T | 0.0 | 60-80 | 70-90 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 2.6 | 0.95 | 3.7 | 43.0 | 2.1 | 5.1 | 3 | 16 | 37.0 | 4.0 | 14 | | | 38 | 38 | 30 | 48 | | | | 0.1 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 517B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 40-60 | 80-100 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.56 | 1.40 | 1.4 | 43.0 | 0.8 | 5.6 | 12 | 4 | 35.0 | 7.0 | 16 | | | 13 | 13 | 17 | 24 | | | | 0.0 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 518A | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 50-70 | 70-90 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 9.21 | 0.80 | 5.0 | 32.0 | 3.4 | 4.8 | 7 | 14 | 25.0 | 6.0 | 5 | | | 71 | 118 | 42 | 53 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 518B | No Crop | | | | 1st Crop: Hardwood,E | .9T | 0.0 | 70-90 | 80-100 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.56 | 1.09 | 2.8 | 36.0 | 1.8 | 4.5 | 0 | 8 | 23.0 | 13.0 | 2 | | | 11 | 11 | 61 | 53 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 518BA | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 60-80 | 60-80 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 5.53 | 0.80 | 5.0 | 46.0 | 2.7 | 5.1 | 6 | 21 | 35.0 | 9.0 | 9 | | | 63 | 105 | 32 | 53 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 518BB | No Crop | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.51 | 1.20 | 2.5 | 36.0 | 1.6 | 4.6 | 0 | 11 | 21.0 | 13.0 | 3 | | | 13 | 13 | 35 | 42 | | | | 0.0 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 519A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 30-50 | 70-90 | 0 | $ | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.19 | 1.19 | 3.1 | 61.0 | 1.2 | 5.3 | 18 | 10 | 45.0 | 15.0 | 4 | | | 54 | 54 | 22 | 32 | | | | 0.0 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 519B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 60-80 | 90-110 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.0 | 1.46 | 0.8 | 63.0 | 0.3 | 5.4 | 3 | 3 | 41.0 | 21.0 | 2 | | | 8 | 8 | 7 | 13 | | | | 0.0 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 519BA | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 40-60 | 40-60 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 8.24 | 0.79 | 6.1 | 39.0 | 3.7 | 5.0 | 14 | 33 | 28.0 | 8.0 | 4 | | | 61 | 101 | 33 | 49 | | | | 0.1 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 519BB | No Crop | | | | 1st Crop: Hardwood,E | .9T | 0.0 | 60-80 | 70-90 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.97 | 1.20 | 2.7 | 22.0 | 2.1 | 4.6 | 3 | 10 | 14.0 | 8.0 | 3 | | | 10 | 10 | 16 | 32 | | | | 0.0 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 520A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 20-40 | 0-20 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 7.45 | 0.87 | 5.5 | 53.0 | 2.6 | 4.9 | 22 | 68 | 35.0 | 11.0 | 28 | | | 136 | 226 | 32 | 48 | | | | 0.0 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 520B | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 60-80 | 60-80 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.31 | 1.15 | 2.2 | 45.0 | 1.2 | 4.9 | 6 | 17 | 29.0 | 15.0 | 4 | | | 15 | 15 | 12 | 29 | | | | 0.0 |

**Field Information** | **Applied Lime** | **Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 521A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 20-40 | 10-30 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 6.58 | 0.98 | 5.2 | 56.0 | 2.3 | 5.1 | 22 | 61 | 41.0 | 9.0 | 8 | | | 122 | 203 | 28 | 44 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 521B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 40-60 | 60-80 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 2.08 | 1.18 | 3.3 | 70.0 | 1.0 | 5.4 | 12 | 18 | 49.0 | 17.0 | 7 | | | 23 | 23 | 18 | 26 | | | | 0.1 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 522A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 20-40 | 20-40 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 6.02 | 0.97 | 7.5 | 68.0 | 2.4 | 5.1 | 25 | 50 | 51.0 | 14.0 | 24 | | | 64 | 106 | 42 | 37 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 522B | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 60-80 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.32 | 1.25 | 1.8 | 56.0 | 0.8 | 5.0 | 3 | 7 | 31.0 | 23.0 | 2 | | | 9 | 9 | 16 | 23 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 523A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 0-20 | 10-30 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 5.69 | 0.89 | 6.9 | 61.0 | 2.7 | 5.0 | 40 | 56 | 39.0 | 19.0 | 24 | | | 85 | 141 | 43 | 48 | | | | 0.0 |

**Field Information**

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Recommendations: Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 523B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 30-50 | 70-90 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.76 | 1.39 | 1.9 | 53.0 | 0.9 | 5.6 | 20 | 11 | 35.0 | 13.0 | 6 | | | 24 | 24 | 14 | 20 | | | | 0.0 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 524A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 60-80 | 60-80 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |
| 524B | No Crop | | | | 1st Crop: Hardwood,E | .6T | 0.0 | 70-90 | 80-100 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |
| 525A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 10-30 | 50-70 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |
| 525B | No Crop | | | | 1st Crop: Hardwood,E | .6T | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |
| 526A | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 50-70 | 60-80 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| Sample No. | Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 524A | ORG | 8.24 | 0.80 | 6.8 | 56.0 | 3.0 | 5.0 | 6 | 17 | 40.0 | 14.0 | 7 | | | 71 | 118 | 34 | 51 | | | | 0.1 |
| 524B | MIN | 0.76 | 1.18 | 2.2 | 36.0 | 1.4 | 4.6 | 0 | 6 | 19.0 | 15.0 | 1 | | | 9 | 9 | 27 | 36 | | | | 0.0 |
| 525A | ORG | 6.78 | 0.95 | 7.6 | 70.0 | 2.3 | 5.1 | 27 | 25 | 50.0 | 19.0 | 13 | | | 101 | 168 | 53 | 62 | | | | 0.1 |
| 525B | MIN | 0.6 | 1.15 | 3.1 | 55.0 | 1.4 | 4.7 | 1 | 13 | 31.0 | 20.0 | 3 | | | 13 | 13 | 30 | 46 | | | | 0.0 |
| 526A | ORG | 9.59 | 0.91 | 5.8 | 45.0 | 3.2 | 4.8 | 9 | 21 | 32.0 | 11.0 | 10 | | | 92 | 153 | 45 | 45 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 526B | No Crop | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 2.15 | 1.07 | 4.3 | 58.0 | 1.8 | 4.8 | 0 | 14 | 38.0 | 19.0 | 4 | | | 23 | 23 | 33 | 49 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 527A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 40-60 | 50-70 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 5.09 | 1.07 | 6.0 | 88.0 | 0.7 | 5.4 | 13 | 28 | 63.0 | 23.0 | 4 | | | 83 | 104 | 33 | 36 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 527B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.13 | 1.28 | 1.6 | 63.0 | 0.6 | 5.1 | 0 | 5 | 34.0 | 26.0 | 1 | | | 8 | 8 | 13 | 20 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 528A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 60-80 | 90-110 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.09 | 1.39 | 0.9 | 56.0 | 0.4 | 5.9 | 3 | 3 | 37.0 | 21.0 | 2 | | | 4 | 4 | 4 | 16 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 528B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 10-30 | 20-40 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M-O | 4.44 | 1.05 | 8.5 | 80.0 | 1.7 | 5.8 | 31 | 51 | 55.0 | 21.0 | 15 | | | 115 | 144 | 42 | 28 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 529A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 30-50 | 20-40 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 9.21 | 0.89 | 9.3 | 66.0 | 3.2 | 5.2 | 16 | 51 | 45.0 | 18.0 | 9 | | | 125 | 208 | 43 | 42 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 529B | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 50-70 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.32 | 1.28 | 1.5 | 47.0 | 0.8 | 5.1 | 7 | 5 | 30.0 | 17.0 | 1 | | | 12 | 12 | 12 | 25 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 530A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 40-60 | 30-50 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 8.86 | 0.90 | 10.0 | 68.0 | 3.2 | 5.3 | 14 | 45 | 47.0 | 19.0 | 7 | | | 173 | 287 | 42 | 41 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 530B | No Crop | | | | 1st Crop: Hardwood,E | .4T | 0.0 | 70-90 | 70-90 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.32 | 1.24 | 2.4 | 54.0 | 1.1 | 4.8 | 1 | 10 | 30.0 | 24.0 | 2 | | | 15 | 15 | 13 | 25 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| 531A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 40-60 | 40-60 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORG | 10 + | 0.91 | 7.6 | 61.0 | 3.0 | 5.0 | 15 | 33 | 41.0 | 17.0 | 4 | | | 91 | 151 | 34 | 36 | | | | 0.0 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 531B | No Crop | | | | 1st Crop: Hardwood,E | .8T | 0.0 | 70-90 | 60-80 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.86 | 1.12 | 3.2 | 47.0 | 1.7 | 4.6 | 0 | 19 | 27.0 | 18.0 | 2 | | | 13 | 13 | 46 | 42 | | | | 0.0 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 532A | No Crop | | | | 1st Crop: Hardwood,E | 0 | 0.0 | 20-40 | 60-80 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 2.76 | 1.17 | 4.9 | 76.0 | 1.2 | 5.5 | 22 | 23 | 58.0 | 16.0 | 8 | | | 111 | 111 | 28 | 28 | | | | 0.0 |

**Field Information / Applied Lime / Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 532B | No Crop | | | | 1st Crop: Hardwood,E | .3T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: | | | | | | | | | | |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.81 | 1.17 | 3.1 | 65.0 | 1.1 | 5.0 | 0 | 9 | 39.0 | 25.0 | 3 | | | 16 | 16 | 24 | 32 | | | | 0.1 |

# APPENDIX E

# RESTORATION SITE PLANT COMMUNITIES LIST

Restoration Site Plant List
Overhills Stream and Wetland Restoration
Harnett County, NC

| **TREES (seedlings and saplings)** | |
|---|---|
| *Acer rubrum* | *Pinus taeda* |
| *Diospyros virginiana* | *Platanus occidentalis* |
| *Liquidambar styraciflua* | *Prunus serotina* |
| *Liriodendron tulipifera* | *Quercus* sp. |

| **SHRUBS** | |
|---|---|
| *Rhus copallinum* | *Sambucus canadensis* |
| *Rubus* spp. | |

| **HERBS, GRASSES,SEDGES, RUSHES, VINES, AND MISC.** | |
|---|---|
| *Allium* sp. | *Lespedeza cuneata* |
| *Agrostis hyemalis* | *Lespedeza* sp. |
| *Ambrosia artemisiifolia* | *Ludwigia linearis* |
| *Andropogon virginicus* | *Parthenocissus quinquefolia* |
| *Arundinaria tecta* | *Phytolacca americana* |
| *Bidens aristosa* | *Polygonum* spp. |
| *Campsis radicans* | *Rhexia mariana* |
| *Carex lurida* | *Rhexia virginica* |
| *Cassia obtusifolia* | *Rhynchospora glomerata* |
| *Dichanthelium* spp. | *Rosa multiflora* |
| *Diodia virginiana* | *Rumex* sp. |
| *Echinochloa crus-galli* | *Scirpus cyperinus* |
| *Eleocharis* sp. | *Senecio anonymus* |
| *Erigeron annuus* | *Smilax* sp. |
| *Erigeron strigosus* | *Solidago canadensis* var. *scabra* |
| *Eupatorium capillifolium* | *Solidago rugosa* |
| *Euthamia tenuifolia* | *Sphagnum* sp. |
| *Gnaphalium obtusifolium* | *Symphyotrichum pilosum* |
| *Hypericum hypericoides* | *Toxicodendron radicans* |
| *Juncus canadensis* | *Vitus aestivalis* |
| *Juncus dichotomus* | *Vitis rotundifolia* |
| *Juncus effusus* | |

Restoration Site Riparian Buffer** Plant List
Overhills Stream and Wetland Restoration
Harnett County, NC

| **TREES** | |
|---|---|
| *Acer rubrum* | *Pinus taeda* |
| *Liquidambar styraciflua* | *Platanus occidentalis* |
| *Liriodendron tulipifera* | *Prunus serotina* |
| *Nyssa biflora* | *Quercus nigra* |
| *Oxydendrum arboreum* | *Quercus phellos* |
| *Pinus serotina* | *Salix nigra* |

| **SHRUBS** | |
|---|---|
| *Alnus serrulata* | *Lyonia lucida* |
| *Aralia spinosa* | *Leucothoe axillaris* |
| *Clethra alnifolia* | *Rosa multiflora* |
| *Cyrilla racemiflora* | *Rubus* sp. |
| *Hypericum* sp. | *Styrax americana* |
| *Ilex glabra* | *Vaccinium arboreum* |
| *Ligustrum* sp. | *Vaccinium formosum* |

| **HERBS, GRASSES, SEDGES, RUSHES, VINES, AND MISC.** | |
|---|---|
| *Arundinaria tecta* | *Osmunda cinnamomea* |
| *Bignonia capreolata* | *Osmunda regalis* |
| *Boehmeria cylindrica* | *Panicum* sp. |
| *Campsis radicans* | *Polygonum* spp. |
| *Carex crinita* | *Scirpus cyperinus* |
| *Carex glaucescens* | *Smilax rotundifolia* |
| *Carex lurida* | *Smilax* spp. |
| *Chasmanthium laxum* | *Solidago rugosa* |
| *Commelina* sp. | *Sparganium americanum* |
| *Dichanthelium* spp. | *Sphagnum* sp. |
| *Eupatorium dubium* | *Toxicodendron radicans* |
| *Euthamia tenuifolia* | *Viola* sp. |
| *Gelsemium sempervirens* | *Vitis rotundifolia* |
| *Glyceria obtusa* | *Woodwardia areolata* |
| *Juncus effusus* | |

** The buffer is a 3 meter area on each side of a channel.

# APPENDIX F

# PHOTOS

Photo 1.  Jumping Run Creek.

Photo 2.  Jumping Run Creek.

Photo 3. Burning of the field on the restoration site.

Figure 4. North part of site after burning.

Figure 5.  Gauge in Jumping Run Creek.

Figure 6.  Weather Station – North of site.

Figure 7.  Groundwater gauge.

Figure 8.  Gravel from Jumping Run Creek.

Figure 9.  Sample from soil pit in interior of restoration site.


Figure 10. Soil pit excavation.

Figure 11. Bibb at North end of site, dark surface from burning.

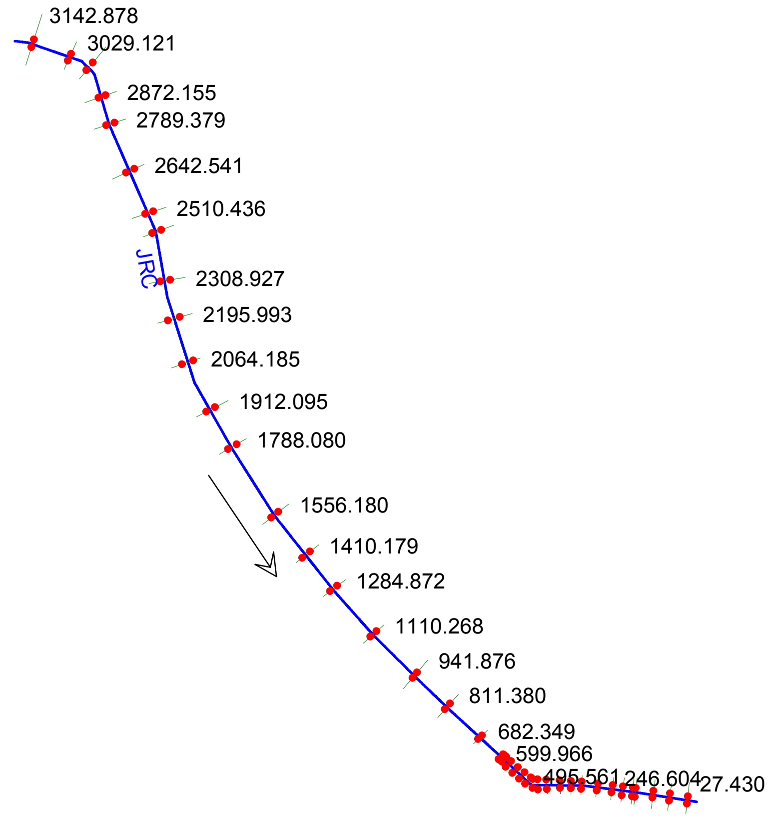
Figure 12. Stream and wetland reference site – Cypress Creek.

Figure 13. Stream and wetland reference site – Cypress Creek.

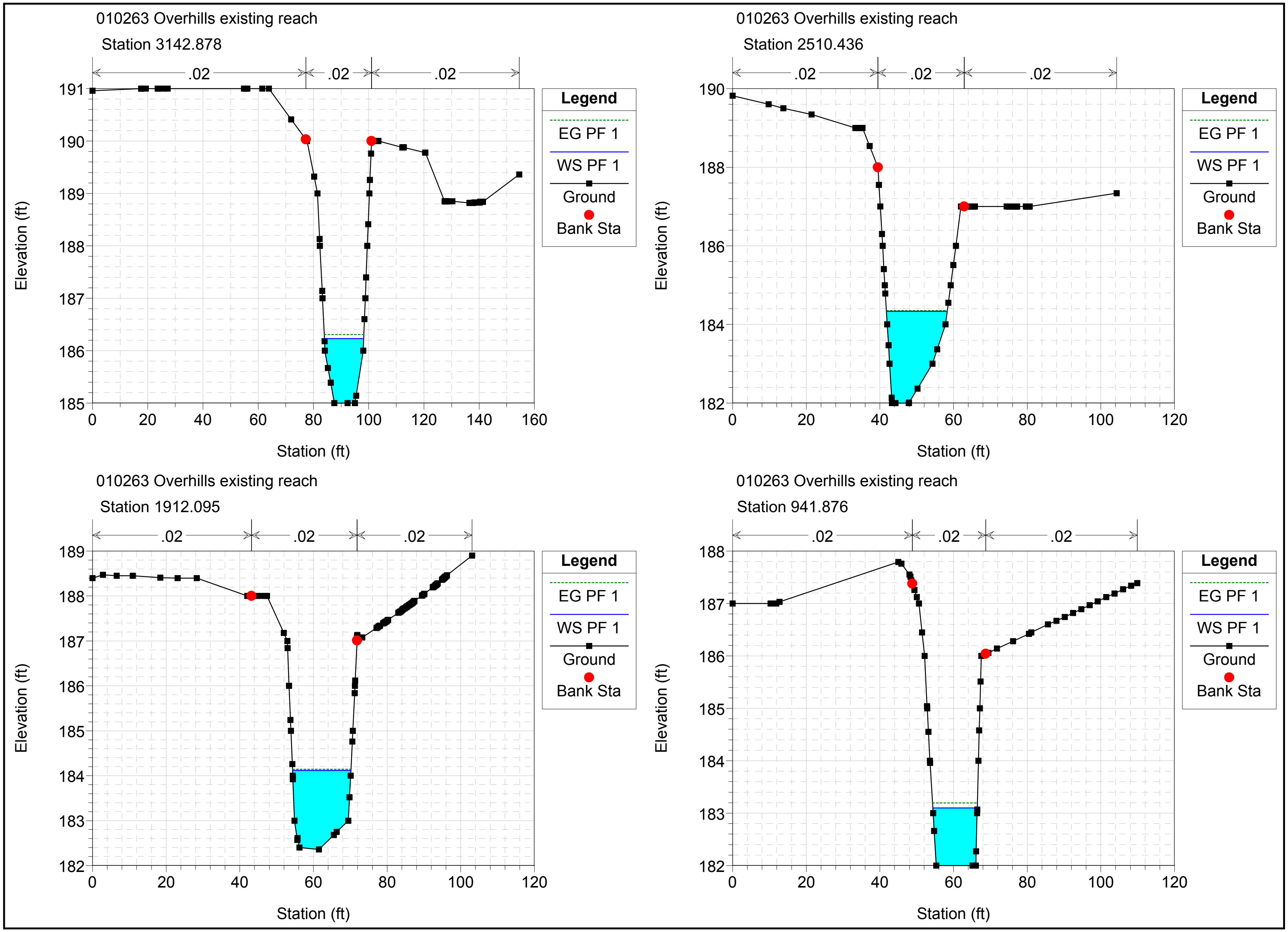
# APPENDIX G

# EXISTING STREAM DATA

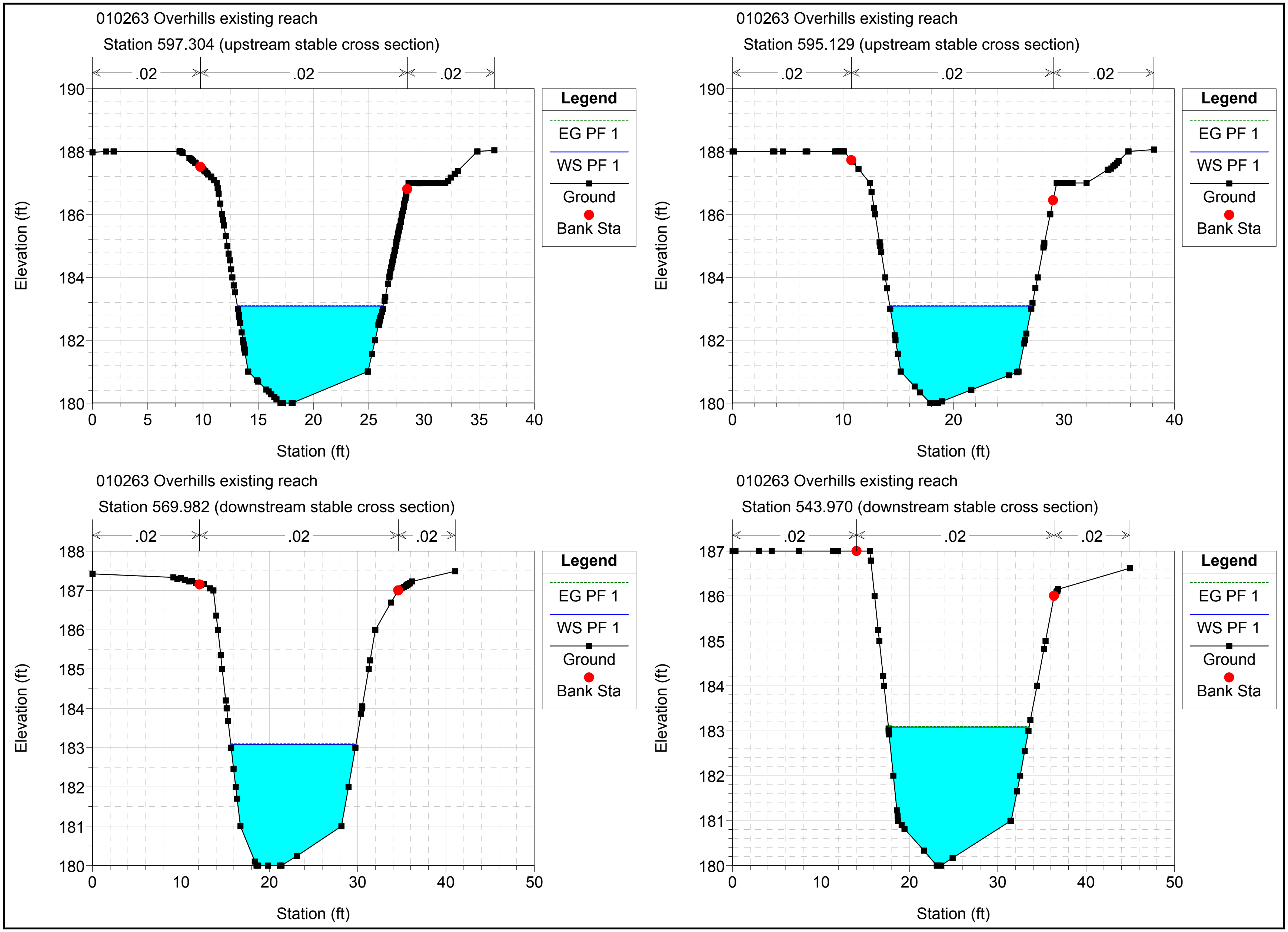
Existing Jumping Run Creek at Project Site - Plan View



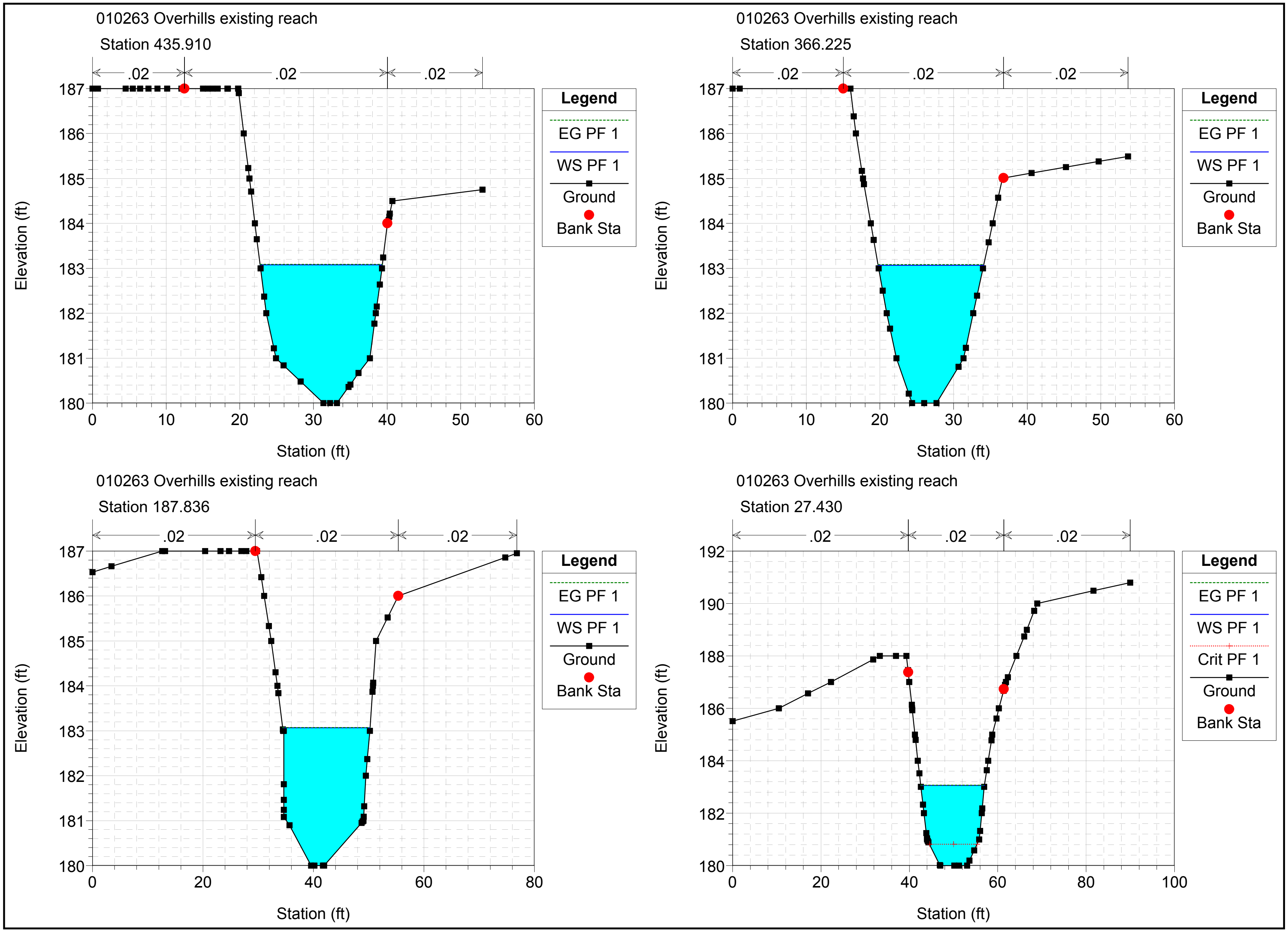
Existing stream cross sections



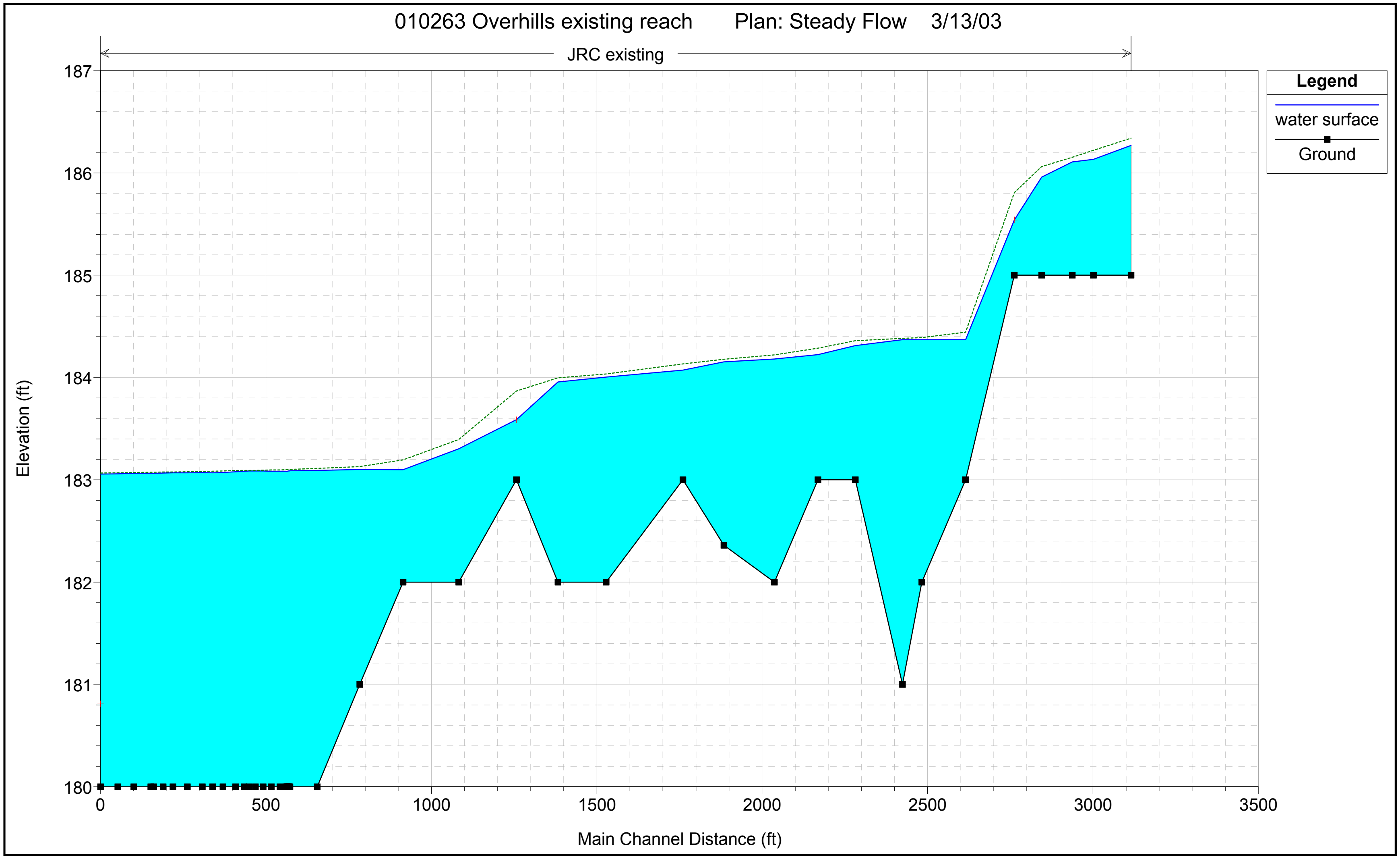
Existing stream cross sections



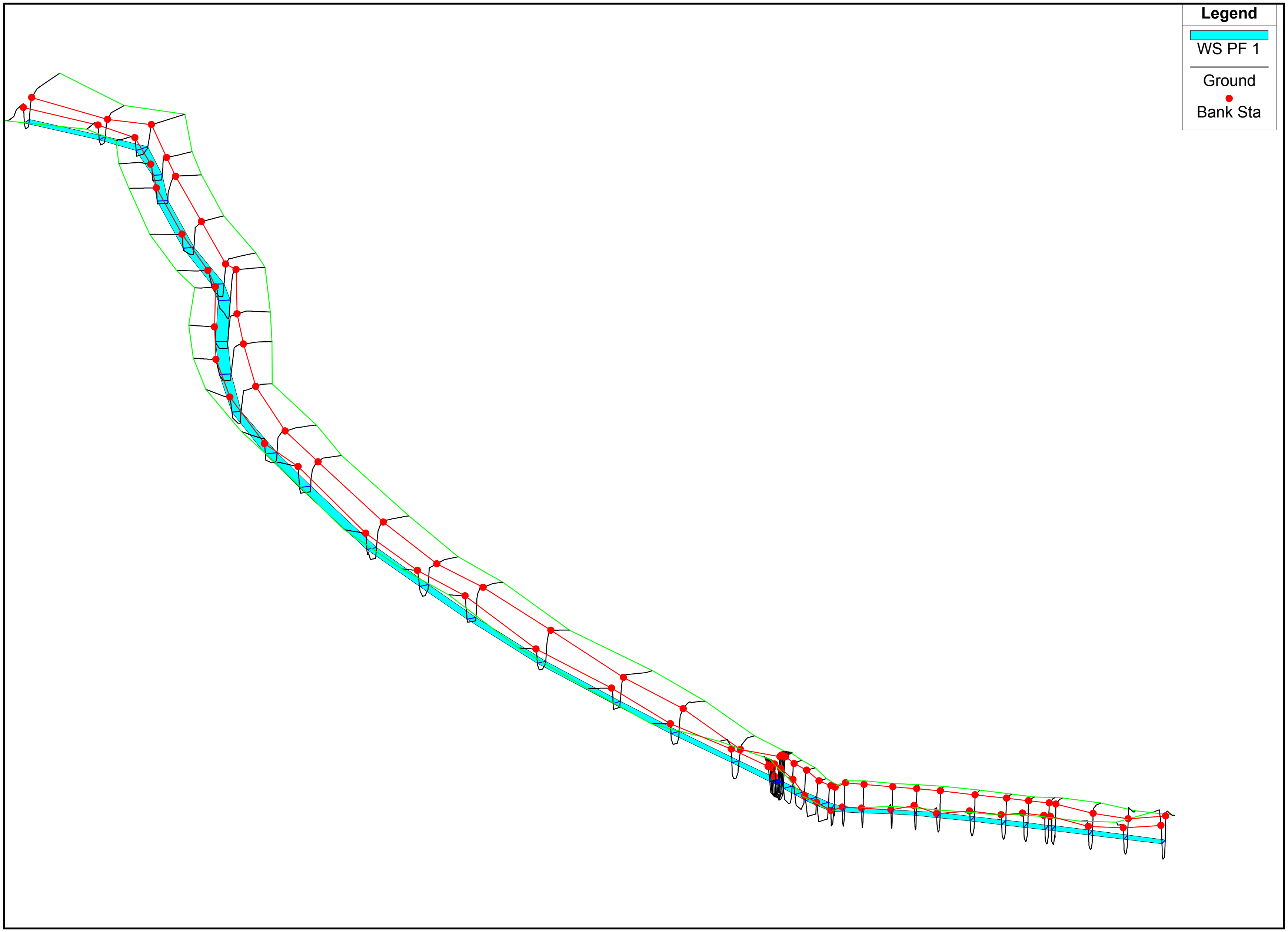
Existing stream cross sections

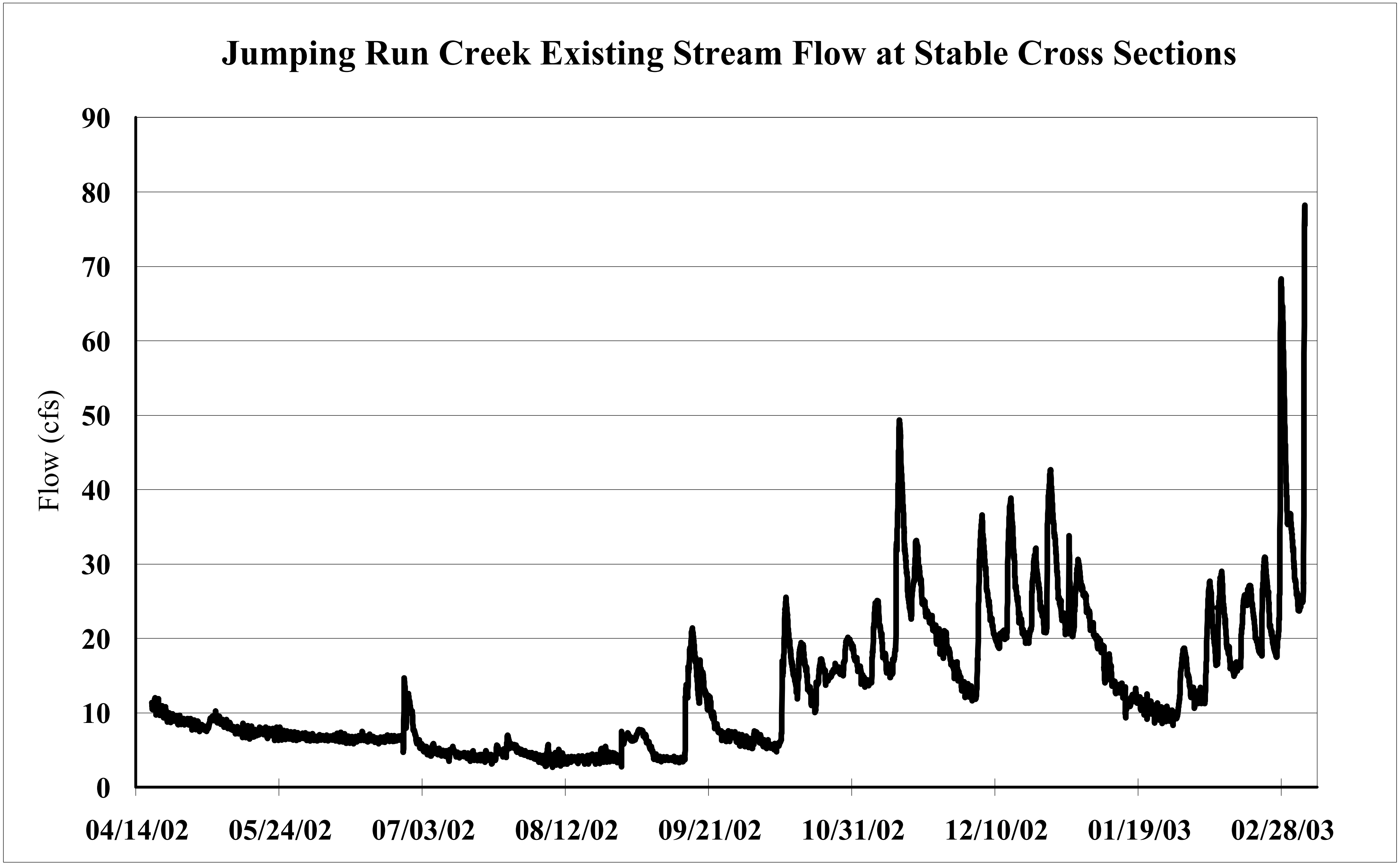


Existing stream profile showing bankfull water surface elevation and thalweg

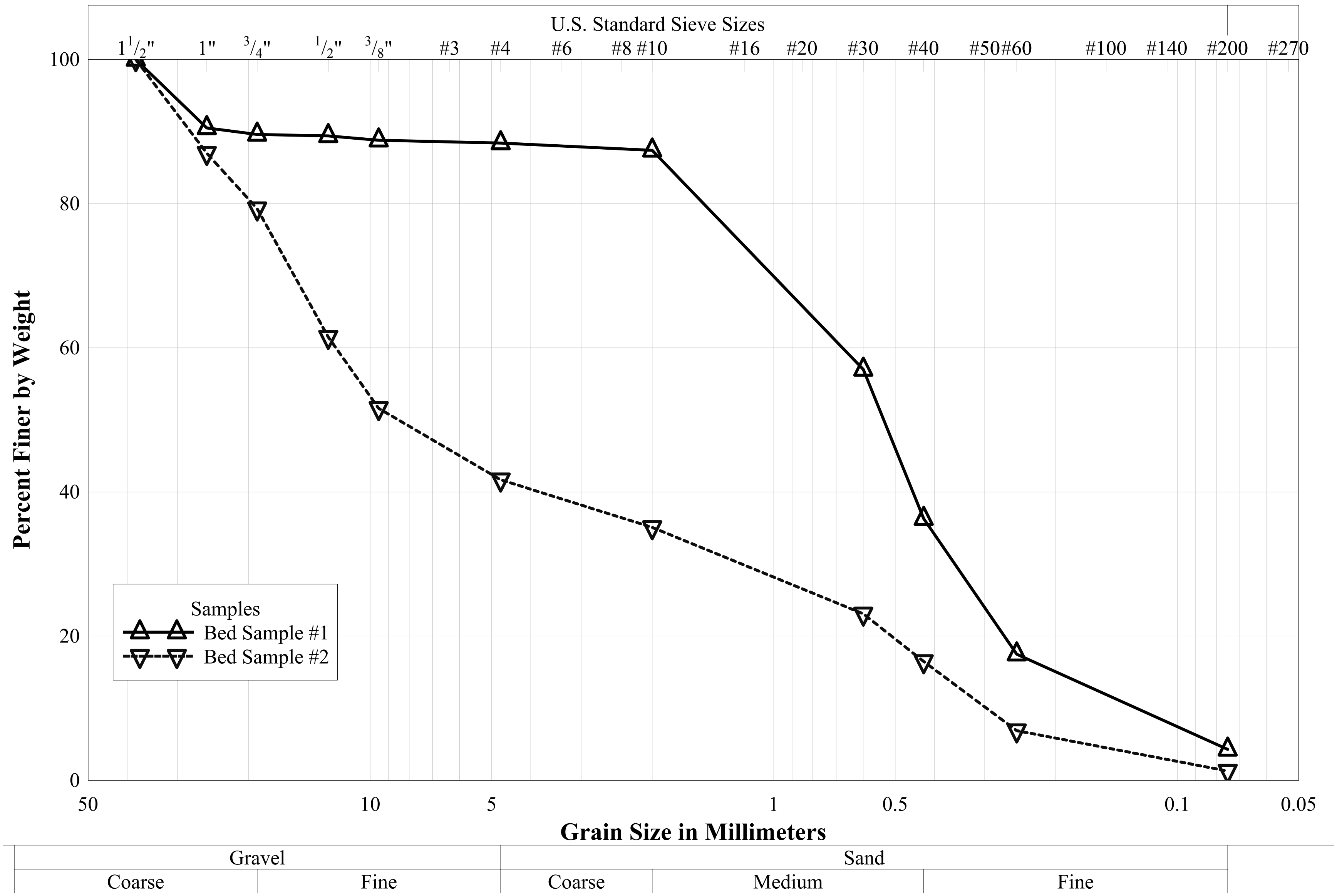


Existing stream 3-D profile showing banks and water surface for a bankfull event

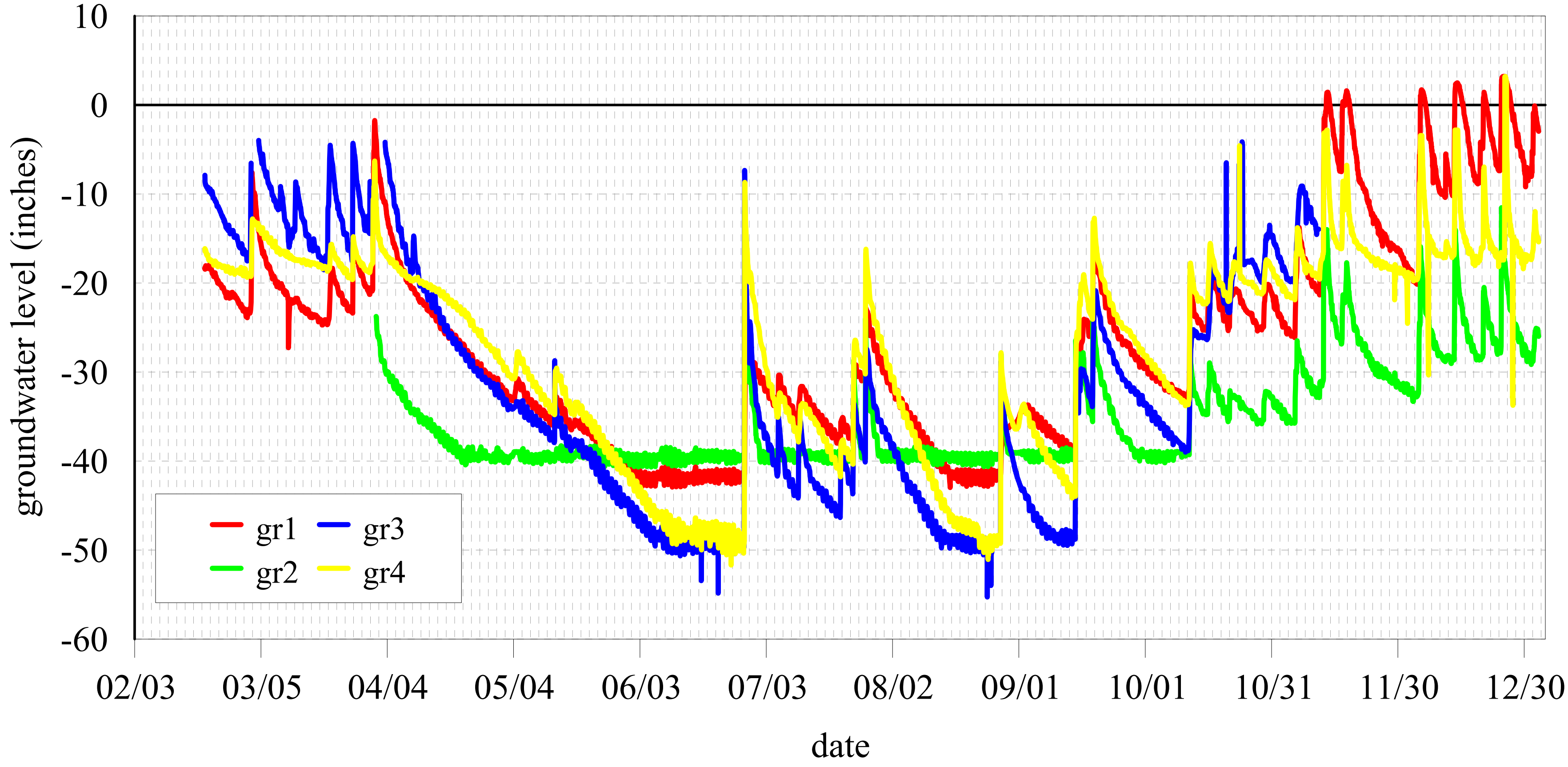



Jumping Run Creek Existing Stream Flow at Stable Cross Sections
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
04/14/02
05/24/02
07/03/02
08/12/02
09/21/02
10/31/02
12/10/02
01/19/03
02/28/03

# Jumping Run Creek Streambed Particle Size Analyses



# Measured Groundwater Levels at Site



# APPENDIX H

# REFERENCE SITE PLANT COMMUNITIES LISTS

Reference Site Plant List
Howard Property, Overhills Stream and Wetland Restoration
Harnett County, NC

| TREES | |
|---|---|
| *Acer rubrum* | *Liriodendron tulipifera* |
| *Amelanchier* sp. | *Magnolia virginiana* |
| *Cyrilla racemiflora* | *Nyssa biflora* |
| *Ilex amelanchier*** | *Quercus nigra* |
| *Ilex opaca* | *Quercus phellos* |
| *Liquidambar styraciflua* | |

| SHRUBS | |
|---|---|
| *Clethra alnifolia* | *Styrax americana* |
| *Hyericum* sp. | *Vaccinium formosum* |
| *Leucothoe axillaris* | *Viburnum nudum* |
| *Lyonia lucida* | *Viburnum recognitum* |
| *Rubus* sp. | |

| HERBS, GRASSES, SEDGES, VINES, AND MISC. | |
|---|---|
| *Arundinaria tecta* | *Lobelia elongata* |
| *Bignonia capreolata* | *Marchantia polymorpha* |
| *Boehmeria cylindrica* | *Orontium aquaticum* |
| *Carex crinita* | *Osmunda regalis* |
| *Carex glaucescens* | *Rhexia virginica* |
| *Carex intumescens* | *Smilax laurifolia* |
| *Carex lonchocarpa* | *Smilax rotundifolia* |
| *Carex lurida* | *Smilax* spp. |
| *Carex* spp. | *Sphagnum* sp. |
| *Cuscuta* sp. | *Sparganium americanum* |
| *Dichanthelium scabriusculum* | *Toxicodendron radicans* |
| *Dichanthelium* sp. | *Triadenum virginicum* |
| *Dulichium arundinaceum* | *Woodwardia areolata* |
| *Eupatorium dubium* | |

** Listed in *Natural Heritage Program List of the Rare Plant Species of North Carolina*, (2002) as Significatly Rare-Peripheral

Overstory Reference Site Plant List
Overhills Stream and Wetland Restoration
Harnett County, NC

| **TREES** | |
|---|---|
| *Acer rubrum* | *Pinus serotina* |
| *Chamaecyparis thyoides* | *Pinus taeda* |
| *Ilex opaca* | *Quercus alba* |
| *Liquidambar styraciflua* | *Quercus nigra* |
| *Liriodendron tulipifera* | *Quercus* sp. (hybrid) |
| *Magnolia grandiflora* | *Taxodium ascendens* |
| *Magnolia virginiana* | *Taxodium distichum* |
| *Nyssa biflora* | |

| **SHRUBS** | |
|---|---|
| *Aronia arbutifolia* | *Myrica heterophylla* |
| *Clethra alnifolia* | *Persea palustris* |
| *Cyrilla racemiflora* | *Rhododendron viscosum* |
| *Ilex coriacea* | *Styrax americana* |
| *Ilex glabra* | *Symplocos tinctoria* |
| *Itea virginica* | *Vaccinium formosum* |
| *Leucothoe axillaris* | *Viburnum nudum* |
| *Lyonia lucida* | |

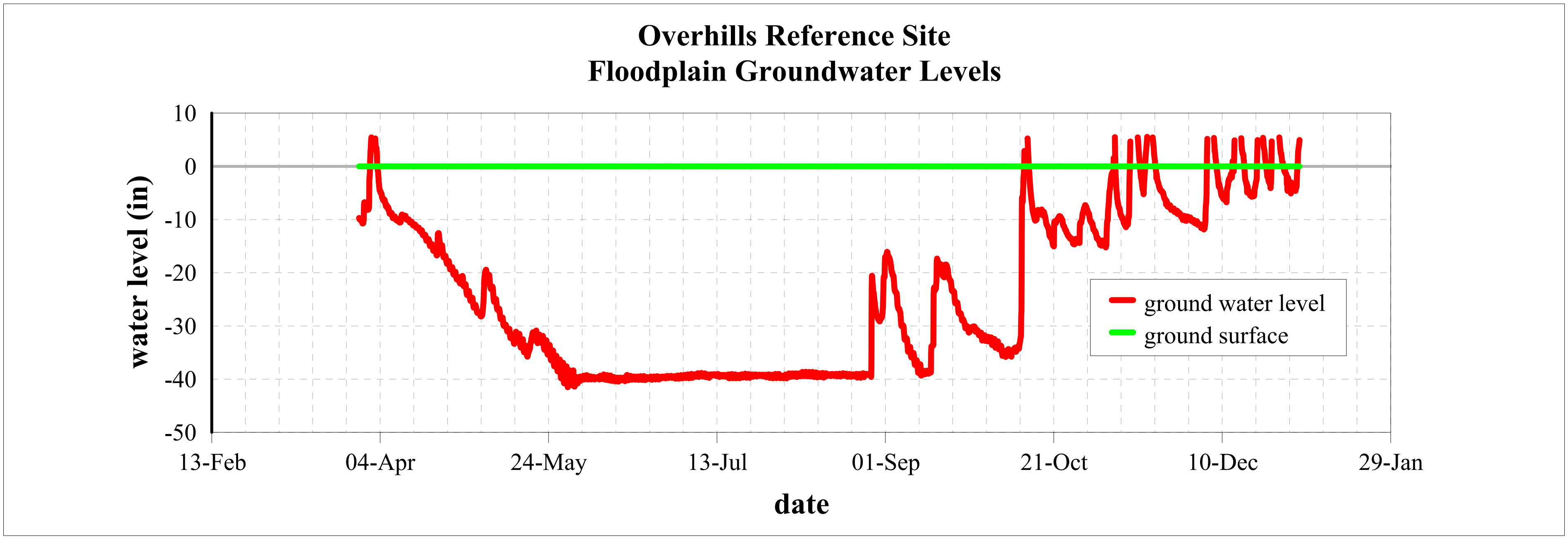
| **HERBS, GRASSES, SEDGES, VINES, AND MISC.** | |
|---|---|
| *Arundinaria tecta* | *Smilax rotundifolia* |
| *Carex* sp. | *Smilax* spp. |
| *Marchantia polymorpha* | *Sphagnum* sp. |
| *Osmunda cinnamomea* | *Toxicondendron radicans* |
| *Osmunda regalis* | *Vitis rotundifolia* |
| *Smilax laurifolia* | *Woodwardia areolata* |

Overstory Percent Occurrence Table
Overhills Stream and Wetland Restoration
Harnett County, NC

| **Species** | **Percent Occurrence** |
|---|---|
| Nyssa biflora | 43.7 |
| Taxodium distichum | 13.9 |
| Taxodium ascendens | 11.9 |
| Pinus taeda | 10.6 |
| Acer rubrum | 9.9 |
| Liriodendron tulipfera | 2.6 |
| Pinus serotina | 2.6 |
| Liquidambar styraciflua | 2.0 |
| Quercus alba | 2.0 |
| Quercus sp. (hybrid) | 0.7 |

# APPENDIX I

# REFERENCE SITE GROUNDWATER DATA


Overhills Reference Site
Floodplain Groundwater Levels
water level (in)
10
0
-10
-20
-30
-40
-50
13-Feb
04-Apr
24-May
13-Jul
01-Sep
21-Oct
10-Dec
29-Jan
date
ground water level
ground surface

# APPENDIX J

# REFERENCE SITE SOIL REPORTS

NCDA Agronomic Division 4300 Reedy Creek Road Raleigh, NC 27607-6465 (919) 733-2655 Report No: 00139

*Grower:* Coleman, Amber
139 G Technology Dr
Garner, NC 27529

*Copies to:* County Extension Director

# Soil Test Report

*Farm:*

7/2/02 SERVING N.C. CITIZENS FOR OVER 50 YEARS Harnett County

Agronomist Comments: I -- 11, $

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1A | | | | | 1st Crop: Hardwood,E | 1.6T | 0.0 | 70-90 | 40-60 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 0-20 | $ | 0 | 0 | | | 11 |

### Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.25 | 0.63 | 4.8 | 21.0 | 3.8 | 4.7 | 0 | 37 | 10.0 | 6.0 | 23 | | | 40 | 40 | 39 | 85 | | | | 0.2 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR1B | | | | | 1st Crop: Hardwood,E | 1.3T | 0.0 | 70-90 | 50-70 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 10-30 | $ | 0 | 0 | | | 11 |

### Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.55 | 0.82 | 4.0 | 23.0 | 3.1 | 4.7 | 1 | 29 | 13.0 | 6.0 | 20 | | | 36 | 36 | 55 | 78 | | | | 0.1 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR2A | | | | | 1st Crop: Hardwood,E | 1.8T | 0.0 | 70-90 | 40-60 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 0-20 | $ | 0 | 0 | | | 11 |

### Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.31 | 0.73 | 4.3 | 14.0 | 3.7 | 4.5 | 0 | 33 | 6.0 | 5.0 | 10 | | | 34 | 34 | 26 | 71 | | | | 0.1 |

## Field Information / Applied Lime / Recommendations

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR2B | | | | | 1st Crop: Hardwood,E | 1T | 0.0 | 70-90 | 70-90 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 40-60 | $ | $ | $ | | | 11 |

### Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.97 | 0.89 | 2.9 | 17.0 | 2.4 | 4.7 | 0 | 14 | 9.0 | 6.0 | 13 | | | 15 | 15 | 20 | 64 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR3A | | | | | 1st Crop: Hardwood,E | 1.7T | 0.0 | 70-90 | 40-60 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 0-20 | $ | 0 | 0 | | | 11 |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.31 | 0.70 | 4.3 | 16.0 | 3.6 | 4.5 | 0 | 33 | 7.0 | 6.0 | 15 | | | 29 | 29 | 34 | 68 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR3B | | | | | 1st Crop: Hardwood,E | 1.1T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 50-70 | 0 | $ | $ | | | 11 |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.41 | 1.20 | 3.1 | 19.0 | 2.5 | 4.6 | 0 | 9 | 5.0 | 11.0 | 7 | | | 12 | 12 | 11 | 32 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR4A | | | | | 1st Crop: Hardwood,E | 2T | 0.0 | 70-90 | 60-80 | $ | $ | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 20-40 | $ | $ | 0 | | | 11 |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.43 | 0.69 | 5.1 | 16.0 | 4.3 | 4.5 | 0 | 22 | 7.0 | 6.0 | 14 | | | 35 | 35 | 13 | 53 | | | | 0.1 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR4B | | | | | 1st Crop: Hardwood,E | 1T | 0.0 | 70-90 | 80-100 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 60-80 | $ | $ | $ | | | 11 |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.76 | 1.19 | 2.4 | 8.0 | 2.2 | 4.5 | 0 | 5 | 6.0 | 3.0 | 7 | | | 10 | 10 | 4 | 22 | | | | 0.0 |

| Sample No. | Last Crop | Applied Lime Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR5A | | | | | 1st Crop: Hardwood,E | 2.1T | 0.0 | 50-70 | 40-60 | 0 | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 50-70 | 0-20 | 0 | 0 | 0 | | | 11 |

Test Results

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.37 | 0.71 | 6.1 | 28.0 | 4.4 | 4.5 | 7 | 34 | 16.0 | 10.0 | 31 | | | 58 | 58 | 43 | 61 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR5B | | | | | 1st Crop: Hardwood,E | 1.6T | 0.0 | 70-90 | 60-80 | $ | $ | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 30-50 | $ | $ | 0 | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.53 | 1.04 | 4.4 | 18.0 | 3.6 | 4.6 | 0 | 17 | 9.0 | 7.0 | 36 | | | 45 | 45 | 8 | 30 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR6A | | | | | 1st Crop: Hardwood,E | 1.5T | 0.0 | 60-80 | 60-80 | $ | $ | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 60-80 | 30-50 | $ | $ | 0 | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.02 | 0.84 | 3.7 | 16.0 | 3.1 | 4.5 | 3 | 18 | 8.0 | 7.0 | 8 | | | 29 | 29 | 21 | 39 | | | | 0.0 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR6B | | | | | 1st Crop: Hardwood,E | 1.1T | 0.0 | 70-90 | 70-90 | 0 | 0 | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 50-70 | 0 | 0 | $ | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.04 | 1.10 | 4.7 | 43.0 | 2.7 | 4.7 | 0 | 10 | 5.0 | 36.0 | 4 | | | 13 | 13 | 40 | 37 | | | | 0.2 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR7A | | | | | 1st Crop: Hardwood,E | 1.6T | 0.0 | 70-90 | 60-80 | $ | $ | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 30-50 | $ | $ | 0 | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.49 | 0.73 | 3.7 | 16.0 | 3.1 | 4.3 | 0 | 19 | 6.0 | 7.0 | 16 | | | 28 | 28 | 21 | 67 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR7B | | | | | 1st Crop: Hardwood,E | 1.4T | 0.0 | 70-90 | 70-90 | $ | 0 | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 40-60 | $ | 0 | $ | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.61 | 0.90 | 3.0 | 10.0 | 2.7 | 4.4 | 0 | 12 | 4.0 | 4.0 | 4 | | | 19 | 19 | 54 | 57 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR8A | | | | | 1st Crop: Hardwood,E | 1.6T | 0.0 | 70-90 | 50-70 | $ | 0 | 0 | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 10-30 | $ | 0 | 0 | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.74 | 0.74 | 4.4 | 20.0 | 3.5 | 4.6 | 2 | 30 | 8.0 | 8.0 | 12 | | | 30 | 30 | 44 | 70 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR8B | | | | | 1st Crop: Hardwood,E | 1.2T | 0.0 | 70-90 | 70-90 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 40-60 | $ | $ | $ | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.25 | 1.10 | 3.1 | 13.0 | 2.7 | 4.6 | 0 | 12 | 6.0 | 6.0 | 8 | | | 11 | 11 | 11 | 31 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR9A | | | | | 1st Crop: Hardwood,E | 1.8T | 0.0 | 70-90 | 60-80 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 20-40 | $ | $ | $ | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.74 | 0.62 | 4.8 | 15.0 | 4.1 | 4.6 | 1 | 23 | 6.0 | 6.0 | 9 | | | 24 | 24 | 23 | 47 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR9B | | | | | 1st Crop: Hardwood,E | 1.2T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 50-70 | 0 | $ | $ | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.41 | 1.11 | 3.6 | 28.0 | 2.6 | 4.6 | 0 | 9 | 8.0 | 18.0 | 35 | | | 12 | 12 | 23 | 33 | | | | 0.1 |

| Field Information | | Applied Lime | | | Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *Last Crop* | *Mo* | *Yr* | *T/A* | *Crop or Year* | *Lime* | *N* | *$P_2O_5$* | *$K_2O$* | *Mg* | *Cu* | *Zn* | *B* | *Mn* | *See Note* |
| HR10A | | | | | 1st Crop: Hardwood,E | 1.8T | 0.0 | 70-90 | 60-80 | $ | 0 | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 20-40 | $ | 0 | $ | | | 11 |

Test Results

| *Soil Class* | *HM%* | *W/V* | *CEC* | *BS%* | *Ac* | *pH* | *P-I* | *K-I* | *Ca%* | *Mg%* | *Mn-I* | *Mn-AI (1)* | *Mn-AI (2)* | *Zn-I* | *Zn-AI* | *Cu-I* | *S-I* | *SS-I* | *$NO_3$-N* | *$NH_4$-N* | *Na* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.97 | 0.53 | 4.6 | 15.0 | 3.9 | 4.6 | 0 | 22 | 7.0 | 6.0 | 24 | | | 23 | 23 | 28 | 43 | | | | 0.1 |

**Field Information | Applied Lime | Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR10B | | | | | 1st Crop: Hardwood,E | 1.2T | 0.0 | 70-90 | 70-90 | $ | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 50-70 | $ | $ | $ | | | 11 |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.43 | 1.09 | 3.0 | 10.0 | 2.7 | 4.6 | 0 | 11 | 5.0 | 4.0 | 6 | | | 17 | 17 | 10 | 22 | | | | 0.1 |

**Field Information | Applied Lime | Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR11A | | | | | 1st Crop: Hardwood,E | 1.5T | 0.0 | 70-90 | 60-80 | $ | 0 | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 20-40 | $ | 0 | $ | | | 11 |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 1.37 | 0.90 | 3.7 | 11.0 | 3.3 | 4.6 | 0 | 22 | 3.0 | 4.0 | 7 | | | 18 | 18 | 27 | 50 | | | | 0.0 |

**Field Information | Applied Lime | Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR11B | | | | | 1st Crop: Hardwood,E | .7T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 60-80 | 0 | $ | $ | | | 11 |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.04 | 1.07 | 2.1 | 24.0 | 1.6 | 4.7 | 0 | 6 | 9.0 | 14.0 | 4 | | | 10 | 10 | 18 | 60 | | | | 0.1 |

**Field Information | Applied Lime | Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR12A | | | | | 1st Crop: Hardwood,E | .9T | 0.0 | 70-90 | 80-100 | 0 | $ | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 50-70 | 0 | $ | $ | | | 11 |

**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.09 | 1.17 | 2.4 | 21.0 | 1.9 | 4.5 | 0 | 8 | 5.0 | 13.0 | 4 | | | 9 | 9 | 23 | 42 | | | | 0.0 |

**Field Information | Applied Lime | Recommendations**

| Sample No. | Last Crop | Mo | Yr | T/A | Crop or Year | Lime | N | $P_2O_5$ | $K_2O$ | Mg | Cu | Zn | B | Mn | See Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HR12B | | | | | 1st Crop: Hardwood,E | 1.1T | 0.0 | 70-90 | 60-80 | $ | 0 | $ | | | 11 |
| | | | | | 2nd Crop: Hardwood,M | 0 | 80-120 | 70-90 | 30-50 | $ | 0 | $ | | | 11 |

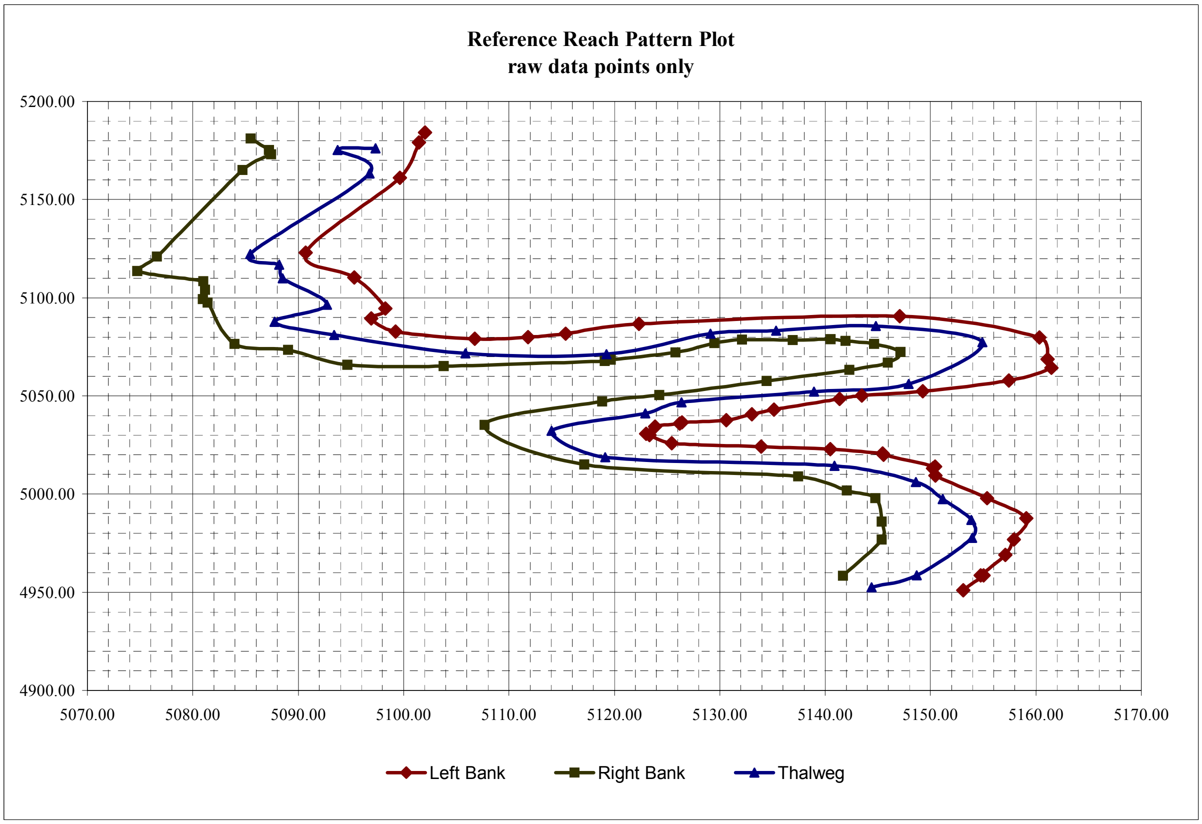
**Test Results**

| Soil Class | HM% | W/V | CEC | BS% | Ac | pH | P-I | K-I | Ca% | Mg% | Mn-I | Mn-AI (1) | Mn-AI (2) | Zn-I | Zn-AI | Cu-I | S-I | SS-I | $NO_3$-N | $NH_4$-N | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN | 0.97 | 0.86 | 2.7 | 15.0 | 2.3 | 4.5 | 0 | 17 | 5.0 | 6.0 | 7 | | | 18 | 18 | 27 | 41 | | | | 0.0 |

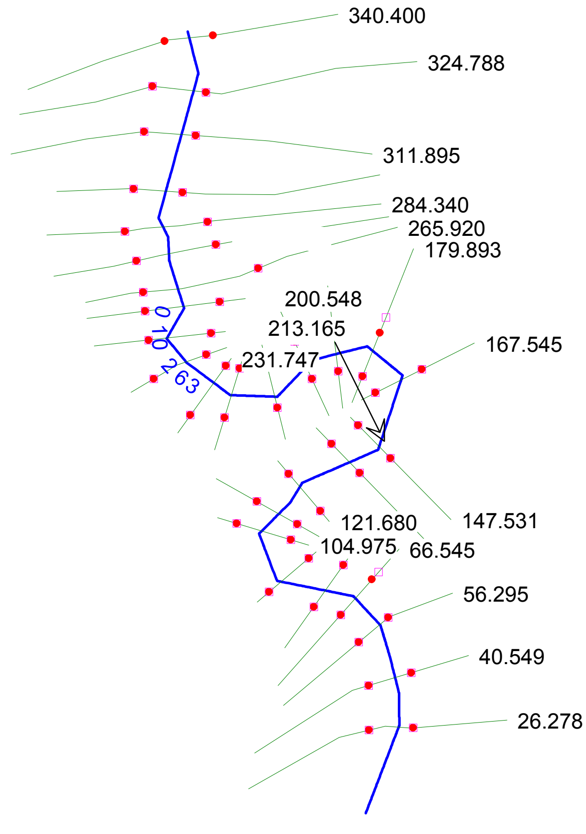
# APPENDIX K

# REFERENCE STREAM DATA

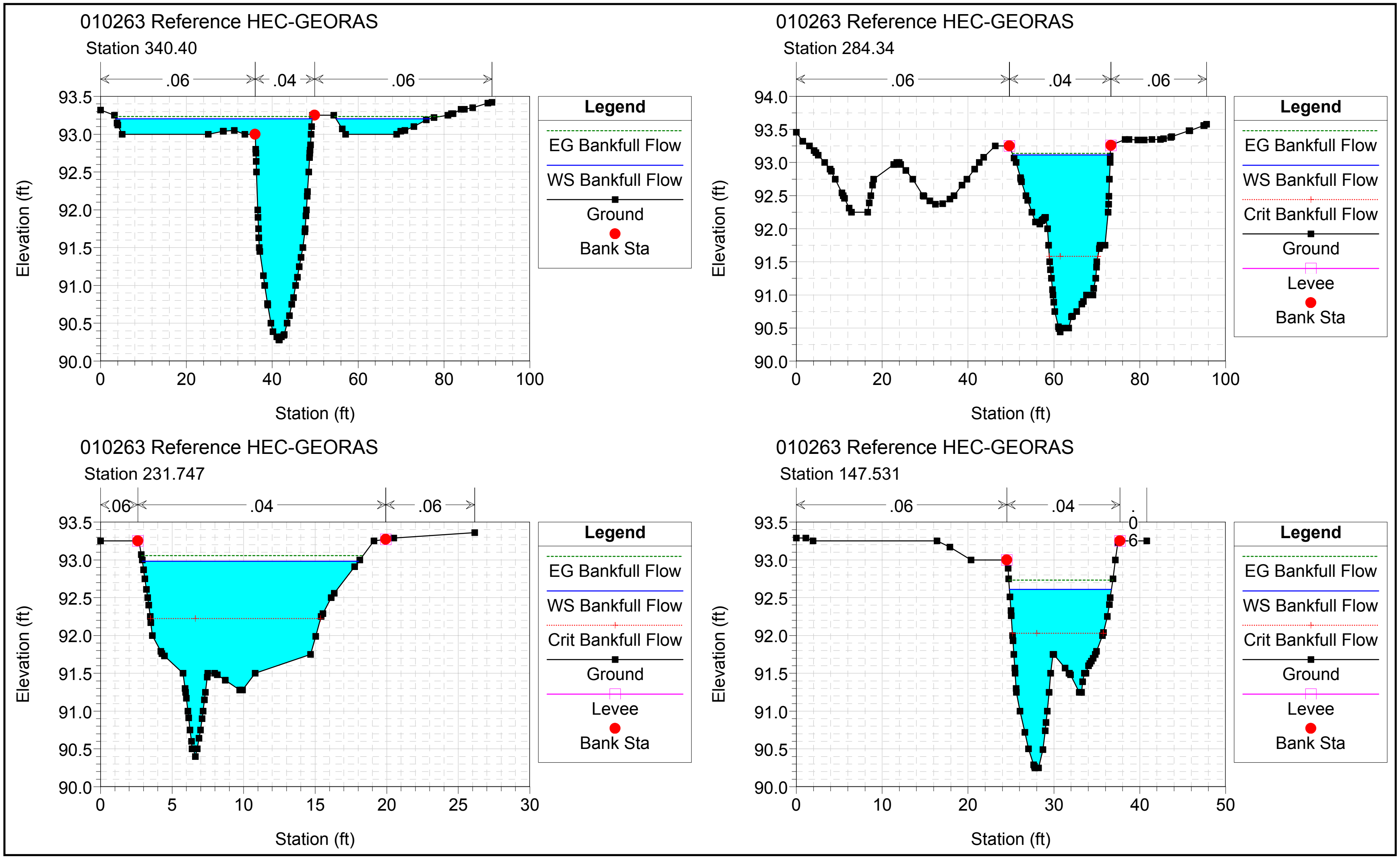
Reference Reach Pattern Plot.



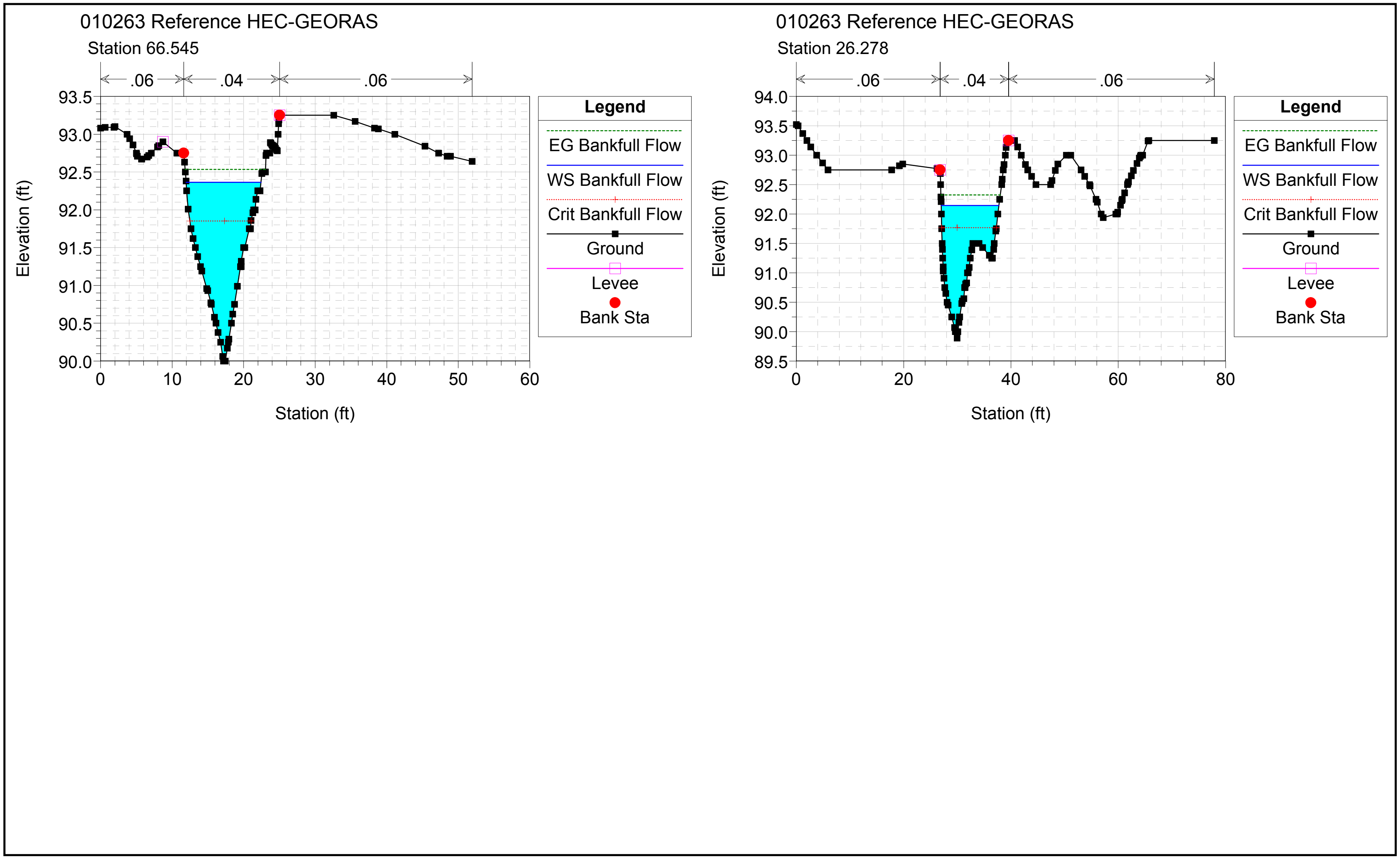
# Reference Reach - Plan View



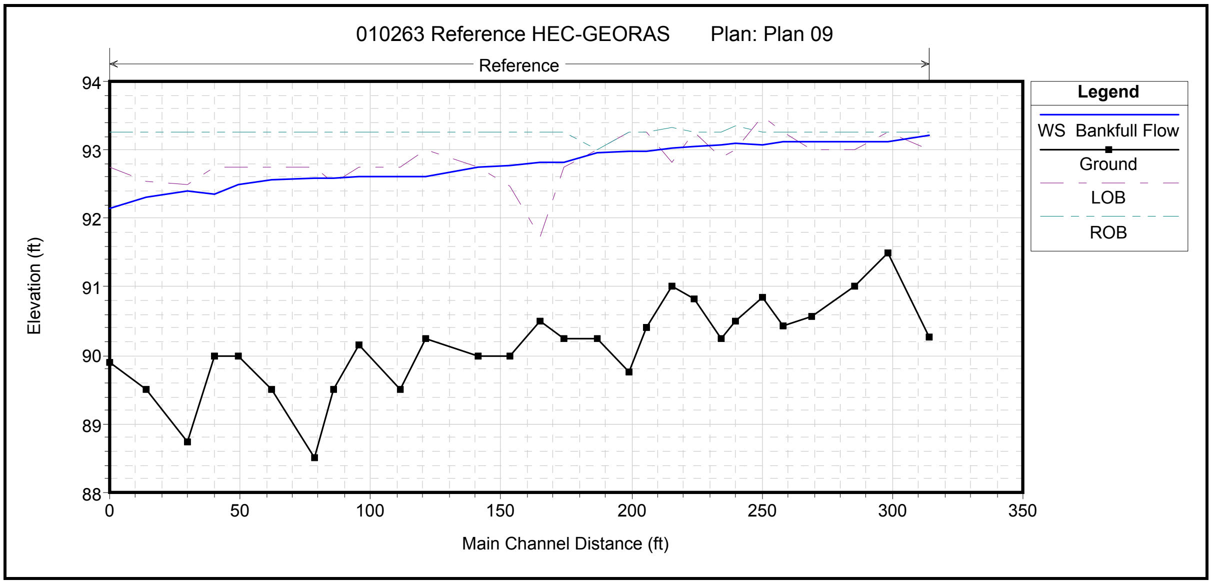
Reference stream cross sections



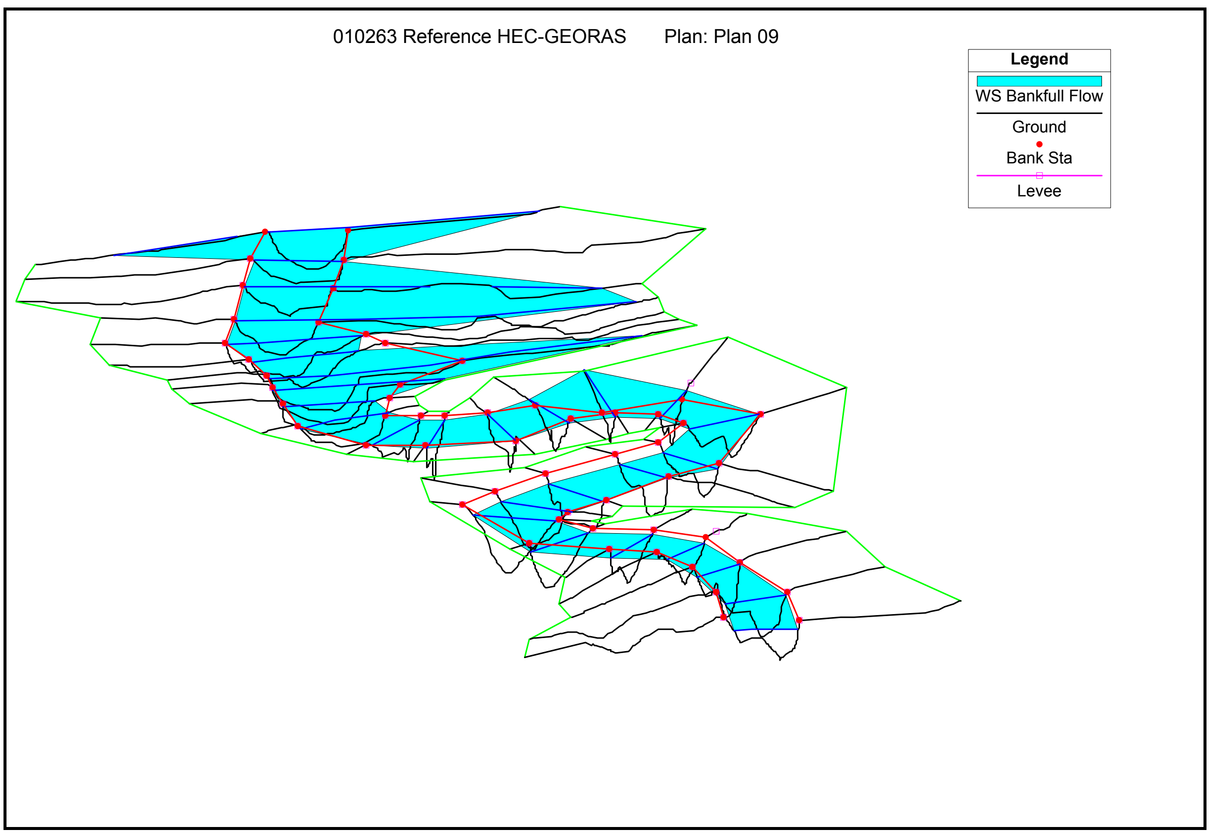
Reference stream cross sections



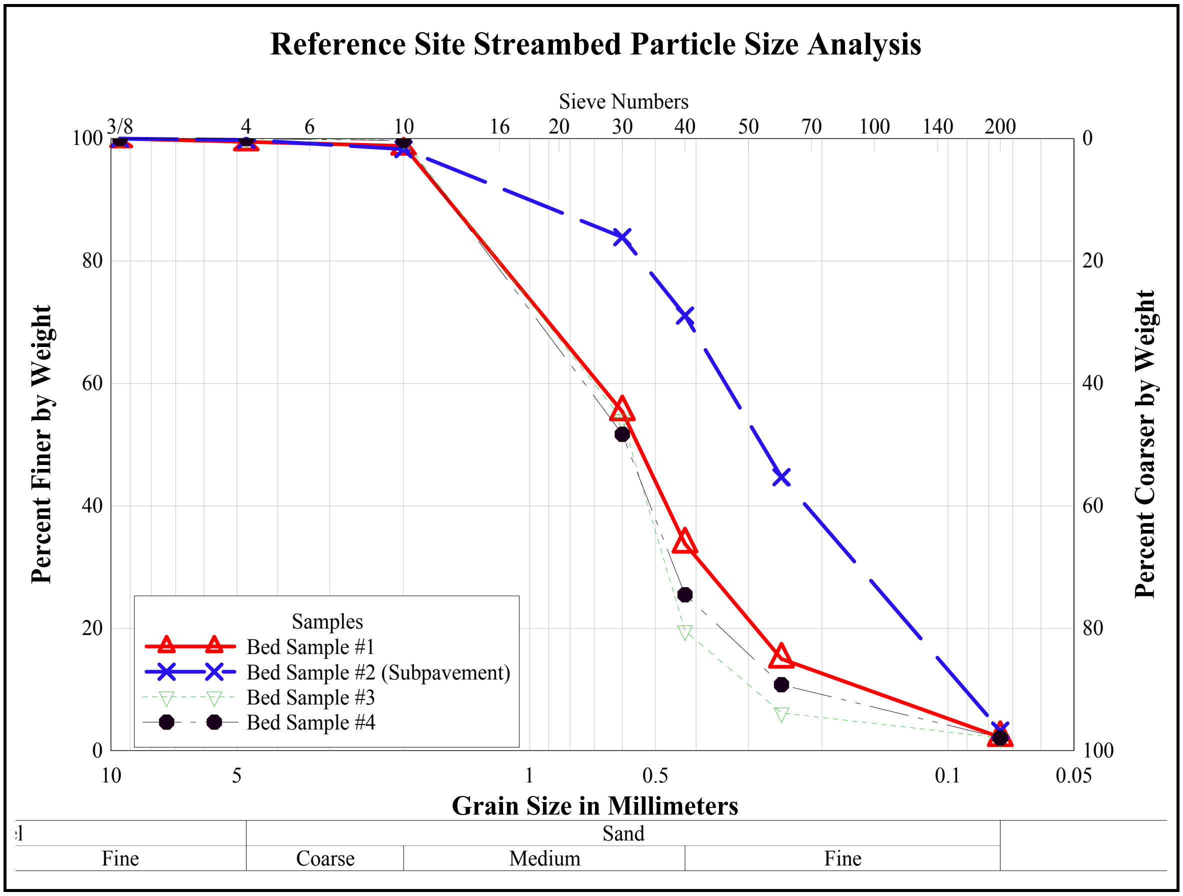
Reference Stream Profile. Showing stream bottom, right and left banks, and bankfull water surface based on modeling.




3-D perspective view of reference stream. Showing water surface modeled for a bankfull event.



Particle Size Samples.



# APPENDIX L

# STREAM RESTORATION DESIGN DATA

| Stream Dimensional Design Methods | Q bkfl | Slope | Depths | Bankfull Width |
|---|---|---|---|---|
| | cfs | ft/ft | ft | ft |
| **Regional Relationship Approaches - Coastal Plain** | | | | |
| NCSU SRI Draft Relationships | 131 | - | 2.9 | 30.7 |
| Ecoscience Draft Relationships | 71 | - | 2.6 | 27.4 |
| | | | | |
| **Stable Channel Method** | | | | |
| HEC-15, limiting velocity and shear | 40-70 | 0.0067-0.001 | 2-2.7 | 7-10 |
| | | | | |
| **Regime Equations** | | | | **Mean Widths** |
| Simon and Albertson Regime | 40-70 | 0.000046-0.000054 | 2.4-2.9 | 19.9-26.4 |
| Blench Regime | 40-70 | 0.00024-0.00027 | 1.3-1.6 | 23.2-30.7 |
| Chang Regime - Region 1 | 40-70 | 0.00039-0.00051 | 0.8 | 18.6-24.2 |
| **Summary - Regime Equations** | 40-70 | .000046-.00051 | 0.8-2.9 | 18.6-30.7 |
| | | | | |
| **Empirical Methods - Mobile Beds** | | | | **Bankfull Widths** |
| HEC-RAS, Copeland - Inflow 0ppm | 40-70 | 0.000067-0.000091 | 3.0-5.1 | 22-37.5 |
| HEC-RAS, Copeland - Inflow 75ppm | 40-70 | 0.00068-0.00081 | 1.9-2.9 | 16.5-26.5 |
| HEC-RAS, Copeland - Inflow 175ppm | 40-70 | 0.001-0.0012 | 1.8-2.6 | 16-25 |
| **Summary - Copeland Method** | 40-70 | .00068-.0012 | 1.8-2.9 | 16-37.5 |

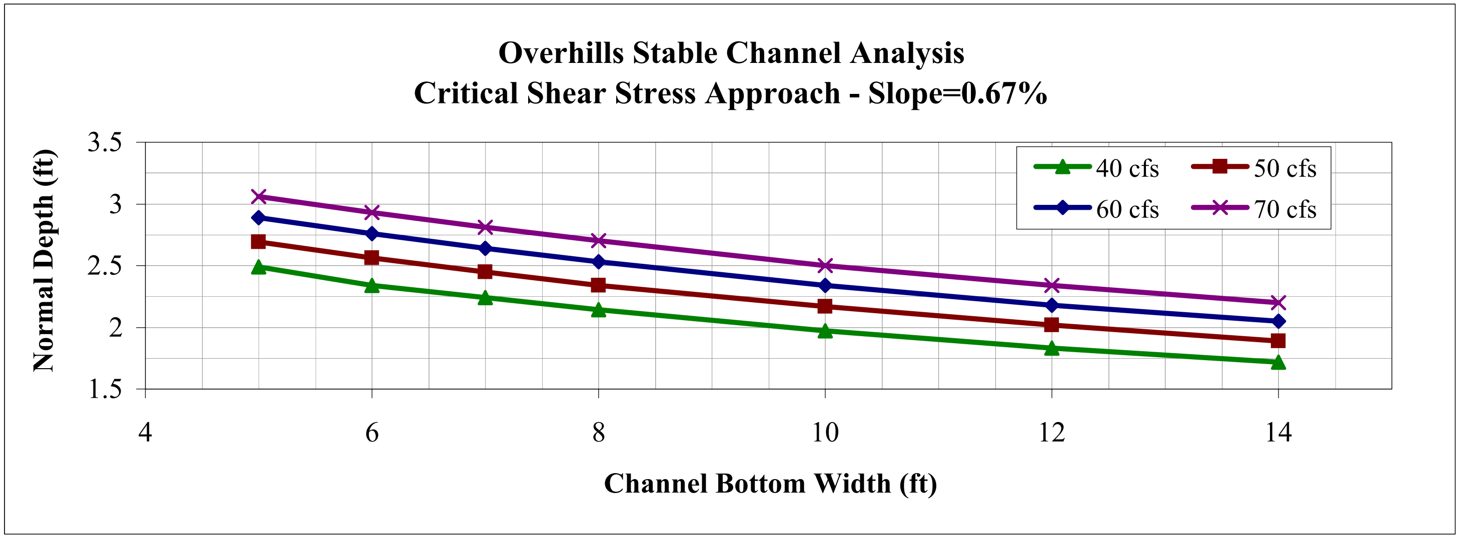
| | Existing Stream | | | Reference Reach | | | Design Stream | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **MIN** | **MAX** | **AVERAGE** | **MIN** | **MAX** | **AVERAGE** | **MIN** | **MAX** | **AVERAGE** |
| Drainage Area, DA (sq mi) | 15.5 | 15.9 | 15.7 | 14.7 | 14.8 | 14.8 | 15.5 | 15.9 | 15.7 |
| Stream Type (Rosgen) | G5c | G4 | G5c | E5 | E5 | E5 | E | E | E |
| Bankfull XSEC Area, Abkf (sq ft) | 54.6 | 77.5 | 56.7 | 13.5 | 22.1 | 21.8 | 35.0 | 46.0 | 41.0 |
| Bankfull Width, Wbkf (ft) | 11.7 | 15.9 | 14.5 | 10.8 | 20.4 | 14.4 | 21.0 | 25.0 | 22.5 |
| Bankfull Depth, Dbkf (ft) | 2.4 | 2.5 | 2.5 | 1.0 | 2.7 | 2.7 | 2.5 | 2.5 | 2.5 |
| Width to Depth Ratio, W/D (ft/ft) | 4.9 | 6.4 | 5.8 | 4.1 | 7.7 | 5.4 | 8.4 | 10.0 | 9.0 |
| Width Floodprone Area, Wfpa (ft) | - | - | 16.5 | - | - | 200 | - | - | 200 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | - | - | 1.2 | - | - | 13.9 | - | - | 8.9 |
| Max Depth @ bkf, Dmax (ft) | 2.4 | 2.5 | 2.5 | 1.8 | 4.2 | 3.2 | 2.5 | 2.5 | 2.5 |
| Max Depth Ratio, Dmax/Dbkf | | | 1.0 | 0.7 | 1.6 | 1.2 | 1.0 | 1.0 | 1.0 |
| Max Depth @ tob, Dmaxtob (ft) | 5.5 | 7.0 | 6.0 | 2.0 | 4.8 | 4.0 | 2.5 | 6.0 | 2.5 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 2.2 | 2.8 | 2.4 | 0.6 | 1.5 | 1.2 | 1.0 | 2.4 | 1.2 |
| Meander Length, Lm (ft) | 315 | 660 | 500 | 125 | 175 | 150 | 125 | 250 | 200 |
| Meander Length Ratio, Lm/Wbkf | 21.8 | 45.6 | 34.5 | 8.7 | 12.2 | 10.4 | 5.6 | 11.1 | 8.9 |
| Radius of Curvature, Rc (ft) | - | 235.0 | 235.0 | 12.0 | 30.0 | 23.4 | 30.0 | 175.0 | 80.0 |
| Rc Ratio, Rc/Wbkf | - | 16.2 | 16.2 | 0.8 | 2.1 | 1.6 | 1.3 | 7.8 | 3.6 |
| Belt Width, Wblt (ft) | - | - | 596.8 | 45.0 | 110.0 | 77.0 | 80.0 | 200.0 | 110.0 |
| Meander Width Ratio, Wblt/Wbkf (ft) | - | - | 41.2 | 3.1 | 7.6 | 5.3 | 3.6 | 8.9 | 4.9 |
| Sinuosity, K | - | - | 1.1 | - | 2.3 | 1.4 | - | 2.1 | 1.6 |
| Valley Slope, Sval (ft/ft) | - | - | 0.0005 | - | - | 0.0007 | - | - | 0.0005 |
| Channel Slope, Schan (ft/ft) | - | - | 0.0016 | - | - | 0.0090 | 0.0007 | 0.0010 | 0.0009 |
| | | | | | | | | | |
| d16 (mm) | 0.22 | 0.42 | 0.2 | 0.32 | 0.40 | 0.35 | 0.2 | 0.4 | 0.22 |
| d35 (mm) | 0.43 | 2.70 | 0.4 | 0.45 | 0.39 | 0.37 | 0.4 | 2.7 | 0.43 |
| d50 (mm) | 0.50 | 9.00 | 0.5 | 0.58 | 0.65 | 0.62 | 0.5 | 9.0 | 0.5 |
| d84 (mm) | 2.60 | 30.00 | 2.6 | 1.70 | 1.70 | 1.70 | 2.6 | 30.0 | 2.6 |
| d95 (mm) | 36.00 | 38.00 | 36.0 | 2.40 | 2.40 | 2.40 | 36.0 | 38.0 | 36 |

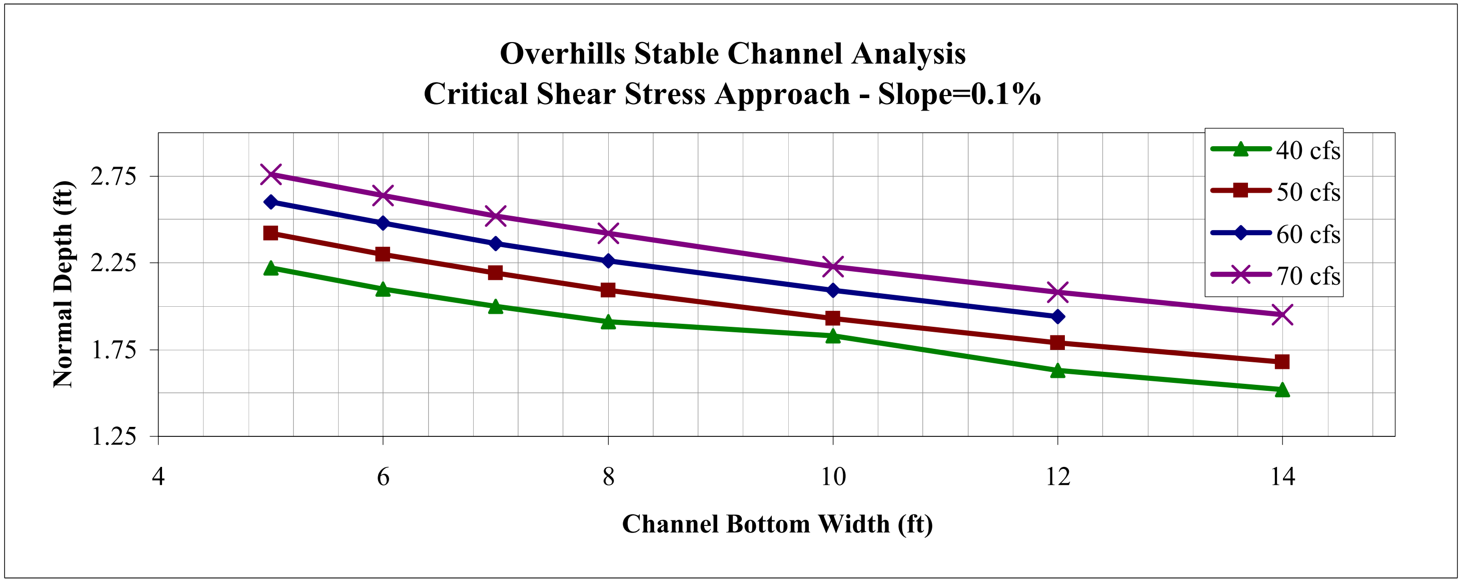
Overhills/Jumping Run Creel
Harnett County, North Carolina
Stream and Wetland Restoration Projec

BLWI Project: 010263

Stable Channel Design and Shear Stress Analysi
Immovable Bed
Critical Shear Stress Approacl

| Design Q (cfs) | Base Width (ft) | Sideslopes (ft/ft) | Slope (ft/ft) | Permissible Shear (lbs/sf) | Normal Depth (ft) | Velocity (ft/s) | Calculated Shear (lbs/sf) | Stability |
|---|---|---|---|---|---|---|---|---|
| 40 | 5 | 2.5 | 0.00067 | 0.035 | 2.49 | 1.45 | 0.016 | yes |
| | 6 | 2.5 | 0.00067 | 0.035 | 2.34 | 1.44 | 0.015 | yes |
| | 7 | 2.5 | 0.00067 | 0.035 | 2.24 | 1.42 | 0.014 | yes |
| | 8 | 2.5 | 0.00067 | 0.035 | 2.14 | 1.4 | 0.013 | yes |
| | 10 | 2.5 | 0.00067 | 0.035 | 1.97 | 1.36 | 0.012 | yes |
| | 12 | 2.5 | 0.00067 | 0.035 | 1.83 | 1.32 | 0.011 | yes |
| | 14 | 2.5 | 0.00067 | 0.035 | 1.72 | 1.27 | 0.01 | yes |
| 50 | 5 | 2.5 | 0.00067 | 0.035 | 2.69 | 1.59 | 0.018 | yes |
| | 6 | 2.5 | 0.00067 | 0.035 | 2.56 | 1.57 | 0.017 | yes |
| | 7 | 2.5 | 0.00067 | 0.035 | 2.45 | 1.56 | 0.016 | yes |
| | 8 | 2.5 | 0.00067 | 0.035 | 2.34 | 1.54 | 0.016 | yes |
| | 10 | 2.5 | 0.00067 | 0.035 | 2.17 | 1.5 | 0.014 | yes |
| | 12 | 2.5 | 0.00067 | 0.035 | 2.02 | 1.45 | 0.013 | yes |
| | 14 | 2.5 | 0.00067 | 0.035 | 1.89 | 1.41 | 0.012 | yes |
| 60 | 5 | 2.5 | 0.00067 | 0.035 | 2.89 | 1.7 | 0.021 | yes |
| | 6 | 2.5 | 0.00067 | 0.035 | 2.76 | 1.69 | 0.02 | yes |
| | 7 | 2.5 | 0.00067 | 0.035 | 2.64 | 1.67 | 0.019 | yes |
| | 8 | 2.5 | 0.00067 | 0.035 | 2.53 | 1.66 | 0.018 | yes |
| | 10 | 2.5 | 0.00067 | 0.035 | 2.34 | 1.62 | 0.016 | yes |
| | 12 | 2.5 | 0.00067 | 0.035 | 2.18 | 1.57 | 0.015 | yes |
| | 14 | 2.5 | 0.00067 | 0.035 | 2.05 | 1.53 | 0.014 | yes |
| 70 | 5 | 2.5 | 0.00067 | 0.035 | 3.06 | 1.8 | 0.023 | yes |
| | 6 | 2.5 | 0.00067 | 0.035 | 2.93 | 1.79 | 0.022 | yes |
| | 7 | 2.5 | 0.00067 | 0.035 | 2.81 | 1.78 | 0.021 | yes |
| | 8 | 2.5 | 0.00067 | 0.035 | 2.7 | 1.76 | 0.02 | yes |
| | 10 | 2.5 | 0.00067 | 0.035 | 2.5 | 1.72 | 0.018 | yes |
| | 12 | 2.5 | 0.00067 | 0.035 | 2.34 | 1.68 | 0.017 | yes |
| | 14 | 2.5 | 0.00067 | 0.035 | 2.2 | 1.63 | 0.015 | yes |
| 40 | 5 | 2.5 | 0.001 | 0.035 | 2.22 | 1.71 | 0.022 | yes |
| | 6 | 2.5 | 0.001 | 0.035 | 2.1 | 1.69 | 0.02 | yes |
| | 7 | 2.5 | 0.001 | 0.035 | 2 | 1.67 | 0.019 | yes |
| | 8 | 2.5 | 0.001 | 0.035 | 1.91 | 1.64 | 0.018 | yes |
| | 10 | 2.5 | 0.001 | 0.035 | 1.83 | 1.62 | 0.017 | yes |
| | 12 | 2.5 | 0.001 | 0.035 | 1.63 | 1.53 | 0.014 | yes |
| | 14 | 2.5 | 0.001 | 0.035 | 1.52 | 1.47 | 0.013 | yes |
| 50 | 5 | 2.5 | 0.001 | 0.035 | 2.42 | 1.87 | 0.026 | yes |
| | 6 | 2.5 | 0.001 | 0.035 | 2.3 | 1.85 | 0.024 | yes |
| | 7 | 2.5 | 0.001 | 0.035 | 2.19 | 1.83 | 0.023 | yes |
| | 8 | 2.5 | 0.001 | 0.035 | 2.09 | 1.8 | 0.022 | yes |
| | 10 | 2.5 | 0.001 | 0.035 | 1.93 | 1.75 | 0.019 | yes |
| | 12 | 2.5 | 0.001 | 0.035 | 1.79 | 1.69 | 0.017 | yes |
| | 14 | 2.5 | 0.001 | 0.035 | 1.68 | 1.63 | 0.016 | yes |
| 60 | 5 | 2.5 | 0.001 | 0.035 | 2.6 | 2.01 | 0.029 | yes |
| | 6 | 2.5 | 0.001 | 0.035 | 2.48 | 1.99 | 0.028 | yes |
| | 7 | 2.5 | 0.001 | 0.035 | 2.36 | 1.97 | 0.026 | yes |
| | 8 | 2.5 | 0.001 | 0.035 | 2.26 | 1.94 | 0.025 | yes |
| | 10 | 2.5 | 0.001 | 0.035 | 2.09 | 1.89 | 0.022 | yes |
| | 12 | 2.5 | 0.001 | 0.035 | 1.94 | 1.83 | 0.02 | yes |
| | 14 | 2.5 | 0.001 | 0.035 | 1.82 | 1.78 | 0.019 | yes |
| 70 | 5 | 2.5 | 0.001 | 0.035 | 2.76 | 2.13 | 0.033 | yes |
| | 6 | 2.5 | 0.001 | 0.035 | 2.64 | 2.11 | 0.031 | yes |
| | 7 | 2.5 | 0.001 | 0.035 | 2.52 | 2.09 | 0.03 | yes |
| | 8 | 2.5 | 0.001 | 0.035 | 2.42 | 2.06 | 0.028 | yes |
| | 10 | 2.5 | 0.001 | 0.035 | 2.23 | 2.01 | 0.025 | yes |
| | 12 | 2.5 | 0.001 | 0.035 | 2.08 | 1.96 | 0.023 | yes |
| | 14 | 2.5 | 0.001 | 0.035 | 1.95 | 1.9 | 0.021 | yes |
| 40 | 5 | 2.5 | 0.002 | 0.035 | 1.84 | 2.27 | 0.039 | no |
| | 6 | 2.5 | 0.002 | 0.035 | 1.73 | 2.23 | 0.036 | no |
| | 7 | 2.5 | 0.002 | 0.035 | 1.64 | 2.19 | 0.034 | yes |
| | 8 | 2.5 | 0.002 | 0.035 | 1.56 | 2.15 | 0.032 | yes |
| | 10 | 2.5 | 0.002 | 0.035 | 1.43 | 2.07 | 0.028 | yes |
| | 12 | 2.5 | 0.002 | 0.035 | 1.32 | 1.98 | 0.025 | yes |
| | 14 | 2.5 | 0.002 | 0.035 | 1.23 | 1.9 | 0.022 | yes |
| 50 | 5 | 2.5 | 0.002 | 0.035 | 2.01 | 2.48 | 0.046 | no |
| | 6 | 2.5 | 0.002 | 0.035 | 1.9 | 2.44 | 0.043 | no |
| | 7 | 2.5 | 0.002 | 0.035 | 1.81 | 2.41 | 0.04 | no |
| | 8 | 2.5 | 0.002 | 0.035 | 1.72 | 2.36 | 0.038 | no |
| | 10 | 2.5 | 0.002 | 0.035 | 1.57 | 2.28 | 0.034 | yes |
| | 12 | 2.5 | 0.002 | 0.035 | 1.46 | 2.19 | 0.03 | yes |
| | 14 | 2.5 | 0.002 | 0.035 | 1.36 | 2.11 | 0.027 | yes |
| 60 | 5 | 2.5 | 0.002 | 0.035 | 2.17 | 2.66 | 0.053 | no |
| | 6 | 2.5 | 0.002 | 0.035 | 2.05 | 2.62 | 0.049 | no |
| | 7 | 2.5 | 0.002 | 0.035 | 1.95 | 2.59 | 0.046 | no |
| | 8 | 2.5 | 0.002 | 0.035 | 1.86 | 2.55 | 0.044 | no |
| | 10 | 2.5 | 0.002 | 0.035 | 1.71 | 2.46 | 0.039 | no |
| | 12 | 2.5 | 0.002 | 0.035 | 1.58 | 2.38 | 0.035 | no |
| | 14 | 2.5 | 0.002 | 0.035 | 1.48 | 2.29 | 0.032 | yes |
| 70 | 5 | 2.5 | 0.002 | 0.035 | 2.31 | 2.81 | 0.059 | no |
| | 6 | 2.5 | 0.002 | 0.035 | 2.19 | 2.78 | 0.055 | no |
| | 7 | 2.5 | 0.002 | 0.035 | 2.09 | 2.75 | 0.052 | no |
| | 8 | 2.5 | 0.002 | 0.035 | 1.99 | 2.71 | 0.049 | no |
| | 10 | 2.5 | 0.002 | 0.035 | 1.83 | 2.63 | 0.044 | no |
| | 12 | 2.5 | 0.002 | 0.035 | 1.7 | 2.54 | 0.04 | no |
| | 14 | 2.5 | 0.002 | 0.035 | 1.59 | 2.45 | 0.036 | no |


Overhills Stable Channel Analysis
Critical Shear Stress Approach - Slope=0.67%
Normal Depth (ft)
3.5
3
2.5
2
1.5
4
6
8
10
12
14
Channel Bottom Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs


Overhills Stable Channel Analysis
Critical Shear Stress Approach - Slope=0.1%
Normal Depth (ft)
2.75
2.25
1.75
1.25
4
6
8
10
12
14
Channel Bottom Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs

Overhills/Jumping Run Creek
Harnett County, North Carolina
Stream and Wetland Restoration Project

BLWI Project: 010263

Stable Channel Design
HEC-RAS 3.1
Copeland Method

Stability Curves
Inflow Sediment Load = 0 ppm

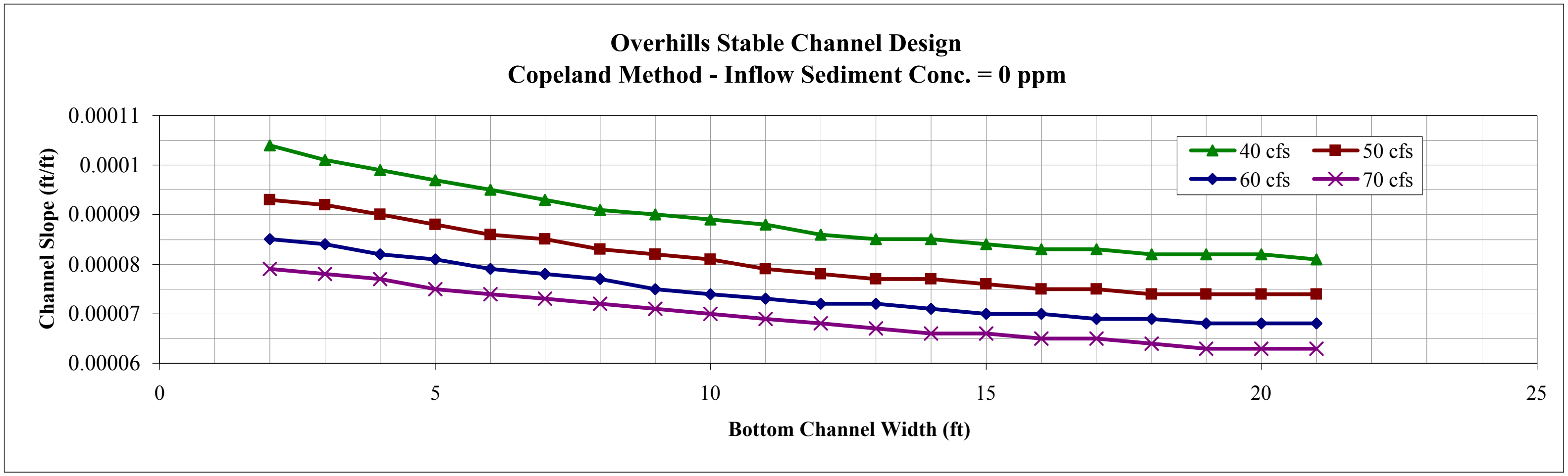
| channel width (ft) | 40 cfs Depth | 40 cfs Energy Slope | 50 cfs Depth | 50 cfs Energy Slope | 60 cfs Depth | 60 cfs Energy Slope | 70 cfs Depth | 70 cfs Energy Slope | 10 cfs Depth | 10 cfs Energy Slope | 5 cfs Depth | 5 cfs Energy Slope |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.7 | 0.000104 | 5.2 | 0.000093 | 5.7 | 0.000085 | 6.2 | 0.000079 | 2.4 | 0.000198 | 1.7 | 0.000273 |
| 2 | 4.5 | 0.000101 | 5 | 0.000092 | 5.5 | 0.000084 | 6 | 0.000078 | 2.2 | 0.00019 | 1.5 | 0.000259 |
| 3 | 4.3 | 0.000099 | 4.9 | 0.00009 | 5.3 | 0.000082 | 5.8 | 0.000077 | 2 | 0.000182 | 1.3 | 0.000245 |
| 4 | 4.1 | 0.000097 | 4.7 | 0.000088 | 5.2 | 0.000081 | 5.6 | 0.000075 | 1.9 | 0.000176 | 1.2 | 0.000235 |
| 5 | 4 | 0.000095 | 4.5 | 0.000086 | 5 | 0.000079 | 5.4 | 0.000074 | 1.7 | 0.000171 | 1.1 | 0.000229 |
| 6 | 3.8 | 0.000093 | 4.3 | 0.000085 | 4.8 | 0.000078 | 5.2 | 0.000073 | 1.6 | 0.000167 | 1 | 0.000224 |
| 7 | 3.7 | 0.000091 | 4.2 | 0.000083 | 4.6 | 0.000077 | 5.1 | 0.000072 | 1.5 | 0.000163 | 0.9 | 0.000221 |
| 8 | 3.5 | 0.00009 | 4 | 0.000082 | 4.5 | 0.000075 | 4.9 | 0.000071 | 1.4 | 0.000161 | 0.8 | 0.00022 |
| 9 | 3.4 | 0.000089 | 3.9 | 0.000081 | 4.3 | 0.000074 | 4.8 | 0.00007 | 1.3 | 0.000159 | 0.8 | 0.000218 |
| 10 | 3.2 | 0.000088 | 3.7 | 0.000079 | 4.2 | 0.000073 | 4.6 | 0.000069 | 1.2 | 0.000159 | 0.7 | 0.000221 |
| 11 | 3.1 | 0.000086 | 3.6 | 0.000078 | 4.1 | 0.000072 | 4.5 | 0.000068 | 1.1 | 0.000158 | 0.7 | 0.000223 |
| 12 | 3 | 0.000085 | 3.5 | 0.000077 | 3.9 | 0.000072 | 4.3 | 0.000067 | 1.1 | 0.000157 | 0.6 | 0.000226 |
| 13 | 2.9 | 0.000085 | 3.4 | 0.000077 | 3.8 | 0.000071 | 4.2 | 0.000066 | 1 | 0.000157 | 0.6 | 0.00023 |
| 14 | 2.8 | 0.000084 | 3.3 | 0.000076 | 3.7 | 0.00007 | 4.1 | 0.000066 | 1 | 0.000158 | 0.5 | 0.000233 |
| 15 | 2.7 | 0.000083 | 3.1 | 0.000075 | 3.6 | 0.00007 | 4 | 0.000065 | 0.9 | 0.00016 | 0.5 | 0.00024 |
| 16 | 2.6 | 0.000083 | 3 | 0.000075 | 3.5 | 0.000069 | 3.8 | 0.000065 | 0.9 | 0.000161 | 0.5 | 0.000245 |
| 17 | 2.5 | 0.000082 | 2.9 | 0.000074 | 3.4 | 0.000069 | 3.7 | 0.000064 | 0.8 | 0.000163 | 0.5 | 0.000252 |
| 18 | 2.4 | 0.000082 | 2.9 | 0.000074 | 3.3 | 0.000068 | 3.6 | 0.000063 | 0.8 | 0.000165 | 0.4 | 0.000257 |
| 19 | 2.3 | 0.000082 | 2.8 | 0.000074 | 3.2 | 0.000068 | 3.5 | 0.000063 | 0.8 | 0.000166 | 0.4 | 0.000264 |
| 20 | 2.3 | 0.000081 | 2.7 | 0.000074 | 3.1 | 0.000068 | 3.4 | 0.000063 | 0.7 | 0.000171 | 0.4 | 0.000269 |

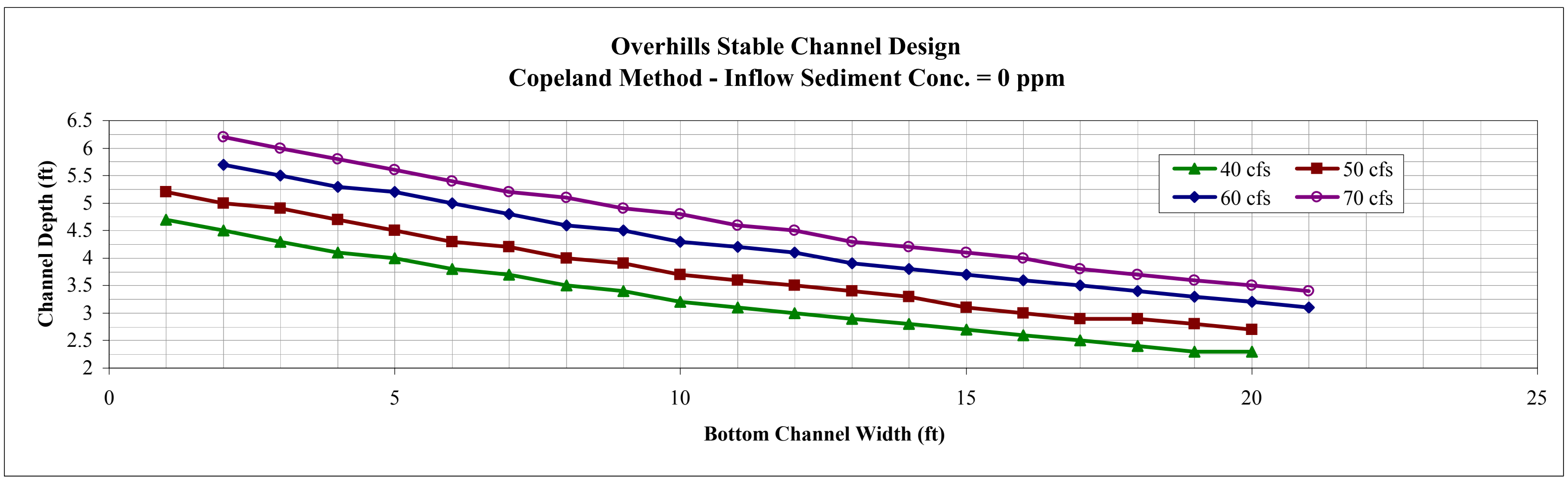
Stability Curves
Inflow Sediment Load = 75 ppm

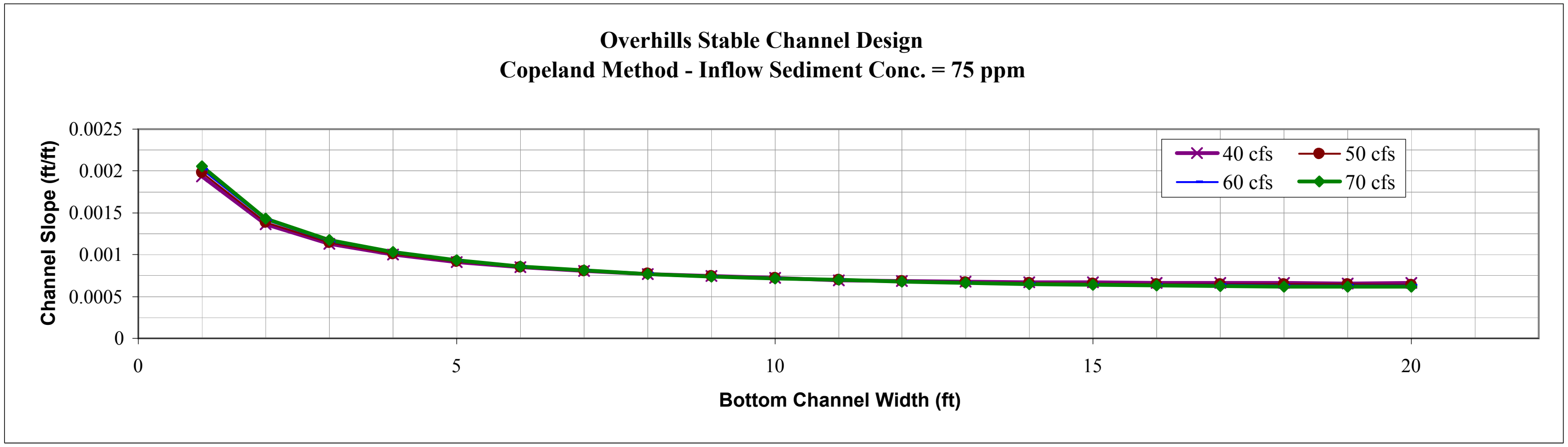
| channel width (ft) | 40 cfs Depth | 40 cfs Energy Slope | 50 cfs Depth | 50 cfs Energy Slope | 60 cfs Depth | 60 cfs Energy Slope | 70 cfs Depth | 70 cfs Energy Slope |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.6 | 0.001938 | 2.9 | 0.001977 | 3.1 | 0.002018 | 3.3 | 0.002057 |
| 2 | 2.6 | 0.001363 | 2.9 | 0.001387 | 3.1 | 0.001416 | 3.3 | 0.001434 |
| 3 | 2.6 | 0.001129 | 2.8 | 0.001147 | 3 | 0.001163 | 3.2 | 0.001174 |
| 4 | 2.5 | 0.000999 | 2.7 | 0.001011 | 3 | 0.001022 | 3.2 | 0.00103 |
| 5 | 2.3 | 0.00091 | 2.6 | 0.000918 | 2.9 | 0.000926 | 3.1 | 0.000931 |
| 6 | 2.2 | 0.000851 | 2.5 | 0.000854 | 2.7 | 0.000858 | 3 | 0.000862 |
| 7 | 2.1 | 0.000804 | 2.4 | 0.000807 | 2.6 | 0.00081 | 2.9 | 0.000812 |
| 8 | 2 | 0.000768 | 2.3 | 0.000772 | 2.5 | 0.000773 | 2.8 | 0.000771 |
| 9 | 1.9 | 0.000744 | 2.2 | 0.000743 | 2.4 | 0.000741 | 2.7 | 0.000739 |
| 10 | 1.9 | 0.000722 | 2.1 | 0.000722 | 2.3 | 0.000719 | 2.6 | 0.000716 |
| 11 | 1.8 | 0.000695 | 2 | 0.000698 | 2.3 | 0.000697 | 2.5 | 0.000697 |
| 12 | 1.7 | 0.000684 | 1.9 | 0.000684 | 2.2 | 0.000676 | 2.4 | 0.000675 |
| 13 | 1.6 | 0.000676 | 1.9 | 0.00067 | 2.1 | 0.000664 | 2.3 | 0.00066 |
| 14 | 1.6 | 0.000673 | 1.8 | 0.000663 | 2 | 0.000655 | 2.2 | 0.000651 |
| 15 | 1.5 | 0.000667 | 1.7 | 0.000657 | 1.9 | 0.000647 | 2.1 | 0.000639 |
| 16 | 1.4 | 0.00066 | 1.7 | 0.000651 | 1.9 | 0.000642 | 2.1 | 0.000631 |
| 17 | 1.4 | 0.000665 | 1.6 | 0.000647 | 1.8 | 0.000637 | 2 | 0.000628 |
| 18 | 1.3 | 0.000662 | 1.6 | 0.000647 | 1.8 | 0.000632 | 1.9 | 0.000621 |
| 19 | 1.3 | 0.000658 | 1.5 | 0.000645 | 1.7 | 0.000632 | 1.9 | 0.000619 |
| 20 | 1.3 | 0.000663 | 1.5 | 0.000643 | 1.6 | 0.00063 | 1.8 | 0.000618 |

Stability Curves
Inflow Sediment Load = 175 ppm

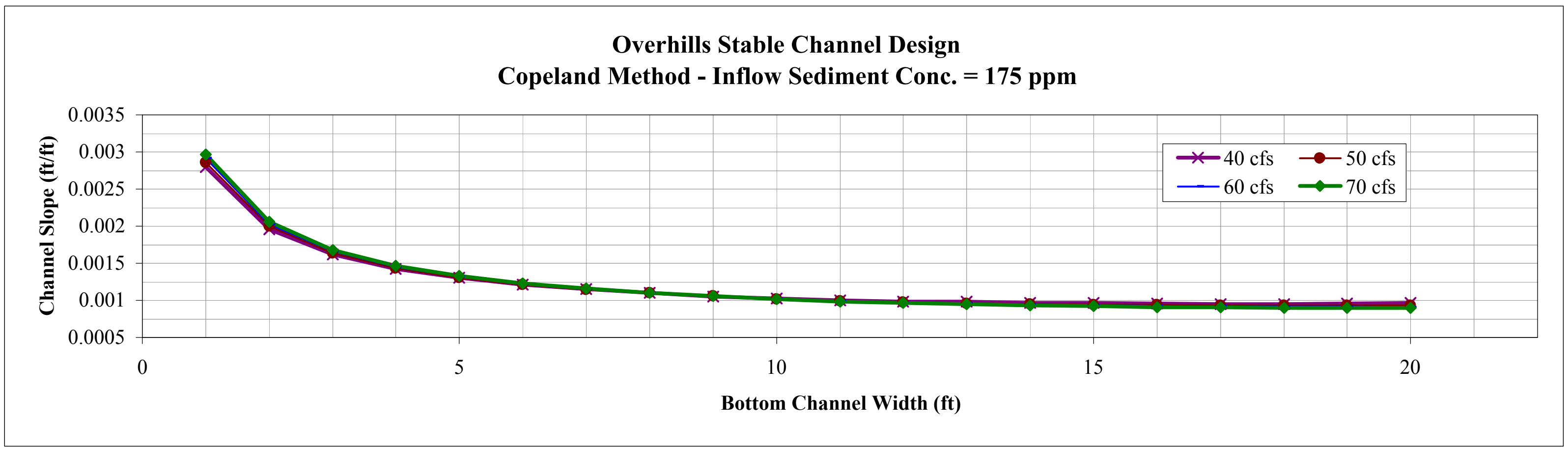
| Bottom Width | 40 cfs Depth | 40 cfs Energy Slope | 50 cfs Depth | 50 cfs Energy Slope | 60 cfs Depth | 60 cfs Energy Slope | 70 cfs Depth | 70 cfs Energy Slope |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.4 | 0.002793 | 2.7 | 0.002856 | 2.9 | 0.002919 | 3 | 0.002968 |
| 2 | 2.4 | 0.001958 | 2.7 | 0.001996 | 2.9 | 0.002023 | 3.1 | 0.002056 |
| 3 | 2.4 | 0.001619 | 2.6 | 0.001637 | 2.8 | 0.001663 | 3 | 0.001682 |
| 4 | 2.3 | 0.001424 | 2.5 | 0.001435 | 2.7 | 0.001453 | 2.9 | 0.001466 |
| 5 | 2.2 | 0.001302 | 2.4 | 0.001309 | 2.6 | 0.001321 | 2.8 | 0.00133 |
| 6 | 2.1 | 0.001211 | 2.3 | 0.001215 | 2.5 | 0.001222 | 2.7 | 0.001227 |
| 7 | 2 | 0.001149 | 2.2 | 0.001148 | 2.4 | 0.001154 | 2.6 | 0.001158 |
| 8 | 1.9 | 0.001098 | 2.1 | 0.0011 | 2.3 | 0.0011 | 2.5 | 0.001103 |
| 9 | 1.8 | 0.001055 | 2 | 0.001058 | 2.2 | 0.00106 | 2.4 | 0.001056 |
| 10 | 1.7 | 0.001022 | 1.9 | 0.001019 | 2.1 | 0.001018 | 2.3 | 0.001021 |
| 11 | 1.6 | 0.000998 | 1.8 | 0.000995 | 2.1 | 0.000993 | 2.2 | 0.000987 |
| 12 | 1.5 | 0.00098 | 1.8 | 0.000974 | 2 | 0.000969 | 2.2 | 0.000965 |
| 13 | 1.5 | 0.000981 | 1.7 | 0.00096 | 1.9 | 0.000954 | 2.1 | 0.000945 |
| 14 | 1.4 | 0.000962 | 1.6 | 0.000952 | 1.8 | 0.000941 | 2 | 0.000929 |
| 15 | 1.4 | 0.000968 | 1.6 | 0.000943 | 1.8 | 0.000931 | 1.9 | 0.000921 |
| 16 | 1.3 | 0.000954 | 1.5 | 0.00094 | 1.7 | 0.000923 | 1.9 | 0.000909 |
| 17 | 1.3 | 0.000953 | 1.5 | 0.000936 | 1.6 | 0.00092 | 1.8 | 0.000904 |
| 18 | 1.2 | 0.000952 | 1.4 | 0.000932 | 1.6 | 0.000917 | 1.8 | 0.000902 |
| 19 | 1.2 | 0.000956 | 1.4 | 0.000932 | 1.5 | 0.000913 | 1.7 | 0.000898 |
| 20 | 1.1 | 0.000968 | 1.3 | 0.000932 | 1.5 | 0.000911 | 1.6 | 0.000895 |


Overhills Stable Channel Design
Copeland Method - Inflow Sediment Conc. = 0 ppm
Channel Slope (ft/ft)
0.00011
0.0001
0.00009
0.00008
0.00007
0.00006
0
5
10
15
20
25
Bottom Channel Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs

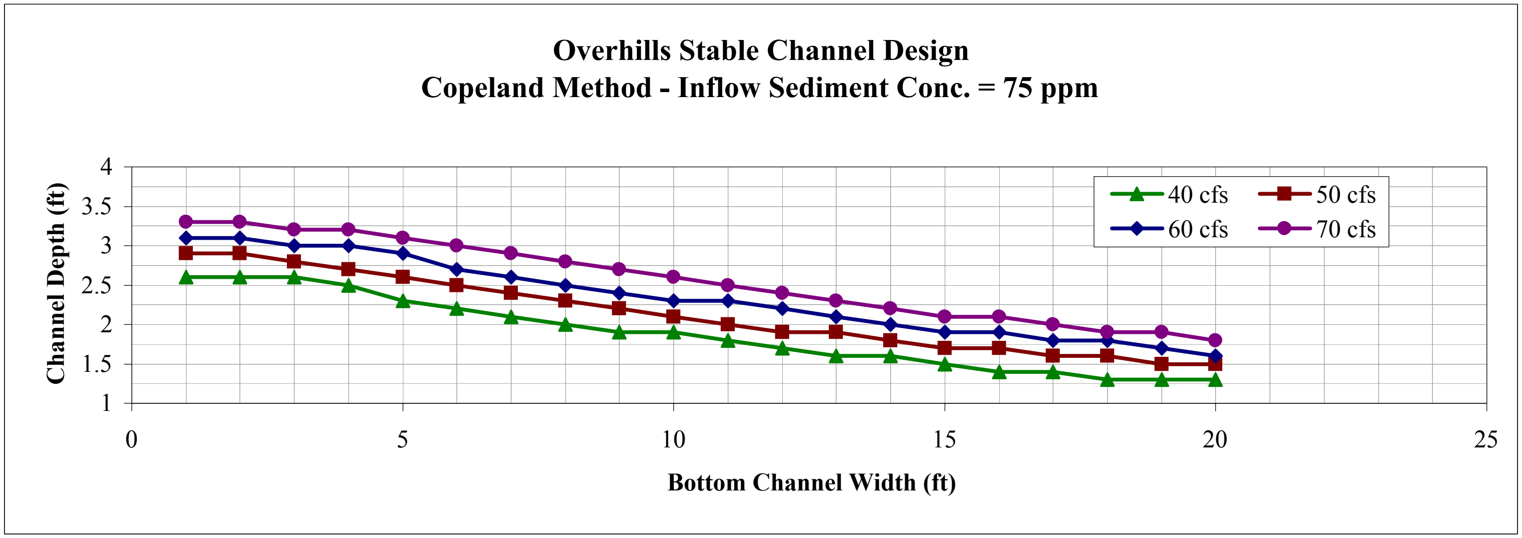

Overhills Stable Channel Design
Copeland Method - Inflow Sediment Conc. = 0 ppm
Channel Depth (ft)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
0
5
10
15
20
25
Bottom Channel Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs

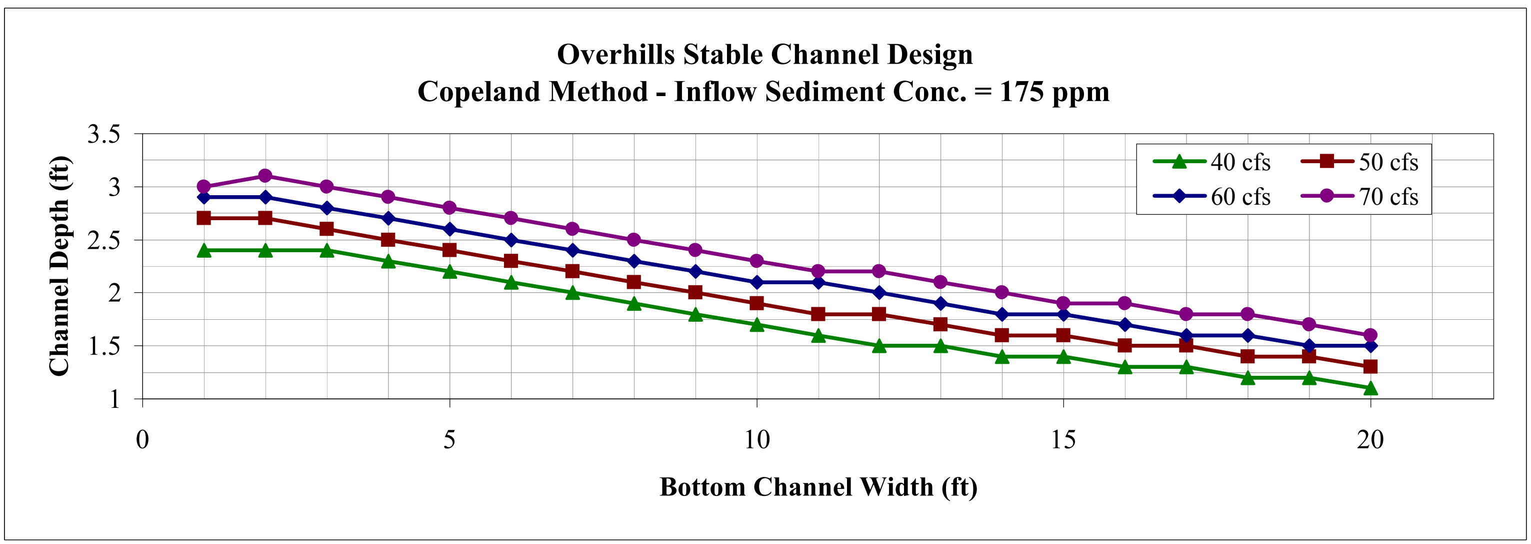


Overhills Stable Channel Design
Copeland Method - Inflow Sediment Conc. = 75 ppm
Channel Slope (ft/ft)
0.0025
0.002
0.0015
0.001
0.0005
0
0
5
10
15
20
Bottom Channel Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs

Overhills Stable Channel Design
Copeland Method - Inflow Sediment Conc. = 175 ppm
Channel Slope (ft/ft)
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
5
10
15
20
Bottom Channel Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs


Overhills Stable Channel Design
Copeland Method - Inflow Sediment Conc. = 75 ppm
Channel Depth (ft)
Bottom Channel Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs
4
3.5
3
2.5
2
1.5
1
0
5
10
15
20
25


Overhills Stable Channel Design
Copeland Method - Inflow Sediment Conc. = 175 ppm
Channel Depth (ft)
Bottom Channel Width (ft)
40 cfs
50 cfs
60 cfs
70 cfs
3.5
3
2.5
2
1.5
1
0
5
10
15
20

# APPENDIX M

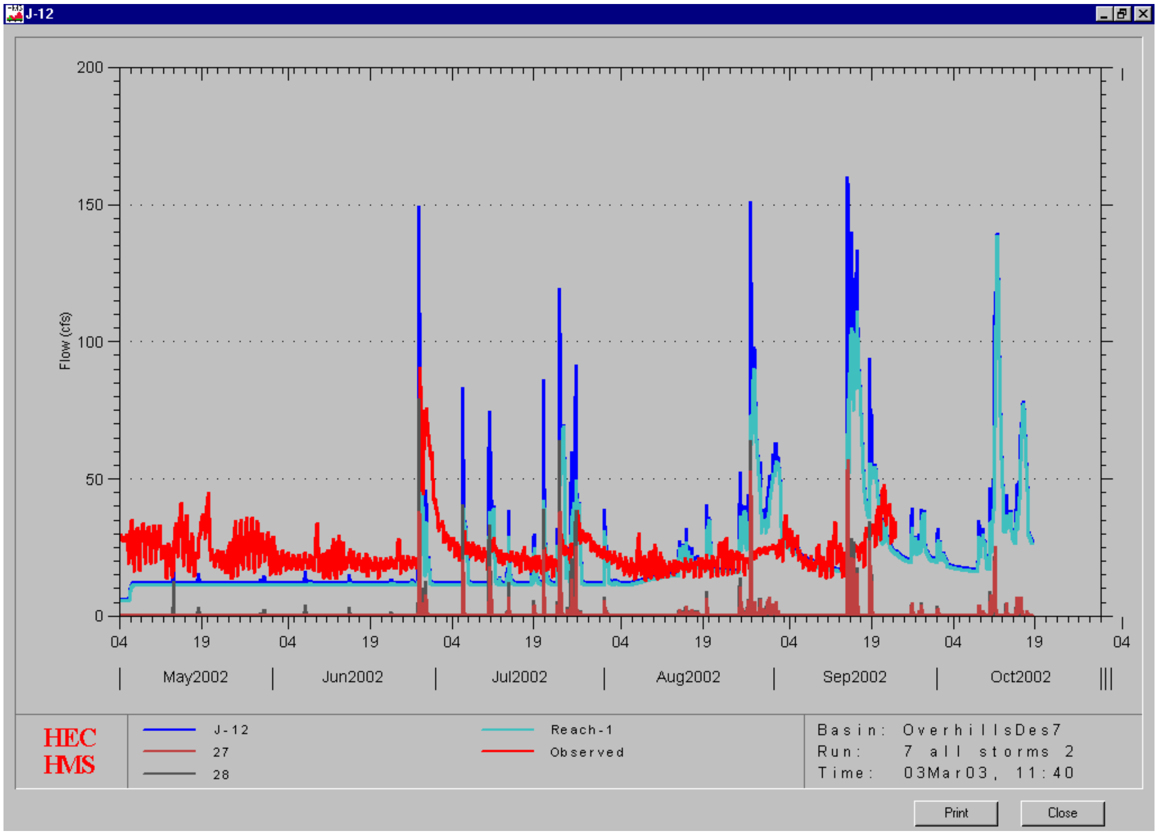
# HMS WATERSHED MODELING DATA

Watershed modeling was approached in two steps for this project. The first step was to create a watershed model using HEC-HMS. The watershed was delineated into subbasins and a stream network was identified using the USGS 7.5M Topographic Maps, aerial photography, and ground truthing. Watershed streams were put in four groups based on stream order, available maps, and survey data. Routing in the reaches was done with the Muskingum Cunge 8 point method which accounts for floodplain storage. Floodplain widths were approximated from GIS data.

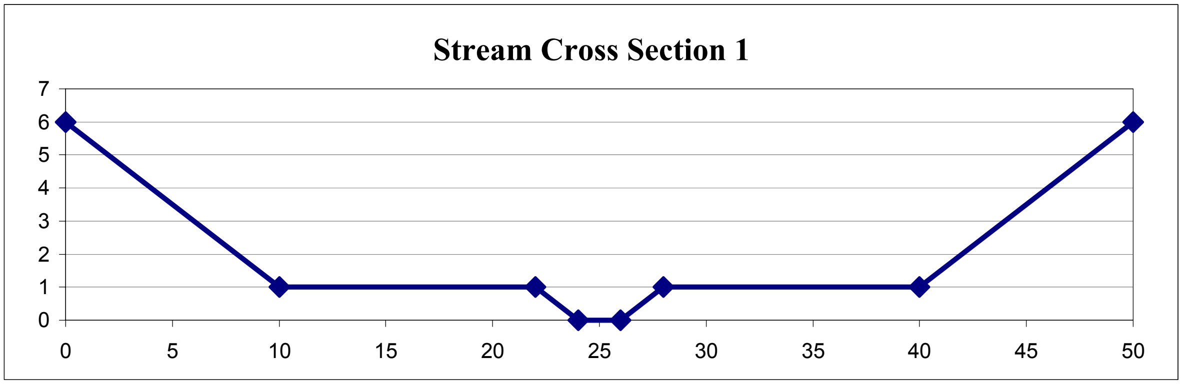
Stage-elevation-outflow data was calculated for each reservoir by routing the 100-year storm event though each. Survey data and topographic maps were used to compile size, elevation, and outlet data for the reservoir routing technique.

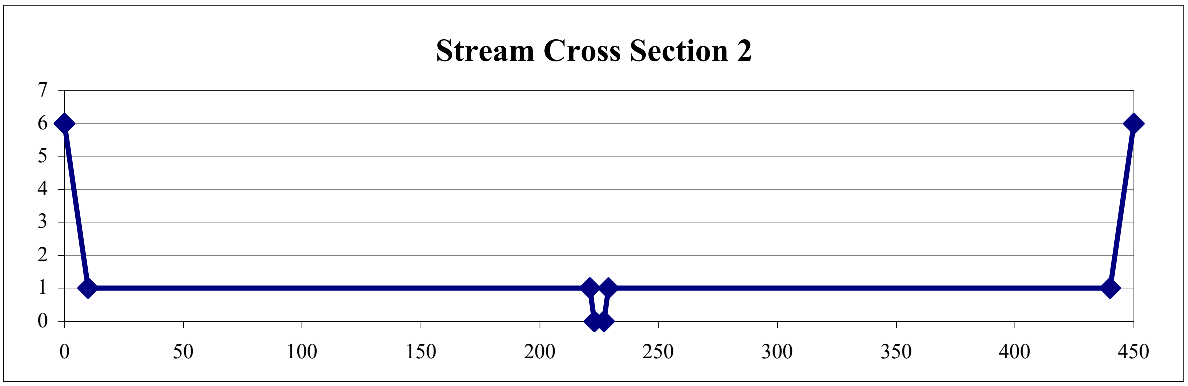
The model was calibrated with 11 months of stage data recorded on the existing stream at the project site. The HEC-RAS model described in Appendix G was used to calculate flows for calibration. Precipitation data was applied to appropriate subbasins for the calibration period using the Theissen polygon method. Baseflow in the channels in each subbasin was determined using the drainage area and the assumption of 1cfs baseflow per mile squared. The SCS method was used to account for subbasin losses and transformation such as evapotranspiration and deep groundwater seepage. However the curve numbers were modified to account for the large amount of depression storage and existing wetland areas in the watershed.

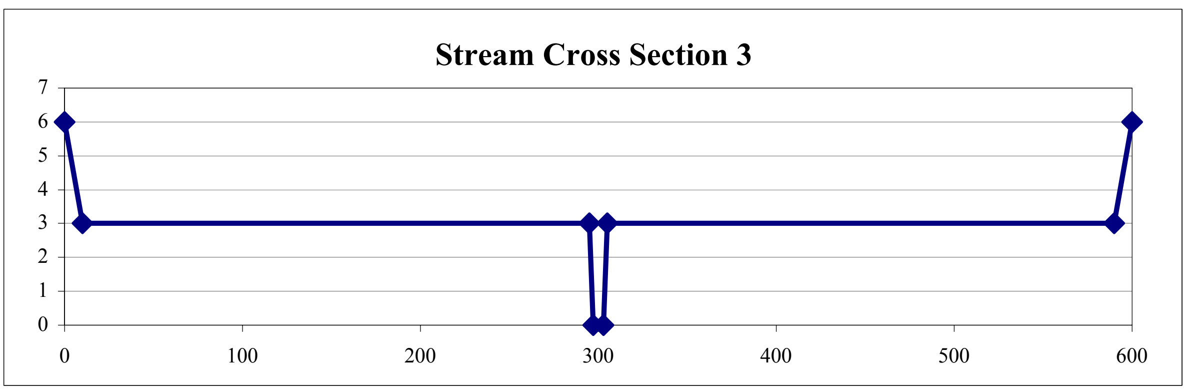
HMS watershed model results compared with measured data

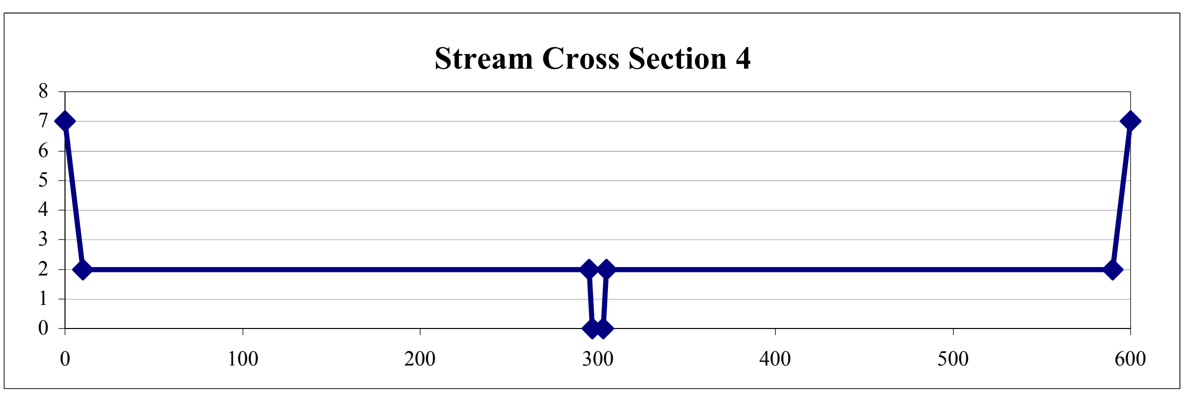


Cross sections used for watershed streams and floodplains



**Buffalo Lake**
**Stage-Storage Coefficient Computation**

| Contour | Contour Area ($ft^2$) | Incr Vol ($ft^3$) | Accum Vol ($S, ft^3$) | Stage (Z, ft) | ln S | ln Z | $Z_{est}$ (ft) |
|---|---|---|---|---|---|---|---|
| 290 | | 0 | 0 | 0 | | | 0.00 |
| 295 | 3468820.61 | 8672051.525 | 8672051.525 | 5 | 15.9756 | 1.6094 | 4.98 |
| 312 | 7557880.24 | 93726957.23 | 102399008.8 | 22 | 18.4444 | 3.0910 | 22.33 |
| 328 | 9789547.6 | 138779422.7 | 241178431.5 | 38 | 19.3010 | 3.6376 | 37.59 |

Regression Output

SUMMARY OUTPUT

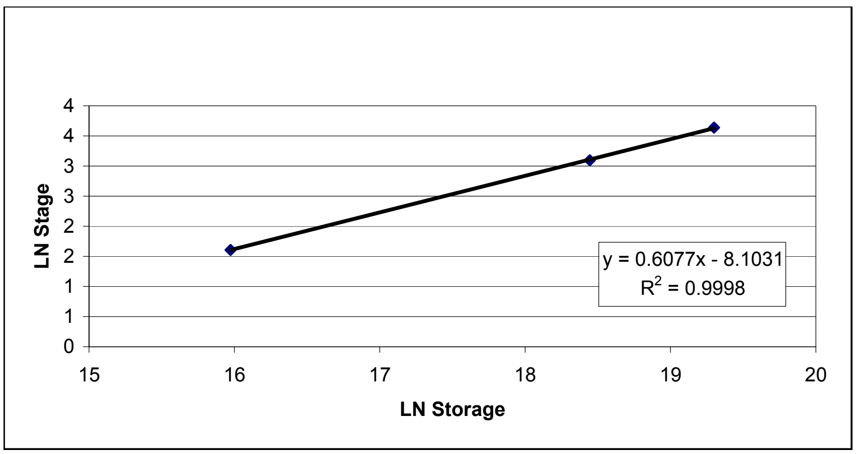
| **Stage-Storage Coefficients** | |
|---|---|
| $K_s$ | 618065 |
| b | 1.65 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999918646 |
| R Square | 0.999837298 |
| Adjusted R Square | 0.999674596 |
| Standard Error | 0.031146314 |
| Observations | 3 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 5.961428402 | 5.961428402 | 6145.21408 | 0.008120599 |
| Residual | 1 | 0.000970093 | 0.000970093 | | |
| Total | 2 | 5.962398495 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 13.33434966 | 0.06104012 | 218.4522204 | 0.00291421 | 12.55876473 | 14.10993459 | 12.55876473 | 14.10993459 |
| X Variable 1 | 1.645225798 | 0.020987321 | 78.39141588 | 0.0081206 | 1.378557744 | 1.911893851 | 1.378557744 | 1.911893851 |



**Buffalo Lake Reservoir Routing**

**Estimated Hydrograph**

$Q_p$= 1530 cfs
$T_p$= 60 min
dT= 5 min

**Riser/Barrel**

N= 1
$D_{riser}$= 42 in
$C_w$= 3
$Z_{cr}$= 18 ft
$D_{barrel}$= 27 in
$C_d$= 0.6

$Z_{inv}$= 0 ft

**Culvert**

N= 0
D= 24 in
$C_d$= 0.6 ft
Inv= 8

**Hydrograph Formulation**

R= 100.0
g= 290.0
h= 25.0
pn6= 5.8 in
A= 900.0 ac
H= 45.0 ft
L= 5000.0 ft
$C_a$= 0.34
CN= 65.0

S= 5.4 in

Q*= 2.2
$T_c$= 33.8 min
I= 4.9 in/hr

**Weir/ES**

L= 2400 ft
$Z_{cr}$= 20 ft
$C_w$= 3

**Stage-Storage**

$K_s$= 618065
b= 1.65
$Z_o$= 0 ft

**Initial Water Level**

$Z_i$= 18 ft

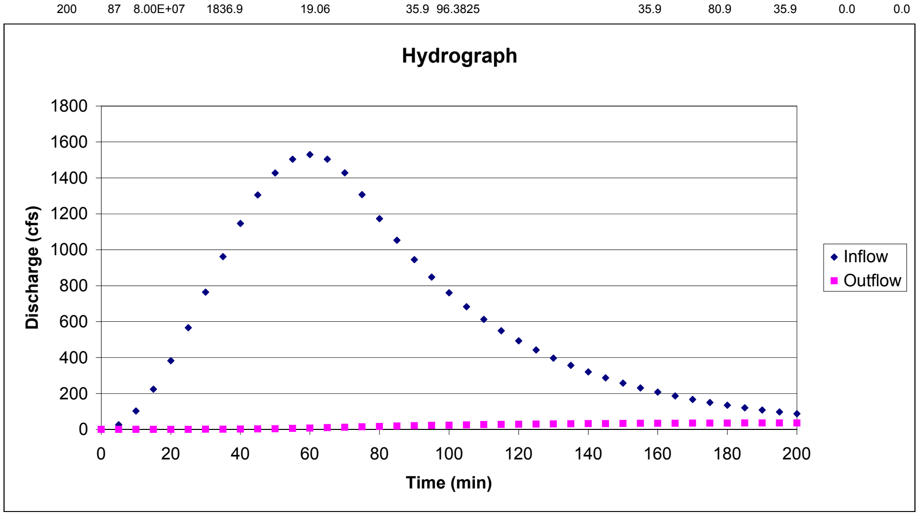
$C_{hrm}$=0.0193CN-0.91
$C_{\text{from CN}}$=

**Computed Results**

Max Surf Area= 96.4 ac
Peak Stage= 19.1 ft
Peak Outflow= 35.9 cfs
Max Storage= 1836.9 ac-ft

**Estimated Hydrograph** $Q_p$= 1529.77 cfs $T_p$= 55.6 min

| Time (min) | Inflow ($ft^3$/s) | Storage ($ft^3$) | Storage (ac-ft) | Stage (ft) | Outflow ($ft^3$/s) | Surface Area (acres) | Riser ($ft^3$/s) | Barrel ($ft^3$/s) | Rbspwy ($ft^3$/s) | Culvert ($ft^3$/s) | Weir ($ft^3$/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 7.28E+07 | 1671.7 | 18 | 0.0 | 92.8696 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 26 | 7.28E+07 | 1671.7 | 18.00 | 0.0 | 92.8696 | 0.0 | 78.5 | 0.0 | 0.0 | 0.0 |
| 10 | 102 | 7.28E+07 | 1671.8 | 18.00 | 0.0 | 92.8735 | 0.0 | 78.5 | 0.0 | 0.0 | 0.0 |
| 15 | 224 | 7.29E+07 | 1672.5 | 18.01 | 0.0 | 92.8889 | 0.0 | 78.5 | 0.0 | 0.0 | 0.0 |
| 20 | 382 | 7.29E+07 | 1674.1 | 18.02 | 0.1 | 92.9226 | 0.1 | 78.6 | 0.1 | 0.0 | 0.0 |
| 25 | 567 | 7.30E+07 | 1676.7 | 18.03 | 0.2 | 92.9801 | 0.2 | 78.6 | 0.2 | 0.0 | 0.0 |
| 30 | 764 | 7.32E+07 | 1680.6 | 18.06 | 0.5 | 93.0653 | 0.5 | 78.7 | 0.5 | 0.0 | 0.0 |
| 35 | 962 | 7.34E+07 | 1685.9 | 18.09 | 0.9 | 93.18 | 0.9 | 78.7 | 0.9 | 0.0 | 0.0 |
| 40 | 1147 | 7.37E+07 | 1692.5 | 18.14 | 1.6 | 93.3239 | 1.6 | 78.8 | 1.6 | 0.0 | 0.0 |
| 45 | 1305 | 7.41E+07 | 1700.4 | 18.19 | 2.7 | 93.495 | 2.7 | 79.0 | 2.7 | 0.0 | 0.0 |
| 50 | 1427 | 7.45E+07 | 1709.4 | 18.24 | 4.0 | 93.689 | 4.0 | 79.1 | 4.0 | 0.0 | 0.0 |
| 55 | 1504 | 7.49E+07 | 1719.2 | 18.31 | 5.6 | 93.9003 | 5.6 | 79.2 | 5.6 | 0.0 | 0.0 |
| 60 | 1530 | 7.53E+07 | 1729.5 | 18.37 | 7.6 | 94.1219 | 7.6 | 79.4 | 7.6 | 0.0 | 0.0 |
| 65 | 1504 | 7.58E+07 | 1740.0 | 18.44 | 9.7 | 94.3462 | 9.7 | 79.5 | 9.7 | 0.0 | 0.0 |
| 70 | 1428 | 7.62E+07 | 1750.2 | 18.51 | 11.9 | 94.5657 | 11.9 | 79.7 | 11.9 | 0.0 | 0.0 |
| 75 | 1307 | 7.67E+07 | 1760.0 | 18.57 | 14.2 | 94.773 | 14.2 | 79.8 | 14.2 | 0.0 | 0.0 |
| 80 | 1173 | 7.71E+07 | 1768.9 | 18.63 | 16.4 | 94.9616 | 16.4 | 80.0 | 16.4 | 0.0 | 0.0 |
| 85 | 1053 | 7.74E+07 | 1776.9 | 18.68 | 18.4 | 95.1298 | 18.4 | 80.1 | 18.4 | 0.0 | 0.0 |
| 90 | 945 | 7.77E+07 | 1784.0 | 18.72 | 20.3 | 95.2799 | 20.3 | 80.2 | 20.3 | 0.0 | 0.0 |
| 95 | 848 | 7.80E+07 | 1790.4 | 18.76 | 22.0 | 95.4137 | 22.0 | 80.3 | 22.0 | 0.0 | 0.0 |
| 100 | 761 | 7.82E+07 | 1796.0 | 18.80 | 23.6 | 95.533 | 23.6 | 80.4 | 23.6 | 0.0 | 0.0 |
| 105 | 683 | 7.85E+07 | 1801.1 | 18.83 | 25.0 | 95.6393 | 25.0 | 80.4 | 25.0 | 0.0 | 0.0 |
| 110 | 613 | 7.87E+07 | 1805.7 | 18.86 | 26.3 | 95.7339 | 26.3 | 80.5 | 26.3 | 0.0 | 0.0 |
| 115 | 550 | 7.88E+07 | 1809.7 | 18.89 | 27.5 | 95.8182 | 27.5 | 80.6 | 27.5 | 0.0 | 0.0 |
| 120 | 493 | 7.90E+07 | 1813.3 | 18.91 | 28.6 | 95.8931 | 28.6 | 80.6 | 28.6 | 0.0 | 0.0 |
| 125 | 443 | 7.91E+07 | 1816.5 | 18.93 | 29.6 | 95.9597 | 29.6 | 80.7 | 29.6 | 0.0 | 0.0 |
| 130 | 397 | 7.92E+07 | 1819.3 | 18.95 | 30.4 | 96.0189 | 30.4 | 80.7 | 30.4 | 0.0 | 0.0 |
| 135 | 356 | 7.94E+07 | 1821.9 | 18.96 | 31.2 | 96.0714 | 31.2 | 80.7 | 31.2 | 0.0 | 0.0 |
| 140 | 320 | 7.95E+07 | 1824.1 | 18.98 | 31.9 | 96.1179 | 31.9 | 80.8 | 31.9 | 0.0 | 0.0 |
| 145 | 287 | 7.95E+07 | 1826.1 | 18.99 | 32.5 | 96.159 | 32.5 | 80.8 | 32.5 | 0.0 | 0.0 |
| 150 | 257 | 7.96E+07 | 1827.8 | 19.00 | 33.0 | 96.1954 | 33.0 | 80.8 | 33.0 | 0.0 | 0.0 |
| 155 | 231 | 7.97E+07 | 1829.4 | 19.01 | 33.5 | 96.2274 | 33.5 | 80.8 | 33.5 | 0.0 | 0.0 |
| 160 | 207 | 7.97E+07 | 1830.7 | 19.02 | 33.9 | 96.2556 | 33.9 | 80.9 | 33.9 | 0.0 | 0.0 |
| 165 | 186 | 7.98E+07 | 1831.9 | 19.03 | 34.3 | 96.2803 | 34.3 | 80.9 | 34.3 | 0.0 | 0.0 |
| 170 | 167 | 7.98E+07 | 1833.0 | 19.03 | 34.6 | 96.302 | 34.6 | 80.9 | 34.6 | 0.0 | 0.0 |
| 175 | 150 | 7.99E+07 | 1833.9 | 19.04 | 34.9 | 96.3208 | 34.9 | 80.9 | 34.9 | 0.0 | 0.0 |
| 180 | 134 | 7.99E+07 | 1834.7 | 19.04 | 35.2 | 96.3372 | 35.2 | 80.9 | 35.2 | 0.0 | 0.0 |
| 185 | 121 | 7.99E+07 | 1835.4 | 19.05 | 35.4 | 96.3513 | 35.4 | 80.9 | 35.4 | 0.0 | 0.0 |
| 190 | 108 | 8.00E+07 | 1835.9 | 19.05 | 35.6 | 96.3634 | 35.6 | 80.9 | 35.6 | 0.0 | 0.0 |
| 195 | 97 | 8.00E+07 | 1836.4 | 19.06 | 35.8 | 96.3738 | 35.8 | 80.9 | 35.8 | 0.0 | 0.0 |
| 200 | 87 | 8.00E+07 | 1836.9 | 19.06 | 35.9 | 96.3825 | 35.9 | 80.9 | 35.9 | 0.0 | 0.0 |



**Carolina Lake**
**Stage-Storage Coefficient Computation**

| Contour | Contour Area ($ft^2$) | Incr Vol ($ft^3$) | Accum Vol ($S, ft^3$) | Stage (Z, ft) | ln S | ln Z | $Z_{est}$ (ft) |
|---|---|---|---|---|---|---|---|
| 236 | | 0 | 0 | 0 | | | 0.00 |
| 246 | 9724959 | 48624795 | 48624795 | 10 | 17.6996 | 2.3026 | 9.95 |
| 262 | 14586070 | 194488232 | 243113027 | 26 | 19.3090 | 3.2581 | 26.37 |
| 279 | 19997317 | 293958789.5 | 537071816.5 | 43 | 20.1016 | 3.7612 | 42.61 |

Regression Output

SUMMARY OUTPUT

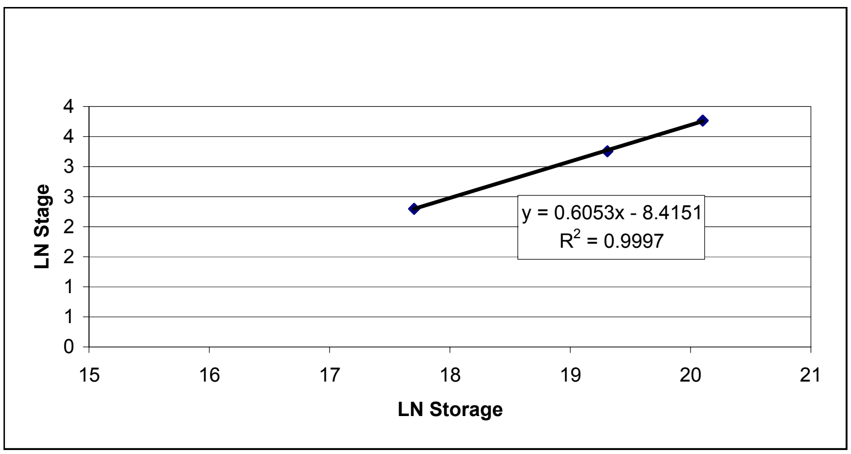
| **Stage-Storage Coefficients** | |
|---|---|
| $K_s$ | 1093036 |
| b | 1.65 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99986114 |
| R Square | 0.999722299 |
| Adjusted R Square | 0.999444599 |
| Standard Error | 0.028844195 |
| Observations | 3 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 2.995156086 | 2.995156086 | 3600.001 | 0.010609346 |
| Residual | 1 | 0.000831988 | 0.000831988 | | |
| Total | 2 | 2.995988073 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 13.90446967 | 0.087144406 | 159.5566527 | 0.00398988 | 12.79719976 | 15.01173959 | 12.79719976 | 15.01173959 |
| X Variable 1 | 1.651695972 | 0.027528262 | 60.00000831 | 0.01060935 | 1.301917733 | 2.001474211 | 1.301917733 | 2.001474211 |



**Carolina Lake Reservoir Routing**

**Estimated Hydrograph**

$Q_p$= 1820 cfs
$T_p$= 70 min
dT= 5 min

**Riser/Barrel**

N= 2
$D_{riser}$= 46 in
$C_w$= 3
$Z_{cr}$= 25 ft
$D_{barrel}$= 27 in
$C_d$= 0.6

$Z_{inv}$= 0 ft

**Culvert**

N= 0
D= 29 in
$C_d$= 0.6 ft
Inv= 20

**Hydrograph Formulation**

R= 100.0
g= 290.0
h= 25.0
pn6= 5.8 in
A= 1414.0 ac
H= 45.0 ft
L= 7350.0 ft
$C_a$= 0.34
CN= 65.0

S= 5.4 in

Q*= 2.2
$T_c$= 52.7 min
I= 3.7 in/hr

**Weir/ES**

L= 0 ft
$Z_{cr}$= 0 ft
$C_w$= 0

**Stage-Storage**

$K_s$= 1093036
b= 1.65
$Z_o$= 0 ft

**Initial Water Level**

$Z_i$= 25 ft

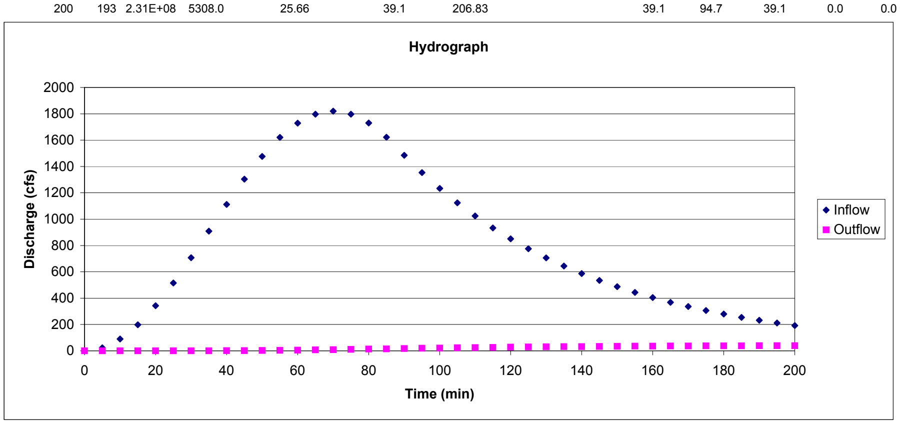
$C_{hrm}$=0.0193CN-0.91
$C_{\text{from CN}}$=

**Computed Results**

Max Surf Area= 206.8 ac
Peak Stage= 25.7 ft
Peak Outflow= 39.1 cfs
Max Storage= 5308.0 ac-ft

**Estimated Hydrograph** $Q_p$= 1818 cfs $T_p$= 73.51 min

| Time (min) | Inflow ($ft^3/s$) | Storage ($ft^3$) | Storage (ac-ft) | Stage (ft) | Outflow ($ft^3/s$) | Surface Area (acres) | | Riser ($ft^3/s$) | Barrel ($ft^3/s$) | Rbspwy ($ft^3/s$) | Culvert ($ft^3/s$) | Weir ($ft^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 2.21E+08 | 5083.3 | 25 | 0.0 | 203.33 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 23 | 2.21E+08 | 5083.3 | 25.00 | 0.0 | 203.33 | | #NUM! | 93.4 | #NUM! | 0.0 | 0.0 |
| 10 | 90 | 2.21E+08 | 5083.5 | 25.00 | 0.0 | 203.34 | | 0.0 | 93.4 | 0.0 | 0.0 | 0.0 |
| 15 | 198 | 2.21E+08 | 5084.1 | 25.00 | 0.0 | 203.35 | | 0.0 | 93.4 | 0.0 | 0.0 | 0.0 |
| 20 | 342 | 2.22E+08 | 5085.5 | 25.01 | 0.0 | 203.37 | | 0.0 | 93.4 | 0.0 | 0.0 | 0.0 |
| 25 | 515 | 2.22E+08 | 5087.8 | 25.01 | 0.1 | 203.40 | | 0.1 | 93.4 | 0.1 | 0.0 | 0.0 |
| 30 | 707 | 2.22E+08 | 5091.4 | 25.02 | 0.3 | 203.46 | | 0.3 | 93.4 | 0.3 | 0.0 | 0.0 |
| 35 | 909 | 2.22E+08 | 5096.2 | 25.04 | 0.5 | 203.54 | | 0.5 | 93.5 | 0.5 | 0.0 | 0.0 |
| 40 | 1112 | 2.22E+08 | 5102.5 | 25.06 | 1.0 | 203.63 | | 1.0 | 93.5 | 1.0 | 0.0 | 0.0 |
| 45 | 1304 | 2.23E+08 | 5110.1 | 25.08 | 1.6 | 203.75 | | 1.6 | 93.6 | 1.6 | 0.0 | 0.0 |
| 50 | 1477 | 2.23E+08 | 5119.1 | 25.11 | 2.5 | 203.90 | | 2.5 | 93.6 | 2.5 | 0.0 | 0.0 |
| 55 | 1621 | 2.23E+08 | 5129.3 | 25.14 | 3.6 | 204.05 | | 3.6 | 93.7 | 3.6 | 0.0 | 0.0 |
| 60 | 1729 | 2.24E+08 | 5140.4 | 25.17 | 5.1 | 204.23 | | 5.1 | 93.7 | 5.1 | 0.0 | 0.0 |
| 65 | 1797 | 2.24E+08 | 5152.3 | 25.20 | 6.7 | 204.41 | | 6.7 | 93.8 | 6.7 | 0.0 | 0.0 |
| 70 | 1820 | 2.25E+08 | 5164.6 | 25.24 | 8.6 | 204.61 | | 8.6 | 93.9 | 8.6 | 0.0 | 0.0 |
| 75 | 1798 | 2.26E+08 | 5177.1 | 25.28 | 10.6 | 204.80 | | 10.6 | 93.9 | 10.6 | 0.0 | 0.0 |
| 80 | 1731 | 2.26E+08 | 5189.4 | 25.31 | 12.8 | 204.99 | | 12.8 | 94.0 | 12.8 | 0.0 | 0.0 |
| 85 | 1623 | 2.27E+08 | 5201.2 | 25.35 | 14.9 | 205.18 | | 14.9 | 94.1 | 14.9 | 0.0 | 0.0 |
| 90 | 1485 | 2.27E+08 | 5212.3 | 25.38 | 17.1 | 205.35 | | 17.1 | 94.1 | 17.1 | 0.0 | 0.0 |
| 95 | 1353 | 2.27E+08 | 5222.4 | 25.41 | 19.1 | 205.51 | | 19.1 | 94.2 | 19.1 | 0.0 | 0.0 |
| 100 | 1233 | 2.28E+08 | 5231.6 | 25.44 | 21.0 | 205.65 | | 21.0 | 94.3 | 21.0 | 0.0 | 0.0 |
| 105 | 1124 | 2.28E+08 | 5239.9 | 25.46 | 22.8 | 205.78 | | 22.8 | 94.3 | 22.8 | 0.0 | 0.0 |
| 110 | 1024 | 2.29E+08 | 5247.5 | 25.49 | 24.5 | 205.90 | | 24.5 | 94.3 | 24.5 | 0.0 | 0.0 |
| 115 | 933 | 2.29E+08 | 5254.4 | 25.51 | 26.0 | 206.00 | | 26.0 | 94.4 | 26.0 | 0.0 | 0.0 |
| 120 | 851 | 2.29E+08 | 5260.6 | 25.52 | 27.5 | 206.10 | | 27.5 | 94.4 | 27.5 | 0.0 | 0.0 |
| 125 | 775 | 2.29E+08 | 5266.3 | 25.54 | 28.8 | 206.19 | | 28.8 | 94.5 | 28.8 | 0.0 | 0.0 |
| 130 | 706 | 2.30E+08 | 5271.5 | 25.56 | 30.0 | 206.26 | | 30.0 | 94.5 | 30.0 | 0.0 | 0.0 |
| 135 | 644 | 2.30E+08 | 5276.1 | 25.57 | 31.1 | 206.34 | | 31.1 | 94.5 | 31.1 | 0.0 | 0.0 |
| 140 | 587 | 2.30E+08 | 5280.3 | 25.58 | 32.1 | 206.40 | | 32.1 | 94.5 | 32.1 | 0.0 | 0.0 |
| 145 | 535 | 2.30E+08 | 5284.2 | 25.59 | 33.1 | 206.46 | | 33.1 | 94.6 | 33.1 | 0.0 | 0.0 |
| 150 | 487 | 2.30E+08 | 5287.6 | 25.60 | 33.9 | 206.51 | | 33.9 | 94.6 | 33.9 | 0.0 | 0.0 |
| 155 | 444 | 2.30E+08 | 5290.7 | 25.61 | 34.7 | 206.56 | | 34.7 | 94.6 | 34.7 | 0.0 | 0.0 |
| 160 | 405 | 2.31E+08 | 5293.5 | 25.62 | 35.4 | 206.60 | | 35.4 | 94.6 | 35.4 | 0.0 | 0.0 |
| 165 | 369 | 2.31E+08 | 5296.1 | 25.63 | 36.0 | 206.64 | | 36.0 | 94.6 | 36.0 | 0.0 | 0.0 |
| 170 | 336 | 2.31E+08 | 5298.4 | 25.64 | 36.6 | 206.68 | | 36.6 | 94.6 | 36.6 | 0.0 | 0.0 |
| 175 | 306 | 2.31E+08 | 5300.4 | 25.64 | 37.1 | 206.71 | | 37.1 | 94.6 | 37.1 | 0.0 | 0.0 |
| 180 | 279 | 2.31E+08 | 5302.3 | 25.65 | 37.6 | 206.74 | | 37.6 | 94.7 | 37.6 | 0.0 | 0.0 |
| 185 | 254 | 2.31E+08 | 5304.0 | 25.65 | 38.0 | 206.76 | | 38.0 | 94.7 | 38.0 | 0.0 | 0.0 |
| 190 | 232 | 2.31E+08 | 5305.5 | 25.66 | 38.4 | 206.79 | | 38.4 | 94.7 | 38.4 | 0.0 | 0.0 |
| 195 | 211 | 2.31E+08 | 5306.8 | 25.66 | 38.8 | 206.81 | | 38.8 | 94.7 | 38.8 | 0.0 | 0.0 |
| 200 | 193 | 2.31E+08 | 5308.0 | 25.66 | 39.1 | 206.83 | | 39.1 | 94.7 | 39.1 | 0.0 | 0.0 |



**Crystal Lake**
**Stage-Storage Coefficient Computation**

| Contour | Contour Area (ft$^2$) | Incr Vol (ft$^3$) | Accum Vol (S,ft$^3$) | Stage (Z, ft) | ln S | ln Z | $Z_{est}$ (ft) |
|---|---|---|---|---|---|---|---|
| 258 | | 0 | 0 | 0 | | | 0.00 |
| 262 | 502071 | 1004142 | 1004142 | 4 | 13.8196 | 1.3863 | 4.01 |
| 279 | 1196708 | 14439621.5 | 15443763.5 | 21 | 16.5527 | 3.0445 | 20.77 |
| 295 | 1979732 | 25411520 | 40855283.5 | 37 | 17.5255 | 3.6109 | 37.30 |

Regression Output

SUMMARY OUTPUT

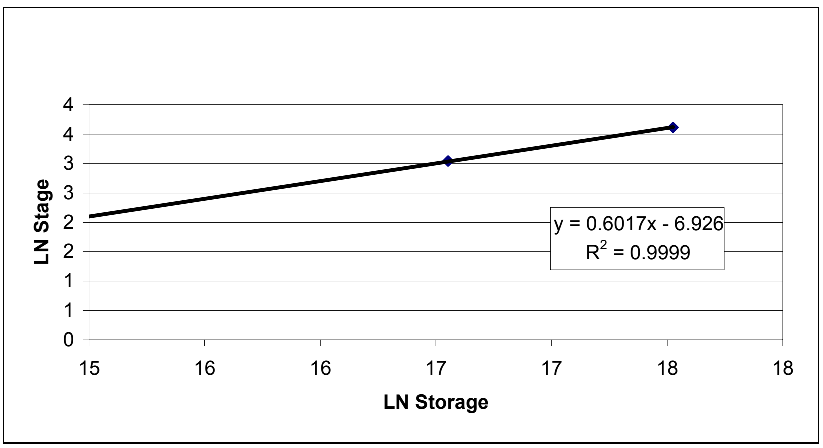
| Stage-Storage Coefficients | |
|---|---|
| $K_s$ | 99828 |
| b | 1.66 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999964128 |
| R Square | 0.999928257 |
| Adjusted R Square | 0.999856514 |
| Standard Error | 0.023015193 |
| Observations | 3 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 7.382735759 | 7.382735759 | 13937.6027 | 0.00539232 |
| Residual | 1 | 0.000529699 | 0.000529699 | | |
| Total | 2 | 7.383265458 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 11.51120351 | 0.040005095 | 287.7434334 | 0.00221245 | 11.00289276 | 12.01951427 | 11.00289276 | 12.01951427 |
| X Variable 1 | 1.661867307 | 0.014076747 | 118.0576244 | 0.00539232 | 1.483006044 | 1.840728569 | 1.483006044 | 1.840728569 |



**Crystal Lake Reservoir Routing**

**Estimated Hydrograph**

$Q_p$= 550 cfs
$T_p$= 40 min
dT= 5 min

**Riser/Barrel**

N= 1
$D_{riser}$= 72 in
$C_w$= 3
$Z_{cr}$= 9 ft
$D_{barrel}$= 36 in

$C_d$= 0.6

$Z_{inv}$= 0 ft

**Culvert**

N= 0
D= 24 in
$C_d$= 0.6 ft
Inv= 8

**Hydrograph Formulation**

R= 100.0
g= 290.0
h= 25.0
pn6= 5.8 in

A= 191.0 ac
H= 40.0 ft
L= 3500.0 ft
$C_a$= 0.48
CN= 72.0

S= 3.9 in

Q*= 2.8
$T_c$= 23.4 min
I= 6.0 in/hr

**Weir/ES**

L= 1210 ft
$Z_{cr}$= 11 ft
$C_w$= 3

**Stage-Storage**

$K_s$= 99828
b= 1.68
$Z_o$= 0 ft

**Initial Water Level**

$Z_i$= 9 ft

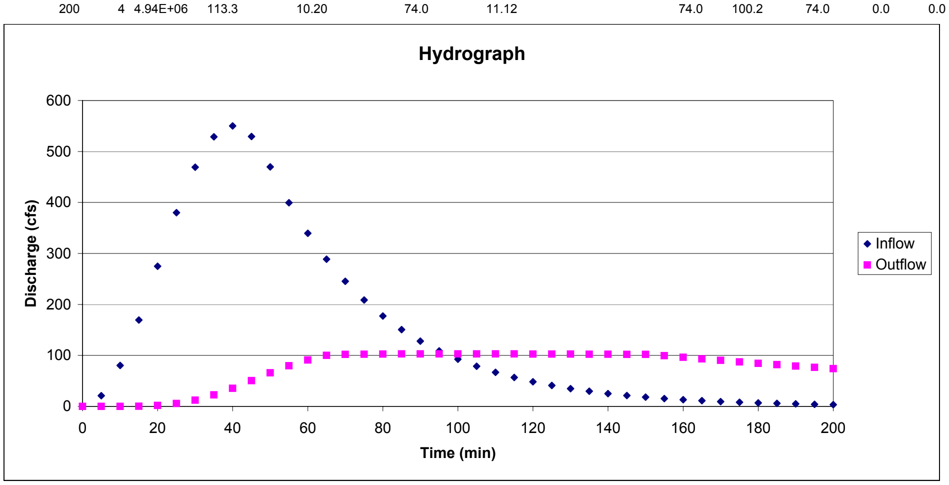
$C_{hrm}$=0.0193CN-0.91
$C_{\text{from CN}}$=

**Computed Results**

Max Surf Area= 11.5 ac
Peak Stage= 10.7 ft
Peak Outflow= 102.9 cfs
Max Storage= 122.5 ac-ft

**Estimated Hydrograph** $Q_p$= 548.8 cfs $T_p$= 42.27 min

| Time (min) | Inflow ($ft^3/s$) | Storage ($ft^3$) | Storage (ac-ft) | Stage (ft) | Outflow ($ft^3/s$) | Surface Area (acres) | | Riser ($ft^3/s$) | Barrel ($ft^3/s$) | Rbspwy ($ft^3/s$) | Culvert ($ft^3/s$) | Weir ($ft^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 4.00E+06 | 91.9 | 9 | 0.0 | 10.21 | | 0.0 | 93.1 | 0.0 | 0.0 | 0.0 |
| 5 | 21 | 4.00E+06 | 91.9 | 9.00 | 0.0 | 10.21 | | 0.0 | 93.1 | 0.0 | 0.0 | 0.0 |
| 10 | 80 | 4.01E+06 | 92.0 | 9.01 | 0.0 | 10.22 | | 0.0 | 93.1 | 0.0 | 0.0 | 0.0 |
| 15 | 170 | 4.03E+06 | 92.6 | 9.04 | 0.5 | 10.24 | | 0.5 | 93.3 | 0.5 | 0.0 | 0.0 |
| 20 | 275 | 4.08E+06 | 93.8 | 9.11 | 2.0 | 10.29 | | 2.0 | 93.7 | 2.0 | 0.0 | 0.0 |
| 25 | 380 | 4.17E+06 | 95.6 | 9.22 | 5.7 | 10.38 | | 5.7 | 94.4 | 5.7 | 0.0 | 0.0 |
| 30 | 469 | 4.28E+06 | 98.2 | 9.36 | 12.4 | 10.49 | | 12.4 | 95.3 | 12.4 | 0.0 | 0.0 |
| 35 | 529 | 4.42E+06 | 101.4 | 9.54 | 22.5 | 10.62 | | 22.5 | 96.4 | 22.5 | 0.0 | 0.0 |
| 40 | 550 | 4.57E+06 | 104.8 | 9.73 | 35.6 | 10.77 | | 35.6 | 97.5 | 35.6 | 0.0 | 0.0 |
| 45 | 529 | 4.72E+06 | 108.4 | 9.93 | 50.6 | 10.92 | | 50.6 | 98.7 | 50.6 | 0.0 | 0.0 |
| 50 | 470 | 4.87E+06 | 111.7 | 10.11 | 65.9 | 11.05 | | 65.9 | 99.7 | 65.9 | 0.0 | 0.0 |
| 55 | 400 | 4.99E+06 | 114.5 | 10.26 | 79.7 | 11.16 | | 79.7 | 100.6 | 79.7 | 0.0 | 0.0 |
| 60 | 340 | 5.08E+06 | 116.7 | 10.37 | 91.0 | 11.25 | | 91.0 | 101.2 | 91.0 | 0.0 | 0.0 |
| 65 | 289 | 5.16E+06 | 118.4 | 10.46 | 100.2 | 11.31 | | 100.2 | 101.7 | 100.2 | 0.0 | 0.0 |
| 70 | 245 | 5.21E+06 | 119.7 | 10.53 | 102.1 | 11.36 | | 107.2 | 102.1 | 102.1 | 0.0 | 0.0 |
| 75 | 209 | 5.26E+06 | 120.7 | 10.58 | 102.4 | 11.40 | | 112.7 | 102.4 | 102.4 | 0.0 | 0.0 |
| 80 | 177 | 5.29E+06 | 121.4 | 10.62 | 102.6 | 11.43 | | 116.8 | 102.6 | 102.6 | 0.0 | 0.0 |
| 85 | 151 | 5.31E+06 | 121.9 | 10.65 | 102.8 | 11.45 | | 119.7 | 102.8 | 102.8 | 0.0 | 0.0 |
| 90 | 128 | 5.32E+06 | 122.2 | 10.67 | 102.9 | 11.46 | | 121.6 | 102.9 | 102.9 | 0.0 | 0.0 |
| 95 | 109 | 5.33E+06 | 122.4 | 10.68 | 102.9 | 11.47 | | 122.6 | 102.9 | 102.9 | 0.0 | 0.0 |
| 100 | 93 | 5.33E+06 | 122.5 | 10.68 | 102.9 | 11.47 | | 122.8 | 102.9 | 102.9 | 0.0 | 0.0 |
| 105 | 79 | 5.33E+06 | 122.4 | 10.67 | 102.9 | 11.47 | | 122.4 | 102.9 | 102.9 | 0.0 | 0.0 |
| 110 | 67 | 5.32E+06 | 122.2 | 10.67 | 102.9 | 11.46 | | 121.4 | 102.9 | 102.9 | 0.0 | 0.0 |
| 115 | 57 | 5.31E+06 | 122.0 | 10.65 | 102.8 | 11.45 | | 120.0 | 102.8 | 102.8 | 0.0 | 0.0 |
| 120 | 48 | 5.30E+06 | 121.7 | 10.64 | 102.7 | 11.44 | | 118.2 | 102.7 | 102.7 | 0.0 | 0.0 |
| 125 | 41 | 5.28E+06 | 121.3 | 10.62 | 102.6 | 11.42 | | 116.1 | 102.6 | 102.6 | 0.0 | 0.0 |
| 130 | 35 | 5.26E+06 | 120.9 | 10.59 | 102.5 | 11.41 | | 113.8 | 102.5 | 102.5 | 0.0 | 0.0 |
| 135 | 30 | 5.24E+06 | 120.4 | 10.57 | 102.3 | 11.39 | | 111.2 | 102.3 | 102.3 | 0.0 | 0.0 |
| 140 | 25 | 5.22E+06 | 119.9 | 10.54 | 102.2 | 11.37 | | 108.4 | 102.2 | 102.2 | 0.0 | 0.0 |
| 145 | 21 | 5.20E+06 | 119.4 | 10.52 | 102.0 | 11.35 | | 105.5 | 102.0 | 102.0 | 0.0 | 0.0 |
| 150 | 18 | 5.18E+06 | 118.8 | 10.49 | 101.9 | 11.33 | | 102.5 | 101.9 | 101.9 | 0.0 | 0.0 |
| 155 | 15 | 5.15E+06 | 118.2 | 10.46 | 99.3 | 11.31 | | 99.3 | 101.7 | 99.3 | 0.0 | 0.0 |
| 160 | 13 | 5.12E+06 | 117.7 | 10.43 | 96.2 | 11.28 | | 96.2 | 101.5 | 96.2 | 0.0 | 0.0 |
| 165 | 11 | 5.10E+06 | 117.1 | 10.40 | 93.2 | 11.26 | | 93.2 | 101.4 | 93.2 | 0.0 | 0.0 |
| 170 | 10 | 5.08E+06 | 116.5 | 10.37 | 90.2 | 11.24 | | 90.2 | 101.2 | 90.2 | 0.0 | 0.0 |
| 175 | 8 | 5.05E+06 | 116.0 | 10.34 | 87.3 | 11.22 | | 87.3 | 101.0 | 87.3 | 0.0 | 0.0 |
| 180 | 7 | 5.03E+06 | 115.4 | 10.31 | 84.5 | 11.20 | | 84.5 | 100.8 | 84.5 | 0.0 | 0.0 |
| 185 | 6 | 5.00E+06 | 114.9 | 10.28 | 81.8 | 11.18 | | 81.8 | 100.7 | 81.8 | 0.0 | 0.0 |
| 190 | 5 | 4.98E+06 | 114.4 | 10.25 | 79.1 | 11.16 | | 79.1 | 100.5 | 79.1 | 0.0 | 0.0 |
| 195 | 4 | 4.96E+06 | 113.8 | 10.22 | 76.5 | 11.14 | | 76.5 | 100.4 | 76.5 | 0.0 | 0.0 |
| 200 | 4 | 4.94E+06 | 113.3 | 10.20 | 74.0 | 11.12 | | 74.0 | 100.2 | 74.0 | 0.0 | 0.0 |



**Hidden Pond**
**Stage-Storage Coefficient Computation**

| Contour | Contour Area ($ft^2$) | Incr Vol ($ft^3$) | Accum Vol (S,$ft^3$) | Stage (Z, ft) | ln S | ln Z | $Z_{est}$ (ft) |
|---|---|---|---|---|---|---|---|
| 255 | | 0 | 0 | 0 | | | 0.00 |
| 260 | 80703 | 201757.5 | 201757.5 | 5 | 12.2148 | 1.6094 | 5.00 |
| 270 | 121581 | 1011420 | 1213177.5 | 15 | 14.0088 | 2.7081 | 14.97 |
| 280 | 199238 | 1604095 | 2817272.5 | 25 | 14.8513 | 3.2189 | 25.04 |

Regression Output

SUMMARY OUTPUT

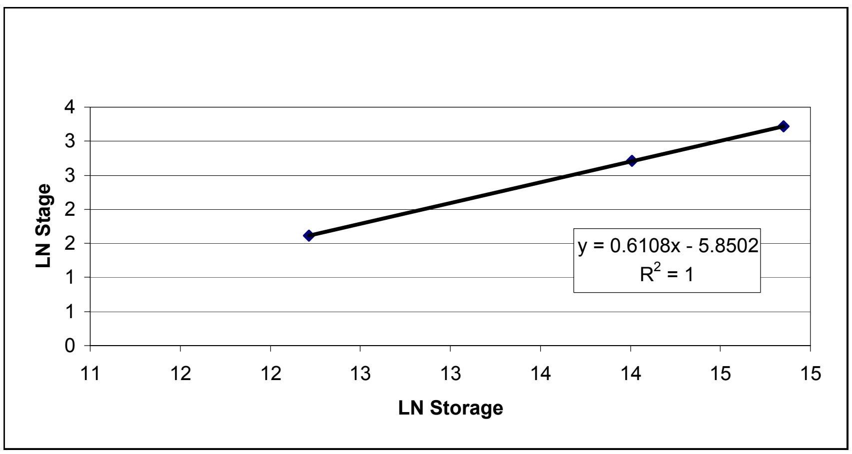
| Stage-Storage Coefficients | |
|---|---|
| $K_s$ | 14451 |
| b | 1.64 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99999711 |
| R Square | 0.999994219 |
| Adjusted R Square | 0.999988438 |
| Standard Error | 0.004578525 |
| Observations | 3 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 3.626296537 | 3.626296537 | 172986.467 | 0.001530641 |
| Residual | 1 | 2.09629E-05 | 2.09629E-05 | | |
| Total | 2 | 3.6263175 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 9.578538661 | 0.010236399 | 935.7332386 | 0.00068034 | 9.448473438 | 9.708604 | 9.448473438 | 9.708603883 |
| X Variable 1 | 1.637293417 | 0.003936592 | 415.9164182 | 0.00153064 | 1.587274482 | 1.687312 | 1.587274482 | 1.687312352 |



**Hidden Pond Reservoir Routing**

**Estimated Hydrograph**

$Q_p$= 550 cfs
$T_p$= 40 min
dT= 5 min

**Riser/Barrel**

N= 1
$D_{riser}$= 72 in
$C_w$= 3
$Z_{cr}$= 9 ft
$D_{barrel}$= 36 in
$C_d$= 0.6
$Z_{inv}$= 0 ft

**Culvert**

N= 0
D= 24 in
$C_d$= 0.6 ft
Inv= 8

**Hydrograph Formulation**

R= 100.0
g= 290.0
h= 25.0
pn6= 5.8 in
A= 191.0 ac
H= 40.0 ft
L= 3500.0 ft
$C_a$= 0.48
CN= 72.0
S= 3.9 in
Q*= 2.8
$T_c$= 23.4 min
I= 6.0 in/hr

**Weir/ES**

L= 0 ft
$Z_{cr}$= 11 ft
$C_w$= 3

**Stage-Storage**

$K_s$= 1445
b= 1.64
$Z_o$= 0 ft

**Initial Water Level**

$Z_i$= 9 ft

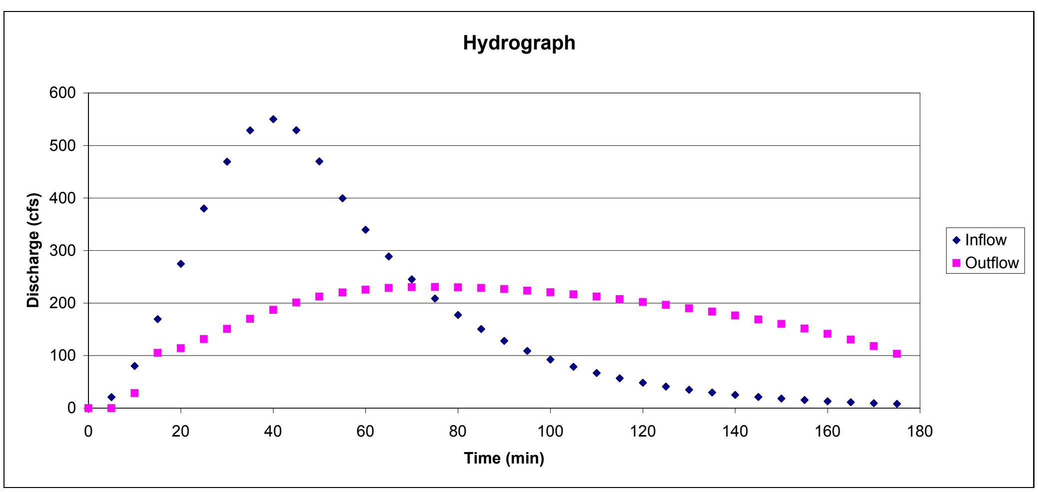
$C_{hrm}$=0.0193CN-0.91
$C_{\text{from CN}}$=

**Computed Results**

Max Surf Area= 0.4 ac
Peak Stage= 47.6 ft
Peak Outflow= 230.7 cfs
Max Storage= 18.7 ac-ft

**Estimated Hydrograph** $Q_p$= 548.75 cfs $T_p$= 42.27 min

| Time (min) | Inflow ($ft^3/s$) | Storage ($ft^3$) | Storage (ac-ft) | Stage (ft) | Outflow ($ft^3/s$) | Surface Area (acres) | | Riser ($ft^3/s$) | Barrel ($ft^3/s$) | Rbspwy ($ft^3/s$) | Culvert ($ft^3/s$) | Weir ($ft^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 5.31E+04 | 1.2 | 9 | 0.0 | 0.14 | | 0.0 | 93.1 | 0.0 | 0.0 | 0.0 |
| 5 | 21 | 5.31E+04 | 1.2 | 9.00 | 0.0 | 0.14 | | 0.0 | 93.1 | 0.0 | 0.0 | 0.0 |
| 10 | 80 | 5.93E+04 | 1.4 | 9.63 | 28.6 | 0.14 | | 28.6 | 96.9 | 28.6 | 0.0 | 0.0 |
| 15 | 170 | 7.49E+04 | 1.7 | 11.11 | 105.3 | 0.15 | | 172.7 | 105.3 | 105.3 | 0.0 | 0.0 |
| 20 | 275 | 9.42E+04 | 2.2 | 12.77 | 114.1 | 0.17 | | 413.8 | 114.1 | 114.1 | 0.0 | 0.0 |
| 25 | 380 | 1.42E+05 | 3.3 | 16.43 | 131.3 | 0.20 | | 1144.8 | 131.3 | 131.3 | 0.0 | 0.0 |
| 30 | 469 | 2.17E+05 | 5.0 | 21.24 | 151.0 | 0.23 | | 2421.1 | 151.0 | 151.0 | 0.0 | 0.0 |
| 35 | 529 | 3.12E+05 | 7.2 | 26.53 | 170.0 | 0.27 | | 4148.8 | 170.0 | 170.0 | 0.0 | 0.0 |
| 40 | 550 | 4.20E+05 | 9.6 | 31.78 | 187.0 | 0.30 | | 6145.3 | 187.0 | 187.0 | 0.0 | 0.0 |
| 45 | 529 | 5.29E+05 | 12.1 | 36.58 | 201.3 | 0.33 | | 8184.5 | 201.3 | 201.3 | 0.0 | 0.0 |
| 50 | 470 | 6.27E+05 | 14.4 | 40.58 | 212.4 | 0.35 | | 10032.8 | 212.4 | 212.4 | 0.0 | 0.0 |
| 55 | 400 | 7.05E+05 | 16.2 | 43.56 | 220.4 | 0.37 | | 11483.8 | 220.4 | 220.4 | 0.0 | 0.0 |
| 60 | 340 | 7.58E+05 | 17.4 | 45.56 | 225.6 | 0.38 | | 12493.2 | 225.6 | 225.6 | 0.0 | 0.0 |
| 65 | 289 | 7.93E+05 | 18.2 | 46.80 | 228.7 | 0.39 | | 13135.5 | 228.7 | 228.7 | 0.0 | 0.0 |
| 70 | 245 | 8.11E+05 | 18.6 | 47.45 | 230.3 | 0.39 | | 13473.0 | 230.3 | 230.3 | 0.0 | 0.0 |
| 75 | 209 | 8.15E+05 | 18.7 | 47.61 | 230.7 | 0.39 | | 13557.6 | 230.7 | 230.7 | 0.0 | 0.0 |
| 80 | 177 | 8.08E+05 | 18.6 | 47.37 | 230.1 | 0.39 | | 13432.9 | 230.1 | 230.1 | 0.0 | 0.0 |
| 85 | 151 | 7.93E+05 | 18.2 | 46.80 | 228.7 | 0.39 | | 13135.4 | 228.7 | 228.7 | 0.0 | 0.0 |
| 90 | 128 | 7.69E+05 | 17.7 | 45.95 | 226.6 | 0.38 | | 12696.1 | 226.6 | 226.6 | 0.0 | 0.0 |
| 95 | 109 | 7.40E+05 | 17.0 | 44.87 | 223.8 | 0.38 | | 12141.5 | 223.8 | 223.8 | 0.0 | 0.0 |
| 100 | 93 | 7.05E+05 | 16.2 | 43.58 | 220.4 | 0.37 | | 11494.1 | 220.4 | 220.4 | 0.0 | 0.0 |
| 105 | 79 | 6.67E+05 | 15.3 | 42.12 | 216.6 | 0.36 | | 10773.2 | 216.6 | 216.6 | 0.0 | 0.0 |
| 110 | 67 | 6.25E+05 | 14.4 | 40.51 | 212.2 | 0.35 | | 9995.8 | 212.2 | 212.2 | 0.0 | 0.0 |
| 115 | 57 | 5.82E+05 | 13.4 | 38.76 | 207.4 | 0.34 | | 9176.4 | 207.4 | 207.4 | 0.0 | 0.0 |
| 120 | 48 | 5.37E+05 | 12.3 | 36.90 | 202.2 | 0.33 | | 8328.0 | 202.2 | 202.2 | 0.0 | 0.0 |
| 125 | 41 | 4.91E+05 | 11.3 | 34.93 | 196.5 | 0.32 | | 7462.2 | 196.5 | 196.5 | 0.0 | 0.0 |
| 130 | 35 | 4.44E+05 | 10.2 | 32.87 | 190.3 | 0.31 | | 6589.5 | 190.3 | 190.3 | 0.0 | 0.0 |
| 135 | 30 | 3.97E+05 | 9.1 | 30.72 | 183.7 | 0.30 | | 5719.4 | 183.7 | 183.7 | 0.0 | 0.0 |
| 140 | 25 | 3.51E+05 | 8.1 | 28.49 | 176.5 | 0.28 | | 4861.4 | 176.5 | 176.5 | 0.0 | 0.0 |
| 145 | 21 | 3.06E+05 | 7.0 | 26.18 | 168.8 | 0.27 | | 4024.6 | 168.8 | 168.8 | 0.0 | 0.0 |
| 150 | 18 | 2.62E+05 | 6.0 | 23.80 | 160.5 | 0.25 | | 3218.4 | 160.5 | 160.5 | 0.0 | 0.0 |
| 155 | 15 | 2.19E+05 | 5.0 | 21.35 | 151.4 | 0.24 | | 2453.4 | 151.4 | 151.4 | 0.0 | 0.0 |
| 160 | 13 | 1.78E+05 | 4.1 | 18.83 | 141.5 | 0.22 | | 1741.6 | 141.5 | 141.5 | 0.0 | 0.0 |
| 165 | 11 | 1.40E+05 | 3.2 | 16.23 | 130.4 | 0.20 | | 1098.9 | 130.4 | 130.4 | 0.0 | 0.0 |
| 170 | 10 | 1.04E+05 | 2.4 | 13.55 | 118.0 | 0.18 | | 548.5 | 118.0 | 118.0 | 0.0 | 0.0 |
| 175 | 8 | 7.13E+04 | 1.6 | 10.77 | 103.5 | 0.15 | | 133.5 | 103.5 | 103.5 | 0.0 | 0.0 |



**Silver Lake**
**Stage-Storage Coefficient Computation**

| Contour | Contour Area ($ft^2$) | Incr Vol ($ft^3$) | Accum Vol (S, $ft^3$) | Stage (Z, ft) | ln S | ln Z | $Z_{est}$ (ft) |
|---|---|---|---|---|---|---|---|
| 270 | | 0 | 0 | 0 | | | 0.00 |
| 279 | 1246136 | 5607612 | 5607612 | 9 | 15.5396 | 2.1972 | 9.00 |
| 295 | 2014817 | 26087624 | 31695236 | 25 | 17.2717 | 3.2189 | 25.00 |
| 312 | 3237535 | 44644992 | 76340228 | 42 | 18.1507 | 3.7377 | 42.00 |

Regression Output

SUMMARY OUTPUT

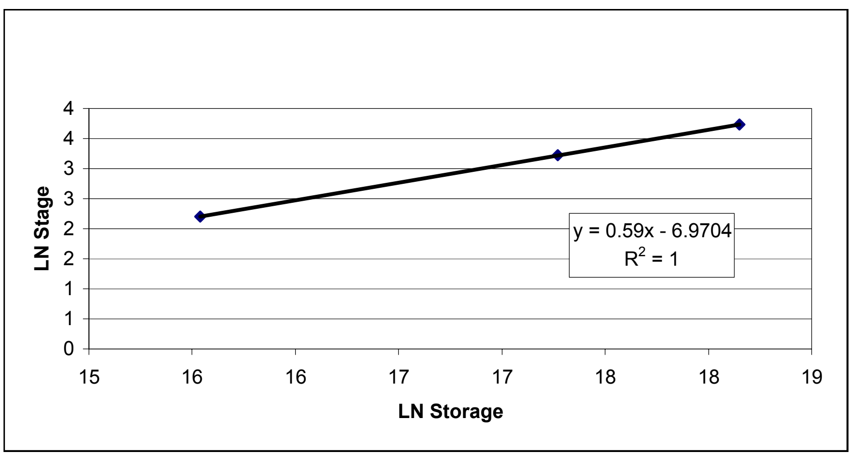
| Stage-Storage Coefficients | |
|---|---|
| $K_s$ | 135304 |
| b | 1.70 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99999999 |
| R Square | 0.99999998 |
| Adjusted R Square | 0.999999961 |
| Standard Error | 0.00026383 |
| Observations | 3 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 3.530126828 | 3.530126828 | 50715754.3 | 8.93941E-05 |
| Residual | 1 | 6.96061E-08 | 6.96061E-08 | | |
| Total | 2 | 3.530126898 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 11.81528302 | 0.000742061 | 15922.2436 | 3.9983E-05 | 11.80585428 | 11.82471 | 11.80585428 | 11.82471176 |
| X Variable 1 | 1.695058316 | 0.00023802 | 7121.499441 | 8.9394E-05 | 1.692034 | 1.698083 | 1.692034 | 1.698082632 |



**Silver Lake Reservoir Routing**

**Estimated Hydrograph**

$Q_p$= 340 cfs
$T_p$= 60 min
dT= 5 min

**Riser/Barrel**

N= 0
$D_{riser}$= 0 in
$C_w$= 3
$Z_{cr}$= 0 ft
$D_{barrel}$= 0 in
$C_d$= 0.6

$Z_{inv}$= 0 ft

**Culvert**

N= 1
D= 24 in
$C_d$= 0.6 ft
Inv= 3

**Hydrograph Formulation**

R= 100.0
g= 290.0
h= 25.0
pn6= 5.8 in
A= 226.0 ac
H= 50.0 ft
L= 5275.0 ft
$C_a$= 0.31
CN= 63.0

S= 5.9 in

Q*= 2.0
$T_c$= 34.5 min
I= 4.9 in/hr

**Weir/ES**

L= 56 ft
$Z_{cr}$= 7 ft
$C_w$= 3

**Stage-Storage**

$K_s$= 135304
b= 1.7
$Z_o$= 0 ft

**Initial Water Level**

$Z_i$= 3 ft

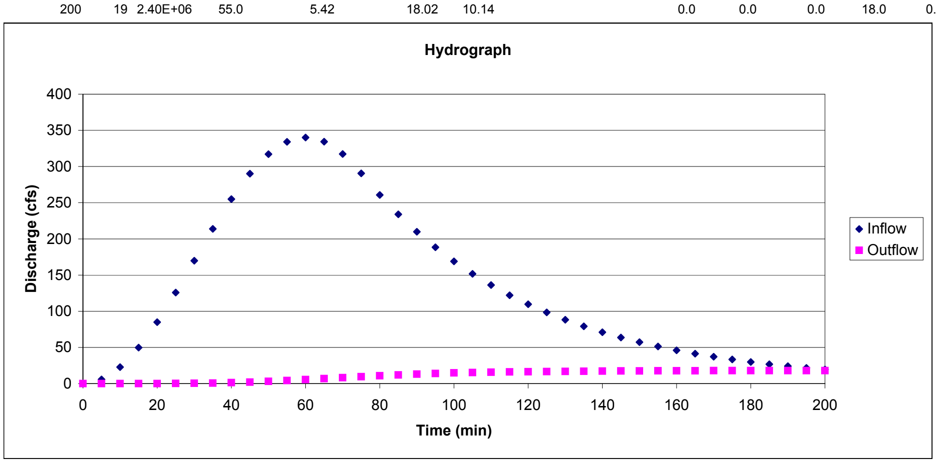
$C_{hrm}$=0.0193CN-0.91
$C_{\text{from CN}}$=

**Computed Results**

| | |
|---|---|
| Max Surf Area= | 10.1 ac |
| Peak Stage= | 5.4 ft |
| Peak Outflow= | 18.0 cfs |
| Max Storage | 55.0 ac-ft |

**Estimated Hydrograph** $Q_p$= 336.9 cfs $T_p$= 58.493 min

| Time (min) | Inflow ($ft^3/s$) | Storage ($ft^3$) | Storage (ac-ft) | Stage (ft) | Outflow ($ft^3/s$) | Surface Area (acres) | | Riser ($ft^3/s$) | Barrel ($ft^3/s$) | Rbspwy ($ft^3/s$) | Culvert ($ft^3/s$) | Weir ($ft^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8.76E+05 | 20.1 | 3.00 | 0.00 | 6.70 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 6 | 8.76E+05 | 20.1 | 3.00 | 0.00 | 6.70 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 23 | 8.78E+05 | 20.1 | 3.00 | 0.00 | 6.71 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 50 | 8.84E+05 | 20.3 | 3.02 | 0.01 | 6.73 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 85 | 8.99E+05 | 20.6 | 3.05 | 0.05 | 6.78 | | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 25 | 126 | 9.25E+05 | 21.2 | 3.10 | 0.16 | 6.85 | | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 |
| 30 | 170 | 9.62E+05 | 22.1 | 3.17 | 0.38 | 6.97 | | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| 35 | 214 | 1.01E+06 | 23.3 | 3.27 | 0.75 | 7.12 | | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 |
| 40 | 255 | 1.08E+06 | 24.7 | 3.39 | 1.30 | 7.30 | | 0.0 | 0.0 | 0.0 | 1.3 | 0.0 |
| 45 | 290 | 1.15E+06 | 26.5 | 3.53 | 2.05 | 7.51 | | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 |
| 50 | 317 | 1.24E+06 | 28.5 | 3.68 | 3.01 | 7.73 | | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 |
| 55 | 334 | 1.33E+06 | 30.6 | 3.84 | 4.14 | 7.97 | | 0.0 | 0.0 | 0.0 | 4.1 | 0.0 |
| 60 | 340 | 1.43E+06 | 32.9 | 4.01 | 5.42 | 8.21 | | 0.0 | 0.0 | 0.0 | 5.4 | 0.0 |
| 65 | 334 | 1.53E+06 | 35.2 | 4.17 | 6.78 | 8.44 | | 0.0 | 0.0 | 0.0 | 6.8 | 0.0 |
| 70 | 317 | 1.63E+06 | 37.5 | 4.33 | 8.18 | 8.66 | | 0.0 | 0.0 | 0.0 | 8.2 | 0.0 |
| 75 | 290 | 1.72E+06 | 39.6 | 4.47 | 9.53 | 8.86 | | 0.0 | 0.0 | 0.0 | 9.5 | 0.0 |
| 80 | 261 | 1.81E+06 | 41.5 | 4.60 | 10.80 | 9.03 | | 0.0 | 0.0 | 0.0 | 10.8 | 0.0 |
| 85 | 234 | 1.88E+06 | 43.2 | 4.71 | 11.95 | 9.19 | | 0.0 | 0.0 | 0.0 | 11.9 | 0.0 |
| 90 | 210 | 1.95E+06 | 44.8 | 4.80 | 12.98 | 9.32 | | 0.0 | 0.0 | 0.0 | 13.0 | 0.0 |
| 95 | 188 | 2.01E+06 | 46.1 | 4.89 | 13.91 | 9.43 | | 0.0 | 0.0 | 0.0 | 13.9 | 0.0 |
| 100 | 169 | 2.06E+06 | 47.3 | 4.96 | 14.74 | 9.53 | | 0.0 | 0.0 | 0.0 | 14.7 | 0.0 |
| 105 | 152 | 2.11E+06 | 48.4 | 5.03 | 15.32 | 9.62 | | 0.0 | 0.0 | 0.0 | 15.3 | 0.0 |
| 110 | 136 | 2.15E+06 | 49.3 | 5.09 | 15.74 | 9.70 | | 0.0 | 0.0 | 0.0 | 15.7 | 0.0 |
| 115 | 122 | 2.18E+06 | 50.2 | 5.14 | 16.10 | 9.77 | | 0.0 | 0.0 | 0.0 | 16.1 | 0.0 |
| 120 | 110 | 2.22E+06 | 50.9 | 5.18 | 16.41 | 9.82 | | 0.0 | 0.0 | 0.0 | 16.4 | 0.0 |
| 125 | 98 | 2.24E+06 | 51.5 | 5.22 | 16.67 | 9.87 | | 0.0 | 0.0 | 0.0 | 16.7 | 0.0 |
| 130 | 88 | 2.27E+06 | 52.1 | 5.25 | 16.90 | 9.92 | | 0.0 | 0.0 | 0.0 | 16.9 | 0.0 |
| 135 | 79 | 2.29E+06 | 52.6 | 5.28 | 17.09 | 9.96 | | 0.0 | 0.0 | 0.0 | 17.1 | 0.0 |
| 140 | 71 | 2.31E+06 | 53.0 | 5.31 | 17.26 | 9.99 | | 0.0 | 0.0 | 0.0 | 17.3 | 0.0 |
| 145 | 64 | 2.33E+06 | 53.4 | 5.33 | 17.41 | 10.02 | | 0.0 | 0.0 | 0.0 | 17.4 | 0.0 |
| 150 | 57 | 2.34E+06 | 53.7 | 5.35 | 17.53 | 10.04 | | 0.0 | 0.0 | 0.0 | 17.5 | 0.0 |
| 155 | 51 | 2.35E+06 | 54.0 | 5.36 | 17.63 | 10.06 | | 0.0 | 0.0 | 0.0 | 17.6 | 0.0 |
| 160 | 46 | 2.36E+06 | 54.2 | 5.38 | 17.72 | 10.08 | | 0.0 | 0.0 | 0.0 | 17.7 | 0.0 |
| 165 | 41 | 2.37E+06 | 54.4 | 5.39 | 17.79 | 10.10 | | 0.0 | 0.0 | 0.0 | 17.8 | 0.0 |
| 170 | 37 | 2.38E+06 | 54.6 | 5.40 | 17.85 | 10.11 | | 0.0 | 0.0 | 0.0 | 17.9 | 0.0 |
| 175 | 33 | 2.38E+06 | 54.7 | 5.40 | 17.90 | 10.12 | | 0.0 | 0.0 | 0.0 | 17.9 | 0.0 |
| 180 | 30 | 2.39E+06 | 54.8 | 5.41 | 17.94 | 10.13 | | 0.0 | 0.0 | 0.0 | 17.9 | 0.0 |
| 185 | 27 | 2.39E+06 | 54.9 | 5.42 | 17.97 | 10.13 | | 0.0 | 0.0 | 0.0 | 18.0 | 0.0 |
| 190 | 24 | 2.39E+06 | 54.9 | 5.42 | 17.99 | 10.14 | | 0.0 | 0.0 | 0.0 | 18.0 | 0.0 |
| 195 | 22 | 2.40E+06 | 55.0 | 5.42 | 18.01 | 10.14 | | 0.0 | 0.0 | 0.0 | 18.0 | 0.0 |
| 200 | 19 | 2.40E+06 | 55.0 | 5.42 | 18.02 | 10.14 | | 0.0 | 0.0 | 0.0 | 18.0 | 0.0 |



**Williams Pond**
**Stage-Storage Coefficient Computation**

| Contour | Contour Area (ft$^2$) | Incr Vol (ft$^3$) | Accum Vol (S,ft$^3$) | Stage (Z, ft) | ln S | ln Z | $Z_{est}$ (ft) |
|---|---|---|---|---|---|---|---|
| 203 | | 0 | 0 | 0 | | | 0.00 |
| 213 | 1123019 | 5615095 | 5615095 | 10 | 15.5410 | 2.3026 | 10.01 |
| 230 | 3705952 | 41046253.5 | 46661348.5 | 27 | 17.6584 | 3.2958 | 26.94 |
| 246 | 6377023 | 80663800 | 127325148.5 | 43 | 18.6623 | 3.7612 | 43.07 |

Regression Output

SUMMARY OUTPUT

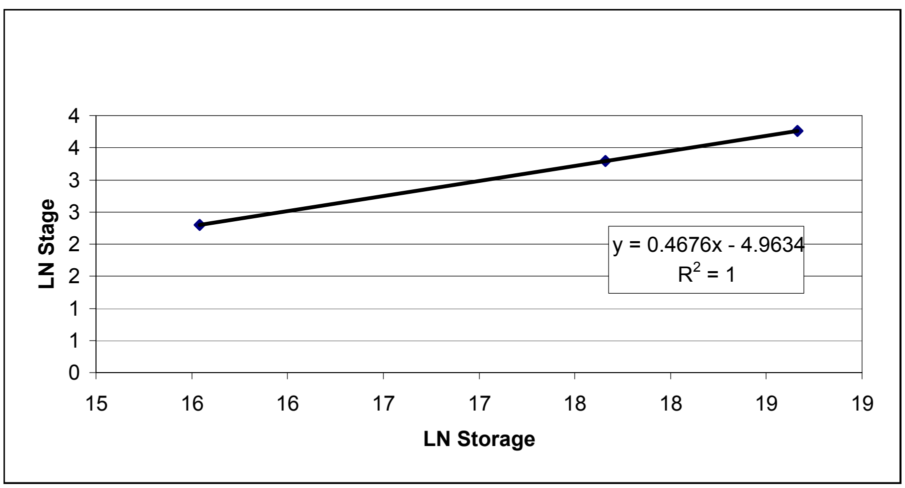
| Stage-Storage Coefficients | |
|---|---|
| $K_s$ | 40740 |
| b | 2.14 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999995976 |
| R Square | 0.999991952 |
| Adjusted R Square | 0.999983904 |
| Standard Error | 0.006392744 |
| Observations | 3 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 5.077866036 | 5.077866036 | 124252.921 | 0.001806033 |
| Residual | 1 | 4.08672E-05 | 4.08672E-05 | | |
| Total | 2 | 5.077906904 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 10.61496366 | 0.01928511 | 550.4227653 | 0.0011566 | 10.36992416 | 10.86 | 10.36992 | 10.86 |
| X Variable 1 | 2.138629021 | 0.006067114 | 352.4952774 | 0.00180603 | 2.061539359 | 2.215719 | 2.061539 | 2.215719 |



**Williams Pond Reservoir Routing**

**Estimated Hydrograph**

$Q_p$= 1070 cfs
$T_p$= 40 min
dT= 5 min

**Riser/Barrel**

N= 1
$D_{riser}$= 36 in
$C_w$= 3
$Z_{cr}$= 4 ft
$D_{barrel}$= 36 in
$C_d$= 0.6
$Z_{inv}$= 0 ft

**Culvert**

N= 1
D= 18 in
$C_d$= 0.6 ft
Inv= 4.6

**Hydrograph Formulation**

R= 100.0
g= 290.0
h= 25.0
pn6= 5.8 in
A= 324.0 ac
H= 99.0 ft
L= 4550.0 ft
$C_a$= 0.54
CN= 75.0
S= 3.3 in
Q*= 3.1
$T_c$= 22.4 min
I= 6.1 in/hr

**Weir/ES**

L= 0 ft
$Z_{cr}$= 0 ft
$C_w$= 3

**Stage-Storage**

$K_s$= 40740
b= 2.14
$Z_o$= 0 ft

**Initial Water Level**

$Z_i$= 4 ft

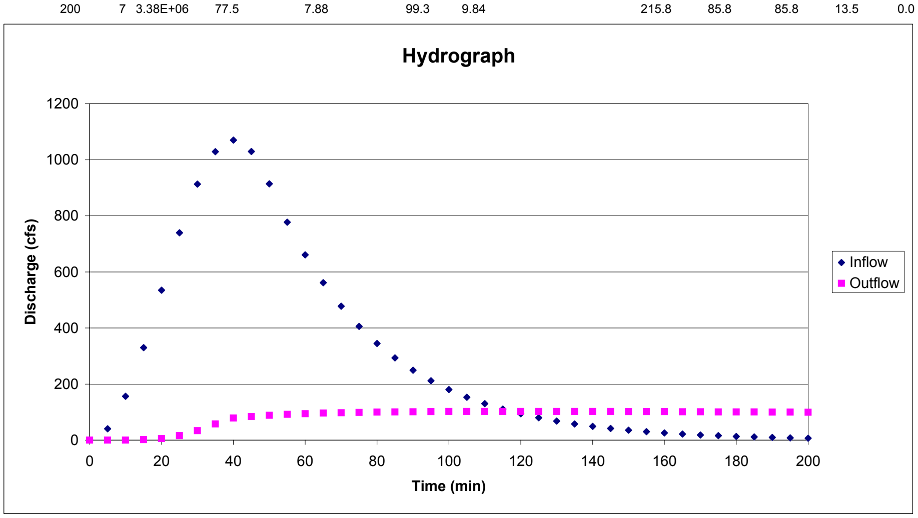
$C_{hrm}$=0.0193CN-0.91
$C_{from\ CN}$=

**Computed Results**

Max Surf Area= 10.3 ac
Peak Stage= 8.2 ft
Peak Outflow= 102.4 cfs
Max Storage= 84.7 ac-ft

**Estimated Hydrograph** $Q_p$= 1066.37 cfs $T_p$= 40.6 min

| Time (min) | Inflow ($ft^3/s$) | Storage ($ft^3$) | Storage (ac-ft) | Stage (ft) | Outflow ($ft^3/s$) | Surface Area (acres) | Riser ($ft^3/s$) | Barrel ($ft^3/s$) | Rbspwy ($ft^3/s$) | Culvert ($ft^3/s$) | Weir ($ft^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 7.91E+05 | 18.2 | 4 | 0.0 | 4.54 | 0.0 | 53.7 | 0.0 | 0.0 | 0.0 |
| 5 | 41 | 7.91E+05 | 18.2 | 4.00 | 0.0 | 4.54 | 0.0 | 53.7 | 0.0 | 0.0 | 0.0 |
| 10 | 157 | 8.04E+05 | 18.4 | 4.03 | 0.1 | 4.58 | 0.1 | 54.0 | 0.1 | 0.0 | 0.0 |
| 15 | 330 | 8.51E+05 | 19.5 | 4.14 | 1.4 | 4.72 | 1.4 | 55.2 | 1.4 | 0.0 | 0.0 |
| 20 | 535 | 9.49E+05 | 21.8 | 4.35 | 6.0 | 5.00 | 6.0 | 57.4 | 6.0 | 0.0 | 0.0 |
| 25 | 739 | 1.11E+06 | 25.4 | 4.68 | 16.0 | 5.43 | 15.9 | 60.6 | 15.9 | 0.1 | 0.0 |
| 30 | 913 | 1.32E+06 | 30.4 | 5.09 | 33.5 | 5.98 | 32.1 | 64.4 | 32.1 | 1.4 | 0.0 |
| 35 | 1029 | 1.59E+06 | 36.5 | 5.54 | 57.6 | 6.58 | 54.0 | 68.3 | 54.0 | 3.7 | 0.0 |
| 40 | 1070 | 1.88E+06 | 43.2 | 5.99 | 78.6 | 7.20 | 79.5 | 72.0 | 72.0 | 6.6 | 0.0 |
| 45 | 1030 | 2.18E+06 | 50.0 | 6.42 | 84.1 | 7.79 | 106.3 | 75.4 | 75.4 | 8.8 | 0.0 |
| 50 | 914 | 2.46E+06 | 56.5 | 6.80 | 88.4 | 8.31 | 132.2 | 78.2 | 78.2 | 10.2 | 0.0 |
| 55 | 777 | 2.71E+06 | 62.2 | 7.11 | 91.7 | 8.75 | 154.8 | 80.5 | 80.5 | 11.3 | 0.0 |
| 60 | 661 | 2.91E+06 | 66.9 | 7.36 | 94.3 | 9.10 | 173.7 | 82.2 | 82.2 | 12.0 | 0.0 |
| 65 | 562 | 3.08E+06 | 70.8 | 7.55 | 96.2 | 9.37 | 189.2 | 83.6 | 83.6 | 12.6 | 0.0 |
| 70 | 477 | 3.22E+06 | 74.0 | 7.71 | 97.7 | 9.60 | 202.0 | 84.7 | 84.7 | 13.1 | 0.0 |
| 75 | 406 | 3.34E+06 | 76.6 | 7.84 | 98.9 | 9.78 | 212.4 | 85.5 | 85.5 | 13.4 | 0.0 |
| 80 | 345 | 3.43E+06 | 78.7 | 7.94 | 99.9 | 9.92 | 220.8 | 86.2 | 86.2 | 13.7 | 0.0 |
| 85 | 293 | 3.50E+06 | 80.4 | 8.02 | 100.6 | 10.03 | 227.4 | 86.7 | 86.7 | 13.9 | 0.0 |
| 90 | 249 | 3.56E+06 | 81.8 | 8.08 | 101.2 | 10.12 | 232.7 | 87.1 | 87.1 | 14.0 | 0.0 |
| 95 | 212 | 3.61E+06 | 82.8 | 8.12 | 101.6 | 10.19 | 236.7 | 87.5 | 87.5 | 14.2 | 0.0 |
| 100 | 180 | 3.64E+06 | 83.5 | 8.16 | 101.9 | 10.24 | 239.7 | 87.7 | 87.7 | 14.2 | 0.0 |
| 105 | 153 | 3.66E+06 | 84.1 | 8.18 | 102.2 | 10.27 | 241.8 | 87.9 | 87.9 | 14.3 | 0.0 |
| 110 | 130 | 3.68E+06 | 84.4 | 8.20 | 102.3 | 10.30 | 243.2 | 88.0 | 88.0 | 14.3 | 0.0 |
| 115 | 111 | 3.69E+06 | 84.6 | 8.21 | 102.4 | 10.31 | 244.0 | 88.0 | 88.0 | 14.4 | 0.0 |
| 120 | 94 | 3.69E+06 | 84.7 | 8.21 | 102.4 | 10.31 | 244.2 | 88.0 | 88.0 | 14.4 | 0.0 |
| 125 | 80 | 3.69E+06 | 84.6 | 8.21 | 102.4 | 10.31 | 244.0 | 88.0 | 88.0 | 14.4 | 0.0 |
| 130 | 68 | 3.68E+06 | 84.5 | 8.20 | 102.3 | 10.30 | 243.3 | 88.0 | 88.0 | 14.3 | 0.0 |
| 135 | 58 | 3.67E+06 | 84.2 | 8.19 | 102.2 | 10.28 | 242.4 | 87.9 | 87.9 | 14.3 | 0.0 |
| 140 | 49 | 3.66E+06 | 83.9 | 8.18 | 102.1 | 10.26 | 241.2 | 87.8 | 87.8 | 14.3 | 0.0 |
| 145 | 42 | 3.64E+06 | 83.5 | 8.16 | 101.9 | 10.24 | 239.8 | 87.7 | 87.7 | 14.2 | 0.0 |
| 150 | 35 | 3.62E+06 | 83.1 | 8.14 | 101.8 | 10.21 | 238.1 | 87.6 | 87.6 | 14.2 | 0.0 |
| 155 | 30 | 3.60E+06 | 82.7 | 8.12 | 101.6 | 10.18 | 236.3 | 87.4 | 87.4 | 14.1 | 0.0 |
| 160 | 26 | 3.58E+06 | 82.2 | 8.10 | 101.4 | 10.15 | 234.4 | 87.3 | 87.3 | 14.1 | 0.0 |
| 165 | 22 | 3.56E+06 | 81.7 | 8.07 | 101.1 | 10.12 | 232.3 | 87.1 | 87.1 | 14.0 | 0.0 |
| 170 | 19 | 3.53E+06 | 81.1 | 8.05 | 100.9 | 10.08 | 230.2 | 87.0 | 87.0 | 14.0 | 0.0 |
| 175 | 16 | 3.51E+06 | 80.5 | 8.02 | 100.7 | 10.04 | 227.9 | 86.8 | 86.8 | 13.9 | 0.0 |
| 180 | 13 | 3.48E+06 | 80.0 | 7.99 | 100.4 | 10.00 | 225.6 | 86.6 | 86.6 | 13.8 | 0.0 |
| 185 | 11 | 3.46E+06 | 79.4 | 7.97 | 100.2 | 9.96 | 223.2 | 86.4 | 86.4 | 13.7 | 0.0 |
| 190 | 10 | 3.43E+06 | 78.8 | 7.94 | 99.9 | 9.92 | 220.8 | 86.2 | 86.2 | 13.7 | 0.0 |
| 195 | 8 | 3.40E+06 | 78.1 | 7.91 | 99.6 | 9.88 | 218.3 | 86.0 | 86.0 | 13.6 | 0.0 |
| 200 | 7 | 3.38E+06 | 77.5 | 7.88 | 99.3 | 9.84 | 215.8 | 85.8 | 85.8 | 13.5 | 0.0 |



# APPENDIX N

# HSPF WATERSHED MODELING DATA

Comprehensive watershed modeling which takes into account unique watershed features such as reservoirs, land uses, soil types, potential development, wetlands, and the stream network was necessary to design a stable stream tailored to the watershed. HSPF was selected as a watershed model because of its capability to represent spatial variability in detail and the ability to predict watershed response to development. The model created with HSPF was the second stage of the watershed modeling, after the creation of the HMS model (See Appendix M).

The data collection and subbasin delineation described in Part 4 General Watershed Information provided information to construct the model. The stream network throughout the watershed was identified from the USGS 7.5M Topographic Maps, aerial photography, and ground truthing. Stream sizes were the same as those used in the HMS model. Each subbasin in the watershed was divided into hydrologically homogeneous land segments based on soil series, land use, and location (see Watershed Modeling Land Segments Map). The land segments were created by using the Land Use/Land Cover GIS layer created by BLWI staff (Appendix A. Watershed Land Use/Land Cover Map), and the USGS soil survey GIS layer (Appendix B. Watershed Soil Type Distribution Map). The 16 soil series in the watershed were grouped into 4 soil groups which would have similar runoff and infiltration properties.

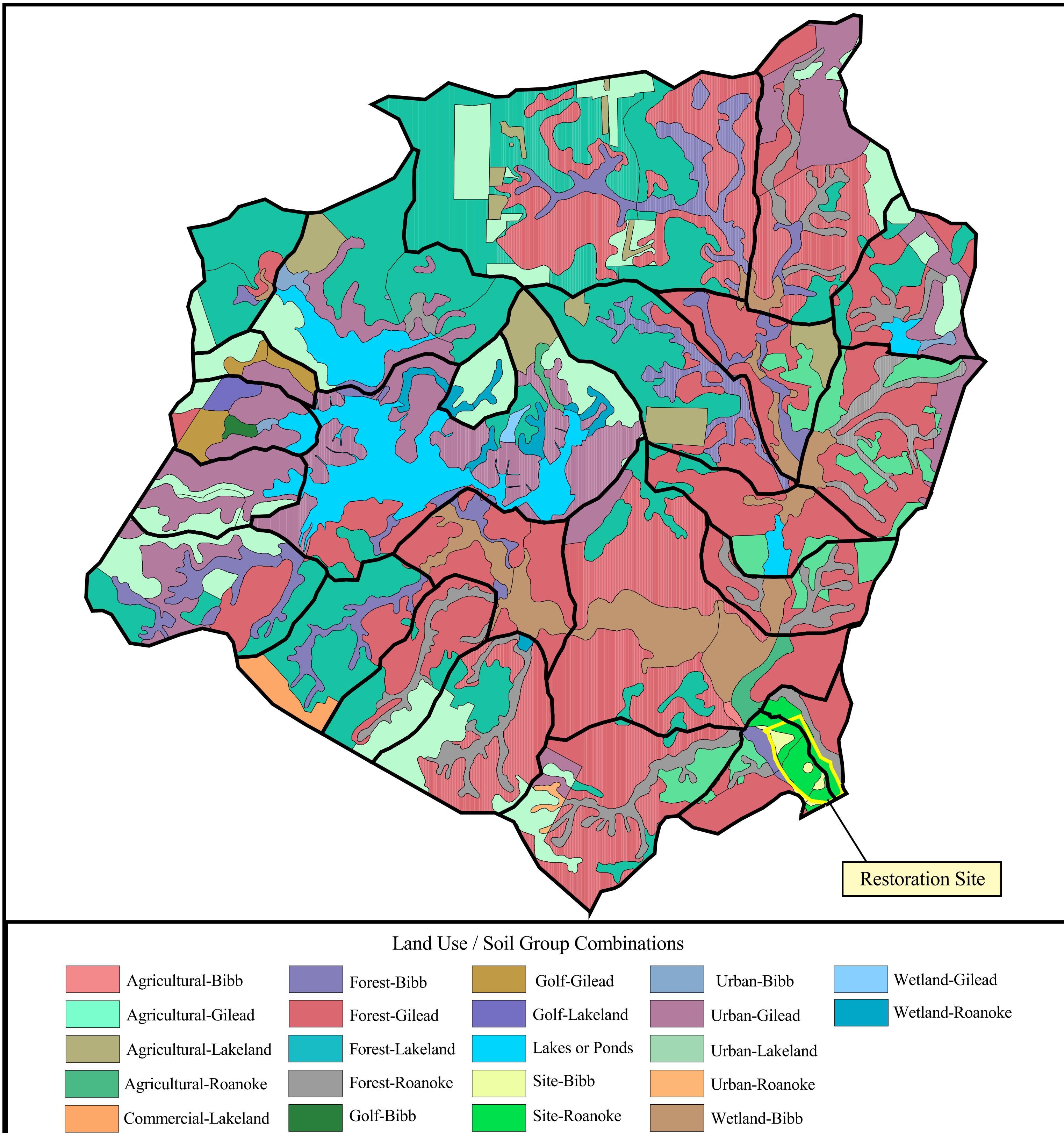
*Table N-1. Soil Series Groupings for HSPF model*

| **Soil Series** | **Group** |
|---|---|
| Bibb, Wehadkee, Wahee | Bibb |
| Gilead, Vaucluse, Augusta, Altavista, Blaney, Norfolk, Orangeburg, Goldsboro | Gilead |
| Lakeland, Candor, Wakulla, Pocalla | Lakeland |
| Roanoke | Roanoke |

The land use and soil grouping layers were overlaid to produce 189 land segments which were connected by the stream network, overland flow paths, and lateral groundwater flow direction. Each land segment is an individual linked element within HSPF with different parameters applied to it. Initial conditions and initial parameter values were set using measured values or suggested values from the U.S. EPA's BASINS Technical Note 6 and other published values. The HMS modeling established that the lakes and ponds have a large effect on the watershed. Therefore, the routing data shown in Appendix M was used to create the reservoir data in the HSPF model also.

The HSPF model was calibrated with one year of flow data from the HEC-RAS model described in Appendix G, Existing Stream Data. This flow data was calculated with measured stream stage data and velocity readings at stable cross sections constructed on the existing stream. The calibration software Visual PEST-ASP was used for calibration. Rain data from the 6 rain gages in the watershed was applied to the appropriate land segments using the Theissen polygon method. The weather station on the project site provided data for calculating potential evapotranspiration which was applied to all land segments.

# Watershed Modeling Land Segments Map




N

400 0 400 800 Feet

Scale: 1" = 4000 feet
Overhills Stream and Wetland Restoration Project - Restoration Plan
March 14, 2003

BLUE Land Water Infrastructure

Modeled flow from HSPF watershed model for monitoring period